Mineral Resources Tasmania
Tasmanian Geological Survey
Record 2006/04

Geology of the Maydena, Skeleton, Nevada, Weld and Picton 1:25 000 scale map sheets

by C. R. Calver, S. M. Forsyth and J. L. Everard

CONTENTS

Figures

Tables

Plates

General remarks

The Maydena, Skeleton, Nevada, Weld and Picton 1:25 000 scale digital geological maps comprise a north–south series of adjoining maps in central–southern Tasmania (fig. 1, 2). Although the area is only 50 km west of Hobart, much of it is little visited and difficult to access, and until the mapping described here was undertaken, most of the area was poorly known geologically.

The small forestry and tourist centre of Maydena is the only permanent settlement, and is situated in the north of the mapped area. The Gordon River Road runs westward through Maydena, and forestry roads branching to the north and south provide access to much of the Maydena and northern Skeleton maps. The forestry industry once utilised rail transport from a railhead just west of Maydena. Currently the useable line stops a few kilometres short of the township.

The eastern parts of the Nevada, Weld and Picton maps are accessed by forestry roads leading from the Huon Valley. Two walking tracks provide access onto the Snowy Range. The western parts of the four southern map sheets can only be reached on foot or by helicopter. The Huon, Weld and Picton rivers were mapped using an inflatable boat.

The area is one of rugged scenic beauty, with a number of mountain ranges rising to over 1000 m above valley floors at elevations between 100 and 300 metres. The Snowy Range, particularly the Lake Skinner area, is regularly visited by bushwalkers. Most of the western parts of the southern four map sheets lie within the Southwest Tasmania World Heritage Area. The bulk of the remaining area is State Forest. The only freehold land occurs adjacent to the Gordon River Road in the Maydena area.

Forestry is the main land use, taking place in the valleys of the Tyenna, Styx, Russell, Little Denison, Weld and Huon rivers. As part of the forestry operations several small quarries have been opened to provide gravel for road construction. The forests are also used by apiarists and florists.

Before the release of these maps in 1997–1999, the geology of the area was mostly very poorly known, with very little previous geological mapping. The 1:50 000 scale Pedder and Huntley geological maps (Turner *et al*., 1985; Brown *et al*., 1982) cover the area to the west of the Maydena, Skeleton and Nevada sheets.

These five maps straddle the roughly meridional divide between deformed Proterozoic and lower Palaeozoic rocks to the west, and flat-lying late Palaeozoic to Mesozoic rocks to the east. The western parts of these maps are thus dominated by the older 'basement' lithologies that belong to a geological terrain known as the Adamsfield–Jubilee region, while the eastern parts are dominated by the younger rocks of the Tasmania Basin, which unconformably overlie the older rocks.

Geological mapping of the western parts of the Maydena, Skeleton and Nevada maps was carried out by C. R. Calver between 1987 and 1990. The eastern parts of these sheets (those parts made up of Tasmania Basin rocks) were mapped at reconnaissance level by S. M. Forsyth between 1995 and 1997. These three sheets were released as digital geological 1:25 000 scale maps in 1997. The Weld and Picton 1:25 000 scale sheets were mapped by C. R. Calver and J. L. Everard between 1995 and 1998, and released in 1997 and 1999 respectively. Part of the rationale for this recent phase of mapping was to investigate the setting of mineralisation in Proterozoic–Cambrian rocks of the Glovers Bluff inlier on the Weld map sheet, and to better understand the geology and prospectivity of the concealed basement rocks of southeastern Tasmania.

This report describes the geology of these five maps, and a narrow (one kilometre) strip west of the Maydena, Skeleton and Nevada map sheets that represents the gap between the eastern edge of the Pedder 1:50 000 scale map and these maps, and also a small area east of the Weld map underlain by Cambrian rocks. Appendix 1 covers The Needles area west of the Maydena map, where fieldwork in 1987–1990 clarified relationships in the type area of the Clark Group. The report thus covers much of the eastern part of the Jubilee region (fig. 1). The southern and southwestern parts of the Jubilee region remain poorly known.

Difficulties of terrain, access and vegetation cover, and a perceived lack of mineral prospectivity, have meant that very little previous systematic geological work has been carried out over most of the mapped area. Lewis (1924, 1940) described in broad terms the geology and glacial geomorphology of the Weld and Tyenna valleys. Blake (1935) described an early geological traverse in the upper Huon valley, in the area covered by the Picton 1:25 000 scale map. Carey and Banks (1954) briefly described the geology of The Needles area. Jago (1972) mapped and described the Parmeener Supergroup at the western end of the Maydena Range, and nearby Cambro-Ordovician rocks in the Pine Hill area. Colhoun and Goede (1979) documented Quaternary deposits, including till, at Blakes Opening (Picton map sheet). Geological mapping at 1:50 000 scale in the adjoining area to the west (Huntley and Pedder maps: Brown *et al*., 1982, 1989; Turner *et al*., 1985; Calver *et al*., 1990) has provided a foundation for the interpretation of the Proterozoic and Cambrian rocks.

There has been intermittent exploration for a range of commodities (gold, base metals, industrial minerals) in both the Glovers Bluff area (Weld map sheet) and west of Maydena (Maydena–Skeleton map sheets) within the last thirty years (Calver *et al*., 2006). Mineral Resources Tasmania has recently carried out specialised studies of the mineralisation at Glovers Bluff (Bottrill and Woolley, 1996; Bottrill *et al*., 1999).

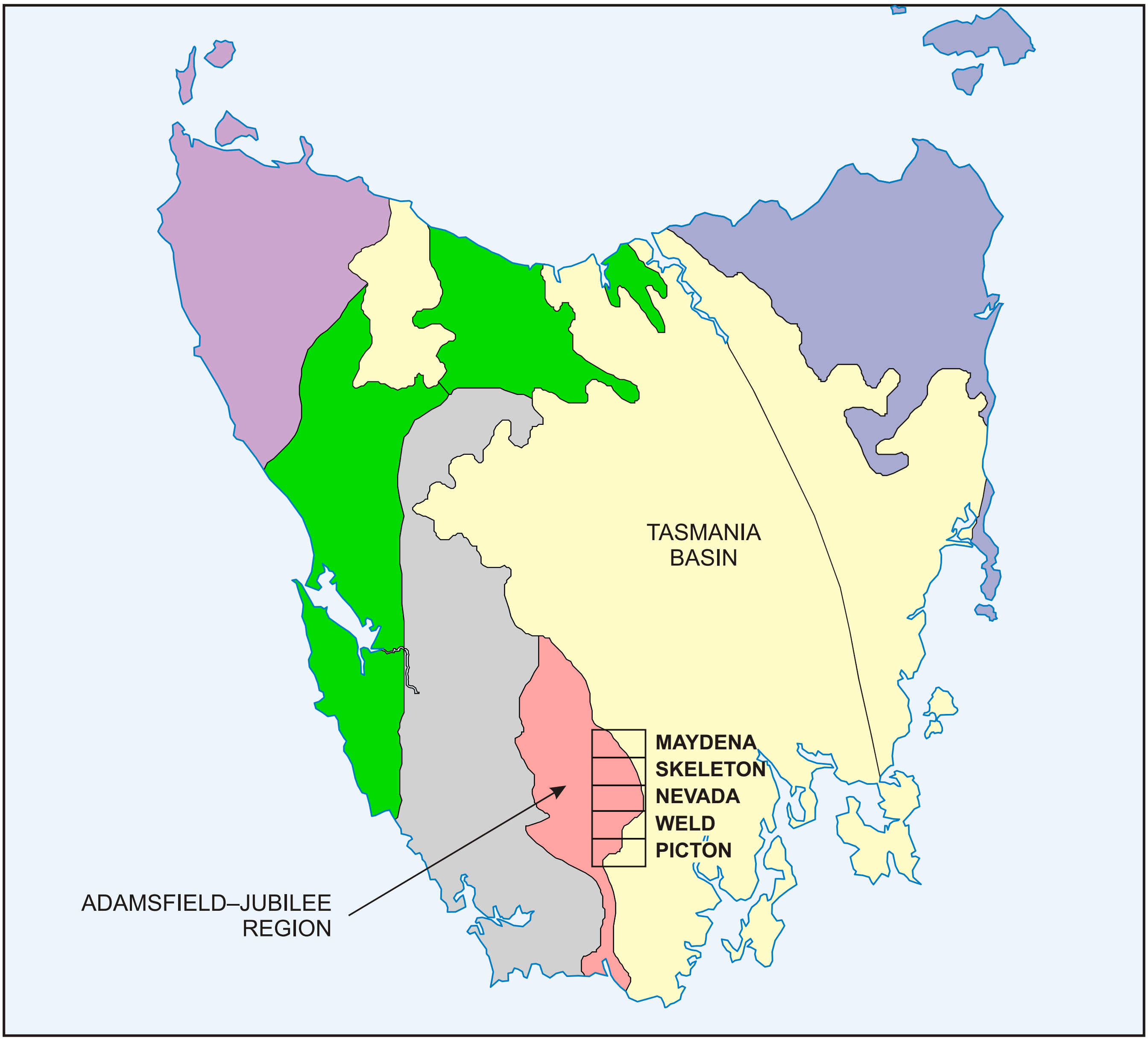


Figure 1

General location plan for Maydena, Skeleton, Nevada, Weld and Picton map sheets, and major adjoining tectonostratigraphic elements.

In this document, full AMG co-ordinates are given for localities. Sample numbers are registered numbers in MRT's TASROCK database. Rock unit mnemonics were revised in 2000; those used in this report are the revised versions used on post-2000 editions of the maps.

Parmeener Supergroup mapping — Maydena, Skeleton and Nevada map sheets (SMF)

The brief reconnaissance mapping program conducted during 1995/1996 in the Maydena, Skeleton and Nevada sheets targetted the Parmeener Supergroup and younger geology that could be reached from the existing road system. The mapping built upon previous work that had established and mapped the stratigraphic succession on the Maydena Range west of Lorkins Lookout, extending from the Tyenna River to the south side of the Styx River (Jago, 1972). Some reconnaissance mapping had also been carried out in the Styx Valley followed by the drilling of two boreholes (Anon., 1981). The basal Parmeener Supergroup unconformity had already been mapped by C. R. Calver during the 1987–1990 mapping period.

One aspect of the new work was to adapt the earlier map (Jago, 1972) to the 1:25 000 scale base map by inspecting new and old road sections and to undertake traverses along the Gordon Power Scheme transmission lines which had recently been cleared of all vegetation. It was commonly found that rock exposures in the old sections had deteriorated significantly and that some spur roads were no longer accessible by vehicle. Consequently significant reliance has been placed on the earlier descriptions (Jago, 1972) in writing this report. To draw a new map it was often found necessary to interpolate boundaries over distances of many kilometres without any ground control. Standard methods involving strike lines based on measured dip or average dip, aerial photo interpretation and fixed points on the early map have been used. The intersections of geological boundaries and drainage lines were not regarded as fixed points in all areas. In addition J. Jago kindly provided information on the location of some traverses that he had undertaken.

Apart from the access roads associated with the electricity transmission line, the Styx Road has been linked to Karanja partly along the route of the old Karanja mill tramway. Several spur roads extend into areas south of Styx Road. Although these roads had been in existence for some time the geology exposed along them was unknown. Similarly the road system in the Russell River, Falls Creek and Little Denison River area had been expanded with new spur roads and a new link road over Compton Hill between McDougalls Road and Russell Road, but the geology was largely unknown. Although the vehicular tracks were useful for navigation some tracks appearing on the maps were badly overgrown, and particularly in the Falls Rivulet catchment almost impenetrable, with cutting grass covering many tracks and surrounding areas.

Upon completion of the road system mapping some additional traverses were conducted along stream sections, foot tracks, cleared logging coupes and through forest. These traverses were not comprehensive, with areas more than a half day walk from vehicular access not being visited.

Special access problems were experienced during mapping because of unseasonable flash flooding and generally high levels of the Styx River. This reduced the opportunity to map the northern side of the Styx River.

Some of the more important traverses carried out include an almost complete traverse of the Styx River within the eastern confines of the Maydena map sheet; Falls Rivulet in the Lower Parmeener section; ascents to the saddle between Snowy North and Mount Styx from both the north and the south directions; Snowy North to the dolerite base; Scrivens Cone; Lake Skinner; and a descent to the saddle between Abbotts Lookout and Marriotts Lookout. Poor weather conditions, with snow or rain and enclosing cloud, was encountered on all ascents near the Snowy Range. Access to the western slopes of the Snowy Range was outside the scope of the project. Less penetration than hoped was made down the western side of the range from South Styx Road partly because the road was impassable to vehicles. For the same reason only walking access was possible for Waterfall Creek Road and Ted Ransleys Road and this limited the time spent mapping in this area. Another area poorly investigated is that between Marriotts Lookout and Lorkins Lookout and the Styx River. Abnormally high river levels prevented access to this area until late in the season and thickets of horizontal scrub (*Anodopetalum biglandulosum*) slowed progress in some areas.

Much of the higher ground is covered in stunted vegetation and in places is above the tree line. These areas have been amenable for aerial photograph interpretation of Jurassic dolerite distribution and Pleistocene glacial features. The mountain slopes and lower ground are densely vegetated, commonly with very tall forest, and few geological features are visible on aerial photographs. Although the project successfully expanded the geological knowledge of the map sheets some areas remain poorly known.

Vegetation

The area has a cool, wet maritime climate with an average annual rainfall of around 1200 mm. Wet sclerophyll forest and temperate rainforest cover most of the area, with some drier forest types on north-facing slopes. Particularly tall *Eucalyptus regnans* forests are developed on soils formed on alluvium and Lower Parmeener strata in the Tyenna and Styx valleys where patches of rainforest are also common. In some areas, such as north of Snowy North, a mosaic of different forest growth stages occurs as a result of the vigorous forest harvesting that has extended to 600–700 mASL. The dolerite soils in the Russell River and Little Denison River valleys support *Eucalyptus obliqua* forest.

There is a progressive reduction in forest height up the western slopes of the northern Snowy Range, passing into low rainforest before this in turn is replaced by scrub, open mountain moors and expanses of rock on the exposed upper part of the range. Low rainforest was also found on some thin soils developed on Upper Parmeener sandstone at lower altitudes. Low *Eucalyptus* forest, scrub and treeless areas are found on the dolerite crests of the Maydena Range with some heath and scrub on poor Lower Parmeener-derived soils at about 900 m elevation near the western end of the range. *Eucalyptus coccifera* and *E. subcrenulata* low forest and sub-alpine scrub occur above the *E. obliqua* forests in the Snowy Range–Mt Styx area, with treeless mountain moors in poorly drained areas giving way to tea tree or melaleuca thickets at lower altitudes.

Open buttongrass sedgeland predominates on the impoverished quartzite-derived soils of the Jubilee Range, Gallagher Plateau and Glovers Bluff–Bernard Spur. A dwarfed alpine flora predominates at high elevations. Pine plantations and some pasture have been developed near Maydena, but some older farms have reverted back to scrubby bushland.

Although vegetation usually impeded access and navigation away from the tracks, and access generally deteriorated in regeneration areas, very difficult conditions were only encountered in high altitude regenerating rainforest, in some areas of dense cutting grass (*Gahnia grandis*) and at local thickets of horizontal scrub (*Anodopetalum biglandulosum*) in virgin forest.

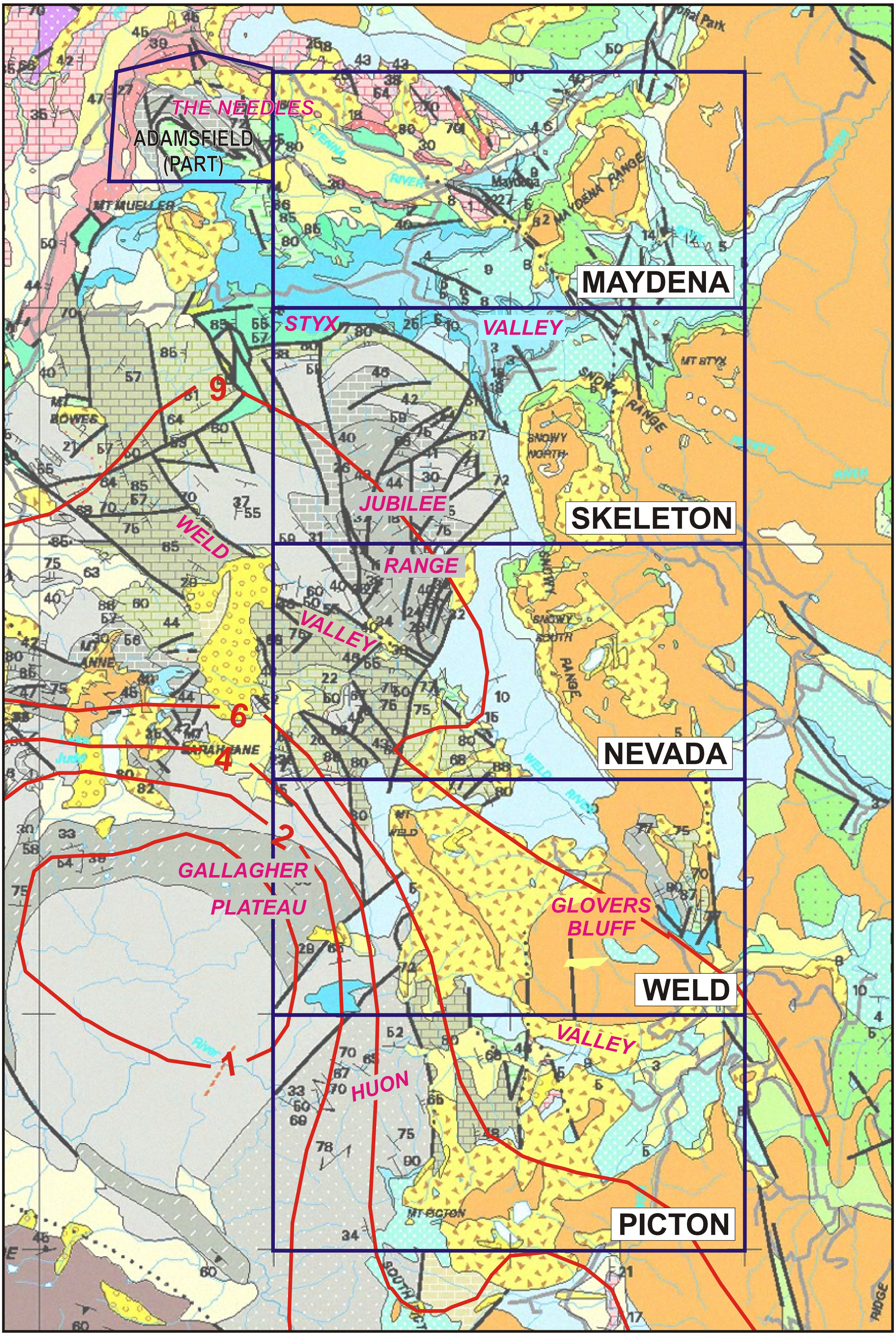


Figure 2

Map sheets on the 1:250 000 scale geology base. The red contours indicate depth to Devonian granite derived from gravity modelling.

Physiography

The area is crossed from east to west by the Tyenna, Styx, Weld and Huon rivers. These rivers occupy mostly narrow valleys separated by discontinuous mountain ranges rising to 800–1400 metres. These comprise the Maydena Range, Jubilee Range, Snowy Range, Weld Ridge, Gallagher Plateau and Mount Picton.

The five map sheets straddle the boundary between two broad physiographic subdivisions of Tasmania which Davies (1965) termed the Fold Structure Province and the Fault Structure Province. The Fold Structure Province is developed on the deformed Proterozoic to lower Palaeozoic rocks to the west, and is characterised by strike ridges of quartzite and valleys underlain by pelitic or carbonate rocks. The Fault Structure Province is characterised by physiography developed on faulted, gently dipping rock units of the late Palaeozoic to Triassic Parmeener Supergroup and Jurassic dolerite, leading to angulate, fault-controlled drainage and tabular mountain forms.

Fold Structure Province

The Jubilee Range (Skeleton, Nevada map sheets) and the Gallagher Plateau (Weld sheet) (fig. 2) are the two largest strike ridges of the Fold Structure Province in this area. The limited elevation and relatively flat tops of these ranges are probably remnants of the pre-Parmeener (Late Carboniferous) erosion surface. A smaller quartzite strike ridge is also present in an inlier at Glovers Bluff (eastern Weld sheet); and discontinuous strike ridges are developed on Cambrian chert and Ordovician quartz sandstone (Pine Hill, Nicholls Spur) in the western part of the Maydena map sheet.

Limestone and dolostone underlie much of the western parts of the map sheets, and retain relatively youthful topography rather than developing flat-floored karst valleys. In part this is because the carbonate rocks have been exposed relatively recently by erosional retreat of the flat-lying Parmeener Supergroup cover at a considerably higher elevation than the base level of the major streams. Thus, significant areas of deep karst or steep karst terrain are developed in the Ordovician limestone in the northern part of the Maydena map sheet, and in Proterozoic dolostone west of Mt Weld and north of Mt Picton. Sinkholes and streamsinks are typically developed where streams cross the base-Parmeener unconformity onto carbonate, a result of the aggressive action of undersaturated allogenic drainage. The Junee River emerges from a large outflow cave at 466900/5268000* near Maydena.

The complex topography in the Proterozoic dolostones of the Styx, Weld and Huon valleys is also partly due to the presence of relatively resistant interbedded diamictite, sandstone and conglomerate, and the presence of resistant silicified zones within the dolostone, for example at 467600/5240900 in the Nevada map sheet. Small karst lakes are present at 470200/5225900 (Picton map sheet) and around 466500/5242900 (Nevada map sheet). Whitewater Creek disappears into a streamsink in dolostone at 457900/5243200. Kiernan (1995) briefly reviews the karst features in some of these areas.

Drainage on the Proterozoic turbidites and slates of the Harrisons Opening Formation in the western Picton map sheet appears to be partly strike-controlled and partly dendritic.

Fault Structure Province

The physiography of the Fault Structure Province in the area mapped is dominated by the Maydena Range, Snowy Range, Weld Ridge and Mt Picton, 1100–1400 m in height and all capped by erosional remnants of an originally continuous sheet of Jurassic dolerite. The linear form of the Weld Ridge, and to a lesser extent the Snowy Range, is attributed to joint-related anisotropy in the dolerite.

Pleistocene glacial landforms are present on most of these ranges. Many cirques and glacial lakes are present on the Snowy Range, Weld Ridge and Mt Picton. These are associated with well-defined, undissected moraine ridges (shown as Qpgm on the maps) of probable Last Glacial age. The ‘snow fence’ effect of the ranges on the prevailing westerly airstream is demonstrated by the occurrence of glacial landforms almost exclusively on the eastern side of the Snowy Range and Weld Ridge. Mt Picton, with an east–west orientation, has glacial landforms on both the north and south sides. Moraines are also present on the eastern escarpment of Gallagher Plateau. On the Jubilee Range, last-glacial landforms appear to be restricted to a small pro-talus rampart, 1–2 m high and 200 m long, in the lee of a quartzite cliff at 463300/5251300.

Deposits of probable till at low elevations along the Huon River (469300/5228200; 471500/5227000; 477900/5228400) and the Snake River (461300/5243600) are not associated with recognisable glacial landforms, but are probably relics of a much older, more severe glaciation, the effects of which on the landscape have been obscured by later erosion.

In a general way the height of the capping dolerite sheet falls from west to east and the stark glaciated features near the summits of the western ranges give way to a more rounded landscape in the east. Very commonly, particularly in the northern areas, the dolerite shoulders of the elevated country pass downslope into frequent benches and low cliffs developed on Upper Parmeener quartz sandstone, and then into uniform or more mature broadly-benched slopes developed on Lower Parmeener strata. Sandstone units within the Parmeener Supergroup (the Minnie Point Formation correlate, the Risdon Sandstone correlate) are erosion

* All grid references are AGD66 datum and are AMG co-ordinates in Zone 55. Grid references quoted in this report are in the form eeeeee/nnnnnnn, where the first six numbers are metres east and the last seven numbers are metres north.

resistant and form cliff-lines in many places. Various factors such as faults, dip and the more strongly transgressive nature of the dolerite in some areas, result in the dolerite extending downslope even to the valley floors, and different types of slope morphologies occur in these areas.

Moderately high (up to 1080 m), irregular dolerite plateaux occur on the eastern side of the Maydena and Skeleton map sheets. East of these maps the dolerite masses combine and are part of a more extensive general plateau area of Jurassic dolerite that extends from the Wellington Range west of Hobart through the Mount Field National Park and beyond. Two streams, the Styx River in the south and the Tyenna River in the north, have breached this dolerite and cut extensive valleys in the underlying Parmeener Supergroup rocks. These streams are tributaries of the River Derwent and flow sub-parallel to each other in a northeasterly direction and exit the map sheets at elevations of ~230 m and 200 m respectively.

The dolerite plateau surfaces are marked by broad ridges and valleys, commonly of southeasterly trend, and less well defined features of northerly trend. These trends are probably related to weakness along small faults, or in some cases possibly irregularities in the original intrusion form. Poorly drained areas, commonly with treeless swamps, occur both near the summits and in the valleys of the plateaux. The longer drainage lines on the plateaux tend to be directed to the southeast, for example Diogenes Creek and the upper catchment of the Plenty River. Although aerial photo interpretation indicated no obvious features that could be attributed to Late Pleistocene glaciation the possibility that some of the linear valleys had experienced older glacial activity could not be discounted.

The plateau edge lacks prominent high dolerite cliff faces and in some areas is poorly defined. Rocky protuberances occur locally on the upper slopes of the escarpment. Some hummocky old landslide deposits occur in dolerite talus that extends into the upper parts of the Russell River.

Some discontinuous incised sandstone benches are found between 500–600 mASL southwest of the Mount Styx plateau area. Beyond these benches the Russell River flows in dolerite to its point of exit from the map at about 250 mASL. Similarly to the plateau area, the main drainage trend in this topographically lower dolerite is towards the southeast, but a few reaches and many tributaries from both banks have northeasterly trends.

The Maydena Range forms the interfluve between the Styx and Tyenna rivers. From the northeast corner of the Maydena sheet, the summit areas along the range illustrate progressive erosion of the dolerite plateau. This is seen starting from the poorly drained and swampy intact plateau near Lorkins Lookout (1034 m), through the similar, but isolated swampy plateau remnant at Marriotts Lookout (~1100 m) to the conical and final dolerite remnant at Abbotts Lookout (1106 m). Because of faulting, equivalent stratigraphic horizons are 300 m higher southwest from Abbotts Lookout and have been subjected to greater erosion. The more rounded range crest is formed on Lower Parmeener rocks with benches formed on the more resistant units.

The structure of the Parmeener Supergroup and dolerite has influenced the broad physiography of the Styx and Tyenna river valleys. The effect of faults and of down-stream dip has resulted in the resistant dolerite being closer to the valley floor downstream and there is a consequent narrowing of the valley walls. The Tyenna River is also broader and of lower gradient upstream from the Parmeener Supergroup river bed. Within the Parmeener sections the thalwegs resemble entrenched meanders with individual reaches influenced by faults, joints and the different resistance to erosion of various rock types. Downstream from its confluence with the South Styx River, the Styx River flows in a confined valley tract and meanders with low sinuosity through a narrow alluvial plain. Similar tracts occur in the Tyenna River. There are only minor occurrences of preserved alluvial terraces.

Similar factors also influence the location and profile of tributaries and minor interfluves of the main Tyenna and Styx valley systems. The more resistant rock units tend to form bench and step profiles, with cliff and waterfall development in some areas. Humboldt Ridge is cuesta-like. A broad irregular bench occurs on the south side of the Styx Valley about 500 mASL. This feature tends to transgress Lower Parmeener rock types and may be an older erosion feature related to an elevated base level. Some treeless and other tea tree-covered swamps are developed on this bench.

Overall the main valley sides associated with the Tyenna and Styx rivers are moderately steep (average ~12–21°) but because of the benches extended slopes of 25° or more are not uncommon. Steep slopes are commonly associated with dolerite bedrock, but at Mount Styx the average slope on dolerite is less than 15°. In some areas the valley sides are mantled by slope deposits, particularly talus below the capping dolerite areas. Some tributary streams have etched valleys along fault zones and have steep (33°) valley sides. Alluvial cones accompany some tributary streams and are rarely developed on the valley-side benches. Very few tributary streams develop an alluvial plain tract before entering the main rivers.

In the Skeleton and Nevada map sheets the boundary of the Fault Structure Province is itself at least partly, if not entirely, a fault. Although the Parmeener Supergroup is down-faulted the remaining resistant dolerite capping results in topographically higher areas than in the adjacent parts of the Fold Structure Province.

The more westerly part of the Snowy Range is highest. This is to be found near the centre of the range at Snowy South (1380 m) and Nevada Peak (1380 m). North of Nevada Peak, the basal contact of the dolerite sheet is locally above 1210 mASL and the underlying Upper Parmeener sandstone forms benches and cliffs at The Wart. Near Scrivens Cone the summit ridge is a lower

(1040 m) narrow, rounded, dolerite crest offset to the east. The ridge broadens northward to a more mountainous area that rises to 1240 mASL at Snowy North and exhibits a glacial moraine feature to the northeast. Below the dolerite the western escarpment of the range forms steep forested concave slopes developed on the Parmeener Supergroup or talus, with some cliff faces developed on the Upper Parmeener sandstone. The average gradient of the lower slopes is about 10°, but at higher elevations the average gradient increases to over 30° below the dolerite. Steeper slopes, cliff lines and other areas of bare rock occur on the higher parts of the capping dolerite.

Southeast from Snowy South the range falls gradually to 900 mASL. Last Glacial cirques with associated moraine-dammed lakes are prominent where the aspect is to the east. Aerial photo interpretation suggests that periglacial ice fractured rock, rock screes and talus deposits formed on slopes of various aspects.

Along this southern section, the southwestern lip of the range is sharply defined by dolerite cliffs of various heights with associated rock scree chutes and cones. Beneath the cliffs, slopes inferred to be developed on Parmeener rocks, and probably some Quaternary dolerite talus, descend to the Weld River which flows from about 190 to 90 m elevation. The shallowly incised courses of short streams that drain the slopes show some sub-parallel alignment suggestive of a structural control, but without great departure from trends of maximum gradient down the slope. Sandy Creek is rather more deeply incised, collects several small tributaries and may be more influenced by geological structure.

The western slopes of the Snowy Range also show, in places, prominent benches probably developed on more resistant Lower Parmeener Supergroup rocks. A small lake occupies a shallow shelf at 700 m elevation, but it is unknown to what extent Quaternary deposits or slumping may have contributed to its formation. The average slope down this part of the western escarpment is about 16°, but in places below the dolerite section average slopes of segments >0.5 kilometre length exceed 30°. Some cliff areas in dolerite maintain average slopes greater than 45° over lateral distances of 200 metres.

On the northern side of the Snowy Range a short dolerite ridge that is orientated parallel to the northern face of the range may be a coherent collapsed mass of dolerite, or dolerite isolated from the general slope by glacial or periglacial erosion concentrated at a structural weakness. The same fault systems that partition the dolerite on the Maydena Range have also led to erosional re-entrants in the dolerite plateau west of Mount Styx. Upper Parmeener sandstone outcrops wrap around from the northern to the eastern side of the Snowy Range beyond the drainage divide at 700 m into the upper catchment of the Russell River. Skeleton Ridge, named after the skeletal appearance of dead gum trees and from which the map sheet is known, occurs immediately west of this drainage divide.

South from here in the Skeleton map sheet, the eastern slopes of the Snowy Range are less steep (7°) and have an unusual terraced appearance, where poorly drained areas of low vegetation are separated by narrow, better-drained steeper zones with taller trees. The underlying rock type may be Jurassic dolerite, Upper Parmeener Supergroup sandstone or dolerite talus covering either of these two rock types. The terracing could be buried sandstone layers, an unusual talus morphology or erosional features on dolerite facilitated by sub-horizontal jointing.

Further south in the Nevada map sheet the crest of the Snowy Range broadens and has a scalloped eastern shoulder as a result of the cirque glaciation. Clearly defined lateral-terminal moraines extend down to about 900 m elevation. Lake Skinner is the largest of the glacial lakes and has an area of less than one square kilometre. Cirque headwalls are 200–300 m high with average slopes of up to about 32°. Parts of the upper shoulder of the range are almost as steep (28°), but averaged over distances of several kilometres the northeast slopes are about 10°.

Scattered pieces of hornfels east of Lake Skinner suggest that the cirque glaciation may have cut through to the base of the dolerite sheet, but the combined effect of tilting, faulting and dolerite intrusive form results in dolerite forming broad rounded ridges that extend much further down the slopes. Some areas lacking prominent interfluve ridges may be talus slopes. Parmeener rocks beneath the dolerite are more clearly exposed in the valley of the Little Denison River between about 400–500 mASL. Further upstream the dolerite valley walls are steep, locally averaging over 40°, but the V-shaped valley profile suggests that if glacial erosion has played a major role in the valley formation then it is unlikely to have occurred during the Last Glaciation. Downstream from the Parmeener rocks, dolerite reappears and has been interpreted as a steeply inclined, east downward transgressive section of the sheet. Most if not all areas of Parmeener rocks to the east or north of this area probably overlie the dolerite sheet.

As a consequence the physiography of the lower area east of the Snowy Range appears to be influenced by the distribution of Parmeener rocks overlying the dolerite and the differential erosion rates of the two gross rock types. For example, the two larger areas of Parmeener rocks on the eastern boundary are occupied by two of the larger streams, the Little Denison River and Falls Rivulet. Similarly the gorge of the Russell River appears to have eroded back from an extension of the Parmeener rocks in the neighbouring Lonnavale map sheet. Also influencing the physiography are faults or other weakness in the dolerite, commonly of northeasterly or northwesterly trend.

The large dolerite mass of Compton Hill forms the interfluve between the Russell River and Falls Rivulet where the streams flow with parallel southeasterly-directed trends. The drainage from Lake Skinner (Falls Rivulet) and from nearby Dungeon Tarn is diverted south and north respectively to flow around Compton Hill. This has probably contributed to the preservation of Upper Parmeener rocks west of Compton Hill. The southern lower slopes of Compton Hill, and both sides of the Russell River valley northeast of Compton Hill, have average inclinations of 20–25°, locally up to 30°.

Acknowledgements

G. S. Kowalik, A. Ezzy, J. McDougall, J. Nye, K. Schaffer, M. Doyle, D. Muscovich, S. Bennett and S. Heawood are acknowledged for their help in the field. A. Ezzy undertook several magnetometer traverses. R. G. Woolley shared his knowledge of the area and led one of us to sandstone outcrops in regenerated logging coupes. E. B. Corbett drew our attention to a siltstone outcrop on Nevada Peak, and to forestry tracks in the Warra area. J. Jago kindly provided information about the location of mapping traverses that he undertook to prepare his map (Jago, 1972).

Proterozoic sedimentary rocks (CRC)

The Adamsfield–Jubilee region is distinct from the adjoining Tyennan region of southwestern and central Tasmania by virtue of generally milder deformation and lower metamorphic grade (Corbett, 1970; Turner, 1989). Lithologically, the Proterozoic rocks of the two regions are broadly similar, and are probably at least, in part, correlative (Turner, 1989; Seymour and Calver, 1995).

Three major Proterozoic successions have been mapped in the Jubilee Region: the Harrisons Opening Formation (new name); the Clark Group (Carey and Banks, 1954); and the Weld River Group (Calver, 1989) (fig. 3). The lower Neoproterozoic Clark Group is separated by a low-angle unconformity or paraconformity from the overlying, upper Neoproterozoic Weld River Group. The Harrisons Opening Formation is of uncertain age, but is probably older than the other two successions.

The Clark Group was named and mapped by Carey and Banks (1954, fig. 3) in The Needles area, and briefly described by Spry (1962). Mapping by CRC has clarified the stratigraphy and structural geology of the type area (Appendix 1), and is the basis for lithological correlation of the other inliers on the Skeleton, Nevada, Weld and Picton map sheets.

The Weld River Group, a distinctive succession almost entirely of dolostone and dolostone-derived diamictite, was named and described by Calver (1989) and Calver *et al*. (1990), from mapping of the Pedder 1:50 000 scale sheet. The new mapping described here significantly increases the known extent of the Weld River Group.

Harrisons Opening Formation (Weld, Picton map sheets)

The Harrisons Opening Formation crops out along the Huon River downstream of the Cracroft–Huon junction as far east as a faulted boundary with Weld River Group rocks upstream of Blakes Opening (at 466450/5228300) (Picton map). Outcrop extends to the north, to the Manuka Creek area on Weld map, and south at least as far as the western flank of Mt Picton (Picton map). The Harrisons Opening Formation consists of a proximal, turbiditic conglomerate-lithicwacke unit (Phc) which passes up transitionally into a distal, pelitic, turbiditic succession dominated by black slate (Php). The base and top of the formation are unknown. Total thickness may be in the order of a few kilometres. It is strongly deformed: conglomerates are highly strained, pelitic rocks are phyllite or slate, there are up to three cleavages and minor folds are common. The prevailing strike of bedding is northwesterly and the rocks dip steeply and mostly young to the northeast.

Relationships with other units are uncertain on present evidence. The formation is faulted against Weld River Group to the east and against unit Pcp (Clark Group?) to the north. Given the stratigraphic relationships established between the Clark Group, Weld River Group and younger (Cambrian?) units, the Harrisons Opening Formation is likely to be older than the Clark Group. Further mapping, and in particular the location of unfaulted stratigraphic contacts of the Harrisons Opening Formation, is needed to resolve this problem.

Turbiditic lithic sandstone, conglomerate and black phyllite (Phc)

This, the lower part of the known Harrisons Opening Formation, consists of interbedded conglomerate, quartz-rich lithic sandstone, grey siltstone and dark grey to black phyllite. Conglomerate and sandstone occur as very thick (up to 4 m) to thin, graded beds (Plate 1). Conglomerate is of granule to pebble, rarely cobble grade, is poorly to moderately sorted and is composed of white, pink or pale green clasts of fine-grained quartzite, quartz siltstone and chert, and wispy intraclasts of black pelite. Quartzite clasts are usually moderately rounded, but less competent lithologies are deformed into lenticular shapes aligned parallel to the main cleavage. Lithic sandstone is moderately to poorly sorted and increasingly quartz-rich in the finer grades. Pelitic intervals consist of banded, black and grey phyllite with thin planar beds of quartzose siltstone.

Phc is evidently a proximal turbidite derived from a terrain of quartzose sedimentary rocks and deposited in a deep, reducing basin.

Black slate and phyllite with minor quartzwacke and diamictite (Php)

This unit consists predominantly of black to dark grey phyllite or slate, in places pyritic, with lesser quartz siltstone and quartzwacke as planar laminae or thin graded beds; and rarely as thick beds. Near the base and top of the exposed section in the Huon River, the unit is predominantly tabular beds of fine to medium-grained sublithic quartz sandstone, with interbeds of dark grey phyllite. Chert and very fine-grained quartzite comprise the lithic component of the sandstone. Quartz grains are well rounded. Zircon is present as an accessory and as inclusions in quartz. At 464000/5227900 in the Huon River, there is a unit of diamictite, at least 15 m thick, consisting of sparse (5–10%) floating clasts of fine-grained quartzite, mostly of pebble, rarely of cobble grade, in a matrix of black phyllite. The diamictite is overlain by several metres of thick-bedded, coarse-grained quartzarenite. Similar diamictite occurs in Manuka Creek (at 465300/5231600). The diamictites are similar in appearance to those of the Weld River Group, but lack the dolostone clasts common in the Weld River Group diamictites.

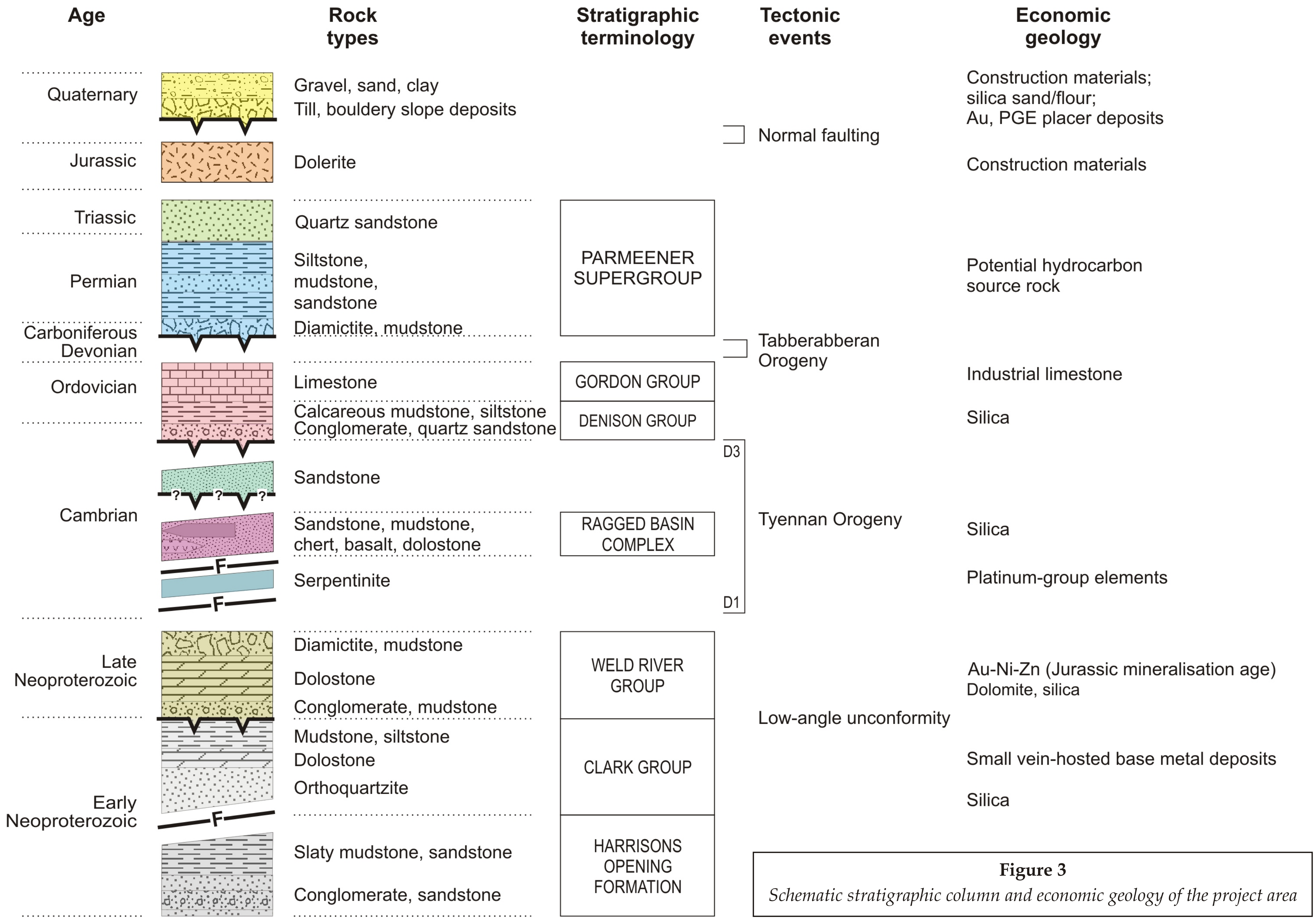


Figure 3

Schematic stratigraphic column and economic geology of the project area

Plate 1

Graded bed of small-pebble to coarse-sand grade, with basal part of a second graded bed in upper right; in Harrisons Opening Formation. Clasts are flattened in S_1. Huon River (462300/5227200).

Plate 2

Thick crossbed set in Needles Quartzite correlate, Jubilee Range.

Php represents a continuation of turbiditic to pelagic sedimentation in a more distal setting than Phc. The diamictites are probably debris flows.

Clark Group

A thick succession of orthoquartzite, siltstone, pelite and minor carbonate comprises inliers — broadly anticlinal in most cases — at The Needles, Jubilee Range, Glovers Bluff and Mt Anne–Gallagher Plateau. Lithological and stratigraphic similarities suggest the same succession is represented in each inlier. The stratigraphic name Clark Group — applied to the succession in The Needles area by Carey and Banks (1954) — has priority. The names Mt Anne Group and Pandani Group, applied to this succession in the Mt Anne area on the Pedder 1:50 000 scale map (Calver *et al*., 1990), are synonymous.

The Clark Group is lithologically similar to, and probably broadly correlative with, the Rocky Cape Group of northwest Tasmania.

The Needles area, just west of the Maydena map sheet, was remapped in the course of this project, allowing clarification of the type area of the Clark Group and correlation into the areas described here. The Needles mapping is outlined in Appendix 1.

Clark Group correlate — Jubilee Range area (Skeleton and Nevada map sheets)

A correlate of the Clark Group crops out extensively around the Jubilee Range (on the Skeleton map sheet and northern Nevada map sheet). The structure of this area is dominated by the Jubilee Range Anticline, consisting of a faulted, northwest-plunging anticlinal core of Needles Quartzite correlate (Pcq), flanked to the west, north and east by correlates of the Humboldt Formation dipping and facing away from the Jubilee Range.

Needles Quartzite Correlate (Pcq)

Unit Pcq on the Jubilee Range is a correlate of the Needles Quartzite. It is a thick formation of erosionally resistant orthoquartzite, comprising a complexly-faulted anticline. The base of the formation is not exposed. A thickness of roughly 1800 m is exposed in the largest fault block, but the true minimum thickness of the formation is uncertain because of the possibility of undetected faulting.

Pcq on the Jubilee Range is a white to pale pink orthoquartzite (quartzarenite) of very fine to coarse (up to 1 mm) grain size. The formation is predominantly thinly bedded, but medium to thick (0.1–1 m) beds, which are internally cross bedded, comprise about 30% of the formation (Plate 2).

A thin section (R007712) of typical coarse-grained (1 mm) orthoquartzite shows a rock consisting entirely of well-rounded quartz sand grains approximately 1 mm in diameter. Authigenic quartz overgrowths are volumetrically minor. Curved, slightly sutured grain-to-grain contacts indicate some pressure dissolution associated with tectonic strain. The quartz displays straight to strongly undulose extinction, and several grains contain inclusions of muscovite, zircon, and rutile. Several polycrystalline quartz grains are present, and a few of these are foliated quartzite of probable metamorphic provenance.

Planar bedding is dominant iIn the thin-bedded intervals, but ripple-marked bedding planes are also common. Both symmetric (wave) ripples and asymmetric (current) ripples are present. Superposed ripple sets ('ladder ripples') at one locality near the top of the formation suggest a very shallow, perhaps tidal flat environment. Convolute lamination is rarely seen.

Cross bedding tends to be planar-tabular, or very broadly trough-shaped (with swings of up to 70º in the strike of individual cross beds). The thickest cross bed set seen was 1.6 m thick.

Within Pcq, a thicker-bedded, more resistant unit of quartzite forms strike ridges on the northern part of the Jubilee Range at 464000/5254700 and 465000/5252400. This unit is about 100 m thick, and is roughly 300 m below the top of Pcq.

A bed, 0.5 m thick, of distinctive, uniform, yellow-green mudstone with a hackly fracture is seen within quartzite at 465100/5251000 and at a few other, possibly correlative locations (e.g. 465400/5247800 and 464750/5247650).

Slump folds were observed at one locality (465775/5246700), with vergence suggesting an east-dipping palaeoslope.

Thirty-nine restored palaeocurrent directions, derived from cross bedding, show a broad, north to northeasterly mode (fig. 4). The directions were determined from a number of localities on the Jubilee Range, all 300–600 m stratigraphically below the top of the formation.

Humboldt Formation Correlate

DOLOMITIC MUDSTONE, SILTSTONE AND INTRACLASTIC CONGLOMERATE (Pcdc)

The Needles Quartzite correlate is overlain by unit Pcdc east of the Jubilee Range. This unit appears to thicken eastward and wedge out to the west, as it was not seen north or west of the range.

Unit Pcdc consists of thinly interbedded, pale green (white to brown-weathering) dolomitic mudstone, siltstone and intraclastic conglomerate. The conglomerate consists of platy intraclasts, up to 10 mm (rarely 40 mm) long, of fine-grained dolomitic mudstone in closed framework, in a siltstone matrix. Typically the base of conglomerate layers is erosive and shallowly scoured into the underlying bed. The conglomerate beds are often graded, fining up over a few centimetres into intraclastic sandstone and dolomitic siltstone. Conglomerate comprises 10–20% of the succession, and tends to decrease up-section.

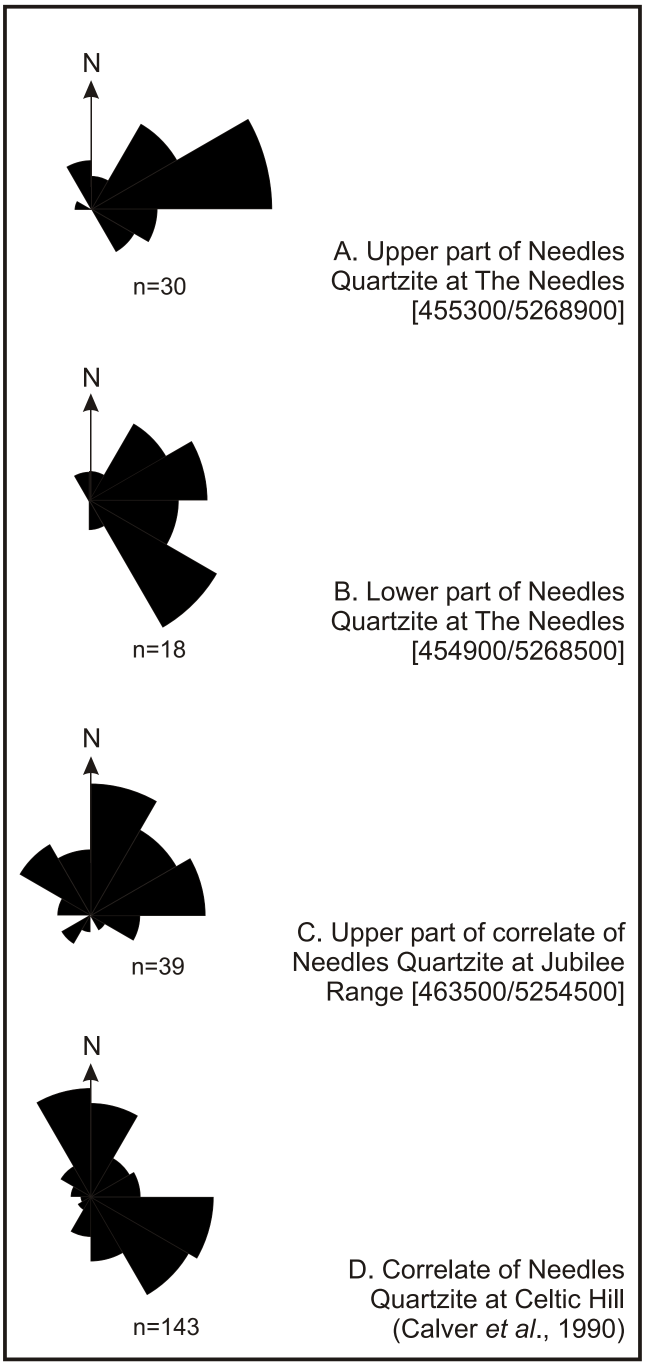


Figure 4

Restored palaeocurrent directions in the Needles Quartzite and correlates in the northern Jubilee Range.

Thin beds and laminae of slightly dolomitic, quartzose siltstone commonly display cross-lamination, grading, basal load casting and convolute lamination.

Like the lower part of the type Humboldt Formation (see Appendix 1), Pcdc locally contains evidence for pre-existing evaporites. At 466650/5250200 (Skeleton) and elsewhere, mudstone layers contain hopper-shaped voids with cubic symmetry, 1–10 mm in size, presumably after halite. These occur with desiccation cracks on some bedding planes (Plate 3). At 466175/5251700 (Skeleton) and 466500/5247000 (Nevada), mudstone horizons near the base of the unit contain subspherical to oblate (in the bedding plane) geodes, 10 to 40 mm across, lined with white to pink quartz. These were also seen in the Glovers Bluff inlier (Weld sheet, see below) and may be replacements of anhydrite nodules.

DOLOMITIC MUDSTONE, SILTSTONE AND CARBONATE (Pcd)

Unit Pcd overlies Pcdc east of the Jubilee Range, and overlies quartzite (Pchq) to the west and north. Contacts are inferred to be conformable, but were not observed. Pcd is roughly 500 m thick and is well exposed in creeks flowing east and north of the Jubilee Range on the Skeleton map sheet.

Near the base, Pcd consists of thinly interbedded red mudstone and quartz siltstone with occasional thicker (100 mm) layers of cross-bedded, fine-grained quartz sandstone (quartzite). Locally, there are horizons with clastic dykes that may be mud crack casts.

The rest of unit Pcd is a variable succession of thinly interbedded mudstone and siltstone, usually dolomitic, and impure (muddy) dolostone and limestone. The rocks are cream to pale green to red or grey in colour. Typically, outcrops of dolomitic mudstone and siltstone are leached of their carbonate content, and have become rather soft, red to brown 'pug' in which bedding and sedimentary structures are still preserved. Siltstone layers — generally thin beds or laminae — are planar-parallel, often graded, and occasionally cross laminated. Carbonate beds are impure, very fine-grained (micritic) dolostone or limestone; some are structureless while others show stratiform to domical stromatolitic lamination. There are also rare beds of oolite. Nodular, impure carbonate and molar-tooth structures were also observed. At 466450/5254300 fine-grained dolomitic limestone contains molar-tooth structures and small authigenic quartz crystals (thin section R007622), identical to Pcd in The Needles area (Appendix 1).

Locally there are non-dolomitic intervals of quartz siltstone interlaminated with green to black mudstone, resembling the overlying unit (Pcmm).

MUDSTONE AND QUARTZ SILTSTONE (Pcmm)

In the Jubilee Range area this unit consists of thinly interbedded or interlaminated quartzose siltstone and mudstone, and is 500–1000 m thick. The rocks are usually grey-green in colour, and of banded appearance, with the siltstone layers generally appearing darker than the mudstone. In places the rock is black or red mudstone interlaminated with pale quartz siltstone.

The siltstone layers are sharp-based and usually graded, <1 mm to 100 mm thick. Small load structures are common at the bases of siltstone layers. The lower and middle part of Pcmm tends to be relatively thickly layered, while the top is characterised by thin lamination. Where thin, the lamination is planar-parallel and continuous, while thicker siltstone layers are often lenticular and erosive into the underlying bed. The upper parts of thicker graded siltstone layers often have thin internal lamination.

Plate 3

Desiccation cracks and probable halite moulds in unit Pcdc from 466650/5250200, near Jubilee Range (Skeleton map sheet).

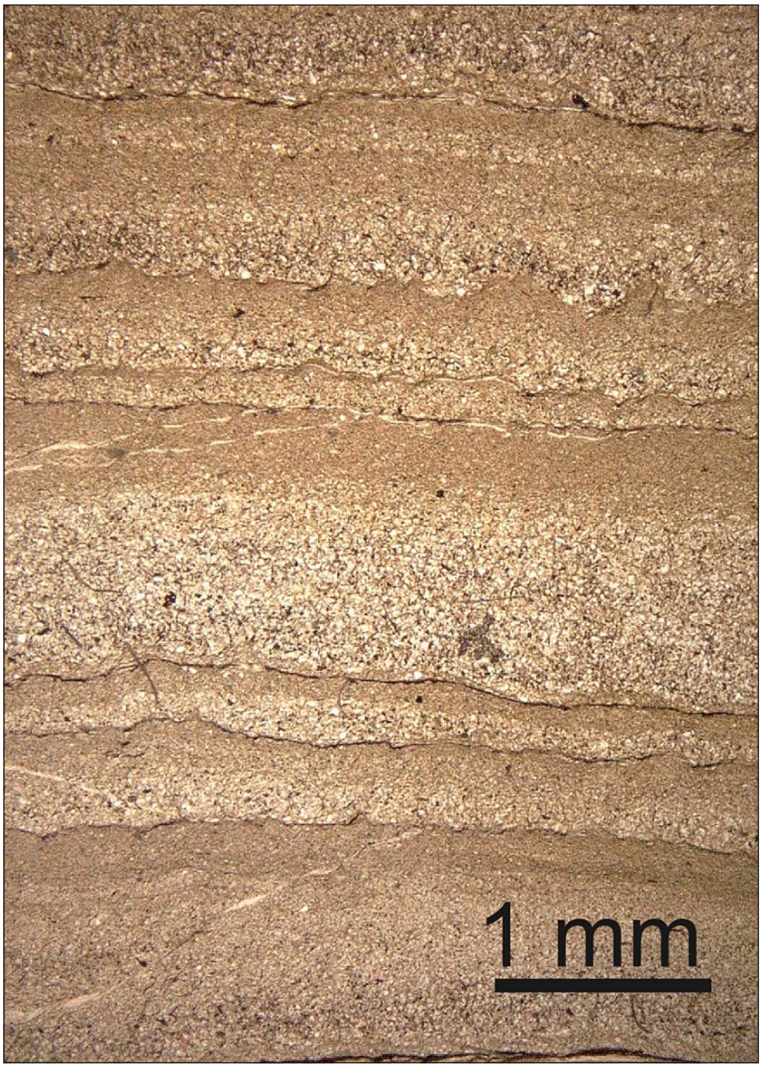


Plate 4

Photomicrograph of very thin, graded siltstone laminae with load casts, from Humboldt Formation, Jubilee Range (Sample R007700) (465850/5250800).

Graded, load-casted siltstone laminae in thin sections may be as thin as 0.5 mm (Plate 4).

