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Geology of the southwestern and north–central parts of the Lyell 1:50 000 scale quadrangle

by C. R. Calver

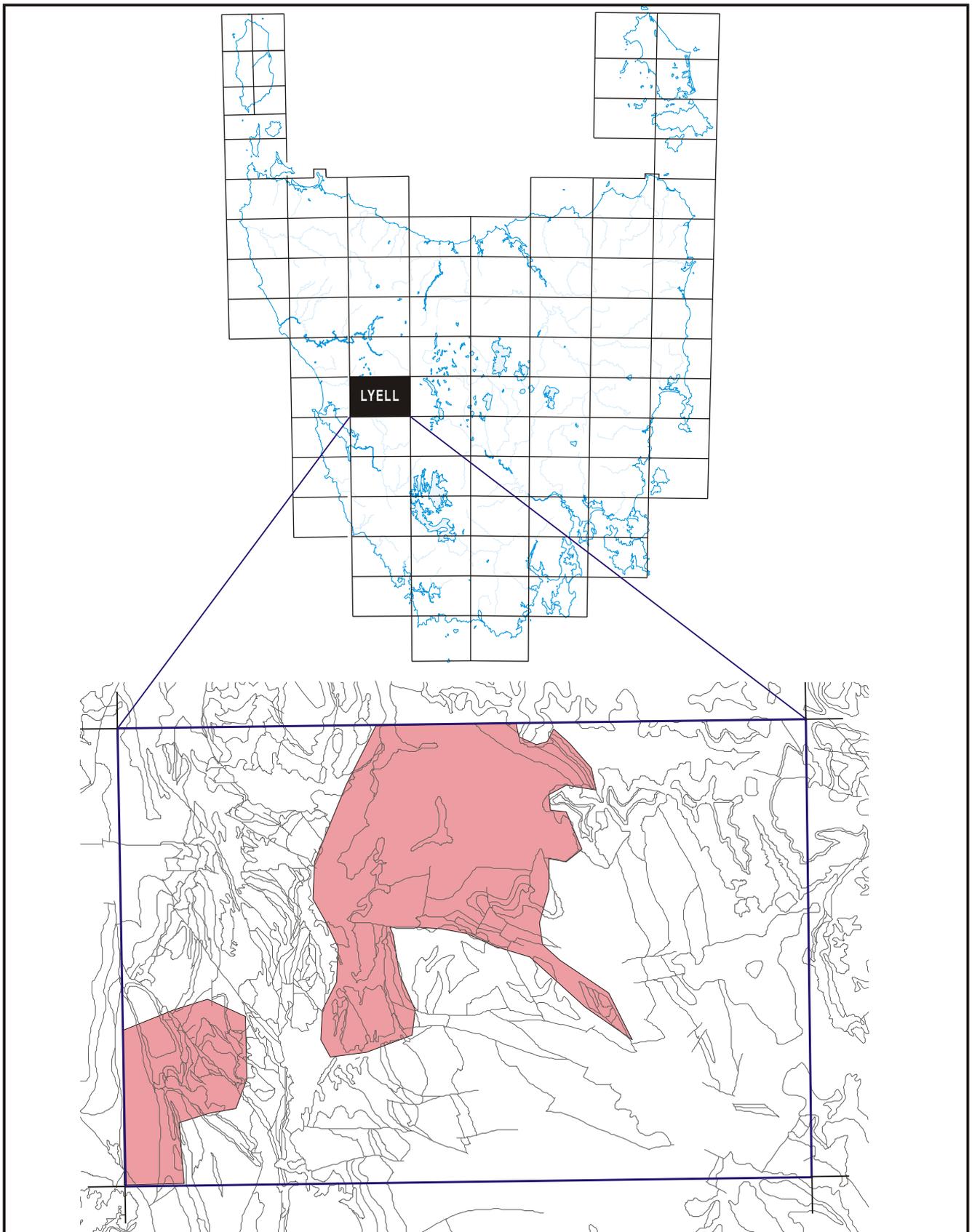


Figure 1. Location map of Lyell 1:50 000 scale quadrangle showing areas described in this report.

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Summary

Two areas of the Lyell 1:50 000 scale map sheet are described: the southwestern part, between Mt Jukes, the King River and Mt Strahan; and the north–central part, east of the King River (now flooded by Lake Burbury). In the southwestern area, the Western Volcano-sedimentary Sequence stratigraphically underlies the Central Volcanic Complex (CVC) near the King River and probably also near Thomas Currie Rivulet. Correlates of the Tyndall Group conformably underlie thin Owen Group rocks in the Flannigans Creek and Garfield River areas. A regional NNE-trending syncline in the CVC in the Mt Jukes area pre-dates deposition of the Owen Group. A further two, more localised movements occurred during deposition of the Owen Group. The last of these was probably synchronous with the Haulage Movement. A correlate of the Pioneer Sandstone unconformably overlies volcanic rocks west of Mt Jukes. A thick correlate of the Owen crops out west of the Mt Strahan Fault; this is distinct from the type Owen, notably in that it lacks red beds. Rocks of the Gordon and Eldon groups occupy a tight synclinal structure west of Newall Creek. Devonian deformation is essentially pervasive and locally, two phases can be demonstrated.

The north–central area consists of a broad, complex synclinal structure, the King Synclinorium (Solomon, 1962) occupied by deformed Gordon Group and Eldon Group rocks. The Pioneer Sandstone correlate is thin or absent along the eastern boundary of the synclinorium where the sequence rests unconformably on the Precambrian of the Tyennan region. Peritidal carbonates characterise the Gordon Group. An erosional disconformity separates the Gordon and Eldon groups. The Crotty Formation was deposited in a tide-dominated, inner shelf environment, while younger units have evidence of storm deposition in relatively shallow (Florence Formation) to deep environments (Amber and Bell formations). The Crotty Formation thickens southwards. The Eldon Group is approximately 5000 m thick in the northern King Synclinorium. Devonian folding and a single associated cleavage, of widely varying trend, characterise the deformation in the synclinorium. Intensity of deformation diminishes from west to east.

INTRODUCTION

This report was written, mainly in 1990, as a contribution to the explanatory notes for the Lyell 1:50 000 scale geological map (Calver *et al.*, 1987). The report describes Cambrian to Devonian rocks in two areas of the Lyell Quadrangle: the southwestern corner of the map sheet, roughly west of Mt Jukes and south of the King River gorge; and a larger north–central area, east of the King River (now flooded by Lake Burbury) (fig. 1). Quaternary deposits are not described here; a detailed account of the Quaternary of part of the north–central area is given in Fitzsimons *et al.* (1993).

The Lyell map sheet legend applied a new, informal nomenclature to two major subdivisions of the Mt Read Volcanics. The names ‘King River association’ and ‘Lynchford association’ were applied to the Central Volcanic Complex and Western Volcano-sedimentary Sequence, respectively, of Corbett and Solomon (1989) and earlier workers. However the earlier informal nomenclatural system, or variations of it (Western Volcano-sedimentary Sequence, Central Volcanic Complex, Eastern Sequence) is well established and is followed here. Stratigraphic nomenclature applied to the Upper Cambrian–Lower Ordovician siliciclastic rocks (Denison Group, including the ‘Owen Conglomerate’) has also changed since publication of the Lyell map. The ‘Owen Conglomerate’ is now the Owen Group, and the ‘Pioneer Beds’ has been separated out as the Pioneer Sandstone and included in the overlying Gordon Group. The term Owen Group has supplanted the term Denison Group in western Tasmania (Corbett, 2001; Noll and Hall, 2003). The newer terminology is used here. Mnemonics used on the Lyell map (Clq, etc.) are also used to refer to mapped units. Grid references are given in accordance with the AGD66 datum used on the map.

The geology of the southwestern area was known only in broad outline before the start of mapping of the Lyell Quadrangle, mainly through regional syntheses of Bradley (1954) and Solomon (1956), and limited traverses by Corbett (1976b, c). The mapping described here resulted in a major upgrade of knowledge of the lower Palaeozoic stratigraphy and structure of the area. A major regional Cambrian syncline was defined in the Central Volcanic Complex northwest of Mt Jukes. Correlates of the Western Volcano-sedimentary Sequence and Tyndall Group were mapped in the Garfield River area, east of Mt Strahan. Subdivisions of the Owen Group, similar to those of the type area on Mt Owen, were mapped on Mt Jukes, and a correlate of the Pioneer Sandstone was recognised at Newall Creek. Two very localised fold phases occurred during Owen deposition, the second probably corresponding to the Haulage unconformity of the Queenstown area. The Owen Group correlate west of the Mt Strahan Fault conformably overlies a probable Tyndall Group correlate, and is significantly different from the Owen Group of the West Coast Range.

Similarly, the north–central area was known only in broad outline prior to the Lyell mapping (Solomon, 1962; Reid, 1963). This area is underlain almost entirely by a folded succession of Ordovician to Devonian rocks (Gordon and Eldon groups). The stratigraphy and sedimentology of the succession is described, and a structural interpretation of the King Synclinorium is presented. The Eldon Group is here considerably thicker (about five kilometres) than previously recognised.

Mainly because of their economic importance, the Mt Read Volcanics are the subject of extensive literature cover, and no attempt is made here at an introductory synthesis. For

recent overviews of the Mt Read Volcanics see Corbett and Solomon (1989), Corbett (1992) and Seymour and Calver (1995).

Since publication of the Lyell 1:50 000 scale map, the areas described here have been reproduced at 1:25 000 scale as part of the Mount Read Volcanics Project map series (Corbett *et al.*, 1989, 1993) and the current digital 1:25 000 scale geological map series (Owen and Darwin map sheets). The production of MRV Map 13 (Corbett *et al.*, 1993)

involved limited remapping of the southwestern (Mt Strahan–Mt Jukes) area described here. No explanatory reports have yet been produced for the 1:25 000 scale maps.

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Western Volcano-sedimentary Sequence

Quartz-feldspar porphyry (Clq)

KING RIVER–NEWALL CREEK AREA

An elongate body of quartz-feldspar porphyry intrusive and extrusive rocks (Clq) extends from Queenstown southwards beyond the King River and terminates against the unconformity beneath the Pioneer Sandstone at Newall Creek [379200/5331200]*. The unit is well exposed in the King River gorge [381300/5333300–378800/5331800]; this transect has been described in detail by Corbett (1976c). In the gorge Clq is seen to include intrusive rocks, pyroclastic rocks and probably lavas. Corbett (1976c) mapped extrusive and pyroclastic rocks separately from intrusive rocks, but genetic distinctions are generally not mappable away from the excellent outcrop in the gorge.

Extensive riverbank outcrop near the power station [378800/5331900] is probably intrusive: uniform, massive pale pink to grey-green quartz-feldspar porphyry, with large (up to 5 mm) phenocrysts, and sparse fine-grained felsic xenoliths up to 100 mm long. A thin section shows phenocrysts of rounded, embayed clear quartz, smaller partly sericitised euhedral feldspar, and partly chloritised biotite in a pink, turbid, uniformly cryptocrystalline groundmass.

Upstream, sedimentary units (Clx, Cls) north of the river strike southward to meet an intrusive boundary with Clq that roughly follows the course of the river. An irregular, intrusive, transgressive contact between porphyry (Clq) and the Miners Ridge Sandstone (Clx) can be observed along the course of the river [between 379700/5332400 and 379800/5332700]. Upstream of the sedimentary unit (Clx) [at 380300/5332700], compositional banding was noted in Clq at several localities. Ragged xenoliths of hornfelsed shale were observed at 380300/5332800 and 380600/5333000, and a six metre long raft of spotted slate was observed at the former locality. At a few places [380300/5332800; 380700/5333200; 380800/5333300; 381100/5333400] a pyroclastic origin is indicated by the presence of lithic fragments with fiamme or larger, dark green vitriclasts that are typically crowded with phenocrysts.

Scattered outcrops of quartz-feldspar porphyry (Clq) south of the King River are of a rather uniform, massive rock with a weakly to strongly developed Devonian cleavage. Phenocrysts of biotite are usually present, and also of hornblende at 379300/5332100. The rocks are probably largely intrusive.

GARFIELD RIVER AREA

In the Garfield River area [380000/5325000 to 379000/5327000], the northern part of the elongate body of quartz-feldspar porphyry (Clq) is interlayered on the map scale with a number of substantial units of bedded tuff and sedimentary rocks shown as Clx on the map. This interlayering, together with some observed transitional

contacts between Clx and Clq, suggests the porphyry is here largely extrusive, and at least in part pyroclastic. The porphyry is nearly everywhere strongly cleaved in this area. It is grey-green in colour, weathering to white. Quartz and feldspar phenocrysts, of subequal abundance, are 1–2 mm in size, rarely up to 4 mm. Cleavage consists of close-spaced phyllitic, sericitic surfaces that anastomose around the phenocrysts. In places the rock is pyritic. Biotite is present in one thin section (R009566) [379200/5325700]. In a small tributary of the Garfield River [379200/5325700 to 379800/5325600], porphyry (Clq) and tuff and sedimentary rocks (Clx) are interbedded on a scale of metres to tens of metres with gradational contacts observed in some outcrops (see below), indicating a pyroclastic local origin for Clq. Quartz veins are extremely abundant around 379200/5326400.

Tuff, agglomerate, mudstone and sandstone (Clx)

KING RIVER–NEWALL CREEK AREA

Two minor occurrences of sedimentary rock (Clx) within porphyry (Clq) are intersected by the King River gorge [at 380300/5332700 and 380500/5332900]. The more westerly occurrence, about 100 m wide, is of abundantly slump-folded mudstone and sandstone. The eastern occurrence is about ten metres wide and consists of black slate and siltstone and is faulted on its southwestern side. Corbett (1976c) suggested these may be large xenoliths.

A persistent and much thicker sedimentary unit is found at the top of the Western Volcano-sedimentary Sequence and extends from Queenstown to Newall Creek. This unit dips and faces towards a structurally conformable contact with the overlying Central Volcanic Complex, and is well exposed in the King River gorge and in road cuts near Newall Creek. In the King River gorge the unit consists of quartz and feldspar-phyric tuff alternating with dark grey, hard cherty laminated mudstone on a scale of metres to tens of metres. The mudstone contains abundant planar laminae of paler siltstone and minor fine-grained sandstone. Load casting and grading give southeasterly facing directions. Discordant folding, due to synsedimentary slumping, is locally present.

Along strike to the southwest, a section through the upper part of this unit is exposed in a creek at 380400/5332400. Coarse volcanic sandstone or tuff at the base of this section grades upwards over several metres into hard, white to green siltstone or siliceous fine-ash tuff, in turn overlain abruptly by several metres of volcanoclastic conglomerate and coarse tuffaceous sandstone. The basal half metre of this second coarse-grained unit contains rounded cobbles of pink quartz-feldspar porphyry. There is a second upward gradation through several metres of tuffaceous sediment into fine-grained tuff or siliceous siltstone at the top of the section.

Further along strike to the south [at 379800/5331300], a cutting on the HEC surge tunnel road (constructed after

* Grid references are in metres in accordance with the AGD66. All references are given in the form of [metres east/metres north].

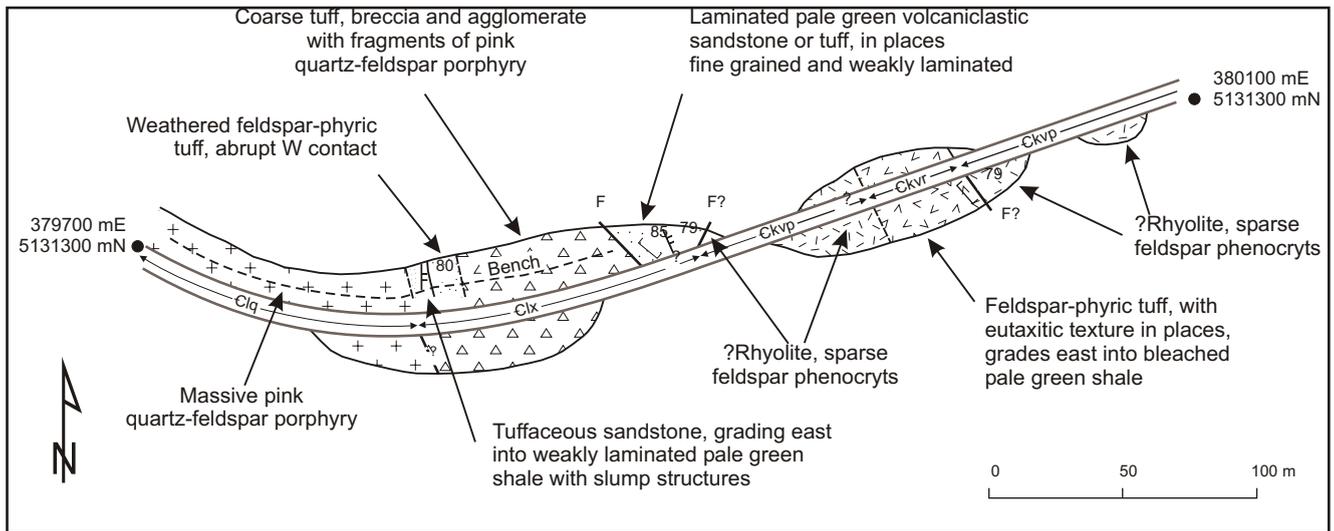


Figure 2

Diagrammatic plan of exposures in road cuttings along surge tunnel road near Newall Creek [379800/5331300], showing Clx and associated units.

publication of the map) exposes a section through this unit (fig. 2). To the west, the cutting intersects massive, pink quartz-feldspar porphyry (Clq), probably largely of igneous origin but exhibiting in the topmost (eastern) few metres an ill-defined fragmental texture. This is overlain by tuffaceous sandstone with weakly laminated green shale (possibly a fine-grained vitric ash tuff) at the base of Clx, followed conformably by a thick (approximately 50 m) unit of coarse tuff, breccia and agglomerate with fragments of pink quartz-feldspar porphyry. Then follows a faulted interval of pale green laminated fine-grained volcanic sandstone or tuff. The eastern contact of this latter unit with feldspar porphyry of the Central Volcanic Complex appears to be a fault.

Nearby road cuts on the Mount Jukes Road near Newall Creek [379600/5331000] provide further good exposure of this unit. Medium to coarse-grained pale green volcanoclastic sandstone, in one spot containing scattered, angular dark grey mudstone intraclasts, occurs about 100 m south of the Newall Creek bridge. Further south there is considerable coarse-grained, lithic-crystal tuff, breccia and probably agglomerate, grading up into a few metres of fine-grained, bedded volcanic sandstone or tuff at the southern end of the exposure, about 400 m south of the bridge.

GARFIELD RIVER AREA

A number of sedimentary units (Clx) were mapped on the interfluvium between Thomas Currie Rivulet and the Garfield River within an area dominated by quartz-feldspar porphyry (Clq).

The Clx unit at 379700/5325700 is strongly cleaved and is mainly a slightly pyritic, pale green phyllite. Westward, the unit includes coarse lithic-crystal tuff and minor volcanoclastic sandstone. One unusual outcrop consists of fine grained siliceous nodule-like bodies several centimetres in size, crowded together in a phyllitic foliated groundmass — possibly a fine vitric-ash tuff with mesoscopic devitrification structures.

The unit of Clx exposed in the Garfield River [at 379000/5326000] dips and faces west, towards an apparently conformable contact with an overlying Tyndall Group correlate. This unit consists predominantly of green to grey, banded (laminated) mudstone and fine-grained (<1 mm), bedded or massive tuff or tuffaceous sandstone. At a few horizons the tuffaceous sandstone contains large (200 mm) ragged or lenticular fragments of black mudstone and dark green (chloritic?) quartz-feldspar porphyry (the latter possibly compacted vitriclasts). The laminated mudstone locally includes thin, weakly graded, fine-grained sandstone beds with laminated tops and load-casted bases giving westward-facing directions. The sequence also includes minor coarse-grained volcanoclastic sandstone.

Within Clx there are also units of massive quartz-feldspar phytic rock, similar to Clq, 100 mm to 10 m thick, conformable and gradational with enclosing mudstone and sandstone, that are probably crystal tuffs. The thickest of these occurs in the small tributary at 379200/5325600, where a tuff, approximately ten metres thick, gradationally overlies grey mudstone and lithic fragments are present in the lower 300 mm; the top of the unit grades into fine-grained volcanic sandstone.

Several small, probably intrusive bodies of resistant, massive quartz-porphyry were noted in the Garfield River. Two of these [at 379100/5325900 and 379200/5325700] appear to transgress bedding. The remaining three occur close together [around 378800/5326400] and are of tabular form, conformable or only slightly transgressive with the enclosing bedded fine-grained tuff and sandstone, and are each roughly two to five metres thick. Thin sections show phenocrysts of muscovite, altered biotite and feldspar as well as quartz, and an incipient microspherulitic texture in the groundmass (R009573).

The remaining small areas of Clx indicated on the map east of the Garfield River are composed of grey to green shale, siltstone and minor sandstone. Possible grading in the unit at 379300/5326400 suggests east facing.

Central Volcanic Complex

Introduction

South of the King River and north of Mt Jukes, rock distribution and facing evidence in the Central Volcanic Complex indicate a major SSW-plunging syncline of pre-Owen Group age. A large area of pyroclastic rocks (Ckvr) occupies the core of the syncline [381600/5331900], with porphyry (Ckvp) overlain by epiclastic rocks (Ckx) on both limbs [380000/5331000; 382500/5331500].

South of Mt Jukes there is a broad eastern belt of feldspar porphyry (Ckvp) extending from Intercolonial Spur [383000/5326000] to Garfield Cirque [383000/5322000], and a western belt of pyroclastic rocks (Ckvr). Facing evidence here is scant. The pyroclastic rocks appear to have a transitional or interfingering relationship with the porphyry. To the east there is a steep, abrupt boundary (partly or wholly faulted) with the Eastern sequence (Cfu). To the west, the Central Volcanic Complex overlies, with at least structural conformity, the Western Volcano-sedimentary sequence in the King River–Newall Creek area and possibly also the Thomas Currie Rivulet area.

Felsic feldspar porphyry intrusive and extrusive rocks (Ckvp)

INTRODUCTION

Occurrences of unit Ckvp south of the King River and at Intercolonial Spur consist essentially of a tough, rather uniform, massive, sparsely phyrlic feldspar porphyry that lacks cleavage or is only weakly cleaved. Phenocrysts comprise less than 10% of the rock, and are sparse in comparison to the crystal content of rocks mapped as pyroclastics (Ckvr). The rock is pink to purplish-grey, less commonly greenish-grey in colour. Weathered outcrop surfaces often have a distinctly granular or 'sandy' texture that is resolvable in thin section as a spherulitic or snowflake (Anderson, 1969) devitrification texture.

KING RIVER–PROPRIETARY PEAK AREA

The body of Ckvp north of Proprietary Peak [383000/5331000], on the eastern limb of the major syncline, is well exposed in cuttings on the Mount Jukes Road and in the King River gorge. Polygonal columnar jointing is well exposed on the road and plunges steeply southeast. The rock is predominantly a pale grey-brown colour but the eastern part of this body has undergone extensive chloritic alteration and is green, weathering to brown. The entire area appears to be characterised by a well-developed snowflake texture that produces a distinct 0.25 mm granularity on weathered outcrop surfaces.

Thin sections (R009612, R009615) show sparse plagioclase phenocrysts and a groundmass with snowflake texture — manifested under crossed nicols as a mosaic of merging, equant patches, each more or less optically continuous, of turbid quartz, 0.2–0.3 mm in size, enclosing scattered smaller random feldspar microlites (Plate 1). In R009612 some snowflakes have an incipient spherulitic structure with differentiation of clear quartz cores and turbid rims.

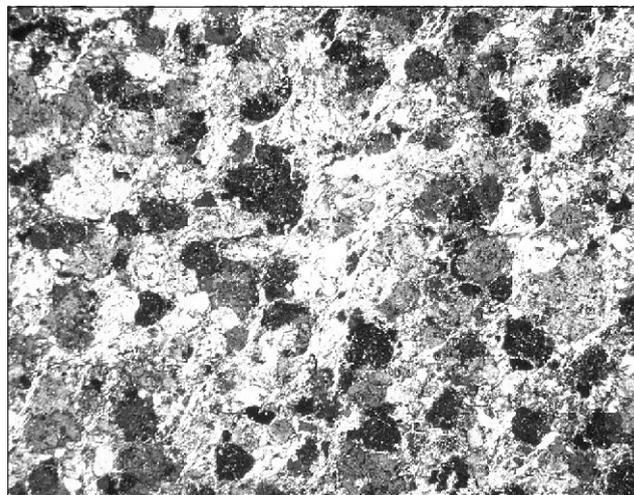


Plate 1

Photomicrograph (crossed nicols) of snowflake-textured rhyolite of unit Ckvp. Thin section R009615 [382700/5331200].

The area of Ckvp shown on the map should be extended northwards to include the undifferentiated volcanic rocks in the King River gorge between 383400/5332000 and 382700/5332400. Outcrops here are snowflake-textured porphyries essentially identical to those on the Mount Jukes Road.

On the western limb of the syncline, feldspar-porphyry near Newall Creek [380000/5331000] is an uncleaved, tough, well-jointed red porphyry with abundant quartz veins up to one metre wide. A thin section shows sparse feldspar phenocrysts in a microspherulitic groundmass. The spherulites are clearly differentiated in plane light as clear, round patches almost wholly of quartz and free of fine opaques, 0.2 to 0.3 mm in diameter, each showing a faint concentric or radial structure and exhibiting, under crossed nicols, strongly undulose extinction. A small body of Ckvp [at 380500/5332400] is a tough pink rock that shows in thin section an ill-defined, incipient snowflake groundmass texture intergrown with abundant, felted plagioclase microlites.

In the King River gorge, most outcrops shown on the map as undifferentiated volcanic rocks (Ckvu) [west of 381800/5332900] appear to be feldspar porphyry mappable with Ckvp. The predominant rock type is a tough, pale grey-green, rather uniform, sparsely phyrlic weakly-cleaved porphyry. At 381800/5332900 the porphyry appears as discrete, close-packed pods about 100 mm wide separated by cleaved, phyllitic layers. A similar rock is described from 381600/5333000 by Corbett (1976c). Small quartz phenocrysts occur further west [at 381400/5333100]. Columnar jointing was noted nearby by Corbett (1976c). Thin sections (75-435, 75-436) from near here show sparse, small (1 mm) plagioclase phenocrysts in a groundmass showing an incipient, fine-grained (0.1 mm) snowflake texture somewhat similar to the eastern (Proprietary Peak) porphyry body described above.

INTERCOLONIAL SPUR

Feldspar porphyry crops out extensively at Intercolonial Spur around 383000/5326000. This rock is a potassic

rhyolite (Wade and Solomon, 1958). This massive pink rock contains irregular wisps and splotches of chloritic green foliated material, and irregular veins of hematite are common. Minor sulphide-bearing quartz veins were observed to the west [at 382200/5327100]. A thin section (R009579, from 382200/5326100) shows about 5% plagioclase phenocrysts, tending to occur clumped together in glomerophyric aggregates of three or four grains, together with minor chlorites and opaques (possibly after hornblende). The groundmass has a microspherulitic texture and quartz microphenocrysts, many of which are polycrystalline and probably secondary. The rock displays an unusual mesoscopic spherulitic texture around 381600/5326300. The spherulites are conspicuous in outcrop as lighter coloured bodies about 5 mm in diameter. In thin section (R009601) these are seen to be clearer patches characterised by snowflake texture, in a more turbid cryptocrystalline matrix. Each spherulite is centred on a feldspar phenocryst or on a lenticular core of clear secondary quartz. Microspherulites, 0.25 mm in size, are scattered through both matrix and snowflake-textured zones. Formation of snowflake texture apparently post-dated microspherulite formation. This complex fabric suggests rather subtle controls on the degree and style of devitrification. Suggestions of a similar fabric are present in the porphyry body near Newall Creek [380000/5331000] where some feldspar phenocrysts have diffuse, lighter-coloured haloes in outcrop.

The boundary of the Intercolonial Spur porphyry body with pyroclastic rocks (Ckvr) to the west appears to be transitional or interfingering. Rock distribution data are limited to creek traverses. Outcrop in the creek between 381600/5326300 and 382400/5327300 is predominantly porphyry (Ckvp) with minor pyroclastic rocks (Ckvr); the next creek west exposes [between 381300/5326600 and 382300/5327400] predominantly Ckvr and lesser porphyry. The boundary as shown on the map therefore appears to be broadly transitional. Rare compositional layering in Ckvr strikes across this boundary [e.g. 381800/5326900], suggesting east-west interfingering of the two units.

Dominantly feldspar-phyric pyroclastic rocks (Ckvr)

INTRODUCTION

Unit Ckvr consists predominantly of unbedded, crystal-vitric and vitric tuffs — mostly ash-flows — with minor lavas and rare epiclastic rocks (shale and mudstone). Excellent exposures of Ckvr are available along the Mount Jukes Road and in the King River gorge.

A broad belt of rock assigned to Ckvr extends from the King River [382300/5332600] south to Thomas Currie Rivulet [381000/5325000]. As previously mentioned, the northern part constitutes the core of a south-plunging major early syncline. South of the Owen Group outlier on Mt Jukes, bedding and facing determinations are scant. Most of the few bedding determinations dip south or southwest and are right-way-up [381800/5328100; 380000/5328000 — the latter not indicated on the map]. In this area Ckvr probably has an interfingering or transitional relationship with Ckvp to the southeast (see previous section).

SOUTH OF THE KING RIVER

The predominant and characteristic rock type is a well cleaved grey-green rock that is feldspar-phyric and fine grained. Phenocrysts tend to be more abundant (estimated up to 50%, usually 20–30%) than in the igneous porphyries (Ckvp) described above. The groundmass, relatively rich in fine-grained phyllosilicates (chlorite and sericite), in places preserves fiamme or eutaxitic texture but these are generally obscured by alteration and cleavage. Fiamme typically appear as darker diffuse ragged clots or wisps a few millimetres to several centimetres in length and sometimes containing a scattering of feldspar phenocrysts. More distinct than the vitriclasts, but much sparser, are lithic fragments — the most conspicuous being resistant, competent white or pink chert-like clasts (fine-ash tuff?) that are 5 to 30 mm, rarely 100 mm, in diameter. Compositional banding is seen in a few places [e.g. 380500/5330800, Mount Jukes Road]. Compositional banding is usually faint, streaky or impersistent. Slumped and convoluted compositional layering was noted in the King River gorge at 382400/5332500.

Limited field and petrographic evidence suggests that these rocks are vitric or crystal-vitric tuffs, probably mostly ash flows. Phenocrysts (crystals) are of sodic plagioclase, altered (sericitised) to varying degrees, and frequently appear fragmented. Minor quartz is rarely present (R009603). In thin sections the matrix consists mainly of devitrified glassy lapilli-sized fragments and shards, their boundaries generally obscured by alteration and cleavage. Vitric fragments are often flow banded, and a vesicular fabric is commonly preserved despite recrystallisation and deformation. Chlorite occasionally replaces fiamme and vesicular texture may survive such replacement. In sample EJI, most of the matrix has an indistinct secondary microspherulitic overprint, probably due to devitrification. In several thin sections (R009606, R009608, EJI, 76-415) some feldspar phenocrysts are partly or totally surrounded by a halo of less turbid, clearer devitrified glass in which vesicles appear particularly well preserved. It appears that the crystals had a partial or complete coating of frothy glass at the time of deposition (Plate 2). A finer-grained variant (R009607) has a glassy devitrified groundmass crowded with indistinct shards. Tectonic cleavage generally consists of strongly developed, anastomosing sericitic seams.

Poorly cleaved, resistant, uniform rocks that are sparsely phyric and usually pink, are present in Ckvr. These rocks are similar to the feldspar porphyries (Ckvp); but because rocks of transitional appearance are common, and because outcrop is generally inadequate, these occurrences have not been differentiated on the map. Limited petrographic work suggests that this rock type, like Ckvp, is predominantly igneous, although one massive pink rock (R009597) appears to be a vitric tuff in thin section (see above). A southeastward increase in abundance of this rock type, in the area mapped as Ckvr south of Mt Jukes, suggests a broadly transitional or interfingering relationship of Ckvr with the Intercolonial Spur rhyolite body (see previous section).

Thin sections of these porphyries show phenocrysts, 1 to 2 mm in size, of plagioclase, often clumped together as

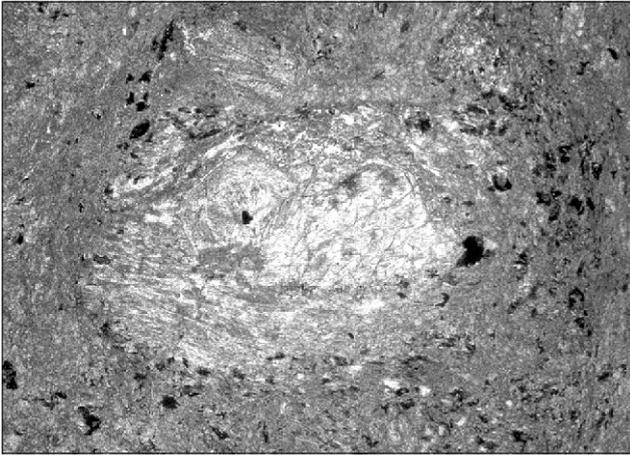


Plate 2

Photomicrograph (plane polarised light) of plagioclase phenocryst with micro-flow-banded (tube pumice?) glassy rim, in altered sericitic groundmass, unit Ckvr. Thin section EJ1.

glomerocrysts. Sample R009563 from Thomas Currie Rivulet [380700/5325700] contains patches of chlorite and opaque minerals probably after phenocrystic hornblende. Minor quartz phenocrysts accompany feldspar at 380700/5328000. The rocks lack the well developed spherulitic or snowflake groundmass textures of the large, mapped igneous porphyry bodies (Ckvp). Typically, these rocks display a uniform groundmass of granular quartz and phyllosilicates, some with a flow banding not apparent in outcrop (EJ2, R009602, R009599). In some cases the groundmass has an incipient snowflake texture (R009563, R009600) or a patchy microspherulitic devitrification texture (R009599). Sample R009600, an altered vesicular lava, contains abundant flow-stretched vesicles, filled with sparry quartz, that are parallel to ill-defined flow banding in outcrop [indicated on the map at 382600/5327600]. Accidental lithic fragments, up to 150 mm long, of mudstone were noted at this locality.

A thin section (75-422) from near the base of Ckvr in the King River gorge [382500/5332400] also appears to be a vesicular, sparsely feldspar-phyric igneous rock. Ovoid to irregular patches of void-filling sparry quartz cement probably represent filled vesicles and comprise a few percent of the rock. The groundmass contains faint, scattered pinkish devitrification spherulites.

There are rare agglomerates in Ckvr. Coarse, monomictic agglomerate composed of feldspar porphyry blocks occurs at 380200/5326200 (Thomas Currie Rivulet). Polymictic agglomerate and coarse lithic tuff are interbedded with red and green slate and siltstone around 381600/5328100 just below West Jukes Peak. In the Newall Creek area polymictic agglomerate containing rare quartz-phyric clasts is well exposed in road cuts at 380300/5330000. Open-framework agglomerate occurs in the King River gorge [at 382400/5332500], with clasts mostly of pale cherty rhyolite and some banded, fine-grained vitric-ash tuff. Isolated outcrops of shale, siltstone and sandstone were noted at 379300/5327300; 380000/5328000 and 381800/5328200. Graded bedding gives east, west, and west-facing respectively at these localities. A thin section (R009578) shows interbedded muscovitic quartz siltstone

and mudstone with a few zircon grains scattered along the base of a graded layer.

ALTERATION IN Ckvr

Hematitic alteration close to the base of the Owen Group is thought to be due to pre-Owen weathering and is indicated on the map as palaeoregolith (pr). An extensive area of feldspar-phyric volcanic rocks (Ckvr) has undergone this type of alteration south of Mt Jukes [around 382000/5328000]. The rocks (tuffs, lavas, agglomerates) have a pervasive purple pigmentation due to finely disseminated hematite, and feldspars are completely altered to pale green sericite (R009600, R009641).

Sericitic alteration, and some silicification, is present in the Newall Creek area [380000/5330200 – 380300/5330100 – 380200/5329000]. Road cuts at 380000/5330200 expose strongly foliated, sheared and highly altered volcanic rocks. In thin section (R009614) the rock is wholly replaced by secondary fine-grained quartz, sericite and chlorite. A thin section of a crystal tuff in nearby Newall Creek (R009586) shows plagioclase crystals with sericitised rims set in a matrix mainly of fine sericite. Similar silicified, sericitised rocks occur immediately beneath Pioneer Sandstone around 380200/5329000.

Undifferentiated Feldspar-phyric Volcanics (Ckvu)

Undifferentiated feldspar-phyric volcanic rocks (Ckvu) are indicated near the King River [380500/5332000]. South of the King, vitric tuff occurs around 380600/5332400 (R009616) while further south, massive pink rock with a spherulitic groundmass — assignable to Ckvp — crops out at 380700/5332000. As previously mentioned, outcrop in the King River gorge [between 381400/5333200 and 381800/5332900, and between 382700/5332400 and 383400/5332000] appears mostly to be assignable to Ckvp.

Bedded tuff, siltstone, mudstone, agglomerate (Ckx)

SOUTH OF KING RIVER

Units mapped as Ckx south of the King River all consist predominantly of two lithologies (fine ash tuff, usually layered, and coarser (lapilli) tuff) interlayered on a scale of decimetres to tens of metres. There are minor fine-grained epiclastic rocks and rare agglomerate. Areas of Ckx near Newall Creek [380300/5331300] and along strike in the King River [381700/5333000] dip and face southeast; probably the same unit dips and faces west on the opposing limb of the syncline [at 382600/5332400 to 382300/5331500]. A road cut section through much of Ckx on the Mount Jukes Road [at 382300/5331500] is shown in Figure 3. West and south of Intercolonial Spur there are several areas of Ckx shown on the map. The inter-relationships are poorly known because of incomplete mapping and lack of facing evidence (overturned bedding shown at 382100/5325900 is incorrect and should be facing unknown).

The fine-grained (<1/16 mm) tuffs are white to pale green or grey in colour, are mostly aphanitic, often chert-like, and are

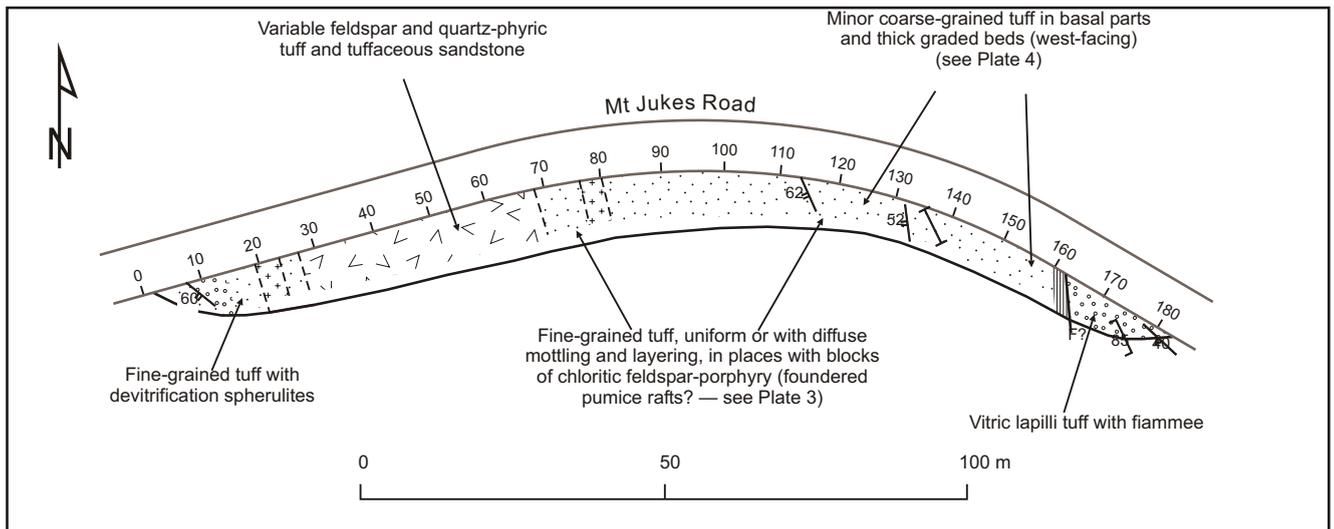


Figure 3

Plan of road cut exposure of Ckx on Mount Jukes Road at 382300/5331500.

frequently massive but usually bedded, suggesting a predominantly water laid ash-fall origin. Layering is generally in the form of planar, thin bedding or lamination and is often rather diffuse and ill-defined. Grading of thin beds, and erosional truncation of laminae provide eastward-facing evidence near Newall Creek. In places, compositional layering in fine-grained cherty tuff is manifested as darker, often diffuse thin shaly layers that anastomose, suggesting a partly secondary origin, perhaps related to devitrification and/or compaction. Transitionally interbedded with the tuffs are fine-grained, probably tuffaceous sandstone and siltstone, that exhibit better layering, better sorting and a more quartz-rich composition than the tuffs. At several localities [382700/5327400; 382300/5330700, Mount Jukes Road — fig. 3] particular beds of fine-grained tuff contain abundant, conspicuous spherulites 5–15 mm in diameter that appear to have a more siliceous composition than the surrounding rock. These structures have diffuse, merging boundaries and no concentric structure, and are therefore probably devitrification features rather than lithic fragments

or accretionary lapilli. A thin section (R009647) from Mount Jukes Road shows a fine-grained vitric ash tuff composed of broken shards and small pumice fragments, with a strong cleavage of anastomosing sericitic seams, with the spherulites being differentiated by a higher proportion of secondary quartz. Fine-grained tuffs on Mount Jukes Road contain, at two or three horizons, large (300 mm) ragged or lenticular masses of dark, vitric porphyry — apparently compacted large vitriclasts — that possibly originated through foundering of pumice rafts (plate 3; fig. 3).

The relatively coarse grained tuffs ($>1/16$ mm, usually 2–20 mm) in Ckx are generally ill-sorted, massive and somewhat altered rocks, similar to Ckvr. Crystal (feldspar, and quartz in places — e.g. Mount Jukes Road, fig. 3), vitric and lithic components are generally present. Dark, wispy compacted vitriclasts, 5–50 mm long (fiamme) are conspicuous and are often crowded with feldspar phenocrysts. More equant, white to pink fine-grained lithic fragments are present. A thin section of a vitric lapilli tuff from west of Intercolonial Spur [382100/5325900]



Plate 3

Large vitriclasts(?) in fine-grained tuff, unit Ckx, Mount Jukes Road [382300/5331500].