A few mudstone horizons have abundant clastic dykes of siltstone. These extend downwards from the base of the overlying siltstone layer. In plan view these are apparently randomly orientated, discontinuous, tapering tabular dykes, 1–3 mm wide and 10–30 mm long. They resemble the sand-filled 'diastasis cracks' of Cowan and James (1992) or syneresis cracks (Plummer and Gostin, 1981). They are probably not desiccation cracks as they do not commonly form a polygonal network in plan view. Rare molar-tooth structures are present.

There are rare carbonate beds in the upper part of the unit, including a dolostone bed with domical stromatolites at 466100/5257000 (Skeleton map sheet).

STROMATOLITIC DOLOSTONE AND MUDSTONE (Pcdos)

This unit is about 100 m thick east of the Jubilee Range where it comprises the topmost part of the Clark Group. It wedges out to the west, perhaps because of erosion at the low-angle unconformity at the base of the overlying Weld River Group. It is lithologically similar to unit Pcd of the lower Humboldt Formation. A rapidly transitional, conformable lower contact, from thinly interlaminated mudstone and siltstone of Pcmm up into stromatolitic carbonate of Pcdos, was observed in the South Styx River (466500/5253800).

The unit consists of interbedded mudstone, dolomitic mudstone, siltstone, dolostone and limestone. Carbonate beds predominate in the lower part of the unit. A 12 m thick bed of stromatolitic carbonate occurs at the base of Pcdos in the South Styx River (at 466500/5253800). This consists of crowded, domical stromatolites 150 mm in width, with interspaces filled with impure, muddy brown-weathering carbonate (Plate 5). In the next 30–40 m (stratigraphic thickness) as exposed in the South Styx River (e.g. at 466900/5254000), beds with stratiform or domical stromatolites alternate with internally uniform, variably impure micritic beds, intraclastic flakestone conglomerate, and oolitic limestone. Oolites, like those seen in Pcd in The Needles area, are partly replaced by fabric-retentive, cryptocrystalline brown chert and isolated, sub-prismatic crystals of inclusion-rich megaquartz up to one millimetre long (thin section R002690). Locally, impure coarse sandy carbonate is interbedded with micritic, relatively pure grey carbonate, the two lithologies comprising graded couplets 50–200 mm thick. Starved ripples of siltstone or fine-grained quartz sandstone in carbonate are present in places. Many carbonate beds are limestone or limey dolostone, although dolostone is the dominant carbonate.

Thin-bedded dolomitic mudstone and siltstone predominate higher up. Like other parts of the Humboldt Formation, the siltstone layers (thin beds and laminae) are frequently graded.

Clark Group correlate, Snake River Valley (Nevada map sheet)

An inlier of Pcmm, about 1.5 km^2 in extent, in the Snake River valley (463000/5243000) consists of mudstone, dark grey, grey-green or reddish in colour, usually with thin, graded siltstone laminae or thin beds. This inlier is lithologically indistinguishable from Pcmm of the Jubilee Range inlier (northern Nevada–Skeleton maps). Bedding mainly dips and faces west. The inlier is interpreted to be faulted on three sides against the Weld River Group; on the fourth (western) side it is unconformably overlain by the basal conglomerate (Annakananda Formation) of the Weld River Group.

Clark Group correlate, Gallagher Plateau area (Weld map sheet)

The western part of the Weld map sheet covers the eastern end of the Gallagher Plateau, which is part of a major strike ridge of orthoquartzite that extends 10 km west to Schnells Ridge. On Gallagher Plateau the orthoquartzite (a probable correlate of the Needles Quartzite) dips moderately northeast and is right-way-up. The strike ridge is terminated at its eastern end by a major northeast-trending fault. The dolomitic and pelitic, lower and upper divisions of the Humboldt Formation were mapped north of Gallagher Plateau, but this area was mapped at reconnaissance level only and remains poorly known.

Orthoquartzite (Pcq)

The orthoquartzite (Pcq) of the Gallagher Plateau is a white to pink, fine to medium-grained quartzarenite very similar to the type Needles Quartzite. A stratigraphic thickness of about 1900 m is present between the lowest (460900/5232300) and highest (462000/5236400) outcrops, but this may not be a true thickness because of the possibility of undetected faulting, and no base is known. Most outcrops are characterised by thin, planar-parallel bedding; ripple marks and cross bedding were seen at relatively few outcrops, except low in the section (460900/5232300) where cross bedding is abundant.

Dolomitic mudstone and siltstone (Pcd)

North of Gallagher Plateau (around 462000/5237000) are rocks correlated with the lower, dolomitic member of the Humboldt Formation. Bedding dips steeply north and is moderately discordant with the orthoquartzite on Gallagher Plateau, suggesting that the contact may be a fault rather than a conformity. These rocks consist of red slate and red argillite with thin beds and laminae of quartz siltstone and dolomitic siltstone, and minor impure (muddy) fine-grained dolostone.

Mudstone and siltstone (Pcmm)

Further north (around 463000/5238000), in probable faulted contact with Pcd to the south, are rocks correlated with the upper, pelitic member of the Humboldt Formation. These rocks consist of

Plate 5

Stromatolites in unit Pcdos, South Styx River.

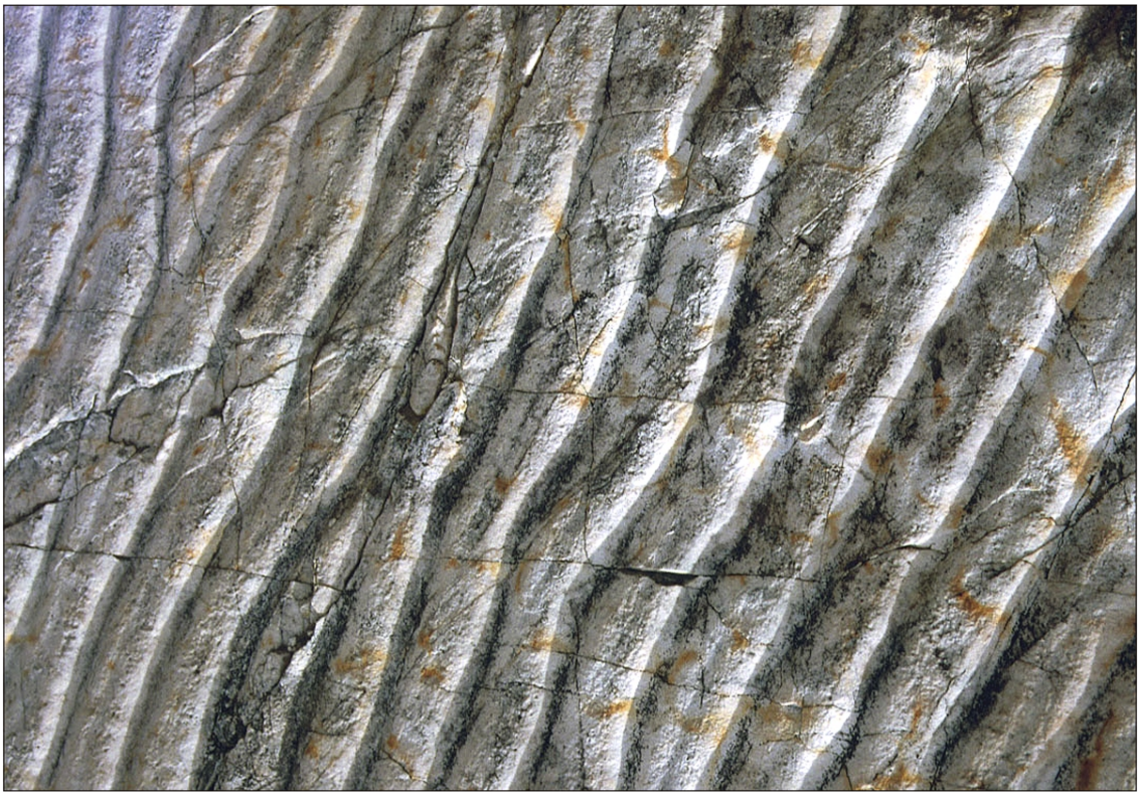


Plate 6

Symmetrical ripples in Needles Quartzite correlate, Glovers Bluff quarry (477200/5234600).

grey-green mudstone interlaminated with paler green quartz siltstone, and in places, red mudstone with minor thin beds of dolostone and graded quartz sandstone.

Unit Pcp (probable Clark Group correlate), Manuka Creek area (Weld map sheet)

East of Gallagher Plateau, in the valley of Manuka Creek, lies a unit of pelite and siltstone with minor conglomerate, orthoquartzite and dolostone, shown as Pcp, that is faulted against the orthoquartzite of the Gallagher Plateau to the west and faulted against Harrisons Opening Formation (Php) to the southeast. The age relationships of this unit are unknown, but it is tentatively correlated, on broad lithological grounds, with the Clark Group.

Unit Pcp is dominated by pelite, in most places interlaminated with quartz siltstone. The pelite has a slaty cleavage and often a crenulation cleavage, and is a slate or low-grade phyllite. It is usually red, less often black or grey-green in colour. Some siltstone laminae are graded, and there are rare clastic dykes. Many outcrops are lithologically very similar to the Scotts Peak Road Member (part of the Humboldt Formation correlative on the Pedder map) of Calver *et al*. (1990), and to outcrops of upper Humboldt Formation (Pcmm) on the Gordon River Road near The Needles. There is minor interbedded orthoquartzite. Dolomitic quartz siltstone, and impure (muddy) fine-grained pale grey dolostone, are also seen in outcrops in, and north of, Manuka Creek. The main dolostone outcrops are indicated on the map (Pcpd). Dolostones may have a seamed phyllitic cleavage, most easily seen on weathered surfaces.

At the northern extremity of Pcp (465900/5234800) is an isolated outcrop of impure (muddy) pale grey massive dolomicrite. This is associated with silicification of overlying basal Parmeener Supergroup rocks, a feature associated with Weld River Group dolostones in several localities (see later sections). This outcrop could belong to the Weld River Group, but its impure nature is unusual for the Weld River Group, and the lithology is better matched by dolostones of Pcp near Manuka Creek (e.g. 464350/5232875).

South of Manuka Creek there are two outcrops of conglomerate, shown as Pcpc on the map (463100/5232600, 462800/5232200). Conglomerate (apart from minor intraformational conglomerate) is unknown from elsewhere in the Clark Group or its correlates. These outcrops are of deformed pebble conglomerate, consisting of discoidal (deformed) clasts, dominantly of chert but with minor quartz siltstone, in a closed framework with a matrix of poorly sorted, foliated green phyllitic quartz sandstone.

Clark Group correlate, Glovers Bluff inlier (Weld map sheet)

At Glovers Bluff, in the eastern part of the Weld sheet, an inlier of Proterozoic and Cambrian rocks, surrounded by Jurassic dolerite, includes correlates of the Needles Quartzite and Humboldt Formation.

Orthoquartzite (Pcq)

An orthoquartzite unit (Pcq, a correlate of the Needles Quartzite) forms the strike ridge of Glovers Bluff, Camels Back and Bernard Spur, which extends along the western side of the inlier (fig. 6). The quartzite has a northwesterly strike, a near-vertical dip and youngs to the northeast. A thickness of about one kilometre is present, and no base is exposed. The orthoquartzite is thinly to thickly bedded, with common cross bedding (in sets up to one metre thick), and common ripple-marked bedding planes (Plate 6). It is lithologically indistinguishable from Pcq on the Jubilee Range and (except for the greater thickness of cross-bed sets here) Pcq on The Needles. In relatively fresh outcrop in the Weld River (476800/5235300) the orthoquartzite has interbeds of grey, micaceous, fine-grained quartz sandstone. The orthoquartzite on Glovers Bluff has been investigated as a source of industrial silica (see Calver *et al*., 2006).

Mudstone, siltstone and intraclastic conglomerate (Pcm, Pcdc, Pcmm)

Unit Pcdc overlies Pcq in the Weld River. Outcrop at 477100/5235400 consists of thinly interbedded siltstone, mudstone and intraclastic conglomerate, with rare, small (10 mm), flattened, hollow quartz nodules. This distinctive lithology, including the quartz nodules (which may be after anhydrite), is identical to basal Humboldt Formation (Pcdc) in the Jubilee Range area, and its occurrence and stratigraphic position strongly support correlation between the Glovers Bluff inlier and the Jubilee Range. Stratigraphically higher outcrop 40 m downstream consists of grey siltstone with thin mudstone beds and minor, thin, fine-grained orthoquartzite beds.

Outcrops of Humboldt Formation correlate in the upper reaches of Eddy Creek, at the northwest end of the Glovers Bluff inlier, consist of thin-bedded to laminated, grey-green siltstone and mudstone, very similar to unit Pcmm of the Jubilee Range area.

Most outcrop of Humboldt Formation correlate in the Glovers Bluff inlier appears to be baked, in places with metamorphic spotting. This is attributed to contact metamorphism by Jurassic dolerite.

Clark Group — age and correlation

The Jubilee Region includes a number of spatially or structurally separated inliers composed of an orthoquartzite unit overlain by pelite and dolomitic pelite. These inliers occur at The Needles, Jubilee Range, Glovers Bluff, Schnells Ridge–Gallagher Plateau, and Celtic Hill–Lake Judd. A good case can now be made for lithostratigraphic correlation of all these inliers, and the name Clark Group (Carey and Banks, 1954), defined in The Needles area, has priority (Appendix 1).

Correlation of the Clark Group between The Needles and Jubilee Range is most convincingly demonstrated by the similarity of unit Pcd, the dolomitic lower half of the Humboldt Formation. A range of identical lithologies is seen in both areas, including stromatolitic carbonates, flat-pebble carbonate breccias, oolites, nodular carbonates, and dolomitic and calcareous shales, some with molar-tooth structures. Rare evaporite indicators are seen in Pcd in The Needles area (Appendix 1) and in Pcdc, near the base of the Humboldt Formation correlate on the Jubilee Range.

The orthoquartzite units are lithologically similar, except that the large (about one metre) cross-bed sets common on the Jubilee Range were not seen in the type Needles Quartzite (Appendix 1). The Needles Quartzite is also much thinner than its correlatives elsewhere in the Jubilee Region, but the major thrust fault below the Needles Quartzite may have removed quartzite from the section. Palaeocurrent patterns are somewhat different (fig. 4); but as palaeocurrent patterns in the quartzite at Celtic Hill vary markedly between different horizons (Calver *et al*., 1990), this is not strong evidence for or against correlation.

Unit Pcmm in the Jubilee Range area, the upper part of the Humboldt Formation correlative, is somewhat dissimilar from the type upper Humboldt Formation. The latter is predominantly massive red mudstone with only minor siltstone (Appendix 1); at Jubilee Range the unit consists of sub-equal, interlaminated, grey-green mudstone and siltstone.

The Clark Group probably correlates with the Rocky Cape Group of northwest Tasmania. The two successions encompass a similar range of lithologies, including cross-bedded orthoquartzite, interlaminated mudstone and siltstone (Gee, 1968), and impure dolostone with molar-tooth structures (Calver and Baillie, 1990).

SHRIMP dating of detrital zircons has been carried out on a sample from the correlative of the Needles Quarzite at Glovers Bluff (Black *et al*., 1997; Black *et al*., 2004). Most of the zircons are between 1650 and 1750 Ma, with a smaller population at about 1400 Ma. This age distribution is similar to many other Tasmanian Proterozoic orthoquartzites, including the Detention Subgroup of the Rocky Cape Group. The Rocky Cape Group is considered to be early Neoproterozoic in age (c. 1000–750 Ma) and a similar age is inferred for the Clark Group (Black *et al*., 2004). The Clark Group is overlain by the Weld River Group, which is probably late Neoproterozoic (see below).

Depositional environments

The orthoquartzite of the Needles Formation and correlates was deposited on a shallow, tide-dominated marine shelf (Calver *et al*., 1990, p. 28). Locally, superposed ripples are seen, suggesting both shallow water and changes in water depth (tidal flats?).

The lower, dolomitic part of the Humboldt Formation (Pcd) contains evidence of very shallow marine conditions (stromatolites, intraclastic beds, oolite). There was evidently periodic subaerial exposure and development of evaporitic conditions on intertidal mudflats or in lagoons, as evidenced by desiccation cracks and relict evaporites. However most of unit Pcd lacks these features and was probably deposited in shallow subtidal, quiescent conditions. Molar-tooth structures are thought to characterise shallow subtidal environments in the Mesoproterozoic to early Neoproterozoic (James *et al*., 1998).

The mudstone with thin, graded siltstone layers characteristic of the upper part of the Humboldt Formation (Pcmm) probably reflects a marine, low-energy shelf environment, below the influence of wave and tidal action. The graded silt layers may have been deposited from storm-induced suspension clouds (Calver *et al*., 1990). Unit Pcdos demonstrates a reversion to shallow, more energetic conditions as shown by locally abundant stromatolites and oolite beds.

Weld River Group

The Weld River Group is a thick, dolostone-dominated succession, probably late Neoproterozoic in age, that unconformably or disconformably overlies the Clark Group and its correlates (Calver, 1989; Calver *et al*., 1990). The Weld River Group consists of a lower part comprising a relatively thin, basal clastic unit, the Annakananda Formation (Pwa), conformably followed by a thick succession almost entirely of dolostone (Pwt); and an upper part consisting of dolostone intercalated with diamictite, mudstone and other lithologies (the Cotcase Creek Formation, Pwc). The lower, dominantly dolostone part of the succession is seen:

- on the southern slopes of Tim Shea (Adamsfield map sheet: see Appendix 1);
- wrapping around the northern and eastern side of the Jubilee Range Anticline (Skeleton map sheet);
- in the Weld River Valley near Mt Weld (Nevada, Weld map sheets); and
- in the Glovers Bluff inlier.

The upper part of the succession (the Cotcase Creek Formation) is found in the Weld River valley (Nevada map sheet) and in the Blakes Opening area (Picton, Weld map sheets). The stratigraphic succession within the Cotcase Creek Formation is uncertain because of poor exposure, lack of bedding and facing evidence, and the likelihood of undetected faulting.

Calver *et al*. (1990) and Calver (1989) discuss in detail the stratigraphy, sedimentology and petrography of the Weld River Group, based on mapping in the Pedder quadrangle.

At least some of the diamictites and dropstone-bearing laminites in the Weld River Group are interpreted to be glacigene (Calver, 1989, and see below). By analogy with Proterozoic successions elsewhere in the world, the Weld River Group is therefore probably at least partly Cryogenian (c. 850–650 Ma) in age (Plumb, 1991). The Weld River Group is probably broadly correlative with the Togari Group of northwest Tasmania, which is around 750–545 Ma in age (Calver, 1998). The Togari Group, like the Weld River Group, lies with low-angle unconformity on an older quartzarenite-pelite succession (see above for evidence supporting correlation of the Clark Group and Rocky Cape Group). The Togari Group also contains much dolostone and two diamictite horizons, but unlike the Weld River Group, it includes a substantial unit of rift tholeiites and associated volcaniclastic rocks (Everard *et al*., 1996).

Conglomerate, sandstone and red mudstone (Pwa: correlate of Annakananda Formation) (Skeleton, Nevada, Weld map sheets)

Correlates of the Annakananda Formation are thin and possibly impersistent on the Skeleton sheet. In the Styx River (at 460400/5257900) the formation consists of red mudstone with very thin, planar laminae of sandstone and siltstone, and is probably no greater than a few tens of metres thick. An identical lithology comprises the Annakananda Formation correlate in the Weld River (456300/5253300), to the west in the Pedder Quadrangle (Calver *et al*., 1990). Two other outcrops attributable to Pwa were seen in the South Styx River (at 466900/5254100) and in a tributary at 466600/5255400. These outcrops are sedimentary breccia, consisting of clasts of dolostone, impure dolostone and mudstone in a matrix of coarse-grained dolomite-cemented quartz sandstone (thin section R007651). At the first of these localities, the conglomerate occupies broad irregular Neptunean dykes, possibly karst-fill structures, in impure dolostone of the uppermost Clark Group.

Correlates of the Annakananda Formation crop out in two areas in the southwest part of the Nevada map sheet (462500/5243000; 462000/5240500). These occurrences are poorly exposed but are predominantly conglomerate of pebble to cobble grade, composed of well-rounded clasts of red and green mudstone, hematitic siltstone, fine-grained pink or white quartzite, dolomitic mudstone and minor dolostone. A few clasts are coarse-grained (0.5–1 mm) orthoquartzite. The larger clasts are mostly quartzite. The conglomerate thus appears to be derived from typical Clark Group lithologies. The matrix is typically a quartzose sandstone with well-rounded grains (thin section R008009). Pwa in these areas also includes minor lithic sandstone, quartz sandstone, siltstone and red mudstone. The formation appears to be a few tens to hundreds of metres thick in these areas.

Pebbly laminated mudstone and sandstone (Pwap) (Nevada map sheet)

Outcrop at 462600/5240300 — at or near the top of the Annakananda Formation — consists of interlaminated black mudstone and white, fine-grained quartz sandstone with dispersed, sparse, well-rounded pebbles (lonestones) up to 70 mm in size. Lamination is distorted by compaction around the clasts. Small load structures are developed along the bases of some of the sandstone laminae. The pebbles, mostly of quartzite, may be glacial dropstones. This outcrop is a lithologic correlate of the Lake Timk Formation, which impersistently overlies the Annakananda Formation in the Pedder 1:50 000 scale quadrangle (Calver *et al*., 1990).

Dolostone (Pwt) (Maydena, Skeleton, Nevada, Weld map sheets)

Unit Pwt includes fine-grained, often massive dolostone (Pwtf) and bedded dolostone that is predominantly oolitic grainstone (Pwtg). In the type area on the Pedder map sheet, a lower unit of fine-grained dolostone (the Gomorrah Dolomite) is followed by bedded grainstone (the Devils Eye Dolomite) and then by fine-grained dolostone again (the Styx Dolomite) (Calver, 1989). Part of this stratigraphy can be recognised in the South Styx River area (468000/5255800, Skeleton map sheet), where fine-grained dolostone (correlate of the Gomorrah Dolomite) passes up into grainstone (correlate of Devils Eye Dolomite). The Gomorrah Dolomite is about 800 m thick in the Pedder Quadrangle (Calver, 1989) and a similar thickness appears to be present in the South Styx River. In the Snake River valley and in the Weld River valley northeast of Mt Weld (Weld and Nevada map sheets), faulting and younger cover have obscured stratigraphic relationships, so that Pwtf and Pwtg are differentiated without any implication of stratigraphic order. Dolostone in the Glovers Bluff inlier (Weld map sheet) is predominantly fine-grained and is presumably a correlate of the Gomorrah Dolomite.

Fine-grained dolostone (Pwtf) (Nevada, Skeleton, Weld map sheets)

Unit Pwtf is a fine-grained, pale grey dolostone that is usually massive, and in places thin bedded or laminated, identical to the Gomorrah Dolomite of the Pedder 1:50 000 scale map sheet to the west (Calver, 1989; Calver *et al*., 1990). Some outcrops — such as along the Weld River (467800/5242400 to 468500/5242000) (Nevada map sheet) are recrystallised to a uniform, medium-crystalline (0.5 mm) sucrosic texture. Some thin sections of apparently uniform, medium-crystalline (recrystallised) dolostones show poorly-preserved ooids (R007696).

Highly irregular vuggy pores, 10–30 mm in size and often aligned parallel to bedding, are commonly lined with an early, thin, dark isopachous dolomite cement and filled with a later, light-coloured sparry dolomite.

There are minor grainstone beds, typically towards the top of the unit in the South Styx River section, similar to those of unit Pwtg described below. Oolitic grainstone with well-preserved texture crops out on the Weld River at 468500/5241875 (thin section R007686). In the Glovers Bluff inlier near Fletchers Eddy (477750/5235600), cross-bedded grainstone beds have been altered to diopside marble by contact metamorphism, while interbedded fine-grained dolostone remains unaltered (see Pwts, below).

In the Glovers Bluff inlier (Weld map sheet), an outcrop of dominantly grainstone in the Weld River (477675/5234600) includes possible small domical stromatolites. Small columnar stromatolites were also seen on the northeast spur of Mt Weld (469150/5239300). In general, stromatolites are very rare in the Weld River Group.

Red mudstone (Pwtm) (Nevada map sheet)

A unit of red mudstone, about 10–20 m thick and conformably enclosed in fine-grained dolostone, occurs on the Snake River at 460200/5241700 (Nevada sheet). The red mudstone is interbedded with dolostone at its base and is overlain by laminated, impure (muddy) dolostone. The red mudstone contains minor, very thin, planar sandstone laminae. It is lithologically identical to red mudstone occurrences in the Gomorrah Dolomite on the Pedder 1:50 000 scale sheet, and very similar to some occurrences of the Annakananda Formation (e.g. Styx River, see above).

A similar red mudstone unit, not indicated on the map, occurs further upstream at 460400/5241050.

Dolostone: dominantly oolitic grainstone (Pwtg) (Nevada, Skeleton, Weld map sheets)

Unit Pwtg consists entirely of pale grey dolostone in which grainstone (dolarenite) is the dominant textural type. The grainstone typically consists of intraclasts, ooids and indeterminate irregular fine sand-size grains (peloids or catagraphs), cemented by sparry dolomite. The grainstone is typically interbedded with fine-grained (micritic or microsparry) dolostone. Quartz is often present in the grainstone beds, as a diagenetic cement phase that post-dates dolomite cement (Calver *et al.*, 1990). The content of quartz cement is variable (0–70%), and tends to be highest in the lithologies with the coarsest primary grain sizes (flat-pebble dolorudites and oolitic dolograinstones), because these lithologies had the largest primary pore spaces. The differential weathering caused by the presence of quartz means that bedding and cross-bedding are usually well-displayed on weathered outcrop surfaces in Pwtg. Cross bedding is common, in sets 100–200 mm thick. However, in some areas, grainstone beds lack quartz cement. In these cases grainstone textures are often very well preserved (e.g. Plate 7) but in some cases, have been obscured by later recrystallisation and are difficult to identify in the field.

Depositional textures and diagenesis of the grainstones from the Pedder Quadrangle are described in detail by Calver *et al.* (1990, p. 36–39) . Depositional textures are often well preserved. For example, R007707 contains well-preserved ooids with micritic, concentrically-layered cortices (Plate 7). Most ooids have large cores that have been replaced by centripetal (pore-filling) clear dolospar; in many examples, the dolospar cement has replaced all but the outermost thin micritic layer of the cortex. Internal, geopetal sediment and ‘dropped

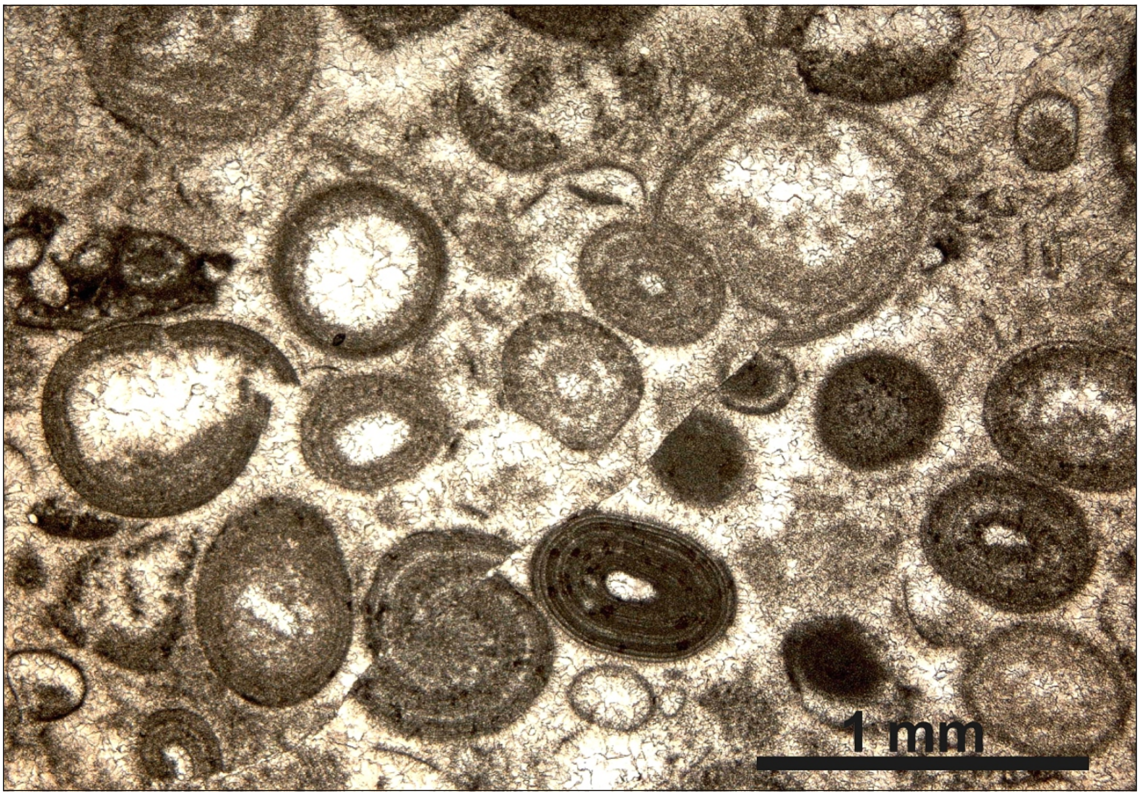


Plate 7

Photomicrograph of oolitic dolograinstone, unit Pwtg, Weld River Group. Many ooid cores have been replaced by clear, void-fillling cement. Note geopetal filling and fractured cortex of ooid on left. (Sample R007707) (467550/5249700).

cores' within such ooids demonstrate that the spaces now filled with sparry cement were once pore space. Compactive fracturing of the cortices, unsupported during this phase of diagenesis, is rare (Plate 7); this observation, and the uncompacted fabric of the grainstones generally, indicates that the rocks were dolomitised and cemented in very early diagenesis (Calver *et al*., 1990). Flat-pebble intraclasts are common, and consist of ooids with a micritic cement. Typically, settling of the sediment prior to cementation has resulted in relatively large, flat-topped pore spaces (later filled with dolospar or quartz cement) beneath flat-pebble intraclasts ('shelter porosity'). This is a useful facing indicator in the field.

Younging directions can be obtained from cross bedding and the shelter porosity associated with the larger, platy intraclasts. Facing can also be deduced in thin section from the geopetal sediment within ooids (Plate 7) (Calver *et al*., 1990).

Dolostone, diamictite, mudstone and sandstone (Cotcase Creek Formation) (Pwc) (Nevada, Weld, Picton map sheets)

The Cotcase Creek Formation is an association of four mappable lithologies whose stratigraphic relationships are poorly known because of faulting, poor outcrop and sparsity of facing evidence. No base or top to the formation is known. The many mapped occurrences of fine-grained dolostone (Pwcd), diamictite (Pwcx) and mudstone and sandstone (Pwcm) are probably in part structurally repeated, but some stratigraphic repetition is also likely, as is suggested on the Pedder 1:50 000 scale map sheet (Calver *et al*., 1990). The fourth mapped lithology (Pwcg: pebbly dolomitic siltstone and grey dolomitic diamictite) is less common and may represent a single stratigraphic unit. On sparse evidence, Pwcg may occur at or near the stratigraphic top of the Cotcase Creek Formation.

A number of observations allow a tentative stratigraphic ordering of some parts of the sequence.

1. At 464500/5243850 (Nevada map sheet), there is an observed upward stratigraphic transition from diamictite to dolostone conglomerate to dolostone. (The dolostone conglomerate is included in Pwcd for mapping purposes).
2. Similarly, on the Pedder map sheet, an upward stratigraphic transition was observed from diamictite to dolostone conglomerate at 454500/5251500 and 454800/5252000.
3. Dolostones on the Picton map sheet, including dolostone conglomerate, closely adjoin diamictite on the Huon River (466900/5228600) and several kilometres southward along strike (at 467100/5223700). Facing evidence on the Huon River suggests the diamictite is older, although the contact was not observed at either locality.
4. At 467000/5229150, on the Picton map sheet, a conformable upward stratigraphic contact from dolostone to pebbly laminated siltstone and mudstone (Pwcg) was observed.

The dolostone conglomerate is a relatively unusual lithology, observations 1 to 3 above accounting for all but one of the known occurrences in the Cotcase Creek Formation (Calver *et al*., 1990, p.40, and below). In the Nevada and Pedder occurrences (1 and 2 above) the diamictite that is overlain by dolostone conglomerate is underlain by mudstone and sandstone (Pwcm), while the base of the diamictite in the Picton map sheet was not observed, being faulted out against Harrisons Opening Formation (Php). It seems reasonable to infer that the same succession is present at each locality.

There are many mapped diamictite occurrences that are not associated with mudstone and sandstone (Pwcm) or dolostone conglomerate, and which appear to be enclosed by massive dolostone (e.g. 465500/5244300 on Nevada, 456300/5251300 on Pedder), although no contacts have been observed.

Thus, conformable successions of Pwcm Pwcx Pwcd (with dolostone conglomerate at the base of Pwcd); Pwcd Pwcx Pwcd; and Pwcd Pwcg, appear to be present within the Cotcase Creek Formation.

Predominantly massive, fine-grained dolostone (Pwcd) (Nevada, Weld, Picton map sheets)

Pwcd is typically a pale grey, fine-grained dolostone that is usually massive, but frequently planar laminated. It can only be distinguished from Pwtf (see above) on the basis of its association with the other rock types of the Cotcase Creek Formation.

Rarely, beds of quartz-bearing grainstone are present, resembling those of Pwtg (see above). An example is at 469300/5228300, in the Huon River at Blakes Opening (Picton map sheet). On the northern slopes of Mt Picton, around 468050/5224600, the dolostone consists of very large (5–10 mm), irregular compound ooids.

There are outcrops of dolostone conglomerate or breccia at three localities that, as noted above, stratigraphically overlie diamictite and may be correlatives. At 464500/5243850 (Nevada map sheet), the conglomerate is several metres thick and consists of well-rounded pebbles and granules of dolostone and rare quartzite, in a fine-grained, pale grey dolostone matrix. In places the conglomerate superficially resembles massive dolostone because of the similarity of clasts and matrix, but sparse quartzite pebbles weather prominently on outcrop surfaces and betray the conglomeratic texture. A thin section shows dominantly angular to rounded dolostone pebbles, with minor chert, orthoquartzite and mudstone, in a matrix of dolospar-cemented coarse quartz sand.

A large outcrop on the Huon River (at 466900/5228700) (Picton map sheet) is an excellent exposure of some unusual breccia fabrics and associated cements. Much of this outcrop is a sedimentary breccia consisting of highly irregular fragments (5–20 mm) of fine-grained medium grey dolostone, with large (10 mm) pore

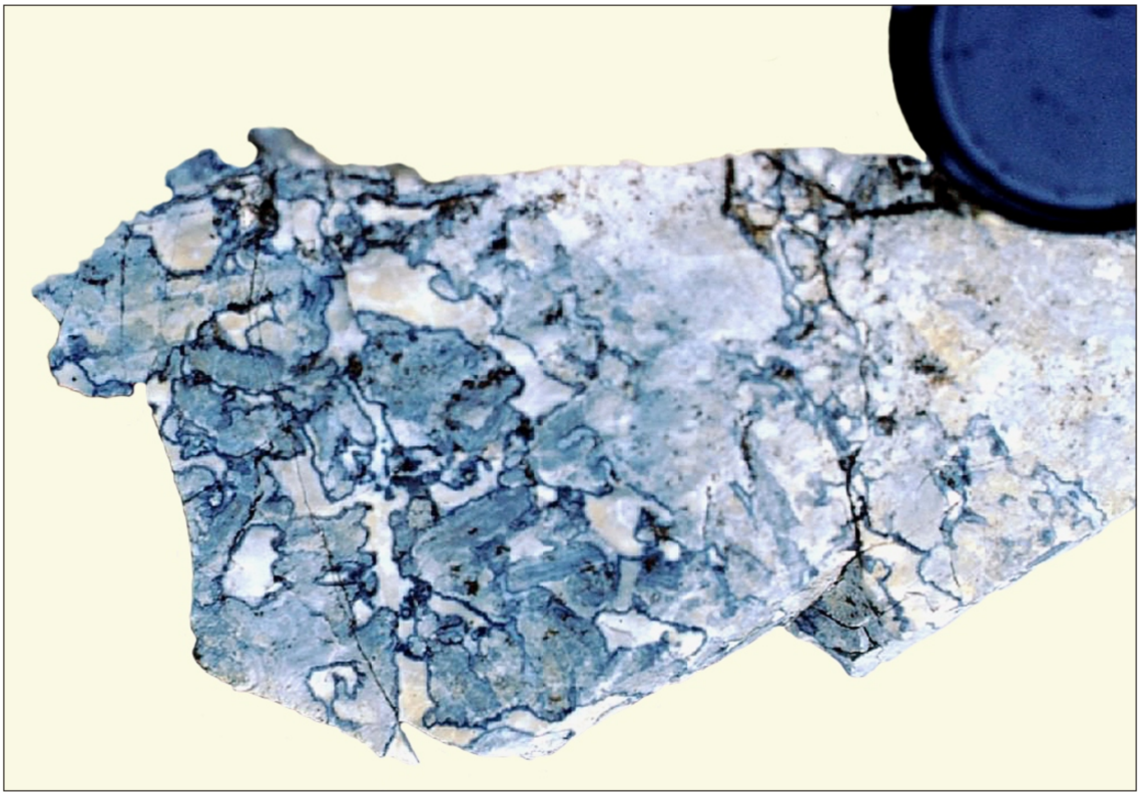


Plate 8

Sedimentary breccia in dolostone of Cotcase Creek Formation (Pwcd), outcrop on Huon River (466900/5228700).

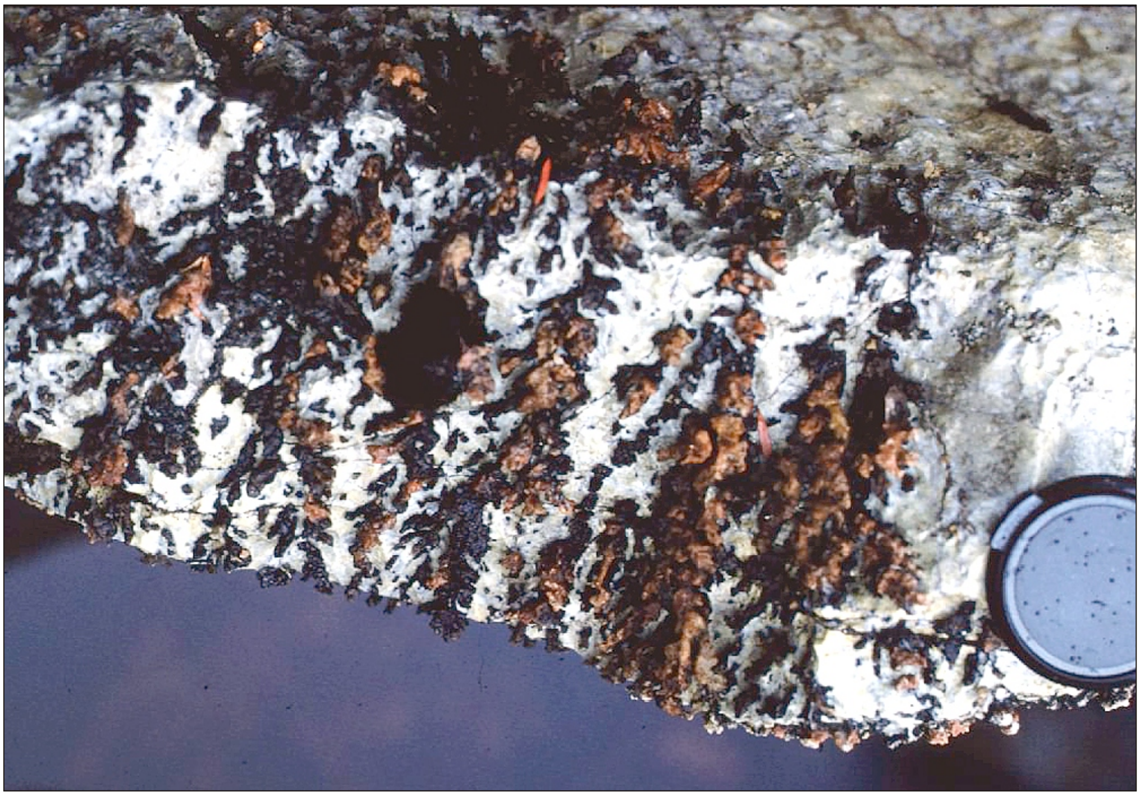


Plate 9

Prominently-weathering quartz cement (dark brown) forming irregularly branching masses in dolostone of Cotcase Creek Formation (Pwcd), outcrop on Huon River (466900/5228700).

spaces that appear to have been solutionally enlarged in very early diagenesis. These pore spaces have been filled with an isopachous dark grey bladed dolomite cement about 0.5 mm thick, followed by an internal sediment of uniform, very pale grey dolomicrite (Plate 8). On the western side of the outcrop (466900/5228650), a similar breccia fabric is obscured by coarse recrystallisation, and instead of the dolomicrite internal sediment, pore spaces are filled mostly by secondary quartz cement. On weathered outcrop surfaces, preferential dissolution of the carbonate has allowed the quartz to stand proud as highly irregular, ramifying shapes, which are casts of the original pore space of the breccia (Plate 9). At the eastern end of the outcrop (466970/5228700) the pore spaces in the breccia are larger (up to 50 mm), and almost certainly solutionally enlarged. There is a phase of pendant, fine-grained pale grey cement that post-dates the dark isopachous phase and precedes the internal fine-grained dolostone sediment, in which layering can be seen here. The pendant cement must have formed in the vadose zone in very early diagenesis, suggesting a depositional environment involving subaerial exposure, such as a tidal flat. In places this outcrop shows gentle culminations in bedding that resemble tepee structures, which is also consistent with subaerial exposure.

A similar breccia texture is seen in Winking Creek, five kilometres to the south (467100/5223600). This occurrence may be the same horizon as the Huon River breccia described above, as probably the same diamictite unit adjoins both occurrences to the west. In Winking Creek there is a poorly preserved intraclastic breccia, with abundant vuggy porosity filled with several phases of dolomite cement, internal geopetal sediment, and quartz (thin section R008166). Also in Winking Creek there are transported boulders of dolostone-in-dolostone granule and pebble-conglomerate, resembling the conglomerate described above in the Nevada sheet (samples R008163, R008164).

Predominantly black dolomitic diamictite (Pwcx)

Pwcx is massive, unstratified diamictite consisting of typically 5–15%, rarely 30% (by visual estimate) clasts of dolomite, quartzite, mudstone and chert in a matrix of dark grey to black, dolomitic sandy mudstone. Clasts are subrounded to well-rounded and are typically of granule, pebble and cobble size, but rare boulders to one metre are present. Smaller clasts (<10 mm) tend to be subangular. A variable proportion, but usually a majority (60–90%) of clasts are dolostone of various types (e.g. dolomicrite, recrystallised sucrosic dolostone, dolograinstone, sandy dolostone) typical of the Weld River Group. There are also impure (muddy) fine-grained dolostone and dolomitic quartz siltstone. Also abundant as clasts are orthoquartzite, quartz siltstone, mudstone and chert. Some of these clasts — in particular, the orthoquartzite — are lithologically very similar to the Clark Group.

There are large diamictite outcrops in the bed of the Weld River around 465600/5244300 (Nevada map sheet). The rock is almost wholly unstratified, but at one point, variations in clast size and content impart a crude decimetric bedding to the diamictite. The bedding is weakly graded. Elsewhere in this section there is a bed of coarse-grained sparsely pebbly quartzose sandstone several metres in thickness, enclosed by massive diamictite. The diamictite is notably sandy in places, suggesting correlation with the diamictite units rich in quartz sand at 456400/5251400 in the Pedder Quadrangle (*cf.* Calver *et al.*, 1990).

Another, more accessible large exposure of diamictite, is found on the southern bank of the Huon River at 466600/5228400 (Picton map sheet) (Plate 10). This exposure is typical of Pwcx, with pebbles, cobbles and rare boulders (0.8 m) dispersed through an abundant, unstratified black dolomitic mudstone matrix. Many clasts have slightly rounded, polygonal shapes that may reflect glacial facetting. No striated clasts could be found.

Predominantly black mudstone and quartz sandstone (Pwcm)

Pwcm is a variable association of lithologies, dominated by black mudstone and tough black quartz sandstone. In many places the mudstone is sheared; it has a scaly, cataclastic cleavage causing the rock to break up into glossy lenticular fragments, and contains lenticular pods of black quartzite. Elsewhere, unsheared mudstone preserves thin laminae, sometimes graded, of quartz siltstone. The quartz sandstone occurs as tough, blocky, internally uniform beds up to five metres in thickness. Outcrop of the quartz sandstone in creeks is usually black, but weathered outcrop or float may be white. Also common in Pwcm is grey, pyritic shale and siltstone interbedded with quartz sandstone. Locally, there is black quartzwacke and diamictite similar to that of Pwcx.

Thin sections of quartz sandstone (R007719, R007724, R007781) show well-sorted coarse-grained quartzarenite with up to several percent platy fragments of mudstone, siltstone and chert; the quartz grains (0.5–1 mm) are well rounded, and the grains are surrounded by a thin fringe of carbonate (siderite?) cement in two slides.

Predominantly pebbly laminated dolomitic siltstone and mudstone and pale grey dolomitic diamictite (Pwcg)

Two distinctive lithologies characterise unit Pwcg. These are as grey, dolomitic siltstone or shale with thin planar laminae of coarse siltstone or sandstone, and sparse (a few percent) rounded pebbles (lonestones) of dolostone and quartzite (Plate 11). Lonestones are usually less than 30 mm in size, rarely up to 150 mm, and in places are concentrated into horizons. Laminae diverge around these clasts, presumably by differential compaction. The fine-grained sandstone or siltstone

Plate 10

Outcrop of diamictite (unit Pwcx) on the Huon River (466600/5228400). Clasts are quartzite (grey, prominently weathering) and dolostone (yellow-brown, recessively weathering). [Photo: Rob Reid]

Plate 11

Outcrop showing lonestone in laminated dolomitic siltstone, unit Pwcg, Huon River (467300/5228500). [Photo: Rob Reid] laminae, of detrital dolostone and quartz, are weakly graded (thin sections R007784, PJ171). This rock type is well exposed on the Huon River around 467300/5228500 (Picton map sheet).

The other distinctive lithology in Pwcg is a diamictite texturally similar to those of Pwcx, but with a pale grey, silty dolostone matrix and a greater proportion (90%) of dolostone clasts. Also present in Pwcg as minor components are grey to black shale with dolomitic siltstone laminae, massive dolostone, and black shale interbedded with chert.

Unit Pwcg is a relatively uncommon component of the Cotcase Creek Formation. It has been mapped at two places in the Nevada map sheet (461000/5246000; 465000/5242000), in the Picton map sheet (467300/5228500), and in the Pedder Quadrangle between 457600/5248700 and 455700/5248800 (Calver *et al.*, 1990, p.41). These may be structurally separated occurrences of a single unit. Sparse facing evidence on the Nevada and Pedder map sheets suggests Pwcg occurs at or near the top of the fault blocks in which it is found. The only observed contact with other units was seen at the base of Pwcg in the Picton map sheet at 467000/5229150, where as mentioned above, there is a conformable upward stratigraphic contact from dolostone (Pwcd) to pebbly laminated siltstone and mudstone of Pwcg. Along strike, on the Huon River, this contact is probably faulted, because there is a slight angular discordance between bedding in Pwcg and the contact with underlying dolostone which is concealed under the river bed for some 300 m, trending 150° (467200/5228700). No top to Pwcg has been observed.

The laminated siltstone and shale with lonestones of Pwcg is texturally very similar to the Lake Timk Formation of the Pedder Quadrangle and its correlate, Pwap on the Nevada map sheet. Lonestones within laminated fine-grained sedimentary rocks are generally accepted as glacial dropstones. By association, at least some of the diamictites (Pwcx) of the Cotcase Creek Formation may also be of glacial origin.

Silicification in dolostones of the Weld River Group

There is widespread silicification, in a variety of styles and ages, of dolostones of the Weld River Group. Some areas of partially or wholly-silicified dolostone, described below, are shown by mnemonic on the maps (Pwts, Pwcds). In the Blakes Opening area, dolostone of the Cotcase Creek Formation (Pwcd) is obscured by an extensive surficial lag of siliceous gravel and sand, shown as Pwcdss, that is derived from partially silicified dolostone that subcrops or crops out, upslope. Pwcdss south of Blakes Opening also contains rare fragments of silicified basal Parmeener Supergroup conglomerate. In many other places the lag is of large quartz boulders, indicated on the maps as Pwtsb or Pwcdsb. Massive quartz rocks (Pwtq) and opaline silica (Pwtqo) in the Glovers Bluff area are thought to be derived, in part, from Weld River Group dolostone and possibly in part from Cambrian, ultramafic-rich lithologies. Pwtq and Pwtqo are described separately below.

Early diagenetic quartz cement

The earliest phase of silicification in dolostone of the Weld River Group is quartz cement that is the final pore-filling phase in many grainstones of unit Pwtg, as described above and by Calver *et al*. (1990). Some grainstones entirely lack quartz cement, while others may contain up to 70% by volume. Where quartz cement is present, the rock typically has a thick, porous, sandy weathering rind where the dolomite component has leached out. These beds tend to weather prominently, and sedimentary structures such as cross bedding are prominently displayed on weathered surfaces. This style of silicification is not indicated on the maps, but is very common in unit Pwtg, affecting probably the majority of outcrops of grainstone in this unit.

The quartz cement is composed of equant clear megaquartz. The preceding phase of sparry dolomite cement typically has rhombohedral, non-corroded terminations against the quartz. Small pores may be filled by a single quartz crystal that accommodates itself to the shape of the pore, while larger pore spaces are filled with a mosaic of equant quartz crystals which increase in size away from the substrate. These observations suggest that the quartz is a passive pore-filling cement rather than a replacement. In rocks with abundant (70%) quartz cement, the pre-existing, tenuous dolomite fabric is uncompacted, suggesting that the quartz formed prior to appreciable overburden (Calver *et al*., 1990, p.38).

Clasts of dolomite grainstone with this style of quartz cementation are common in late Cambrian basal Denison Group conglomerate at Tim Shea. This is consistent with relatively early timing of formation of this quartz.

Boxwork and massive to vuggy silicification

The youngest known phase of silicification is post-Carboniferous in age, because it locally affects basal Parmeener Supergroup sedimentary rocks that unconformably overlie silicified Weld River Group dolostone.

At a number of locations, massive or boxwork, in part coarsely crystalline silicification, has affected several metres of Weld River Group dolostone immediately underlying the basal Parmeener Supergroup unconformity. The basal one to two metres of Parmeener Supergroup diamictite is also silicified. These locations include a small inlier near Cliff Creek (467600/5258700, Skeleton map sheet); in the saddle between the Jubilee Range and the Snowy Range (467400/5249600, Nevada map sheet); on an eastern spur of Mt Weld (469000/5239300, Weld map sheet); and on Red Rag Scarp (468600/5224400, Picton map sheet).

These localities all display a similar vertical profile over 5–15 m consisting of an upward transition from dolostone with sparse (<10%), relatively thin, sheet-like quartz veins, then dolostone pervaded by a more voluminous (10–30%) quartz-vein boxwork, then massive to vuggy, finely to coarsely crystalline quartz. The uppermost zone may be several metres thick, and entirely lacks dolostone. Typically complex cross-cutting veins and patches of quartz-cemented quartz breccia, suggestive of multiple phases of fracturing and vein formation, occur in the uppermost zone. The vugs may be up to one metre in size and some appear to result from dissolution of dolostone from the interspaces of quartz-vein boxworks. The vugs are typically lined with coarse euhedral quartz, the crystals lacking prism faces and up to 30 mm in diameter. Upward-facing crystal surfaces are frosted with a thin (<1 mm) coating of fine sparry quartz in some vugs. This uppermost, intensely silicified zone is overlain by several metres of silicified Permo-Carboniferous conglomerate or diamictite of the Parmeener Supergroup. The conglomerate appears indurated and bleached and in places has quartz veins. Some of the clasts in the conglomerate — probably originally dolostone — have dissolved out and the voids are lined with sparry quartz. There is an upward transition over a few metres to unsilicified conglomerate.

A large vug in the upper, wholly-silicified zone at the Mt Weld locality is partly filled by a metre-thick, horizontally-layered lens of fine-grained quartz or silicified travertine, with sparse small pebbles of quartz and spar-lined vugs (formerly dolostone). This may be a silicified cave deposit or it may represent internal sedimentation coeval with the hydrothermal activity.

These silicified rocks crop out prominently, forming cliff-like exposures. Sinkholes with cave entrances are developed in the dolostone at the foot of some of these exposures (Red Rag Scarp, Mt Weld).

Not all exposures of the Parmeener Supergroup unconformity upon dolostone are marked by silicification. For example, in a creek exposure of the unconformity at 468500/5224400 (Picton map sheet), neither dolostone nor Parmeener Supergroup conglomerate are silicified, while nearby outcrops to the north are marked by strong silicification. Similarly a sinkhole about 100 m east of the Mt Weld locality exposes the unconformity with no silicification.

A fluid inclusion study of quartz from the Mt Weld locality showed low temperatures of formation (<100°C: Bottrill *et al.*, 1999). Low-temperature, silica-bearing hydrothermal fluids appear to have locally migrated upward through fractures in the Weld River Group dolostone, and tended to dissolve carbonate and precipitate quartz at or just below the unconformity, presumably because of the drop in pH that would have accompanied the upward change from carbonate to diamictite.

There are similar outcrops of massive secondary quartz with a downward transition into quartz-veined dolostone, lacking the silicified Permo-Carboniferous diamictite 'cap', and distant from known Parmeener Supergroup outcrop, at a few localities (e.g. 467100/5254400, Skeleton map sheet; 467500/5240900, Nevada map sheet). These areas have conceivably been stripped of Parmeener Supergroup in the recent geological past.

More common are large lag boulders of secondary quartz, commonly 2–5 m, rarely 10 m in size, that are shown as Pwtsb. Outcrop (Pwts) and lag boulders (Pwtsb) are typically located on ridge tops, in locations that conceivably have been stripped of Parmeener Supergroup cover in the recent geological past. For example, a broad area between the South Styx River and Cliff Creek (466000/5256300 to 467000/5256000 to 467600/5256500) on the Skeleton map has scattered surficial lag boulders of quartz up to ten metres in size, and has common, rounded orthoquartzite pebbles and cobbles in the soil. The latter are probably lag derived from basal Parmeener Supergroup.

Partial silicification, usually as a boxwork of planar to irregular quartz veins 1–100 mm wide, is common in locations well away from possible involvement with the Parmeener unconformity, and the age of this silicification is unknown. Similarity in style with the unconformity-related silicification suggests that they may be the same age. Examination of outcrop and lag of silicification products on the north side of Mt Picton shows varied parageneses, the most common being:

(1) Fracturing of dolostone

(2) Growth of successive isopachous layers of void-filling quartz on dolostone substrate, the earlier layers fine-grained (including agate in places), the latest phase typically coarse spar (>1 mm), totalling 5–50 mm in thickness.

(3) Fracturing. Remaining voids partially filled with angular fragments (1–20 mm) of both dolostone and quartz.

(4) Remaining void space filled with uniform, coarse quartz spar.

The second phase of fracturing may be absent. Void filling may be incomplete, in which case voids are lined with coarse euhedral quartz, lacking prism faces.

In outcrop on the north slope of Mt Picton at 468700/5224900 (Picton map sheet), relatively broad megaquartz veins are partly filled with angular dolostone clasts up to 20 mm in size. The dolostone clasts are in closed framework, and in one place form a reverse-graded layer with a horizontal top (fig. 5). The quartz shows a passive void-filling fabric, showing in thin section fine opaque minerals outlining successive euhedral terminations in places (thin section R008160). This quartz-cemented dolostone breccia is the result of fragmentation and limited transport of the dolostone wallrock within open fractures, prior to precipitation of quartz. The horizontal top to the breccia is consistent with a post-Devonian age for the fracturing and quartz growth.

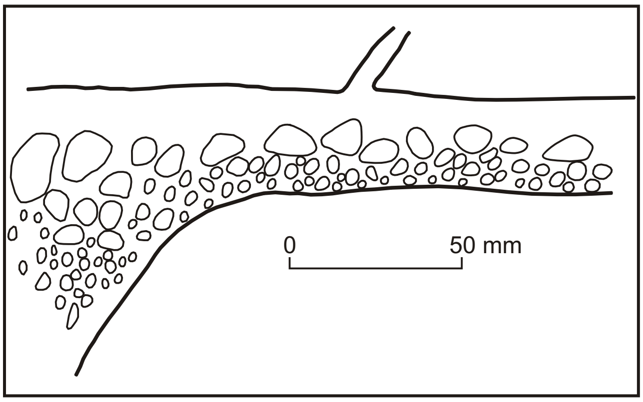


Figure 5

Field sketch of reverse-graded dolomitic breccia layer with horizontal top partially filling quartz vein. Near Red Rag Scarp, Mt Picton (468600/5224800).

Some areas of massive silicification appear to be related to faults rather than proximity to the Parmeener Supergroup unconformity. A large area (0.2 2 km) on the Skeleton map sheet (463000/5259200 to 464000/5259200) is characterised by an abundance of large boulders and possible outcrop of fine-grained, massive quartz. This zone follows a major fault; silicification may be fault-related in this case.

Other occurrences of possible fault-related silicification of dolostone are on the Nevada map in the Snake River (463000/5244400) and near the Weld River (462700/5246700). Abundant talus boulders of quartz in the Weld River near, and downstream of the latter locality, may be derived from the faulted contact between Pwcd and Pwcm along strike from that locality. These occurrences are all fine-grained, massive quartz, in places with a breccia fabric, with little or none of the vuggy porosity or coarsely crystalline quartz that characterises the unconformity-related silicification. These localities are indicated as Pwts on the maps.