Plate 4
*Coarse-grained tuff abruptly overlying
 thin-bedded, fine-grained tuff,
 unit Ckx, Mt Jukes Road
 [382300/5331500].*

(R009643) consists mostly of flow-banded and pumiceous vitric fragments, with minor (10%) feldspar crystals and minor secondary chlorite. Rarely diffuse, poorly defined layering is developed, and the coarse tuffs are interlayered with the finer tuffs described above with both abrupt and transitional boundaries. Coarse tuff units with sharp, irregular basal contacts with fine tuff suggest west-facing on Mount Jukes Road (plate 4; facing direction not indicated on map). Similarly [at 382800/5327400], lenses of coarse lithic tuff in fine-grained tuff have sharp bases and diffuse tops.

A section in the King River gorge [382600/5332400] consists of (from east to west) thin-bedded, crystal-vitric tuffs, in places with scattered cherty blocks, succeeded at 382600/5332400 by a 15 m thick unit of laminated, cherty mudstone and siltstone. Convolute lamination and probable ripple bedforms indicate west-facing. The laminated cherty unit passes westward back into predominantly fine-grained tuffaceous rock, largely massive but with rare textural layering. One thin section from this interval (75-421) appears to be a snowflake-textured porphyry similar to Ckvp to the east.

Agglomerate with equant, rounded siliceous aphanitic clasts and ragged, lenticular probable vitric clasts with a preferred orientation at a high angle to cleavage occurs around 382300/5330700. Minor dispersed sulphide mineralisation occurs at 382400/5326600.

Black mudstone, siltstone and sandstone (Ckm)

NEWALL CREEK AREA

A unit of epiclastic rocks assigned to Ckm overlies volcanic rocks (Ckvr) in the Newall Creek area [380300/5329000 to

380500/5330000]. These rocks are folded and cleaved, but predominantly dip and face eastwards. The basal contact with Ckvr was not observed. To the east, the sequence is covered by surficial boulder deposits (Qpto) and is probably unconformably overlain by Owen Group rocks.

The unit is well-exposed in road cuttings and in nearby Newall Creek. The lower part (exemplified by road cut exposures at 380400/5330200) is black, well-cleaved mudstone with minor laminae and thin beds of pale micaceous siltstone and fine-grained sandstone. The mudstone weathers to white or green. Small-scale load casting and weak grading is apparent in some of the sandy layers.

Up Newall Creek, south of the road, sandstone and siltstone become more significant, constituting about 50% of the outcrop at 380500/5330000 where a three metre thick bed of very coarse-grained massive volcanoclastic sandstone occurs. In thin section this rock consists of sub-rounded fragments of quartz-rich chert-like felsic volcanic rocks, including snowflake-textured rhyolite, and about 10% volcanic quartz. No Precambrian component (metamorphic quartz or quartzite) is present. This thick bed of coarse sandstone is overlain by a few metres of volcanoclastic sandstone and mudstone (with graded beds 0.5 to 0.1 m thick); followed by medium to thin-bedded fine-grained muscovitic quartz sandstone, of the order of 30–50 m thick. Some quartz sandstone beds appear to be bioturbated, a few are graded, and black mudstone interbeds are present.

Other creek sections to the south [380300/5329600; 380300/5329000] are similar to Newall Creek, predominantly consisting of mudstone and fine-grained sandstone, with minor coarse volcanoclastic sandstone beds.

Tyndall Group

Introduction

The Tyndall Group represents the final phase of Cambrian volcanic activity. It overlies, in most places unconformably, the older volcanic sequences (Central Volcanic Complex, Western Volcano-sedimentary Sequence) (Corbett *et al.*, 1974; Corbett, 1989). The Tyndall Group overlaps Precambrian basement at Marble Bluff. Occurrences east and west of the West Coast Range may represent two separate, or partly separate, meridional basins of deposition, as Owen Group rocks rest unconformably on older (pre-Tyndall) volcanic rocks along the axis of the West Coast Range. White and McPhie (1996) described the stratigraphy and palaeovolcanology of the Tyndall Group, and revised the stratigraphic nomenclature. There are four main areas of outcrop on Lyell map sheet.

(1) The Sedgwick–Lyell–Comstock area

The lower, pyroclastic part of the sequence (Comstock Formation) includes a thin fossiliferous limestone dated as late Middle or early Late Cambrian (Jago *et al.*, 1972). The upper, volcanoclastic part of the sequence, the Zig Zag Hill Formation (White and McPhie, 1996; equivalent to the Dora Conglomerate of the Tyndall Range: Bradley, 1954; Baillie, 1989) is succeeded conformably and transitionally by Owen Group on the eastern end of Mt Lyell (Corbett *et al.*, 1974) and has an apparently conformable relationship with the Owen east of Mt Sedgwick (Corbett, 1979, p. 59). Rare Precambrian-derived metaquartzite detritus is present in the Zig Zag Hill Formation and its correlates. The Sticht Range Formation (Corbett *et al.*, 1974; Baillie, 1989), of Middle to Late Cambrian age, is at least in part a facies equivalent of the lower part of the Tyndall Group (Baillie, 1989) and is largely of Precambrian-derived quartz-rich sandstone and rests unconformably on Precambrian rocks at Marble Bluff. The Owen also overlaps Dora Conglomerate in a westerly direction, resting directly on the Central Volcanic Complex west of Mt Sedgwick, suggesting a rather narrow meridional basin of deposition for the Tyndall Group, at least to the north of the Sedgwick Valley.

(2) The Lynchford area

A correlate of the Comstock Tuff overlies, with apparent conformity, rocks of the Western Volcano-sedimentary Sequence, and is unconformably overlain by the Pioneer Sandstone.

(3) The Flannigans Creek area

A correlate of the Zig Zag Hill Formation overlies, with apparent conformity, the Western Volcano-sedimentary Sequence. This unit appears to thicken rapidly to the west and south. In the northern part of the area it is overlain, probably with a gently angular unconformity, by a unit correlated (see below) with the Pioneer Sandstone. To the south, it is overlain conformably and transitionally by Owen Group.

(4) Eastern flank of the West Coast Range

A fourth major area, consisting of the eastern flank of the West Coast Range between Mt Huxley and Mt Darwin, is

occupied by a correlate of the Tyndall Group. This was shown as 'Eastern sequence' by Corbett (1979), and is shown as Cfu on the Lyell map sheet. This unit has a steep, and for the most part probably faulted boundary with the older volcanic rocks except south of the map sheet at Mt Darwin, where the relationship is unconformable (Corbett, 1976a). The relationship with the Owen Group is an inferred unconformity (D. B. Seymour).

Correlate of Zig Zag Hill Formation (Ctd)

GARFIELD RIVER–FLANNIGANS CREEK AREA

In the Garfield River–Flannigans Creek area [379000/5322000 to 378500/5326000], a lithologic correlate of the Zig Zag Hill Formation (Ctd) occupies a major synclinal structure, and conformably underlies Owen Group in the core of the fold. The sequence is faulted against a thick Owen Group correlate to the west and overlies, with apparent conformity, rocks belonging to the Western Volcano-sedimentary Sequence to the east. The sequence extends southward beyond the boundary of the map sheet at least as far as Mt Sorell, where a thick sequence of volcanoclastic conglomerate underlies, probably transitionally, a correlate of the Owen Group (Corbett, 1976a).

The predominant rock type shown as Ctd in this area is a coarse to very coarse-grained, massive or poorly-bedded volcanoclastic sandstone. This rock type is grey-green in colour and weathers to brown or white. The sandstone is moderately to poorly sorted, commonly with abundant dark green chlorite (as replacement of grains or matrix or as a secondary cement) and contrasting grey, green and white volcanic fragments. Rarely, beds are graded. The sandstone usually contains sparse, rounded pebbles (rarely, cobbles) of resistant volcanic lithologies and metaquartzite (of Precambrian derivation). Conglomerate is common, and is usually open framework, rarely closed framework. Volcanic clasts are pink, white or green quartz and quartz-feldspar porphyries, and chert-like vitric-ash tuffs.

The metaquartzite component is minor (usually less than 5% of clasts) and shows no particular preferred lithostratigraphic distribution, except for a greater relative abundance (10 to 30% of clasts) in several metres thickness of conglomerate and pebbly sandstone overlying a porphyry unit (Ctdq) [between 378500/5325300 and 378500/5325000].

Thin sections of coarse sandstone and fine conglomerate (R009567, R009568, R009571, R009572, R009590, R009593, R009594) show around 10% volcanic quartz. Plagioclase is abundant in some rocks but absent in others. The dominant constituent is fine-grained felsic volcanic rock fragments; largely cherty vitric ash tuff, quartz and quartz-feldspar porphyries, and probably rhyolites with spherulitic or snowflake devitrification textures resembling those of the Central Volcanic Complex. A few clasts are replaced by chlorite in R009571. Rare metaquartzite clasts are present in some sections. The rocks have little or no matrix. Porosity is occluded by deformation (compactive and tectonic) of lithic grains. Unreworked pyroclastics are rare (see below). Even the most immature sandstones

(R009571, R009593), which are rich in fragmental plagioclase and volcanic rock fragments, show rounding of some grains and contain rare metaquartzite grains, testifying to some reworking and incorporation of extrabasinal material. Sample R009593 contains abundant (10–20%) secondary chlorite, and common, distinctive lenticular fragments of pink feldspar porphyry which has a turbid, cryptocrystalline, possibly vesicular glassy groundmass. There is a single basic or intermediate volcanic rock fragment consisting of felted altered plagioclase laths.

Mudstone, siltstone and fine-grained pale green lithic sandstone are present as minor interbeds throughout the sequence, and also locally as intervals several metres in thickness. The greatest development is a 40 m thick interval in Flannigans Creek [at 378700/5325100] underlain and overlain by massive volcanoclastic coarse sandstone. This unit consists of grey slate with abundant thin planar laminae of lighter coloured siltstone and sandstone. Many laminae are graded, load casted, or exhibit erosional bases and planar tops (giving eastward-facing directions). There is minor syn-sedimentary slumping. Sandy layers are thicker (20 mm) towards the base of the unit. Similar occurrences, probably belonging to the same unit, crop out along strike to the south [at 378700/5324600 and 378800/5324100] and to the north [at 378600/5325800].

A conformable unit of quartz-feldspar porphyry (Ctdq) within Ctd is indicated [378400/5325800 to 378400/5325200]. This unit, of the order of 20 m in thickness, has a strongly cleaved, pale green, phyllosilicate-rich (almost phyllitic) groundmass with about 20% quartz and feldspar phenocrysts up to about 3 mm in size. There are diffuse chloritic wisps suggestive of fiamme and rare lithic fragments. The unit is probably a crystal-vitric tuff.

A metre-thick unit of bedded vitric tuff occurs within conglomerate at 378500/5324800. A thin section (R009640) shows about 25% crystals of quartz and feldspar, and flow-banded, vitric fragments, in an abundant devitrified glassy matrix of compacted shards and secondary chlorite.

An attenuated sequence of Ctd appears on the eastern (west-facing) limb of the syncline, and is well exposed in the Garfield River around 378700/5326400. Ctd is about 100 m thick here. The basal contact of Ctd upon Clx (Western Volcano-sedimentary Sequence) is taken as the abrupt, conformable contact of fine-grained green volcanoclastic sandstone (Ctd) upon black mudstone, thinly interbedded with sandstone (Clx), at 378775, 5326375. The section exposed in the river bed to the west consists of (with approximate stratigraphic thicknesses) at the base, fine-grained volcanoclastic sandstone (10 m) grading up into very coarse, immature, massive tuffaceous chloritic sandstone with sparse, rounded pebbles and rare cobbles, mostly of resistant felsic volcanic rock types but with a few of orthoquartzite (20 m); laminated, chert-like, probably fine vitric-ash tuff interbedded with shale, the former a more competent lithology exhibiting bedding-perpendicular quartz veins (6 m); open-framework pebble-cobble conglomerate (again mostly volcanoclastic but with a minor metaquartzite component); passing up through pebbly sandstone to a pebble-free, immature, coarse tuffaceous sandstone (50 m); overlain at 378575,

5326350 by a correlate of the Pioneer Sandstone. Upstream of this section a westward bend in the river again intersects Ctd at 378850/5326200. Here about 20 m of volcanoclastic conglomerate, coarse sandstone and mudstone crops out. The base is not exposed, possibly with the exception of an outcrop upstream at 378950/5326150 where a sandstone, possibly belonging to Ctd, rests with a highly irregular contact with about one metre of erosional relief, upon laminated fine-grained tuff of Clx.

The Zig Zag Hill Formation correlate of the Flannigans Creek–Garfield River area is lithologically very similar to Osv, the volcanoclastic sandstone at the base of the Denison Group correlate west of the Mt Strahan Fault. Overall, Ctd is generally more immature, both in texture and composition, and richer in conglomerate than Osv.

Quartz-feldspar phyric pyroclastic rocks, lavas, volcanoclastic rocks (Cfu)

SOUTH JUKES PEAK AREA

Unit Cfu is faulted against the massive rhyolite (Ckvp) of Intercolonial Spur west of South Jukes Peak. Adjacent to the fault [at 383300/5326800], the rock appears to be a cleaved, crystal lithic tuff with abundant feldspar and quartz with fragments of quartz porphyry, feldspar porphyry and chert-like lithologies (rhyolite or fine vitric tuff). On the col between South Jukes Peak and Pyramid Peak [383200/5327400] there is extensive outcrop of a strongly cleaved, probably igneous quartz porphyry with a white to pink, uniform, finely granular groundmass. There are scattered small flakes of pale green sericitic material entrained in the cleavage direction that may represent an altered phenocryst phase. A thin section (R009577) shows 5–10% subhedral, rounded, embayed volcanic quartz phenocrysts (up to 3 mm in diameter), rare altered feldspar, chlorite replacing minor book-like crystals of muscovite or biotite, and wispy blebs of sericite in a uniform fine-grained groundmass rich in fine-grained sericite (related to cleavage), quartz and minor secondary carbonate.

KING RIVER GORGE

Unit Cfu is well-exposed in the gorge of the King River downstream of the dam [385300/5331300]. Between the fault [at 384100/5331700] and a point some 500 m downstream [383700/5331900], Cfu consists of strongly cleaved agglomerate, breccia and coarse-grained crystal vitric tuff. There is rare, ill-defined compositional layering in the tuff. The agglomerate and breccia are open-framework with fragments up to 300 mm in size of pink to white feldspar porphyry, quartz-feldspar porphyry and cherty fine-grained vitric tuff. One pinkish rhyolite fragment is crossed by hematite veins that pre-date incorporation of the clast in Cfu. The matrix is rich in quartz crystals (20–30%) that are purplish-tinted and up to 5 mm in size, and there are probable fiamme in places. Quartz-rich crystal vitric tuff, compositionally similar to the coarse pyroclastic rocks (but essentially free of bombs and blocks), crops out towards the western end of this interval. West of 383700/5331900, as far as the fault marking the western boundary of Cfu, the predominant rock type exposed in the gorge is a massive, poorly cleaved, resistant quartz-feldspar

porphyry, grey-green to pink in colour with a uniform, aphanitic or finely granular matrix. Abutting the fault on the northern side of the river [384300/5332050] is a large mass of uncleaved, resistant, pink, sparsely phyric porphyry — possibly a rhyolite plug — approximately 50 m wide at river level but appearing to widen upwards to roughly 150 m at a level 100 m above the river.

Owen Group and Pioneer Sandstone

Introduction

The term 'Owen Group' replaces 'Denison Group' of the Lyell map sheet legend. The Owen Group, of quartzose conglomerate and sandstone, records the widespread deposition of coarse detritus almost wholly of metaquartzitic (Precambrian) provenance in the Late Cambrian to Early Ordovician. The Owen Group in most places is unconformable on older rocks, but is transitional with Tyndall Group volcanoclastic rocks in many locations. Local unconformities occur within the Owen Group. The Owen Group is paraconformably, and locally unconformably overlain by the Middle Ordovician Pioneer Sandstone, which is now assigned to the Gordon Group (Corbett, 2001; Noll and Hall, 2003).

The Lyell map can be divided into three discrete areas that contain quite different Owen/Pioneer sequences (fig. 4) that are described separately below. There is no continuity of outcrop between the areas. The most complex and best-known area embraces the West Coast Range, the type area of the Owen Group. This area (fig. 4) can be further subdivided into a western part, where only the Pioneer Sandstone is present, and an eastern part where a much thicker and more complete sequence is generally preserved.

In the southwest corner of the map sheet, the thick siliciclastic sequence cropping out west of the Mt Strahan Fault, while in broad lithostratigraphic terms a correlate of the Owen Group, is sufficiently different to warrant a separate nomenclature. The third area extends over the eastern two-thirds of the map sheet, where a thin veneer of quartzose siliciclastic rocks rests unconformably on Precambrian basement of the Tyennan region, and is a probable correlate of the Pioneer Sandstone.

West Coast Range area

PREVIOUS WORK

The intimate association of Owen Group rocks with ore-bearing Cambrian rocks, particularly in the Mt Lyell mines area, has led to a long, if sporadic, history of previous investigation that is summarised below.

Officer *et al.* (1895) provided the first adequate definition and naming of the Owen Conglomerate, although observations had been recorded since 1862 (Banks, 1962). Hills (1914) described the sequence on Mt Jukes, subdividing it into the same five units (comprising the "West Coast Range Conglomerate series", including what is now known as the Jukes Conglomerate) as are recognised there on the Lyell map sheet; and describing the unconformable relationship with the underlying volcanic rocks. Hills and

Carey (1949) named the Jukes Breccia (Jukes Conglomerate of present usage), an impersistent basal volcanoclastic unit here treated as part of the Owen Group. Bradley (1954) recognised the local unconformity, now known as the Haulage Unconformity, and provided a broad regional synthesis of Owen stratigraphy. Bradley inferred a palaeogeographic high, the Dundas Ridge, in the western area where the Pioneer Sandstone rests directly on pre-Owen rocks. Banks (1962) described a type section and provided a palaeogeographic synthesis using mainly Solomon's (1957) data. Mapping by Solomon (Solomon, 1957; Banks, 1962; Wade and Solomon, 1958) resulted in a subdivision of the sequence that is similar to that used on the Lyell map sheet and an informal nomenclature: the 'lower Owen' (on the map legend equivalent to Oolc); the 'middle Owen' consisting of sandstone (Ools) overlain by conglomerate (Ooc); and the 'upper Owen' consisting of the 'chocolate sandstone' (Oos) below and the Pioneer beds (Oop) above. Below, to be consistent with recent usage (Corbett, 2001; Noll and Hall, 2003), unit Oos is referred to as the 'upper Owen sandstone' and Oop as the Pioneer Sandstone. Campana and King (1963), in a regional synthesis of tectonics and palaeogeography, suggested a rift valley setting for the deposition of the Owen Conglomerate, the graben being filled by terrestrial fanglomerates from the uplifted Tyennan block. Corbett *et al.* (1974) correlated the thin Owen in the western area with the Pioneer Sandstone and discussed relationships with the underlying Tyndall Group. Subsequent work by Corbett (1976a, b, c, 1979, 1982) elucidated the relationships at the base of the formation in many areas. Detailed mapping by Corbett and others (Mt Read Volcanics Project), mostly to the north of the Lyell Quadrangle, has resulted in the recognition of a number of widespread mappable units within the Owen, and complex facies and thickness variations. Important recent work on sedimentology and structural evolution has been undertaken by Noll and Hall (2003, 2005a).

The name 'Jukes Breccia' (Hills and Carey, 1949) or 'Jukes Conglomerate' was for a time applied to thick sequences of volcanoclastic rocks conformably underlying the Owen, including the upper part of the Tyndall Group (Corbett *et al.*, 1974). On the Lyell map and in other recent work (e.g. Corbett and Jackson, 1987; Corbett, 1979, p.53; Baillie, 1989), this name is used in a more restricted sense, more in accord with the originally-designated type area (see below), to refer to impersistent, discontinuous, coarse volcanoclastic units of local derivation that conformably or transitionally underlie Owen Group in many localities. The Jukes Conglomerate is treated here as part of the Owen Group.

RELATIONSHIPS WITH OLDER ROCKS

The Owen Group, as a rule, rests unconformably on pre-Tyndall Group volcanic rocks, a relationship exemplified by the type Jukesian Unconformity on the north face of Mt Jukes (Carey and Banks, 1954; Corbett, 1976b). The Owen is conformable and transitional with the Dora Conglomerate (Tyndall Group) at Garfield River (see below) and at the eastern end of Mt Lyell (Corbett *et al.*, 1974) and is paraconformable upon Dora Conglomerate

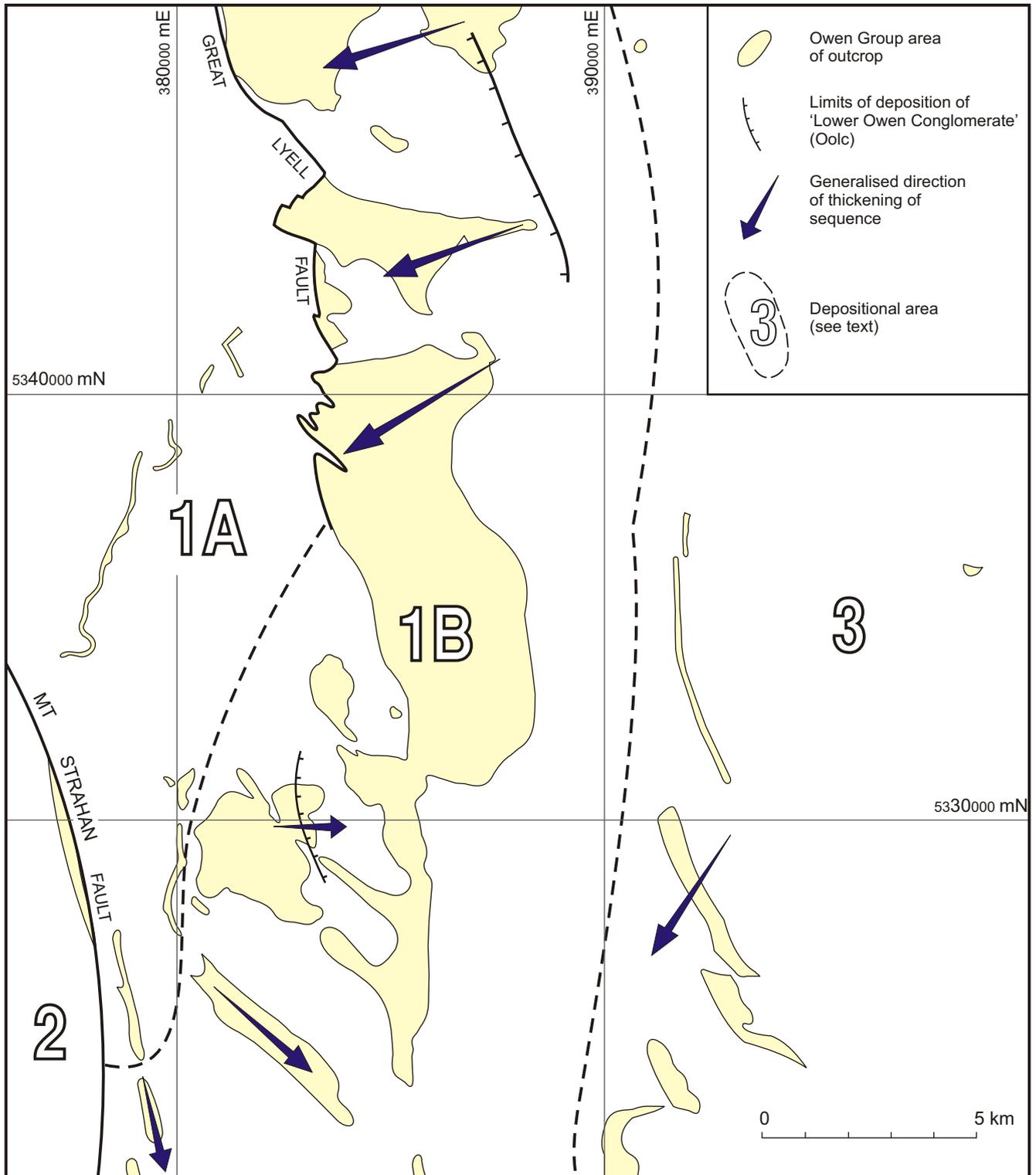


Figure 4

Regions of Owen Group–Pioneer Sandstone sedimentation. No palinspastic reconstruction.

Region 1a: Pioneer Sandstone (10–100 m thick), unconformable on Cambrian rocks.

Region 1b: Owen Group sequence (<1 km thick) conformable or unconformable on Cambrian rocks, generalised directions of thickening shown; limits of 'lower Owen conglomerate' (Oolc) indicated where known.

Region 2: Thick (1–2 km) Owen Group correlate present, conformable on probable Tyndall Group.

Region 3: Pioneer Sandstone correlate unconformable on Precambrian rocks.

east of Mt Sedgwick (Baillie, 1989). The Pioneer Sandstone rests unconformably on Tyndall Group at Lynchford (Corbett *et al.*, 1974) and at Garfield River the Pioneer Sandstone rests with paraconformity or gently angular unconformity on Tyndall Group (see below). On the eastern flanks of the southern part of the West Coast Range, south of Mt Huxley, the Owen overlies, with inferred unconformity, a Tyndall Group correlate (Fish Creek association, Cfu: D. B. Seymour).

The unconformity at the base of the Tyndall Group (Comstock Unconformity of Corbett *et al.*, 1974) appears to represent a more significant structural break than the local unconformity that separates Tyndall Group from Owen Group (Corbett *et al.*, 1974). The type Jukesian Unconformity represents a summation of the pre-Tyndall and Tyndall–Owen movements (cf. Solomon, 1979).

BASIN GEOMETRY AND SEDIMENTATION

The Owen Group, essentially comprising alternating quartzite-conglomerate and quartz sandstone, occupies a meridional belt roughly coincident with the Mount Read Volcanic arc and with the present-day West Coast Range. The formation is almost wholly of Precambrian metaquartzite provenance except for an impersistent basal volcanoclastic unit (Jukes Conglomerate), rare volcanic clasts in higher units, and some chert in the 'upper Owen sandstone' (Oos). Relatively sudden uplift of the Tyennan region, probably by faulting, is inferred (e.g. Wade and Solomon, 1958). The rocks are typically compositionally and texturally mature. A red, purple or pink, hematitic 'red-bed' pigmentation is characteristic.

Only the Pioneer Sandstone is present, resting directly on basement in the western area extending from the Garfield River in the south, to the Comstock valley and probably beyond. A major syndepositional fault, the Great Lyell Fault, defines the western limit of the Owen Group in the Mount Owen–Philosophers Ridge–Mt Lyell area. The fault is generally assumed to represent the western margin of a graben but the relative importance of non-deposition versus erosion in the disappearance of the Owen Group west of the fault is uncertain (Arnold, 1985). The nature of the Great Lyell Fault at the time of Owen sedimentation has been obscured by a complex history of later movements on the fault. Arnold (1985) interpreted locally east-dipping segments of the volcanics-conglomerate contact in the Mt Lyell mines area as remnants of the original basin or graben margin — the fault would therefore have been originally a normal growth fault (Arnold, 1985, fig. C12) during sedimentation, only later broken up by west-dipping imbricate thrusts associated with the Haulage deformation. This issue remains controversial, with important recent contributions including Corbett (2001) and Noll and Hall (2005b).

The Owen to the east of the Great Lyell Fault forms an east-thinning wedge that extends from Mt Owen in the south northwards through the Tyndall Range (Corbett and Jackson, 1987). The wedge has a maximum thickness of one kilometre close to the fault at Mt Owen (Corbett *et al.*, 1989) and 1.8 km west of Mt Sedgwick. This suggests syn-depositional 'trapdoor-style' subsidence adjacent to the

fault (Corbett, 1989), or uplift and removal by erosion of equivalent sediments west of the fault prior to Pioneer Sandstone deposition. Most of the eastward thinning of the sediment wedge in the Mt Owen, Mt Lyell and Mt Sedgwick areas is evident in the 'lower Owen conglomerate' (Oolc), little if any being evident in the younger units. Units successively wedge out against basement in an easterly direction in the Mt Sedgwick area, with the 'upper Owen sandstone' (Oos) resting directly on basement east of Mt Sedgwick.

Thick Owen Group sections occur west of the southern extension of the Great Lyell Fault at Mt Huxley, Mt Jukes and further south. The succession at Mt Jukes is similar to that at Mt Owen, except that the 'middle Owen sandstone' correlate (Ools) rests on basement over a wide area with 'lower Owen conglomerate' (Oolc) only appearing east of Mt Jukes, as an east-thickening wedge. No outcrops of Pioneer Sandstone remain on Mt Jukes, but do occur nearby to the west at Newall Creek where Pioneer Sandstone rests on volcanic basement, indicating an abrupt western limit to the distribution of the Owen Group. The control here was apparently not syndepositional faulting but a large east-facing monocline developed in the Owen Group (fig. 8, see later section).

The Owen Group (undifferentiated) thickens rapidly in a S–SE direction in the Garfield River–Snake Spur area.

Prior to Pioneer Sandstone deposition and after 'upper Owen sandstone' deposition, west-side-up reverse movement on the Great Lyell Fault in the Mt Lyell mines area caused local folding in the still unconsolidated but coherent 'upper Owen sandstone' (Williams, 1988) and led to local unconformity — the Haulage Unconformity — between 'upper Owen sandstone' and Pioneer Sandstone (Bradley, 1954; Wade and Solomon, 1958; Corbett *et al.*, 1974; Corbett, 2001).

The Pioneer Sandstone lies directly on volcanic rocks over a broad area extending from just west of the Great Lyell Fault (Corbett *et al.*, 1974) in the Philosophers Ridge area, west to Queenstown and south to the Garfield River. The Pioneer Sandstone thickens southward from approximately 10 m in the Queenstown area to about 100 m at Newall Creek–Garfield River. At one locality (North Lyell) Gordon Group limestone overlaps Pioneer Sandstone to rest directly on volcanic rocks (Solomon, 1969).

The 'upper Owen sandstone' and Pioneer Sandstone are shallow-marine deposits as indicated by the abundance of trace fossils and rare marine shelly fossils. Older units apparently represent continental alluvial fans and sandy floodplains (e.g. Banks, 1962) or possibly fan-delta deposits, with rare marine incursions suggested by minor units of interbedded bioturbated sandstone and shale (see also Noll and Hall, 2003).

AGE

The Owen Group is essentially unfossiliferous except for trace fossils, but there are some constraints from adjacent units and from correlates outside the Lyell map sheet. A thin fossiliferous limestone in the Comstock Tuff, of late Middle or early Late Cambrian age (Jago *et al.*, 1972), places a maximum limit on the age of the Owen Group. The Newton

Creek Sandstone Member, a unit low in the Owen Group in the Tyndall Range, is a lithostratigraphic correlate of the 'middle Owen sandstone' (Ools) (Corbett *et al.*, 1989) and contains a post-Idamean, pre-Payntonian (roughly middle Late Cambrian) fauna (Jago in Corbett, 1975). A sandstone at Misery Hill, on lithostratigraphic grounds a probable correlate of the 'upper Owen sandstone' (Jago and Corbett, 1990, p. 236), contains a Payntonian (late Late Cambrian) fauna (Jago and Corbett, 1990).

The Pioneer Sandstone is locally fossiliferous. Banks (1962) and Banks and Baillie (1989) recorded coarsely ribbed brachiopods and euomphalid gastropods of Ordovician aspect from two localities. At least one of these localities ('100 yards east of Murray High School', M. R. Banks, pers. comm.) is known to be in the Pioneer Sandstone; the other, recorded as 'top of Owen, south of Gormanston' probably is too. A similar euomphalid–rhyconellid association of Ordovician aspect (M. J. Clarke, pers. comm.) occurs in Pioneer Sandstone at Newall Creek (see below) and euomphalids also occur in the upper part of the Pioneer Sandstone at Moores Creek [383600/5340000]. The presence of rhyconellids indicates that the Pioneer Sandstone is no older than late Darriwilian (late Middle Ordovician) (Laurie, 1996).

Mt Jukes–Newall Creek area

INTRODUCTION

An outlier of Owen Group rocks caps Mt Jukes and the high country extending south of Mt Jukes as far as Pyramid Peak [383100/5327700] and west to Crown Spur [381400/5330300] and West Jukes Peak [381800/5328300].

Stratigraphy and structure of the Owen Group on the Mt Jukes outlier are similar to Mt Owen. Dipping predominantly southwest, the formation is dismembered by northwest-trending major faults that produce a cuesta-like repetition of the sequence in adjoining fault blocks. An almost complete sequence through the Owen is well exposed on the steep northeast-facing slope below the summit of Mt Jukes (Plate 5, Plate 6). Here the main components of the type section can be recognised (Oolc, Ools, Ooc, Oos). The Pioneer Sandstone (Oop) has apparently been removed by erosion from the Mt Jukes outlier but occurs immediately to the west at Newall Creek.

JUKES CONGLOMERATE (Ooj)

Three or more impersistent lenses of Jukes Conglomerate unconformably overlie volcanic rocks on the north slope of Mt Jukes. This should be regarded as the type area of the Jukes Conglomerate (Hills, 1914, p. 42; Hills and Carey, 1949; Corbett, 1976b) rather than the Lake Jukes area (see Banks, 1962, p. 149). The basal contact of the Owen Group or Jukes Conglomerate upon the volcanic rocks is generally abrupt and where the underlying rocks are bedded, the contact can be seen to be a steeply angular unconformity—the type Jukesian Unconformity of Carey and Banks (1954).

Ooj underlies 'lower Owen conglomerate' (Oolc) at 383000/5330800 to 383400/5330800. Ooj underlies 'middle Owen sandstone' (Ools) at 382700/5330800 and consists of approximately 20 m of massive volcanoclastic

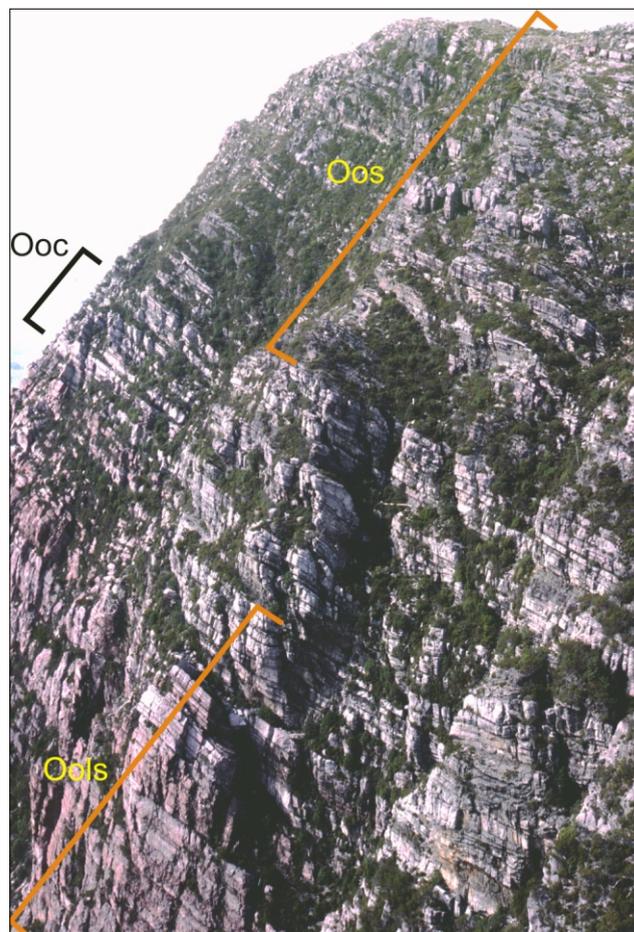


Plate 5

Owen units Ools, Ooc and Oos on the steep eastern flank of Mt Jukes [382800/5330100].

conglomerate, of boulder grade in the basal 2–3 m and cobble grade higher up. The contact with Ools is a two metre transitional interval in which conglomerate of an almost wholly volcanoclastic composition is replaced by conglomerate of almost wholly quartzitic composition with a purplish quartz sandstone matrix. Westward, Ooj pinches out at around 382600/5330800, at which point a green mudstone marker unit occurs approximately 30 m stratigraphically above the base of the Owen. Lower beds wedge out against rising basement further west and the green mudstone becomes the basal unit of the Owen, except for the Jukes Conglomerate which reappears as a two metre thick interval of volcanoclastic sandstone and pebble conglomerate separating the green mudstone from the volcanic basement. This thin development of Ooj, not shown on the map, extends from 382400/5330900 to around 382100/5330300. The green mudstone unit in this area contains beds of volcanoclastic sandstone and conglomerate.

The Jukes Conglomerate thus represents an impersistent, diachronous, thin basal conglomeratic facies; probably patchy, locally-derived slope deposits that formed on the eroded volcanic surface, and that were locally reworked to interfinger with the quartzose Owen-type sediments.

'LOWER OWEN CONGLOMERATE' (Oolc)

On the northeastern slopes of Mt Jukes and Proprietary Peak the 'lower Owen conglomerate' (Oolc) consists of



Plate 6

Gentle syncline in 'lower Owen conglomerate' (Oolc) unconformably overlain by 'middle Owen sandstone' (Ools) on east flank of Mt Jukes. [382900/5330100].

poorly-bedded or massive pebble-cobble conglomerate with minor beds of coarse quartz sandstone passing up into well-bedded, medium to thick-bedded sandstone and pebble-conglomerate. Sandstone layers often exhibit trough cross bedding, and the upper part of the unit consists of about 70% sandstone. The unit is white to pale grey in outcrop. Unit Oolc is unconformably overlain by the 'middle Owen sandstone' (Ools) on the northeast face of Mt Jukes. Here, bedding in Oolc is thrown into a gentle southwest-plunging syncline that is truncated by the nearly planar surface of erosion at the base of Ools (Plate 6). At this point Oolc attains a maximum local thickness of approximately 200 metres. To the southeast the unit thins in response to both overstep of the upper beds by Ools at the upper unconformity and wedging out of the lowermost beds onto basement that rises gently to the southeast. Relationships are less clear north of Proprietary Peak but Oolc wedges out completely at 382900/5330800, probably largely due to onlap of basement that rises to the west. Oolc is recognised in this area on the basis of its white outcrop colour, contrasting with the reddish overlying unit (Ools).

'MIDDLE OWEN SANDSTONE' (Ools)

The succeeding unit, the 'middle Owen sandstone' (Ools), is roughly 150 m thick in the section below Mt Jukes. The base of the unit is abrupt and locally unconformable on Oolc, and there is a colour change at the boundary from predominantly white to predominantly purplish grey or pink. The lower third of Ools in the Mt Jukes–Proprietary Peak area is a poorly-bedded, purplish-grey pebble conglomerate; the remainder consists of thick-bedded pink quartz sandstone with minor pebbly horizons.

Near the base of Ools north of Proprietary Peak is a 20 m interval of interbedded green mudstone and fine-grained quartz sandstone. Some of the sandstone beds are trough cross bedded, some are graded, and a few bedding planes display abundant worm casts suggesting a marine or marginal marine environment. The base of this unit is about 30 m above the base of Ools at 382600/5330800 which here rests directly on Jukes Conglomerate. Further west, from 382400/5330900 to around 382200/5330700, Ools onlaps rising basement and the green mudstone-sandstone unit

rests directly upon volcanic rocks or very thin Jukes Conglomerate. The green mudstone-sandstone unit here includes beds of volcanoclastic pebble-conglomerate and coarse sandstone. The green mudstone-sandstone unit is absent at the outlier of Ools further west [382100/5330300 to 381600/5331000], and Ools consists of alternating cross-bedded pink quartz sandstone and purple, hematitic volcanoclastic conglomerate.

The basal contact of Ools upon volcanic rocks is well exposed at several points below West Jukes Peak [381500/5328200 to 382100/5328200]. The contact is an angular unconformity; for example at 381600/5328100 bedding in the volcanic rocks dips 70° to 160° and Ools dips 45° to 340°. Volcanic clasts are restricted to an impersistent layer, up to 300 mm thick, of cobble-conglomerate in which about 30% of clasts are volcanic rock types. One such cobble has a 3 mm thick hematitic rind. Laminated fine-grained purple sandstone with sparse vertical worm burrows rests immediately upon the unconformity at 382100/5328200. The rest of the sequence at West Jukes Peak consists of pebble conglomerate, pink sandstone and minor purplish siltstone and shale, passing up into fine-grained pink sandstone with minor conglomerate. Several examples of cross bedding in the sandstone indicate a prevailing palaeocurrent direction towards the southeast.

Similarly, near Lake Jukes, volcanoclastic detritus is limited to the lowest few metres of Ools, and the Jukes Conglomerate is probably absent (Corbett, 1976b; D. B. Seymour).

At Newall Creek [380700/5329800] conglomerate predominates for 100 m (approximate stratigraphic thickness) before passing up into predominantly pink sandstone. Near the base the conglomerate is massive and contains rare volcanic clasts.

'MIDDLE OWEN CONGLOMERATE' (Ooc)

The succeeding unit, the 'middle Owen conglomerate' (Ooc) is a prominent white pebble-conglomerate that forms a good marker unit as it stands out well from the reddish sandstone above and below (Plate 5). The unit is generally 20–30 m thick, but pinches out to the southeast and is absent in the Pyramid Peak [383000/5327700] area.



Plate 7
Cross bedding in 'upper Owen sandstone' (Oos), Mt Jukes.

Maximum clast size is approximately 30 mm. The unit is generally poorly-bedded to massive, but is well-bedded in the Mt Jukes–Proprietary Peak area where thin interbeds of pink sandstone and greenish cleaved mudstone are present.

'UPPER OWEN SANDSTONE' (Oos)

The 'upper Owen sandstone' (Oos) correlate at Mt Jukes consists of thin to medium-bedded, fine-grained purplish-grey quartz sandstone, siltstone and shale, with occasional thick beds of coarse sandstone or fine-grained conglomerate. Bioturbation in the fine-grained sandstone is very common, and is manifested as wormcast-covered bedding planes and occasional churned beds. Ripple-marked bedding planes and small-scale trough cross lamination are also present in the fine-grained sandstone. Shale interbeds are usually well cleaved and are purplish or green in colour. Each thick bed of coarse sandstone, pebbly sandstone or fine conglomerate typically comprises a single cross-bed set, 0.5–1 m, rarely two metres in thickness (Plate 7). The sets are probably trough-shaped, and foresets occasionally exhibit water-escape cusp structures. The maximum clast size noted was approximately 10 mm. Clasts are still almost wholly of Precambrian quartzitic provenance but there is (as at Mt Owen) a small proportion of red and purple chert pebbles.

Nineteen foreset orientations from the thick coarse-grained beds indicate a dominant palaeocurrent direction to the south (fig. 5).