Silicification is notably absent from the thick dolomitic limestone succession of the Gordon Group. This may be due, at least in part, to the relatively high content of argillaceous material in the Gordon Group, which would have rendered it more ductile and less amenable to brittle fracture than the Proterozoic dolostone. The latter may therefore be more prospective for vein-related and replacement-style mineralisation.

Altered dolostones of the Weld River Group, Glovers Bluff area (Pwts, Pwtq, Pwtqo) (Weld map sheet)

Along the eastern side of the Glovers Bluff inlier, in the eastern part of Weld map sheet, dolostone belonging probably to unit Pwtf of the Weld River Group has been extensively altered to marble and secondary quartz. The marbles consist of variable proportions of diopside, serpentine, talc and brucite as well as calcite and dolomite. These rocks have been termed magnesian skarns (Bottrill and Woolley, 1996; Bottrill *et al.*, 1999); 'calc-silicate hornfels' is an alternative general term. The skarns are shown as Pwts and occur as two belts:

- a western belt that extends from the western slopes of the ridge east of Eddy Creek (478000/5237500) to Glovers Plain; and
- an eastern belt that underlies the Forster Prospect and extends northward at least as far as the Weld River (fig. 6).

The secondary siliceous rocks are seen at the eastern end of Forster Road, cropping out in the Weld River at 478100/5234400, forming the crest of Hogsback Hill (478150/5235100) and cropping out again on the ridge east of Eddy Creek (477900/5237500). Some of the quartz rocks are chromite-bearing and may have originated from ultramafic rocks or ultramafic-derived conglomerate of unit Calc (see below).

Most or all of the alteration in these rocks can be attributed to contact metamorphism and minor metasomatism associated with the intrusion of the Jurassic dolerite (Bottrill *et al.*, 1999). The dolerite adjoins and probably shallowly underlies these rocks (fig. 6; and see later section). The petrography and mineralogy of these rocks have been described in detail by Bottrill and Woolley (1996) and Bottrill *et al*. (1999), so these aspects are only briefly dealt with here.

Magnesian skarn (Pwts)

The western belt of Pwts crops out on the western slope of the ridge east of Eddy Creek (477500/5237500) and in the Weld River, intermittently for about one kilometre downstream of Fletchers Eddy (477700/5235600). On the western slope of the ridge east of Eddy Creek, outcrop is of massive, tough, finely crystalline marble, mostly white but less commonly pale green or grey. Thin sections and XRD show the marble to range in mineralogy from diopside + quartz (R007639), through diopside + quartz + calcite, to calcite + brucite (R007646). In places there are irregular patches of coarse sparry calcite and quartz, 30–100 mm wide. Weathered surfaces of the marble commonly have a porous rind 5–50 mm thick from which calcite has been leached. Sample R007639 consists mostly of very finely granular diopside (<50 μm) with irregular patches of hornfels-textured quartz. Sample R007646 is a white calcite marble with scattered small (<1 mm) aggregates of brucite, visible in hand specimen as inconspicuous, pale grey flecks. The brucite in this sample is pseudomorphous after periclase (Bottrill and Woolley, 1996).

There is a transitional contact, over several tens or hundreds of metres, with unmetamorphosed, pale grey, fine-grained dolostone (Pwt) to the west. Outcrop in Eddy Creek (around 476900/5237400) consists of apparently unaltered grey dolostone with diffuse, irregular patches of translucent white finely crystalline dolomite and calcite marble, probably reflecting the distal effects of contact metamorphism.

Outcrop of Pwts in the Weld River downstream of Fletchers Eddy has a variety of noteworthy metamorphic textures. At 477750/5235600 there is extensive outcrop of fine-grained grey dolostone and

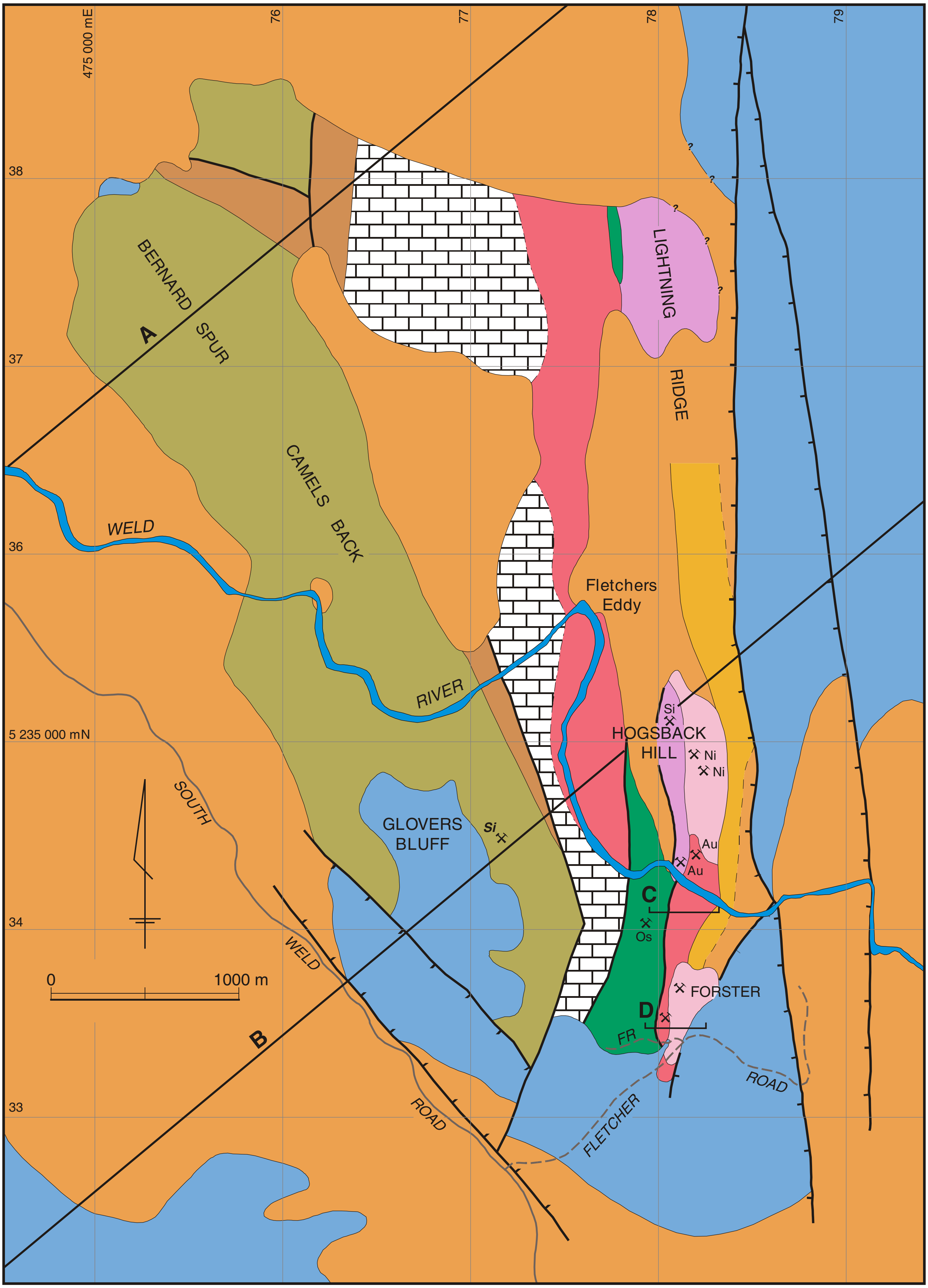


Figure 6

Bedrock geology of the Glovers Bluff inlier. Based on 1:25 000 scale mapping, ground magnetic traverses and drilling in the Forster Prospect area (Carthew et al.*, 1988; Summons, 1997; Young, 1997). See Figure 7 for legend.*

white dolomite marble. The dolostone and the marble have irregular, diffuse to sharp boundaries with each other. There are also tabular bodies of diopside marble, 20 mm–1 m thick. These bodies weather prominently and are palimpsest beds, formerly of oolitic, siliceous dolograinstone. Cross bedding is visible in places within these beds. Some of these diopside bodies are surrounded by reaction rims (haloes) of white, fine-grained calcite, 10–20 mm wide. The diopside marble is white, weathering to a pale yellow. The outer rims (5–10 mm) of some diopside bodies are solid diopside, while the inner parts contain a variable proportion of fine-grained calcite and have a porous weathering rind. Dolograinstone in the Weld River Group usually has a proportion of fine-grained quartz as a diagenetic cement phase (e.g. Pwtg, see above), while interlayered fine-grained dolostones typically lack quartz. Diopside and calcite would have formed from grainstone layers by isochemical reaction of dolomite and quartz during contact metamorphism. A thin section of one of the diopside marble layers (R007647) at this locality shows irregularly intergrown, very fine-grained diopside and coarse, brownish pseudopleochroic calcite, and minor patches of hornfels-textured quartz. In places a remnant oolitic texture is evident, with ooid cortices preferentially replaced by diopside, and interstitial cement by calcite.

Further downstream, outcrop at 477550/5235200 consists of ovoid to highly irregular metamorphic aggregates, 20–300 mm wide, mainly of coarse (2 mm) white sparry calcite and talc within relatively unaltered, pale grey, fine-grained dolostone. The calcite-talc aggregates are surrounded by thin (1–2 mm) selvedges of serpentine and talc (see thin sections R007641, R007642). The origin of the morphology of these metamorphic aggregates is unclear. They are hosted by relatively unaltered, fine-grained dolostone in which sedimentary structures (bedding, intraclasts) are still preserved in places. At 477525/5235050 a similar outcrop has sparry calcite bodies containing planar to anastomosing veins of serpentine. Outcrop of stromatolitic dolostone at 477675/5234600 appears unmetamorphosed, but a thin section (R007648) contains rare, small serpentine patches (Bottrill and Woolley, 1996). The presence of serpentine and talc in these rocks suggests minor hydrous metasomatism.

Natural outcrop of the eastern belt of Pwts is restricted to the southern bank of the Weld River where it is crossed by the exploration grid baseline (478200/5234360) and downstream of this point. This outcrop consists of massive, cream to pale brown marble with thin veins of common opal. The opal is black, brown or blue-grey in colour, and in places has diffuse boundaries with the marble, suggesting it is in part a replacement. A thin section (R007640) shows a calcite marble, with minor serpentine, largely replaced by pale brown opal. The replacive opal has a reticulate or meshwork fabric. This lithology has also been described as a partly opalised ophicalcite (Bottrill and Woolley, 1996).

South of the river the magnesian skarn is obscured by surficial deposits, and its extent has been delineated by exploration drilling, costeaning and ground magnetics (fig. 6, 7). Boulders of opal-veined marble or ophicalcite, identical to the riverbank outcrop just described, have been exhumed from costeans around 478200/5234030. A notable feature of this marble/ophicalcite is that freshly-broken surfaces, initially white, tarnish rapidly (one day) to pale grey-green, then (over a few weeks) to pale brown. Drilling has shown that the eastern marble unit extends as far south as the Forster Road–Fletcher Road junction (Summons, 1997). In the southern part of this area, the marble unit is largely covered by a thick (up to 40 m) body of clay and silicification products (the 'silica-clay zone') and surficial gravel (unit Qss, see below). Drilling shows that Jurassic dolerite underlies the marble unit at subsurface depths of 15–80 m (fig. 7). The western boundary of the marble is probably a subvertical meridional fault against Cambrian altered mafic conglomerate (Calct), and is marked by a strong magnetic gradient that is indicated on the 1:25 000 scale geological map (Appendix 2). Drill core from hole BC15 (= SW1 of Bottrill and Woolley, 1996) shows, underlying siliceous rocks, ophicalcite marble (66.5–c.75 m) underlain by skarn predominantly composed of quartz, xonotlite and diopside, with minor calcite, magnetite, sulphides and other minerals (c.75–82 m: Bottrill and Woolley, 1996). Drill core from hole BC5 (= SW2 of Bottrill and Woolley, 1996) intersected predominantly ophicalcite marbles between 45 m and 103.7 m, between weathered silicification products above and Jurassic dolerite below (Bottrill and Woolley, 1996). Cross sections of the eastern belt of Pwts (fig. 7) are derived mainly from RC drill holes (Morrison, 1990; Summons, 1997; Young, 1997) with some constraints from ground magnetic traverses (Appendix 2).

There is no outcrop of the eastern magnesian skarn unit north of the river, and sparse shallow drilling has only intersected clay and siliceous gravel, probably lag deposits (shown as Qss on the map). On the Weld Track (around 478300/5235100) there are bouldery masses of leached, in part porous and chalky-textured, opaline silica. Tailings around nearby old shafts just south of the track (at 478250/5235025, 478320/5235000 and 478325/5234980) consist of similar leached, porous, chalky silica, dark brown opal and quartz boxwork. These silicification products are very similar to those associated with the eastern marble unit south of the Weld River, and suggest that the marble, partly or wholly silicified, may extend north of the river to underlie Fletchers Plain between the Hogsback Hill quartzite on the west and Jurassic dolerite to the east.

A number of RC, percussion and 'wacker' holes have been drilled in this area (Fletchers Plain, east of Hogsback Hill) without encountering definite bedrock except for Jurassic dolerite in the northernmost holes (BC11, 12, 14) (see Summons, 1996*b* for holes HB85-01–07; Carthew *et al.*, 1988 for Wacker holes; Morrison, 1990 for RC holes BC9–BC14). The deepest

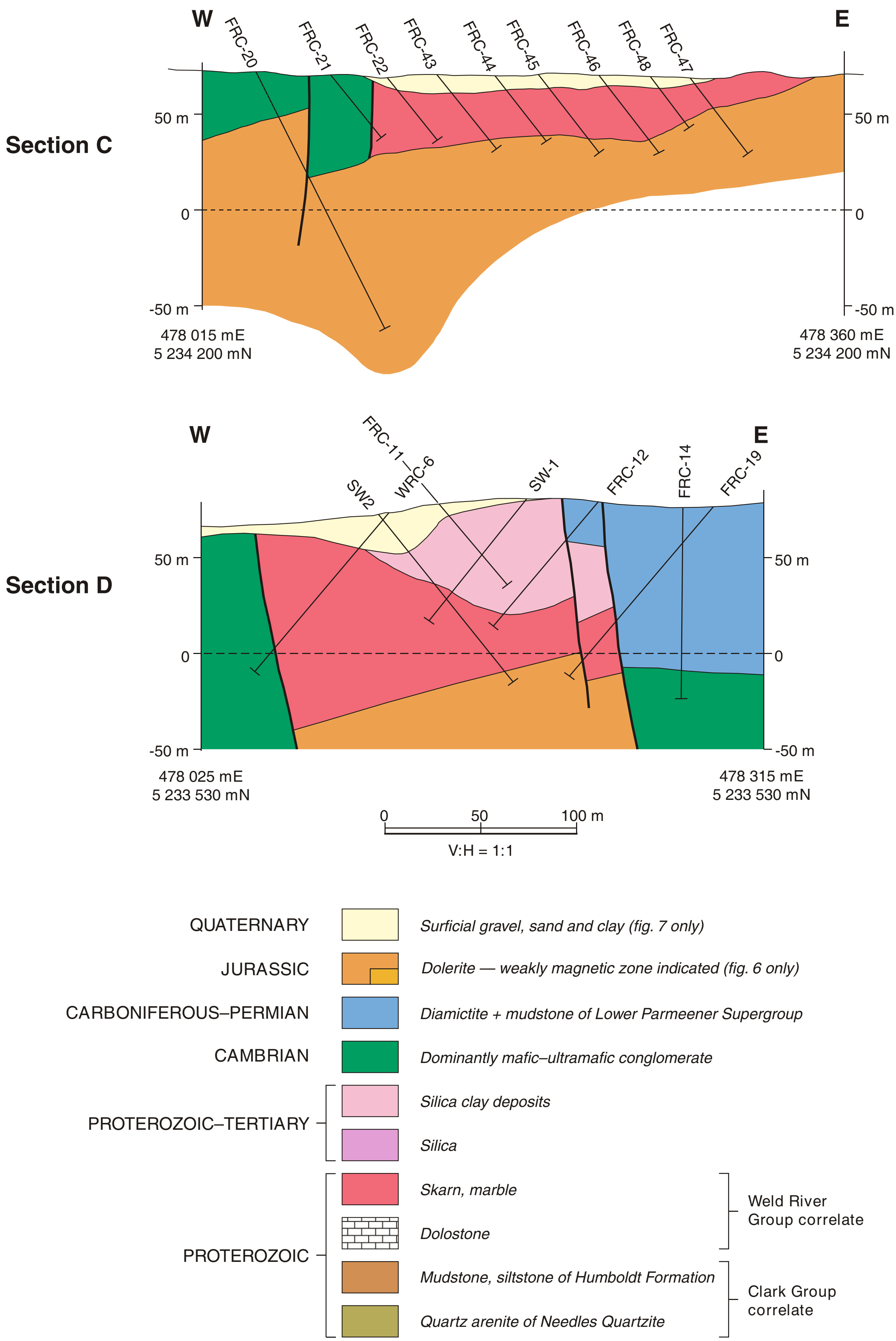


Figure 7

Cross sections, Forster Prospect area. Based on ground magnetic traverses (fig. 35) and drilling (Morrison, 1990; Summons, 1997; Young, 1997).

relevant hole is BC9, drilled at the western edge of Fletchers Plain at 478200/5235150, inclined 50° to the east to a depth of 47 m (36 m true). This intersected clay, quartz fragments, and minor decomposed ultramafic fragments. Some Cr assays were over 1000 ppm, suggesting derivation from ultramafic rocks (Morrison, 1990).

Secondary quartzite, quartzitic breccia and opaline silica (Pwtq, Pwtqo)

Generally massive and fine to coarse-grained quartz and opaline silica crop out at four places in the Glovers Bluff inlier:

- at Fletcher Road–Forster Road junction (478000/5233500);
- in the Weld River and immediately north (478150/5234400);
- on 'Hogsback Hill' (a strike ridge of this material) (478150/5235000);
- and on the ridge east of Eddy Creek (477900/5237500).

These occurrences lie on a north–south line, although the latter two are separated by an area of Jurassic dolerite. The siliceous rocks are interpreted to lie along a largely concealed, faulted contact between Cambrian rocks to the west and altered Weld River group carbonate rocks to the east (fig. 6, 7, 33). The contact has been invaded and obscured by Jurassic dolerite west and north of Hogsback Hill. Massive silicification of the carbonate rocks (and Cambrian conglomerate?) adjacent to the fault may have resulted from fluid movement along the fault, and may have pre-dated Jurassic dolerite intrusion. Part of the quartz may also derive from silicification of the Cambrian rocks.

Probably related to these rocks and also discussed here is the 'silica-clay zone', a shallow-subsurface unit extending north of the Forster Road–Fletcher Road junction, known from exploration drilling (fig. 6, 7). This is not shown on the Weld geological map, being covered by derived thin surficial slope and lag deposits of siliceous gravel (Qss).

Those siliceous rocks shown as Pwtq on the map consist essentially of massive fine-grained quartz, pale grey in colour and weathering to white. With a grainsize of mostly 10–100 µm, these rocks are mostly too coarse to be termed cherts *sensu stricto*. Outcrops typically show minor irregular patches and veins of slightly coarser-grained quartz, and small patches of quartz boxwork with small (<1 mm) drusy quartz crystals lining voids. Thin section and XRD of outcrop on the south bank of the Weld River (at 478140/5234370) shows minor fibrous clinopyroxene, carbonate, opal and prehnite. This outcrop is interpreted to be silicified skarn (sample G402207, Bottrill and Woolley, 1996). Just north of the Weld River (at 478150/5234450) an adit has been driven into similar, massive fine-grained quartz. Fresher material here contains patches of coarsely crystalline calcite. Magnetic susceptibility of the quartz at the adit and on Hogsback Hill is low (0.03 0.02 10^{-3} SI units, n = 31). Magnetic susceptibility is mostly similarly low on the ridge east of Eddy Creek, but about 5% of float fragments have a much higher susceptibility (7–14 10^{-3} SI units). Trace chromite is locally present in the quartz on Hogsback Hill (Bottrill and Woolley, 1996). The presence of chromite and the locally higher magnetic susceptibility suggests an origin in part by silicification of ultramafic rocks.

Twelve short vertical percussion holes (HB85-08–HB85-19) were drilled in a north–south line along the crest of Hogsback Hill in a search for economic silica deposits (Summons, 1986*b*). These holes show that the massive quartz rock comprising the strike ridge is only 6–12 m in vertical thickness, and is underlain by poorly consolidated siliceous sand, silt and clay several metres or more thick (no holes penetrated this material to bedrock). A few percent chromite was reported in the quartz in the three holes at the northern end of the ridge (HB85-08, 09, 10) (Summons, 1986*b*). However quartz in HB 85-08 and HB 85-10 does not show elevated Ir or Ni (Summons, 1988).

An origin for the Hogsback Hill silica (and possibly other areas of Pwtq) as Tertiary regolith, in part over ultramafic rocks or ultramafic-derived clastic rocks (Calc), was suggested by Summons (1986*a*). The relatively thin and flat-lying morphology of this silica mass could also be explained as a result of localisation of silicification immediately beneath the Lower Parmeener unconformity, a phenomenon seen at many other places in the region (see previous section). This would require the Lower Parmeener Supergroup to have been eroded from Hogsback Hill in the relatively recent past. In support of this idea, fragments of silicified conglomerate, probably lag after basal Lower Parmeener rocks, are present on nearby Fletchers Plain (478300/5234900).

Alternatively, boulders of silicified conglomerate which occur at nearby locations (478440/5233880 and 477600/5234680) are probably lag after Tertiary 'greybilly', and are consistent with some development of Tertiary siliceous regolith in surrounding areas.

The northernmost part of the ridge east of Eddy Creek is composed of common opal, shown as Pwtqo on the map. Outcrops are massive opal, white to brown or red in colour, with several generations of random fracturing marked by narrow veins that are themselves filled with opal. Similar opal is locally seen as fragments in Qss in the Forster prospect area, and opal occurs as veins and as a partial replacement in the eastern marble unit (Pwts) (see above).

'Silica-clay zone' of Forster Prospect area

A body of quartz, quartz-breccia and clay, known as the 'silica-clay zone' and known mainly from exploration drilling, extends north from the Fletcher Road–Forster Road junction about half way to the Weld River (fig. 6). Up to 60 m in vertical thickness, this unit is not shown on the 1:25 000 scale map, being covered by thin surficial slope deposits of siliceous gravel (Qss).

Float fragments of siliceous rock in the gravel (Qss), derived from the silica-clay zone, are variable. There is common brecciated, dark grey fine-grained quartz that has been re-cemented by coarser milky quartz that forms drusy, void-filling crystals (up to 10 mm) in places. Several generations of quartz cementation are evident in some fragments. Like the quartz crystals developed on silicified dolomite at Mt Weld and elsewhere (see previous section), no prism faces are developed on the quartz crystals. Invariably the host material (presumably carbonate) has been leached so that a dense boxwork of quartz veins is all that remains.

There are fragments of common opal, brown to white or pale green in colour, at 478200/5233800. Semi-consolidated, leached white fine-grained quartz, and derived silica flour, are seen in excavations below the B soil horizon. The silicification style is similar to that seen in Weld River Group dolostone (see below) except for the presence of common opal.

Drilling shows that the silica-clay zone overlies and apparently interfingers with the eastern marble-skarn unit, and overlies Jurassic dolerite along its northeastern side (fig. 7).

In diamond-drill core (hole BC15) this unit is vuggy, medium to fine-grained quartz and chert, grey and pink in colour, with minor skarn and opal (Bottrill and Woolley, 1996). The quartz rocks have been subjected to several stages of silicification and veining. The fine grained, earliest phase of quartz is characterised in thin section by carbonate inclusions, suggesting replacement of carbonate (Taheri, 1990).

In RC drill logs (Young, 1997), the silica-clay zone is described as predominantly quartz breccia, mainly pale grey in colour, with varying proportions of light brown to cream, kaolinitic clay. The breccia shows evidence of fragmentation and recementation by quartz. There is minor chalcedony, either massive or as veins in quartz, and silica flour. Several voids, up to five metres in size and presumably of karstic origin, were encountered in the drilling (e.g. FRC55: 31–36 m; FRC56: 39–45 m, 50–54.5 m).

Fluid inclusion work by Taheri (1989, 1990) and Bottrill *et al.* (1999) showed that the quartz crystallised from low-salinity, high-CO_2 fluids at relatively high temperatures (250–390°C). Low salinities at such relatively high temperatures, and oxygen isotope data, suggest the fluids were predominantly meteoric (Bottrill *et al.*, 1999).

The silica-clay zone is thought to be a mostly deeply weathered, leached and karstified body of partially silicified marble/skarn, derived from the adjoining and underlying magnesian skarn of Pwts. The brecciation in the silica-clay zone was probably caused by devolatilisation of the parent siliceous dolomite that accompanied contact metamorphism by Jurassic dolerite (Bottrill *et al.*, 1999).

Weld River Group

Depositional environments

Depositional environments of the Weld River Group are discussed in detail by Calver *et al.* (1990). The grainstones of unit Pwtg suggest a shallow-marine tide-dominated ramp setting. Massive dolostones remain enigmatic. Vadose cements and possible tepee structures in Pwcd west of Blakes Opening are the first good evidence for subaerial exposure to be found in the Weld River Group. The origin of the diamictites in the Cotcase Creek Formation — whether debris flow or glacial — is discussed by Calver *et al.* (1990). The dropstone-bearing laminites of Pwap and Pwcg are almost certainly glacial, and by association some of the diamictites probably are as well. The Neoproterozoic carbonate-tillite association has received much study in recent years, and recent advances have gone some way to resolving the palaeoclimatic paradox (e.g. Hoffman *et al.*, 1998).

Age and correlation

The Weld River Group is unfossiliferous except for rare stromatolites. The presence of probably glacigene rocks on at least two horizons (Pwap and Pwcg, near the base and top of the group respectively) suggests a Cryogenian (mid-Neoproterozoic: c. 850–600 Ma) age, as there is globally widespread evidence for two or more glaciations within this period (Plumb, 1991; Knoll and Walter, 1992).

The Weld River Group is probably broadly correlative with the Togari Group of northwest Tasmania (Calver, 1989). The Weld River Group bears a similar relationship with the underlying Clark Group (a low-angle unconformity) as the Togari Group does with the Rocky Cape Group, which is probably equivalent to the Clark Group (see previous section). Like the Weld River Group, the Togari Group contains diamictite and abundant dolostone. However in detail the groups are dissimilar and no formation-level lithologic correlation is possible. There is nothing in the Weld River Group that corresponds to the mafic rift volcanic rocks and associated sedimentary rocks of the Kanunnah Subgroup. Neither can any lithostratigraphic resemblance be discerned between the Weld River Group and Neoproterozoic successions on mainland Australia.

In an attempt to better constrain correlation of the Weld River Group, a reconnaissance carbon isotope chemostratigraphic study was undertaken by Calver (1995). Thirty-one stable isotopic analyses were undertaken of widespread samples from the Pedder Quadrangle and from the area covered by the Skeleton, Nevada and Picton map sheets. Samples were mainly of fine-grained dolostones, sparry dolostones being avoided as possibly diagenetically altered. Results show that the lower part of the Weld River Group (the Devils Eye Dolomite (Pwtg) and Gomorrah Dolomite (Pwtf)) are characterised by slightly depleted carbon isotopic compositions (averaging -1‰, and none greater than +1‰) (fig. 8). By contrast, isotopic

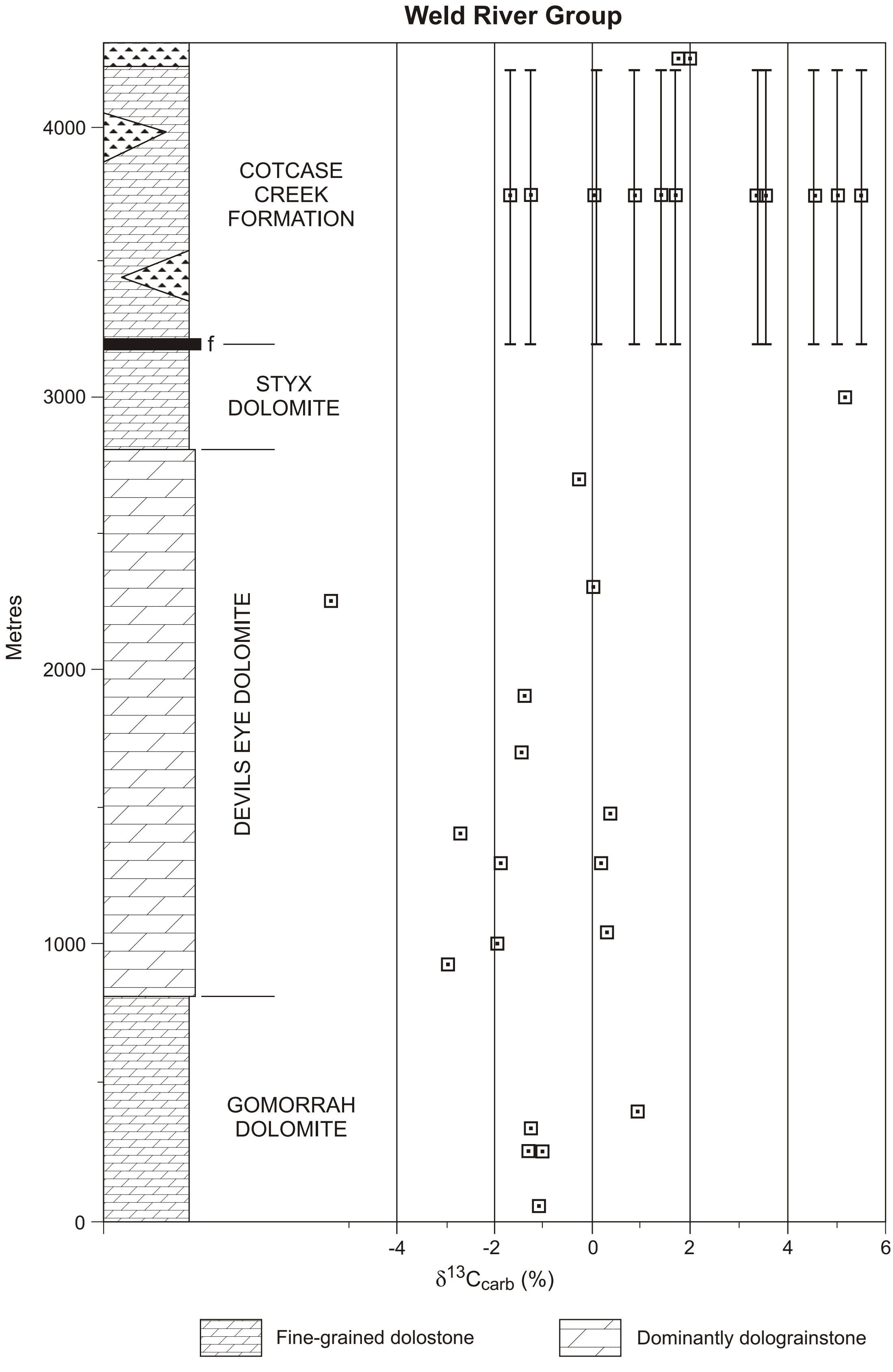


Figure 8

Generalised lithological column and stratigraphic plot of $\delta^{13}C$ for the Weld River Group. Vertical error bars indicate uncertainty of stratigraphic placement. From Calver (1995).

compositions of the dolostones of the Cotcase Creek Formation are mostly greater than +1‰, with some as high as +5‰. Oxygen isotopic compositions are not strongly depleted (-3.8 ± 2.2‰ PDB), so carbon isotopic compositions probably approximate depositional values (*cf.* Knoll and Walter, 1992).

Isotope chemostratigraphy of the Togari Group is described by Calver (1998). The lower part of the Togari Group (the lower and middle Black River Dolomite) is characterised by relatively enriched carbon isotopic compositions (+5‰). Results from the Weld River Group (fig. 8) suggest that there is no equivalent of this interval in the Gomorrah and Devils Eye dolomites. However there may be correlates of the Black River Dolomite in the Cotcase Creek Formation. Thus, much of the Weld River Group may be older than the Togari Group, and the Weld River Group may be entirely older than the rift volcanic rocks (Kanunnah Subgroup). Further isotope work on the Weld River Group may help to refine these tentative conclusions.

?Early–Middle Cambrian rocks (CRC)

Correlates of the Ragged Basin Complex (Maydena, Skeleton, Weld and Glen Huon map sheets)

An association of micaceous lithic sandstone, mudstone, chert and basalt, correlative with the Ragged Basin Complex of Turner (1989), is found in the western part of the Maydena map sheet, in the northwestern Skeleton map sheet, and as very small areas in the Weld map sheet and immediately east of the Weld map sheet. A unit of dolostone, mudstone and chert (Ccwd) was also mapped in the western part of the Maydena map sheet. This unit may belong to the Proterozoic Clark Group (see below).

Because of poor exposure, a lack of bedding and facing determinations and the likelihood of undetected faulting, no stratigraphic order can be inferred for the units that were differentiated and which are described below.

Micaceous lithic sandstone, mudstone and chert (Ccwl)

Unit Ccwl comprises the bulk of the rocks mapped as Ragged Basin Complex correlatives. This unit is poorly exposed and is dominated by sandstone and mudstone in roughly equal proportions. The sandstone is a micaceous, feldspathic lithicwacke of fine to medium, rarely coarse grain size. Typically the rock is deeply weathered, yellow-brown, and apparently poor in quartz but with conspicuous coarse detrital muscovite. There are also some quartz-rich feldspathic wackes, grey-green in colour and typically much less weathered. Only the latter could be sampled for petrography, so petrographic compositions given below (Table 1) are not fully representative.

The sampled sandstones (Table 1) are rich in quartz, feldspar and detrital muscovite, with biotite also present. Lithic fragments comprise metamorphic rock fragments (metaquartzite and quartz schist), chert, mafic volcanic rock fragments, and pelitic sedimentary rock fragments. The mafic fragments are typically composed of altered, felted plagioclase laths in an altered, turbid, chloritic groundmass. In some thin sections there are turbid pale brown grains with apparent snowflake devitrification texture that are interpreted as probable felsic volcanic rock fragments. These sandstones lack detrital dolostone, which is common in the otherwise similar sandstone of Cals (Table 1; see below).

Mudstone is reddish or maroon, or grey-green in colour, pyritic in places, and tends to be massive except for a hackly or anastomosing, scaly fracture. As sandstone tends also to be massive, bedding is rarely seen in Ccwl. Mudstone and sandstone are thinly interbedded in a few places. Sandstone and mudstone appear to be chaotically intermixed in many places, probably due to slumping. Road cuts on the Mueller Road around 459000/5260700 (just west of the Maydena map sheet) expose thinly interbedded red mudstone and lithic sandstone, that in places are irregularly intermixed. In the Arve Plains inlier, just east of the Weld map sheet (fig. 9), are good exposures of sedimentary breccia on the Huon River (at 480250/5232750) and on the Weld River (at 480650/5233350). This consists of ragged or wispy sandstone fragments, 5–50 mm long, elongate in the cleavage direction, in a grey sandy mudstone matrix.

Chert, similar to unit Ccwc (see below), is also present in Ccwl, and is locally interbedded with mudstone. There is a large outcrop of thin-bedded, dark grey chert, with two adits, beside the Tyenna River at 459750/5268550 (just west of the Maydena map sheet, fig. 34). Chert is widespread as float in areas mapped as Ccwl, but its abundance as float may not reflect volumetric abundance in the bedrock because of chert's relatively high resistance to weathering.

A single conical sinkhole, 5–6 m deep and 8–10 m wide, was located within an area mapped as Ccwl at 460040/5268000 (near the western edge of the Maydena map sheet) by Sharples (1998). Carbonate may therefore be present here, although there is no outcrop and only sandstone and siltstone are found as float in this area.

The area on the north side of Maynes Hill (462700/526330, Maydena map sheet) mapped as Ccwl is characterised by a deep reddish-brown friable clay soil, with very little identifiable float, and no outcrop. The nature of bedrock in this area is uncertain. On the neighbouring basalt (Ccwb), the soil is different, being yellowish-brown and rich in rock fragments. At one spot, indicated as Ccwbb, there are fragments in float of felsic or intermediate volcanic breccia (see below). A drillhole (Styx 3) at 463550/5263300 on the northern edge of this area intercepted bedrock of red mudstone below 32 m of soil and colluvium.

Chert, with minor mudstone (Ccwc)

Chert forms a mappable unit (Ccwc) on the Maydena map sheet, where a formation about 300 m thick

Table 1

Petrography of Cambrian sandstones

Unit	Field No.	Reg. No.	mE	mN	Description	Locality	Max. grainsize (mm)	Quartz	K-feldspar	Plagioclase	Muscovite	Biotite	Garnet	Metamorphic rock frags	Chert	Detrital dolostone	Mafic VRF's	Felsic VRF's	Microgranite	Sedimentary rock frags	Chlorite	Zircon	Tourmaline	Other
Ccl	S87	R002681	459500	5259700	coarse-grained feldspathic wacke	Upper Styx River	2	A	C		M	M		M	M		M	M		M				vein quartz
Ccl	S88	R002682	459600	5259400	micaceous quartzwacke	Upper Styx River	0.5	C	M	M	C	M		M	M		M			M	M		M	
Ccl	S76	R002676	464600	5264400	micaceous lithic sandstone	Pine Hill	0.5	C			C	M		C	M					M	M			
Ccl	S113	R002694	467150	5257600	feldspathic wacke	Cliff Creek	1	M	A	M	M	M		M			C	M			M			epidote
Ccl	S163	R007628	464500	5259250	feldspathic wacke	Styx River	1	A	A	M	M	C			M		M			M	M			
Ccl	WR76	R008074	480925	5232850	micaceous feldspathic wacke	Arve Plains inlier	0.5	C	M	M	C	M			M		M	M		M	M			
Ccb	WR138	R008115	477800	5237500	volcaniclastic sandstone	Glovers Bluff inlier	0.5	M	M								A	M						
Cals	BO1	R008141	470000	5228400	feldspathic-lithicwacke	Blakes Opening	1	C	C	C	M	M		M	M		M		M	M	M			spinel
Cals	BO2	R008142	470000	5228400	feldspathic-lithicwacke	Blakes Opening	0.5	C	C	C	M	M		M	M	M	M				M		M	spinel, rare embayed quartz
Cals	BO7	R008147	469700	5228525	granule conglomerate	Blakes Opening	4	C	M		M	M	M	C	C	C	M	M	M	C	M			
Cals	BO52	R008183	470400	5228800	feldspathic-lithic sandstone	Blakes Opening	1	C	A	M			M	A	M	M	M	M		M	M			volcanic quartz
Calc	S321	R007737	466325	5245000	granule conglomerate	middle Weld River	4	M	M	M					M		A		C		M			spinel, pyroxenite
Calc	S341	R007751	467125	5244500	pebble conglomerate	middle Weld River	8	M	M	M							A		A		M			
Cals	S3	R002634	458600	5267750	lithicwacke	Gordon River Road	0.5	C	M	M	M	M		C	C		M			C	M			
Cals	W79	R002480	458200	5264200	lithicwacke	E slopes Mt Mueller	0.5	C		M	M	M		C	M	C	M			M	M		M	
Cals	K6	R002489	458600	5265250	lithicwacke	E slopes Mt Mueller	0.5	C			M			A	M	M	M			M	M		M	
Cals	K7	R002490	458300	5265300	granule conglomerate	E slopes Mt Mueller	8	M						C	M	C				M				orthoquartzite
Cals	S39	R002656	460400	5261900	lithic sandstone	E slopes Mt Mueller	0.5	A			M	M		C	M		M			M	M			
Cals	S180	R007649	459200	5263700	coarse-grained lithic sandstone	E slopes Mt Mueller	1	M			M			A	C	C				C	M			
Cals	S182	R007650	459500	5265300	fine-grained micaceous sandstone	E slopes Mt Mueller	0.25	A			C			M	M	M					M		M	
Cals	K3	R002488	458500	5266400	granule conglomerate	South of The Needles	4	M						M	M	A	C			C	M			orthoquartzite, pyroxenite, chromite
Cals	S78	R002677	455300	5268000	sublithic quartzwacke	South of The Needles	0.5	A	M	M	M			M	M					M	M		M	
Cals	S85	R002680	455900	5267300	sublithic quartzwacke	South of The Needles	0.5	A	M	M	M			M	M		M			M	M			
Cals	S204	R007664	455600	5267600	sublithic quartzwacke	South of The Needles	0.5	A		M	M			M	M					M	M	M		
Cals	S207	R007665	455550	5266900	coarse-grained lithic sandstone	South of The Needles	1	C	M	M	M			C	M	C	M			M	M	M	M	
Cals	S212	R007669	456225	5267350	lithicwacke	South of The Needles	0.5	C	M	M	M			C	M	M	M			M	M			

A = abundant (red square), C = common (green square), M = minor (blue square)

abundant   common   minor

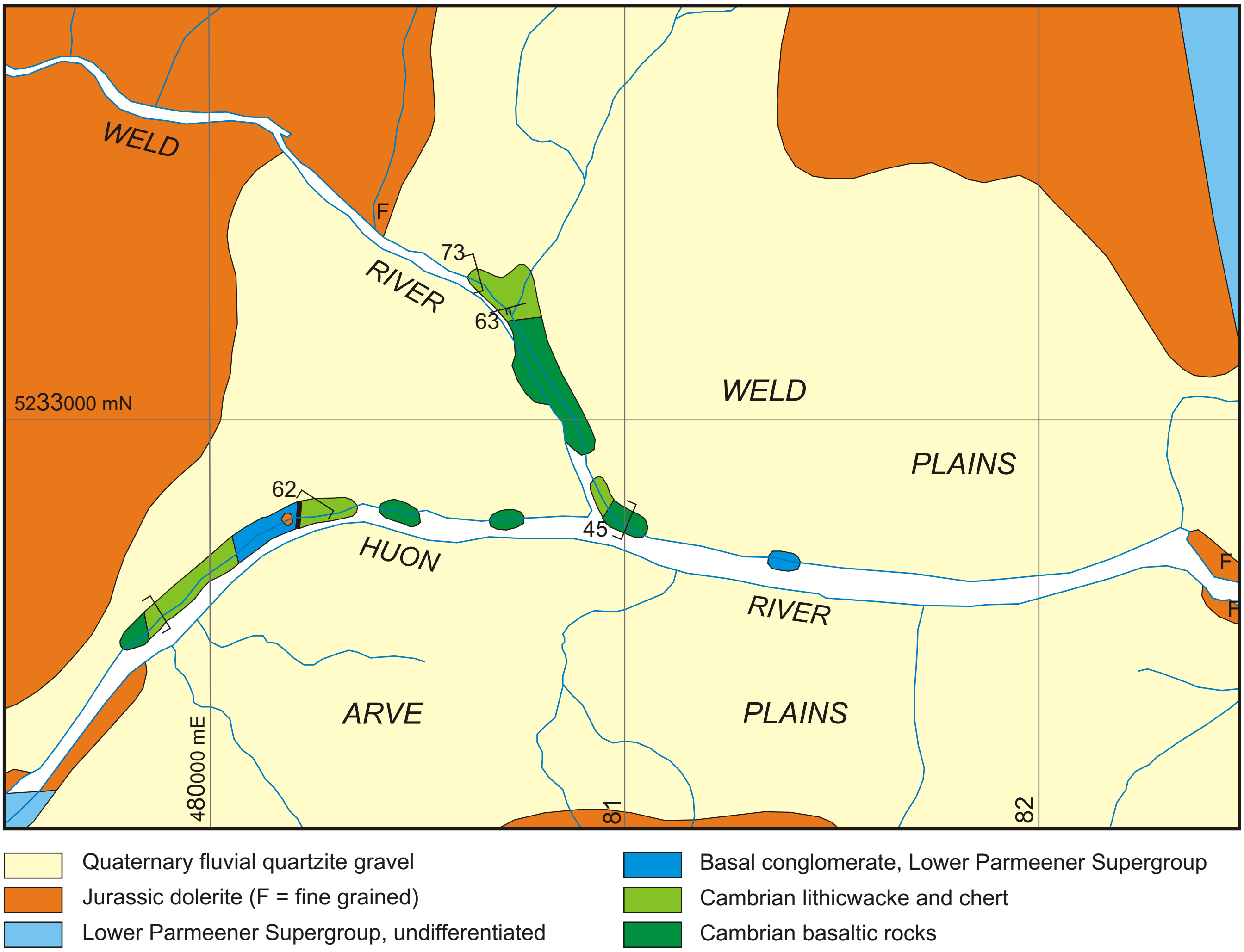


Figure 9

Geological map of the Arve Plains inlier and environs.

extends discontinuously, offset by faults, from just west of the Kallista Creek bridge (464200/5264600) to near Pillinger Creek (468800/5263300). The chert is typically massive, well-jointed, and white to reddish-brown in colour. In places, for example in the quarry on the south side of Pine Hill (464400/5264100), the chert forms a breccia, cemented by fine-grained quartz. Minor mudstone and lithic sandstone are present as float.

At Kallista Creek and near Pillinger Creek the chert is grey and pyritic, and is shown as Ccwcp on the map. At 468700/5263300 pyrite is limited to the fine-grained quartz that forms the matrix of a chert breccia; elsewhere in Ccwcp, pyrite is more or less evenly disseminated through massive chert. West of the bridge over Kallista Creek, road cuttings (464300/5264700) expose pyritic, fractured dark grey chert, sheared mudstone and pyritic lithic sandstone.

An isolated area of Ccwc surrounded by alluvial flats near the Tyenna River (462700/5266300, Maydena map sheet) is mapped on the basis of abundant angular chert float. The angularity of the float suggests that it does not derive from the more rounded chert nodules of the Ordovician Wherretts Chert Member (see below). A drill hole (Styx 7) here reached chert bedrock at 31 metres. The two small areas of Ccwc north of Maynes Hill (463500/5263500) were also mapped on float.

Dolostone, mudstone and chert (Ccwd)

Interbedded dolostone, mudstone and chert forms a mappable unit (Ccwd) that crops out along the Gordon River Road west of the Kallista Creek bridge, and on an isolated small hill south of the road ('Kallista Hill' – 463300/5264200). These areas are surrounded by alluvial flats and unconformably overlain by Tim Shea Sandstone (COlt) to the north. A surficial lag of silicification products, including silica flour and shown as Qs on the map, is associated with this unit. Qs also forms a thick deposit, with no known bedrock outcrop, in an area further east, near the Styx Road (466000/5263800). This area is probably also underlain by Ccwd. A drillhole (Styx 4) at 466575/5263750 within this area reached pale grey, fine-grained dolostone at a depth of 55 metres. This area of concealed probable Ccwd lies between basalt (Ccwb) to the south, and sandstone etc. (Ccwl) to the north. A small area of Qs, perhaps also indicating Ccwd subcrop, adjoins the Maynes Hill basalt on its northern side (462200/5264000).

Ccwd is thus intimately associated spatially with correlates of the Ragged Basin Complex, but it is lithologically dissimilar to them and to the 'type' Ragged Basin Complex of Turner (1989). Unit Ccwd is somewhat similar, but not identical, to the dolomitic part of the Proterozoic Humboldt Formation (Clark Group), and may represent faulted inliers (or a thrust slice) of this unit. It may be significant that the outcrop area of the Clark Group around The Needles narrows eastwards to a narrow fault block (thrust slice?) enclosed by Cambrian sedimentary rocks (Cals), just west of the Maydena map sheet (fig. 34). Umit Ccwd on the Maydena map sheet may be an eastward continuation of this structure.

Plate 12

Exposure of ?Cambrian pillow lava (unit Ccwb) in quarry at Maynes Hill, west of Maydena (462200/5263200). [Photo: David Gatehouse]

Unit Ccwd is well exposed in disused quarries beside the Gordon River Road (461850/5265350; 461950/5265150; 462400/5265050). These outcrops consist of interbedded, fine-grained, pale grey dolostone, black shale, black and white (banded) chert, black siliceous mudstone (weathering to white), and fissile siliceous siltstone. A thin section of black, laminated cherty dolostone (R007675) consists of dolomite microspar with wavy anastomosing dark brown ?kerogenous seams, diffusely interlaminated with dolomitic chert. The chert is mostly brown, with rhombic to irregular clear patches (100 µm) probably after a carbonate. The black shale is not micaceous, unlike that of the Humboldt Formation. The waxy black chert is also not characteristic of the Humboldt Formation.

There is a patchy surficial lag of silica flour and angular fragments of box-work vein quartz, shown on the map as Qs where continuous and extensive. 'Kallista Hill' consists of fine-grained grey dolostone, capped by massive fine-grained quartz that is probably silicified dolostone.

The siliceous gravel and sand (Qs) near Styx Road (466600/5263700) includes crumbly, leached fragments of porous fine-grained white quartz with an oolitic or sponge-like texture, probably resulting from leaching of a partly silicified oolitic carbonate (R002697). There is a possible small sinkhole at 465700/5263800. There is outcrop (or a large boulder) of massive, fine to coarse-grained milky quartz at 465700/5264000, presumably a secondary silicification product. Bedrock intersected at 55 m in drill hole Styx 4 is a pale grey dolostone breccia, a thin section showing fragments of medium to coarsely recrystallised dolostone, some with remnants of original sedimentary layering, in a finely granular dolostone matrix with scattered larger dolomite rhombs.

Basalt (Ccwb)

Rocks mapped as basalt (Ccwb) occur on the Maydena and Skeleton map sheets, in the Glovers Bluff inlier on the Weld map sheet, and in the Arve Plains inlier at the eastern edge of the Weld and adjoining Glen Huon map sheets. The occurrence in the Glovers Bluff inlier has been described as a lamprophyre or spessartite, and may be Devonian in age, although this is far from certain (Bottrill *et al*., 1999, and below). Detailed petrography and geochemistry of the basaltic rocks are given in a later section (see ***Igneous Rocks***).

Maynes Hill and near Pine Hill (Maydena sheet)

Basalt crops out on the Maydena map sheet on the western side of Maynes Hill (462000/5263500) and in a small creek one kilometre southeast of Pine Hill (465800/ 5263600). The best exposure is in a quarry on the flank of Maynes Hill (462050/5263750). Pillows are well developed here, with a poorly developed asymmetry suggesting the original horizontal plane dips approximately 30° to the southwest. The pillows are about one metre across, with slickensided, dark grey-green glassy rims around 5 mm thick, and an outer layer of chilled basalt about 30 mm thick (Plate 12). No amygdules or vesicles were seen. There are traces of sulphide minerals on pillow surfaces, and the basalt is cut by minor thin carbonate veins. No sediment is preserved in pillow interstices, but chert is present between poorly-exposed pillows nearby (462100/5263500).

Thin sections (R002653, R007653) show laths of slightly altered plagioclase (1 mm) and granular well-preserved augite (0.1–0.2 mm) with an interstitial turbid mesostasis including chlorite and finely granular carbonate. Opaque minerals are rare. A chilled pillow margin (R002661) shows abundant mesostasis and skeletal terminations on plagioclase laths.

Similar basalt in the creek southeast of Pine Hill has minor, small (1 mm) amygdules. A thin section (R002696) is strongly altered, with plagioclase laths in an abundant matrix of secondary chlorite, carbonate and chalcedony.

A basalt outcrop was also seen within sediments of unit Ccwl, at 461900/5259000 north of the Styx River on the Skeleton map sheet. A thin section (R002700) shows an altered basaltic rock with plagioclase laths in an abundant, turbid, cryptocrystalline mesostasis, and minor chlorite-filled amygdules.

Glovers Bluff inlier (Weld map sheet)

On the ridge east of Eddy Creek in the northeastern corner of the Glovers Bluff inlier (Weld map sheet), there is a small area of predominantly basaltic rocks lying between secondary quartz and opal (Pwtq, Pwtqo: formerly Weld River Group carbonate?) to the east and the western marble/skarn unit (Pwts) to the west (477800/5237500). This area was mapped on float. A ground magnetic traverse suggests a sub-cropping magnetic unit (magnetic susceptibility 60 10^{-3} SI units) about 30 m thick, dipping steeply west, bounded by relatively weakly magnetic units (Appendix 2). A variety of lithologies are present as float over the magnetic peak, predominantly hornblende-rich basalt, with some mafic-volcanic sandstone. Sample R008116 is a basalt composed of altered feldspar, brown hornblende, tremolite-actinolite, chlorite and minor quartz. R007645 is similar, with minor clinopyroxene, minor altered olivine, and possible vesicles. R008096 includes a chilled margin, with augite microphenocrysts (0.1–0.5 mm), mostly wholly altered, in a groundmass of mainly very fine-grained hornbende and altered plagioclase. R008115, of basaltic appearance in hand specimen, is seen in thin section to be a mafic-volcanic sandstone, with rare felsic grains. R007644 is probably a highly altered glassy mafic-volcanic sandstone, mostly replaced by prehnite.

At 478050/5234200, on the alluvial flats near the Forster Prospect, there are a few rounded boulders, up to 0.7 m in size, of coarse-grained hornblende-rich igneous rock. These have probably been excavated from exploration costeans in the area. They may have been transported some distance, as rounded boulders and cobbles of diverse lithologies, including Proterozoic quartzite, are also present. Thin sections (e.g. 107640) show predominantly brown hornblende, augite, and altered plagioclase.

Petrographically, the hornblende-rich rocks from these two localities are lamprophyres, a diagnosis supported by chemical analyses of the boulders near the Forster Prospect (Bottrill *et al*., 1999, and see *Igneous Rocks* section below). Lamprophyres are not known in the Cambrian elsewhere in Tasmania, although these rocks are compositionally unlike known Devonian lamprophyres (see later section). The fine grain size and possible vesicles at the northern locality suggest an extrusive origin and thus a Proterozoic or Cambrian age in common with the enclosing succession.

Arve Plains inlier (Weld, Glen Huon map sheets)

Outcrop of Cambrian rocks along the Huon and Weld rivers, just downstream and upstream of their confluence, comprises a separate basement inlier, discovered in the course of this mapping, and named the Arve Plains inlier. Only the westernmost outcrops on the Huon River lie on the Weld map sheet. The Cambrian rocks include basalt, gabbro, micaceous lithic sandstone, chert and red mudstone. Away from the rivers the rocks are covered by alluvium and surrounded by Jurassic dolerite (fig. 9).

Most of the basalts (R008071, R008081, R008082) have an intersertal texture, with felted plagioclase laths, granular clinopyroxene, and pseudomorphous chlorite in an abundant mesostasis rich in fine-grained opaque minerals. R008069 is slightly coarser, with an intergranular texture and abundant opaques. R008069, R008071 and R008081 have plagioclase glomero-phenocrysts to 2 mm and minor phenocrystic clinopyroxene. These rocks are strongly magnetic (magnetic susceptibility (MS) around 50 10^{-3} SI units). Their high magnetic susceptibility readily differentiates them from chilled Jurassic dolerite (e.g. R008042, R008068, R008092) to which they are similar in appearance. These latter samples have MS <3 10^{-3} SI units.

Gabbros (R008079, R008070) contain 60% turbid plagioclase up to 3 mm long, granular clinopyroxene, chlorite and opaque minerals. R008103 consists of altered feldspar, chlorite, opaques and minor quartz. In contrast to the basalts, the gabbros are only weakly magnetic (0.3–0.6 10^{-3} SI units).

R008080 is an altered, sheared basalt or basaltic agglomerate, consisting of lenticular fragments of basalt in an abundant matrix largely altered to chlorite and prehnite.

Volcanic breccia (Ccwbb) (Maynes Hill, Maydena map sheet)

Float of feldspar porphyry is common on the northern slope of Maynes Hill (at 463000/5263000). In thin section (R002675) this rock is a poorly-sorted glassy volcanic breccia, with angular fragments up to 10 mm across, dominantly of turbid brown cryptocrystalline flow-banded volcanic rock, with common chlorite-filled amygdules, feldspar phenocrysts (1 mm) and glomerocrysts, and minor subhedral or embayed quartz phenocrysts (0.5 mm). The presence of quartz phenocrysts suggests a felsic to intermediate composition for the volcanic fragments, and indicates that this breccia is not genetically associated with the nearby basalt (Ccwb).

Lithic sandstone and conglomerate (Calc, Calct, Cals, Cdi) (Maydena, Nevada, Weld, Picton map sheets)

Turbiditic lithic sandstone, mudstone and conglomerate form successions of probable Cambrian age in the western part of the Maydena map sheet, in the middle reaches of the Weld River (Nevada map sheet), in the Glovers Bluff inlier (Weld map sheet), and east of Blakes Opening on the Huon River (Picton map sheet). These rocks are also found south of The Needles on the Adamsfield map sheet (Appendix 1). The rocks have been derived from a metasedimentary terrain similar to the Tyennan region, from unmetamorphosed sedimentary rocks including dolostones similar to the Weld River Group, and there is also mafic volcanic detritus and rare ultramafic detritus. A few thin sections show a felsic volcanic input, and there are minor granitoid clasts in conglomerate.

These rocks are unfossiliferous, and a Middle Cambrian age is inferred from their similarity to fossiliferous, Middle Cambrian successions in the Pedder and Huntley quadrangles. The presence of rare ultramafic detritus and chromite in units Cals and Calc suggests that these rocks are younger than the ultramafic complexes. The presence of dolostone clasts suggests the rocks are younger than the Weld River Group, of probable late Neoproterozoic age.

Unit Cals in the western part of the Maydena map sheet is continuous with an area shown as Cals on the Pedder 1:50 000 scale geological map and described by Calver *et al*. (1990). Cals and Calc are thus correlatives of this and other areas shown as Cals and Calsc on the Pedder map sheet, such as north of Mt Bowes. Cals and Calc are also probably broadly correlative with middle Cambrian quartzose sandstone and conglomerate, the Island Road Formation and Trial Ridge beds, of the Adamsfield district (Brown *et al*., 1989). These rocks also resemble the polymict Cambrian conglomerate of the Tyler Creek beds, which crop out on the south coast of Tasmania (Berry and Harley, 1983).

Unit Cals is similar to Ccwl of the Ragged Basin Complex (see above), which is likewise dominated by lithic sandstone and mudstone. The petrography of sandstones of Cals and Ccwl shows a similar range of compositions (Table 1). These units can usually be differentiated in the following ways. Most sandstones of Ccwl tend to be more deeply weathered, probably reflecting a higher proportion of labile constituents, and contain more abundant coarse muscovite. Ccwl is also mapped on the basis of the presence of chert, which is absent or very rare in Cals, but common — at least as float — in Ccwl. Other differences are that Ccwl is more poorly bedded than Cals, and that mudstone comprises a greater proportion of Ccwl. These mudstones are commonly reddish or maroon in colour, instead of grey as in Cals. Petrographically, one consistent difference is the absence of detrital dolostone in Ccwl (Table 1). Also, reflecting their appearance in the field, sandstone of Ccwl tends to be more muscovitic in thin section, and biotite is present or common in most slides, unlike Cals.

Polymict conglomerate, lithic sandstone and shale (Calc) (Nevada, Weld map sheets)

Conglomerate and lithic sandstone (Calc) crop out at the Weld River (467100/5243900) and nearby in Redwater Creek (466300/5244900) on the Nevada map sheet. These sedimentary rocks are associated with basalt, amphibolite (Ccwba) and feldspathic ?volcanic sandstone (Cdi), and all are inferred to be faulted to the southwest against Weld River Group, faulted to the northeast against Clark Group, and unconformably overlain by the Parmeener Supergroup rocks. Bedding in this area of Calc dips steeply southwest and, on scanty facing evidence, is right way up.

The outcrop on the Weld River (467100/5243900) is of conglomerate of cobble to boulder grade. The conglomerate is closed framework, with well-rounded clasts up to 0.7 m wide, of dolostone typical of the Weld River Group, pink orthoquartzite, and dark grey-green basalt, in a sheared, foliated green mudstone matrix. In addition to these lithologies, clasts of microgranitoid and pyroxenite were noted in nearby outcrops. Basalt tends to be the most common clast type. Other conglomerate occurrences are usually of pebble grade, and are interbedded with dark grey-green, coarse-grained lithic sandstone. These rocks are massive to poorly bedded. There is minor purplish-grey to grey-green mudstone interbedded with the sandstone in places.

Thin sections of conglomerate (R007734, R007737, R007751) show compositionally immature sediments of largely volcanic origin. There are rounded clasts of dominantly basalt and microgranitoid, with minor pyroxenite, carbonate, crystal tuff and intermediate or felsic volcanic rocks. The matrix contains sand grains of K-feldspar, plagioclase, quartz, hornblende, actinolite, augite and chlorite.

Some basalt clasts are intergranular in texture, consisting of elongate plagioclase laths, pale green, granular or fibrous actinolite, chlorite and minor opaque minerals. Rare feldspar phenocrysts may be present (R007734). In a few clasts, equant patches of chlorite may be after olivine. Other basalt clasts are intersertal, with acicular or skeletal plagioclase (R007751) in a turbid cryptocrystalline groundmass. Microgranitoid clasts consist of quartz, plagioclase and K-feldspar with minor hornblende, biotite and chlorite, and are 0.5 to 1 mm in grain size. One clast in R007751 consists of 70% quartz anhedra (2 mm) poikilitically enclosing subhedral feldspars, hornblende and biotite. In R007737 there are minor grains of coarse (3 mm) pyroxenite, partly altered to chlorite, and common brown spinel grains. Minor pale brown, glassy spherulitic-textured clasts in R007737 may be of rhyolitic or dacitic composition.

There are outcrops of basaltic rock within the area mapped as Calc, indicated on the map as Ccwba, at 467750/5242750 and 467150/5244025.

Feldspathic sandstone (Cdi) (Nevada map sheet)

Outcrop of feldspathic sandstone, shown on the first edition of the map as diorite, occurs at the western limit of Cambrian outcrop in the Weld River (466900/5243600). Outcrop is massive but well-jointed, medium to very coarse-grained volcanic sandstone, in places with minor, impersistent, darker, finer-grained laminae. One thin section (R007694) shows rounded feldspar grains, around 1 mm in size, and lesser (20%) green hornblende, in closed framework, with a finely comminuted matrix. Plagioclase is andesine in composition (optical determination). There are also accessory opaque grains (partly oxidised to hematite) and traces of secondary epidote and prehnite. Another thin section (R007746) is similar, but with abundant secondary quartz and less (5%) hornblende. The absence of detrital grains other than feldspar and hornblende suggests that this rock may be a reworked crystal tuff.

Talc-hematite-chlorite altered rocks of unit Calc (Calct) (Weld map sheet)

In the southern part of the Glovers Bluff inlier, south of the Weld River, there is a narrow meridional wedge of altered, dominantly mafic-ultramafic derived conglomerate, which is inferred to be faulted against dolostone of the Weld River Group and derived marbles (Pwts) to the west and east (fig. 6). The southern end of the wedge of Calct is well exposed in road cuttings along Forster Road; the northern end is exposed on the banks of the Weld River. Before being altered, these rocks were probably lithologically similar to Calc occurring on the Nevada map sheet (described above), and these units are probably correlates. Calct has undergone talc-hematite-chlorite alteration, at least in part associated with the skarn alteration of the adjoining dolostone (Bottrill *et al.*, 1999).

Outcrop along Forster Road is predominantly weathered conglomerate. The conglomerate is variable in appearance, in part at least because of variation in the style and intensity of alteration and deformation. The central part of the Forster Road traverse (fig. 10) is characterised by a texturally well-preserved, brown-weathering conglomerate of pebble to cobble grade, with rare boulder-sized clasts. The conglomerate is moderately to strongly foliated, with some clasts deformed into lenticular shapes parallel to foliation; other clasts retain subrounded to well-rounded shapes. About half the clasts are of an aphanitic, dark grey rock that is probably mostly altered basalt. Also represented as clast lithologies are shale, siltstone, lithic sandstone, foliated red chromite-bearing talc (altered ultramafic?), gabbro, granitoid, and feldspar porphyry. Granitoid, gabbro

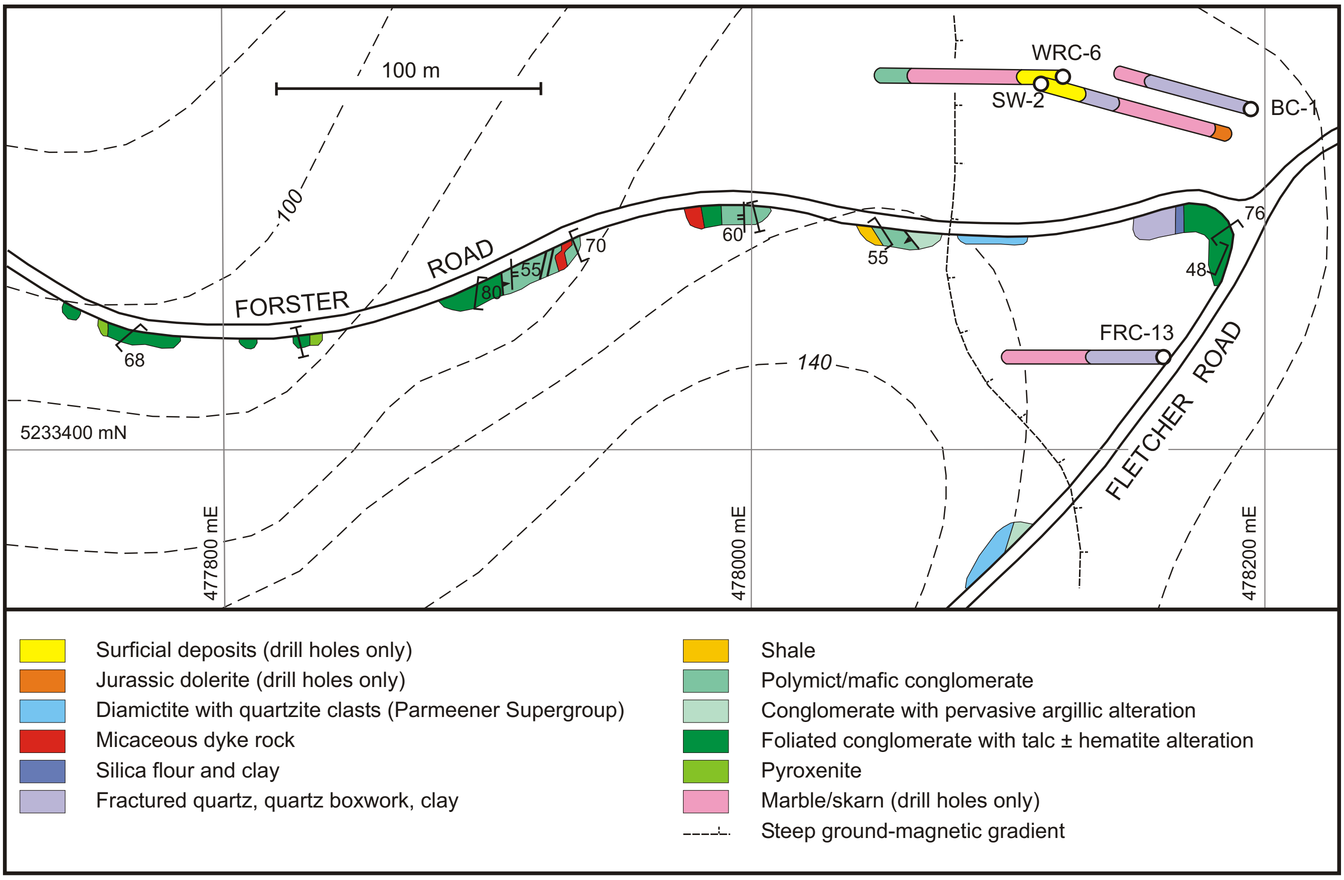


Figure 10

Geology of road cuttings and inclined drill holes projected to surface, Forster Road, Glovers Bluff inlier.

and porphyry clasts have resisted deformation and retain rounded, equant shapes. Bedding — discernible as variation in clast size — may be seen locally, inclined to the tectonic foliation. The easternmost part of this conglomerate has a strong magnetic response on ground traverses (fig. 36, 37). The resultant linear magnetic anomaly extends as far north as the Weld River (Carthew *et al*., 1988; and see Appendix 2).

Faulted against the above, brown-weathering conglomerate type to the east is a pale grey-green conglomerate that appears to have undergone a more pervasive argillic alteration. This is exposed in the eastern cuttings on Forster Road and on Fletcher Road south of the junction with Forster Road. Clasts are soft, pale grey-green to white, foliated, and predominantly deformed into lenticular to wispy shapes. An XRD analysis of one clast shows predominantly halloysite, while there are rare clasts of red chert. This conglomerate type is unconformably overlain by diamictite of the Parmeener Supergroup on Fletcher Road. The diamictite is also altered or deeply weathered to a whitish silty clay with dispersed clasts. The Permo-Carboniferous diamictite is superficially similar in appearance to the Cambrian conglomerate but can be distinguished by its open framework and the presence of quartzite clasts.

A third Cambrian conglomerate type on Forster Road (fig. 10) is still more altered and deformed, such that the conglomerate texture is largely obscured. The rock is a red to yellow-brown, strongly foliated or sheared talcose phyllite with clasts, mostly altered to white or red clay or talc, deformed into wispy or lenticular shapes. This lithology occupies cataclasite zones in places.

Within Calct on Forster Road there are also minor intervals of coarse-grained lithic sandstone, micaceous siltstone and shale. There are two deeply weathered dykes, a few metres wide, unfoliated, with chilled margins and containing white mica. These were probably originally of mafic to intermediate composition; the presence of mica suggests they are not Jurassic dolerite. Towards the western end of the Forster Road transect are two occurrences of poorly-outcropping, weathered, pale green pyroxenite; the westernmost outcrop is about 2.5 m wide, suggesting this is not merely a boulder.

Costeans just south of the Weld River (between 478000/5234200 and 478100/5234200) uncovered deformed, foliated conglomerate with dark grey-green, lenticular (deformed) clasts of altered basalt and lithic sandstone, and clasts of red chromite-bearing talc (probably altered ultramafic rock). Rounded boulders (0.5–1 m) of lamprophyre and orthoquartzite exhumed from these costeans may also be derived from unit Calct, but more likely are transported or are lag out of nearby basal Parmeener Supergroup rocks. The lamprophyre may also be derived from a dyke, and is described in detail in a later section.

Altered conglomerate crops out again on the banks of the Weld River. A sample (R007643) consists of subrounded to lenticular (deformed?), dark grey, aphanitic pebbles, that in thin section are composed of fine-grained talc with rims of serpentine, set in a matrix of fine-grained carbonate with minor garnet (100 µm). The talc-serpentine clasts contain sparse chromite grains (0.5 mm), and exhibit a remnant mesh texture defined by the distribution of fine opaque minerals. This sample is evidently predominantly of ultramafic provenance. The conglomerate in the river is adjoined to the west by foliated grey-green shale, which crops out just upstream and along strike in nearby costeans to the south.

Turbiditic lithic sandstone, etc. (Cals) (Maydena, Nevada, Weld, Picton map sheets)

Unit Cals is essentially a lithicwacke-mudstone turbidite succession, that crops out in a number of spatially and structurally separate areas which are described below. Petrography of the sandstones (Table 1) shows minor variations between some of these areas, but the overall similarity in composition suggests that these areas are all essentially the same formation. There are minor fine-grained conglomerates in Cals that are similar to those described as Calc (above).

The sandstones are mostly quartz-rich, with a lithic component (10–80%) that is more abundant in the coarser grades. Metamorphic rock fragments, with lithologies consistent with derivation from the Tyennan region (metaquartzite and quartz-mica schist), are abundant in every thin section (Table 1). Detrital dolostone, similar to the Weld River Group, and mafic volcanic rock fragments are usually present in the coarser grades. Felsic volcanic rock fragments and volcanic quartz are seen only in the occurrence on Huon River (Picton map sheet).

Eastern slopes of Mt Mueller (western Maydena–eastern Adamsfield map sheets)

A lithic sandstone-dominated succession, included in Cals, crops out on the eastern foothills of Mt Mueller, along the western edge of the Maydena map sheet (460000/5263000). This area is continuous with identical lithic sandstone shown as Cals on the Pedder 1:50 000 scale sheet to the west (Turner *et al*., 1985) and described by Calver *et al*. (1990, p.49). The succession as a whole dips and faces northeast. To the northeast, the lithic sandstone succession is adjoined by micaceous lithic sandstone (Ccwl); the contact was not observed and may be a fault. This area of Cals is unconformably overlain by flat-lying Parmeener Supergroup rocks to the west and south.

The succession is dominated by tough, fine to medium-grained, slightly micaceous quartzose lithic sandstone, grey-green in colour, weathering to white or brown. There is considerable interbedded siltstone and dark grey, finely micaceous mudstone. Sandstone beds are weakly graded in places, but are usually internally structureless. Rarely, sole marks (flame structures), low-angle cross-lamination and parallel-lamination are seen in sandstone beds. The sandstone beds are probably turbidites. Sandstone beds in many outcrops are disrupted, occurring as dismembered pods within mudstone. There is no evidence that disruption was accompanied by brittle fracture, suggesting this was an early (syn-sedimentary) phenomenon.

The sandstones of Cals are similar to those of Ccwl, but they have less abundant coarse muscovite and in general appear more quartz rich.

The succession in the Pedder Quadrangle (Calver *et al.*, 1990) n includes rare conglomerate beds that contain clasts of dolostone, quartzite, basalt and shale, and accessory grains of chromite (R002488).

Thin sections of sandstone and fine-grained conglomerate (R002480, R002488, R002489, R002490, R002656, R007649, R007650) show an abundance of metamorphic rock fragments (quartz-mica schist) and common to abundant, detrital dolostone clasts. Orthoquartzite is common as clasts in conglomerate. Angular quartz grains are abundant, particularly in the fine-grained sandstone. There is common chert, sedimentary rock fragments, chlorite and detrital muscovite. Biotite, plagioclase, and tourmaline are minor constituents in some slides. There are rare mafic volcanic rock fragments (typically one per slide). One conglomerate (R002488) contains common mafic volcanic rock fragments and accessory chromite.

Huon River (Picton map sheet)

A fault wedge of lithicwacke turbidite is transected by the Huon River downstream of Blakes Opening (around 470000/5228500) on the Picton map sheet. There is excellent, almost continuous exposure of this unit for almost a kilometre along the northern bank of the river (Plate 13). With the exception of the westernmost extremity of this section, bedding dips moderately (about 30°) to the ENE and is right-way-up. Bedding at the western end dips gently west. A fault is inferred against Weld River Group dolostone to the west, and the eastern contact is inferred to be faulted against Gordon Group limestone. A total thickness of approximately 350 m of sediment is present, most of it very well exposed, in this section. Away from the river, the unit is mapped mainly on the basis of float.

The river section is well bedded and essentially undeformed, with only a weak cleavage visible in some mudstone beds. The section consists of medium to thick beds of brown-weathering, fine to medium-grained, grey-green lithic sandstone interbedded with grey mudstone. The sandstone beds are graded, internally structureless, and with planar or weakly load-casted bases. Near the base of the river section there are rare beds of up to granule conglomerate (4 mm) grain size.

Thin sections (R008141, R008142, R008147, R008183) show abundant metamorphic rock fragments (metaquartzite, quartz-mica schist) and sedimentary rock fragments (shale, micaceous sandstone, recrystallised dolostone and chert). There are minor mafic volcanic (chlorite-carbonate altered) and felsic (glassy rhyolite) fragments. There are grains of quartz, K-feldspar, minor plagioclase, garnet, and accessory spinel, zircon and tourmaline. Most quartz is strained (undulose extinction) but BO52, from near the top of the section, contains a small proportion of straight-extincting volcanic quartz as rounded euhedra or embayed grains up to 1.5 mm across. This rock

Plate 13

Outcrop of ?Cambrian volcaniclastic lithicwacke and siltstone (unit Cals) on the Huon River at 470000/5228400.

contains abundant (40%) feldspar, many grains being zoned and apparently little worn. R008147, a granule conglomerate from near the base of the section, and R008141 contain rare microgranitoid clasts. R008147 also contains common dolostone, including recrystallised oolitic dolostone similar to the Weld River Group.

Weld River, Nevada map sheet

A small area of Cals crops out on the Weld River downstream (southeast) of the extensive conglomerate and sandstone of Calc on the Nevada map sheet. This is thought to be an extension of the same fault block, and bedding similarly dips and faces steeply southwest. This area consists of massive green quartzose siltstone, and hackly grey-green mudstone with siltstone laminae. No sandstone or conglomerate was seen, but these rocks lithologically resemble siltstone and mudstone in Calc upstream, and in Cals in the Huon River on the Picton map sheet. The rocks also resemble unit Pcmm of the Clark Group, and it is possible that they correlate with this unit.

Denison Group (CRC)

The Denison Group consists of siliceous conglomerate, sandstone and siltstone that unconformably overlie Cambrian and older rocks. Together with the conformably overlying Gordon Group and Tiger Range Group, these rocks were deformed in the Middle Devonian. A major northwest-plunging syncline in Denison Group and Gordon Group rocks extends northwest from Maydena on the Maydena map sheet.

Two formations have been recognised in the Denison Group in the Maydena area; the Tim Shea Sandstone and the Florentine Valley Formation (Corbett and Banks, 1974).

Tim Shea Sandstone (COlt) (Maydena map sheet)

The Tim Shea Sandstone on the Maydena map sheet consists of coarse to fine-grained quartzarenite, pebbly quartzarenite and conglomerate. Clasts in the conglomerate are angular to well rounded, and consist almost entirely of chert, mostly white, less often red in colour. There are rare clasts of quartz boxwork, probably derived from dolostone. Near the top of the formation (at 465900/5266500; 467400/5266100; and 467700/5266000) there is bioturbated, fine-grained quartz sandstone interbedded with yellow-brown to green shale (this facies appears to have been included in the Florentine Valley Formation by Stait and Laurie, 1980). The upward-conformable transition into yellow-brown leached calcareous mudstone of the Florentine Valley Formation is exposed in a railway cutting at 467700/5266000.

The Tim Shea Sandstone is unfossiliferous except for trace fossils. Mapping in the Huntley Quadrangle to the west shows that the Tim Shea Sandstone is a correlate of the upper sandstone member of the Reeds Conglomerate (Brown *et al*., 1989). In the Huntley Quadrangle, an Early Late Cambrian fauna occurs in the Singing Creek Formation, below the Reeds Conglomerate. The Tim Shea Sandstone is thus of Late Cambrian to earliest Ordovician age.

Florentine Valley Formation (COucf) (Maydena map sheet)

The Florentine Valley Formation consists predominantly of weathered yellow-brown mudstone with an abundance of small (5 mm) voids that are interpreted to be leached-out, diffuse, formerly calcareous nodules. Low-spired gastropods and orthid brachiopods are abundant in places. Weathered, probably formerly calcareous siltstone with minor thin beds of chert occurs in cuttings on the Gordon River Road north of Pine Hill. Thick-bedded quartz siltstone and fine-grained sandstone with interbeds of green shale occur in railway cuttings around 468000/5266300.

The lithostratigraphy and biostratigraphy of the Florentine Valley Formation are documented by Stait and Laurie (1980), from areas west and north of the Maydena map sheet. Three members and seven faunal assemblages are recognised. The formation is Lower Ordovician, ranging from early Tremadoc to late Arenig in age.

Gordon Group (CRC)

The Gordon Group is a thick succession, predominantly of limestone, that conformably succeeds the siliciclastic rocks of the Denison Group (Corbett and Banks, 1974). The Gordon Group is about two kilometres thick in the Florentine Valley area, just northwest of the Maydena map sheet. It is wholly Ordovician (lower Whiterockian–Maysvillian) in age (Banks and Burrett, 1980; Banks and Baillie, 1989). The Gordon Group in the Maydena–Florentine Valley area is divided into three conformable formations; the Karmberg Limestone, the Cashions Creek Limestone and the Benjamin Limestone (Corbett and Banks, 1974), which were also recognised on the Picton map sheet. The Benjamin Limestone is further subdivided into two sub-equal members (Corbett and Banks, 1974; Banks and Baillie, 1989); the Lower Limestone Member and Upper Limestone Member.

The structure in the limestone sequence in the Maydena area is dominated by a major, gently northwest-plunging syncline, which is a southern extension of the Westfield Syncline of Corbett and Banks (1974). A fault (perhaps the southern extension of the Misery Fault) downthrows a small area of limestone in the John Bull valley (469500/5267500). A separate area of limestone at Risbys Basin (468000/5264000), south of Maydena, is isolated by major faults.

Correlatives of the Karmberg, Cashions Creek and Benjamin limestones are found in the Huon Valley east of Blakes Opening on the Picton map sheet. The limestones are inferred to be faulted against Cambrian turbidites to the west and Parmeener Supergroup rocks to the east, and are unconformably overlain by the Parmeener Supergroup. Bedding dips gently (20°) to the east.

The Gordon Group on the Maydena map sheet was mapped and sampled as part of a survey of industrial limestone resources by Calver (1990*b*). Detailed stratigraphy of the Benjamin Limestone, based on three measured sections, is given in that report. A 519 m diamond-drill hole at Risbys Basin (Maydena-1) penetrated the lower part of the Benjamin Limestone and the Cashions Creek Limestone. The log and analyses are given in Calver (1992). The results of further surface sampling and percussion drilling in the Risbys Basin area are given by Wrigley (1992, 1993).

Karmberg Limestone (Olk) (Maydena, Picton map sheets)

The Karmberg Limestone is a thickly bedded to massive, grey to grey-brown, argillaceous micrite. It has a characteristic stylonodular fabric of strongly anastomosing seams or layers of brown dolomitic mudstone and insoluble stylolitic material that weather prominently on outcrop surfaces. In the upper part of the formation, irregular nodules and layers of dark grey chert comprise a few percent to 50% of the rock. Outcrop in a small abandoned quarry at 469300/5266800 (Maydena map sheet) lacks chert, but has numerous small dolomitic blebs and sparse pyrite nodules. The formation is about 450 m thick.

The Karmberg Limestone crops out on the north bank of the Huon River (471400/5227950) on the Picton map sheet. This is an impure, diffusely bedded micrite with a well-developed stylonodular fabric, and a fossiliferous horizon with gastropod and other molluscan fragments. North of the river (at 470800/5228700) outcrop around an outflow cave consists of dark grey micrite with abundant dolomitised random to bedding-parallel burrows. This outcrop is shown as Karmberg Limestone on the map, but there is insufficient evidence to rule out a correlation with the Benjamin Limestone.

Faunas recovered from the Karmberg Limestone in the Florentine Valley are documented by Corbett and Banks (1974) and Banks and Burrett (1980). An Early Ordovician (upper Canadian–lower Whiterockian) age is indicated.

Cashions Creek Limestone (Olc) (Maydena, Picton map sheets)

This is a distinctive unit consisting of about 150 m of thick-bedded, oncolitic fine-grained calcarenite. Oncolites are 10–20 mm in diameter, comprise 10–30% of the rock, and are dispersed through a matrix of fine-grained, slightly dolomitic grainstone (calcarenite). Much of the formation in the Risbys Basin area consists of calcarenite in which oncolites are very sparse or absent.

The large pseudoplanispiral gastropod *Maclurites* is common, and characteristic of the Cashions Creek Limestone, but other fossils are rare. The formation is Middle Ordovician (upper Whiterockian) in age (Banks and Burrett, 1980; Banks and Baillie, 1989).

The Cashions Creek Limestone contains the most consistently high $CaCO_3$ grades in the Gordon Group in the Maydena area (Calver, 1990*b*; 1992; and see below).

The Cashions Creek Limestone in the Picton map sheet is limited to a single small outcrop on the south bank of the Huon River at 471750/5227950, about 400 m downstream of the Karmberg Limestone outcrop. This outcrop consists of oncolites, about 10 mm in diameter, in fine-grained calcarenite. *Maclurites* is present.

Benjamin Limestone (Olb) (Maydena, Picton map sheets)

The Benjamin Limestone is about 1300 m thick in the Florentine Valley, but only the lower third is present at Maydena (a correlate of the Lower Limestone Member), and probably a similar interval on the Picton map sheet. The detailed stratigraphy of three measured sections on the Maydena map sheet is given in Calver (1990*b*). These sections are located at Sunshine Spur (465000/5269600), Junee Quarry (466100/5268800) and Risbys Basin (468700/5264300). The Benjamin Limestone is a heterogeneous succession of different limestone types interbedded on a scale of metres to tens of metres. Calver (1977; 1990*a*, *b*) recognised ten limestone types or lithofacies.

In the measured sections, the lower 150–200 m of the formation consists predominantly of poorly fossiliferous grey dolomitic micrite. Dolomite is present as wavy seams (stringers) of stylolitic origin, and as dolomitised burrows, which tend to be sub-perpendicular or randomly orientated with respect to bedding. The remainder of the formation, as exposed on the Maydena map sheet (200–460 m above the base) contains, in addition to the dolomitic micrite just described, micrite with abundant, bedding-parallel, *Chondrites*-like dolomitised burrows; pale grey micrite with abundant birds-eye structures; and algal-laminated limestone. Argillaceous micrite, bioclastic calcarenite and boundstone rich in fasciculate or dendritic varieties of *Tetradium* are also common. These limestone types or lithofacies tend to be arrayed in shallowing-upward cycles or parasequences a few metres to tens of metres thick (Calver, 1977; 1990*a*, *b*). A six metre thick unit of coralline calcarenite, 290 m above the base of the formation in the Sunshine Spur section, is the 'Sunshine Spur Coralline Member' of Whyte (1974). This unit can also be recognised in the Florentine Valley (Calver, 1977).

The Benjamin Limestone is found at the northern foot of Mt Riveaux (471700/5226300) on the Picton map sheet. Cereoid *Tetradium* is present at 471710/5226580, suggesting correlation with the upper part of the Lower Limestone Member or higher. Around 471500/5226000, the limestone contains an anastomosing stylolitic network and chert nodules, and strongly resembles the Karmberg Limestone. However, outcrop further west consists of lithologies typical of the Lower Limestone Member, including birds-eye limestone and *Tetradium*-bearing micrite. The Karmberg-like interval is therefore probably merely a local facies variant within the Benjamin Limestone.

The Benjamin Limestone is Middle to Late Ordovician (upper Whiterockian to Maysvillian) in age, but only the Middle Ordovician (upper Whiterockian to Blackriveran) parts are represented on the Maydena map sheet, and a similar interval is probably represented on the Picton map sheet.

Parmeener Supergroup (SMF)

Upper Palaeozoic to early Mesozoic rocks are widespread in central, southeastern and other parts of Tasmania and are known as the Parmeener Supergroup (Banks, 1973). This succession comprises the sedimentary fill of the Tasmania Basin. The strata are generally subhorizontal and regionally rest with pronounced landscape unconformity on Devonian granitoids and older folded rocks which have a basement relief of about 1000 metres. A significant change of depositional environment within the Parmeener Supergroup enables recognition of two major subdivisions (Forsyth *et al.*, 1974). The Lower Parmeener Supergroup (Upper Carboniferous–Permian) includes all glacigene and glaciomarine rocks and a thin interval with coal measures, freshwater or paralic rocks. The Upper Parmeener Supergroup (Upper Permian–Upper Triassic) consists of freshwater rocks and includes coal measures in parts of Tasmania.

The Lower Parmeener Supergroup is well developed in the five map sheets described here, but less than the basal half of the Upper Parmeener is preserved in the more complete sequences in this area and commonly significantly less (fig. 11). The most complete successions mapped occur in the Maydena–Styx valley area where they obtain a thickness of about one kilometre and have been described by Jago (1972). The Parmeener Supergroup, either as outcrop or beneath capping Jurassic dolerite intrusions, extends through more than half the area of the map sheets.

Much of the Parmeener Supergroup remains unmapped or mapped at reconnaissance level only, and so is shown as undifferentiated on the maps.

Lower Parmeener Supergroup

The Lower Parmeener Supergroup occurs within a large continuous area on the eastern side of the map sheets (fig. 2). Several of the boundaries with older rocks are faulted. Some outliers occur in more westerly areas, for example a remnant of ~30 m thickness of undifferentiated Lower Parmeener rocks occurs at an altitude of about 700 m on the Jubilee Range. Erratics that are probably lag derived from basal Parmeener Supergroup conglomerate are present on the Jubilee Range. These include a 500 mm rounded granite boulder at 465200/5249350 and an 800 mm boulder of siliceous pebble conglomerate at 465150/5249000. Similarly, rounded pebbles and cobbles of quartzite are common on the rather flat ridge-tops between Cliff Creek and South Styx River on the Skeleton map sheet (e.g. 466000/5256300; 467000/5256000.

In common with many other areas of Tasmania the basal beds of the Lower Parmeener were deposited on a basement with considerable local relief. The lower areas contain glacigenic diamictite overlain by poorly fossiliferous uniform grey siltstone, but the higher basement areas were not buried until more open marine conditions prevailed and varied pebbly glaciomarine muddy silt, sand, some calcareous beds and richly fossiliferous horizons were deposited. The shelly faunas enable biostratigraphic subdivision (Clarke and Farmer, 1976; Farmer, 1985; Clarke, 1987; Clarke, 1989; Clarke, 1992).

The most complete succession is seen in the Styx Valley–Maydena area, where the Bundella Formation correlate is underlain by 200 m of Woody Island Siltstone correlate and 120 m of Truro Tillite correlate. These units wedge out against higher basement north of Maydena and the Bundella Formation correlate rests directly on basement (464000/5270000 to 470000/5268000). The unconformity is about 200 m below the top of the Minnie Point Formation correlate north of Mt Weld, suggesting similarly high basement there. West of Weld Ridge, basement is somewhat lower (relative to Parmeener stratigraphy), and a thin Woody Island Siltstone correlate overlaps a Truro Tillite correlate (466000/5235000). High basement is again seen west of Mt Picton, where the unconformity is about 160 m below the top of the Minnie Point Formation correlate. Relatively high basement (at the level of the Bundella Formation correlate) is also seen at Mt Anne, west of the mapped area (Calver *et al.*, 1990). Thus, the Jubilee Region as a whole was probably a basement high during deposition of most of the lower glaciomarine sequence.

Some aspects of the stratigraphy and palaeogeography of the Lower Parmeener Supergroup throughout the Tasmania Basin have been discussed by Clarke and Banks (1975), Banks and Clarke (1987) and Clarke (1989).

Truro Tillite correlate (Ptx)

The Truro Tillite type section is near Cygnet, where the Truro Tillite forms the basal formation of the Lower Parmeener Supergroup and consists predominantly of unstratified glacigenic diamictite (Farmer, 1985). The massive, dark grey unfossiliferous diamictite contains poorly-sorted clasts, predominantly of pebble or cobble size, supported in a matrix of silt, clay and rock flour. Very few clasts exceed 300 mm in length and there is a slight variation in the proportion of clast to matrix, both laterally and vertically through the sequence. Subordinate lithologies include banded mudstone and laminate in intervals up to a few metres thick, and rare cross-bedded sandstone and closed-framework conglomerate lacking the typical matrix of the diamictite.

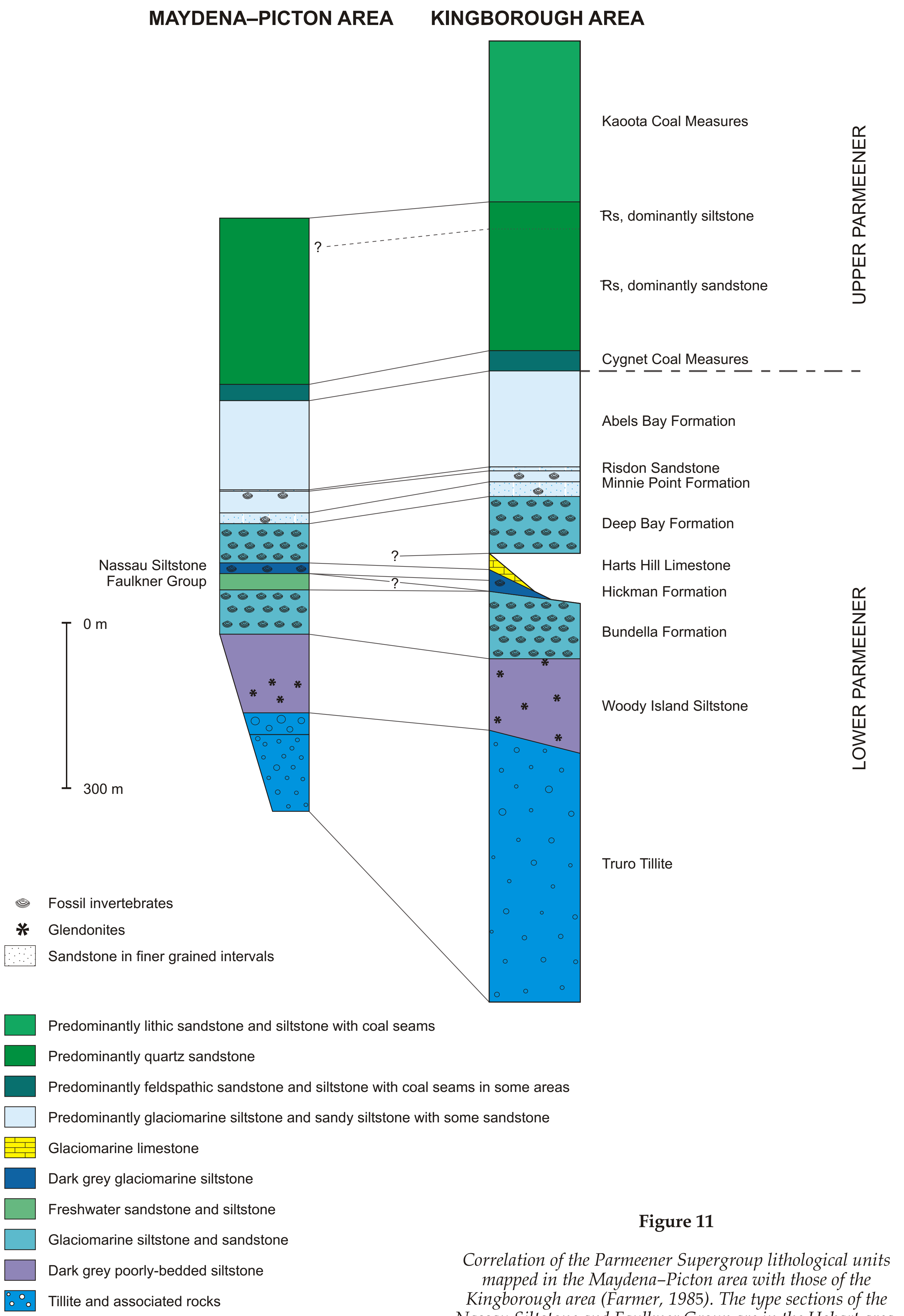


Figure 11

Correlation of the Parmeener Supergroup lithological units mapped in the Maydena–Picton area with those of the Kingborough area (Farmer, 1985). The type sections of the Nassau Siltstone and Faulkner Group are in the Hobart area.

The Truro Tillite reaches a thickness of over 450 m and is overlain by the Woody Island Siltstone (Farmer, 1985). The upper boundary of the Truro Tillite is recognised by the highest occurrence of common pebbles.

Jago (1972) described rocks similar to the Truro Tillite in the Maydena and Styx River valley area and correlated them with the Wynyard Tillite of northwestern Tasmania. Based on their proximity to Cygnet and possible subsurface continuity of the glacigene rocks, correlation with the Truro Tillite is now preferred.

The recent mapping has demonstrated a continuous distribution of the Truro Tillite correlate west to link with known occurrences in the Mt Mueller area (Calver *et al.*, 1990) and to extend a little further south than mapped by Anon. (1981) to the limit of Parmeener mapping at Snowy North. As the Parmeener Supergroup on the western flank of the Snowy Range was not mapped it is only beyond there at the Weld River that the occurrence of the Truro Tillite correlate is again established. In addition to the areas depicted on the current map, Ptx crops out in the Weld River between 470900/5240100 and 472600/5238800 (shown as undifferentiated on the map).

The correlate has also been mapped further south in the Glovers Bluff region and overlying basement rocks on the hills north and south of Manuka Creek (Weld map sheet).

The distribution and thickness of the Truro Tillite correlate is considerably influenced by basement relief and in places the correlate is absent over basement highs (see above). Borehole information from the Hobart area, 50 km to the east, also suggests that the tillite may pass laterally into siltstone of the Woody Island Formation (Clarke and Farmer, 1982).

The glacigene rocks may be subdivided into two units in the Maydena Range and Styx Valley; a lower tillite and siltstone unit in which clasts are predominantly of pebble size, and an upper unit predominantly of conglomerate in which clasts are larger (Jago, 1972). This subdivision is quite marked and has also been recognised in some nearby areas in the Maydena and Skeleton map sheets, but has not been mapped. Basal conglomerate mapped 30 km to the south on the Picton map sheet (Plbc) may be equivalent to the upper unit near Maydena, but the relationship of the basal conglomerate to other stratigraphic units is uncertain.

Lower unit

Although described by Jago (1972) as a poorly-sorted, pebbly, dark grey arenite, the predominant lithology of the lower unit contains much clay and silt comparable to the Truro Tillite matrix at Cygnet. Associated lithologies include intervals of massive dark grey siltstone and rarer finely laminated siltstone that may be glacial rhythmites.

Discontinuous outcrops of the lower unit are exposed along Mueller Road near the western edge of the Maydena map sheet (460000/5260700 to 460800/5260800) and indicate that dark grey siltstone occurs within a few metres of the basal unconformity over a local basement high of ~80 m relative height. From 10 to 30 m above the basement, the siltstone contains about 5% granules and 1% large angular pebbles, but then becomes more pebbly beneath a second interval, 30 to 60 m above the unconformity, in which outcrops of diamictite with either pebble or cobble-size clasts are exposed.

Siltstone is exposed from ~70 to 100 m above the unconformity. A four metre interval within the siltstone contains <2% granules and rare zones with 5% pebbles. Much of the other siltstone is clast-free, some is flaky, and at one locality two weathered-out concretions of 200 mm diameter were found.

The succeeding interval, from 100 to 140 m, commences with diamictite with common pebbles and some cobbles in the first ten metres, then fewer pebbles and cobbles are found. Pebbles occur only sparingly through most of the top twenty metres.

Although some higher intervals are probably exposed within the next two kilometres east along Mueller Road, the uncertainty in correcting for regional dip, the lack of clear bedding planes, and the down-dip component of the road prevent reliable estimates of stratigraphic position. Outcrops of siltstone occur commonly and clasts are not conspicuous. A few beds are arenaceous.

The most striking feature of the siltstone and diamictite sequence on Mueller Road compared to other areas, for example the tillite in the Tunbridge Tier borehole (Forsyth, 1989*a*) and at Cygnet (Farmer, 1985), is the small size of the clasts, the high ratio of matrix to clasts, and the common occurrence of clast-free siltstone. At least at the level of the cursory examination undertaken, in isolation the pebble-free siltstone lithology could easily be mistaken for Woody Island Siltstone.

Rock similar to the lower unit on Mueller Road occurs on Jubilee Road south of the north branch of the Styx River. These rocks have been interpreted to belong to a transitional zone between the top of the Truro Tillite correlate and the Woody Island Siltstone correlate, but could represent a fault-isolated part of the lower unit.

Some other features help characterise the lower unit of the Truro Tillite correlate. Jago (1972) interpreted laminated siltstone as varves on Styx Road on the northern side of Maydena Range (near 466075/5262300) and in the Styx Valley on the Skeleton map sheet, where the siltstone rests on a Proterozoic basement high near 467600/5258700. Further examples of laminated siltstone occur on the Styx Road (466270/5263375), on South Styx Road (468675/5256275) and on Jubilee Road (465850/5258675).

Closed framework conglomerates do not commonly occur, and only one example, a pebble conglomerate, was observed near the junction of Styx and Mayne roads (466425/5263500).

The clast type in the lower unit varies. Jago (1972) noted "The pebbles, some well faceted are usually quartzite fragments up to 8 cm across, with some fragments of black slate, siltstone and chert." Larger clasts occur at the base of the lower unit on Risby Road (468600/5263300) and include fossiliferous sandstone clasts up to 0.6 m across, probably derived from the Tiger Range area which lies about 16 km to the northwest (Jago, 1972; Clarke, 1989).

Fragmented fossil stenoporids, fenestellids, spiriferids and crinoid plates of the marine Tamarian shelly fauna (Clarke and Farmer, 1976) occur sparsely in the lower unit on the Styx Road near Maydena and more commonly in the Styx Valley (Jago, 1972). A stenoporid was observed on Mayne Road (465900/5263625).

There are rare marine fossils in Ptx on the Weld and Picton map sheets. Agglutinating forams are present in Ptx in the Manuka Creek area (463200/5233600; 464700/5233400). A solitary *Tomiopsis* was seen in the Glovers Bluff inlier (478300/5233400) (CRC).

Upper unit

The upper unit of the Truro Tillite correlate was described by Jago (1972) at and near a sharp bend in Styx Road (465900/5263200). Some parts of the 40 m thick section are now poorly exposed due to collapsed rock and soil and vegetation; the description below is after Jago (1972).

Thickness (m)	Lithology/bedding (thickness in mm)	Clast size (mm)	Matrix
8	siltstone		
7.6	inter-bedded (1) conglomerate < 600 and (2) graded sandstone 150	(1) boulders (2) pebbles	
3.65	poorly-bedded conglomerate	maximum 500	
0.3	coarse-grained sandstone bed	pebbles	
15	very poorly-bedded conglomerate bedding is clearer up sequence	mean 20–150, maximum 300	
4.6	'tillitic' sandstone	maximum 150	poorly-sorted sandstone
1.2	conglomerate bed	maximum 300	

According to Jago (1972) the basal conglomerate bed sharply overlies the lower unit of diamictite and contains clasts of 'Owen-type' conglomerate, quartzite, quartz, schist and sandstone. Clasts of similar lithologies are found in the fifth (3.65 m) unit, where other clasts include Gordon Group limestone to 150 mm diameter, black slate, chert, adamellite, feldspar porphyry and quartz porphyry. Clasts between 20–150 mm diameter tend to be moderately well rounded, whereas small and larger clasts are angular. These clast lithologies persist in the overlying conglomerate beds where the clasts show some tendency to imbrication.

Angular pebbles of Gordon Group limestone are the largest clasts in the sandstone beds. Small well-rounded boulders of Siluro-Devonian crinoidal fine-grained sandstone were recently found in this section.

A few graded sandstone beds occur within the top siltstone interval that appears to represent a transitional zone from the Truro Tillite correlate into the Woody Island Siltstone correlate, but the boundary is not fully exposed.

Clasts are smaller (<200 mm) within the upper unit of the Truro Tillite correlate in the Styx Valley, quartzite clasts are more common and Gordon Group limestone less common than in the Styx Road section (Jago, 1972). Fossil are moderately common in the top 10 to 13 metres of the conglomerate unit in a road section exposure near the Styx River (467500/5259000) and include *Pyramus* sp., *Eurydesma* sp. and *Deltopecten illawarensis* (Runnegar, 1969), but the graded sandstone beds and siltstone beds of the Styx Road section were considered to be absent (Jago, 1972). The dip of the beds is locally steeper (10–13°) and the area may be faulted.

Apparently overlying the coarser conglomerate layers is a dark grey siltstone with small pebble-size holes (467175/5259300), and siltstone with holes, some pebbles and granules, all concentrated in bedded bands (467150/5259500). Pebbly coarse-grained sandstone with some fossils is exposed nearby (467625/5259625) less than ten metres below the Woody Island Siltstone correlate. The holes are probably the moulds of weathered carbonate clasts of Proterozoic or Gordon Group provenance. Overall the interval in which they occur is probably a transition zone between the Truro Tillite correlate and the Woody Island Siltstone correlate.

The upper unit of the Truro Tillite correlate is discontinuously exposed about three kilometres to the west where Mueller Road descends an escarpment. Clasts to about 150 mm diameter occur through an interval of about ten metres, but towards the base clasts up to 500 mm occur. Pebbly siltstone is exposed about 20 m above the base. Above this there is a progressive upward fining to siltstone with <5% pebbles, siltstone with granules and 1% sand, to uniform siltstone comparable to the Woody Island Siltstone correlate in which a single marine fossil was found.

The transitional beds between the Truro Tillite correlate and the Woody Island Siltstone correlate may be exposed on South Styx Road, but because of the close proximity to faulted contacts with the Proterozoic rocks and the moderate (~20°) dips of the beds it is possible that undetected fault slivers of older Truro Tillite correlate horizons may also be present. Dark grey siltstone with small pebble-size cavities occurs at 468700/5259200 and a current-deposited? pebble conglomerate bed occurs at 468725/5258525, stratigraphically one metre below the Woody Island Siltstone correlate. Other siltstone with pebbles occurs either laterally or vertically close to the Woody Island Siltstone correlate.

Weld and Picton map sheets (CRC)

On the Weld and Picton map sheets this unit is a diamictite with sparse (10–20%) subrounded pebbles and cobbles of quartzite, schist, chert, and dolostone, in a dark grey structureless silty mudstone matrix. Massive pebbly mudstone (<10% clasts) is also present. There are rare boulder-sized clasts. The largest seen was a quartzite boulder three metres long in the Weld River (471300/5239700). Dolostone clasts appear to be rare near the base, but are abundant at higher levels.

Outcrop of Ptx on Fletcher Road and Forster Road, close to the unconformity (Weld map sheet, 478100/5233300) is unusual in that the matrix is a soft white silty clay (fig. 10). This is thought to be the result of argillic hydrothermal alteration, also affecting the underlying Cambrian conglomerate (see previous section). The white silty clay matrix consists of quartz and kaolinite (R008084, XRD determination).

Discussion

The age of the Truro Tillite correlate is partly indicated by early Tamarian faunas in a stratigraphically higher formation (Clarke, 1992). Elements of the Tamarian fauna *Pyramus* sp., *Eurydesma* sp. and *Deltopecten illawarensis* occur within the upper unit of the Truro Tillite correlate in the Styx Valley and more fragmentary remains extend down at least 80 m into the lower unit. In the absence of palynological data it is not possible to determine whether the Truro Tillite correlate is wholly of Tamarian age or whether the lowest part is of Hellyerian age (Clarke, 1992).

The opinion of Carey and Ahmad (1961) that the tillite was deposited as lodgement moraine from wet-based glacial ice in a marine environment has been widely accepted and supported by the presence of marine fossils (Jago, 1972; Farmer, 1985; Clarke, 1989). Evidence in the Wynyard Tillite of fossil leaves (Gulline, 1967) and a fossil dragonfly (Riek, 1976) in laminates interbedded with tillite suggests the presence, at times, of glaciolacustrine environments and deposition of terrestrial moraine. Farmer (1985) also noted that the presence of cross-bedded sandstone and thick continuous framework conglomerate within the tillite might indicate running water and terrestrial glaciofluvial activity rather than sub-glacial marine deposition.

Jago (1972) proposed that a fall in sea level occurred after deposition of the lower unit of the Truro Tillite correlate and that the conglomerate of the upper unit was likely to have then been deposited as esker or kame deposits. He considered that the graded coarse-grained sandstone layers with clasts that exhibited imbrication were deposited as glacial outwash. It was further proposed that a palaeo-shoreline existed between the graded sandstone and laterally equivalent conglomerate with marine fossils in the Styx Valley (Jago, 1972). Evidence for an exact time equivalence of the inferred outwash deposits and the marine conglomerate appears to be lacking. A fall in sea level is likely to have led to some closer source areas for a component of the clasts and this could be supported by the increase in clast size, the angularity of some clasts, and by the likely provenance of Gordon Group clasts (Jago, 1972).

Basal conglomerate (Plbc) (CRC)

A basal conglomerate unit, 10–20 m thick, crops out in places as a prominent cliff line west of Mt Picton (e.g. 465300/5221600, 465100/5223100). This is a massive pebble-cobble conglomerate, with some pebbly dark grey sandstone. Basement is relatively high in this area, and this unit is probably younger than the Truro Tillite correlate (Ptx).

Woody Island Siltstone correlate (Plw)

The Woody Island Siltstone type section lies on the eastern end of the renamed Satellite Island (518000/5203500) situated in D'Entrecasteaux Channel offshore from Alonnah on Bruny Island (Banks, Hale and Yaxley, 1955). An interval of about 26 m of thick to very thick-bedded siltstone without a base forms the type section. Pyrite concretions and calcareous concretions are common, but lonestones and marine fossils are rare. The blue-grey siltstone breaks easily but irregularly into small blocks.

Siltstone beds in the top few metres differ by being white to yellow in colour, finely cross bedded and bioturbated. They are overlain by the Sunset Bay Sandstone, which consists of seven metres of sparsely fossiliferous glendonitic sandstone that is succeeded by richly fossiliferous siltstone (6.5 m) of the Satellite Siltstone (Banks, Hale and Yaxley, 1955).

West of a fault that crosses the island, siltstone very similar to the Woody Island Siltstone is dark grey and contains numerous glendonites. This siltstone was considered to be a lower member of the Woody Island Siltstone (Banks, Hale and Yaxley, 1955).

An interval of siltstone 120–172 m thick, correlated with the Woody Island Siltstone, occurs north of Satellite Island in the Kingborough Quadrangle and overlies the Truro Tillite (Farmer, 1985). The Woody Island Siltstone on the western side of Satellite Island appears to be only a small part of this thicker sequence, but is very typical of it. In the Kingborough Quadrangle Farmer (1985) noted that the Woody Island Siltstone consisted of monotonous thick to massive-bedded siltstone and mudstone which in outcrop readily fractured into small angular fragments. Where present, dropstones are characteristically almost always small. Fossils are rare to absent except in the top ten metres of the formation where *Eurydesma hobartensis* and *Trigonotreta stokesi* occur. Glendonites occur sporadically throughout the formation and in places are abundant. Spherical pyrite nodules are common in some parts.

The Woody Island Siltstone in the Kingborough Quadrangle is overlain by rocks correlated with the Bundella Mudstone. "The base of the Bundella Mudstone is marked by the incoming of a coarse-grained sandstone succeeded by beds of much greater lithological variety than any in the Woody Island Siltstone. The appearance of the sandstone coincides with greatly increased fossil abundance and a notable increase in faunal diversity. In marked contrast to the Woody Island Siltstone the Bundella Mudstone is characterised by abundant dropstones." (Farmer, 1985).

Further north in the Hobart area the Woody Island Siltstone is thicker and is in excess of 255 m thick in the Mt Nassau bore (Clarke and Farmer, 1982). It is considered to extend subsurface to the Maydena–Styx Valley area where rocks displaying all the essential characters of the Woody Island Siltstone have been mapped by Jago (1972) and Anon. (1981).

In particular Jago (1972) noted that glendonites and pyrite nodules were quite common in the lower half of the formation and that bedding was poorly developed, especially in the lower two thirds. Fossils were rare, with only a few specimens of spiriferids and pelecypods (possible *Eurydesma*) found in the lower half, but richly fossiliferous beds with diverse faunas were found in the top 37 m of the formation (Jago, 1972). A few pebbles, mostly of quartzite up to 50 mm diameter, were found in the lower part of the formation, but in the top 13 m of the formation pebble bands were common (Jago, 1972).

Jago mapped an informal unit which he called 'Fossiliferous Siltstone' above the Woody Island Siltstone, but unlike in the Cygnet and Satellite Island areas, the base of this unit did not show an especially marked increase in clast frequency or an introduction of sandstone. The only increase in clast frequency reported by Jago (1972) was in the underlying beds where the faunal diversity is similar to the 'Fossiliferous Siltstone'. If the top of the Woody Island Siltstone correlate is partly based on changes in faunal diversity, a difficulty arises in deciding where to place the boundary within a uniform or stepped continuum of change.

The logs of two cored BHP exploration bores (S1 and S2) in the Woody Island Siltstone correlate provided useful information regarding variations throughout the entire formation.

In the Styx River bore S1 (468625/5259150) log (Anon., 1981) the underlying Truro Tillite can be recognised by an increase in clast frequency (40%) and the more diverse suite of clast lithologies compared to the predominantly quartzite clasts that occur in the Woody Island Siltstone correlate. An eleven metre transitional zone occurs above the Truro Tillite correlate in which the clast frequency falls to 10–20%, although the maximum limit of the clast size range (1–100 mm) initially remains similar to that of the Truro Tillite correlate. Above this interval, for the next nine metres, smaller clasts (1–40 mm) are recorded, occasionally reaching 2–5% and in one thin (30 mm) band clasts form 70%. Above this, pebbles and granules are rare through the remaining 40 m cored interval.

Small nodules or stringers of pyrite are distributed throughout this section of Woody Island Siltstone correlate and most modified Fischer pyrolysis analysis results indicated that small potential oil yields persist throughout this section.

The second bore (S2) drilled on Waterfall Road (469125/5256525) and collared in Bundella Formation correlate penetrated the entire Woody Island Siltstone correlate interval, terminating within the top metre of the Truro Tillite correlate or within the transitional zone immediately above it. Only chips were obtained from the top ~27 m of the hole.

From the log (Anon., 1981) the basal metre consists of pebbly black siltstone or tillite with 10–60% clasts. Above this, through an interval of 14.6 m, the average proportion of clasts of sand to pebble-size varies but drops in stages (5–40%, 5–10%, 2%) and above this horizon to <1%.

Within the basal 23 metre interval of both bores, and especially in S1, the predominant lithologies of black siltstone or pebbly black siltstone contain various subordinate thin to medium (50–370 mm) layers of grey siltstone, brown siltstone, laminated sandy siltstone or sandstone (some of which show contorted lamination) and intervals of brown-tinged siltstone. These features may indicate slight bottom currents or fluctuations through time of the types of material in suspension. There is a 370 mm brown interval within the pebbly transitional zone of S2l in which one millimetre diameter circular impressions on broken surfaces occur. Similar impressions were logged in hole S1 in a 4.8 m thick interval of brown-tinged black and grey siltstone and subordinate grey siltstone which showed a relative increase in potential oil yield compared to adjacent intervals. It was considered that the brown colouration perhaps indicated an increase in carbonaceous matter, that the brown layers were possible correlates of the Tasmanite oil shale which occupies a similar stratigraphic position in northern Tasmania, and that the impressions could be fossils of *Tasmanites* cysts (Anon., 1981). Generally the cyst walls of *Tasmanites* are preserved as detachable orange or brown bodies if the enclosing rock has not been subjected to high temperatures and this type of preservation was not described from the bores.

The 90 m interval that overlies the transition zone in hole S2 is remarkably uniform and consists of black siltstone with less than 1% clasts. A poorly-sorted sandstone bed and a thin pebble band are the only lithologies logged that are coarser than siltstone and these constitute less than 0.5% of the interval. A single shell fossil fragment and a well-preserved fossil leaf were found. Pyrite stringers and concretions occur. Glendonites were not recorded although small rounded and angular holes occur on one horizon; if these were not soluble clasts they could be glendonite moulds. A thin (80 mm) bed of deformed interlaminated siltstone and grey-white, quartzose sandstone that exhibits soft-sediment differential compaction effects is found in this interval within hole S1 (Anon., 1981).