PIONEER SANDSTONE (Oop)

A unit of sandstone and conglomerate correlated with the Pioneer Sandstone crops out discontinuously in the Newall Creek area from 378700/5332000 to 380000/5327400. This unit, very approximately 100 m thick, dips steeply west, rests abruptly on volcanic rocks and is overlain by Gordon Group limestone (Ogu). In places limestone crops out adjacent to volcanic rocks with no intervening Pioneer Sandstone, as at 379300/5331100 in Newall Creek where limestone crops out two metres from volcanic rocks, suggesting either faulting subparallel to strike or lateral impersistence of Oop.

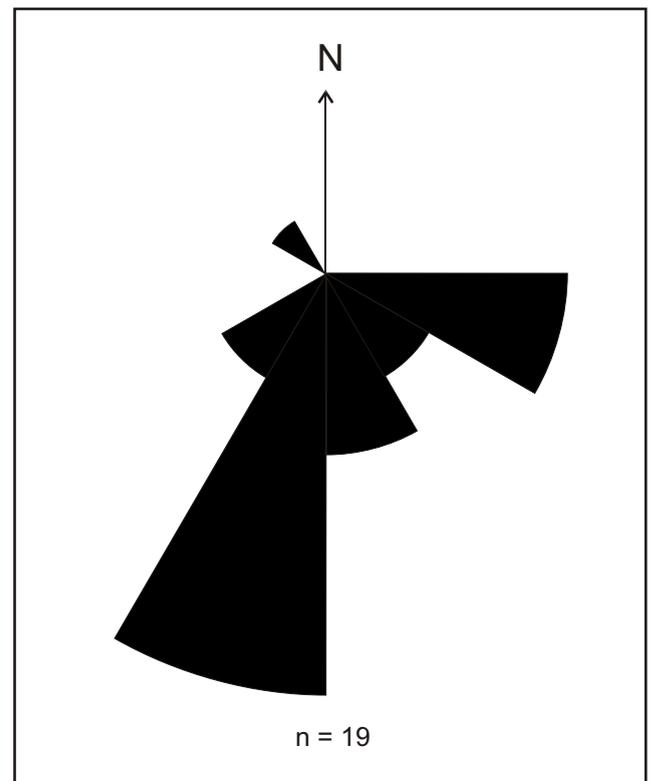


Figure 5
Palaeocurrents in 'upper Owen sandstone' correlate (Oos), Mt Jukes area.

The sudden disappearance of the older Owen units, passing west from the highlands of Mt Jukes to the Newall Creek area, points to a rapid wedging out of the older units, or (as in the Mt Lyell mines area) a structural control on their distribution. As in the Mt Lyell mines area, the western limit of the lower units is roughly north–south (fig. 6), but the southern extension of the Great Lyell Fault lies some distance to the east. It is here suggested that the large east-verging monoclinial fold evident along the western limits of the Mt Jukes outlier pre-dated the Pioneer Sandstone and allowed overstep of the older units by the Pioneer Sandstone (see later section; fig. 8).

The base of the Pioneer Sandstone is exposed at 379900/5330900 and in the creek at 380200/5329000. At the former locality, there is a sharp, planar contact with feldspar porphyry, and 20–30% of clasts in the basal conglomerate are volcanic rock types. At the latter locality volcanic rocks are abruptly overlain by conglomerate containing volcanic cobbles, interbedded with purplish quartzite.

The Pioneer Sandstone consist of fine to very coarse-grained quartz sandstone with green shale interbeds, and lesser pebble conglomerate. The sandstone is moderately to well sorted, usually white but occasionally pink or purplish, and is slightly feldspathic. Some bedding planes exhibit a vivid green patina — possibly the chromian mica, fuchsite (R. S. Bottrill, pers. comm.). Cross bedding and ripple-marked bedding planes are present in places, as are discoidal mudstone intraclasts. Bioturbation is common. In a few places there are concentrations of a black heavy mineral (probably detrital chromite) along bedding planes, and in one example, filling vertical burrows.

The conglomerates are of pebble, rarely cobble, grade. Clasts are mostly of Precambrian quartzite but locally include up to 50% white or reddish chert. Minor volcanic clasts are present near the base of the unit.

Weathered sandstone around 379800/5330800 has yielded poorly-preserved rhyconellid brachiopods and euomphalid gastropods of late Darriwilian or younger age (Laurie, 1996).

The Pioneer Sandstone probably extends further south than indicated on the map. Rocks shown as undifferentiated Owen Group (Oou) in the Garfield River–Flannigans Creek area as far south as 379000/5324300 are lithologically and lithostratigraphically very similar to Oop (see below).

Garfield River–Thomas Currie Rivulet area

QUARTZ-RICH VOLCANICLASTIC SANDSTONE AND CONGLOMERATE (Oov)

In the Flannigans Creek area, in the southwest of the map sheet [379000/5324000], there is an apparently conformable, transitional passage from volcanoclastic rocks (Ctd, Zig Zag Hill Formation correlate) up into Owen Group (Oou), and the unit Oov consists of the transitional rocks between these two units. Oov is of the order of 300 m thick around 379000/5323000 but rapidly thins northward, wedging out in the northern part of Flannigans Creek.

Oov is predominantly a massive to thick-bedded, coarse-grained pebbly sandstone. Pebbles are of both felsic volcanic rocks and Precambrian quartzite, and either type may predominate. The sandstone is grey-green in colour, and weathers to white; it is feldspathic and moderately to poorly sorted. The rock is generally more quartz rich and better sorted than Ctd. One thin section (R009595) shows a very coarse-grained volcanoclastic sandstone, rich in volcanic quartz and with rare grains of metaquartzite and quartz schist. Several metres of black shale with thin siltstone laminae occur at 379100/5322700. At a northern locality [378800/5325300], pebbly volcanoclastic sandstone is interbedded with conglomerate, quartzite and purple shale.

UNDIFFERENTIATED OWEN GROUP (Oou)

Quartz sandstone and conglomerate sequences that overlie volcanic rocks in the Thomas Currie Rivulet and Garfield River–Flannigans Creek areas are indicated as undifferentiated Owen Group.

In Thomas Currie Rivulet [at 380200/5326300] Oou consists of white to pale pink quartz sandstone and quartzite, in places cross bedded, with fine-grained pebble conglomerate and pale green shale. Clasts are predominantly of Precambrian derivation. These rocks are lithologically similar to the Pioneer Sandstone correlate to the north, but appear to pass southeastwards along strike into rocks correlated with lower Owen units.

Rocks as far south as 379000/5324300 in the Garfield River–Flannigans Creek area probably belong to the Pioneer Sandstone. These rocks form a thin (30–50 m) sequence of white quartz sandstone and fine-grained pebble conglomerate, overlain by Gordon Group limestone in the Garfield River. Clasts in the conglomerates are predominantly Precambrian metaquartzite but include red and yellow chert. Sandstone is medium to thick bedded, commonly cross bedded, and interbeds of purple shale are present. The Pioneer Sandstone here appears to be structurally conformable upon Dora Conglomerate (Ctd) and basal Owen Group (Oov) but the relationship is probably a paraconformity or a gently angular unconformity considering the overstep of Ctd by Pioneer Sandstone to the north, where it rests on older volcanic rocks (Clq).

Further south, the outlier of Oou [at 379200/5323800 to 379500/5322500] consists of pebble conglomerate and pink sandstone, with minor ripple-marked, laminated fine-grained quartzite and shale. Clasts consist entirely of quartzite and quartz schist of Precambrian derivation, except near the base in the south of the area [at 379300/5322600] where 20% of clasts are volcanic rocks, suggesting downward transition to Oov. The sequence appears to rapidly thicken southwards from the north of the outlier (approximately 100 m) to the southern part (approximately 300 m). Strike of bedding in Oou is slightly oblique to the western lithological boundary of the outlier, suggesting that a bedding plane traced northwards would pass laterally from Oou into Oov. This transgressive boundary is apparently due to a northward-migrating lateral facies change from Oou to Oov. A similar northward migrating facies change from volcanic to quartzitic conglomerate was noted at South Darwin Peak by Hills (1914, p. 43) and Wade and Solomon (1958, p. 399).

This southern outlier is considered to be a correlate of the lower part of the Owen Group.

Mt Strahan Region

INTRODUCTION

A folded, conformable sequence of volcanoclastic sandstone (Osv), mudstone and siltstone (Osm), quartz sandstone (Oss) and quartzite conglomerate (Osc) crops out on the ridge extending north from Mt Strahan in the southwestern corner of the map sheet. The outcrop area is bounded on the east by the Mt Strahan Fault. No fossils have been found, and the sequence is correlated with the Owen Group on

broad lithostratigraphic grounds, but differs considerably from the type Owen Group. The oldest unit, Osv, is regarded as a correlate of the Tyndall Group by Corbett and McNeill (1988). Other units probably represent a thick, distal, probably mostly marine equivalent of the Owen. The great disparity between this sequence and the thin Pioneer Sandstone correlate, resting directly on volcanic rocks immediately east of the Mt Strahan Fault, suggests growth faulting or considerable transcurrent and/or convergent movement on the fault. The first three units of this sequence are well exposed in the King River around 377000/5329700.

VOLCANICLASTIC SANDSTONE (Osv)

This, the oldest unit, crops out in the King and lower Garfield rivers.

Bedding dips steeply and faces west. Osv is faulted against Eldon Group rocks to the east, and conformably succeeded by Osm to the west.

The predominant lithology is a pale green volcanoclastic sandstone. The sandstone occurs as graded beds approximately 0.1–1.5 m thick, typically of very coarse sand or granule maximum grain size. Basal parts of graded beds frequently contain ragged mudstone intraclasts and scattered, rounded pebbles and cobbles of felsic volcanic rocks (quartz and quartz-feldspar porphyry) and rarely of quartzite. Thin sections (R009569, R009570, R009587, R009588) of coarse sandstone show a moderately to poorly sorted rock composed mostly of felsic volcanic grains including spheroidal and snowflake-textured rhyolites and welded tuffs, about 20% volcanic quartz, some feldspar, and rare grains of quartz schist and quartzite.

Thin-bedded to laminated intervals of mudstone, siltstone and fine-grained sandstone are interlayered with the sandstone. These fine-grained intervals constitute perhaps 30% of the sequence, occurring as units up to 10 m thick in the King River and predominating along the Garfield River above the confluence with Thomas Currie Rivulet. The interlayering of grey mudstone and lighter coloured siltstone and sandstone results in a strongly banded appearance in outcrop. The sandstone and siltstone layers often show thin planar lamination, and some are weakly

graded. A few of these show gently load-casted bases and laminated tops.

Osv is lithologically very similar to the Dora Conglomerate and has been interpreted as part of the Tyndall Group by Corbett and McNeill (1988). Osv is clearly predominantly turbiditic in origin.

MUDSTONE, SILTSTONE, MINOR SANDSTONE (Osm)

There is an upward transition, well exposed in the King River, from Osv to Osm, marked by the disappearance of thick, coarse-grained sandstone beds and an increasing predominance of laminated grey mudstone, siltstone and fine-grained sandstone. The lower 100 m or so of Osm in the King River retains, interbedded with mudstone and siltstone, considerable (approximately 60%) fine-grained, thin-bedded sandstone. Many sandstone beds are graded and may exhibit load-casted bases and laminated tops. There are minor gently lenticular, cross-laminated sandstone beds, each bed enclosing a single set.

The sandstone-dominated part of the sequence is stratigraphically overlain to the west by a succession of grey, planar-laminated siltstone and slate with minor (approximately 10%) thin sandstone beds (Plate 8). Syn-sedimentary slumping and convolute lamination are common (Plate 9). Near the top of Osm, around the Garfield–King confluence, fine-grained sandstone again becomes predominant.

Fine-grained sandstone similarly predominates in the lower part of the unit in the southern part of the outcrop area of Osm [e.g. around 377700/5327600]. The overlying bulk of the sequence is grey, well cleaved fine-grained siltstone and slate, massive but with faint internal planar lamination, and with rare very fine-grained sandstone laminae. A few sandstone and siltstone laminae are graded. The increasingly pelitic nature of Osm from north (King River area) to south is accompanied by an apparent increase in the thickness of the unit, from approximately 300 m in the King River to approximately 600 m around 377500/5327500.



Plate 8

Laminated mudstone with bundled thin quartzose sandstone beds, Unit Osm, King River [376900/5329800].



Plate 9

Convolute laminae in upper part of sandstone bed, unit Osm, King River [376900/5329800].

QUARTZ SANDSTONE (O_{ss})

The base of O_{ss} at 377700/5326400 is a rapid transition from slate and siltstone with lesser sandstone beds (O_{sm}), through an increasing sandstone bed thickness, to medium-bedded quartz sandstone over a stratigraphic interval of about fifteen metres. The predominant lithology throughout O_{ss} is a medium to thick-bedded, medium to fine-grained, white, well-sorted quartz sandstone or quartzite. This and the overlying unit (O_{sc}) are erosionally highly resistant, forming the prominent strike ridge extending north from Mt Strahan. Sandstone beds are nearly always internally structureless. In places, beds are weakly graded with sharp bases that have incipient load structures. Only a single example of cross bedding was observed. Ripple-marked bedding planes are common in exposures along the King River. There are minor beds of coarse sandstone and granule conglomerate, and uncommon pebbly horizons. Pebbles are entirely of Precambrian metaquartzite. There are interbeds, and rare intervals several metres in thickness of pale grey micaceous siltstone and dark grey slate. An interval, approximately 70 m thick, of laminated shale and siltstone with thin, wavy sandstone beds occurs at 377400/5325300.

CONGLOMERATE (O_{sc})

Unit O_{sc} consists predominantly of white quartzite-pebble conglomerate, with subordinate quartz sandstone identical to that of O_{os}. Graded bedding was observed at several localities, beds being 0.5–2 m thick, rarely up to cobble (200 mm) grade at the base, and sandstone at the top. Bases of some graded units are erosional. Clasts appear to be wholly of resistant Precambrian rock types; quartzite, cleaved quartzite, and quartz schist. Medium-bedded, graded-bedded quartz sandstone crops out at 377600/5323600, the beds containing granule-rich basal parts and laminated tops. O_{sc} and O_{ss} notably lack the pink and purple hematitic pigmentation so characteristic of the Owen Group.

Tyennan Region

INTRODUCTION

Along the western margin of the Tyennan region in the central parts of the map sheet, a relatively thin (<100 m) sequence of quartz sandstone and minor conglomerate unconformably overlies Precambrian metaquartzite and schist, and is conformably overlain by Ordovician limestone of the Gordon Group. This outcrop area is separated from the Owen Group of the West Coast Range area by a major synclinal structure, the King Synclinorium, filled with younger (Gordon Group and Eldon Group) rocks.

This attenuated siliciclastic sequence resting on Tyennan rocks probably correlates with the Pioneer Sandstone of the West Coast Range. This is suggested by the conformable upward transition into Gordon Group limestone, and by the pattern east of Mt Sedgwick of progressive overlap of older Owen units by the 'upper Owen sandstone' (O_{os}) in the direction of the Precambrian massif. North of the Governor River the sequence is regarded as a probable lithostratigraphic correlate of the Pioneer Sandstone and is shown on the map as O_{op}; more southerly occurrences may also be partly Owen Group correlates, being somewhat thicker, and are shown as O_{ou}.

GOVERNOR RIVER TO BUBS HILL

A section through the probable Pioneer correlate on the Governor River [at 391600/5330300; this section of the river now flooded by Lake Burbury] consists of (from the base) 0.6 m of quartzite-derived conglomerate, one metre of laminated grey shale and fine-grained quartzite, followed by approximately 18 m of thick-bedded, probably bioturbated, fine-grained quartzarenite, pebbly in places and with greenish shaly partings towards the top. This is conformably overlain by limestone (Gordon Group).

Exposures north of the Governor River [around 392600/5331600] include wormcast quartz sandstone and minor grey, pyritic, fine-grained sandstone.

Outcrops at Nelson River consist predominantly of fine-grained, grey, mottled (bioturbated) quartz sandstone.

Just west of Bubs Hill [398400/5336100] a creek exposure reveals a mere 0.5 m of hard, grey, fine-grained quartzite unconformably overlying Precambrian rocks and underlying limestone, while nearby at the col south of Bubs Hill, several metres or more of Pioneer correlate is preserved. This consists of tough, quartzitic, cross-bedded quartzarenite, with worm tubes in places and Precambrian-derived conglomeratic horizons.

Equivalent rocks are very thin or absent at scattered outliers in the eastern part of the map sheet. At Cardigan River [404500/5333200] impure limestone (Gordon Group) rests directly on Precambrian. In the South Eldon River area no Pioneer equivalent is exposed and at 403600/5347300, limestone crops out within a few metres of Precambrian rocks. Likewise, no Pioneer equivalents are known from the Franklin River outlier [415000/5326200].

Limestone of the Gordon Group (Og)

Introduction

Limestone (Og) conformably succeeds the Pioneer Sandstone and correlates, except at two localities where limestone unconformably overlies older rocks (Cambrian volcanic rocks at North Lyell (Solomon, 1969); Precambrian rocks at Cardigan River). Being relatively susceptible to erosion, the limestone unit generally crops out poorly and underlies narrow, flat valley floors flanking the West Coast Range at Garfield River–Newall Creek, Queen River, Chamouni Valley, and in the Crotty–Darwin area. Around the margin of the Tyennan region, Gordon Group limestone underlies a discontinuous series of valley floors from the Wright River to the Balaclava River; there are outliers within the Tyennan region further east at South Eldon River, Cardigan River and Franklin River. Outcrop is generally obscured by Quaternary cover, but in a few areas of moderate relief (Bubs Hill, Cardigan River, South Eldon River) the unit crops out relatively well.

At Bubs Hill the Gordon Group is approximately 300 m thick and is divided into a lower unit of predominantly micrite (Ogg) and an upper unit of impure limestone and dolomite (Ogb). At some other nearby localities the Gordon Group is substantially thinner (e.g. approximately 200 m at Nelson River; approximately 120 m at Cardigan River) and lacks much or all of Ogb, suggesting a phase of erosion prior to deposition of the succeeding Crotty Formation. A third subdivision of mudstone, siltstone and impure limestone (Ogr) occurs at the top of the group in a few localities, mostly in the western part of the map sheet, and may be a lateral equivalent of the upper unit (Ogb) of Bubs Hill. Again, absence of Ogr in some places suggests a phase of pre-Crotty erosion.

Most outcrop in the poorly exposed areas around the West Coast Range is shown as undifferentiated Gordon Group (Ogu). Limestone in these areas is deformed and more recrystallised than that from the Tyennan region. Deep leaching of impure limestone has, in many places, left a lag of black clayey residue or 'black pug' — indicated as Ogu'.

Fauna and sedimentary structures such as ooids, birds-eye structures and desiccation cracks indicate shallow marine and peritidal environments of deposition for the limestone of the Gordon Group.

The limestone in the Lyell Quadrangle ranges in age from probably assemblage-zone OT12 (late Darriwilian, late Middle Ordovician) (the base of the limestone at Linda) to OT19 (late Eastonian, Late Ordovician) at Bubs Hill (Banks and Baillie, 1989).

Bubs Hill area

DOMINANTLY MICRITIC LIMESTONE (Ogg)

The lower unit (Ogg) is approximately 120 m thick at Bubs Hill, where the base is exposed in the narrow fault wedge south of the summit [398400/5336100]. Here the one metre thick basal bed consists of impure, orange-brown weathering carbonate, overlying thin Pioneer Sandstone correlate, and is succeeded by poorly outcropping dolomitic micrite characteristic of the bulk of the unit.

Essentially consisting of pale grey-weathering, dark grey to black micritic limestone, Ogg comprises a number of limestone types interbedded on a scale of metres. The lithology making up the bulk of the unit is dark grey micrite with 10–20%, rarely 50%, secondary dolomite as irregular layers and lenses ('stringers') and dolomitised burrows. The burrows are cylindrical branching forms 2–5 m in diameter, commonly parallel to bedding but also with random orientations, and may comprise up to 40% of the rock. Stringers of dolomite may be of stylolitic origin or may derive from densely-burrowed horizons. The dolomite is pale brown, sucrosic and finely crystalline (0.2 mm).

Another common limestone type, making up to approximately 10–20% of the sequence, is micrite with persistent planar lamination — possibly of algal origin — defined by incipient stylolites and thin secondary dolomite laminae. Sub-vertical dolomite-replaced burrows are locally developed, and desiccation cracks are commonly present. Mud crack fillings are dolomitised, or more rarely, spar filled. Domical stromatolites are present at a few horizons. Rarely, dolomitisation is pervasive, resulting in beds of laminated, fine-grained dolostone. Thin beds of flat-pebble breccia are associated with the laminated facies.

Some beds consist of more or less uniform micrite with minor small blebs or cylindrical bodies of spar (possibly spar-filled burrows). There are rare, thin beds of intraclastic conglomerate or calcarenite. A few beds contain abundant *Tetradium* as either disaggregated masses or colonies in growth position.

Rare, small (a few millimetres) patches of sphalerite were observed on the northern and northwestern slopes of Bubs Hill. Unit Ogg becomes pervasively dolomitised and brecciated near faults west and south of the summit of Bubs Hill. A thin section (L20) shows an even-grained dolomite with patches of coarser saddle dolomite.