The overlying 41 m interval (62.8 to 103.5 m) in S2 shows an eight-fold increase in logged sandy and/or pebbly bands. The beds or bands range from 180 to 300 mm thickness and constitute 4% of the interval. Apart from the pebble concentrations, clasts form less than 2% of the rock and are generally quite small (<10 mm) except near the base of the interval. Here an 80 mm thick sandy siltstone bed, with a possible *Gangamopteris* fossil leaf, contained 10–20% clasts up to 80 mm size. A single dolomite? clast of 110 mm diameter was found three metres above this bed. Two metres higher a moderately well-sorted sandstone bed contained 5–10% fossils, mostly gastropods. Two brachiopods and *Fenestella* sp. were recorded from the overlying beds.

A marked change in the gamma-gamma density log at the base of this interval may be instrument rather than lithologically induced, but a gradual change of the self-potential log seems genuine. No changes are revealed in the gamma log.

The overlying 11.4 m interval (51.4–62.8 m) appears to show a doubling of the proportion of sandy or pebbly bands to 7%, but this figure may be exaggerated because of assumptions made in reading the log. The lower three metres is mainly unfossiliferous grey-black siltstone with only a trace of sand or pebble-size clasts, but within the siltstone occur subordinate beds (50–340 mm thick) with 10–15% fossil brachiopods, *Fenestella* and other bryozoans and 5–10% small (10 mm) clasts. The highest common pyrite in the bore occurred in these layers. The upper 8.5 m of slightly micaceous siltstone contains only a trace of usually fragmentary fossils, but more clastic debris is present than below as rounded sand-grade quartz clasts (0–2%) and pebbles (10–20mm rarely 50 mm, 0–2%) dispersed in the siltstone, and also concentrated in pebble bands (50–100 mm). The upward increasing sand and pebble content appears to be reflected in the gamma log.

The top 24.4 m cored interval shows further increases in the coarse clastic content. The beds are finely micaceous, but fossils are fairly insignificant except in the top 8.45 metres.

The lower 15.9 m of this interval contains about 11% of sandy or pebbly beds. The basal bed is 460 mm thick and the siltstone matrix contains 10 to 30% sand and granule-size quartz in addition to 10–20% pebbles (10–30 mm), with minor brachiopods and bryozoan fossils. The overlying siltstone generally contains 5 to 10% sand and granule-grade quartz, but in three beds (150, 240 and 620 mm thick) the quartz forms 40 to 50% of the rock. Pebbles (10–20 mm, but up to 40 mm) are dispersed through the siltstone and form 2 to 5% of the rock, but they are also concentrated in five bands generally up to 100 mm thick where they constitute 40% of the rock. The only fossils are rare dispersed brachiopod fragments.

The upward coarsening continues and in the remaining top 8.5 m of core the sand-grade quartz becomes more common throughout the siltstone (averaging 5–20%), and the slightly larger pebbles (10–30 mm) form 5% of the interval and are generally concentrated in bands 100 mm thick. Large spiriferids and minor bryozoans form 2 to 5% of the interval and are concentrated in the less pebbly bands 200–300 mm thick.

The evidence for deposition of the Woody Island Siltstone under reducing conditions (Banks, 1962) from quiet waters in a near freezing, restricted basin with little or no traction currents and isolated from fully marine conditions has been discussed by Farmer (1985). The change from glacigene to glaciomarine deposition has been regarded as the result of decoupling of glacial ice from its bed.

The features which best exemplify the Woody Island Siltstone are shown in hole S2 below 103.5 m depth. The intervals above this show a gradual dilution of the characteristic Woody Island Siltstone lithology and suggest that conditions for free movement or melting of surface ice had developed. Improved water circulation is probably indicated by the introduction of mica particles, the much less frequent occurrence of pyrite in the sequence, and the more common occurrence of fossil fauna.

Many of the lithological entities are described as bands rather than beds and even in the top 24.4 m interval bedding is not evident (Anon., 1981). The lack of well-defined boundaries to the beds suggests that bottom currents were not sufficiently strong to cause winnowing under the rate of deposition taking place.

Domack *et al*. (1993) considered that the Woody Island Siltstone and correlates were deposited in a deep open basin after decoupling of the ice sheet from its marine bed. High biological productivity associated with the sea-ice marginal zone resulted in early higher Total Organic Carbon values (Domack *et al*., 1993).

Locally at least it would seem useful to consider the Woody Island Siltstone correlate as composed of two parts: a uniform lower unit such as that below 103.5 m in hole S2, and an upper more variable unit. There are suggestions that a similar subdivision could be made in other areas. For example a slightly coarser-grained, lighter coloured and bioturbated siltstone, that generally lacks shelly fossil fauna, occurs in the upper part of the Quamby Mudstone in the Tunbridge Tier bore (Forsyth, 1989*a*).

The most appropriate point to draw an upper boundary to the Woody Island Siltstone correlate could lie above the cored interval in S2, or if within the cored interval possibly at the base of the sandy quartz-rich pebbly siltstone at 51.4 m or at the base of the fossiliferous sandy quartz-rich pebbly siltstone at 35.45 metres.

Observations of the Woody Island Siltstone correlate and Bundella Formation correlate along Waterfall Creek Road are shown below.

Height (masl)	Description	Estimated topographic depth (m) below collar of DDH_S2
526 on road	Well-bedded siltstone and sandy siltstone with lonestones.	-2
520	Fossiliferous cobbly sandstone and unfossiliferous siltstone (Bundella Formation correlate).	2
520	Scrape exposing richly fossiliferous rocks with *Trigonotreta stokesi*, *Strophalosia subcircularis* (Bundella Formation correlate).	2
510	Fossiliferous sandy siltstone (sand fine grained). Fossils include *Strophalosia subcircularis* and a spiriferid.	12
495	Siltstone less uniform than below with bands of fragmentary? fossils.	27
485	Siltstone enclosing pebble band, clasts include possible dolomite? pieces.	37
482–485	Overgrown quarry exposes poorly-bedded grey siltstone that is coarser-grained than in lower parts of sequence. Pebble clasts dispersed and in layers, rare dispersed cobbles, one 300 mm quartzite clast. Possible pyrite nodules. Scattered fossils include *Trigonotreta stokesi*, *Megadesmus* and pelecypods.	37–40
380–440	Uniform dark grey siltstone (Plw). May continue to 480 masl.	142–82

Less than 500 m west of the collar of hole S2 the base of the Woody Island siltstone is exposed topographically 100 m higher than in the bore. This discrepancy may be caused by a moderate (20°) easterly dip towards the bore in the western area and possibly some throw on a fault that bounds the area of steeper dips. Dip observations are at variance nearer the collar, but the shelf morphology of the Bundella Formation correlate suggests that the dip is of low angle near the collar and most likely that the strike is similar to that of the more steeply dipping zone. Correcting for a low angle dip may require the addition of 10 to 15 metres to the 37–40 m topographic depth to convert topographic depth to stratigraphic depth for the quarry face locality in the table above. Some of the surface-exposed Woody Island Siltstone correlate 142 to 82 metres below the bore collar lies west of the inferred position of the fault.

For mapping purposes the top of the Woody Island Siltstone correlate was taken near the small quarry at 482 masl. This could correspond to a stratigraphic depth of 40 to 55 metres in the bore, but perhaps the best lithological correlation suggests that the rocks exposed in the quarry may correspond to rocks at a depth of 63 m in the bore. The small quarry has been re-opened and greatly enlarged and could now provide more continuous exposure of this part of the succession.

During the recent regional mapping the top of the Woody Island Siltstone correlate has probably been drawn a little lower in the succession than as mapped by Jago (1972) or Anon. (1981), although the boundaries appear to correspond closely to those noted by Jago (1972) in the Styx Road spur (467450/5260325). The first persistent occurrence up the sequence of either bedding defined by lithological variation and/or of common fossils was the criteria used to map the top of the Woody Island Siltstone correlate. By extrapolating sufficiently along strike these changes were generally found to be coincident with an increase in pebble frequency and fossil diversity within the limits of mapping accuracy. Similar difficulties in recognising the top boundary of the equivalent Quamby Formation in transitional intervals in the Tunbridge Tier and Ross bore holes in the Central Midlands of Tasmania were discussed by Forsyth (1989*a*).

The superior section on the Styx Spur Road mentioned above was partly obscured by vegetation in 1996 and only superficially observed in fading light. The observations on the spur road east of Styx Road (467075/5260350) are shown below.

Approx. height (masl)	Observations
540	Hard unfossiliferous coarse-grained siltstone
530	Sandy siltstone, some fossils
528	Fossiliferous cobbly silty sandstone
525	Fossiliferous sandy siltstone
519	Similar to below, but some beds increasingly pebbly and some less regular layers with large fossils — *Deltopecten* sp., *Keeneia* sp., *Eurydesma* sp. and spiriferids
518	Richly fossiliferous siltstone, *Strophalosia* sp., *Stenopora* sp., some spiriferids, rare *Deltopecten* sp.
517	Sandy siltstone, *Trigonotreta stokesi*, *Strophalosia subcircularis*?
512	Pebbly sandy siltstone with some cobbles
512	Light to medium grey siltstone with two fossiliferous beds. *Deltopecten* sp., *Strophalosia*? brachiopods
510	Grey siltstone
501	Grey fine-grained siltstone
500	Poorly-bedded siltstone (Woody Island Siltstone correlate)
485	Poorly-bedded siltstone (Woody Island Siltstone correlate)

In this section the impure limestone at 519 m shows the greatest correspondence to the unit mapped as 'Darlington Limestone' (Jago, 1972). Using the terminology employed by Jago, the interval between 510 and 519 metres is probably the 'Fossiliferous Siltstone', implying that the underlying rocks would have been included by Jago (1972) in the Woody Island Siltstone. Although the section was incompletely inspected because of moss and fern cover, the only feature recorded that might suggest reassignment of the beds below 510 m to the Bundella Formation correlate is the development of poorly defined bedding in the siltstone, and this feature alone is hardly convincing.

The Woody Island Siltstone was considered to be 137 m thick on the northern slopes of the Styx Valley (Jago, 1972). The thickness may be slightly greater, in part based on the thickness of 40+ m for the basal beds of the formation recorded from the exploration borehole immediately north of the Styx River bridge (468625/5259150) (Anon., 1981). If most fossiliferous beds are excluded from the Woody Island Formation, the formation is about 140 m thick in the second exploration bore (S2) on Waterfall Creek Road. The formation is absent over basement highs north of Maydena and may show some thinning over lower basement highs entirely buried by the Truro Tillite correlate.

Exposures of the Woody Island Siltstone correlate within the Maydena and Skeleton sheets are largely confined to the area west of the Pillinger Fault, which passes to the west of Abbotts Lookout. The formation is well exposed in this area, particularly in road cuts along Styx Road and in quarries in the Styx Valley, but is less well exposed along Mueller Road, Jubilee Road, South Styx Road, Waterfall Creek Road and some unnamed spur roads. The recent mapping extends the previous mapped distribution only slightly further south near Snowy North (Jago, 1972; Anon., 1981).

Unfossiliferous grey coarse-grained siltstone is exposed on the Gordon River Road (468400/5265275) east of the Pillinger Fault near Maydena. The siltstone is uniform except for wispy lamination and may belong to the upper part of the Woody Island Siltstone correlate. Few exposures exist in this area and it was not possible to find evidence for or against faulting between these outcrops and the nearby Ordovician Tim Shea Sandstone. Poorly exposed siltstone beneath the Bundella Formation correlate has been mapped as Woody Island Siltstone correlate east of the Pillinger Fault in the Styx Valley (475800/5260800).

Eight outcrop samples from the Styx Valley (Maydena sheet) were recently analysed by rock-eval pyrolysis to test their hydrocarbon source potential and maturity (Bacon *et al.*, 2000). Results showed the formation to be a lean, but possibly gas and oil-prone, potential source rock, and that the formation has attained late oil window–early gas window maturation temperatures at this locality (Bacon *et al.*, 2000).

Weld and Picton map sheets (JLE, CRC)

A small area of possible Woody Island Siltstone correlate crops out west of Weld Ridge (465500/5234700) on the Weld map sheet. This is a massive dark grey muddy siltstone, with sparse sand-sized and granule-sized grains. The rock is unfossiliferous except for sparse agglutinating foraminifera. The siltstone interval is about 70 m thick and partly overlies Truro Tillite correlate rocks and partly laps on to a basement high. At 465900/5234800, close to the unconformity upon Proterozoic dolostone, the rock is strongly silicified and veined with quartz.

Outcrop of dark grey, unfossiliferous micaceous pyritic mudstone beside the Weld River (473600/5238300) may be a Woody Island Siltstone correlate.

Small outcrops of soft weathered unfossiliferous mudstone, locally with a cuboidal fracture, crop out on the West Picton Road southwest of 474600/5220600 near the southern boundary of the Picton map sheet and extend on to the adjoining unmapped Burgess sheet. These are depicted as undifferentiated Lower Parmeener Supergroup. However as Ordovician basement (Gordon Group limestone) crops out nearby in the Picton River (south of 474500/5218900, Burgess map sheet), they probably belong to one of the lower formations, and are lithologically most similar to the Woody Island Siltstone correlate (JLE).

Bundella Formation correlate (Pln)

The Bundella Mudstone was defined at Mt Nassau, north of Hobart, where it is overlain by the Faulkner Group and forms the lowest strata exposed (Banks and Hale, 1957). The exposed interval is about 43 m thick and consists of alternations of fissile and non-fissile, often richly fossiliferous siltstone and subordinate sandstone. Fewer fossils are found towards the top of the formation, but lonestones are common and occur throughout. Similar beds were included in the Bundella Formation in the adjacent Collinsvale–Glenlusk area (Sutherland, 1964) and at Maydena (Jago, 1972) and were considered to overlie strata correlated with the Darlington Limestone. Various rocks below the Darlington Limestone correlate were considered to show similarities with rocks between the Darlington Limestone correlate on Satellite Island and the Woody Island Siltstone.

Because no base could be defined for the Bundella Mudstone at Mt Nassau in 1957, a broader interpretation of the Bundella Mudstone has also been possible. Rocks previously correlated with the Darlington Limestone at Glenlusk, and underlying fossiliferous siltstone and calcareous siltstone, were included in the Bundella Formation which was considered to be about 80–90 m thick in the Hobart area (Leaman, 1976). A similar sequence of rocks has been mapped as Bundella Formation in the Kingborough area overlying the Woody Island Siltstone (Farmer, 1985). Rocks directly equivalent to the strata in the original type section may be partly missing at a paraconformity in the Cygnet area (Farmer, 1985).

A fully-cored bore hole through the Bundella Formation (Clarke and Farmer, 1982) near the type section revealed an interval 117.5 m thick underlain by the Woody Island Siltstone and abruptly overlain by rocks of the Faulkner Group. The Bundella Formation in the borehole "consists of a fairly uniform sequence of fossiliferous, medium grey to dark grey, in places heavily bioturbated siltstone with more-sandy siltstone and patches of granule conglomerate scattered throughout. Thin (50–150 mm) bands of bioclastic limestone occur towards the base. Dropstones are common throughout and there is much disseminated pyrite. The fossil fauna includes *Stenopora*, *Trigonotreta stokesi* Koenig, *Eurydesma*, *Tomiopsis*, *Strophalosia*, *Deltopecten illawarensis* (Morris) and crinoid fragments." (Farmer, 1985).

Within the Maydena, Skeleton, Nevada, Weld and Picton map sheets the broader interpretation of the Bundella Formation has been adopted following Leaman (1976), Clarke and Farmer (1982) and Farmer (1985). The units mapped by Jago (1972), namely the

Bundella Mudstone, Darlington Limestone, Fossiliferous Siltstone and possibly some underlying fossiliferous rocks, have all been included as Bundella Formation correlate in the recent mapping (see table below). The units recognised by Jago (1972) are useful and distinctive subdivisions and with more detailed mapping would probably be mapped separately. Too few sections were obtained during the recent mapping to locate the boundaries of the subdivision units and their depiction on a map would be meaningless when in most areas the position of the Bundella Formation correlate boundaries are themselves inferred by interpolation. The units previously mapped are summarised in the table below; fuller descriptions of the top three units, entirely derived from Jago (1972), are also given below.

Current subdivision	Jago (1972)	Lithology	Thickness (m)
Bundella Formation correlate	Bundella Mudstone	Interbedded pebbly sandstone and richly fossiliferous siltstone, bedded pebbly sandstone. Some layers with cobbles.	32
	Darlington Limestone	Richly fossiliferous pebbly limestone. *Eurydesma*-rich bed. Pebbly calcareous fenestellid siltstone. Some layers with cobbles.	3.7
	Fossiliferous Siltstone	Siltstone, calcareous siltstone, thick bedded, well sorted. Strophomenid-rich beds. Pebbles rare.	9.2
	Top beds of Woody Island Siltstone	Siltstone with pebble beds. Some richly fossiliferous beds.	13?

The difficulty of selecting a lower boundary for the Bundella Formation correlate in the transitional sequence in the Styx Valley area has been discussed above. Some intervals previously included in the Woody Island Siltstone (Jago, 1972; Anon., 1981) are here included in the Bundella Formation correlate because of the proportion of sand and coarser clastic debris dispersed in the rock or concentrated in beds, and because of the presence of fossiliferous beds. The fossil content noted by Jago (1972) suggests that at least thirteen taxa occur in this interval and that the fauna is as diverse as that of younger horizons excluded by Jago (1972) from the Woody Island Siltstone.

The overlying 'Fossiliferous Siltstone' unit (Jago, 1972) is characterised by the basic lithology of siltstone overlain by calcareous siltstone, the rarity of pebble clasts, and rich usually strophalosid and bryozoan-dominated fauna. The top metre of this unit consists almost entirely of *Strophalosia* shells (Jago, 1972).

The dark grey, richly fossiliferous 'Darlington Limestone' unit consists of almost equal proportions of spiriferid-fenestellid calcareous siltstone, overlain by *Eurydesma*-rich limestone and spiriferid dominated limestone at the top (Jago, 1972). Pebbles are common towards the top of the calcareous siltstone and prominent near the top of the *Eurydesma*-rich limestone, where clasts reach small boulder size and then gradually become less common through the remainder of the unit. The clasts are of various lithologies (quartzite, schist, Gordon Group limestone, siltstone and sandstone) and some are faceted, indicating a glacial origin (Jago, 1972). A brachiopod from an exposure on the Styx spur road (467575/5260250), recorded as *Streptorhynchus* (Jago, 1972), is most likely the Early Tamarian index fossil *Grumantia costellata*. The latter fossil is known from some neighbouring areas further west, including Mt Mueller and Mt Anne (Clarke, 1992).

The uppermost 32 m unit near Maydena is notably more arenaceous than all lower units. Abundant faunas continue to be found mainly in the siltstone beds, but become less abundant towards the top of the unit. Pebble to small boulder-size clasts are of similar size range to those of the underlying unit (Jago, 1972).

The basal, rather poorly-sorted, pebbly, silty sandstone (three metres) of this unit contains 30% brown silt matrix, fine-grained angular quartz sand 35%, almost equal proportions of slightly coarser-grained feldspar and lithic grains, and 5% dark minerals (Jago, 1972). A similar sparsely fossiliferous sandstone lithology then alternates with richly fossiliferous siltstone in beds mostly 0.6–0.9 m thick through the overlying thirteen metre interval. Siltstone is absent in the succeeding interval (9.2 m), the sandstone is thinner bedded than below, some cobbles are present, and fossils are only common near the interval base (Jago, 1972).

Above this in the Styx Valley the overlying interval (4.6 m) consists of moderately fossiliferous calcareous siltstone, but the top interval (3 m) of poorly fossiliferous pebbly sandstone with some small boulder clasts is best exposed in the Tyenna River bed (470700/5267500) (Jago, 1972).

Without giving more precise geographical data Clarke (1992) noted that the Maydena area is a locality for two other important fossils; *Strophalosia concentrica*, an index for the early Tamarian, and *Eurydesma cordatum*, an index for the middle Tamarian.

New mapping

Changes in the lithology, bedding style and fossil abundances were the main features used to recognise the Bundella Formation correlate in conformable sequences. The development of shelf morphology in the Bundella Formation correlate, and occasionally a cliffed edge to some units, has assisted interpolating boundaries through unmapped areas. In benched areas the boundary between the Woody Island Siltstone and Bundella Formation correlates is commonly located on the steep slopes below the bench.

In faulted areas the distinctive Tamarian faunas, with index species such as *Trigonotreta stokesi* and *Strophalosia subcircularis* or faunal associations of common *Deltopecten illawarensis*, *Eurydesma* spp. and abundant *Stenopora* spp. have often been more useful than lithology for detecting faulted boundaries of the Bundella Formation correlate. In some areas the Bundella Formation correlate exhibits strong brown weathering colours and overlying brown soil development, which seems related to the brown silt matrix present above the limestone unit (Jago, 1972). Brown weathering colours have also been noted in the Mt Nassau type section and in the Cygnet area (Farmer, 1985).

Some observations on sections through the Woody Island Siltstone correlate/Bundella Formation correlate boundary north of the Styx River and on Waterfall Creek Road are given in the tables below. The first of these sections, and nearby areas, may be the section described by Jago (1972).

In a general way the fossiliferous sandstone with common large pebbles and cobbles at 520 m in the Waterfall Creek Road section (469150/5256500) correlates with the layers with large clasts in the 'Darlington Limestone' or overlying pebbly sandstone and interbedded fossiliferous siltstone of Jago (1972). Similar cobble-rich sandstone was found at the same height 400 m further south (469200/5256100) and fenestellid shaly siltstone was found about ten metres higher. Pebbly to cobbly, almost conglomeratic sandstone layers are exposed further north at and near gravel pits on Waterfall Creek Road. One of the layers contains *Eurydesma* and overlies sandstone and shaly siltstone with fenestellids (469300/5257825). Part of the overlying interval includes well-bedded unfossiliferous siltstone and sandy siltstone with lonestones. Further east on Waterfall Creek Road the exposed strata mapped as Bundella Formation correlate are probably close to the top of the formation, but may extend into the Faulkner Group correlate. Assuming a gentle southeasterly dip, successive rocks consist of:

- soft bioturbated uniform coarse-grained siltstone (470430/5257880);
- soft grey crudely laminated siltstone with rare pebble lonestones and some micaceous and carbonaceous laminae (470470/5257730);
- a four metre interval of grey fissile and non-fissile shale with no lonestones and minor mica (470525/5257750).

The eastern end of Waterfall Creek Road ascends the Bundella Formation correlate near the Pillinger Fault (472800/5259400), however dips that range from 0 to 22° suggest that the exposed rocks are affected by faulting. Fossils become uncommon above the fossiliferous Bundella Formation correlate, except for some layers with common fenestellids. Higher beds include well-bedded fissile and non-fissile layers, with some other layers showing cuboidal to spheroidal weathering features. A cobbly, silty sandstone bed was included within the Bundella Formation correlate but overlying beds are referred to the Faulkner Group correlate.

Additional exposures of the Bundella Formation correlate have become available where the HEC Gordon River transmission line and access tracks cross the formation iIn the Maydena Range area.

In the west, the lowest ascending section of track at the transmission line poorly exposes sparsely fossiliferous siltstone. Fossils include *Merismopteria*. About ten metres higher fossiliferous siltstone with *Trigonotreta stokesi* and *Deltopecten* is better exposed and a 900 mm granitoid clast was found (600 masl, 466725/5261400).

An ascent off the track to a shelf feature about 500 m to the south revealed the Bundella Formation correlate to be significantly more sandy above 605 masl and cobble-bearing sandstone was located at 610 masl. Some well-sorted, almost white sandstone with irregular sub-horizontal partings is overlain by rocks with Tamarian faunas. These rocks are considered to be equivalent to part of the upper 32 m thick unit of the Bundella Formation in the section described by Jago (1972) on the Maydena Range.

In the east, where the transmission line descends into the Styx Valley, Faulkner Group correlate rocks, comprising well-sorted micaceous and carbonaceous sandstone, are exposed only a few metres above Bundella Formation correlate rocks with brachiopods. The brachiopods occur about 30 m southeast of a pylon tower and the section line follows the transmission line. The eleven metre section below the brachiopods (471800/5261100) is dominantly of siltstone with subordinate interbedded sandstone and a bed with fossils.

Thickness (m)	Description
	Brachiopods 555 masl.
8	Siltstone.
0.2	Hard very pebbly silty sandstone.
<1	Siltstone.
0.5	Hard silty sandstone. *Trigonotreta stokesi*, fenestellids.
2	Siltstone with occasional fossils.

These rocks are again well exposed near where the main track turns northward to detour away from the transmission lines, but the section is covered by talus further north. Observations on the second section are shown below.

Thickness (m)	Description.
2.5	Spheroidally weathering and fretting siltstone.
2	Harder sandy siltstone with very common fossils and common lonestones to cobble size.
1.2	Siltstone with numerous clasts, tending towards a conglomerate.
~4	Richly fossiliferous silty sandstone. *Trigonotreta stokesi* and other fossils.
~7	Thick-bedded hard sandy siltstone with occasional fossils.
	Quaternary talus.

After descending northwards the track crosses a creek and then veers sharply southward past a small quarry (472000/5261150). The quarry exposes medium grey sandy siltstone including a two metre calcareous interval with about one metre of impure limestone in the upper part. The siltstone is overlain by fenestellid shale. Fossils commonly preserved as original shell include *Eurydesma* sp., *Deltopecten* sp., *Strophalosia* sp. and spiriferids including *Pseudosyrinx*? The strata dip at 31° and are probably down faulted within the Pillinger fault zone. The beds may correlate with the 'Darlington Limestone' unit of Jago (1972).

The Bundella Formation correlate is exposed immediately south of Maydena township in excavations off Junee Road and on a link track between Junee Road and Roberts Road. Most outcrops are of weathered siltstone with some sparsely to richly-fossiliferous layers. The fossils are almost exclusively fenestellids and no diagnostic Tamarian faunas were located. An outcrop on the Gordon River Road on the eastern outskirts of Maydena consists of unfossiliferous siltstone with some nearby loose blocks of sandstone of uncertain provenance. A distinctive Tamarian fauna was noted in rocks on Roberts Road (467725/5265375), but 100–200 m further east rocks consist of shale and sparsely fossiliferous siltstone.

At Humboldt Ridge, north of Maydena, a solitary outcrop of hard, bioturbated, poorly-sorted siltstone with granules exposed on a forestry track is very near the top of the Bundella Formation correlate (470100/5267650). A second track traverses the Bundella Formation correlate one kilometre to the northwest, where successive outcrops in ascending order over an interval of 20 m display:

- mudstone with common fenestellids, *Deltopecten* and strophalosids;
- siltstone with rare fenestellids;
- fenestellid-rich siltstone overlain by poorly-sorted fossiliferous sandstone with *Trigonotreta stokesi*.

At Humboldt Ridge the Bundella Formation correlate may rest directly on Ordovician rocks and similarly nearby west of John Bull Creek, but the clearest demonstration of this occurs three kilometres further west on the Maydena map boundary.

Somewhat unexpectedly Bundella Formation correlate was found in two faulted areas east of the Pillinger Fault in the Styx Valley. In the western area the Bundella Formation correlate dips moderately steeply towards the northwest and is exposed in the bed of the Styx River; for example fossiliferous fissile siltstone (475700/5261600) with *Trigonotreta stokesi* and hard thin to medium-bedded strata with abundant fossils (475800/5261700) on Styx Road and on a bulldozed track running southwest off Styx Road. Above the track fossils include *Trigonotreta stokesi*, *Strophalosia subcircularis*?, *Keeneia* and *Eurydesma* near pebbly sandstone (475850/5260850).

The second area of Bundella Formation correlate is exposed in the Styx River and dips towards the northeast. The lowest beds exposed contain common *Eurydesma* and *Deltopecten* (476600/5262800).

The Bundella Formation correlate is richly fossiliferous at the southernmost limit of mapping west of Snowy North. From here the formation probably extends across the Skeleton and Nevada map sheets, but the Lower Parmeener sequence was not inspected in these areas. The Bundella Formation correlate is not exposed on the eastern side of the Snowy Range on the Nevada map, but is exposed immediately east of the Nevada map in the valley of Little Denison River (Ford, 1956) including fossiliferous beds in a quarry (482300/5242000).

The Bundella Formation correlate on the Maydena–Skeleton map sheets broadly corresponds to the Golden Valley Group of northern Tasmania. A distinctive coarser-grained unit, with numerous cobble-size clasts, calcareous matrix and *Eurydesma* fossils, occurs about 40 m below the top of the Golden Valley Group in bores near Ross and Tunbridge Tier (Forsyth, 1989*a*). Forsyth suggested that these deposits may have been related to the same event that resulted in the Billop Sandstone, which occurs about 30 m below the top of the Golden Valley Group. The introduction of particularly abundant cobble to small boulder-size clasts associated with common *Eurydesma* in the Maydena area, 32 m below the top of the Bundella Formation correlate, may also be related, but the Billop Sandstone is of late Tamarian age, the Darlington Limestone on Maria Island is of middle Tamarian age and, based on the possible occurrence of *Grumantia costellata*, the *Eurydesma*-rich beds near Maydena may be as old as early Tamarian.

Picton map sheet (JLE)

Abundant float of a richly fossiliferous, massive, bioturbated siltstone was noted on a spur about 2.7 km NNE of Mt Riveaux (472200/5226200) at an altitude of about 330 m, about 80 m above the unconformity with the Gordon Group. The fauna indicates correlation with the Bundella Formation (S. M. Forsyth, pers. comm.). Mainly due to lack of time and difficulty of access, the unit has not been mapped in this area, and other formations are probably present. The formation probably extends, disrupted by faults and partly obscured by dolerite talus, southwestward to the Mt Picton area.

In the Huon River, about 0.6 km above Tomalah Creek (472530/5228320), the first Parmeener Supergroup outcrops encountered east of a major fault consist of a matrix-supported pebble to cobble conglomerate, containing both angular and well-rounded clasts. The conglomerate dips variably but gently, and downstream passes into a poorly-sorted, pebbly and sandy siltstone with marine fossils, possibly a correlate of the Bundella Formation. There are numerous outcrops of similar pebbly siltstone and sandstone downstream as far as Riveaux Rapids.

Faulkner Group correlate (Pfk)

The rocks between the 'Lower Marine Sequence' and the 'Upper Marine Sequence' in Tasmania have been referred to as the 'Lower Freshwater Sequence'. In the Maydena area the rocks occupying the stratigraphic position of the 'Lower Freshwater Sequence' have been previously correlated with the Mersey Group near Devonport (Jago, 1972), whereas rocks 20 km to the northwest have been correlated with the Liffey Sandstone (Brown *et al*., 1989; Baillie, 1989). Rocks west of Maydena have been correlated with the Faulkner Group (Calver *et al*., 1990).

A variety of depositional environments have been interpreted for rocks of the 'Lower Freshwater Sequence', ranging from terrestrial, through paralic to near-shore marine (Martini and Banks, 1989; Forsyth, 1989*a*), while some equivalent rocks south of Hobart are fully marine (Farmer, 1985). The features displayed by the Faulkner Group in its type section at Mount Nassau suggest a paralic rather than a freshwater depositional environment. It is preferable to correlate successions dominated by the paralic facies with the Faulkner Group, rather than with formations from northern Tasmania for which a more terrestrial depositional environment has been suggested. Unfortunately in the Maydena–Picton area the detailed stratigraphy of the 'Lower Freshwater Sequence' is not known adequately enough to determine if marine influenced beds are present. About 100 km to the northwest a marine intercalation in the 'Lower Freshwater Sequence' is known west of Lake St Clair, but the degree of lateral proximity to possible basin margins and possible alluvial systems to the west of Maydena is not understood. Coal seams have not been reported from Maydena and therefore a correlation with the Mersey Group is not favoured. Thick-bedded sandstone appears to be absent in the Maydena area, but an isolated occurrence on the Picton sheet appears to be composed only of sandstone and is coarser grained. Somewhat tentatively the Maydena sequence has been correlated with the Faulkner Group.

Based on a section exposed in the Tyenna River bed, the Faulkner Group correlate at Maydena has been considered to have a maximum thickness of 52 metres. This section is composed of basal siltstone (3 m), feldspathic sandstone (12 m) and a 37 m gap with no exposure until overlying 'Upper Marine' rocks are found (Jago, 1972). The basal interval is very thin to thin-bedded (20–150 mm), dark grey, fine-grained micaceous siltstone with common plant fragments and some pelletal conglomerate. The well-sorted micaceous sandstone is thin bedded, commonly cross bedded, and contains carbonaceous layers with plant fragments, and clay pellet conglomerate (Jago, 1972).

The rocks show some similarities with the Rathbones Formation and the Parramore Formation of the Faulkner Group described at Mt Nassau (Banks and Hale, 1957).

Micaceous, carbonaceous shale and well-sorted, very fine-grained feldspathic sandstone form part of the Faulkner Group correlate on the northern slopes of the Maydena Range (469450/5266295) (Jago, 1972). Jago noted a few beds of pebbly sandstone, some of which were cobbly, some worm tubes, occasional fossil seed cases and the general characteristics of thin to medium bedding (100–300 mm) and well-sorted texture.

New mapping

The Faulkner Group correlate was present in all sections in which the Lower Parmeener Supergroup was differentiated in the Maydena and Skeleton map sheets. Outcrops found in the Huon River upstream from the confluence with the Picton River in the Picton map sheet are currently the southernmost Lower Freshwater Sequence occurrences known in Tasmania.

It has not proved possible in the Maydena area to remedy the lack of complete sections through the Faulkner Group correlate noted by Jago (1972), although tighter constraints on the upper and lower boundaries suggest that the Faulkner Group correlate is significantly thinner than previously thought. The thickness is probably towards the lower end of the range of 20–30 m, but the equivalent interval in the Weld map sheet is thicker (35 m).

Lithologies similar to those described by Jago (1972) were found at most localities, but some sandstone was probably less feldspathic and more quartzose. In poorly-exposed areas with only weathered float material, the well-sorted sandstone rocks generally proved easier to recognise, particularly where sedimentary structures, such as parts of the curved surfaces of ripple lamination or well developed planar lamination, were present.

The Faulkner Group correlate north of Maydena township includes both sandstone and grey mudstone (469325/5268375) and within a few metres of the top of the Faulkner Group correlate shaly beds are stripy in appearance. Well-sorted, carbonaceous, fine-grained sandstone with poorly-sorted granules occurs one kilometre south of the township, on the track near Maydena Creek (469575/5265225), and coarse-grained siltstone occurs nearby. Plentiful sandstone float enabled more accurate mapping of the upper boundary almost one kilometre to the southeast (470100/5266570). Southwest of Maydena, on the track linking Junee Road and Roberts Road, thin to very thin-bedded siltstone with very micaceous and carbonaceous laminae is overlain by medium to coarse-grained sandstone with small probable hydroplastic or bioturbation siltstone structures (469100/5265830). Outcrops about ten metres lower are of soft, uniform, unfossiliferous cream-coloured siltstone that may be part of the Faulkner Group correlate or the Bundella Formation.

Cuttings on the branch track off Roberts Road that extends along the north side of the Maydena Range west of Abbotts Lookout expose finely laminated, rarely wavy laminated, grey and purple-tinted micaceous siltstone and fine-grained sandstone (470000/5263200). These exposures appear to be very near the top of the Faulkner Group correlate as nearby rocks contain shell fossils, bioturbation and quartz granules.

A similar sequence is found on the HEC transmission line access track at the western end of the Maydena Range, where a three metre thick interval ten metres below beds with *Cancrinella farleyensis* consists of laminated siltstone with very fine-grained sandstone laminae. Faulkner Group correlate rocks also occur on the ridge to the south near 466800/5260900.

Strata near the base of the Faulkner Group correlate are exposed where the transmission lines cross a shelf on the descent from the Maydena Range into the Styx Valley. Beds of siltstone and well-sorted micaceous sandstone up to 300 mm thick are present (471750/5261140). The shelf is partly covered by talus, which includes blocks of well-sorted Upper Parmeener sandstone that superficially resembles the Faulkner Group correlate sandstone. More detailed mapping would be required to resolve the stratigraphic position of grey bioturbated siltstone with lonestones that may be interbedded in the Faulkner Group correlate (471500/5261300).

Well-sorted sandstone was found near the southern limit of mapping on the southern side of the Styx Valley (469600/5254800). A single plant fragment was found in soft, massive, bedded grey siltstone on the spur road leading south from Waterfall Creek Road (469300/5256125), while well-laminated coarse-grained siltstone occurs a further 150 m south along the track. Grey siltstone on Waterfall Creek Road contains lenticles and very thin laminae of very coarse-grained siltstone (469300/5256470). The original field descriptions interpreted the plant-bearing siltstone outcrop as part of a transitional interval within the very top of the Bundella Formation, but the interpretation was revised to Faulkner Group correlate during map compilation, although some moderately steep dips in this area may indicate a nearby fault.

East of the Pillinger Fault a small area of Faulkner Group correlate that consists of stuctureless thick-bedded sandstone and ripple-laminated sandstone was found in the banks of the Styx River (475450/5261525). Further downstream (475900/5262200) undifferentiated Lower Parmeener rocks have been depicted between areas of Bundella Formation and 'Upper Marine' rocks with *Cancrinella farleyensis*. No traverses were conducted in this area, but if not faulted a band of Faulkner Group correlate rocks is expected to approximately correspond to the undifferentiated rocks possibly extending to shaly siltstone and flaggy sandstone on Styx Road.

The easternmost exposure in the Styx River is on a prominent bend (476870/5263200) where a cliff exposes thin-bedded strata including grey micaceous siltstone with sand laminae and very fine-grained quartz sandstone.

South of Styx Road (near 475925/5260900) rocks near the Bundella Formation–Faulkner Group correlate boundary occur as outcrops and floaters and include grey flaky shale, sand and pebble free 'marginal marine' olive-grey siltstone with a mottled appearance but lacking definite bioturbation, and bioturbated grey siltstone with fossil wood and rare marine fossils. No definitive Faulkner Group correlate rocks were found in this area.

Weld and Picton map sheets (JLE, CRC)

South of Weld Ridge (at 468700/5230100, Weld map sheet) there is a 35 m thick unit of cross-bedded medium-grained quartzarenite, its base being about 75 m above the unconformity and roughly 200 m below the Risdon Sandstone correlate. Enclosing units are poorly exposed and so correlation of this unit is uncertain, but lithologic correlation with the Faulkner Group correlate seems reasonable. Deposition appears to have taken place in a higher energy environment than in the Maydena and Skeleton map sheets.

On the Picton map sheet, unit Pfk crops out on and near the south bank of the Huon River. Flat-lying, micaceous and slightly carbonaceous, thinly bedded fine-grained sandstone with small-scale cross bedding crops out in Codeine Creek, between 15 and 20 m from its mouth (473500/5227600). The sandstone is directly overlain by a one metre thick bed of massive siltstone. A further 30 m upstream, and a few metres higher in the sequence, the next outcrop is pale orange-brown mudstone with abundant marine fossils, assigned to the Deep Bay Formation correlate.

A similar cross-bedded, medium to fine-grained sandstone, dipping gently (about 5°) to the southeast, crops out on the banks of the Huon River about 100 m above Codeine Creek (473490/5227600). Outcrops 150 m upstream (west) and 250 m downstream (east) are assigned to the Bundella and Deep Bay formations respectively.

On the basis of lithology and stratigraphic position (assuming a slight overall easterly dip of the sequence) the cross-bedded sandstone outcrops are tentatively assigned to the Faulkner Group correlate. Although its base has not been definitely observed, the unit is probably thin (no more than a few metres) and/or impersistent, suggesting a marked thinning from the exposure south of Weld Ridge, five kilometres to the ENE. Its top is about 150 m stratigraphically below the Risdon Sandstone correlate in this area, compared to 200 m at Weld Ridge.

These outcrops are the most southerly known occurrence of the Faulkner Group, which wedges out south of Hobart (Farmer, 1985).

Deep Bay Formation and Nassau Formation correlate (Puh)

Unit Puh has been used to depict an interval of approximately 90 m thickness, of thin to thick-bedded, generally richly fossiliferous glaciomarine siltstone and sandstone with lonestones that overlies the Faulkner Group. The interval extends up to the base of massive cliff-forming thick-bedded sandstone that forms the base of an interval of rocks correlated with the Minnie Point Formation.

The detailed stratigraphy of unit Puh is not well known, although beds near the base can be correlated with the Nassau Formation defined at Mt Nassau (Banks and Hale, 1957) and much of the overlying sequence can be correlated with the Deep Bay Formation defined near Cygnet (Farmer, 1985).

Some of the fossil fauna has been listed by Jago (1972) and biostratigraphic correlations made by Clarke (1989). In particular Bernacchian faunas are present near Maydena and Lymingtonian faunizones 7, 8 and 10 are present in equivalents of the Malbina Formation (Clarke, 1989). It is probable that some rocks included in the Malbina correlate of Clarke (1989) are herein included in unit Puh, although the majority of the Malbina Formation correlate (Clarke, 1989) is equivalent to the Minnie Point Formation correlate (Pun herein).

The beds with *Cancrinella farleyensis* correspond to the Bernacchian faunizones 4–5 and partly support the correlation of the beds with the Nassau Siltstone. Faunizone 5 is partly based on the index fossil *Taeniothaerus subquadratus* which occurs near Maydena in a sandstone lithology (M. J. Clarke, pers. comm.). In the Mt Nassau type section faunizone 5 faunas are developed in the Berriedale Limestone but no similar rock unit is present at Maydena. It is possible that the Bernacchian transgression did not reach the Maydena area until faunizone 5 time and that a diachronous relationship exists between the Nassau Formation at Mt Nassau and the correlate near Maydena (M. J. Clarke, pers. comm.).

No further specimens of *Taeniothaerus subquadratus* were observed during the recent mapping, but specimens in sandstone have been found by N. Cashion a short distance east of the Nevada map sheet near the Little Denison River valley. This contrasts with the complete absence of Bernacchian faunizones 4 and 5 further east in the Cygnet area, where Lymingtonian faunizones 6–8 developed in the Deep Bay Formation directly overly Tamarian faunas of the Bundella Mudstone (Farmer, 1985).

Two of the shortcomings in the Maydena–Styx Valley sections are that the nature of the boundary between the Bernacchian and Lymingtonian intervals is not known, and neither is the stratigraphic location of the beds with *Taeniothaerus subquadratus*.

New mapping

Several sections were inspected that span the Faulkner Group correlate–Puh unit boundary. Well exposed sections were limited to thin intervals, which commenced in siltstone near the top of the Faulkner Group correlate, rather than the more characteristic sandstone lithologies.

A section on the HEC transmission line at the western end of the Maydena Range reveals a transitional interval (10–13 m) of siltstone and sandy siltstone that extends between laminated siltstone and sandstone referred to the Faulkner Group correlate and a higher bed with *Cancrinella farleyensis*. Marine fossils first appear about three metres below the *Cancrinella* bed.

Some of the unit Puh is down faulted above this section.

Thickness (m)	Section base 70 m east of the pylon tower (466850/5261425).
3.5	Bryozoan shale (top).
3.5	Shaly siltstone with some bryozoans.
4.5	Grey fine-grained sandstone with pebble lonestones, some fossils.
1.5	Siltstone.
	Bed with *Cancrinella farleyensis*.
3–4	Siltstone, sparse marine fossils.
4–5	Siltstone and slightly micaceous coarse-grained siltstone, some laminated, some soft with spheroidal weathering.
3–4	Sandy siltstone that becomes more mottled (bioturbated) downwards.
3	Laminated siltstone with interbedded laminated very-fine grained sandstone (Faulkner Group correlate).

Three kilometres to the east, on the northern side of the Maydena Range (470000/5263200), a similar interval is inferred to overlie finely laminated, rarely wavy laminated, siltstone and fine-grained sandstone referred to the Faulkner Group correlate. Marine fossils occur in lower beds in this section compared to the previous, but the section does not extend up to the horizon with *Cancrinella farleyensis*.

Thickness (m)	Observations on spur road off Roberts Road
3–4	Sandy siltstone with occasional granule size dropstones.
1+	Sandy siltstone over pebbly sandstone with marine fossils.
1	Soft to hard bioturbated siltstone.

Higher beds are revealed further west along the track 60 m past a bend and include grey poorly-sorted siltstone and calcareous siltstone with fossils preserved as original shell and siltstone (469950/5263040). The siltstone is overlain by loose floaters with linoproductids, possible *Cancrinella* and very small productids that could be *Wyndhamia preovalis*. A short distance further east sandstone contains *Sulciplica* sp., *Trigonotreta* sp., *Myonia corrugata* and *Schuchertella*. The *Trigonotreta* is neither *T. hobartensis* nor *T. cracovensis* and the fauna is younger than faunizone 4 and may be Lymingtonian. Some poorly fossiliferous, fissile and non-fissile siltstone beds occur with only a few *Sulciplica* sp. (469850/5263000).

Nearby, a 20 m high cliff rising from the track appears to consist of thin to medium-bedded spheroidally weathering and massive siltstone. The beds are poorly to richly fossiliferous, and contain a linoproductid (probably *Terrakea*), *Deltopecten*, a conularid and a relatively transverse *Sulciplica* sp. *S.* cf. *transversa*. Small faults may separate individual outcrops along the track in this area (Jago, 1972) and further mapping would be required to establish stratigraphic ordering.

In some other areas there is a suggestion of variably fossiliferous, poorly-sorted pebbly sandstone similar to and occupying the same stratigraphic position as the

Raynor Sandstone in the Mt Nassau type section, i.e. between the Faulkner Group and the Nassau Siltstone. Some pebbly fossiliferous sandstone floaters occur on the link track between Junee Road and Roberts Road near Maydena. Bioturbated pebbly sandstone underlies siltstone with *Cancrinella farleyensis* on the eastern end of Waterfall Creek Road about one kilometre west of the HEC transmission line on the Skeleton map sheet (473400/5259450).

Additional occurrences of Bernacchian faunas were found in the Styx River. Medium to thick-bedded grey calcareous siltstone contains *Cancrinella farleyensis* at 475900/5262300 and in a re-entrant meander, very tough calcareous sandy siltstone with pebbles contains *Tomiopsis ovata*, *Sulciplica* sp., *Wyndhamia preovalis*, *Cancrinella*? and *Deltopecten* (476325/5262600). Slightly further east, and possibly separated by a fault, *Deltopecten* sp. occurs with *Eurydesma* sp.

Further downstream within a separate fault block, an outcrop of richly fossiliferous grey siltstone contains, as original shell, brachiopods including small productids possibly *Echinalosia preovalis*, *Deltopecten* and *Stenopora* spp. (477725/5262550). The lithology resembles beds within the basal part of Puh. If this correlation was correct it would imply unmapped faults had affected the rock distribution.

No special attempt was made to establish sections through unit Puh other than the information gathered fortuitously in attempting to establish the upper and lower boundaries, and whilst undertaking general traverses. Variably fossiliferous beds down dip and downstream from the preceding locality probably occur towards the middle of the unit. The beds tend to be thin to medium-bedded and of silty sandstone and sandy siltstone. Thicker beds (<1 m thick) of pebbly sandy siltstone and fissile siltstone contained common brachiopods including *Wyndhamia jukesi*, *Sulciplica stutchburii* and *Trigonotreta cracovensis* (478325/5262430) indicative of a Lymingtonian faunizone 6 or 7 age.

Assuming no significant intervening faults, similar horizons occur at two other localities. Sandy shale with abundant fenestellids and *Trigonotreta cracovensis*, *Sulciplica transversa*, *Etheripecten* and *Streblopteria* occurs at 478725/5261650, while grey fossiliferous sandy siltstone with pebble lonestones and *Sulciplica* and *Fenestella* occur 100 m to the north. The presence of *Sulciplica transversa* and *Trigonotreta cracovensis* indicates a Lymingtonian faunizone 7 or 8 age (Farmer, 1985). Locally the occurrence of *T. cracovensis* may prove useful to help recognise similar horizons.

Very few outcrops are well exposed nearby on the Styx Road. About 1.2 km west of the eastern boundary of the Maydena map sheet (478800/5261200) a road cutting exposes soft, shaly, dark grey, pyritic siltstone overlain by tough, coarse-grained sandy siltstone with fossil brachiopods, fenestellids and bryozoans. Some nearby loose blocks of soft yellow-brown silty sandstone were abundantly fossiliferous, but could not be matched with the rock exposed. The fossils were dominantly *Cancrinella farleyensis*, with rarer *Anidanthus* sp., *Etheripecten* sp., *Tomiopsis* spp. and other small spiriferids. If locally derived, this Bernacchian fauna supports the possibility of undetected faulting noted above.

A nearby area of almost two square kilometres that was being logged has been left undifferentiated on the map as outcrop was poor, and in places it was not possible to reliably distinguish transported talus from bedrock. Lithologies found along and above Styx Road included glaciomarine siltstone, sandy siltstone and sandstone. The rocks are unfossiliferous to sparsely fossiliferous with pelecypods, and in places quartz lonestones are prominent. No abundance of richly fossiliferous float was found.

Beyond this area fossiliferous Puh is exposed at scattered localities on Styx Road and includes a pebble-rich layer and a resistant fossiliferous bed with *Wyndhamia jukesi* near 477150/5262500. A single transported block with *Trigonotreta hobartensis*, indicative of a Bernacchian age, was found on the roadside, but the origin of the block is unknown. More continuous exposure of thin to medium-bedded soft fossiliferous siltstone, an estimated 60 m above the base of Puh, resembled parts of the Deep Bay Formation correlate (476800/5262550). Outcrops on the old Jubilee Road south of Maydena township, about 40-60 m above the base of Puh, are similar.

Well exposed medium-grey richly fossiliferous siltstone and some poorly-sorted sandstone occur at the junction between Styx Road and Andromeda Link Road (476600/5261700). Fossils include small neospiriferids and a relatively wide hinge line form, possibly *Fusispirifer*. *Sulciplica* and *Fusispirifer* were found an estimated 40 m above the base of Puh at the western end of the Maydena Range (466800/5261700).

Unit Puh is exposed along parts of Waterfall Creek Road and Ted Ransleys Road north of the Snowy Range. The best exposures on Waterfall Creek Road occur east of a fault, and based on the position of the overlying Minnie Point Formation correlate, the beds are considered to be about 40 m above the base of Puh. The dominant lithology at scattered outcrops is thin to medium-bedded, weathered, cream-coloured siltstone with common to abundant fenestellids interbedded with commonly to richly fossiliferous sandstone. Fossils include *Tomiopsis plica*, which indicates a faunizone 6 or 7 age, and a specimen that may be *Tomiopsis plana* that could indicate a faunizone 5b–6 age. A very pebbly sandstone bed 0.5 m thick contains brachiopods including *Sulciplica transversa* (indicative of a post-faunizone 6 age) on Waterfall Creek Road (471650/5257725). Some of the inferred overlying interval is rather less fossiliferous coarse-grained siltstone.

West of the fault, on Ted Ransleys Road and on Snowy North foot track, fenestellid shale similarly occurs about 40 m above the base of Puh. Fenestellid-bearing siltstone and shale are also the more common fossiliferous lithologies exposed southwest from the junction of Ted Ransleys and Waterfall Creek roads. Here the beds may be slightly lower in Puh, about 20–30 m above the base. *Fletcherithyris parkesi* was found at 469825/5256825 and leached calcareous? sandstone with *Sulciplica*, *Terrakea* and *Streblopteria* occurred at 469750/5256670.

On the western side of Snowy North, weathered buff coloured fenestellid mudstone, about 30 m above the base of Puh, contains *Trigonotreta cracovensis*, *Tomiopsis brevis*?, *Schuchertella* sp., *Wyndhamia dalwoodensis* and *Promytilus mytilformis* (469525/5255250). The fauna indicates a Lymingtonian faunizone 7 into 8 age.

The northern of two tracks that ascends Humboldt Ridge north of Maydena exposes grey siltstone with layers of pebbles and fossils, but no diagnostic fauna was found (469450/5268375). Siltstone is common east and north of here about 20 to 40 m above the base of unit Puh. Some higher beds are of sandy siltstone and silty sandstone, and contain fewer and in places fragmentary fossils and large pebble lonestones.

Conularids occur at several localities and appear to be more common near the base of Puh. *Paraconularia derwentensis* was found near Roberts Road (469000/5265100) and more fragmentary specimens were found off Roberts Road west of the Pillinger Fault and in the Styx Valley in sparsely to moderately fossiliferous siltstone and sandy siltstone beds (476175/5260975).

Unit Puh on Roberts Road includes shale with *Sulciplica* and *Deltopecten*.

Upper beds

In several areas the top 25 m interval contains some unfossiliferous beds. On Styx Road, west of Andromeda Creek, weathered, almost white mudstone with red stains on irregular joints is devoid of fossils (475240/5261075). Some fossiliferous beds inferred to be above this horizon contain *Sulciplica* sp. and *Tomiopsis* sp. (475210/5261275).

A similar poorly fossiliferous interval is partly exposed in track cuttings beneath the HEC transmission lines on the western bank of Gee Creek. Approximately 20 m below the top of Puh occurs siltstone with 5% fossiliferous beds that contain *Sulciplica* sp. Unfossiliferous siltstone occurs higher and this is overlain by interbedded unfossiliferous siltstone, siltstone with crinoidal pieces and rare sandstone. These rocks are cream coloured with orange stains on irregular joints (474700/5259450). *Deltopecten* sp. is present in beds exposed in the Styx River near the eastern boundary of the Maydena map sheet an estimated 15 m below the top of Puh (479225/5261360). Sparsely fossiliferous siltstone overlies this horizon downstream. In contrast the uppermost beds (3 m) on an old spur road consist of abundantly fossiliferous massive to fissile siltstone and fine-grained sandstone directly overlain by the Minnie Point Formation correlate.

The upper beds are relatively sparsely fossiliferous near Maydena township. Unfossiliferous sandstone and fissile siltstone occur about ten metres below the top of Puh on the Gordon River Road east of Maydena (472650/5267325), while unfossiliferous white mudstone occurs about 20 m below the top of Puh between Roberts and Junee roads. The spiriferids *Sulciplica* and *Tomiopsis* occur rarely in track cuttings at the south end of Humboldt Ridge, but a more fossiliferous layer with bryozoans was also recorded here about ten metres below the top of the unit.

Fossils are generally quite plentiful more than 20 m from the top of unit Puh with fenestellids probably the most common fossil type throughout the unit. Fenestellid shale occurs about 20 m below the top of unit Puh at the western end of the Maydena Range (467075/5261100).

Unit Puh was observed in the valley of the Little Denison River on the Nevada map sheet, including a thermally metamorphosed outcrop in the river (477775/5241675), as alluvial boulders and outcrops 1.5 km downstream, and in road cuttings a short distance into the Lonnavale map sheet.

Picton map sheet (JLE)

Confirmed outcrops of unit Puh on the Picton map sheet are restricted to the Huon and Picton rivers, immediately above their confluence and in the immediate area. Here the unit consists of fossiliferous, medium to thick beds of fine-grained, poorly-sorted sandstone, interbedded with *Fenestella*-rich mudstone. The rocks are possibly slightly hornfelsed, although distant from known Jurassic dolerite. They are correlated on lithological and palaeontological grounds with the Deep Bay Formation as defined near Cygnet (Farmer, 1985). Correlates of the Nassau Formation (or its age equivalent at Cygnet, the Hickman Formation of Farmer, 1985) have not been identified in the Picton area. Their apparent absence may be due to overstep of older rocks by the Deep Bay Formation correlate southwards from Maydena, similar to the relationship of these units between Granton and Cygnet (Farmer, 1985).

On the southwest bank of the Picton River, about 700 m below the Riveaux Road bridge (476300/5226800), pebbly dark grey to grey-green siltstone contains an abundant marine fauna (brachiopods, bryozoans) diagnostic of the Deep Bay Formation (M. J. Clarke, pers. comm.).

Poorly sorted, commonly pebbly, richly fossiliferous and bioturbated, thin to medium-bedded, usually pale to dark-grey siltstone sporadically crops out in Codeine Creek between about 50 and 220 m above its mouth. The exposed section is about 30 m thick and rests on probable Faulkner Group correlate, but its top is obscured by dolerite talus.

Similar richly fossiliferous grey siltstone was noted in the Huon River about 250 m below Codeine Creek (476270/5227830) and is assigned to the Deep Bay

Formation correlate. Although not examined in detail, the unit sporadically crops out downstream for about 2.7 kilometres. Some beds with small boulder-sized clasts were noted (475610/5227530). Similar fossiliferous lithologies were noted on McKays track, just south of the Huon River near Riveaux Rapids.

Minnie Point Formation correlate (Pun)

The Minnie Point Formation correlate includes all the strata between the base of a prominent pebbly sandstone that overlies unit Puh and the base of the Risdon Sandstone. The correlate consists of about 60 m of poorly to well-sorted glaciomarine sandstone and siltstone with some fossiliferous horizons. These rocks have been previously correlated with the Malbina Formation (Jago, 1972).

The uppermost part of the Malbina Formation (Member E) is equivalent to the uppermost part of the Minnie Point Formation, as faunas of faunizone 10 appear in this interval. In its type area near Cygnet, the Minnie Point Formation is considerably thinner (46 m) compared to the Malbina Formation in its type area near Mt Nassau (91 m, Banks and Read, 1962). In their respective type sections, the base of the Minnie Point Formation is younger than the base of the Malbina Formation.

The basal beds of the Minnie Point Formation are coarser grained and more thickly bedded than those of the Malbina Formation. The medium-grained sandstones that occur near the base of the Malbina Formation tend to be rather patchily developed around Hobart and replaced in some areas by rocks that are only marginally coarser than those of the overlying intervals.

In the Maydena–Picton area the basal sandstone is arguably the most readily recognised mapping horizon in the Lower Parmeener Supergroup, as it commonly develops prominent cliff faces and waterfalls where other rocks are not exposed. The massive sandstone cliffs have shed equally massive boulders that can be found hundreds of metres below their source. One of the few difficulties presented is distinguishing some of these boulders from bedrock. The thickness of the Minnie Point Formation correlate near Maydena is intermediate between that in the type section and that of the Malbina Formation at Mount Nassau. In the south, on the western slopes of Mount Picton, the correlate may be thinner than at Cygnet, but it is much thicker near the confluence of the Picton and Huon rivers.