Shelly fossils are rare in Ogg except for occasional thin bioclastic beds. Forms present include fasciculate and cateniform species of *Tetradium*, low-spined gastropods including a euomphalid close to *Ecculiomphalus*, bivalves

(small palaeotaxodonts, cyrtodontids), orthids, rhynchonellids, and rare nautiloids. The brachiopods are often silicified. Fauna and lithologies of Ogg closely resemble the lower two-thirds of the Lower Limestone Member of the Florentine Valley (type area of the Gordon Group).

IMPURE LIMESTONE AND DOLOMITE (Ogb)

Unit Ogb, of predominantly brown-weathering, impure limestone and dolomite, is shown on the map only in the Bubs Hill area. This unit also occurs at Nelson River but this occurrence is not indicated on the map. On Bubs Hill Ogb comprises the upper 180 m of the Gordon Group.

The base is exposed in the transmission line firebreak at 398300/5336600. Here, grey micrite (Ogg) is abruptly overlain by a resistant, metre-thick bed of blotchy, orange-brown weathering dolomite, followed by a thin interbed of black mudstone, then another metre-thick bed of dolomite, weathering to dark grey-brown. This pair of dolomite beds, marking the base of Ogb, can be followed along strike around the western side of the hill to 398300/5336200 and can also be recognised in the upfaulted wedge south of the summit at 398600/5335900.

Thick-bedded to massive, rarely laminated, brown to orange-weathering dolomite continues to be an abundant and characteristic component through the rest of the sequence. The dolomite is often faintly mottled (probably bioturbated). Commonly there are small blebs and veins of sparry dolomite, and small irregular vugs filled with saddle dolomite, calcite and quartz. Thin sections show even-grained idiopic-xenopic dolomite spar with a grain size of approximately 0.2 mm.

There are intervals of cross-bedded sandy dolomite and dolomitic quartz sandstone in the upper half of Ogb. One six metre thick unit of cross-bedded sandy dolomite crops out prominently just north of the summit [at 398600/5336300], at a level about 20 m stratigraphically below the top of the unit. Cross-bed sets here are approximately 100 mm in thickness, have reactivation surfaces and contain micrite rip-up clasts. A thin section (R009547) appears to be a dolomitised oolite, in places with single dolomite crystals filling circular ooid outlines approximately 0.2 mm in diameter. Terrigenous sand grains are of metamorphic quartz and strained metaquartzite.

Terrigenous impurities are characteristic of Ogb. Scattered, medium to coarse quartz sand grains are common through the unit, particularly in the cross-bedded units mentioned above, and dark grey calcareous siltstone, mudstone and impure muddy limestone are common. There are rare beds of fine-grained calcareous quartz sandstone. Grey-weathering micrites with dolomitised burrows or with algal lamination, identical to typical Ogg lithologies, are a subordinate component of Ogb.

The top of Ogb is exposed in the cliff face just west of the summit of Bubs Hill. Here, massive orange-weathering dark grey sucrosic dolomite is overlain, via an abrupt and planar contact, by fine-grained quartz sandstone of the Crotty Formation.

Although mostly unfossiliferous, Ogb locally contains a diverse, partially silicified shelly fauna. In the lower 50 m of

the unit, there are corals including heliolitids, *Eofletcheria*, cereiod *Tetradium* and a rugosan; orthids; rhynchonellids; gastropods including very common *Lophospira*; the rostroconch *Bransonia*; palaeotaxodonts, nautiloids and bryozoans. This fauna resembles that of the uppermost Lower Limestone Member and lower Upper Limestone Member of the Benjamin Limestone in the Florentine Valley.

Palaeophyllum, stromatoporoids and gastropods occur above the cross-bedded unit near the top of the unit. Corals and conodonts from this level indicate correlation with the top of the Benjamin Limestone (Edenian–Maysvillian) (Banks and Baillie, 1989, p. 210).

NELSON RIVER–GOVERNOR RIVER

Limestone crops out in the lower Nelson River downstream of 391900/5336800. This tract has now been flooded by Lake Burbury. The limestone, shown as Ogu (undifferentiated Gordon Group), for the most part resembles Ogg (grey-weathering micritic limestone). The base [exposed at 391800/5336500] is a thick bed of brown-weathering impure carbonate resting abruptly on quartz sandstone of the Denison Group, and limestone is well exposed along the river banks to the west. The predominant lithology in this section is massive, dark grey micrite. There is a tectonic foliation, close to bedding, with a contained lineation (L-S fabric) approximately down dip. The foliation consists of thin, planar, incipient stylolites and small aligned blebs and augen of calcite and dolomite spar. A thin section (R009639) shows a limestone of fine-grained (5–10 m) microspar — probably recrystallised micrite — with abundant ovoid to irregular coarse spar-filled fenestrae or birds eyes. The tectonic foliation appears as diffuse, streaky segregations of slightly coarser microspar, and wraps around the fenestrae. Irregular patches of white calcite spar, up to several centimetres in size, occur at 391800/5336600. These are of pre-tectonic age and may be replacements of evaporites.

Nearby [at 391600/5336600], a possible correlate of the upper unit (Ogb) of Bubs Hill crops out close to the base of the Crotty Formation. This is a brownish-weathering, finely crystalline dark grey carbonate with thin wavy slate layers. Further south [between 391400/5335100 and 391300/5333900], similar outcrops comprise a stratigraphic interval roughly 50 m in thickness at the top of the Gordon Group. These outcrops include brown-weathering dolomitic carbonate with rare quartz sand grains and black calcareous siltstone with layers and pods of micrite. The underlying part of the Gordon Group in this area consists, like Ogg, of micrite, usually with abundant (20–60%) dolomite stringers and dolomitised burrows, calcareous siltstone, and minor impure, thinly-laminated limestone with desiccation cracks. An outcrop at 391600/5334400 includes a bed with fasciculate *Tetradium* colonies in growth position and the enclosing limestone contains abundant fragments of *Tetradium*. A black micrite with *Lichenaria* crops out a few metres to the west.

The base of the Gordon Group is exposed in the Governor River at 391500/5330200, where roughly ten metres of west-dipping limestone overlies fine-grained quartzarenite of the Denison Group. The sequence is initially a massive

orange-brown weathering carbonate, succeeded by grey-weathering micritic limestone with tectonically flattened wisps and blebs of fine-grained sucrosic dolomite. A five metre gap in outcrop, probably coinciding with a fault, separates the limestone from Crotty Sandstone further west. Other Gordon Group outcrops in the Governor River area [392400/5331800; 390800/5329500] consist predominantly of impure, black fine-grained limestone.

EASTERN OUTLIERS

In the South Eldon River area [403000/5348000] a similar suite of carbonate rock types is present as in the Gordon Group at Bubs Hill and elsewhere, but no lithostratigraphic differentiation is possible. The rocks lack cleavage. Rock types seen include dolomitic micrite, laminated carbonates including thinly interlaminated dolomite and limestone, calcareous siltstone, micrite with blebs of calcite spar, and *Tetradium*-bearing micrite. Outcrop in the northern creek [between 402200/5348500 and 401700/5348700] is predominantly pale grey sucrosic dolomite, mostly massive, and in places laminated. Irregular veins, filled with orange-weathering sparry dolomite and quartz, are common in these outcrops.

Limestone at the Cardigan River is assigned to Ogg (predominantly micritic limestone). There is good outcrop along the ridge between 405000/5332300 and 405300/5331700. The Denison Group is absent and an impure limestone or calcareous siltstone rests directly on Precambrian rocks in the river at 404700/5332300.

An outcrop close to the Franklin River [414000/5326200] near the base of the Crotty Sandstone is of fine-grained impure muddy limestone resembling Ogb at Bubs Hill.

SMELTERS QUARRY, QUEENSTOWN

Limestone in this disused quarry [380400/5340900] dips steeply and youngs southwards, as indicated by stromatoporoids in growth position and geopetal vug fillings. The quarry exposes an interbedded sequence of fine-grained, dark grey limestone, in places with dolomitised burrows; thinly interbedded limestone/dolomite; fine-grained dolomite; and laminated pale grey limestone. Within the dark grey limestone there are rare, unusual stromatactis-like vugs that are irregularly hemispherical to tubular in shape and 50–200 mm in diameter. These are filled with coarse calcite spar and a later mineral, probably saddle dolomite; a few are floored with laminated internal sediment. There are common, coarsely calcified stromatoporoids, gastropods (*Lophospira*, *Lesueritella*), calcareous algae, and silicified *Tetradium*. Hill (1955) and Hill and Edwards (1941) recorded several species of *Tetradium* and other corals from this locality. Corals and cephalopods here suggest correlation with the upper part of the Lower Limestone Member (Banks and Baillie, 1989).

NEWALL CREEK–GARFIELD RIVER

Limestone in the Newall Creek [379300/5331000] – Garfield River [378400/5326700] area nearly everywhere carries a strong tectonic fabric. Dark grey, very finely crystalline limestone (probably recrystallised micrite) is the most common lithology. There are common, impersistent thin layers of mudstone, dolomite and occasionally

dolomitised burrows. Birds-eye limestone is common in the Newall Creek area. Cleavage in the birds-eye limestone and other relatively pure limestones is a planar fabric composed of faint streaks of paler microspar and flattened blebs of sparry calcite and dolomite. Thin sections (R009583, R009584) show abundant birds eyes, up to 2 mm in diameter, of coarse calcite and lesser saddle dolomite spar in a matrix of foliated microspar. Calcite filling the birds eyes shows intense deformation twinning while the brown pseudopleochoric saddle dolomite shows none, even though it pre-dates tectonism. Tectonic fabric in the matrix consists of streaky segregation of coarser and finer microspar. The tectonic fabric is strongly deflected around the birds eyes. Individual microspar grains are equant or only slightly elongated, suggesting some post-deformational partial recrystallisation (D. B. Seymour, pers. comm.).

Outcrop and large boulders in Thomas Currie Rivulet [at 378600/5327800] show pale grey birds-eye limestone overlain, via an irregular erosional surface, by dark grey, bioclastic limestone containing abundant calcareous algae (*Solenopora*), crinoid ossicles, *Tetradium*, trilobites, rugose corals, and silicified rhynchonellids; followed by micritic limestone with silicified bivalves and nautiloids. Fossils are all considerably strained. There are scattered small patches (10 mm) of coarse brown saddle dolomite.

Also common in the Newall Creek–Garfield River area are impure carbonate rocks — muddy fine-grained limestones — which have a cleavage of thin, anastomosing stylolitic seams. Black clay or pug, a residual deposit after leached impure limestone, is present at several localities, generally near the base of the sequence [e.g. 378600/5326400; 379900/5330800] or at the top [378700/5331500].

Mudstone and siltstone (Ogr) crops out at the top of the Gordon Group at Thomas Currie Rivulet [378700/5328100; 379200/5328200]. Ogr consists here of grey, slightly calcareous, slightly micaceous cleaved siltstone and mudstone. The rock weathers to a yellow-brown colour, lacks bedding and is well cleaved. There is an abundant, poorly preserved fauna of fenestellid-like and ramose bryozoans, orthids, and possibly trilobites.

Eldon Group

Introduction

The Eldon Group is a thick sequence of marine sandstone and shale, Early Silurian to Early Devonian in age (Banks, 1962). These rocks occupy two large Devonian synclinoria in the Lyell Quadrangle, one on either side of the meridional structural high represented by the mostly Cambrian rocks of the West Coast Range. The western synclinorium, named the Dubbil Barril Synclinorium by Solomon (1962), lies mostly outside the map sheet in the neighbouring Strahan Quadrangle. The King Synclinorium (Solomon, 1962) separates the mostly Cambrian rocks of the West Coast Range from the Precambrian rocks of the Tyennan region. The Eldon Group may be of the order of five kilometres thick in the King Synclinorium.

The Eldon Group and its constituent formations were defined by Gill and Banks (1950) and Blissett (1962) in the

Zeehan area. The sequence is divided into correlates of the Crotty, Amber, Florence and Bell formations over most of the Lyell map sheet. The Eldon Group rests with probable disconformity on the Gordon Group as shown by the abrupt contact exposed at Bubs Hill, and the stratigraphic variations in the Gordon Group suggestive of an erosive phase (see previous section). The sequence is Early Silurian at the base and is terminated above by the regional unconformity brought about by the Middle Devonian Tabberabberan Orogeny.

Crotty Sandstone (Scc, Scs)

INTRODUCTION

The contact between the Gordon Group and overlying Crotty Sandstone was observed just west of the summit of Bubs Hill [398600/5336100] where it is sharp, planar and probably disconformable. The contact is also abrupt at Newall Creek [378800/5331500] where quartz sandstone rests sharply on residual black 'pug'. The Crotty Formation, of quartz sandstone, is approximately 150 m thick in the southwest (Garfield River valley) and northern (South Eldon River valley) parts of the Lyell map sheet and appears to become substantially thicker (of the order of 0.5–1 km) in the central–southern parts (southern King valley). Here an upper fine-grained sandstone unit (Scs) can be differentiated, which is included in the Crotty Formation on broad lithostratigraphic grounds.

The Crotty and Florence formations are lithologically very similar and may be difficult to distinguish in the field where (as is usually the case) fossils are absent or not sufficiently well preserved to provide biostratigraphic control. The lower and more widespread part of the Crotty (shown as Scc) has a slightly coarser average grain size, and is less mature, than the Florence. Cross bedding is nearly everywhere present in Scc but is less common in the Florence. Fossiliferous horizons are more common and show better preservation in the Florence Formation than in Scc, particularly near the top of the Florence Formation. However, the upper finer division (Scs) of the southern King River valley is essentially lithologically indistinguishable from the Florence Formation. Areas of Scs shown north of the Governor River [390000/5330000–389000/5333000; 390000/5334000–391000/5333000] could conceivably be Florence Formation as no biostratigraphic control exists in this area, and the sequence is faulted and poorly exposed.

Minor map revisions are here suggested by a reassessment of lithologies in some areas where no fossil control is available. Outcrop on the ridge at 393500/5337100 to 393700/5337200, shown on the map as Df, is lithologically similar to Scc. Similarly an area shown as Df on the map (south of a line joining 394200/5338500 to 395500/5338000) is probably Scc on lithological grounds, suggesting a fault along this line, an extension of that further east. This area includes an isolated bed [at 394300/5338200] of coarse-grained crinoidal limestone, and several metres of fine-grained, impure, silty unfossiliferous limestone at 394300/5338400.

SANDSTONE (Scc)

This unit consists predominantly of white to grey quartz sandstone that is moderately to well sorted and predominantly fine grained, although grain size ranges from rare coarse-grained sandstone to siltstone and rare mudstone. The unit usually forms well-defined strike ridges. Outcrop is well bedded and jointed, and characteristically sheds copious blocky float that in places forms talus deposits indicated on the map as Qpte.

Weathered outcrop tends to be porous due to leaching of calcareous cement and fossil fragments. Fine-grained quartzite (with a siliceous cement) occurs in a few places. Cross bedding is abundant in sets 30–150 mm thick, and herringbone reversal patterns are frequently seen. In places there is a patchy greenish pigmentation, possibly derived from weathering of detrital chromite.

Bioturbation is nearly everywhere apparent in Scc. Many 'massive' sandstone or siltstone outcrops display a faint, pervasive mottling that attests to complete reworking by burrowing organisms. Foreset lamination is usually partly disrupted by narrow (2–6 mm) subvertical cylindrical worm casts. A large and conspicuous type of vertical burrow was seen at several localities [e.g. 391400/5336900; 388600/5333600; 390600/5328800; 391100/5331000]. The burrows are elliptical, and approximately 10 × 15 mm in cross section, and have a vertical extent of 100–150 mm. They constitute up to 20% of the rock volume and are sharply delineated from the matrix.

Only rarely is fossil preservation good enough in the Crotty Formation to allow biostratigraphically useful identification to be made. The coarse-ribbed brachiopod *Rostricellula* is the most common index fossil. Large crinoid ossicles were not found to be a useful index fossil as they are also found in rocks considered to be Florence Formation correlates (cf. Gill, 1950). Swarms of spine-like tentaculitids are occasionally found in the Crotty Formation in the Lyell Quadrangle but were not observed in the Florence Formation. Large vertical burrows of the type described above appear to be restricted to the Crotty Formation correlate.

SANDSTONE AND SILTSTONE (Scs)

The sandstone unit Scc is overlain, in the region of the southern King River valley, by fine to very fine-grained quartz sandstone, siltstone and minor shale (Scs). This unit generally crops out as a separate strike ridge, paralleling that of Scc, and the transition was not observed. Scs differs from Scc in having a finer average grain size and little or no bioclastic component. Cross bedding may be present, generally in the form of low-angle troughs and possible hummocky cross-stratification. Parallel lamination is common.

Outcrop in the King and lower Nelson rivers (now flooded by Lake Burbury; 388900/5333600 to 391300/5333700) consists of thick-bedded, pervasively bioturbated siltstone, dark grey pyritic shale with thin beds of very fine-grained quartz sandstone, and rare lenses of impure limestone. The sandstone shows a variety of sedimentary structures. Intervals of uninterrupted sandstone several metres or more in thickness typically show alternating plane-laminated

and bioturbated beds. Thin sandstone beds within predominantly mudstone intervals are gently lenticular, with sharp bases; some are graded, others show low angle cross bedding. Graded beds may have plane laminated tops and rare basal flame structures. Along the King River [from 389800/5336700 to 390000/5335300], in probably the upper part of Scs, there is interbedded siltstone, cleaved dark grey micaceous shale, and slate.

Large vertical burrows with elliptical cross sections, like those locally present in Scc, are found at 390400/5337000 and along strike at 390500/5336700 where they constitute 40–50% of a five metre thick interval of very fine-grained sandstone.

Amber Formation (Sa)

INTRODUCTION

The Amber Formation consists predominantly of cleaved mudstone or slate with minor sandstone and rare limestone, and conformably succeeds the Crotty Formation. It is 200–400 m thick with a greater apparent thickness in the axial parts of major folds. In the middle of the formation in the Garfield River area, a thin sandstone unit (Sas) was mapped that may be a correlate of the Keel Quartzite. Apart from this no lithostratigraphic equivalent of the Keel Quartzite and Austral Creek Siltstone can be differentiated in the Lyell Quadrangle. Graptolites from the Amber Formation at 397300/5337300 (on the Lyell Highway) are of Pridolian (Late Silurian) age (M. R. Banks, pers. comm.) indicating that part of the Amber Formation, as mapped in the Lyell Quadrangle, is equivalent to the Austral Creek Siltstone or the lower part of the Florence Quartzite of the Zeehan area.

KING SYNCLINORIUM

Here the Amber Formation consists predominantly of black, grey-green or yellow-brown, shaly mudstone or slate and muddy micaceous siltstone. Most outcrops have a proportion (0–50%) of thin beds or laminae of light-coloured, very fine to fine-grained, quartz sandstone. The mudstone generally lacks sedimentary structures except for occasional plane lamination, or mottling indicative of thorough bioturbation. The sandstone layers show a variety of sedimentary structures. Bases of sandstone beds are sharp, rarely with groove casts. Tops are either sharp or bioturbated. Sandstone beds are often internally structureless, but commonly display plane lamination, or very low angle cross lamination including possible small-scale hummocky cross-stratification. Many thin beds are gently lenticular or display gentle pinch and swell geometry with internal cross lamination suggestive of starved ripple formation. Rare, thick sandstone beds contain convolute lamination.

GARFIELD RIVER AREA

The Amber Formation is strongly cleaved in the Garfield River–Newall Creek area [379000/5329000]. It is a pale grey slate or well-cleaved mudstone with thin graded beds (up to 30 mm thick) of limestone, calcareous siltstone, and sandstone. Some limestone layers are of very coarse-grained crinoidal calcarenite.

A thin sandstone unit (Sas) has been mapped within the Amber Formation in the Garfield River area [379000/5329000]. This unit is erosionally resistant and forms a narrow strike ridge. It is composed of very fine-grained white quartz sandstone and quartzite, medium to thick bedded, well jointed and with interbeds of cleaved mudstone. Sandstone beds appear to be internally uniform and some are thoroughly bioturbated.

The Amber Formation is locally fossiliferous (e.g. at 398400/5338700 north of Bubs Hill). Forms present here include crinoid ossicles, trilobites, horn corals and brachiopods including *Liangella* (M. J. Clarke, pers. comm.). Graptolites found at the old '15 mile peg' locality, Lyell Highway [397300/5337300] are Pridolian (Late Silurian) (M. R. Banks, pers. comm.).

Sandstone beds in the Amber Formation have sedimentary structures characteristic of storm-deposited layers. An outer shelf depositional setting, below fair-weather wave base but within storm wave base, may be inferred.

Florence Formation (Df)

INTRODUCTION

The Florence Formation, predominantly of quartz sandstone, is 500–1000 m in thickness and forms prominent, broad-topped strike ridges. The unit appears to be relatively thin in the northern parts of the quadrangle (e.g. north of Queenstown and in the South Eldon River) and thickens southward. As previously discussed, the Florence Formation is lithologically similar to the Crotty Formation. The Florence Formation is perhaps most readily distinguished by common fossiliferous horizons with a relatively well preserved shelly fauna characterised by such forms as the brachiopods *Eatonia*, *Leptostrophia* and *Isorthis*.

KING SYNCLINORIUM

The formation is predominantly a well-sorted quartz sandstone of mainly very fine ($1/16$ – $1/8$ mm) grain size. Very rare coarse-grained (1–2 mm) sandstone horizons are the coarsest grades seen. Siltstone and shale intervals are common. Like the Crotty Formation, many sandstone beds are porous in outcrop indicating an originally calcareous composition prior to weathering. Beds showing faint internal parallel lamination, and beds that are internally structureless or that show pervasive bioturbation ('churned beds'), comprise the bulk of the sequence and often occur in alternation. Churned beds are of a slightly muddy sandstone, while parallel-laminated and cross-laminated beds are better sorted, and slightly coarser grained. Low angle cross bedding is commonly developed and is difficult to distinguish from parallel lamination on small outcrops. Parallel-laminated and cross-laminated beds often have sharp, scoured bases and bioturbated tops that grade upward into churned beds. This alternation of laminated and churned beds probably results from partial reworking, by burrowing organisms, of successive storm-deposited sand units (Sellwood, 1978). Trough cross bedding is common but is not as abundant as in the Crotty Formation. Sets are up to 400 mm thick, and herringbone patterns are locally present. Ripple cross lamination, and asymmetric climbing ripple cross lamination, were observed in places.

Bioturbation is abundant, and is most commonly manifested as the churned or homogenised beds mentioned above. Bedding planes often show a variety of burrow forms; branching, radiating, and rarely chevron-shaped casts.

The Florence Formation correlate in the South Eldon River area [399000/5349000–402000/5347000] is finer grained than elsewhere and consists of interlayered grey siltstone, mudstone, very fine-grained sandstone and minor calcareous mudstone. No rock coarser than very fine sandstone was observed. At 402000/5347300, storm beds 70–100 mm thick have erosional bases, lower parts of plane-laminated or low-angle cross-laminated very fine-grained sandstone, grading up through an increasingly mottled transition into an homogenised, muddy siltstone upper part. In places there are mudstone interbeds that may represent relatively slow, 'background' sedimentation.

A relatively well preserved shelly fauna is found at several localities, for example in the Nelson River [at 392400/5338000]. Brachiopods are the most abundant elements, in particular *Eatonia*, *Leptostrophia* and *Isorthis*. Crinoid ossicles are abundant. Ramose bryozoans, a dalmanitid trilobite, and *Pleurodictyum* were also observed.

LOWER KING RIVER AREA

The Florence Formation is well exposed in the King River downstream of its confluence with the Queen River [378400/5331700–377400/5330400]. The unit is folded into a tight syncline and the top of the formation is not present. Four units can be differentiated and are repeated on both sides of the synclinal axis. Thicknesses given below are approximate. The units are, from the base upwards:

- (1) 400 m of fine to very fine-grained, medium to thick-bedded quartz sandstone. Most beds show faint, internal plane lamination. Cross bedding, usually as small low-angle troughs, is common, including swaley cross stratification (Plate 10, Plate 11). Hummocky cross stratification was observed at the top of this unit on the western limb of the syncline. Many structureless beds are probably thoroughly bioturbated.
- (2) 60–100 m of thick-bedded, thoroughly bioturbated (mottled) muddy siltstone, with thin (20–50 mm), weakly graded, planar-laminated beds of very fine-grained sandstone. Tops and bottoms of many sandstone beds are partly disrupted by burrows. Syn-sedimentary slump structures occur near the top of this unit. Near the base [377600/5331000] there are a few beds of medium to very coarse-grained, cross-bedded sandstone.
- (3) 100 m of fine to very fine-grained quartz sandstone similar to (1).
- (4) Approximately 100 m of interlaminated and thinly interbedded subequal dark grey to black slate and very fine quartz sandstone. Sandstone layers are lenticular and impersistent. This unit may represent the upward transition into Bell Shale, but no Bell Shale proper (of predominantly pelite) crops out in the core of the syncline.

A thin section (R009581) of the coarse sandstone at 377600/5331000 shows a moderately sorted sublithic

quartz sandstone with rock fragments of chert, metaquartzite, quartzwacke, mudstone, and a single basic or intermediate volcanic fragment composed of plagioclase laths in a turbid cryptocrystalline groundmass. There are common crinoid ossicles with syntaxial overgrowths, and bryozoan fragments. There are rare grains of sodic plagioclase, and accessory tourmaline and zircon.

Bell Formation (Db)

INTRODUCTION

The Bell Formation consists of black mudstone and siltstone that is everywhere cleaved and frequently of slate grade. There are minor thin beds and laminae of siltstone and sandstone in parts of the sequence, and rare limestone occurrences.

This, the youngest formation of the Eldon Group, crops out in the central parts of the large Devonian synclinoria. The northern part of the King Synclinorium, in the Little Eldons area, widens out to a partly fault-bounded basin about ten kilometres wide. Bedding consistently dips and faces towards the central part of the basin over wide areas [e.g. north of 398000/5341500], indicating that the preserved thickness of the Bell Formation may be as much as 3000 metres.

In the Dubbil Barril Synclinorium, the Bell Formation includes a lower, heterolithic facies that includes sandy layers with sedimentary structures suggestive of deposition by waning currents in a shallow shelfal environment (Baillie and Williams, 1975). A similar facies is present in the King Synclinorium but occurs some distance above the base of the formation. The sandy layers are probably essentially storm beds.

KING SYNCLINORIUM

The overwhelmingly predominant lithology is dark grey to black slate and cleaved mudstone. Cleavage is nearly everywhere inclined to bedding. Along the eastern border of the outcrop area, between Nelson Creek and the upper Balaclava River, cleavage is weak or absent, but elsewhere, cleavage is well developed and pervasive and the rock is a slate. However, the resultant fracture planes are generally insufficiently well developed for the slate to be of commercial interest.

About 5% of outcrop in the Bell Formation constitutes a heterolithic facies in which thin beds of lighter-coloured quartz siltstone or very fine-grained quartz sandstone are present. These layers generally have sharp bases, are planar and persistent, 20–100 mm thick, and constitute up to 30% of the rock volume, the rest being pelite. The siltstone or sandstone layers typically display planar-parallel lamination, and commonly cross lamination. The bases of some of the sandstone layers exhibit groove casts (Plate 12). This facies crops out along the discontinuous ridge of outcrop between 390400/5339400 and 389700/5339500, and along Princess Ridge between 389800/5340700 and 390800/5342100. Other occurrences are few and scattered across the whole outcrop area of the Bell Formation. Around 390000/5339400, where bedding and cleavage are at a high angle, sedimentary structures are strongly deformed.

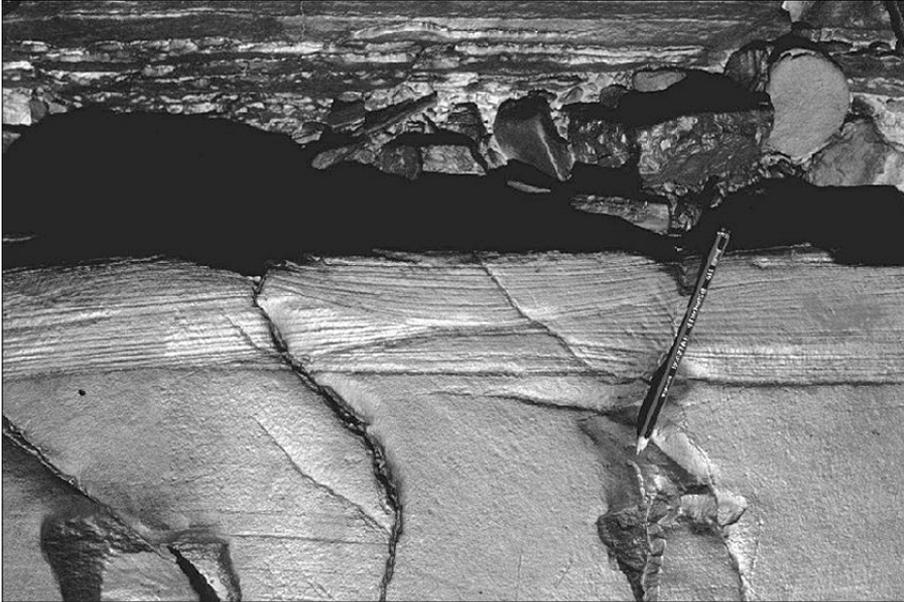


Plate 10
*Swaley cross-stratification,
Florence Formation, King River
[378000/5331600].*



Plate 11
*Alternating low-angle cross bedding and
plane lamination, Florence Formation,
King River [377600/5331000].*



Plate 12
*Groove casts in Bell Shale,
Lyell Highway [389600/5340400].*

The great bulk of the remainder of the sequence constitutes a probably more distal facies in which siltstone layers are absent or at most, present only as sparse, thin laminae, typically comprising a few per cent or less of the outcrop. The laminae are planar, persistent, often bundled, commonly calcareous and sometimes graded. A few are bioturbated. In the absence of siltstone laminae, bedding in the slate can usually still be discerned as bedding planes spaced 50 mm to one metre apart. In a minority of outcrops bedding is not discernible.

There is rare limestone in the Bell Formation. At 397800/5348800 and along strike at 398800/5348100, dark grey richly fossiliferous calcareous siltstone with discontinuous thin beds and nodules of limestone is present. Elsewhere there are rare beds of impure, silty, fine-grained unfossiliferous limestone and calcareous siltstone with slumped lamination.

The Bell Shale correlate is locally richly fossiliferous. Crinoid columnals are the most typical faunal element. Other forms observed include small orthids, *Notanoplia*, '*Nucleospira*', *Pleurodictyum*, a rugose coral and trilobite fragments (M. J. Clarke, pers. comm.).

'LAMPROPHYRE' (DI)

A small outcrop shown as lamprophyre within Bell Shale, at 393600/5346200 in the Little Eldon Range, is a pale pink rock, aphanitic except for rare, clear quartz phenocrysts 1–2 mm in diameter. The outcrop is two metres wide and roughly 50 m long, and the long dimension trends 160° (subparallel to bedding and cleavage in the surrounding rock). A weak parting in the 'lamprophyre' also trends 160° and dips steeply east. In thin section (R009621) the rock consists mainly of a very fine-grained (20 µm) intergrowth of quartz, probably feldspar, and lesser brownish-green biotite, with common larger plates (0.5 mm) of biotite, weakly aligned, scattered throughout. The rare, clear quartz phenocrysts are perfectly euhedral. The rock lacks cleavage. There are also rare, euhedral phenocrysts of probably plagioclase largely replaced by carbonate. The abundance of quartz and lack of olivine and pyroxene in this rock indicates a felsic composition quite unlike typical lamprophyres of western Tasmania. The fine grain size suggests an origin as a rhyolitic sill or flow.

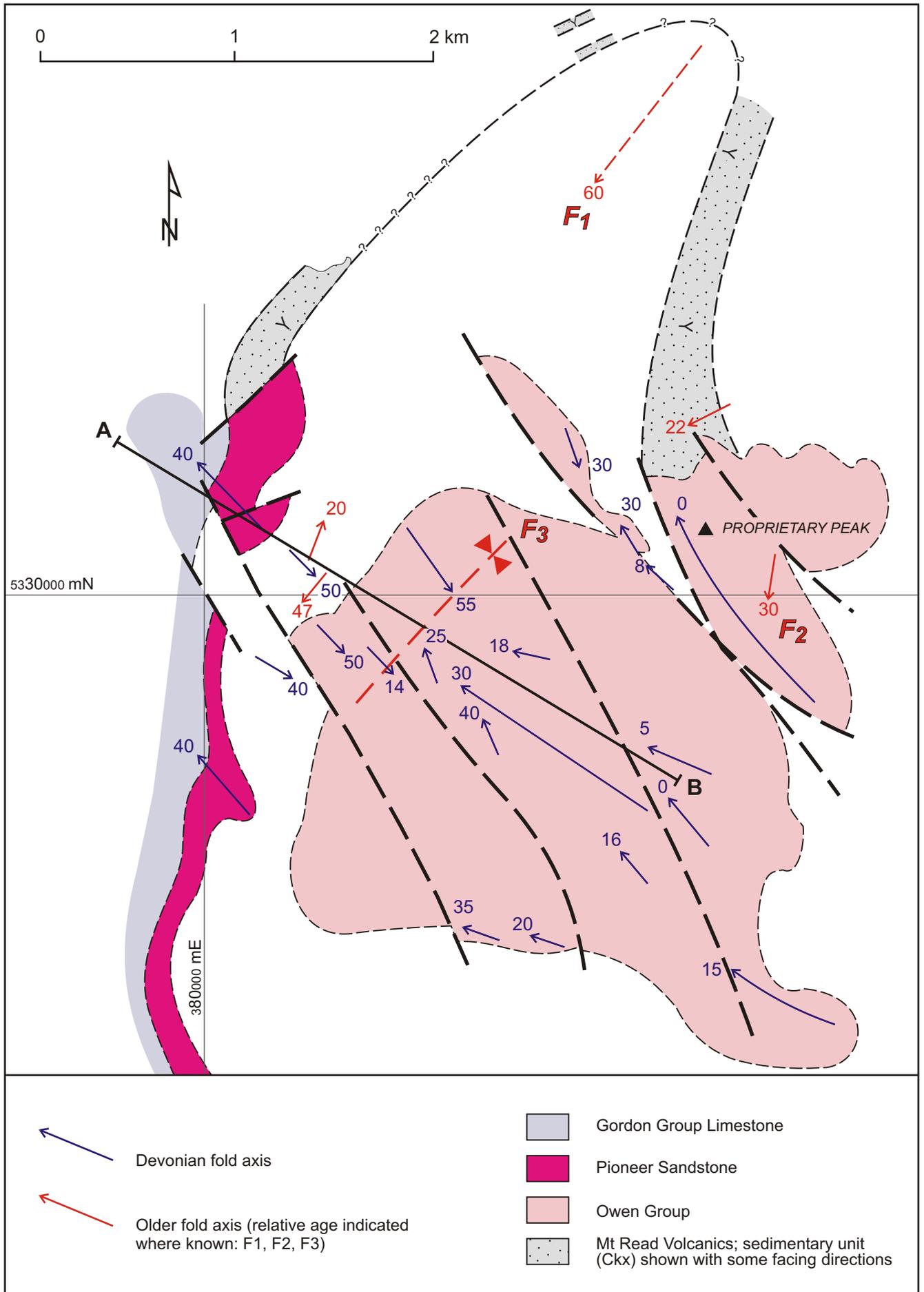


Figure 6

Relative ages of folds, Mt Jukes–Newall Creek area. For section A–B, see Figure 8.

Cambrian deformation

Mt Jukes–Mt Strahan area

There is evidence for two Cambrian phases of deformation in the Mt Jukes–King River gorge–Newall Creek area, and a probable third phase coeval with the Haulage movement (Early Ordovician) of the Mt Lyell mines area. All three phases produced open, southwest-trending folds with no known cleavage.

The first phase affects Central Volcanic Complex volcanic rocks and pre-dates the Owen Group. The volcanic rocks are folded into a major southwest-plunging syncline as demonstrated both by facing directions in the sedimentary unit Ckx, and a repetition of units (Ckvp, Ckx) on both limbs, with pyroclastic rocks (Ckvr) occupying the core of the fold (fig. 6). That this structure is Cambrian is shown by the angular unconformity where the eastern limb is truncated by the base of the Late Cambrian Owen Group at 382400/5330900 — the type Jukesian unconformity of Carey and Banks (1954). The trend of the fold is unlike Devonian trends, and north to northwest-trending Devonian cleavages transect the fold.

The unconformity is well exposed on a northern spur of Proprietary Peak [382400/5330900]. There are repeated exposures along the crest of the spur as the unconformity is offset by minor faults parallel to the major, northwest-trending fault shown on the map. Thin bedded fine-grained tuffs immediately under the unconformity at one locality dip 42° towards 310°, and at another nearby location 81° to 265°. Basal beds of the Owen dip gently (20°) to the southeast. Steep, west to northwest dips are inferred for the limb of the fold at the time of Owen deposition.

The southern extension of this syncline, south and southwest of the Owen Group outlier of Mt Jukes, is doubtful. Four very scattered facing directions in Ckvr and Ckx all face west or northwest, which is tenuous evidence for the large area of Ckvr between Thomas Currie Rivulet and the Mt Jukes outlier being all on the eastern limb of the syncline.

Rare, minor (outcrop-scale) folds of a southwesterly trend occur in the volcanic rocks, and may belong to this first Cambrian phase. One such minor fold in Newall Creek [380400/5330100], developed in a sedimentary unit (Ckm) within the volcanic rocks, lacks an axial planar cleavage but is transected by a northwest-trending Devonian cleavage.

The second Cambrian phase of deformation is strictly localised and affects the 'lower Owen conglomerate' (Oolc) on the northeast face of Mt Jukes [383000/5330000]. Bedding in Oolc is thrown into an open syncline that is truncated unconformably by the approximately planar base of the overlying 'middle Owen sandstone' (Ools) (Plate 6). The fold is asymmetric, with a steeper northwest limb. The fold axis plunges approximately 30° towards 190°. Poles to bedding of the unit overlying the unconformity fall on the same great circle as the folded beds, indicating that the fold axis was horizontal at the time the overlying beds were deposited (fig. 7). The movement that produced this fold

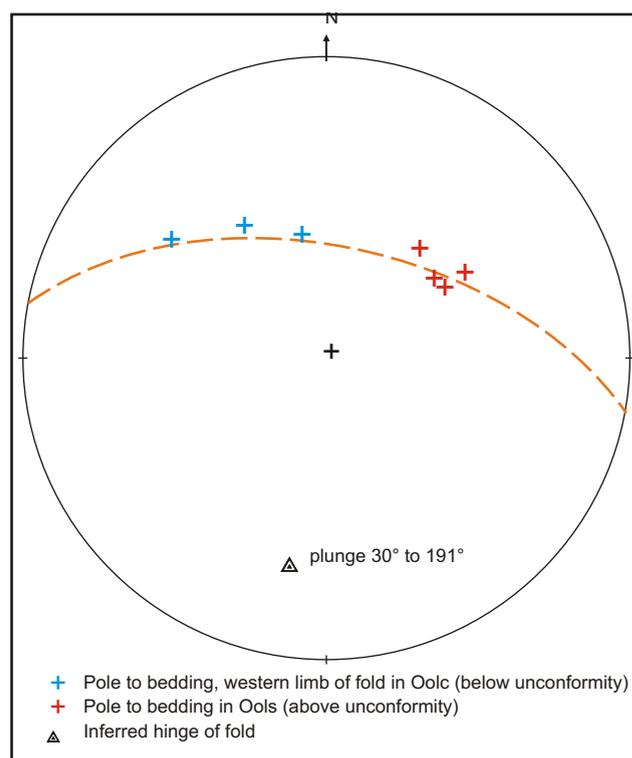


Figure 7
Poles to bedding, northeast face of Mt Jukes.

may also be manifested at Mt Owen and in the Tyndall Range, where a similar, gently angular unconformity occurs within, or towards the top of, the 'lower Owen conglomerate' (Corbett *et al.*, 1989; Corbett and Jackson, 1987).

The third phase, inferred rather than proven, is suggested by the presence of southeast-dipping beds in Owen Group along the northwestern edge of the Mt Jukes Owen outlier [380900/5330100]. This bedding orientation is anomalous with respect to the regional northwest-plunging Devonian folds and produces a southwest-trending syncline on which are superimposed minor Devonian cross folds. A Haulage age (i.e. post-'upper Owen sandstone' (Oos), pre-Pioneer Sandstone) for this structure is suggested by its coincidence with the westward disappearance of the Owen Group. It is suggested that this fold constituted an east-facing monocline during Pioneer time, allowing overstep of the upturned older units by the Pioneer Sandstone, which rests directly on basement nearby (fig. 8). This fold has a similar trend to the earlier Cambrian structures, and a similar sense of asymmetry to the fold produced by the second phase. The Great Lyell Fault, which forms the western limit of pre-Pioneer Owen units in the Mt Lyell mines area, passes well to the east of this area.

Another structural element of possible Haulage age is suggested by the highly disparate nature of the Denison Group correlates on either side of the Mt Strahan Fault. The thick sequence west of the fault appears to be a distal, possibly largely marine, equivalent of the Owen Group, possibly conformably overlying Tyndall Group rocks (see *Stratigraphy* section). Immediately east of the fault (for

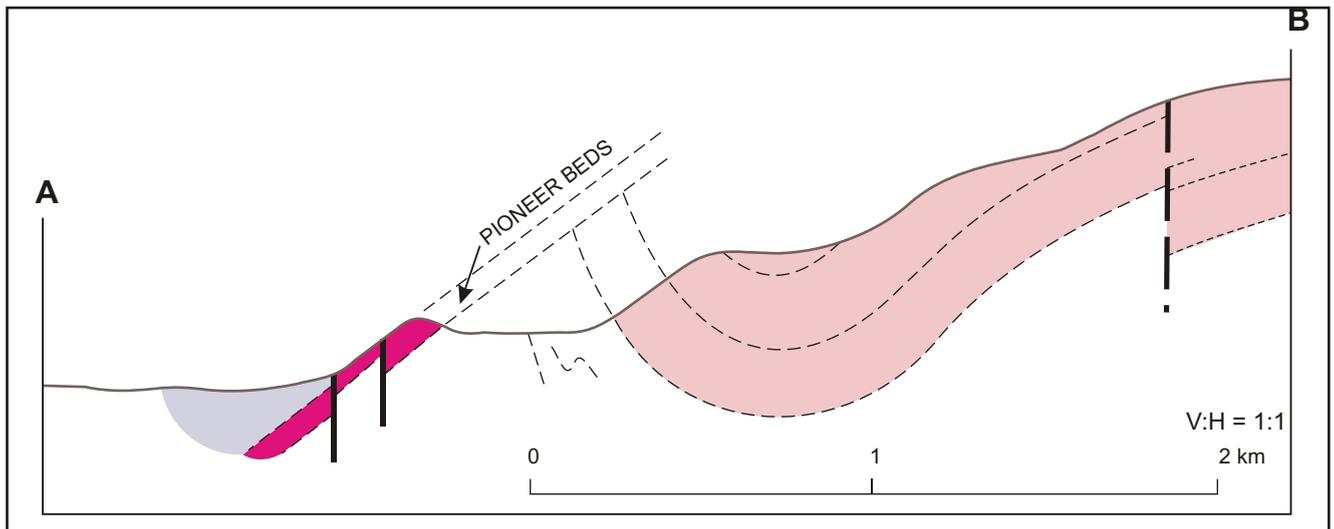


Figure 8

Section A–B on Figure 6, showing projected overstep of Pioneer Sandstone on older Owen Group. Legend as for Figure 6.

example at 378600/5326800), a Pioneer Sandstone correlate about 100 m thick rests unconformably or disconformably on volcanic rocks. A southward-thickening trend is apparent on both sides of the fault and hence dextral movement and/or convergence (thrusting) on the fault, with movement of many kilometres, could explain the present juxtaposition of disparate Owen–Pioneer sequences. While Devonian or post-Devonian movement has clearly occurred on the fault, which now has a subvertical orientation, much or all of the movement proposed above was probably pre-Devonian as suggested by the lack of substantial displacements in the Devonian synclinorium to the north. Alternatively, the Mt Strahan Fault may have been a west-side-down growth fault during deposition of the Owen Group. The Mt Strahan Fault may be a southward extension of the South Henty Fault, considered by Corbett and Lees (1987) to have been active as a thrust during the Cambrian.