Jago (1972) subdivided the sequence into four units (see table below). Three pebble bands are present 12 m below the top of unit 1 and the top metre is a conglomerate with rounded and angular, occasionally faceted quartzite clasts to 200 mm size (Jago, 1972). Unit 2 contains common quartz pebbles (3 mm), slate and schist fragments to 50 mm and quartzite rarely to 250 mm size. In unit 3, where pebbles form 10% of the rock, some beds take on a conglomeratic appearance (Jago, 1972). In contrast, unit 4 contains very few pebbles, but both units 3 and 4 contain moderately well rounded sand (Jago, 1972), a feature shared with the sandstones in the top Member E of the Malbina Formation at Mt Nassau (Banks and Read, 1962).

Unit	Thick. (m)	Predominant lithology	Sorting	Bedding	Fossils
4	1.5	Medium-grained sandstone	Well sorted		Highly abundant
3	9	Coarse-grained sandstone	Poorly sorted	Well bedded	Moderately abundant
2	33.5	Grey quartz sandstone	Poorly sorted	Moderately well bedded	Poorly fossiliferous
1	20	Sandstone	Well sorted	Very poorly bedded	Not common

Units 1 and 3 are described from sections west of the Pillinger Fault on the northern side of the Maydena Range (Jago, 1966) and Units 2 and 4 are probably also based on sections in the same area. The poorly-sorted sandstone is typical glaciomarine sandstone with much matrix and clasts as dispersed lonestones and concentrated in layers. Interbedded sandy siltstone, fissile and non-fissile siltstone beds are present within unit 2 in most areas and parts of the unit in isolation could be mistaken for Abels Bay Formation.

New mapping

In the Maydena and Skeleton map sheets the Minnie Point Formation mostly occurs as a relatively narrow band on the slopes above the Tyenna and Styx rivers until a northeasterly dip component eventually causes the strata to dip into the river beds. A broader outcrop area is developed at Humboldt Ridge, which takes the form of a northeasterly dipping cuesta. Faulting associated with the well known, steeply-dipping bedding plane exposure on the Gordon River Road near Sharpes Siding, in the adjacent Dobson map sheet, uplifts the formation so that it reappears further east in Routs Creek. Faults that appear to be part of the same system also result in the formation dipping northwesterly and westerly into the Styx River south of Marriotts Lookout.

Another thin band of the formation, exposed in road cuttings on the Lonnavale map sheet, extends around Barn Back and crosses from the Nevada into the Weld map sheet. A small isolated area surrounded by Jurassic dolerite is poorly exposed to the immediate northwest just north of the Little Denison River (477900/5241700).

The formation is inferred to be present west of the Snowy Range and around parts of Mt Weld, but the sequence has not been differentiated in these areas.

Basal beds (Unit 1)

In the Styx Valley slightly weathered exposures of the basal massive sandstone unit are typically an olive-grey to green-brown colour. Bedding is defined primarily by thin layers with sub-angular pebbles which are commonly quite large and reach cobble size

(>64 mm). The bedding may also be defined by changes in grain size and texture, but overall bedding plane partings are not well developed and the outcrops maintain a massive appearance with joints and other defects widely spaced. Moderately well-sorted fine to medium-grained sandstone with about 20% muddy silt matrix is the most common lithology, but some layers show an increase in the proportion of matrix and the development of a coarse and irregular bedding fissility. More commonly the variation is to planar or lenticular beds with less matrix and coarser-grained sand that ranges up to granule size. The best sorted layers part readily along lamination. Feldspar sand and granules form about 5–10% of the rock and in some localities green grains are present that may be glauconite.

Rolled and abraded fossil shell fragments are common in some pebbly medium to coarse-grained sandstone, but in some areas fossils are rare or absent. Beds with well-preserved fossils are present in some areas.

The base of unit 1 is exposed on an old logging track south of the Styx River where fossiliferous sandstone with *Fusispirifer*, *Aperispirifer wairakiensis* and cobble clasts directly overlies a fossiliferous bed of the Puh unit (476525/5261150). The boundary is also exposed in a nearby culvert where soft clayey siltstone with *Terrakea* (Puh) is overlain by a one metre thick sandstone bed that includes a thin layer of granule sandstone with *Peruvispira* at the top. Immediately above this occurs medium-bedded and lenticular-bedded siltstone (2 m) with thin interbeds of hard silty sandstone (476680/5261400). Bold outcrops of unit 1 sandstone, including feldspathic granule sandstone, are exposed at a sharp bend on Styx Road (475150/5261450) and are repeated to the west by a fault (474620/5260825). Fine-grained sandstone on Jacques Road (at 475275/5260300) and further east is fossiliferous.

Slightly above the transmission line crossing of Styx Road, fossiliferous sandstone of Unit 1 contains *Tomiopsis undulosa*?, *Sulciplica transversa* and *Etheripecten*. Associated siltstone contains *Wyndhamia* and *Fenestella* (473600/5260150). These rocks are overlain by hard coarse-grained sandstone. About one kilometre to the southeast the transmission line track descends into Gee Creek and a green sandstone overlain by coarse and medium-grained sandstone are the lowest beds encountered above a small gap between them and unit Puh. West of Gee Creek the sandstone is weathered and bleached white in the vicinity of a large swamp, but otherwise shows typical characters such as pebble layers, granule sandstone lenses and fossils (473200/5258600).

The position of the basal sandstone in the Styx Valley is more accurately located south of the river and several cliff and waterfall exposures (e.g. 478350/5260900) were visited (as indicated by the use of the *geological boundary position approximate* line-type on the map. West of Snowy North the southernmost occurrence on the Skeleton map sheet consisted of fossiliferous sandstone overlain by a cliff and bench-forming sandstone three metres thick.

Only a few localities with basal sandstone were visited on the northern side of the Styx Valley and the position of the boundary is inferred by extrapolation, but with some degree of confirmation provided by boulders of the sandstone in the talus. The boundary west of the Pillinger Fault on the Maydena Range is better defined at cliffs near the eastern and western areas (466800/5261900, 467150/5261000) of outcrop. The sandstone forms cliffs up to 20 m high in the west (467450/5260775) while six metre high cliffs occur beneath the transmission line descent to the Styx River, at significantly higher elevation on the Maydena Range than previously indicated (Jago, 1972). The latter cliff reveals pebble bands and common fossils in the basal metre and nearby displaced boulders are of granule sandstone.

Near Maydena outcrops occur along the old Jubilee Road and at various localities along the northwest slopes of Abbotts Lookout, where Jago (1972) indicated a thickness of 64 m for the correlate. East of the boundary of Jago's map near Proctors Creek, the basal sandstone descends and crosses the Gordon River Road and was found as floaters of sandstone with cobbles and fossils between the road and the Tyenna River. North of the Tyenna River outcrops commonly occur within the pine plantation road network and as natural exposures on Humboldt Ridge. Thickly-bedded, poorly-sorted silty sandstone with pebbles and cobbles of slate occurs at the Tyenna River. Both well-sorted and poorly-sorted sandstone are exposed on the road above the river (470950/5267950).

The Humboldt River appears to have cut into Unit 1 at various places upstream for one kilometre from the mapped fault (470600/5269250), but some tough sandy siltstone present may be part of Unit 2. Interbedded tough grey unfossiliferous siltstone and siltstone containing horizons with numerous fossils (469775/5269425) occurs between outcrops of sandstone with *Deltopecten* and cobbles to 150 mm downstream and fine-grained sandstone upstream. Some fine-grained sandstone and coarse-grained siltstone with poorly preserved fenestellids are exposed at localities on the pine plantation roads nearby to the south (470100/5260050), but most outcrops expose sandstone.

Middle siltstone and sandstone (Unit 2 + Unit 3)

Rocks overlying the basal sandstone include poorly-sorted sandstone, silty sandstone and fissile and non-fissile siltstone. Near the Tyenna Road bridge over the Tyenna River, very resistant, thickly-bedded, poorly-sorted sandstone with pebbles, black mud defined bioturbation, and some fragments of fossil plant matter, occurs interbedded with siltstone. Siltstone is exposed in several road cuttings in the pine plantation near 471200/5268700 and includes fretting types lacking lonestones. Further north sparse fossils include *Stutchburia costata*. Siltstone with fine to medium-grained sand or silty sandstone is exposed downstream from the fault in the Humboldt River.

Unit 2 is exposed at scattered localities on the Gordon River Road and on the old Jubilee Road, while silty sandstone occurs above the track on the northern side of Roberts Hill, and east and west of the Pillinger Fault on Roberts Road.

At the western end of the Maydena Range, on the transmission line track, buff and cream-coloured interbedded sandy siltstone and sandstone with pebble lonestones and a few poorly-sorted pebble layers has developed a cuboidal to spheroidal weathering style (467200/5261500). These beds are about 20 to 30 m below the Risdon Sandstone correlate and grade up to interbedded spheroidal weathering and fissile siltstone that extends almost to the Risdon Sandstone correlate. Beds with larger scale spheroidal weathering and interbedded fissile beds occur about 20 m below the Risdon Sandstone correlate 3.5 km to the east (470625/5261750). Some of the overlying beds are very hard, thick-bedded, sandy siltstone–silty sandstone similar to beds (Unit 3, Jago, 1966) occupying the same stratigraphic position below the Risdon Sandstone correlate and exposed in a quarry on Roberts Road (470400/5262800).

Talus obscures much of Unit 2 on Styx Road near the eastern boundary of the Maydena map sheet, but Unit 2 is exposed on the main spur roads to the south. Pebbly sandy siltstone, yellow coarse-grained siltstone and sandstone are exposed at 476575/5261075. Tough silty sandstone with pebbles and cobbles, thick-bedded sandy siltstone and fretting fissile siltstone are exposed at various localities on Styx Road, Jacques Road and in the bed of the Styx River in the down-faulted areas east of Gee Creek. Broken siltstone on Styx Road contains *Warthia micromphala* and *Myonia corrugata* (474740/5260400). Unfossiliferous, buff coloured coarse-grained siltstone with feldspar occurs 100 m to the northeast. Siltstone with some fenestellids occurs on Gee Road near the junction with Styx Road. Other exposures of siltstone and unfossiliferous to sparsely fossiliferous grey coarse-grained siltstone occur near the transmission line ford over the Styx River.

On the Skeleton map sheet Unit 2 is exposed on the spur road west of Gee Creek and on Ted Ransleys Road east of the fault, where fissile siltstone occurs about 20 m above the base of Unit 1. West of Snowy North Unit 2 contains *Sulciplica transversa* and *Atomodesma* (469750/5255650).

Member E (Unit 4)

Fossils become common near the top of the Minnie Point Formation correlate and, similarly to the Hobart and Cygnet areas, are most plentiful in the beds immediately beneath the Risdon Sandstone correlate. Fossils were found at this horizon on the spur southeast of Maydena (479975/5265975), in Haltons Creek, along the road east of Humboldt Creek and on the slopes above Routs Creek where *Terrakea*, very large *Tomiopsis* and *Etheripecten* are present.

On the Maydena Range fossils occur at the quarry on Roberts Road (470350/5263100), at the transmission line at the western end of the range (*Terrakea*, *Echinalosia*, *Sulciplica* and *Etheripecten*), on and near the transmission line about one kilometre west of the Pillinger Fault (*Tomiopsis isbelli*, *Undopecton fittoni*) and east of the main Pillinger Fault (*Fenestella*).

South of the Styx River fossils were found on an abandoned logging track (*Echinalosia ovalis*?, *Terrakea*, *Sulciplica*, bivalves) (476925/5261200), on Jacques Road (abundant *Terrakea*, *Sulciplica*, *Keeneia* and *Fenestella* (474875/5269000), at several localities east of Jacques Road (475600/5260300), beneath the transmission line east of Gee Creek, in Gee Creek (*Terrakea*, *Tomiopsis* and *Sulciplica transversa* (475300/5258300), west of Gee Creek (*Echinalosia ovalis* and *Tomiopsis isbelli*) (474950/5258450), on Ted Ransleys Road (*Terrakea*) and on the Snowy North walking track. Fossiliferous outcrop or loose boulders contain fossils at 477400/5261900.

The fossiliferous rocks range from well-sorted to moderately-sorted sandstone to coarse-grained siltstone. *Echinalosia ovalis* indicates a late Lymingtonian (faunizone 10) age.

Picton map sheet (JLE, CRC)

Rocks probably belonging to Unit 1 of the Minnie Point Formation correlate are well exposed in cliffy outcrops, up to ten metres high, alongside the Picton River between the contact with the dolerite (476600/5224400) to just below the Riveaux Road bridge (477600/5226800). These exposures consist of thick-bedded to massive, slightly glauconitic, feldspathic pebbly sandstone. Pebbles and sparse marine fossils tend to be concentrated into horizons. The pebbles are varied in composition, and include common quartz-feldspar porphyry, granite, and black slate. The uppermost few metres of these exposures consist of medium to coarse-grained pebbly feldspathic quartzarenite, free of glauconite. The quartzarenite is bioturbated in some beds, cross bedded in others. On the east bank of the Picton River (477300/5226800), very coarse-grained quartzarenite of the Risdon Sandstone correlate crops out about 25 m above this interval.

Similar outcrops occur along the West Picton Road (e.g. at the major creek at 475500/5224400) and in the lower reaches of creeks running east of Pear Hill. Small outcrops of greenish-grey to buff-coloured, gritty to pebbly, poorly-sorted sandstone at the confluence of the Huon and Picton rivers, and around the Tahune picnic area, are probably also Unit 1 of the Minnie Point Formation correlate.

Probably the same interval as in the cliffs along the Picton River is seen in the prominent cliff line that skirts the western ridge of Mount Picton (e.g. 465500/5221600). These cliffs expose about 15 m of thick-bedded to massive, brown-weathering, slightly glauconitic, pebbly, fine to medium-grained sandstone, which is better sorted and white weathering at the top. On the Picton map sheet, the top of unit Pun is drawn at the top of the cliff line. However, if indeed this interval corresponds to Unit 1, the top of the Minnie Point correlate lies some 25 m higher, at the base of a probable Risdon Sandstone correlate (see below).

An isolated outcrop of tough, medium-grey, thickly bedded, poorly-sorted pebbly sandstone/siltstone, probably Minnie Point Formation correlate, occurs as a window beneath dolerite talus in Codeine Creek (473100/5227200).

East of the Picton River, the unit is poorly exposed in weathered road cuttings along Arve Spur 2 as off-white to brown-stained, very poorly-sorted pebbly sandstone and soft argillaceous siltstone/mudstone. Clasts (up to 70 mm) in the sandstone beds are angular and include quartz and dark grey quartzite. Brachiopods and bryozoans are common, and fauna collected at 479200/5227330, about 60 m below the Risdon Sandstone correlate, is diagnostic of the unit (S. M. Forsyth, pers. comm.).

The base of the unit has not been observed in this area. Based on a thickness of about 90 m west of the Picton River, the lower contact with the Deep Bay Formation correlate would be expected to occur on Arve Road somewhere near or below Arve Spur 1 (479800/5228200). However nearby cuttings expose off-white to pale grey, argillaceous, massive to occasionally thin bedded, fine to medium-grained sandstone and siltstone. The rocks are neither pebbly nor fossiliferous. Occasional cross bedding was noted in thinly laminated fine-grained sandstone 50 m south of the start of the 'zig-zag walk' (479300/5227950). The stratigraphic assignment of these rocks is uncertain and they are shown as undifferentiated Lower Parmeener Supergroup on the Picton map sheet. Undetected faulting may be present.

On the Weld map sheet, a cliff line skirts the northern ridge of Mount Weld (464200/5240000 to 464300/5239400) at about 900 m altitude. This was not visited on the ground, but appears from the air to be a massive sandstone resembling the cliff line of Minnie Point Formation correlate west of Mount Picton. On the Picton map sheet, richly fossiliferous medium-grey fine-grained sandstone occurs at the base of a waterfall (474150/5224050), immediately below the Risdon Sandstone correlate. These beds probably correspond to units 3 or 4 of Jago (1972) and 'Member E' of the Malbina Formation of Banks and Read (1962), but the age of the fauna has not been determined.

Risdon Sandstone correlate (Pui)

The Risdon Sandstone is a thin, commonly cliff-forming, moderately well-sorted sandstone formation which is widespread in southern Tasmania. The sandstone lithology contrasts strongly with enclosing formations. In addition, underlying fossiliferous rocks, usually a richly-fossiliferous productid bed immediately beneath the Risdon Sandstone, provide a supplementary means to recognise the horizon. The Risdon Sandstone is an excellent 'marker bed'.

At Mt Nassau the Risdon Sandstone is a richly feldspathic fine to coarse-grained sandstone three metres thick (Banks and Hale, 1957). The formation varies in thickness around Hobart, but is rarely thinner and the maximum thickness reported is 7.7 m at Risdon Brook (Jennings, 1965) close to the type section. A few horizons or surfaces with common pebbles occur within the sandstone. Lamination is generally absent and signs of bioturbation can sometimes be seen.

In the Kingborough Quadrangle, the Risdon Sandstone is variable but generally tends to be thicker (2–8 m), coarser grained (commonly coarse sand to granule grade), more pebbly with basal and other lenses of conglomerate, and commonly contains beds with cross bedding (Farmer, 1985). Although variable, these changes become more pronounced to the south and west.

In the Maydena and Skeleton map sheets the Risdon Sandstone correlate is more like the formation at its type section, whereas in the Nevada, Weld and Picton map sheets the formation mirrors the changes near Cygnet and is coarser grained and commonly cross bedded.

On the Maydena Range the Risdon Sandstone correlate consists of well-sorted, buff, feldspathic sandstone 2.4 m thick, and is best exposed above the quarry on Roberts Road (Jago, 1972). The formation can be subdivided into two units. The lower unit is one metre thick and is much more pebbly and not as well sorted as the upper unit. The pebbles are mostly well-rounded quartzite, but slate, granite and schist occur. A few spiriferids and plant material are confined to the lower unit (Jago, 1972).

The Risdon Sandstone correlate was observed on some tracks and spurs east of Maydena township, but it seems to be obscured by talus on the Gordon River Road where only loose boulders were found below the road. It was not located in the Tyenna River and is probably faulted out along Haltons Creek. It crops out on the old Junee Road south of Maydena and was also observed on the HEC transmission line at the western end of the Maydena Range and upfaulted on a nearby shelf. Generally the sandstone is buff to white in colour, but near the transmission line southwest of Abbotts Lookout some of the associated sandstone is a similar olive green colour to that of the basal beds of the Minnie Point Formation correlate. This was the only locality where green sandstone was noted. The Risdon Sandstone correlate has a minimum thickness of 2.5 m in the southeast corner of the Maydena map sheet (478750/5260700). On Ted Ransleys Road the Risdon Sandstone correlate is fine-grained. Most Member E localities also expose Risdon Sandstone correlate.

On the Nevada map sheet Risdon Sandstone correlate was observed on a small shelf between Daves Creek and Wallaby Creek (478700/5240400) and north of the Little Denison Rivulet (477900/5241800). Risdon Sandstone correlate was also found a short distance east of the map boundary in the neighbouring

Lonnavale map sheet between Russell River and Denison Ridge.

Picton map sheet (JLE, CRC)

The Risdon Sandstone correlate is a useful marker horizon on the Picton map sheet, occurring as a unit about 10–15 m thick on the lower eastern slopes of Pear Hill.

In cuttings in the Riveaux Road 1.5 km ENE of Pear Hill (near 475200/5226350), deeply-weathered, very pebbly, poorly-sorted sandstone contains fairly abundant quartz and quartzite pebbles up to 40 mm across. The base of the unit in the road section is obscured by dolerite talus, but up-section the unit becomes better sorted and cross bedding is present. The unit passes upward into pebbly brown weathered siltstone assigned to the Abels Bay Formation near 475000/5226400.

The unit is also exposed in waterfalls in a small creek 1.5 km further south (near 475100/5224800) where it consists of medium to coarse-grained, relatively well-sorted off-white quartz sandstone, interbedded with minor, less resistant, orange-brown weathering siltstone.

In a larger creek further south, very pebbly, poorly-sorted sandstone, probably the base of the Risdon Sandstone correlate, forms the top of a major (20 m) waterfall at 474150/5224050. As noted above, the richly fossiliferous uppermost beds of the Minnie Point Formation correlate occur at the base of the waterfall. Richly fossiliferous, poorly-sorted fine-grained sandstone crops out in another smaller waterfall about 180 m above the main falls. This outcrop is tentatively assigned to the Risdon Sandstone correlate, although elsewhere (e.g. Farmer, 1985) the unit is poorly fossiliferous. The first outcrop of fairly unequivocal Abels Bay Formation in this creek is in a spectacular 15 m high waterfall at 473850/5223950. Boulders of very coarse-grained pebbly Risdon-type sandstone were noted in a southern branch of this creek (474500/5223300) but no definite outcrop was located.

Recent roadworks have exposed the Risdon Sandstone correlate on a small spur above the West Picton Road (475900/5224000). The Permian sequence is abruptly truncated by a major transgressive intrusion of Jurassic dolerite immediately southeast of this locality.

East of the Picton River, the Risdon Sandstone correlate is well exposed in cliffs immediately below the East Picton Road (477350/5226800). About one kilometre to the northeast (near 478000/5227800), in cuttings on the Arve Road and in an adjacent gravel pit, mostly deeply weathered and friable, medium to coarse-grained, very pebbly, poorly-sorted sandstone contains rounded to angular clasts of quartzite and other Proterozoic rock types. Risdon Sandstone correlate is probably also present in the same stratigraphic position near 476800/5225000, but this has not been confirmed in the field.

These outcrops of the Risdon Sandstone correlate east of the Picton River lie at an elevation of 70 to 80 m, well below the 160 to 180 m elevation of the unit about 1.5 to 2 km away, west of the Picton River. Although the rather sparse bedding readings provide some evidence for an overall easterly dip, it seems insufficient (5–7° required) and too inconsistent to account for this difference. Accordingly an east-side-down fault in this area is tentatively suggested.

The Risdon Sandstone correlate also forms a conspicuous marker horizon near the eastern margin of the Picton map sheet, east of the narrow and tapering dolerite dyke extending north of Loop Hill. The unit here lies at an elevation of about 320 m, suggesting that this block of Parmeener Supergroup rocks has been uplifted about 250 m by an underlying dolerite sill terminating at the dyke. It is most easily examined at the start of Arve Loop Spur 5 (480000/5226200) where there are large boulders and sub-outcrop of pale grey to white or occasionally brownish, thinly bedded, fine to coarse-grained sandstone with some cross bedding, and minor interbedded brown mudstone. On the northwest side of a low saddle, the unit is indicated by coarse-grained sandstone float (479250/5226720) and a slight break of slope.

The Risdon Sandstone correlate was not differentiated west of Mount Picton. A two metre thick unit of very coarse-grained quartzarenite and granule conglomerate, cross bedded in places, occurs about 25 m above the top of the cliff section between 465600/5221500 and 465300/5221000 and probably correlates with the lower part of the Minnie Point Formation. This is a probable correlate of the Risdon Sandstone.

Abels Bay Formation correlate (Pub)

The Abels Bay Formation is defined near Cygnet where it overlies the Risdon Sandstone and consists of alternations of thin to medium-bedded, poorly-sorted, pebbly fissile and non-fissile fine-grained sandstone and sandy siltstone (Farmer, 1985). Bioturbation is common at many intervals, but shell fossils are uncommon throughout the formation. The uppermost interval (6.4 m) consists of dark grey, carbonaceous mudstone with occasional siltstone bands and convolute lamination. The Abels Bay Formation is overlain by the Cygnet Coal Measures (Farmer, 1985). The Abels Bay Formation is 145 m thick in its type section, but may be up to 175 m thick elsewhere (Farmer, 1985).

The Abels Bay Formation passes laterally into the Ferntree Mudstone (185 m), which was defined without a strato-type and consists of interbedded fissile and non-fissile siltstone (Banks and Hale, 1957). The top beds of the Abels Bay Formation have commonly been excluded from sequences mapped as Ferntree Mudstone and this appears to be the case with the previous mapping at Maydena (Jago, 1972).

Excluding these top beds, the Abels Bay Formation correlate in the Maydena Range area is, for the main part, the same as the Ferntree Mudstone (Jago, 1972). It is probably 140–150 m thick (Jago, 1972). In the southeast corner of the Maydena map sheet the formation is about 160 m thick. Intervals from near the base and top of the formation, from either side of the Pillinger Fault, have been described on Roberts Road (Jago, 1972). The basal ten metre interval was described as thin to medium-bedded (300–450 mm), poorly-sorted dark grey sandstone. Above this, subordinate siltstone beds (100–150 mm) start to appear and then alternate with the sandstone through to the top of the next 25 m interval. Lonestones to 300 mm become more prominent 27–35 m above the base (Jago, 1972). In the top 60 m interval, interbedded sandstone and siltstone is pale grey and weathers to a buff colour. Lonestones persist, but are less common (Jago, 1972). Jago excluded from the 'Ferntree Mudstone' an interval 4.4 m thick consisting of thin-bedded (100 mm), well-sorted, very micaceous carbonaceous fine-grained sandstone with quartz sandstone stringers, clay pellets, abundant plant fragments and common worm tubes, and instead correlated the interval with the Cygnet Coal Measures. These rocks were less well exposed in 1996, but appeared to be comparable to transitional intervals at the top of the Lower Parmeener Supergroup that are widespread in Tasmania (Forsyth, 1989*b*). The interval has been included in the Abels Bay Formation correlate.

In the Styx Valley in the neighbouring Uxbridge map sheet area to the east, the uppermost beds of the Abels Bay Formation correlate become increasingly carbonaceous and dark grey in colour as the top of the formation is approached. There is a corresponding decrease in bioturbation and a decrease in the proportion of pebble and sand-grade clasts. Siltstone beds, some with agglutinated foraminifera, initially persist into an interval in which siltstone and sand laminae appear, while some thin to medium-bedded, soft, very fine-grained micaceous sandstone is interbedded higher in the sequence.

The Abels Bay Formation correlate forms outcrops of medium grey, coarse-grained siltstone in the Tyenna River downstream from Haltons Creek and is distributed through surrounding areas. On the Gordon River Road it forms alternations of medium-bedded massive silty sandstone and fissile siltstone (472925/5269000). The formation is exposed on the transmission line tracks and on the access road to Abbotts Lookout on the Maydena Range. Bioturbated siltstone occurs at and near the transmission line pylons at 467550/5261525 and some spheroidal weathering was noted in beds above the Risdon Sandstone correlate.

On the southern side of the Styx Valley exposures in road cuttings and in areas stripped of soil occur on Ted Ransleys Road, west of Gee Creek and northeast of the Pillinger Fault, Gee Creek Road along the transmission line, and on Jacques Road and various spur roads. In the southeast corner of the Maydena map sheet, approximately 100 m above the Risdon Sandstone correlate near 478600/5261500, occurs conspicuous cliff-forming, fine-grained sandstone that contains granule layers and a conglomeratic layer with pebbles and cobbles. Near the top of the formation the highest siltstone with pebble lonestones contains large agglutinated foraminifera near 479725/5261000. Fine-grained sandstone and shaly sandstone approximately 13 m higher is considered to occur within the overlying correlate of the Cygnet Coal Measures. Grey micaceous siltstone occurs to the northeast (near 479925/5261225) and is considered to occur within the transitional beds at the top of the Abels Bay Formation correlate.

Similar laminated siltstone occurs in the west branch of Gee Creek (473750/5255975). At two separate localities an unusual lithology that superficially resembles Upper Parmeener sandstone was noted apparently interbedded with typical glaciomarine strata several tens of metres below the top of the Abels Bay Formation correlate. In hand specimens the green sandstone consists of well-sorted fine to medium-grained quartz sand with 30% euhedral feldspar and exhibits rare mud-defined bioturbation.

An interval of 140–160 m of Abels Bay Formation correlate occurs at Denison Ridge on the Nevada map sheet . The underlying Risdon Sandstone correlate was not found in Falls Rivulet, but occurs on the northeast side of Denison Rivulet in the neighbouring Lonnavale map sheet. The nature of the contact between the Abels Bay Formation correlate and Upper Parmeener Supergroup rocks on McDougalls Road is uncertain, but some beds similar to the top beds of the Abels Bay Formation are present. An interval near the top of the Abels Bay Formation correlate that contains dark grey carbonaceous siltstone is well exposed in the upper reaches of the Little Denison River. However the dip of the beds is very similar to the average stream gradient and the boundary with the Upper Parmeener Supergroup is not exposed.

Along the eastern boundary of the Weld map sheet, on the slopes of Barn Back, the Abels Bay Formation correlate is an estimated 160–210 m thick. The formation also occurs on Edwards Road, in the Huon River and on the southern slopes of Weld Ridge.

No shelly fauna was found in the Abels Bay Formation correlate, but elsewhere late Lymingtonian faunas are present (Clarke, 1989).

Picton map sheet (JLE, CRC)

The formation is an estimated 160 m thick on the western slopes of Mount Picton. East of the lower Picton River, the Abels Bay Formation is about 170 m thick. Outcrops on Arve Road, west of the dolerite dyke (478900/5227900), are medium to dark grey but paler weathering, poorly-sorted, variably pebbly siltstone and fine-grained sandstone. Similar rock types sporadically crop out to the south along East Picton Road, its spur roads and in adjacent creeks. Well-rounded siliceous clasts up to a few centimetres diameter are occasionally present, but more typically clasts are smaller and angular. Pebble-sized granite clasts and smaller angular quartz clasts were noted in a minor creek at 478500/5227200. No fossils were noted but bioturbation is common. The unit is usually medium to thick-bedded in this area, but there are some thinner bedded shaly intervals.

The lower part of the unit is sporadically exposed along the Arve Loop and adjacent spur roads east of the dolerite dyke. Perhaps the best exposure at the start of Spur 6 (479650/5220350) is a massive to rather thinly bedded, flaky to cuboidal, medium to dark grey paler weathering siltstone. In this area northeast of Loop Hill, the upper part of the unit is absent due to the dolerite intrusion and/or obscured by talus, the extent of which has not been mapped in detail.

Few traverses were done in the Abels Bay Formation west of the Picton River, where its top is probably concealed beneath dolerite talus, the depicted extent of which is approximate. The unit rests on the Risdon Sandstone correlate at 474900/5224900 in a creek section southeast of Pear Hill. The lower 80 m or so of the unit is sporadically exposed and consists of uniformly dark to medium grey, rather massive, tough, bioturbated but apparently unfossiliferous siltstone. It is less sandy than the Minnie Point Formation correlate and has fewer clasts. South of Pear Hill, the lithologically similar basal beds of the unit are exposed in a 15 m high waterfall (473850/5223930), just above a creek junction.

Weathered float of pale grey argillaceous, variably pebbly siltstone and sandstone, noted on the ENE shoulder of Mt Riveaux, is tentatively correlated with the Abels Bay Formation.

Upper Parmeener Supergroup

In the Maydena, Skeleton, Nevada, Weld and Picton map sheets the Upper Parmeener Supergroup consists of:

- a lower unit of freshwater cross-bedded feldspathic sandstone, micaceous siltstone, carbonaceous beds and coal lenses that is correlated with the Cygnet Coal Measures; and
- an upper unit dominantly of freshwater, cross-bedded quartzose sandstone and subordinate micaceous siltstone and mudstone that is correlated in part with the Ross Formation.

The Upper Parmeener Supergroup is exposed mostly as a band between exposed Lower Parmeener Supergroup rocks and overlying dolerite that caps the mountain ranges. On the Maydena Range the distribution is confined to east of the Pillinger Fault. On the southern side of the Styx Valley, the band extends west from Mount Styx and crosses the extension of the Pillinger Fault system. It then extends across the northern side of Snowy North and wraps around the western side of the Snowy Range at an altitude in excess of 850 metres.

East of Snowy North the Upper Parmeener rocks cross the watershed into the headwaters of the Russell River and outcrops continue intermittently, mostly between Dolerite Road and Russell Road in a sequence that lacks surface exposures of the underlying Lower Parmeener. Upper Parmeener rocks are directly in contact with an underlying dolerite intrusion in some areas east of the Snowy Range in the Nevada map sheet. On the Weld map sheet the Upper Parmeener rocks are exposed on the western slopes of Barn Back. No outcrops are known from the Weld Range, but a thin interval of the Upper Parmeener Supergroup could be present immediately beneath the dolerite. A thin interval occurs beneath dolerite on the western side of Mount Picton and similarly northwest of Loop Hill east of the Picton River. Upper Parmeener Supergroup rocks also occur northeast of a fault on Edwards Road.

Cygnet Coal Measures correlate (Pwtq)

Some rocks previously mapped as Triassic sandstone and siltstone (Jago, 1972) have been reassigned to the Cygnet Coal Measures correlate. These rocks were previously correlated (Jago, 1972) with the Barnetts Member of the Springs Sandstone. The Barnetts Member, in its type section, was subsequently found to be redundant as it was the close lateral equivalent of the productive Cygnet Coal Measures (Farmer, 1985).

Jago (1972) described the basal 15 m interval exposed on Roberts Road as predominantly feldspathic sandstone containing plant fragments and other carbonaceous matter. A thick (600 mm) bed of well-sorted quartz sandstone occurs one metre above the base and rip-up clasts to small boulder size of micaceous, carbonaceous siltstone occur 4.3 m above the base. Cross bedding indicates currents from the north, southwest and south (Jago, 1972). These rocks are included in the Cygnet Coal Measures correlate. Unfortunately the overlying 30 m interval is not exposed on Roberts Road.

The next strata exposed in this section occur in Pillingers Creek about 45–54 m above the Cygnet Coal Measures correlate and consist of "fine-grained slightly micaceous siltstone associated with beds of micaceous sandstone up to 75 cm across…The sandstone weathers to a greenish colour. The siltstone is pale brown and has rather fissile bedding. Some beds contain many unidentifiable plant fragments" (Jago, 1972). Re-inspection of these beds found no features which would necessarily suggest their exclusion from the dominantly quartzose sandstone sequence above the Cygnet Coal Measures correlate.

Outcrops of feldspathic sandstone occur north of Marriotts Lookout immediately east of Canaways Creek. Boulders of feldspathic sandstone were found in Quaternary talus further west, but the lowest bedrock exposed above the Lower Parmeener was cross-bedded quartzose sandstone assigned to rocks above the Cygnet Coal Measures correlate. Cliffs of cross-bedded quartzose sandstone to the north of Lorkins Lookout exhibit overturned cross bedding structures and occur 20–30 m above Lower Parmeener rocks. Although the Cygnet Coal Measures correlate does not crop out, it is considered to be constrained to be within this 20–30 m interval which is taken as indicative of the formation thickness.

Between Haltons Creek and Marriotts Creek and 100–200 m north of the Maydena map sheet boundary occurs feldspathic sandstone that contains pieces of carbonaceous matter and moulds and casts of plant debris. These rocks are also referred to the Cygnet Coal Measures correlate and are associated with loose boulders of coarse-grained quartzose sandstone, probably derived from the overlying unit.

In the Styx Valley the Cygnet Coal Measures correlate was observed near the eastern boundary of the map sheet as fine-grained sandstone and shaly sandstone (479800/5261000 and near 479010/5262800), south of Marriotts Lookout (474900/5263150) and possibly at a low cliff of flaggy, very fine-grained sandstone (473500/5262000).

The best outcrops occur on new logging roads off Jacques Road where a section of road extends across the Abels Bay Formation/Cygnet Coal Measures boundary near 476575/5258950. Typical glaciomarine siltstone beds with quartz granules and bioturbation are overlain by a transitional interval (4–5 m) of banded and striped grey and brown weathering micaceous carbonaceous siltstone that is bioturbated near the base. The overlying Cygnet Coal Measures correlate consists of feldspathic sandstone that contains some lenses of quartz pebbles and granules and beds of coaly matter 100 mm thick.

A second section further west on the same road is disrupted by faults that may cause repetitions of some beds. North from 475800/5257500 sandstone (0.6 m) is overlain by very thin-bedded siltstone (3–4 m) followed by sandstone (0.6 m) and then similar very thin-bedded siltstone. Near a breccia of carbonaceous grey siltstone, similar to the transitional zone at the top of the Abels Bay Formation correlate, occurs a fault followed by grey siltstone (4 m) with soft sediment deformation. This siltstone appears to be faulted against feldspathic sandstone (3 m) overlain by very thinly-bedded siltstone (3–4 m) which passes up into interbedded sandstone and very thin-bedded siltstone (3 m) and then further very thin-bedded siltstone (2 m) that contains a coal seam (150 mm) at the top. The coal is overlain by cross-bedded sandstone (2 m) laminated to thin bedded grey siltstone with some soft sediment slump features and then sandstone (6–8 m) which is coarse-grained at the base. Beyond a gap, further feldspathic sandstone and coal occur close to a fault which uplifts glaciomarine beds.

It was not possible to depict fine detail on the compiled map. The dolerite intrusion shown south of this section intrudes the Abels Bay Formation correlate on the eastern side and not Cygnet Coal Measures correlate as depicted. The Abels Bay Formation correlate east of the intrusion is probably faulted against steeply-dipping laminated black shale at the turning circle at the end of the road, but the latter disappears below a three metre thick Quaternary slope deposit.

Abundant floaters and some outcrops of micaceous siltstone and micaceous feldspathic sandstone on the ridge between Gee Creek and the western major branch of Gee Creek could be referred to the Cygnet Coal Measures correlate, but coarse-grained sandstone with granules and small pebbles of feldspar and quartz to 6 mm that occurs near a fault is of uncertain structural position. Consequently these rocks have been depicted as undifferentiated Upper Parmeener Supergroup. Carbonaceous calcite-cemented concretions were found higher on the same ridge (474975/5257800). These are similar to concretions found in equivalent rocks in the Oatlands area (Forsyth, 1984). Fine-grained feldspathic sandstone and micaceous siltstone occur near the drainage divide between the Styx and Russell river valleys.

Feldspathic sandstone occurs near the 420 m contour on Denison Road near the southeast corner of the Nevada map sheet, but no boundary between overlying quartzose sandstone could be established and the rocks have been depicted as undifferentiated Upper Parmeener.

West of Mount Picton (466800/5221200), a stratigraphic thickness of about 25 m of Cygnet Coal Measures correlate occurs between the Abels Bay Formation correlate and the base of the dolerite sheet. This is predominantly fine-grained, slightly feldspathic quartzarenite. The rock is mostly plane-laminated, but there is some cross bedding. There is minor, very coarse-grained quartzarenite with sparse small pebbles of vein quartz. Sparse, small angular fragments of dark silicified peat are present as float (CRC).

No new evidence of age was found, but elsewhere fossil flora and microflora indicate a Late Permian age for the correlates of the Cygnet Coal Measures.

Quartz sandstone sequence (Trqp)

The section described by Jago (1972) on the northwestern side of Abbotts Lookout is the only measured section through the quartz sandstone unit (Trqp). The base of the unit is ill-defined, but may occur midway through a 30 m gap above the exposed Cygnet Coal Measures correlate or perhaps 15–25 m higher above an interval (9 m) with fragmentary fossil plants. Above the latter zone occurs a further 55 m gap in outcrop but float material suggests the presence of well-sorted sandstone through most of the interval (Jago, 1972). About 55% of the overlying sequence is exposed and consists predominantly of sandstone, including continuous intervals of 30 m and 75 m thickness. Some pale brown well-sorted micaceous siltstone (6 m) and very micaceous dark carbonaceous siltstone occurs in the interval between the two thick sandstone intervals, but the proportion of siltstone could be considerably higher, as 43 m of the interval is not exposed.

The 75 m sandstone interval exhibits cross bedding and a marked decrease in bed thickness from up to 600 mm near the base to 30–50 mm near the top. The sandstone is feldspathic and becomes increasingly so up the interval and some beds are very micaceous. The top bed contains 60% quartz, 10% plagioclase and ferruginous clay matrix and occurs 30 m below the lowest dolerite outcrop (Jago, 1972). The top bed may be from 230–250 m above the Cygnet Coal Measures correlate.

Based on the lithologies seen at other localities near the base of the unit Trqp and on the published description (Jago, 1972), the Trqp unit at Abbotts Lookout can be correlated with the Trp unit mapped in the Oatlands Quadrangle (Forsyth, 1984) and the Ross Sandstone at Poatina. The lithology of the top bed is similar to some ferruginous matrix-rich sandstone that occurs in unit Trm overlying Trp in the Oatlands Quadrangle, but the absence of interbedded siltstone and mudstone does not suggest correlation with Trm. An inspection of the sandstone saddle between Abbotts Lookout and Marriotts Lookout appeared to confirm the absence of siltstone and mudstone. A northeasterly-directed palaeocurrent vector for one sandstone bed in the saddle was determined from festoon current bedding.

Palaeocurrents determined from cross-bedded sandstone north of Lorkins Lookout (476650/5269200) are towards the northeast and east.

The mapped boundaries of unit Trqp are generally poorly-defined and seldom based on traverses. The lower boundary has usually been drawn based on extrapolation from the position of Lower Parmeener horizons and sandstone bedding traces visible on aerial photographs. The upper boundary is largely aerial photo interpreted, but was traversed in a few areas. A magnetometer was used in an attempt to better define the upper boundary of unit Trqp where it was in contact with dolerite on some tracks, but poor orientation of the tracks commonly led to difficulties in interpretation of the data.

All areas mapped as Trqp within one kilometre of the eastern boundary of the Maydena map sheet are based on ground inspection. Areas depicted as Trqp along the southwestern side of Lorkins Lookout are based on aerial photo interpretation combined with binocular observation from the south side of the Styx Valley. The extension of Upper Parmeener Supergroup rocks through the saddle between Lorkins and Marriotts lookouts is entirely based on aerial photo interpretation. The extremity of the long sandstone ridge that extends from Abbotts Lookout was visited.

On the northern side of Mount Styx, in the Skeleton map sheet, Trqp was observed on some tracks near the transmission line and on some short traverses away from the track verges. The ridge to the west of Gee Creek was inspected as far south as a sandstone shelf, which had very deep, narrow and hazardous fissures (475900/5256100). Unit Trqp was observed northeast of Snowy North (473600/5256100) and on the Snowy North walking track, but all other areas mapped along the western side of the Snowy Range were interpreted from aerial photographs, except for the area immediately west of Scrivens Cone and Wet Pants Peak which was ground inspected. The distribution northwest of Snowy North was partly supported by blocks of quartz sandstone in slope deposits below the Risdon Sandstone. The areas mapped near Dolerite Road and Russell Road were mapped in more detail. The small areas on the eastern side of the Snowy Range (Nevada map sheet) were also ground inspected, but the larger area of undifferentiated Upper Parmeener Supergroup rocks west of Compton Hill was inferred based primarily on vegetation type.

Some areas of shaly siltstone interbedded with sandstone were found west of Compton Hill (476800/5246700), and along the track from McDougalls Road (474100/5251300, 474300/5253200 to 474300/5253600) towards the upper Russell River. Siltstone occurs high on Nevada Peak (E. B. Corbett, pers. comm., 1996) (471100/5248300).

No fossils were found in the quartz sandstone sequence (Trqp), but elsewhere similar rocks contain Early Triassic microfloras and vertebrate faunas (Forsyth, 1989*b*).

Upper Parmeener Supergroup (undifferentiated) (Tr) (CRC, JLE)

A new spur road off Edwards Road, in the northeast corner of the Picton map sheet (479800/5229400), has exposed coarse to fine-grained quartz sandstone and siltstone. Cross bedding is present in some beds. Horizons rich in platy claystone intraclasts are present, and there are minor beds of pale grey shale or claystone.

Cliff exposures of quartz sandstone (probably assignable to Early Triassic unit Trqp) were also noted in the upper reaches of a creek northwest of Loop Hill on the Picton map sheet (478100/5224600).

Quaternary deposits

Dolerite topples (Qptf)

Dolerite topples on the north side of Mount Picton consist of large masses of dolerite with columnar jointing, previously vertical, now plunging shallowly south, indicating large-scale undermining and downslope rotation.

Deeply weathered dolerite boulder deposits including till (Qpdb)

These deposits are marked by collections of large (1–5 m) dolerite boulders at several places along the Huon River between Blakes Opening and Tahune Bridge.

These boulders lack the angular joint-bounded shapes of younger talus and till deposits such as Qpgm. In contrast, boulders exhumed by recent riverine erosion are smoothly rounded and scalloped, indicating a long history of *in situ* chemical weathering since deposition. Dolerite boulders still embedded in clayey matrix have thick weathering rinds. These deposits are probably tills that belong to the penultimate or earlier glacial age (Colhoun and Goede, 1979).

Similar weathered dolerite boulders occur in the Snake River (western Nevada map sheet) at 461400/5243400, and may be an erosional remnant of pre-Last Glacial till.

A deposit of extremely weathered small dolerite boulders in a clayey matrix is exposed in a road cut west of Compton Hill in the Nevada map sheet (476800/5246700). The deposit overlies Upper Parmeener shale, the top layers of which are broadly folded and disrupted. In some places a thin breccia of Upper Parmeener clasts occurs beneath the dolerite boulders. The weathered dolerite deposit is overlain by more recent dolerite talus with hard rocky clasts.

Weathered till (Qpgw)

An area between Mt Riveaux and the Huon River (471500/5227000) is characterised by surface float of varied sources (Proterozoic quartzite and quartz, Parmeener Supergroup, Jurassic dolerite) and a lack of bedrock outcrop despite dissection by small modern streams. A recent road cutting at the eastern edge of this area exposed a weathered open-framework diamicton, probably till, consisting of pebble to boulder-size clasts of quartzite, chert, lithic sandstone (Cambrian?), Jurassic dolerite, and Parmeener Supergroup sandstone, in an abundant clay matrix. The weathering rinds on the dolerite clasts are about 50 mm thick.

Till of undissected moraines (Qpgm)

Most of these deposits were differentiated on geomorphic grounds to include the well-defined moraine ridges flanking small cirques and glacial valleys on the Snowy Range, Weld Ridge, Gallagher Plateau and Mount Picton. Except for the Gallagher Plateau moraines, which are inferred to be composed of quartzite, the moraines consist predominantly or entirely of dolerite boulders, and are indistinguishable from the more widespread talus deposits (Qpt).

The walking track to Lake Skinner passes through an area of very large and isolated dolerite boulders that have also been included in Qpgm (474400/5245300). Between the boulders the ground surface is covered by much smaller dolerite fragments and rare hornfels clasts that become more common east of the boulders. The deposit may be older than the well-formed lateral moraine flanking Lake Skinner.

South of Woolleys Tarn some of the deposits contain small mudstone clasts that may be derived from Upper Parmeener rocks closer to Nevada Peak. An area east of The Wart, depicted as an undifferentiated Quaternary deposit, has a hummocky appearance on aerial photographs and may be moraine derived from Upper Parmeener Supergroup sandstone (470500/5249000). A single ridge-like feature in the Snowy North area has been interpreted as a moraine (472750/5256000).

Last-glacial effects on the Jubilee Range are relatively minor because of its relatively low maximum altitude (c. 1000 m). A small pro-talus rampart, one to two metres high and 200 m long, trends SW–NE in the lee of a quartzite cliff at 463300/5251300.

Periglacial non-vegetated scree deposits (Qptnv)

These deposits have been mapped entirely by aerial photo interpretation. They are particularly well displayed on the higher parts of the Snowy Range near Nevada Peak, between 1100 and 1300 m altitude on slopes with northerly through westerly to southwesterly aspect. The deposits appear to consist of large dolerite boulders with no near-surface matrix and are commonly associated with areas interpreted as dolerite fragmented by periglacial processes. The latter areas are distinguished from the former by a more intimate association with boldly outcropping dolerite, their less uniform surface topography, and lack of features, suggesting transport or flow of materials.

South from Nevada Peak, along the western shoulder of the Snowy Range, the deposits descend to lower altitudes (820 m) primarily as rock debris chutes and possibly as direct fall cliff debris. Similar deposits may be hidden by some of the nearby scrubby vegetation. The higher deposits may be of similar age to the well-preserved moraine features on the eastern side of the Snowy Range, whereas the origin and age of some of the lower deposits may be more varied.

Talus (Qpt)

Talus is the most widespread deposit of Quaternary age on the map sheets. Most areas which are capped by a dolerite sheet and are of moderate height have extensive downslope deposits of dolerite talus. These deposits may grade into moraine on the highest mountains or downslope they may incorporate other rocks types and gradually change to a deposit of mixed composition or grade into fan deposits partly deposited from water. Some talus deposits are derived from rock types other than dolerite and a variety of talus types, based on provenance, are depicted on the maps. Clasts in the talus may provide the only indication of the presence of some rock types in some areas where bedrock is not exposed.

The reliability of talus mapping is very variable as it includes ground-mapped talus, aerial photo interpretation and inferred deposits. Depiction of talus deposits may also be influenced by deposit thickness, the amount of protruding bedrock and preferential depiction of important underlying rock types. Many deposits of limited distribution have been omitted as there were insufficient data to interpret boundaries around the deposits or because there was insufficient contrast with bedrock lithologies to conveniently demonstrate significant transport of clasts. In this respect dolerite talus over Parmeener or older rock types is usually preferentially depicted, as the clasts are commonly larger and transport is readily recognised. In general the omission of talus from the map does not indicate the absence of deposits.

In places, talus derived from dolerite has been depicted as a fringe beside upslope dolerite areas. Where information is more complete the talus commonly occurs as broad tongues that descend to much lower altitudes. Jago (1972) described a deposit of this type that descended into Risbys Basin from Abbotts Lookout, a lateral distance of over two kilometres through a vertical height of 500 metres. Jago (1972) noted clasts to 1.5 m diameter in a weathered dolerite-derived matrix and a unit thickness of seven to eight metres in Pillingers Creek. The thickness is around four metres nearby on Roberts Road. Similar and larger scale deposits occur west of Maydena and at other places in the Maydena Range. Some deposits are of more local derivation, for example Lower Parmeener Supergroup sandstone boulders to 1.5 m diameter mixed with some dolerite clasts occur in Routs Creek (447610/5259900).

Talus deposits containing boulders of Upper Parmeener quartzose sandstone are also present in the Maydena Range and Styx Valley. Mixed deposits with sandstone and dolerite clasts occur in places such as north of Lorkins Lookout. Some sandstone clasts are many metres across, and boulders up to five metres in size occur near the transmission line (472100/5261100).

In the Styx Valley, near the eastern boundary of the Maydena map sheet, unmapped deposits of talus are common along Styx Road. The deposits range from 1.5 to four metres (rarely five metres) thick and contain angular blocks of rock mostly derived from the Abels Bay Formation. In places larger boulders of sandstone are more commonly derived from the Risdon Sandstone. The matrix is usually cream or grey coloured and consists of mixtures of silt, sand, clay and small rock particles.

Large boulders of Minnie Point Formation correlate and similar rocks were found in and near (south of) the channel of the Styx River not far from a potential source area on the northern side of the river. The initial transport mode is uncertain, but the boulders may have rolled individually, or they may be the lag of river-eroded talus, landslide or mudflow debris. A four metre diameter boulder was found resting on alluvium in a tributary creek (478825/5261600). Upstream in the Styx River a talus deposit of angular clasts has been depicted on the map (478500/5262400). Abundant Lower Parmeener boulders of two metre diameter occur nearby in the river channel, in places stacked on top of each other.

Some very large masses of dolerite may be incorporated in some slope deposits that may be of landslide origin. North of Snowy North a ridge of dolerite several hundred metres long, lying across the slope, is separate from upslope dolerite and may be topographically lower than the local dolerite base. Whether this dolerite has been down faulted, transported or is purely an erosional feature is uncertain. A smaller mass on Roberts Road near Abbotts Lookout could be an unmapped dyke or irregularity in the dolerite sheet base, a fault sliver, or a landslide block-failed mass.

Old landslide features in dolerite-derived talus occur on the eastern side of the saddle between Snowy North and the Mount Styx plateau.

A large area of dolerite talus has been depicted east of the northern part of the Snowy Range in an area with an unusual terraced morphology. No conclusive evidence of rock type was gathered for this area, which could be underlain by either Jurassic dolerite or Upper Parmeener sandstone. Dolerite boulders were found on the eastern margin and none of the creeks draining the area were found to contain sedimentary rock clasts or quartz sand. Airborne magnetic survey maps do not indicate any high amplitude or short wavelength anomalies of the type normally characteristic of thick Jurassic dolerite intrusions except associated with some of the dolerite outcrops along the crest of the range. The necessity for aircraft ground clearance to fly over the range could play some part in this.

There is a general displacement of the relatively uniform gradient of the magnetic field developed on Proterozoic rocks west of the Snowy Range to more positive values in this area of shelf morphology, which could indicate the presence of thin dolerite.

The non-committal approach of inferring talus cover over inferred benched sandstone has been adopted, but the benching may also be related to horizontal jointing in dolerite or some particular geomorphological process.

The area depicted as dolerite talus east of Lake Skinner presented a similar problem. There are no areas which can convincingly be interpreted as dolerite outcrop visible on aerial photographs between the dolerite that forms the top of the Snowy Range and dolerite and sandstone areas lower on the range. The presence of hornfels float east of Lake Skinner indicates that erosion has penetrated completely through the dolerite in some areas. The magnetic map generally lacks anomalies that might suggest underlying dolerite, but some neighbouring areas with dolerite outcrop have a similar magnetic field. Talus has been depicted in this area, particularly where the relief of the interfluves is not marked. Talus between McDougalls Road and Denison Ridge could indicate that the talus slope was continuous from there to Lake Skinner, but the mapping undertaken and the magnetic map do not support this.

Dolerite and other talus deposits are particularly extensive around Mount Weld and Weld Ridge. Some deposits extend five kilometres from the source and descend to below 200 masl.

In addition to the generally coarse deposits, weakly stratified fine gravel and sand occurs at 472700/5235300 (Weld map sheet), and in the Styx Valley talus deposits include fine-grained gravel of siltstone pieces.

Siliceous lag and colluvium (Qss) (Weld map sheet)

Deposits of siliceous lag and colluvium, derived predominantly from silicified Proterozoic and Cambrian rocks, were mapped near the Forster Prospect (478200/5233700), east of Hogsback Hill (478300/5235000) and near Eddy Creek

(476500/5237300) in the eastern part of the Weld map sheet. Deposits in the Forster Prospect–Hogsback Hill area were mapped from float of angular quartz fragments of varied texture (massive fine-grained quartz; boxwork quartz; coarsely crystalline quartz; opal) derived from unit Pwtq and the 'silica-clay zone' (see previous section). The deposit east of Hogsback Hill was mapped mainly from the occurrence of clay in shallow drill holes, and is at least 15 m thick (Carthew *et al*., 1988). Drilling also shows that this deposit overlies Jurassic dolerite north of Hogsback Hill.

Siliceous lag and colluvium including silica flour (Qs) (Maydena map sheet)

Surficial deposits of angular quartz gravel, sand and silt, including silica 'flour', occur in the western part of the Maydena map sheet. These appear to be residual deposits derived from deep leaching of partly silicified or cherty dolostone of the Cambrian unit Ccwd.

The largest area of Qs, just east of Pine Hill (466000/5263800), is of economic interest (Calver *et al*., 2006). Pits excavated in the eastern part of this deposit expose several metres of unbedded, white quartz sand and silt with dispersed angular fragments of quartz. Lower parts of some exposures are stained orange-brown with iron oxides. Quartz fragments are texturally uniform or show boxwork structure. Some fragments of fine-grained quartz have an oolitic texture, probably due to replacement of an oolitic carbonate precursor. Large masses (>2 m) of similar quartz are present around the crest of the hill at 466000/5263800, and may be bedrock outcrop of silicified carbonate.

A drill hole within this area (Styx 4; 466600/5263750) intersected dolostone basement at a surprisingly deep 55 metres. Little core was recovered from the overlying deposit, but this appears to consist of predominantly quartz sand with some transported gravel and clay.

Alluvial gravel, sand and clay (Qa, Qaf, Qpao)

Alluvial gravel, sand and clay has been depicted (Qa). In some areas alluvial fans (Qaf) and alluvial terraces (Qpao) have been differentiated.

Downstream from Maydena the gradient of the Tyenna River increases in the Lower Parmeener terrain. Accompanying alluvial deposits about two metres thick are exposed in the river banks and in some railway cuttings. The deposits consist of small boulders, cobbles and pebbles overlain by finer deposits. Clasts are mostly of dolerite with some Lower Parmeener Supergroup rocks.

Subtle terrace development adjacent to the mouth of Haltons Creek has been indicated by photo lineament lines. An older deposit with weathered dolerite clasts forms a terrace about ten metres above the Humboldt River (472000/5268800). Some very large dolerite boulders occur 2.5 km upstream in the Humboldt River. A small and isolated area with dolerite boulders about 25 m above the Tyenna River occurs at 472550/5268700 and may be part of a former terrace of the Tyenna River or be derived from tributary drainage. Alluvial fan deposits, mostly of cobble-size clasts, are associated with some tributary streams draining from the Maydena Range.

Alluvial deposits have been mapped in the Styx River valley downstream from the junction with the South Styx River. At the time of mapping the river had undergone severe summer flooding. Fresh, well-sorted sand and muddy silt deposits were found on the top of adjacent terraces within the rainforest several metres above normal river level. Many of the river banks are composed of similar muddy or sandy sediments rather than gravel and contain large embedded logs. Shingle occurs in some reaches, particularly as point bars, and commonly includes silicified rocks with quartz-crystal lined vugs.