Devonian deformation

Mt Jukes–Mt Strahan area

Devonian deformation is pervasive in this area, producing NW-NNW trending, open to tight folds and cleavage development in all but the most competent lithologies. Practically all the deformation can be attributed to a single phase, but a crenulation is locally present.

West of the Mt Strahan Fault, the thick Denison Group sequence (Os) is folded into a major SSE-plunging syncline, the western limb occupying Mt Strahan and its western slopes; the eastern limb occupies the eastern slopes and the lower Garfield and King River gorge areas. The eastern limb is steep and mostly overturned in the King and lower Garfield areas. Minor folds are abundantly developed and well exposed in the river sections. Minor folds plunge gently (10–30°) SSE in the King River gorge but plunges tend to be steeper (c. 40°) further south (fig. 9). Mudstone (Osm) is well cleaved, while quartz sandstone and conglomerate (Oss, Osc) tend to lack cleavage.

East of the Mt Strahan Fault, the pattern is one of north or northwest plunges, until the eastern flank of the West Coast Range is reached where plunges are once again to the southeast. In the Garfield River–Thomas Currie Rivulet area, two major synclines, each with a narrow core of Owen Group [379000/5325000; 381000/5326000] plunge north and northwest, converging to meet in a single major synclinal structure at the King River with Florence Sandstone at the core [378000/5331000]. It is not certain whether the two merging synclines are of two different generations. No two distinct generations of cleavage are preserved except at 377900/5328900 where, in slate in the Amber Formation, a northwest-trending second cleavage crenulates a north-trending, slaty primary cleavage. The more western of the two synclines is well expressed in the Tyndall Group and Western Volcano-sedimentary Sequence rocks as shown by abundant facing evidence on the opposing limbs in the Flannigans Creek and Garfield River areas. The eastern syncline is underlain by Central Volcanic Complex volcanic rocks in which facing directions are too scant to suggest a concordant synclinal structure. The western limb is overturned in places [380100/5326400; 381200/5325200].

The Owen Group on Mt Jukes has a prevailing westerly dip but is cut by a number of northwest-trending faults, nearly all with a west-side-up sense of movement, that result in a cuesta-like repetition of the sequence in adjoining fault blocks. The faults are probably steep reverse faults associated with the Devonian deformation. The fault immediately west of the summit of Mt Jukes has a surface trace that suggests a dip of 60° to the east and normal movement, as shown on the map sheet cross section. Fold axes have a prevailing northwest plunge, except for southeast plunges on the east-facing limb of the inferred early monocline (fig. 6). At the culmination of the West Coast Range, fold axes are roughly horizontal; on the eastern flanks they plunge southeast. A pattern of northwest-trending cross folding on an early, broad meridional anticline centred on the West Coast Range is indicated.

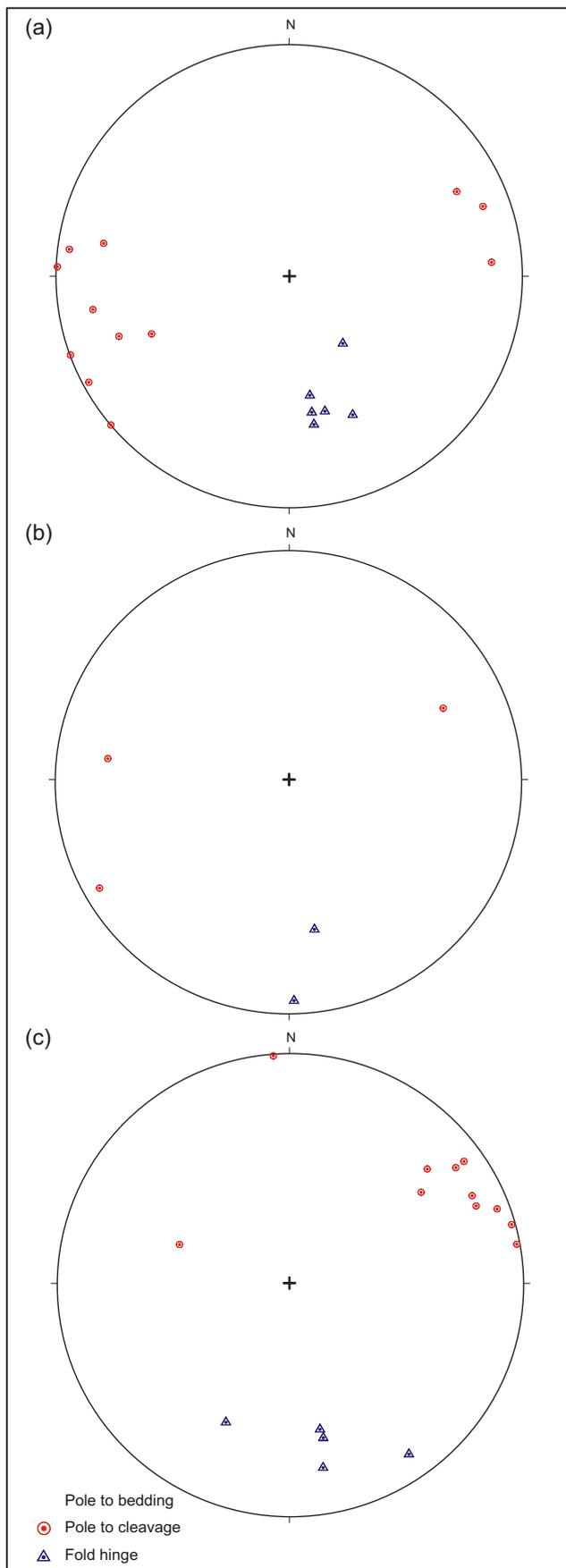


Figure 9

Equal-area plots of structural elements in Os, west of the Mt Strahan Fault.

- (a) Northern domain (King River area, north of 5329200 mN).
 (b) Central domain (lower reaches of Garfield River, between 5329200 mN and 5327000 mN).
 (c) Southern domain (Mt Strahan area, south of 5327000 mN).

The Devonian cleavage is generally a pervasive, slaty surface in mudstone and fine-grained tuff. Feldspar porphyry (Ckvp) is only weakly cleaved or, more usually, lacks cleavage altogether. Lack of strain in this competent lithology is also suggested by the preservation of essentially undeformed columnar jointing at 383100/5331200 and other localities. Quartz-feldspar porphyry of the Western Volcano-sedimentary Sequence (Clx) is similarly only weakly cleaved. Other porphyritic rock types, particularly the crystal-rich pyroclastic rocks (Ckvr; Clx of the Garfield River area), are usually strongly cleaved. Cleavage usually wholly overprints any eutaxitic foliation, except for a few outcrops of coarser tuff where cleavage and eutaxitic foliation are well separated in orientation.

Cleavage in the volcanic rocks consists of anastomosing sericitic seams. Frequently two distinct surfaces, of indeterminate relative age, are present and are shown as 'synchronous cleavage' (superimposed cleavage symbols) on the map. The surfaces are typically inclined at 20–30°. In some outcrops these surfaces appear to merge imperceptibly over several metres, through increasing parallelism into a single, planar to weakly anastomosing surface, presumably through an increase in strain. Phyllitic rock types, that are the product of intense cleavage development and some hydrothermal alteration (sericitisation of feldspars, minor silicification) occur locally [around 379900/5325500–379100/5326400; 380000/5330100].

Strong fanning of cleavage in mudstone beds in minor folds is typical in Oos. Similar fanning (divergent cleavage) is shown on the map scale in Amber Formation at 378400/5328600 to 379200/5328200. The competent quartzarenites and conglomerates of the Denison and Eldon groups — the bulk of the Owen, the Crotty and most of the Florence Formations — tend to lack cleavage.

The response of the Gordon Group limestones to tectonism is varied. Some outcrops appear to lack cleavage while others — typically the relatively pure carbonates — carry a strong foliation consisting in thin section of streaky segregations of coarser and finer microspar, that tend to be deflected around the larger sparry bodies (fenestrae, calcitised fossils). Calcite spar of fenestrae and veins is strongly twinned by deformation, but saddle dolomite remains unaffected despite its pre-tectonic age. Deformed, silicified rhynchonellids weathered out of black pug at 379900/5330800 indicate a maximum strain ratio (X:Z) of approximately 2:1.

King Synclinorium

The northern part of the King Synclinorium (Solomon, 1962) widens out into a broad structural basin or brachysyncline centred on the Princess River–Little Eldons area [395000/5345000]. The basin is faulted on its western side and along parts of its southern and eastern boundaries. The western boundary fault — the King River Fault of Wade and Solomon (1958, p. 380) — is a major concealed structure for the most part not shown on the map. The basin is occupied mostly by Bell Shale, of the order of three kilometres thick.

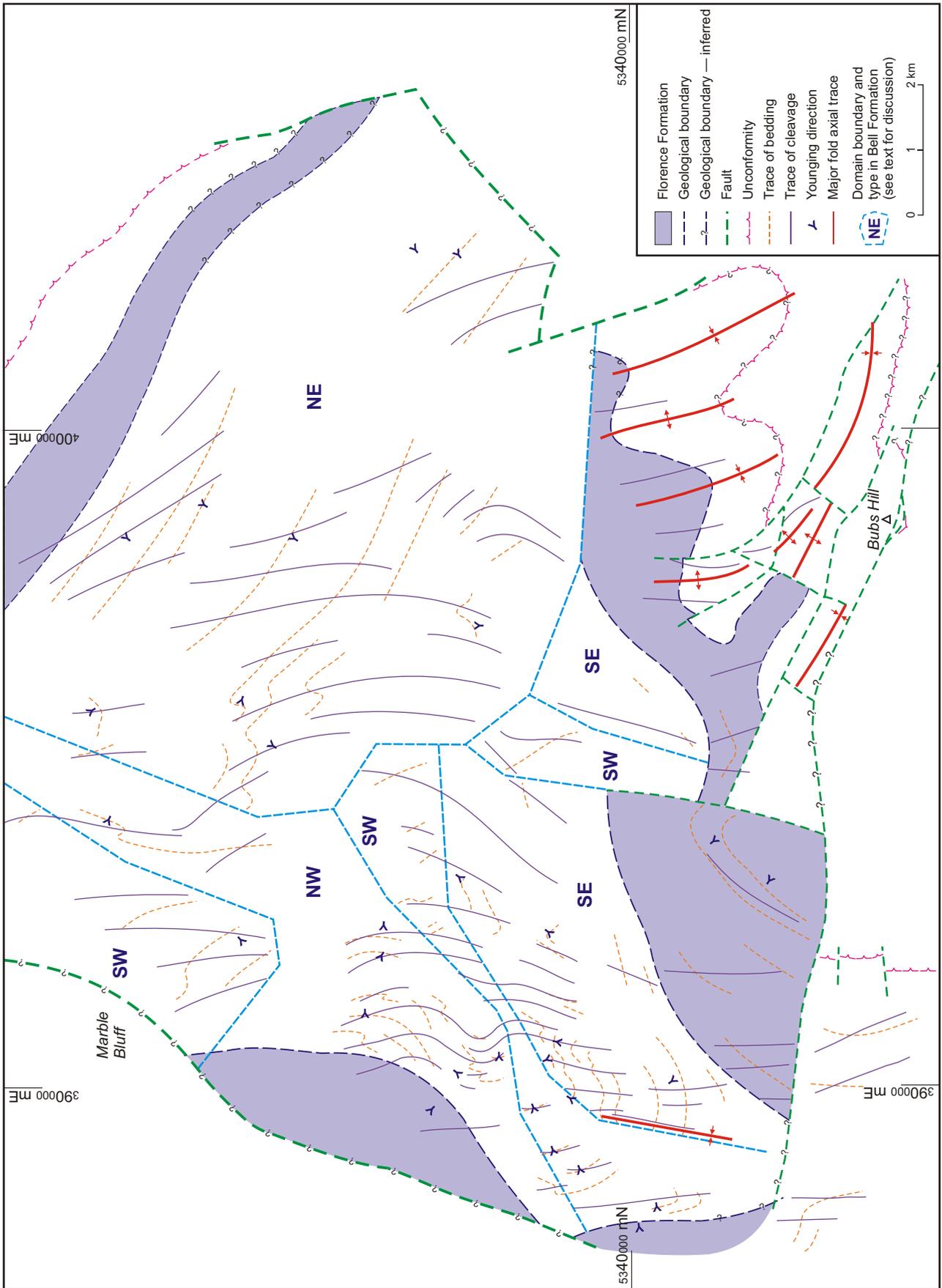
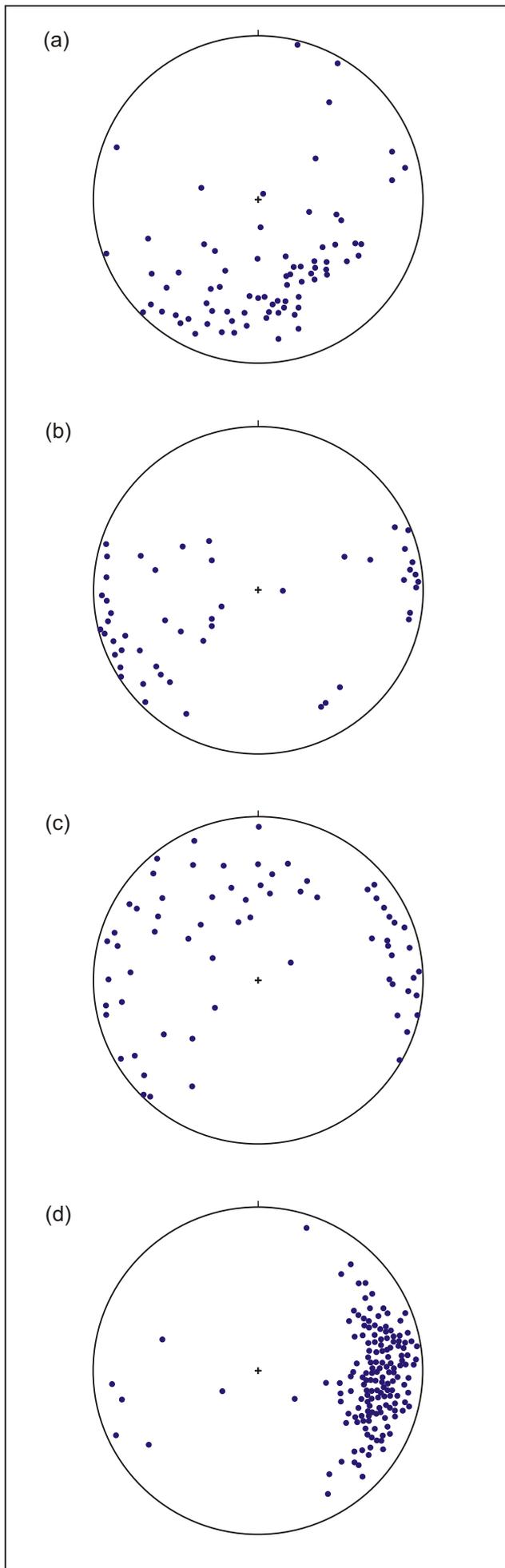


Figure 10. Structure of basin at north end of King Synclinorium.



Fold trends, and associated cleavage trends, vary widely but no evidence was found for more than one cleavage-forming event. Complex faulting, mostly of a WNW trend, affects the Gordon and Eldon groups in the Bubs Hills area at the southern margin of the basin, and results in a narrow faulted inlier of Precambrian rocks exposed on the Lyell Highway [398000/5337000]. Folding of 1–2 km wavelengths, of a similar WNW trend and subhorizontal plunges affects the sequences in this area, and swings to NNW orientations and steeper plunges further north. This more-or-less continuous swing in orientation is also reflected in the axial planar cleavage (fig. 10). Although there is considerable variation in the trend of cleavage across the basin, the apparent continuity of the trace of the single cleavage, and the lack of crenulation, suggests only one phase. Cleavage trends in the remainder of the basin approximate north–south, with steep, usually westerly dips. There are gentle warps, with wavelengths of 2–3 km or more, affecting the cleavage that locally cause a variation in trend of as much as 60° [e.g. around 390300/5342300] (fig. 10).

Minor folds in bedding are uncommon; indeed there are areas several kilometres in extent with more-or-less constant dip and facing [e.g. 398000/5349000–398000/5342000–402000/5347000]. The eastern part of the basin appears less strongly deformed than the western part. In the west (particularly south and west of 394000/5345000) a strong planar slaty cleavage is ubiquitous in the Bell Shale and there is an eastward transition to Bell Shale with weak or no cleavage, for example around 399000/5342000 to 303000/5343000.

As a preliminary structural analysis, the Bell Shale part of the basin was divided into domains based on facing and vergence. Four types of domain can be distinguished based on their position in an idealised, equi-dimensional basin crossed by a north–south cleavage: the SW domain, of north facing and predominantly sinistral vergence (the latter in practice taken from the sense of intersection of bedding and cleavage); the SE domain, of north facing and dextral vergence; the NW domain of southward facing and dextral vergence; and the NE domain of southward facing and sinistral vergence. The basin is substantially asymmetrical, with a large NE domain and subsidiary SW and SE domains (fig. 10). The centre of the basin is shown to be at about 395000/5344000. Stereoplots of bedding and cleavage from the southwestern part of the basin (south and west of 395000/5345000) show the change in fold plunges across this part of the basin, and the steep west-dipping cleavage displaying a spreading of poles due to the broad warping mentioned above (fig. 11).

Cleavage in the Bell Shale is strongest in the southwestern part of the structural basin (south and west of 395000/5345000) where the rock is predominantly a slate. A strong, approximately down-dip lineation is common on cleavage surfaces. In thin sections (R009560, R009638, R009562) the

Figure 11

- Poles to bedding and cleavage, Bell Shale*
 (a) Poles to bedding in main SE domain (see fig. 10).
 (b) Poles to bedding in main SW domain.
 (c) Poles to bedding, NW domain south of 5345000 mN.
 (d) Poles to cleavage corresponding to (a), (b) and (c).

cleavage is resolvable into a seamed cleavage, with 50 µm wide microlithons, crenulating primary fissility. In F11 there are quartz overgrowths in pressure shadows on pyrite euhedra, and bedding-parallel books of muscovite and chlorite that form small, clear augen 0.1 mm in size. Sedimentary structures in siltstone and fine-grained sandstone layers are strongly deformed, and cleavage in these layers is seen in outcrop as a spaced, differentiated surface.

Outside this southwestern area, the Bell Shale is a cleaved mudstone or siltstone, with cleavage becoming weak and in places difficult to detect in the eastern parts of the basin. Pencil structure — a rod-like fracture pattern typical of weakly cleaved mudstone caused by two sets of steeply intersecting fractures (Reks and Gray, 1982) — occurs around 398500/5342000.

At a few widely scattered localities there are significant surface accumulations of vein quartz rubble, apparently lag upon subcropping, large quartz veins. The veins, up to one metre wide and several tens of metres long, usually have a trend parallel to cleavage. Minor chlorite and limonite occur

with the quartz. These vein quartz occurrences were recorded at 390800/5342200; 390200/5337400; 389800/5340800; 390200/5340900; 391400/5344100 and 391500/5343000.

Silty mudstone and siltstone in the Florence Formation and upper Crotty Formation (Scs) typically carry a cleavage consisting of a differentiated surface; dark anastomosing seams spaced at 0.5–3 mm apart. Coarser-grained rocks tend to lack cleavage. The Gordon Group limestone at Bubs Hill mostly appears undeformed and generally lacks cleavage. However two sets of tectonic stylolites are present at one locality southwest of Bubs Hill; the earlier set dips 75° towards 273°, and the later set (also developed as a crenulation within the seams of the first set) dips 73° towards 202°. Further west, in the Nelson River–Governor River area, the limestones are more generally cleaved but some outcrops remain undeformed. Around 391700/5336500 cleavage is developed as lighter and darker streaky zones that appear in thin section as slightly coarser and finer zones of microspar (probably recrystallised micrite). A strong down-dip lineation is present on cleavage surfaces in this area.

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