Thick (five metre) sections of alluvial gravel that commonly overlie bedrock river banks, and terrace deposits of similar height, occur in some reaches, for example at 478252/5261650 and 475600/5261600. A higher terrace deposit about 20 m above river level contains dominantly quartz, quartzite and dolerite clasts (475700/5262000). Terrace cobbles exposed east of the Maydena map sheet at the Styx River bridge are overlain by a cream-coloured gravel slope deposit three metres thick.

Relatively thick Quaternary deposits choke some minor streams. These vary from well-sorted alluvial gravel to poorly-sorted deposits which may be mud-flow or talus deposits focussed into valley floors. In the Styx Valley, near the eastern boundary of the Maydena map sheet, an unmapped alluvial deposit five metres thick consists predominantly of dolerite clasts (479200/5260130). A road cut on Waterfall Road reveals a four metre thick interval that consists of sedimentary rock chips and overlies dolerite cobbles (470875/5257775).

Alluvial deposits (Qa, Qpao) that occupy the floor of the Huon Valley in a tract extending from above the Picton River junction to Arve Plains (Picton and Weld map sheets) are predominantly composed of coarse gravel of Proterozoic quartzite, even though the nearest bedrock of this lithology is some distance (>10 km) upstream. These deposits form terraces 20–30 m above the level of the river. Exposures in a quarry at 475800/5227400 show about a four metre thickness of poorly stratified, pebble to cobble-grade sandy gravel, with the clasts nearly entirely composed of Proterozoic quartzite. There are rare clasts of Jurassic dolerite, with weathering rinds about 10 mm thick.

These deposits overlie weathered dolerite boulder deposits (probable till) (Qpdb) at Tahune Bridge. These quartzite-gravel alluvial deposits were interpreted by Colhoun and Goede (1979) as glacial outwash of penultimate or earlier glacial age. Terrace deposits (Qpao) in the Manuka Creek valley (western Weld map sheet) are also probably glacial outwash.

Marsh and swamp deposits (Qhab)

Treeless swamp areas have been interpreted from aerial photographs on poorly-drained dolerite plateau areas on the Snowy Range, at Mount Styx and adjacent areas, and on the Maydena Range (Qhab). Some of these swamps contain common protruding dolerite outcrops or boulders (Qbj). Lower altitude swamps occur on Lower Parmeener shelf areas on the southern side of the Styx Valley at about 500 masl.

Man-made deposits (Qhmm)

The Maydena refuse area has been depicted as a man-made deposit.

Cambrian mafic and ultramafic igneous rocks (JLE, CRC)

Amphibolite (Ccwba) (Nevada map sheet)

There is a large riverbank outcrop of a fine-grained, dark grey-green rock with a penetrative foliation on the Weld River at 467800/5243375. Similar rocks crop out intermittently for some distance downstream. These rocks are weakly magnetic (magnetic susceptibility 0.5×10^{-3} SI units). A thin section (R007689) shows a strongly foliated metamorphic rock, consisting mostly of aligned xenoblastic grains (mostly 50–150 µm) of amphibole (α very pale yellow, β colourless to pale yellow-green, χ medium grey-green; biaxial negative). There are subordinate, fine-grained, mostly intergranular prehnite grains and rather sparse scaly opaque blebs flattened in the foliation. A few veinlets (to 200 µm wide) of coarser-grained prehnite cross-cut the foliation.

Serpentinite (Cspla) (Maydena, Skeleton map sheets) (CRC)

Serpentinite crops out in a creek near the southwestern corner of the Maydena map sheet (460200/5261700). This is a massive, green, fine-grained, mesh-textured serpentinite (R002655). Contacts were not observed, but the outcrop is mostly surrounded by Parmeener Supergroup rocks. To the east (downstream), there is outcrop of micaceous lithic sandstone and bouldery float of chert. The presence of chert suggests that the rocks immediately adjoining the serpentinite may belong to the Ragged Basin Complex (Ccwl), rather than Cals as shown on the map.

Serpentinite crops out well in the Styx River at 464300/5259200. This is a green, massive fine-grained rock with sparse chromite grains which in places is layered. A thin section (R007629) shows fine-grained serpentine with about 5% carbonate grains (0.2 mm), and minor chromite grains to one millimetre.

Basaltic rocks (Ccwb) (Maydena, Skeleton, Weld map sheets)

Field relationships and brief descriptions of the Cambrian basaltic rocks are given in the *Stratigraphy* section. The unusual lamprophyric rocks of uncertain age in the Glovers Bluff inlier (Weld map sheet) are treated separately to the other Cambrian basaltic rocks.

Petrography

Maydena area

A typical sample (R002653) from the Maynes Hill quarry (462050/5263750) is a fine-grained aphyric basalt with a dominantly intersertal texture. The main minerals are abundant randomly-orientated laths (some skeletal to acicular with swallow-tail terminations) of altered plagioclase (mostly 200–500 × 10–30 µm) and similar sized laths and more equant granules (100–300 µm) of colourless clinopyroxene. There are also less abundant broader ragged fragments (up to 500 µm long) of pale-green chlorite. In a few places plagioclase laths have a subophitic relationship to more equant clinopyroxene granules. The fine-grained turbid groundmass probably also consists mainly of altered plagioclase and clinopyroxene microlites. Rather sparsely scattered, small elongate opaque grains (up to 100 × 15 µm) are also present.

Samples R002661 and R007653, also from the quarry area, are very similar but slightly coarser grained, with plagioclase and clinopyroxene laths up to one millimetre long, whilst some patches in the groundmass may be altered glass. The latter contains a few narrow veinlets of prehnite ± quartz, and fine-grained prehnite is also recognisable as an alteration of plagioclase.

The texture of these three samples suggests fairly rapid cooling, consistent with their origin as pillow basalt.

Sample R002696, from near Pine Hill (465800/5263600), is a fine-grained aphyric basalt. Randomly orientated skeletal to acicular laths of pale yellow augite (100–500 µm) grade down to a largely indeterminate, probably originally glassy, groundmass in which small granules of possible sphene are also recognisable. No plagioclase remains. Anastomosing veinlets of quartz ± carbonate are also present, some of which have selvages up to 200 µm wide of fine-grained, colourless to pale yellow-green acicular tremolite-actinolite, which has grown inward towards the veinlet. This rock was probably a quenched, originally glassy, basalt.

Skeleton map sheet

A sample (R002700) from the isolated basalt outcrop on the Skeleton map sheet (461900/5259000) is a severely altered rock with some textural similarities to samples R002661 and R007653 from Maynes Hill quarry. Randomly orientated laths up to one millimetre long of plagioclase, partly replaced by prehnite, grade into a fine-grained, largely indeterminate but probably chloritic groundmass with extensive areas of carbonate veining and alteration. Some generally equant grains (mostly less than 250 µm across) of pale yellow-green chlorite, and blebs of sphene (mostly less than 25 µm) are present, but no primary ferromagnesian minerals remain. There are a few small subspherical amygdales filled mainly with chlorite.

Arve Plains inlier

The samples described below from the Arve Plains inlier, at the eastern edge of the Weld map sheet (480000/5232700) and on the neighbouring Glen Huon map sheet, are all essentially similar plagioclase-rich basalts of varying grain size and intensity of metamorphism and deformation.

Samples R008070 and R008079 are relatively coarse-grained metamorphosed basalts consisting mainly of plagioclase, clinopyroxene, chlorite, sphene and opaque minerals in an interlocking consertal texture. Plagioclase occurs as elongate to irregular turbid subhedra up to 3 mm long, and is probably albite. Clinopyroxene (probably augite) grains are smaller (<1.5 mm) and usually idiomorphic against plagioclase; they are colourless to pale yellow and may be zoned with clear cores and turbid yellowish mantles. Chlorite is yellow-green and occurs mainly as pseudomorphs probably after single olivine phenocrysts (up to 500 μm) and glomerocrysts, but also as veinlets. Irregularly equant opaque iron-titanium oxide grains (up to 500 μm across) display varying degrees of replacement by sphene; in some only minor relict opaque phase remains as parallel acicular splinters, suggestive of original exsolution lamellae. Trace amounts of small subhedral to anhedral flakes of pleochroic (nearly colourless to yellow-brown) biotite are present.

In sample R008079, the corner of the slide is traversed by part of a veinlet, at least 6 mm wide, of finely crystalline to coarse-grained sheaves of prehnite, subordinate yellow-green chlorite and minor epidote. In sample R008070 there is also a patch, about 2 mm across, of radiating prehnite.

Sample R008103 is texturally similar to, but finer-grained and more thoroughly metamorphosed than, R008070 or R008079. It consists of interlocking, generally equant subhedra of turbid plagioclase (generally 200–500 μm across), pale yellow-green aggregates of fine-grained chlorite and altered opaque grains (150–300 μm across), together with rather common but small splintery anhedra of brown biotite and minor interstitial quartz anhedra. No clinopyroxene remains. Under strong illumination, opaque minerals are seen to be mostly replaced by brown aggregates of very fine-grained (?)sphene. A few narrow sinuous veinlets of chlorite are present.

Sample R008080 is a severely sheared and altered rock, now consisting mainly of chlorite and prehnite. Some less deformed lenticular basaltic fragments consist of interlocking turbid plagioclase subhedra and smaller colourless clinopyroxene grains, together with opaque grains mostly altered to sphene, and resemble the coarse-grained basalt samples R008070 and R008079. In the remainder of the rock these minerals (with plagioclase largely converted to prehnite) are variably comminuted to smaller and more rounded grains set in a very fine-grained, probably mainly chloritic groundmass. Numerous later veinlets of prehnite, some with central zones of carbonate, transect the slide.

Sample R008069 is a medium-grained, very plagioclase-rich metabasalt. Clear plagioclase phenocrysts (up to 1 mm) may be clustered in interlocking glomerocrysts (up to 3 mm across). These grade down to an intergranular groundmass of plagioclase laths (typically 150–400 μm), subordinate clinopyroxene, minor pale green chlorite, opaque grains (50–150 μm) partly altered to sphene, and rare pale yellow epidote. A few prehnite veinlets are present.

Sample R008082 is a similar but somewhat sheared, sparsely plagioclase-phyric basalt with a medium-grained intergranular groundmass. Occasional plagioclase phenocrysts (up to 1.5 mm) grade down to a groundmass of plagioclase laths (typically 150–400 μm), clinopyroxene granules, pale yellow-green chlorite grains and equant to elongate opaque grains frequently rimmed by sphene. There are also rather diffuse, anastomosing, foliated cataclastic zones, up to a few millimetres wide, in which rounded grains (30 μm or less) of the main rock-forming minerals, together with coarser-grained (later?) prehnite and epidote, are set in a very finely comminuted matrix. Numerous anastomosing veinlets of chlorite, prehnite and/or albite, with minor epidote, are present. In places, veinlets of mainly prehnite cross-cut the cataclastic zones and are therefore later.

Sample R008071 is a fine-grained plagioclase- (minor clinopyroxene)- phyric basalt with an intergranular/ intersertal groundmass. Somewhat turbid plagioclase phenocrysts, up to 1.5 mm long, are frequently clustered in interlocking glomerocrysts, and grade in size downward to groundmass laths (typically about 100 × 5–15 μm). Equant euhedral phenocrysts of colourless clinopyroxene (up to 500 μm) are rare, but clinopyroxene is abundant in the groundmass. Abundant but small (100–200 μm) grains of pale green chlorite may be pseudomorphs after olivine. The poorly crystalline mesostasis includes chlorite, abundant altered opaque minerals and minor epidote. Epidote also occurs as a fine-grained aggregate partly replacing some plagioclase phenocrysts. Several narrow veinlets of fine to coarse-grained albite, associated with variable amounts of chlorite, epidote and prehnite, are present.

Sample R008081 is a fine-grained plagioclase-phyric basalt similar to R008071. It contains only slightly turbid, euhedral to slightly embayed plagioclase (probably albite) phenocrysts up to 2.5 mm long, and occasional glomerocrysts. These grade downward to an intergranular/intersertal groundmass of plagioclase laths, interstitial colourless clinopyroxene, pale green chlorite pseudomorphs and an opaque-rich mesostasis. Narrow, sinuous, often discontinuous veinlets of chlorite and minor albite are present.

Geochemistry

Summary

The nine analysed samples are from two widely separated areas, about 36 km apart. The samples comprise four from Maynes Hill quarry near Maydena (three analysed in 1988 and one in 1996) and five (analysed in 1996) from the Arve Plains inlier near the confluence of the Weld and Huon rivers.

The Maydena samples are basaltic andesites with distinctly tholeiitic affinities, although they are also mildly potassic.

The Arve Plains rocks are weakly tholeiitic and relatively sodic basalts, with lower SiO_2, K_2O and Mg#, and higher total iron (FeOt) and Na_2O, compared to Maydena. They are also higher in Ni and Cu and lower in Zr, Nb and light rare earth elements.

Marked differences in key incompatible element ratios (e.g. Ti/Zr, Nb/Zr, Nb/Y, Zr/P_2O_5) and degree of light rare earth enrichment preclude any correlation or direct relationship between Maydena and Weld River.

Most applicable tectonomagmatic discrimination diagrams indicate that both were erupted in a within-plate, probably continental, tectonic environment. However the Arve Plains basalts in particular show some features transitional to enriched mid ocean-ridge basalt (E-MORB) compositions, and a failed continental rift seems to be the most likely setting.

The Arve Plains rocks have similarities to some ensialic Neoproterozoic basalts within the Spinks Creek Volcanics (Smithton Synclinorium) and the Crimson Creek Formation (Dundas Trough). A broad correlation with the Cleveland–Waratah Formation basalts and the Motton Spilite, thought to have oceanic affinities and to have been structurally emplaced in the Early Cambrian, cannot be ruled out on the basis of the available data. However the Arve Plains rocks are unlike the oceanic arc basalts (low-titanium tholeiites) of the inferred allochthon, or the continental arc basalts of the Mt Read Volcanics.

Analytical methods and data interpretation

Major and trace elements were determined at the MRT laboratories by x-ray fluorescence (XRF), except for Fe_2O_3/FeO, CO_2 and combined water (H_2O^+) for which classical techniques were used. Rare earth elements (REE) were also determined in the 1996 samples by instrumental neutron activation analysis (INAA) at Becquerel Laboratories, Sydney.

All samples have been affected by greenschist facies metamorphism which is known to cause mobility of certain elements. The internal similarity of analyses from the same area (particularly those from Maydena) suggests that element mobility has been limited, and the rocks may preserve original contents of many, probably most, elements. This is reinforced by the moderate H_2O^+ (<4%) and low CO_2 (<0.30%) values, and the constant Y/Ho ratios (24.8–27.6), close to the chondritic ratio (about 27.7, e.g. Sun and McDonough, 1989; Bau, 1996). In all the Maydena samples, and in two out of five Arve Plains samples, Fe_2O_3/FeO is low (<0.25) and probably close to original magmatic values; the other three have probably been affected by secondary oxidation. Sulphur (≤0.16% expressed as SO_3) is sufficiently low to be disregarded for most purposes.

Major elements

Major element analyses were recalculated to 100% anhydrous (also excluding CO_2 and SO_3, and with all iron expressed as FeO) for the purposes of the following discussion.

The principal difference between the two groups in terms of major element chemistry is that the Maydena samples have consistently higher SiO_2 and K_2O, and lower total iron (FeOt), Na_2O and total alkalis (Na_2O + K_2O) than those from Arve Plains.

CIPW norms of metamorphosed rocks need to be considered with particular caution due to the possibility of element mobility (particularly of Na_2O). It is probably significant that, when norms are calculated at Fe_2O_3/FeO = 0.20, all the Maydena samples are quartz-normative tholeiites (1.7 < Q < 6.0), whilst the Arve Plains samples are olivine-hypersthene normative (1.5 < hy < 10.8, 9.9 < ol < 19.5) and could be termed transitional olivine basalts.

Alkali-silica-alumina relationships

A total alkali-silica diagram (fig. 12*a*) clearly shows the different fields occupied by the Maydena and Arve Plains basalts. If it is assumed that these elements have been relatively unaffected by alteration, the Maydena samples (SiO_2 53–55%) are classified as basaltic andesites in the scheme of Le Maitre *et al*. (1989). They also fall below the line of Macdonald and Katsura (1964), implying tholeiitic affinities. On the other hand, samples from Arve Plains (SiO_2 50–53%) classify as basalts, verging to trachybasalts and basaltic trachyandesites, and due to their higher alkali content appear to have mildly alkalic affinities.

This is supported by a Na_2O-SiO_2 plot (fig. 12*b*), in which the Maydena samples fall in the subalkalic (tholeiitic) field, and the Arve Plains samples in the alkalic field, as defined by Middlemost (1975).

In a K_2O-SiO_2 plot (fig. 12*c*) both groups fall in the subalkalic field of Middlemost (1975), with some of the Arve Plains rocks falling in the low-K subalkalic subfield that was defined mainly by mid-ocean ridge basalts (MORB). Because of the apparent ambiguity of the Arve Plains samples (alkalic in terms of Na_2O and subalkalic in terms of K_2O), they would be termed transitional basalts in Middlemost's classification. Peccerillo and Taylor (1976) used a similar K_2O-SiO_2 plot to define various magma series; on this basis the Maydena rocks mostly belong to the 'medium-K (calc-alkaline)' series and the Arve Plains rocks to the 'low-K (tholeiitic) series'. These series roughly correspond to the subalkalic and low-K subalkalic subdivisions of Middlemost (1975).

A plot of K_2O against Na_2O (fig. 12*d*) emphasises the sodic nature of the Arve Plains samples and the contrasting relatively potassic nature of the Maydena rocks, although both fall well within the sodic field as defined by Middlemost (1975). This classification is strictly only applicable to alkalic rocks (i.e. not Maydena, and doubtfully Arve Plains).

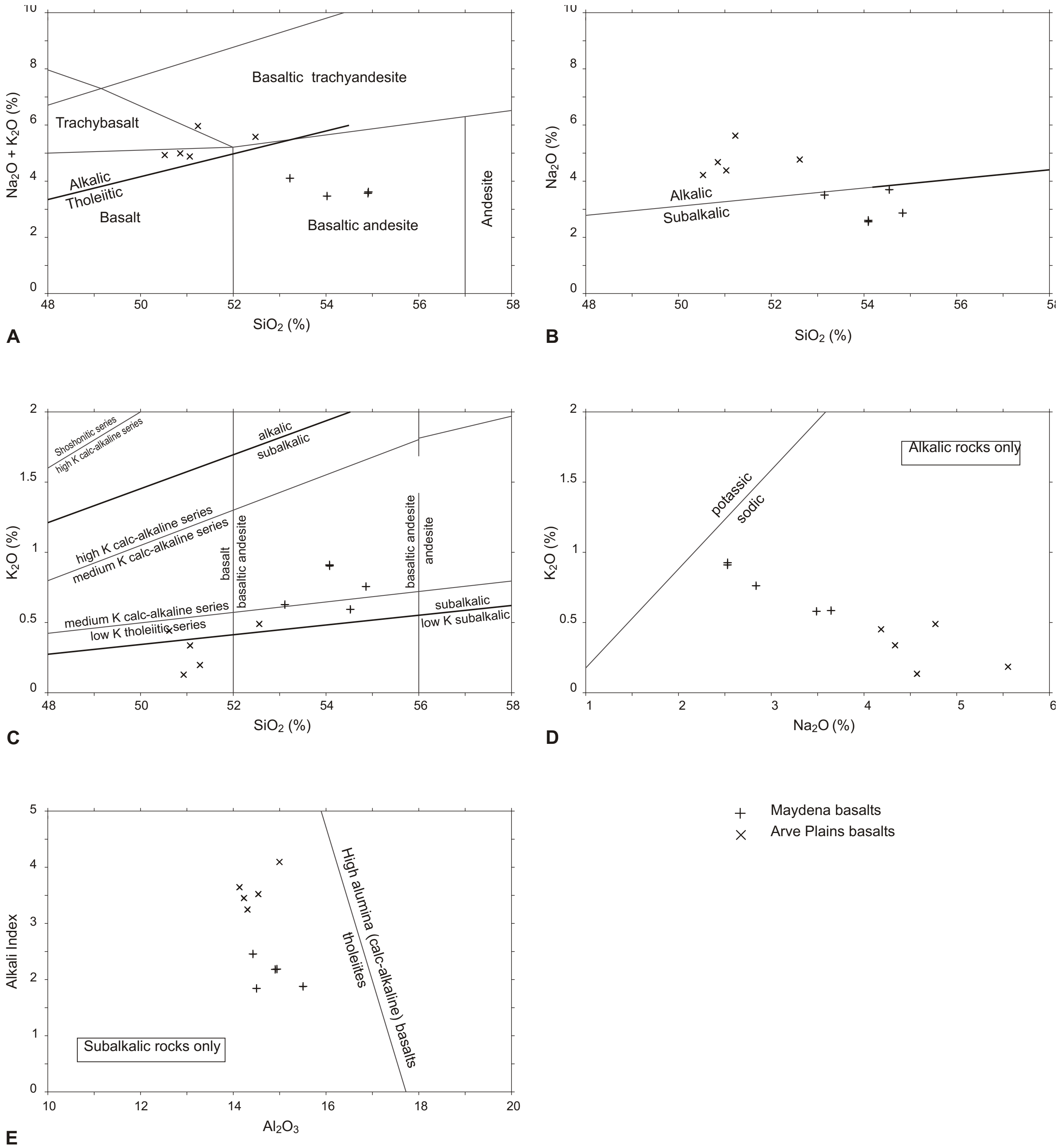


Figure 12

Basaltic rocks plotted on various bivariate major element diagrams. Analyses normalised to 100% major elements (excluding H_2O, CO_2 and SO_3) with all iron recalculated as FeO.

(a) *Total alkalis–SiO_2. Volcanic rock nomenclature of Le Maitre et al. (1989) and boundary between Hawaiian alkalic and tholeiitic basalts of Macdonald and Katsura (1964) also shown.*

(b) *Na_2O–SiO_2. Boundary between alkalic and subalkalic fields after Middlemost (1975).*

(c) *K_2O–SiO_2. Field boundaries after Peccerillo and Taylor (1976) and Middlemost (1975) also shown.*

(d) *K_2O–Na_2O. Boundary between potassic and sodic rocks (alkalic rocks only) after Middlemost (1975).*

(e) *Alkali Index–Al_2O_3 diagram of Middlemost (1975) for distinguishing tholeiitic and high alumina basalts (applicable only to subalkalic rocks). Alkali Index = $(Na_2O + K_2O)/0.17*(SiO_2-43)$.*

In order to distinguish tholeiites (including MORB and tholeiitic continental flood basalts) from high-alumina or 'calc-alkali' basalts characteristic of convergent plate margins (i.e. island arcs and active continental margins), Middlemost (1975) devised an 'Alkali Index' and plotted it against Al_2O_3. On this diagram (fig. 12*e*) both the Maydena and Arve Plains basalts plot in the tholeiitic field. In both groups, Al_2O_3 is similar (14–15.5%) and well below the field of high-alumina basalts.

MgO-total FeO relationships and Mg#

The Arve Plains samples have higher and more variable total iron (FeOt 11.84–13.89%) than the Maydena samples (8.96–9.96%), whilst having similar but also more variable MgO. The higher FeOt results in the Arve Plains samples having lower Mg# (calculated at $Fe_2O_3/FeO = 0.20$) of 47.9–57.5, compared to the less evolved Maydena samples (Mg# 59.5–61.4). Of the Arve Plains rocks, samples WR73, WR84 and WR85 have the lowest MgO, Mg#, Ni and Cr and are the most evolved. Neither group of basalts has the high Mg# (67–75) considered characteristic of primitive magmas derived directly from the upper mantle.

In an AFM (total alkali-total iron-magnesia) triangular plot (fig. 13), derived by normalising these oxide weight percents to 100, both groups straddle the boundary between the tholeiitic and calc-alkaline field differentiation trends as defined by Irvine and Baragar (1971), but plot in the calc-alkaline field if the boundary of Kuno (1968) is taken. The Arve Plains samples suggest a trend direction towards iron enrichment (relative to MgO) more characteristic of the tholeiitic differentiation trend, while the Maydena samples are too similar to suggest any trend.

MnO is slightly higher in the more iron-rich Arve Plains samples than at Maydena.

Other major elements

CaO is more variable but slightly lower (except for sample WR85) in the Arve Plains samples. In both groups it correlates negatively with Na_2O, but otherwise shows no systematic variation. TiO_2 and P_2O_5 show no clear differences between groups or systematic variation within groups when compared to other major elements. However these are immobile incompatible elements and can usefully be compared with similar trace elements (see below).

Trace elements

High field strength elements

These elements (Zr, Nb, REE, Y, together with Ti and P) are probably the most reliably diagnostic as they are relatively immobile during metamorphism and mild hydrothermal alteration. As most of these elements are more-or-less incompatible with respect to most possible phenocryst phases (olivine, pyroxene and

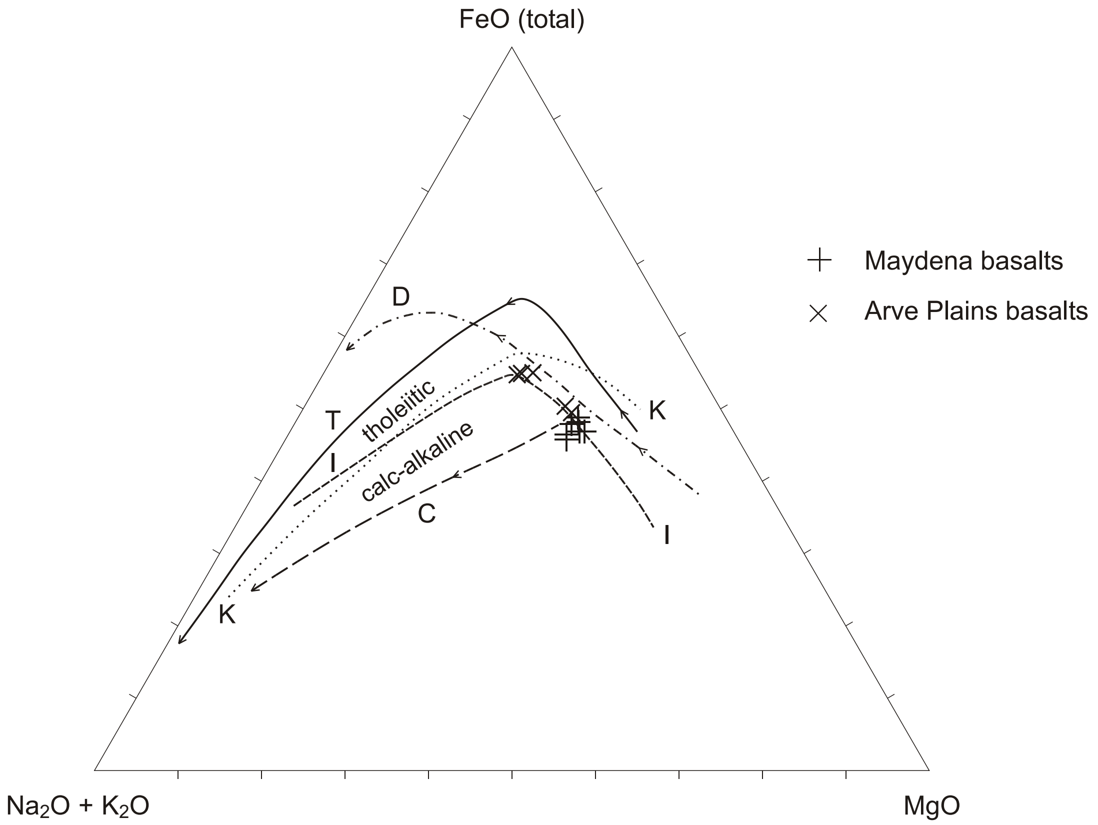


Figure 13

Basaltic rocks plotted on AFM (total alkalis-total iron-magnesia) diagram. Boundaries between tholeiitic and calc-alkaline fields of Kuno (1968) (labelled K) and Irvine and Baragar (1971) (I) also shown. Differentiation trends for Cascades lavas (C) and Thingmuli (T) from compilation of Rollinson (1993) and Tasmanian dolerites (D) from Hergt (1987) and MRT database.

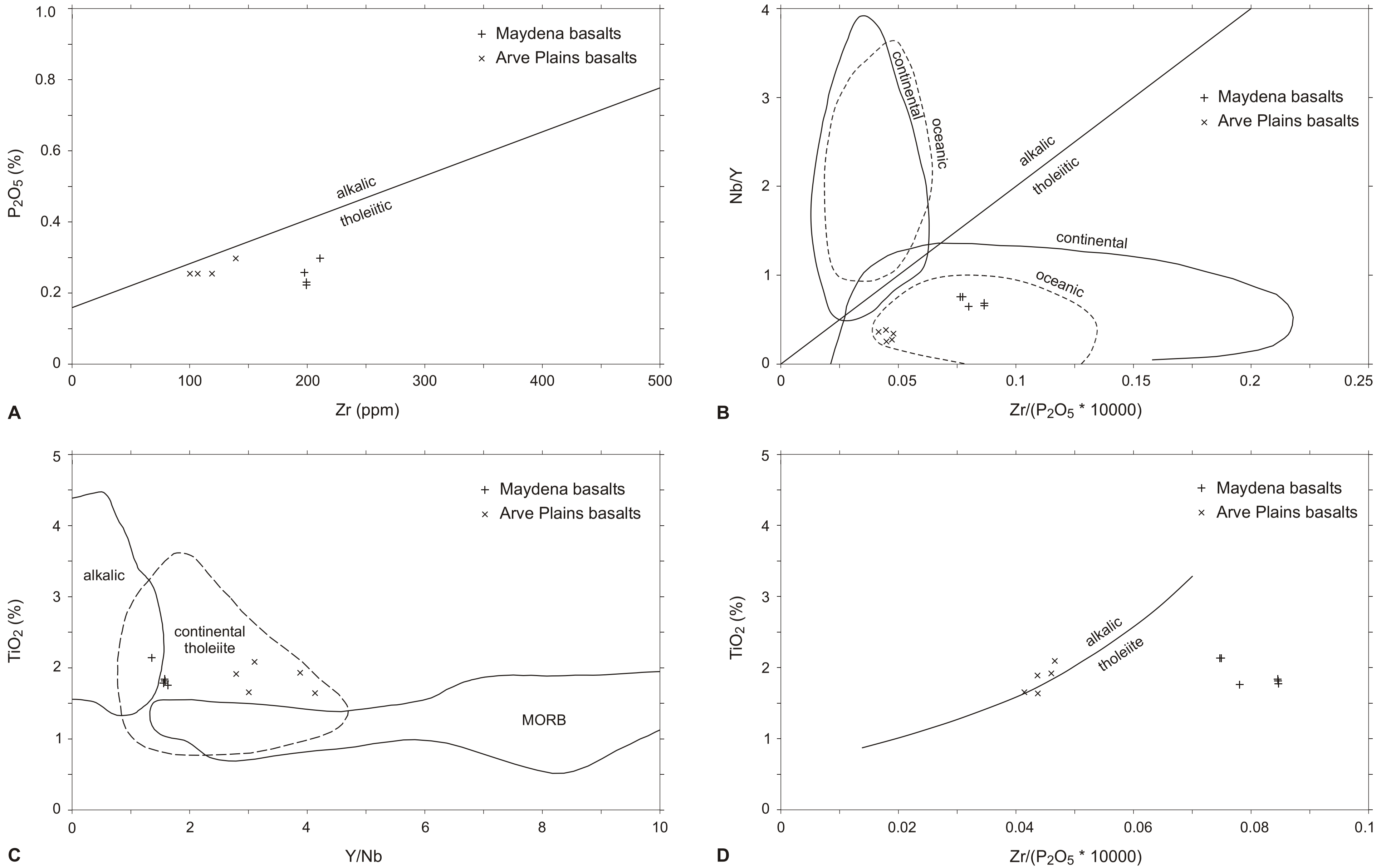


Figure 14

Basaltic rocks plotted on discrimination diagrams of Floyd and Winchester (1975) and Winchester and Floyd (1976), showing alkalic and tholeiitic, continental and oceanic, and mid-ocean ridge basalt (MORB) fields. (a) Zr–P_2O_5; (b) Nb/Y–Zr/P_2O_5; (c) TiO_2–Y/Nb; (d) TiO_2–Zr/P_2O_5.

plagioclase) their ratios will be little affected by crystal fractionation.

Zr, Nb and the light rare earth elements (see below) are about twice as abundant in the Maydena samples compared to Arve Plains, whilst Y and the heavy rare earth elements (HREE) are similar in both groups. Taken alone this could indicate that the former are derived by a lower degree of partial melting than the latter, with perhaps some residual garnet in the mantle source buffering Y and HREE. This interpretation is inconsistent with the similar levels of TiO_2 and P_2O_5 in both groups, and the striking difference in Ti/Zr (54 to 61 at Maydena, 92 to 108 at Arve Plains). It is also difficult to reconcile with the difference in major element composition, such as K_2O/Na_2O, total FeO and SiO_2. It seems more likely that the samples were derived from different mantle sources.

Several authors (e.g. Floyd and Winchester, 1975; Winchester and Floyd, 1976) have noted systematic differences between tholeiitic and alkali basalts in these elements. The relatively low Nb/Y and high Zr/P_2O_5 ratios of these samples are generally typical of tholeiitic basalts (fig. 14*a, b, c*). These diagrams are of little use in distinguishing oceanic and continental environments, although both the Maydena and Arve Plains groups have slightly higher TiO_2 (particularly at given Y/Nb) than MORB and are more akin to continental tholeiites (fig. 14*c*). On the TiO_2-Zr/P_2O_5 plot (fig. 14*d*) of Winchester and Floyd (1976) the Arve Plains samples appear to be mildly alkalic.

Rare earth elements

Although La, Ce and Nd were routinely analysed by XRF, only REE data obtained by the more sensitive and accurate INAA method are considered here. Of the Maydena rocks, only sample S466 was analysed by this method, but XRF data (including for Ce) show that the other three are chemically very similar rocks. REE plots (fig. 15*a,b*) are normalised using the average C1 chondrite of Boynton (1984).

All samples are enriched in light REE relative to heavy REE, but Maydena sample S466 ($(La/Yb)_N$ = 6.19) is more so than the five Arve Plains samples (2.07–2.97). La is about 72 times chondritic values in S466 and 23–31 at Weld River, whilst heavy rare earths (Lu, Yb and Ho together with Y) are similar, with Yb_N of 9 to 13 in all samples (including S466).

Of the Arve Plains samples virtually all REE are slightly higher in sample WR84. This could be due to crystal fractionation, but samples WR73 and WR85 also have low Mg#, Ni and Cr. Sample WR84 also has the largest negative Eu anomaly (Eu/Eu* = 0.79), suggesting the possibility of significant plagioclase fractionation. This is consistent with its low CaO, but is probably discounted by its slightly higher Al_2O_3, and the absence of Sr depletion. The remaining four Arve Plains samples have very similar REE patterns, with small negative Eu anomalies (Eu/Eu* = 0.84–0.95), for which mild hydrothermal alteration is an alternative explanation.

Large-ion-lithophile elements

These elements (Rb, Ba and Sr together with K) are also highly incompatible with respect to most minerals during crystal fractionation or partial melting of the upper mantle. However they are highly mobile and can easily be affected by metamorphism, alteration or weathering processes, and thus the data must be interpreted with particular caution.

The higher SiO_2, K_2O and Rb at Maydena could indicate significant crustal contamination, but this process is in itself inadequate to account for the differences in incompatible elements (particularly Nb which is relatively depleted in continental crust).

Ba is particularly mobile, and the very variable values at Arve Plains probably indicate mobility during hydrothermal alteration or weathering. The more constant values of most of these elements at Maydena suggest that their magmatic concentrations may be preserved.

Compatible elements

In both groups, Ni and Cr are well below the levels (300–500 ppm) considered typical of unfractionated (primitive) magmas. Ni is particularly low in the Maydena samples, suggesting more substantial olivine (± pyroxene) fractionation, but this is not reflected in Mg# which is higher than at Weld River. At Weld River, both Ni and Cr are much higher in the less evolved samples WR72 and WR82, which also have higher MgO and Mg#. Cr can be controlled by clinopyroxene fractionation, but there is no clear correlation between Cr and CaO either within or between groups, although sample WR84 is low in both elements. An alternative explanation for the low Cr in the three more evolved Arve Plains samples could be spinel fractionation, possibly as inclusions in olivine.

V, Co and possibly Zn (together with MnO) are slightly higher in the Arve Plains samples than at Maydena; this is possibly related to their higher total iron (FeO*). In the Arve Plains samples, Co has a weak positive correlation with Mg#, Ni and Cr, suggesting some control by olivine (± pyroxene) fractionation, whilst V possibly shows a negative correlation.

Other trace elements

Cu is strikingly more abundant in the Arve Plains samples (84–210 ppm) compared to Maydena (5 ppm or less). Compared to typical basalts, Cu is rather high at Arve Plains and unusually depleted at Maydena. (For example, a varied suite of 49 Tasmanian Tertiary basalts analysed by the ICPMS method contained from 25 to 85 ppm Cu; M. Zhang and J. L. Everard, unpublished data). Copper in basalts often varies in a quasi-random manner, uncorrelated to other elements, and may be chiefly controlled by differences in sulphur activity, and processes such as silicate-sulphide melt immiscibility, rather than ionic charge and size factors.

Sc and Ga show no clear differences between trends within the two groups.

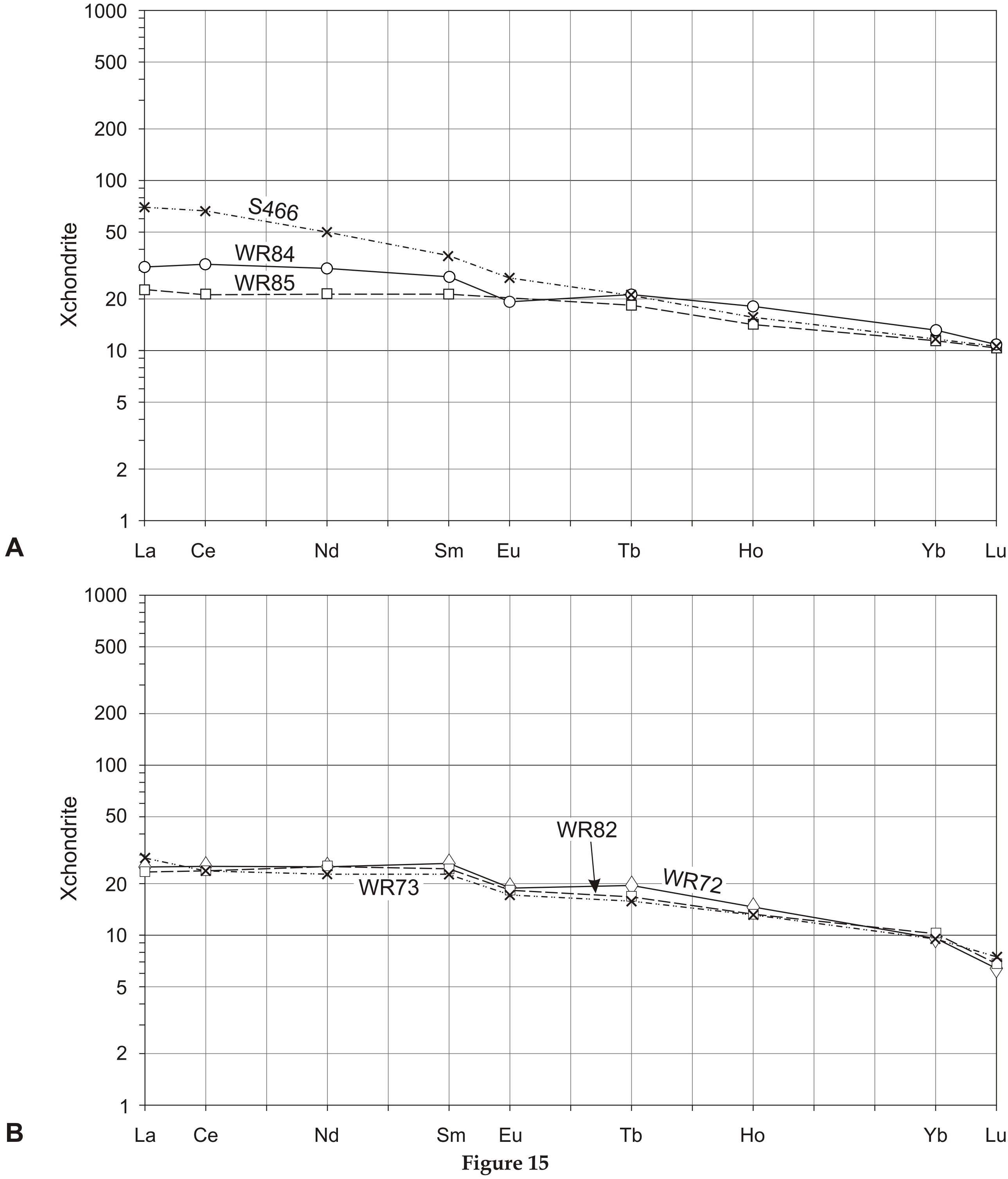


Figure 15

Rare-earth diagrams (chondrite normalising factors after Boynton, 1984). (a) Maydena (sample S466) and Arve Plains (samples WR84, WR85) basalts. (b) Arve Plains basalts (samples WR72, WR73, WR82).

The very high values for W and Sn in the three 1988 Maydena samples are highly questionable, particularly as they are not present in the otherwise similar 1996 sample (S466) collected from the same area. They are most likely attributable to laboratory contamination. On the other hand, the higher Th values in the 1996 samples (Arve Plains and one from Maydena) may be due to calibration problems (this has also been observed in unrelated samples analysed at about the same time). If not affected by crustal contamination, mantle-derived rocks are expected to have near-chondritic Th/Nb ratios of about 0.12 (e.g. Sun and McDonough, 1989).

As, Mo, Pb, Bi and U are below detection limits. Typically the levels of these elements in basalts are too low to be determined by XRF.

Primitive-mantle normalised spider diagrams

These are shown (fig. 16*a, b, c*) for those samples for which full REE data are available. Elements are normalised against the model primitive mantle composition of Sun and McDonough (1989) and

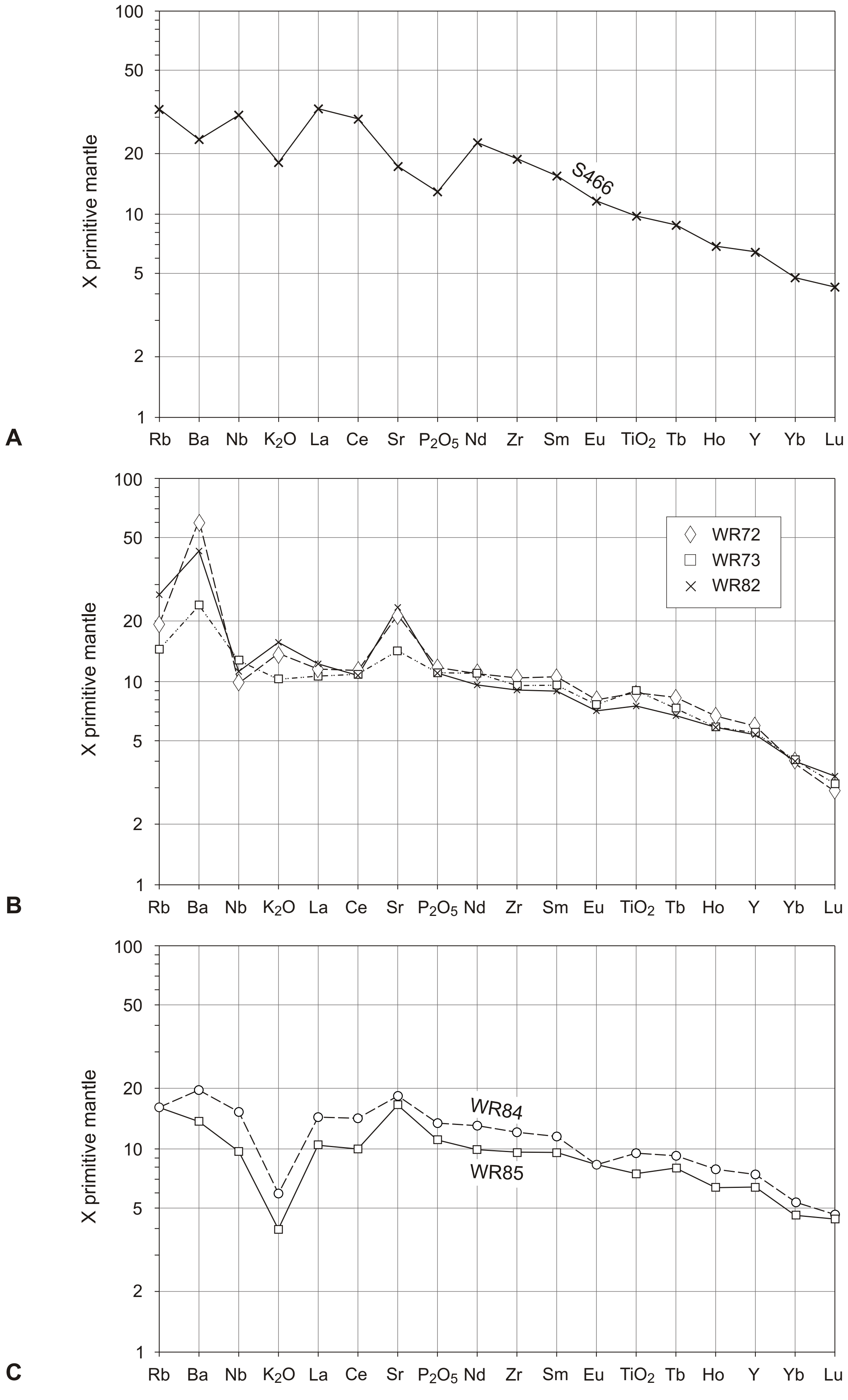


Figure 16

Incompatible element spider diagrams, normalised to model primitive mantle of Sun and McDonough (1989). INAA data for REE, XRF data for other elements. (a) Maydena basalt (sample S466); (b) Arve Plains basalts (samples WR72, WR73, WR82); (c) Arve Plains basalts (samples WR84, WR85).

arranged in order of decreasing incompatibility in an inferred four-phase lherzolite mantle source.

The Maydena sample (S466) shows moderate depletions at Ba, K_2O, Sr and P_2O_5. Except possibly for Ba, these are probably primary features inherited from the source. Elements to the right of Nd show a smooth, steadily falling pattern. The absence of a negative Nb anomaly tends to discount any subduction association.

All the Arve Plains samples show a positive Sr anomaly, and all except WR85 also have a positive Ba anomaly. These are particularly marked in samples WR72 and WR73, and almost certainly are due to element mobility. Two (WR84 and WR85) are markedly depleted in K_2O, but it is uncertain whether or not this is a primary magmatic feature. There is a hint of a negative Nb anomaly in samples WR72 and WR73, and possibly (masked by depletion of adjacent K_2O) in WR85. The La/Nb ratios of these samples (1.11–1.02) are only slightly higher than the chondritic value of 0.96. The other two samples (WR82 and WR84), with La/Nb of 0.81 and 0.88 respectively, do not show this feature.

Tectonomagmatic discrimination diagrams

Following Pearce and Cann (1973), many authors have attempted to devise discrimination diagrams to determine the tectonic setting of ancient basaltic rocks from their chemical composition, particularly of immobile trace elements. A recent compilation and review is given by Rollinson (1993). These schemes are usually based on data sets of young unaltered volcanic rocks from unequivocal tectonic environments. They need to be applied with caution, because of problems including an intended limited applicability, element mobility, analytical accuracy and in some cases an insufficiently large or comprehensive original data set. In recent years this highly empirical approach has somewhat given way to a more theoretical one based on petrogenetic models.

On the diagrams of Pearce and Cann (1973) designed for tholeiitic basalts, the Maydena samples plot in the within-plate basalt field of the Ti-Zr-Y diagram (fig. 17*a*), although close to the calc-alkali basalt field. The Arve Plains basalts plot ambiguously, straddling the field between within-plate basalts and the field of overlapping MORB, calc-alkali basalt and island-arc tholeiite. A well known problem with this diagram is that it mis-classifies many continental tholeiites (including Tasmanian Jurassic dolerite) as calc-alkali basalt (e.g. Holm, 1982).

On the Ti-Zr-Sr diagram (Pearce and Cann, 1973; fig. 17*b*) designed to discriminate between these plate margin environments, the Arve Plains basalts (assuming that they are not within-plate basalts) plot mostly in the island-arc tholeiite field. The Maydena samples fall in the calc-alkali basalt field, but if they are within-plate basalts they should not be plotted on this diagram.

On the Ti-Zr diagram (Pearce and Cann, 1973; fig. 17*c*) the Arve Plains samples plot in the MORB field, and the

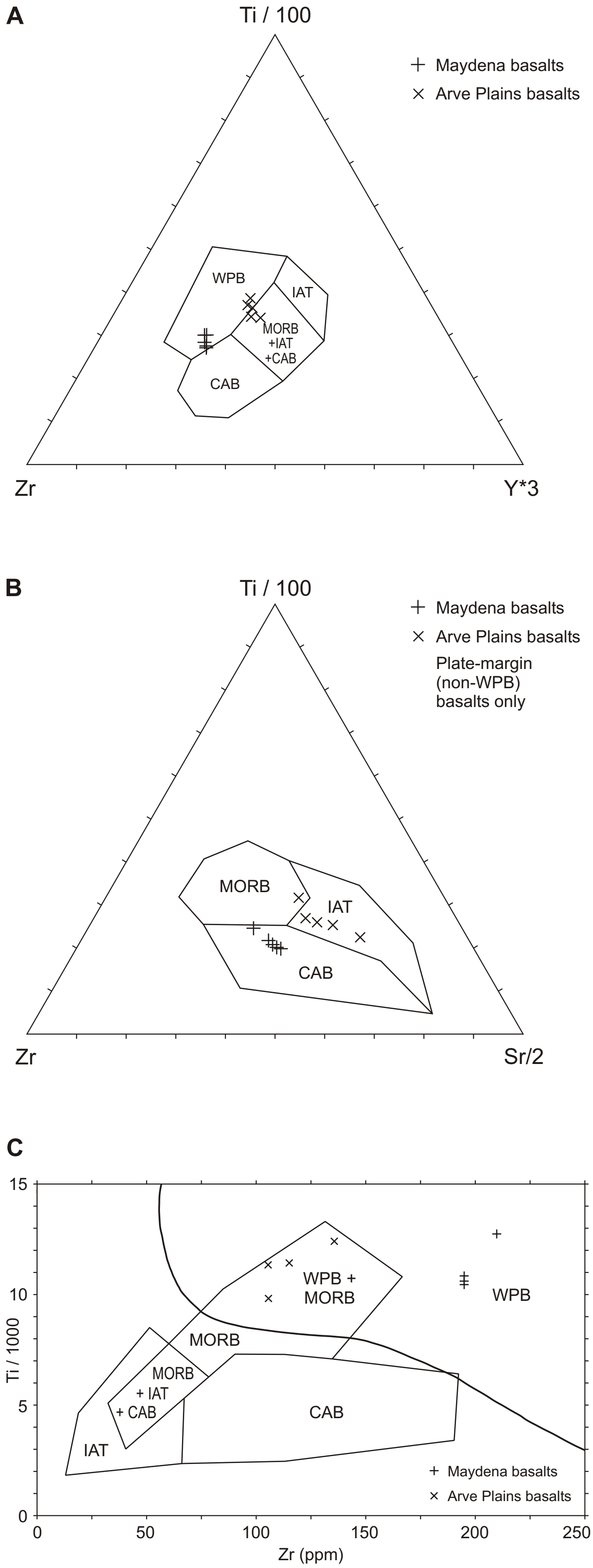


Figure 17

Basaltic rocks plotted on discrimination diagrams of Pearce and Cann (1973), showing fields of within-plate basalts (WPB), island-arc tholeiite (IAT), calc-alkaline basalt (CAB) and mid-ocean ridge basalt (MORB).
(a) Ti-Zr-Y diagram; (b) Ti-Zr-Sr diagram (for plate-margin basalts); (c) Ti-Zr diagram (WPB field extracted from Pearce, 1982).

Maydena samples outside the defined fields, principally due to their high Zr content. However this diagram has no field for within-plate basalts. Pearce (1982) later modified this diagram, and on the revised diagram, the Maydena basalts clearly plot as within-plate, whilst those from Arve Plains could be either within-plate or MORB.

On the Zr/Y-Zr diagram (fig. 18) of Pearce and Norry (1979), the Maydena samples also clearly plot as within-plate basalts. Those from Weld River, which have lower Zr and Zr/Y, plot within or near the region of overlap between within-plate basalts and MORB.

Likewise on the Ti/Y- Zr/Y diagram (fig. 19) of Pearce and Gale (1977), the Maydena samples plot as within-plate basalts, whilst the Weld River rocks straddle the within-plate and plate margin field boundary. On the Nb/Y-Ti/Y diagram (fig. 20) of Pearce (1982), basalts from both areas straddle the boundary between tholeiitic within-plate basalt and MORB/volcanic arc basalt. On both diagrams this is due to variations in their Ti/Y ratio between 340 and 460.

On the Zr-Nb-Y diagram (fig. 21) of Meschede (1986), the Maydena samples plot unequivocally as within-plate, whilst those from Arve Plains plot in the overlap field of within-plate tholeiites and volcanic arc basalts, but also close to the E-MORB field.

On the La-Y-Nb diagram (fig. 22) of Cabanis and Lecolle (1989), the Arve Plains samples straddle the field boundary between continental basalts and weakly to strongly-enriched E-MORB. The sole Maydena sample analysed for La (S466) plots a little more unequivocally as a continental basalt.

On the Ti-V diagram (fig. 23) of Shervais (1982) both the Maydena and Arve Plains samples plot within the region of overlap between continental flood basalts and MORB (including back-arc basin basalts). According to this diagram neither are arc tholeiites, calc-alkaline basalts, oceanic-island basalts or alkali basalts.

Cr-Y and Cr-Ce/Sr (fig. 24*a, b*) diagrams were devised by Pearce (1982) mainly to distinguish subduction-related arc basalts (typically lower in Cr and Y and enriched in Sr relative to Ce) from within-plate basalts and MORB. On these diagrams the Maydena samples plot in the WPB/MORB overlap field. The Arve Plains rocks plot very ambiguously in the Cr-Y diagram, whilst in the Cr-Ce/Sr diagram four out of five samples plot in the arc field. However as Sr, Ba and K in all these rocks are probably affected by hydrothermal alteration (see above), this may be misleading, particularly as the possibly least altered sample (WR82) plots closer to the WPB and MORB fields.

On the MnO-TiO_2-P_2O_5 minor element diagram (fig. 25) of Mullen (1983), the Maydena samples tend to plot as oceanic island basalt (OIB) and the Arve Plains rocks as MORB. Both groups lie close to the MORB-OIB field boundary and also just outside the field of island arc tholeiite. The only unambiguous result from this diagram is that neither group resembles the calc-alkaline basalts of island arcs. Note that this diagram is constructed from, and intended for, data from oceanic basalts only, and there is no field for continental within-plate basalts.

The MgO-total iron (FeOt)-Al_2O_3 diagram (fig. 26) of Pearce *et al*. (1977) is intended for basalts and basaltic andesites with 51–56% SiO_2 (calculated anhydrous) and thus should be applicable to both the Maydena and (marginally) the Weld River samples. However this diagram also gives equivocal results. The Maydena samples plot around the continental–MORB-OIB field triple point, whilst three of the Arve Plains samples plot near the continental-OIB field boundary, and the two less evolved ones in the OIB field. As noted by Rollinson (1993), the effects of crystal fractionation and element mobility limit the usefulness of this discrimination diagram.

The K_2O-TiO_2-P_2O_5 diagram (fig. 27) of Pearce *et al*. (1975) was designed to distinguish oceanic (MORB and ocean island tholeiite) and continental subalkaline basalts. Both the Arve Plains and Maydena samples plot in the oceanic field, the former more decidedly so. This diagram is not applicable to fractionated, alkalic or altered basalts, and so is of doubtful validity for these rocks, particularly the Arve Plains samples.

Pearce (1976) used a statistical analysis of major elements in young fresh basalts to derive three discrimination functions to distinguish between various tectonic settings. On his F_1-F_2 diagram (fig. 28) both the Maydena and Arve Plains samples plot in the MORB field (as opposed to the field of within-plate basalts and various arc-related basalts). In the F_2-F_3 diagram (not shown) they plot in the shoshonitic basalt field (which is in conflict with their modest degree of LREE and HFSE enrichment). Recalculation of the analyses to 100% anhydrous only marginally alters these functions and does not change these assignments. Rollinson (1993) notes that alteration and weathering has a severe effect on these variables, and basalts from different tectonic environments overlap extensively in major element composition.

Possible correlates in western Tasmania

Comparison with Neoproterozoic basalts of continental shelf sequences

These are best known from the Smithton Synclinorium, where the mainly tholeiitic basalts of the Spinks Creek Volcanics have been divided into seven suites, principally on the basis of TiO_2 and Nb/Zr (Everard *et al*., 2001; Brown, 1989*a*). The Arve Plains samples most resemble Group C of the Spinks Creek Volcanics. They are slightly more LREE-enriched and have similar or slightly higher levels of other immobile incompatible elements such as TiO_2, Nb and Zr, P_2O_5, but ratios of these elements are very similar. Major elements in the Arve Plains samples are generally also similar. The only clear difference is the higher Sr at Arve Plains (290–490 ppm) compared to Group C at Smithton (43–300 ppm). The Arve Plains samples could possibly

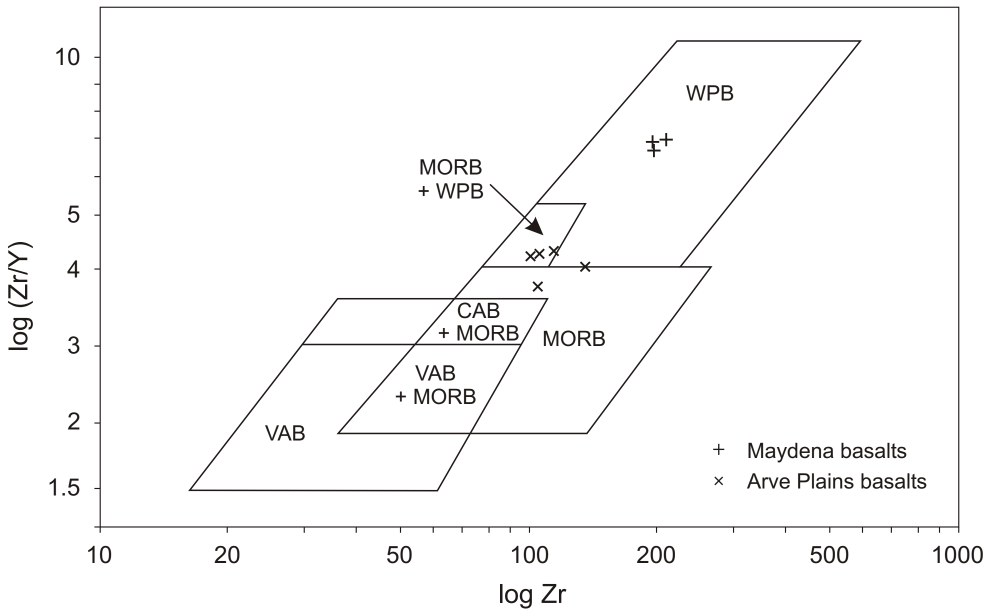


Figure 18

Basaltic rocks plotted on the Zr/Y-Zr discrimination diagram of Pearce and Norry (1979) and Pearce (1983). Note logarithmic scales. Field labels similar to Figure 17; OAB (oceanic arc basalt) and CAB (continental arc basalt) roughly correspond to IAT and CAB respectively.

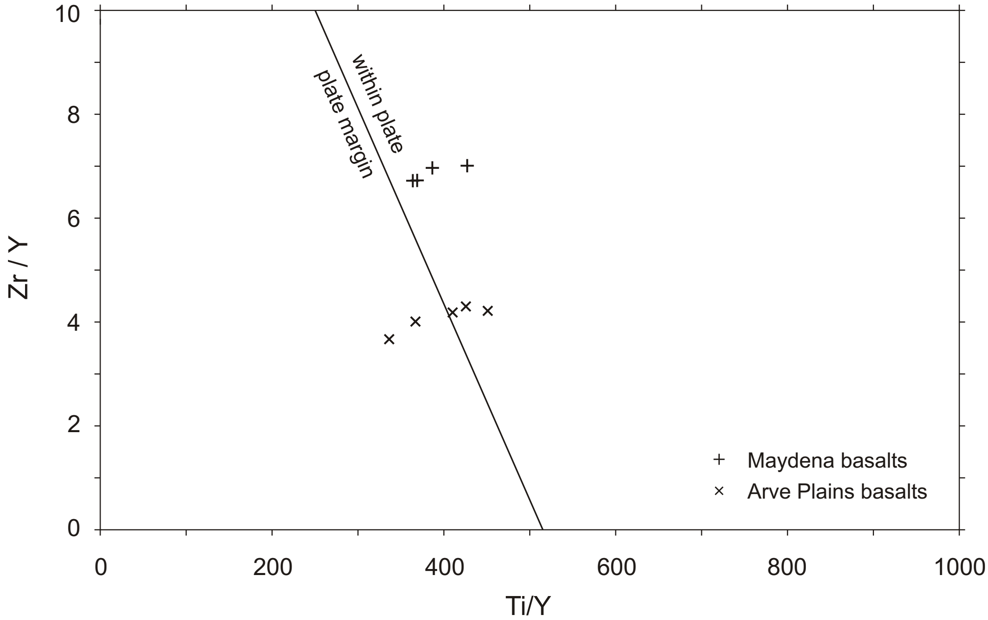


Figure 19

Basaltic rocks plotted on the Zr/Y– Ti/Y discrimination diagram of Pearce and Gale (1977), showing line dividing plate margin and within-plate basalts.

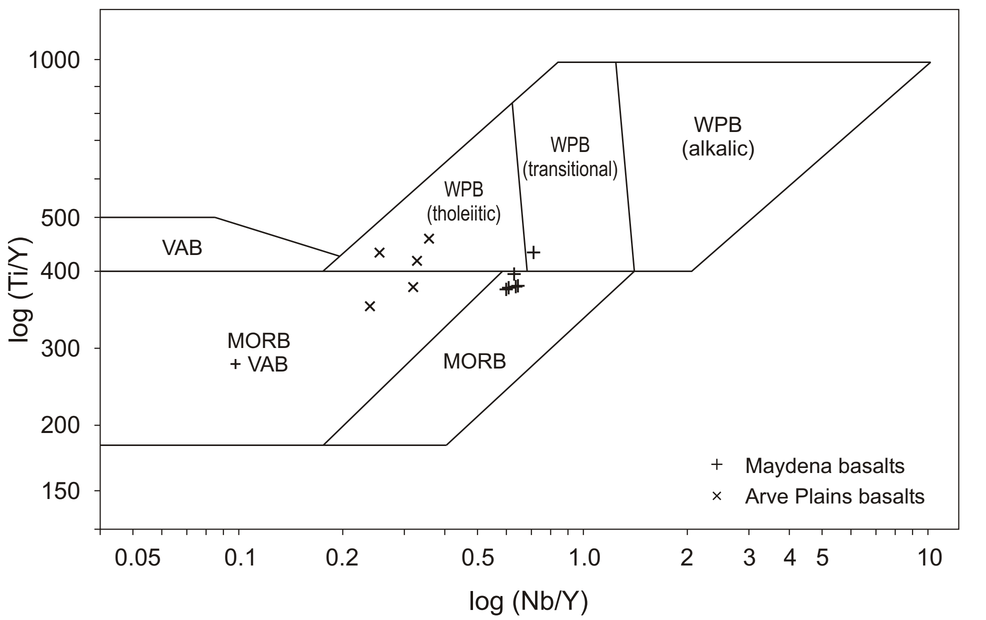


Figure 20

Basaltic rocks plotted on the Ti/Y–Nb/Y discrimination diagram of Pearce (1982). Note logarithmic scales. VAB are volcanic arc basalts (= CAB + IAT), other field labels as for Figure 17.

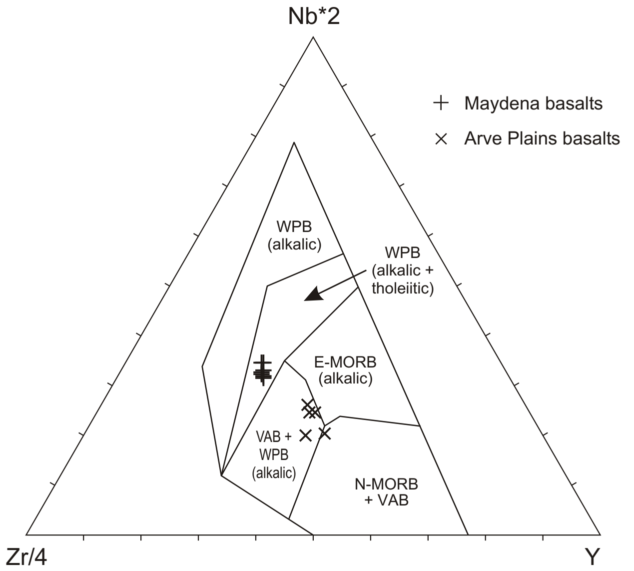


Figure 21

Basaltic rocks plotted on the Zr-Nb-Y discrimination diagram of Meschede (1986). Mid-ocean ridge basalts are subdivided into enriched (E-MORB) and normal (N-MORB) types; other field labels as for Figures 17 and 20.

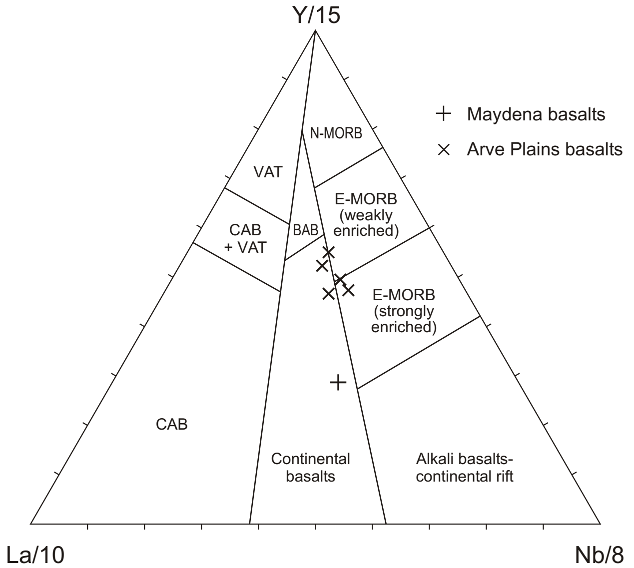


Figure 22

Basaltic rocks plotted on the La-Y-Nb discrimination diagram of Cabanis and LeColle (1989) (see also Rollinson, 1993). BAB are back-arc basin basalts, VAT are volcanic arc tholeiites, other field labels as for Figures 17 and 21.

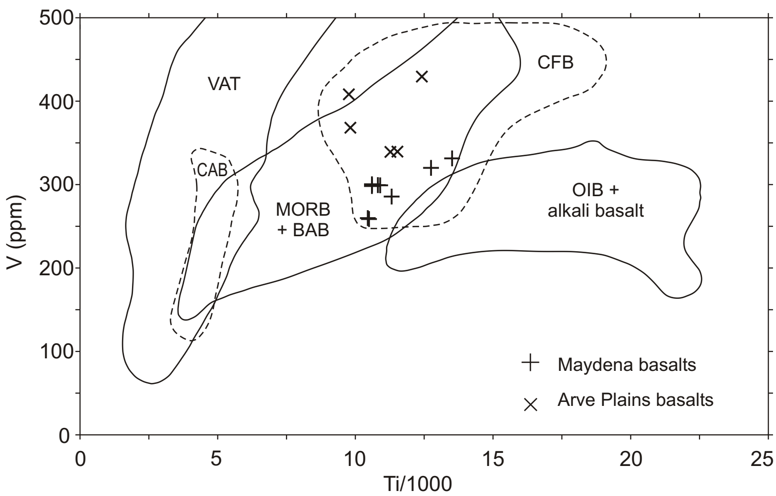
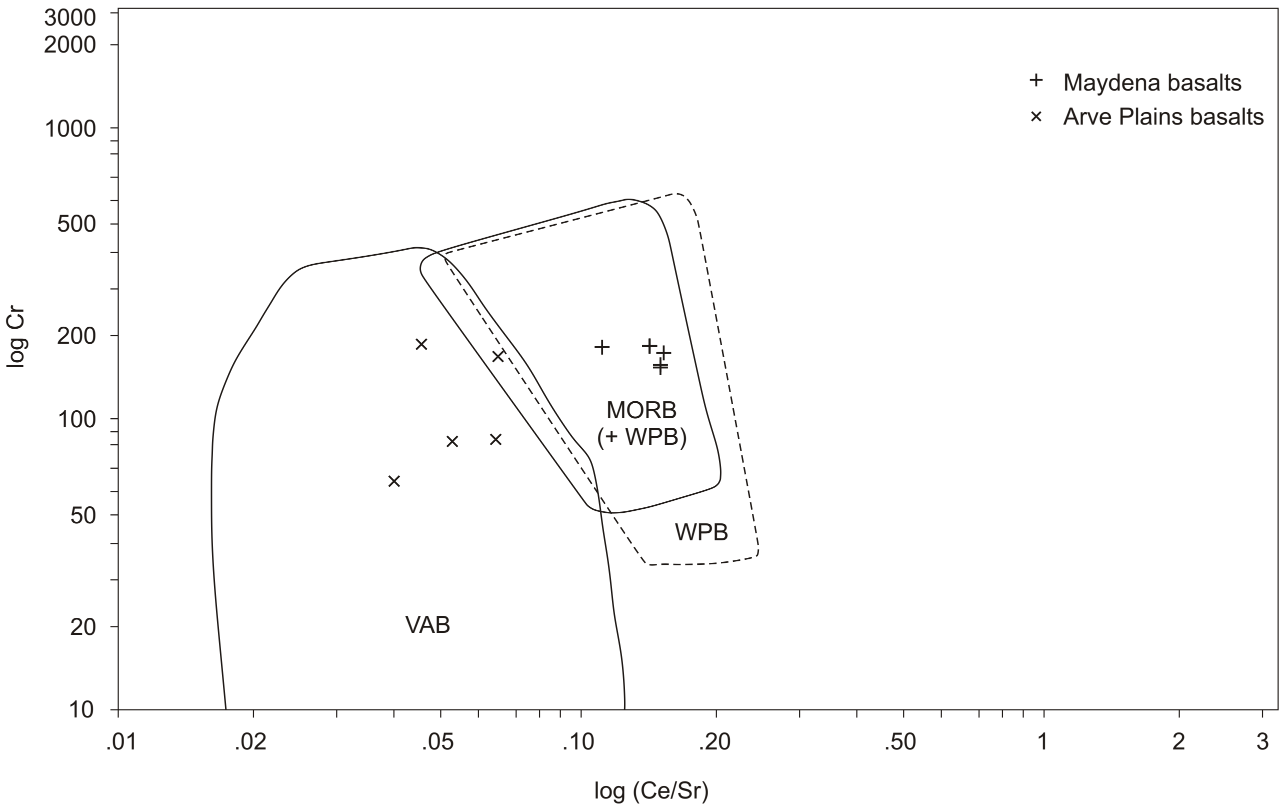


Figure 23

Basaltic rocks plotted on the V-Ti discrimination diagram of Shervais (1982). CFB are continental flood basalts, OIB are ocean island basalts, other field labels as for Figures 17 to 22.

A



B

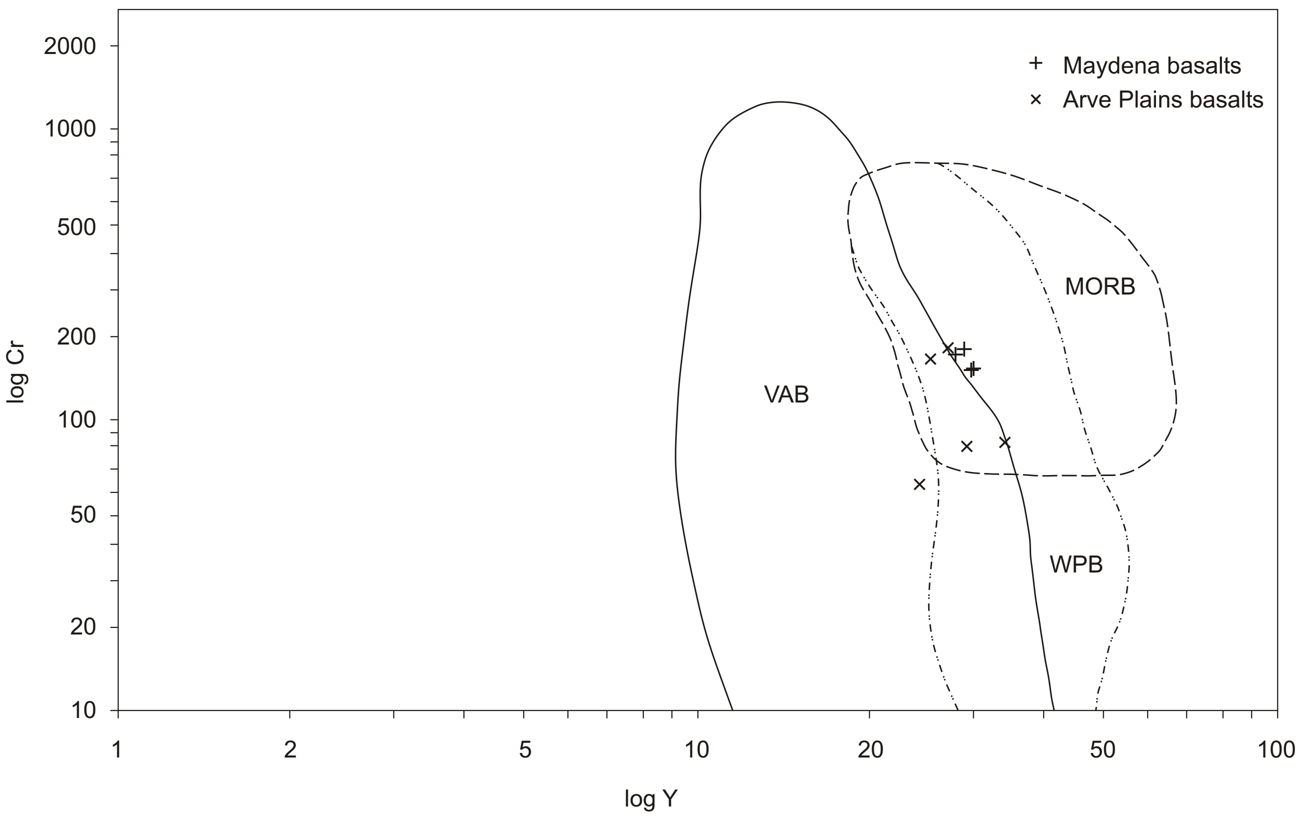
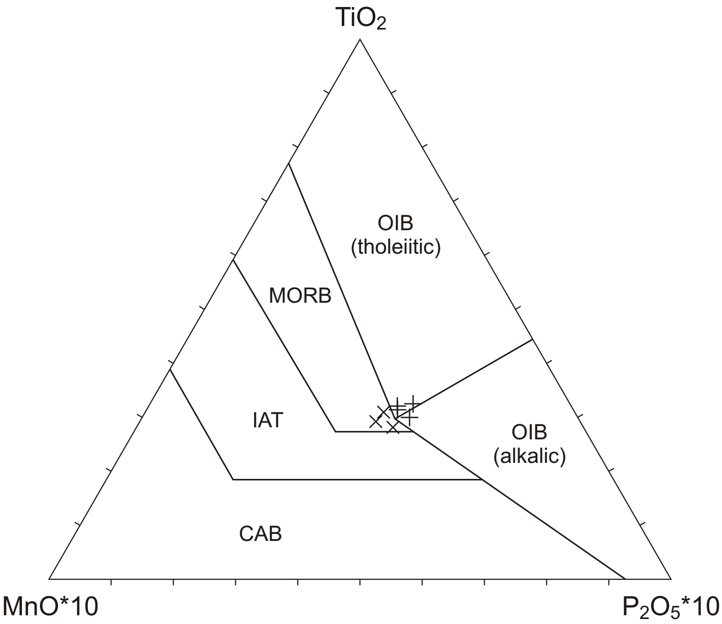


Figure 24

Basaltic rocks plotted on discrimination diagrams of Pearce (1982). Note logarithmic scales.
Field labels after Figures 17 and 21.
(a) Cr–Y; (b) Cr–Ce/Sr.



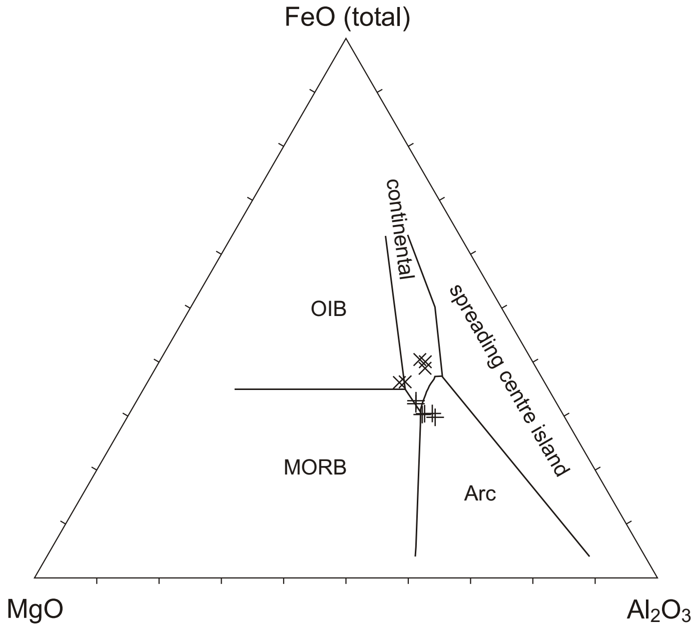
Oceanic basalts only

+ Maydena basalts

× Arve Plains basalts

Figure 25

Basaltic rocks plotted on the MnO–TiO_2–P_2O_5 discrimination diagram of Mullen (1983) for oceanic basalts and basaltic andesites. Field labels as for Figures 17 and 23.



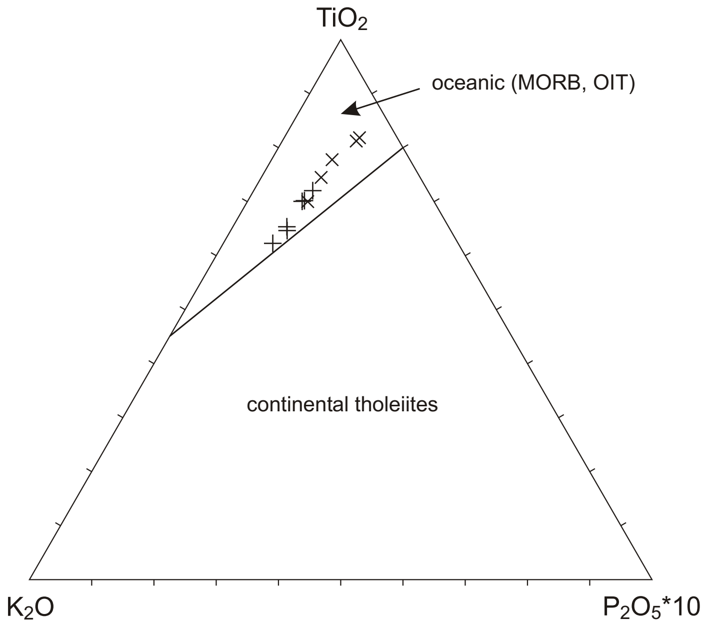
Subalkalic rocks
SiO_2 51–56% (dry)

+ Maydena basalts

× Arve Plains basalts

Figure 26

Basaltic rocks plotted on the MgO–total FeO–Al_2O_3 discrimination diagram of Pearce et al. (1977) for subalkalic rocks.



Unfractionated,
subalkalic basalts only

+ Maydena basalts

× Arve Plains basalts

Figure 27

Basaltic rocks plotted on the K_2O–TiO_2–P_2O_5 discrimination diagram of Pearce et al. (1975) for unfractionated subalkalic rocks, showing line dividing oceanic (MORB and ocean island) and continental tholeiites.

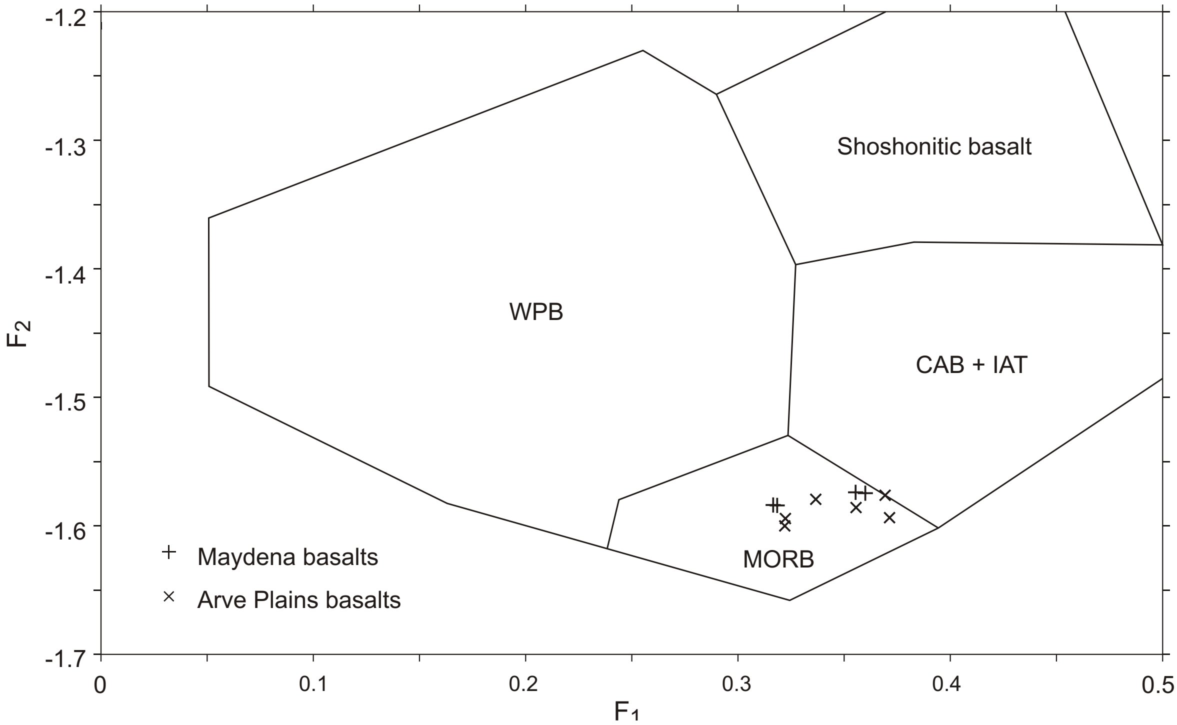


Figure 28

Basaltic rocks plotted on the major element discrimination function diagram of Pearce (1976). Field labels as for Figure 17.

have formed by a slightly lower degree of partial melting of a similar mantle source.

The Maydena samples most resemble Group D of the Spinks Creek Volcanics, but are more LREE and HFSE-enriched. Their higher SiO_2 and distinctly lower Ti/Zr ratios (53–61) probably preclude any correlation.

The relatively limited amount of data available from the basalts within the Crimson Creek Formation (Brown, 1986) show weak to moderate LREE-enrichment and a broad spread of incompatible element abundances and ratios. This encompasses both the Maydena rocks at the more enriched end, and the Arve Plains rocks at the more depleted end of the Crimson Creek Formation basalts.

South of Macquarie Harbour, the Lucas Creek Volcanics have been lithogeochemically correlated with the Crimson Creek Formation by McClenaghan and Findlay (1993).

Comparison with Early(?) Cambrian basalts of allochthonous(?) oceanic sequences

The 'low-titanium tholeiites' associated with mafic-ultramafic complexes (Brown, 1986; Brown and Jenner, 1988) of western Tasmania have markedly different trace element chemistry to both the Maydena and Arve Plains basalts, and are LREE depleted. The associated boninites (termed high magnesium-andesites by Brown, 1986) are also petrographically dissimilar, and differ in major as well as trace element geochemistry. Both the boninites and low-Ti tholeiites have geochemical signatures found only in fore-arc settings in modern tectonic environments.

Tholeiitic basalts and picrites at Miners Ridge near Queenstown (Crawford *et al*., 1992; Everard, unpublished data), most samples of the Birchs Inlet Volcanics (McClenaghan and Findlay, 1993) and possible correlates in the Mainwaring River area (A. V. Brown, unpublished data) are also LREE depleted.

The tholeiitic basalts of the 'Cleveland–Waratah Association' (Brown, 1986, 1989*b*), including the Deep Creek Volcanics (Collins, 1983) and possible correlates such as the Motton Spilite (Sproule, 1994), have less unambiguously oceanic affinities and less distinctive chemistry. They are difficult to distinguish from the Crimson Creek basalts on the basis of chemistry alone. Again, both the Arve Plains and Maydena samples overlap in terms of key immobile elements and their ratios.

Comparison with Middle–Late Cambrian arc basalts associated with Mt Read Volcanics

Crawford *et al*. (1992) distinguished five geochemical suites within the Middle–Late Cambrian Mt Read Volcanics. Of the three mafic–intermediate suites, one ('Suite 5') is typified by the Miners Ridge basalt and, as noted by these authors, may represent an unrelated inlier of older basement.

'Suite 3' comprises certain basalts and andesites within the Que–Hellyer Volcanics, the Lynch Creek 'basalts' near Queenstown, and possible correlates. These rocks have shoshonitic affinities and may be very LREE enriched, with La up to 400 times chondrites. They are also characterised by high P_2O_5/TiO_2 ratios (0.23–1.24) and low Ti/Zr (19–42). These parameters are all very different to both the Maydena and Arve Plains basalts.

'Suite 4' comprises tholeiitic basalts cropping out between two splays of the Henty Fault, and the possibly related Henty Dyke Swarm which intrudes the main felsic calc-alkaline rocks of the Central Volcanic Sequence. Although they have the highest TiO_2 (1.0–1.6%) of the Mt Read Volcanics suites, these values are still slightly lower than in the Maydena and Arve Plains samples. They are weakly to moderately LREE enriched with La_N of 17–53, and Ti/Zr of 90 to 107, within the range of the Arve Plains samples. Although some parameters (e.g. P_2O_5/TiO_2) are also similar, their very low Nb contents (<3 ppm XRF detection limit) are not seen at Arve Plains.

Lamprophyres, Glovers Bluff inlier

A narrow band of float on the ridge east of Eddy Creek (477800/5237500) is composed of fragments of basaltic rock and mafic volcaniclastic sandstone. The basaltic rocks are probably calc-alkaline lamprophyres, specifically spessartites, but are petrographically distinct from known western Tasmanian Devonian lamprophyres, which are generally minettes. Boulders on the alluvial flats near the Forster Prospect (478050/5234200) are also calc-alkaline lamprophyre or appinite (Bottrill *et al.*, 1999), but are coarser grained than the rocks east of Eddy Creek. The age of these rocks is uncertain (see discussion in *Stratigraphy* section).

Petrography

In thin section sample R008096, from the ridge east of Eddy Creek, is aphyric to sparsely microporphyritic. Sporadic pseudomorphs up to 800 μm across of euhedral former amphibole are now replaced by chlorite, probable epidote and brown oxidised material. There are also rare microphenocrysts (200–400 μm across) of euhedral colourless clinopyroxene. The fine-grained groundmass appears to consist mainly of splinters (up to 100 μm long) of pale brown to yellow pleochroic amphibole and altered plagioclase. The section includes a chilled contact against altered hornfels.

In sample R007645, also from east of Eddy Creek, sparse phenocrysts (up to 1 mm) of euhedral colourless clinopyroxene have equant octagonal basal sections and elongate longitudinal sections. They grade into the groundmass of euhedral to subhedral prisms (10–200 μm) of brown to straw-yellow pleochroic amphibole, largely altered (prehnitised?) feldspar, pale yellow chlorite, minor augite and altered olivine. There is a rather sparse dissemination of small (<100 μm), equant to scaly opaque grains.

Sample R008116 is similar to R007645 from the same locality, but coarser grained and lacking in clinopyroxene. It consists mainly of prismatic brown amphibole (up to 500 μm), altered plagioclase and pale yellow chlorite. There is also minor secondary amphibole (tremolite-actinolite) and rare brown biotite, sparse small opaque grains and minor interstitial quartz.

The coarser-grained amphibole-bearing rocks from near the Forster Prospect have been collected and described by Bottrill and Woolley (1996). They are briefly described below.

Sample 402039 consists of euhedra and subhedra (up to 1 mm) of chloritised clinopyroxene, together with interlocking ('subophitic') brown amphibole (up to 500 μm), plagioclase laths (<1 mm) partly altered to sericite ± prehnite, and rather sparsely distributed equant opaque minerals.

Sample 402040 consists mainly of plagioclase laths (altered to albite, clinozoisite and sericite), subhedral brown hornblende (up to 5 mm, but typically 1–2 mm, embayed and partly replaced by finely granular to fibrous tremolite and minor epidote) and colourless clinopyroxene. There is also minor olivine and pyrite, and traces of magnetite, apatite, rutile, sphene, carbonate and epidote.

Sample 107807 consists of generally euhedral brown hornblende (up to 3 mm) intergrown with coarse-grained plagioclase, but there are extensive areas of alteration to prehnite and minor epidote. Ilmenite/leucoxene and severely altered ragged laths (up to 1 mm) of possible former biotite are also present.

Electron microprobe work by R. S. Bottrill showed that the amphibole in these rocks is edenite and Ti-rich magnesiohastingsite, with secondary actinolite and ferroactinolite.

Geochemistry

Two chemical analyses from samples collected near the Forster Prospect (Table 2) have been obtained and previously discussed by Bottrill and Woolley (1996). Both have the major element composition of strongly to mildly potassic alkali basalts, and the high Mg#, Cr and to a lesser extent Ni suggests that they are near-primitive, whilst the relatively low levels of high field strength elements such as Zr, Nb and the light rare-earths are more like tholeiitic basalts. These features are consistent with assignment to the calc-alkaline branch of the lamprophyre clan (e.g. Rock, 1991).

Lamprophyre dykes are rare but widespread in western Tasmania, and have been reported from localities as diverse as the Hellyer mine, Queenstown, Nielson River, Varna Bay, Point Hibbs, Elliott Bay, Nye Bay, Wreck Bay, Raglan Range, Mt McCall, Gordon Dam and the Florentine River headwaters (see Sutherland and Corbett, 1974 and McClenaghan *et al.*, 1994 for reviews). Most contain abundant biotite (> hornblende) and potash feldspar (> plagioclase) and are therefore petrographically minettes, but hornblende-augite-phyric spessartites occur in the Raglan Range (Gee, 1963) and at Gordon Dam. Devonian radiometric ages have been obtained from minettes at and near Varna Bay (366 ± 9 to 378 ± 8 Ma, McClenaghan *et al.*, 1994) and from Prince Lyell mine (363 ± 3 Ma, Baillie and Sutherland, 1992).

Three chemical analyses of western Tasmanian lamprophyres, from south of Macquarie Harbour (McClenaghan and Findlay, 1993) and from Prince

Table 2

Analyses of igneous rocks

													Comparative W Tas lamprophyres		
	Maydena (Maynes Hill area)				Weld and Huon Rivers (Arve Plains Inlier)					Weld River aplite	Glovers Bluff area		Varna B	Nielson R	Mt Lyell
Field No.	S189	S190	S191	S466	WR72	WR73	WR82	WR84	WR85	WRS	402040	107639	MH111a*	MH258a*	101698b#
Anal. No.	881499	881500	881501	960777	960778	960779	960780	960781	960782	970009	970373	970399	820300	830645	851325
mE	462300	462050	462050	462050	480775	480825	480450	480700	480725	475950	477600	478200	355700	357200	382500
mN	5263200	5263750	5263750	5263750	5233100	5233050	5232775	5232750	5232750	5235880	5234800	5234100	5294900	5301600	5342600
SiO_2	52.45	52.30	52.94	51.16	48.40	50.72	48.88	49.07	49.03	71.33	48.00	47.53	48.12	45.93	48.14
TiO_2	1.77	1.81	1.75	2.13	1.91	1.64	1.89	2.07	1.63	0.09	1.26	1.33	1.17	0.51	0.89
Al_2O_3	15.00	14.27	14.00	13.87	13.54	13.76	13.60	14.30	13.99	15.10	14.01	14.00	10.52	20.77	10.94
Fe_2O_3	1.85	1.28	1.59	2.03	2.00	5.70	1.50	6.40	5.19	1.37	1.95	2.07	2.51	2.07	2.24
FeO	7.54	7.96	7.53	8.13	10.35	7.71	10.49	8.13	7.99	0.49	6.65	8.85	5.05	5.55	5.69
MnO	0.16	0.16	0.16	0.17	0.21	0.18	0.19	0.19	0.18	0.04	0.16	0.21	0.11	0.16	0.19
MgO	6.45	6.58	6.78	6.97	7.82	5.61	7.43	6.12	5.82	0.28	10.72	10.43	11.64	7.87	13.8
CaO	8.35	7.36	8.20	7.76	6.88	6.46	7.15	4.27	8.18	0.26	8.88	6.07	5.09	9.68	7.47
Na_2O	2.49	3.50	2.75	3.37	4.02	4.62	4.16	5.33	4.42	5.13	2.26	3.15	1.49	2.73	0.89
K_2O	0.85	0.54	0.71	0.54	0.41	0.47	0.31	0.18	0.12	4.07	2.04	1.40	3.11	0.20	3.59
P_2O_5	0.23	0.23	0.25	0.28	0.25	0.24	0.24	0.29	0.24	0.03	0.33	0.34	0.75	0.19	0.34
SO_3	0.13	0.13	0.14	0.10	0.16	0.08	0.10	0.08	0.08	0.07	0.10	0.15	0.20	<0.05	0.17
CO_2	0.07	0.05	0.12	0.15	0.07	0.16	0.08	0.26	0.26	0.00	0.00	0.64	5.88	0.15	1.78
H_2O^+	3.35	3.54	3.27	3.18	3.86	2.44	3.72	2.93	2.82	0.74	3.18	3.73	3.69	4.49	3.62
TOTAL	100.69	99.71	100.19	99.81	99.89	99.77	99.74	99.61	99.94	99.00	99.53	99.43	99.33	100.32	99.75
FeOt	9.21	9.11	8.96	9.96	12.15	12.84	11.84	13.89	12.66	1.72	8.40	10.71	7.31	7.41	7.71
Mg# (0.20)	59.58	60.3	61.41	59.55	57.51	47.89	56.89	48.1	49.16		72.85	67.18	77.01	69.07	79.02
Li	na	na	na	na	na	na	na	na	na	6	na	na			
B	na	na	na	na	na	na	na	na	na	<25	na	na			
F	na	na	na	na	na	na	na	na	na	<100	na	na			
Sc	31	31	33	36	36	37	32	49	35	<9	38	39	33	40	23
V	300	300	260	320	340	370	340	430	410	6	280	270	210	120	165
Cr	195	185	195	165	195	63	180	90	87	47	620	320	560	580	830
Co	39	40	41	32	53	40	48	41	37	<8	39	43	38	27	45
Ni	30	29	31	42	125	65	120	64	66	6	230	140	81	120	460
Cu	5	<4	<4	<5	140	125	210	180	84	6	84	15	81	23	78
Zn	86	77	79	96	99	92	95	100	91	40	75	94	50	91	79
Ga	nd	nd	nd	20	18	16	17	16	19	20	18	18	12	9	13
As	nd	nd	nd	<20	<20	<20	<20	<20	<20	<20	<20	<20	<10	<10	30
Rb	29	19	24	21	12	17	9	10	10	120	57	41	185	8	130
Sr	360	360	370	360	440	490	290	380	340	51	390	125	100	490	320
Y	29	28	29	30	27	24	25	34	29	28	18	20	26	14	28
Zr	195	195	195	210	115	100	105	135	105	195	135	98	170	42	200

	Maydena (Maynes Hill area)				Weld and Huon Rivers (Arve Plains Inlier)					Weld River aplite	Glovers Bluff area		*Comparative W Tas lamprophyres*		
													Varna B	Nielson R	Mt Lyell
Field No.	S189	S190	S191	S466	WR72	WR73	WR82	WR84	WR85	WRS	402040	107639	MH111*	MH258*	101698#
Anal. No.	881499	881500	881501	960777	960778	960779	960780	960781	960782	970009	970373	970399	820300	830645	851325
mE	462300	462050	462050	462050	480775	480825	480450	480700	480725	475950	477600	478200	355700	357200	382500
mN	5263200	5263750	5263750	5263750	5233100	5233050	5232775	5232750	5232750	5235880	5234800	5234100	5294900	5301600	5342600
Nb	19	18	18	22	7	8	9	11	7	51	20	17	7	17	10
Mo	na	na	na	<5	<5	<5	<5	<5	<5	5	<5	<5	<2	<2	bd
Sn	14	25	54	<9	<9	<9	<9	<9	<9	<9	<9	<9	<3	<4	nd
Ba	140	130	135	155	440	310	165	135	94	420	420	210	2000	42	2600
La	<25	<25	<25	<20	<20	<20	<20	<20	<20	36	<20	<20	33	19	60
Ce	50	53	41	54	36	<28	<28	30	<28	59	47	42	110	64	125
Nd	36	26	32	39	<20	<20	<20	31	21	25	21	23	41	15	46
W	88	110	195	<10	<10	<10	<10	10	<10	<10	<10	<10	nd	nd	nd
Pb	<11	<11	<11	<10	<10	<10	<10	<10	<10	15	10	<10	<4	4	45
Bi	<6	<6	<6	<5	<5	<5	<5	<5	<5	<5	<5	<5	nd	nd	bdl
Th	<10	<10	<10	20	10	19	14	12	13	19	15	13	20	4	18
U	<12	<12	<12	<10	<10	<10	<10	<10	<10	<10	<10	<10	6	<4	5
inaa data															
La	na	na	na	22.30	7.77	8.40	7.32	9.70	7.15						
Ce	na	na	na	52.10	19.90	19.20	19.10	24.70	17.60						
Nd	na	na	na	30.30	14.30	13.00	14.30	17.30	13.00						
Sm	na	na	na	6.77	4.60	3.94	4.19	5.02	4.14						
Eu	na	na	na	1.92	1.35	1.19	1.29	1.40	1.41						
Tb	na	na	na	0.97	0.89	0.73	0.78	1.00	0.86						
Ho	na	na	na	1.14	1.09	0.96	0.96	1.30	1.05						
Yb	na	na	na	2.43	1.90	1.91	2.00	2.73	2.33						
Lu	na	na	na	0.33	0.21	0.25	0.23	0.35	0.33						
key element ratios															
Ti/Zr	54.4	55.6	53.8	60.8	99.6	98.3	107.9	91.9	93.1		56.0	61.2	41.3	72.8	26.7
Nb/Zr	0.097	0.092	0.092	0.105	0.061	0.068	0.086	0.081	0.067		0.148	0.174	0.041	0.405	0.050
Zr/Y	6.72	6.96	6.72	7.00	4.26	4.17	4.20	3.97	3.62		7.50	4.90	6.54	3.00	7.14
Ti/Y	366	388	362	425	423	410	453	365	338		420	399	307	501	109
Nb/Y	0.66	0.64	0.62	0.73	0.26	0.33	0.36	0.32	0.24		1.11	0.85	0.27	1.21	0.36
Zr/P_2O_5	0.085	0.085	0.078	0.075	0.046	0.042	0.044	0.047	0.044		0.041	0.0288	0.0227	0.0221	0.0588
P_2O_5/TiO_2	0.130	0.127	0.143	0.133	0.133	0.144	0.129	0.142	0.150		0.262	0.256	0.641	0.373	0.382
(La/Yb)N				6.19	2.76	2.97	2.47	2.4	2.07						

* McClenaghan & Findlay (1993)

\# Baillie & Sutherland (1992)

Lyell (Baillie and Sutherland, 1992), are quoted in Table 2. Six further analyses (also with trace element data) are given by White (1975). Even on the basis of this limited data these rocks are clearly highly variable, and may include representatives of several suites. The lamprophyre boulders near Forster Prospect have significantly lower K, Rb, Ba and REE, and higher Al_2O_3, Ti/Zr and Nb/Zr than the Varna Bay and Prince Lyell minettes (and, apart from Al_2O_3, also White's data). However these parameters (except Ce) are respectively higher and lower than the petrographically dissimilar, strongly altered rock from the Nielson River area.

Jurassic dolerite (SMF)

Jurassic dolerite intrusions are widespread in Tasmania and occur primarily as gently transgressive thick sheets in the Parmeener Supergroup. The sheets are considered to arise from pipes and dykes one to two kilometres across that develop into crude cone-sheet like T-shaped intrusions at or near the base of the Parmeener Supergroup (Leaman, 1975). These T-sections are usually a few kilometres across, asymmetrical, and composed of stepped, sub-horizontal weakly transgressive and near-vertical to moderately inclined more strongly transgressive sheet segments that ascend through the Parmeener Supergroup. Intermediate intrusion forms are found between the central zone and the more sill-like extensive sheets that surround them. Multiple periods of intrusion may lead to complex structures.

Radiometric methods indicate that the emplacement probably occurred over an interval of less than twenty million years and a mid-Jurassic average age of 174.5 ± 8 Ma is indicated (Schmidt and McDougall, 1977; Banks *et al.*, 1989). The tholeiitic magma was probably generated as a precursor to the break up of the Gondwana landmass (Morrison *et al.*, 1989) and petrogenetic studies indicate that it has a distinctive continental crustal-type signature (Hergt and McDougall, 1989).

Typically the dolerite is fine to medium-grained and consists of labradorite, pigeonite and augite in subophitic intergrowths with a felsic-siliceous mesostasis with accompanying iron minerals. Very fine-grained to devitrified glassy quenched textures are present near the margin contacts, commonly with conspicuous small phenocrysts of orthopyroxene. Although the margins are remarkably uniform in composition, differentiation in thicker dolerite intrusions results in mineralogical and textural variations, including coarse-grained granophyre in the upper third of some intrusions.

Detailed petrological studies have been done by Edwards (1942) and McDougall (1962, 1964), while Banks *et al.* (1989) gave general descriptions.

A non-standard subdivision of igneous rock grainsize has been depicted on the maps, with vf = 0.2–0.7 mm, f = 0.7–1.5 mm, m = 1.5–3 mm and c >3 mm. Fine-grained dolerite with orthopyroxene phenocrysts has been depicted as *fo* and granophyre and pegmatite as *g*.

Dolerite is widespread in the eastern parts of the Maydena–Picton map sheets and occurs mostly as eroded sheets, 200–400 m thick, that cap the mountain ranges.

Isolated small (few metres) outcrops occur distant from the main intrusions north of the Jubilee Range at 462250/5256500 and 466050/5257050.

Particularly in the southern part of the area, exposures in road cuttings are commonly very to extremely weathered with occasional protuberances of fresh rock. Slope deposits, usually 0.5–1.5 m thick, that contain less weathered dolerite clasts usually overlie the bedrock. Blue-grey when fresh, the weathered rock is usually light yellow-brown in colour, but at high altitudes the weathered rock and the matrix of the slope deposits is usually a stronger orange or red-brown colour. Slightly weathered rock protuberances are more prevalent on the crests and shoulders of ridges and unweathered rock is found in the channels of some of the streams and rivers. Strong vertical columnar jointing (Leaman, 1999) facilitates the development of high cliff faces on the highest mountain ranges.

Much of the high altitude dolerite has been photo interpreted. The most reliable features used in the interpretation are sub-horizontal surfaces of exposed rocks, cliff lines showing columnar jointing, and the presence of regular sets of joint-related linears. The lines marking the lower edges of photo-interpreted dolerite have been joined to produce a long curved photo lineament on the maps. Such lines have been depicted in the Maydena area and in parts of the Snowy Range to delimit areas of photo-interpreted dolerite. Dolerite has been inferred to occur downslope from this line, but these extensions are not strongly supported by features visible on the aerial photographs. Several sinuous photo lineaments depicted northwest of Lake Skinner may be streams or tension joints related to the glacial erosion at Lake Skinner. On the southern side of Marriotts Lookout the airborne magnetic maps (Curtis and Hartman, 1966) suggest a larger area of dolerite than expected based on the mapped distribution of dolerite. Additional dolerite bedrock may underlie some of the area mapped as dolerite talus.

Glovers Bluff cone sheet (CRC)

In the Glovers Bluff (Forster Prospect) area (Weld map sheet), contact metamorphism of Proterozoic dolomite, associated with the dolerite, has resulted in an unusual assemblage of magnesian skarn and siliceous breccia, described in a previous section and by Bottrill *et al.* (1999). Chilled margins of dolerite against skarn are in places bleached and partly or completely altered to prehnite, serpentine, amphiboles and smectites (Bottrill *et al.*, 1999). A ground magnetic survey in this area (Appendix 2) shows the existence of a belt of relatively weakly magnetic dolerite, 100–200 m wide and about three kilometres long, extending from immediately east of the Forster Prospect northwards to the crest of the ridge east of Eddy Creek, at least as far north as 478200/5236400. This is shown as subdued sections on magnetic profiles and by relatively very low magnetic susceptibility determinations (see Appendix 2). A dolerite from the weakly magnetic zone on the ridge east of Eddy Creek (R008107) contains minor biotite, and relatively sparse opaque minerals. A polished thin section shows that the opaque minerals are dominated by ilmenite and pyrite; there is minor chalcopyrite and pyrrhotite, and an apparent absence of magnetite (R. S. Bottrill, pers. comm.). The dolerite at this locality has a magnetic susceptibility of only 0.4×10^{-3} SI units, compared to typical values of 5 to 20×10^{-3} SI units elsewhere. The weakly magnetic zone may indicate a more widespread zone of subtle alteration associated with the Forster Prospect mineralisation.

A thin section from the chilled upper margin of the 'cone sheet' at 476550/5232050 (near Warra Road, Weld map sheet) (R008042) shows sparse orthopyroxene phenocrysts (1 mm) in an intergranular groundmass of felted plagioclase and granular clinopyroxene, with almost no opaque minerals.

A thin section from the base of the sheet at 479190/5234275 (Weld River, Weld map sheet) has a groundmass similar to R008042, but contains common phenocrystic plagioclase and clinopyroxene (1–2 mm) as well as orthopyroxene. R008092, a fine-grained dolerite from 480500/5233900 just east of the Weld map sheet, similarly contains phenocrysts and glomerophenocrysts of clinopyroxene, plagioclase and minor orthopyroxene.

Aplite of uncertain age (Ksa) (Weld map sheet)

There is an isolated outcrop of aplite in the Weld River (475950/5235880) at, or close to, the contact between Proterozoic quartzite and Jurassic dolerite, at the western edge of the Glovers Bluff inlier. The aplite occurs as a single, low, water-polished outcrop, a few metres across, on the north bank of river. No contacts are exposed and the outcrop is surrounded by river alluvium. The Proterozoic Needles Quartzite correlate crops out about 250 m downstream, and Jurassic dolerite crops out about 100 m upstream of the aplite outcrop.

The aplite is a tough, fine-grained massive rock, in thin section consisting mainly of sericitised alkali feldspar, quartz and minor altered probable biotite. The petrography and chemistry of this occurrence are described by Everard (1999).

Everard (1999) concluded that although the composition of the aplite plots close to the haplogranite minimum at pressures of 400–500 MPa, trace element geochemistry suggests that it is not a fractionated melt. The aplite probably formed as a minimum melt at lower to mid crustal levels (15–20 km). Its age is unknown, and it is geochemically dissimilar to both the Cretaceous alkaline rocks at Port Cygnet and, to a lesser extent, mid-Palaeozoic Tasmanian granites. Nearby gold mineralisation at the Forster Prospect is probably unrelated.

Proterozoic to lower Palaeozoic rocks (CRC)

Harrisons Opening Formation (western Picton and Weld map sheets)

The rocks with the strongest regional deformation in the five map sheets described here belong to possibly the oldest succession, the Harrisons Opening Formation, in the western Picton and southwestern Weld map sheets. This succession, of turbiditic conglomerate, sandstone and black phyllite, dips steeply and predominantly faces northeast (fig. 29*a*). These rocks have a strong, pervasive first cleavage (S_1) that is a rough cleavage or differentiated surface in sandstone, and a slaty cleavage in phyllite. Clasts in conglomerate are usually strongly flattened into lenticular or spindle-shaped bodies aligned in S_1. Tight to isoclinal, outcrop-scale F_1 folds were observed in places. S_1 is nearly everywhere steep and trends northwest (fig. 29*b*). F_1 hinges mainly plunge northwest, and a weak girdle in the stereoplot of bedding is consistent with this (fig. 29*a*).

A crenulation cleavage is usually present and is the dominant cleavage in some phyllite outcrops. A stereoplot of crenulation cleavages from the whole area shows two predominant orientations; one NE–SW trending, with a steep northwest dip, and the other NW–SE trending and subvertical (fig. 29*c*). These are domainal with little or no overlap; the northeasterly-trending crenulation is found in the western area (west of Harrisons Opening, on the western slopes of Mount Picton), while the northwesterly-trending crenulation is found to the east (east of Harrisons Opening, and in the Manuka Creek area on the Weld map sheet). No overprinting relationships between the two crenulations were observed. In the eastern area, the northwesterly-trending crenulation is frequently the predominant cleavage in outcrop, with S_1 obscured or visible only in microlithons.

The Harrisons Opening Formation is faulted against diamictite of the Weld River Group to the east. The fault appears to coincide with an abrupt eastward decrease in degree of deformation. Exposures west of the fault in the Huon River (466450/5228300) show a strong slaty cleavage in black phyllite of the Harrisons Opening Formation. By contrast only a weak cleavage is present in the dolomitic mudstone matrix of the diamictite on the eastern side of the fault.

In the Mt Anne–Mt Bowes area (Pedder Quadrangle; Calver *et al*., 1990) and also possibly the Jubilee Range area, F_1 folds plunge moderately northwest (as in the Harrisons Opening Formation) but in those areas, F_1 major folds are overturned to the northeast and S_1 dips

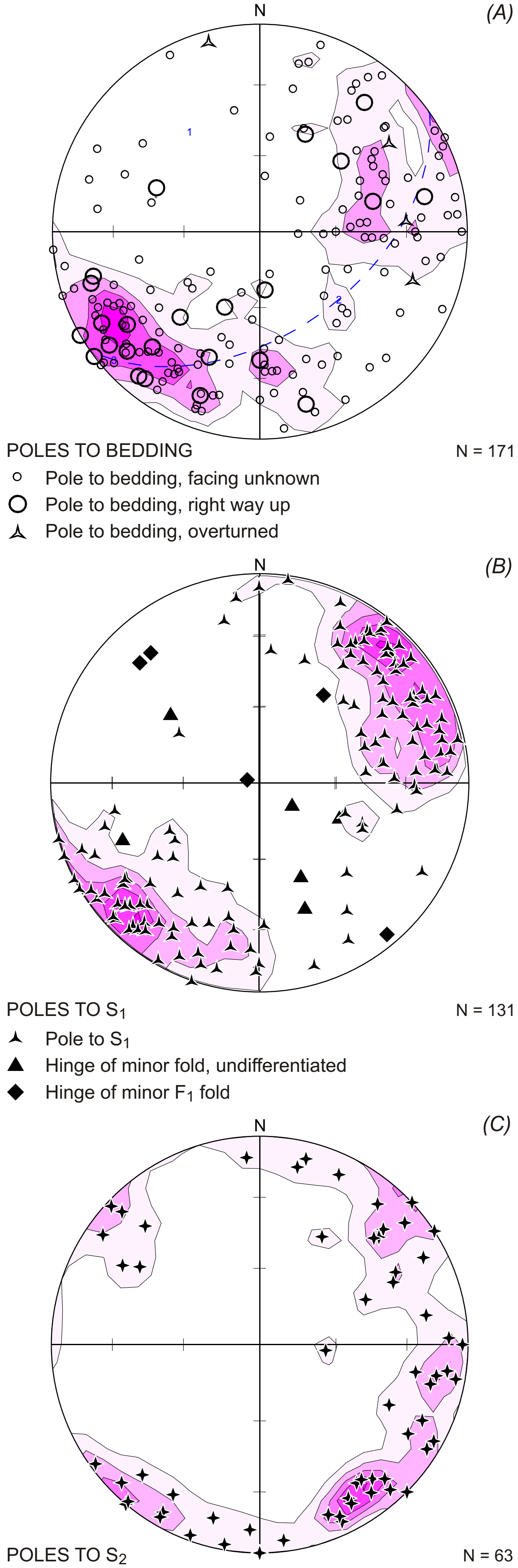


Figure 29

Equal area plots, Harrisons Opening Formation.

southwest. The crenulation cleavages in the Harrisons Opening Formation are similar in orientation to those in the Mt Anne area, where the northeast-trending, steeply northwest-dipping crenulation is S_2, and the northwest-trending crenulation is S_3 (Calver *et al.*, 1990, p. 87).

Blakes Opening area (Picton, Weld map sheets)

A major meridional fault separates the Harrisons Opening Formation from the Cotcase Creek Formation (Weld River Group) in the Picton and Weld map sheets. The Cotcase Creek Formation (dolostone, diamictite, pebbly siltstone) dips steeply and faces east. There is a weak northwest-trending steep slaty cleavage in diamictite and siltstone, probably equivalent to S_1 in the Harrisons Opening Formation.

East of Blakes Opening, Cambrian lithicwacke dips moderately east, and is inferred to be faulted against the Cotcase Creek Formation. In the lithicwacke turbidite succession there is a very weak subvertical NNW-trending cleavage in some mudstone interbeds.

Further east, Ordovician Gordon Group limestone also dips moderately east. A fault is inferred against the Cambrian lithicwacke succession, because of the absence of any Denison Group correlative underlying the Gordon Group.

Clark Group and Weld River Group, Jubilee Range area (Skeleton, Nevada map sheets)

The Jubilee Range Anticline dominates the structure of the Proterozoic rocks in the western Skeleton and northwestern Nevada map sheets. Spatially averaged data and a stereoplot of bedding from the whole area (fig. 30, 31, 32) show the first-order structure to be an anticline plunging about 20° to the northwest. The anticline is considerably modified by north to northeast-trending cross faults. The north-facing limb — mostly lying within the Skeleton map sheet — encompasses the whole of the Clark Group and the lower part of the Weld River Group, which conformably overlies the Clark Group in this area. This limb dips moderately to steeply north, and in places is overturned. On the southwest-facing limb, lying mostly within the Nevada map sheet, the Weld River Group and much of the Clark Group are faulted out, and dips are mostly gentle. The first-order anticline is thus inclined, with a southwest-dipping axial surface.

Open, reclined folds in quartzite in domain 8 (e.g. 466000/5251000) (fig. 30) have hinge lines that plunge 30° to the northwest, and are probably related to the first-order structure.

No cleavage has been identified which can be related to the Jubilee Range Anticline. With the exception of mudstones, which carry a weak bedding-parallel

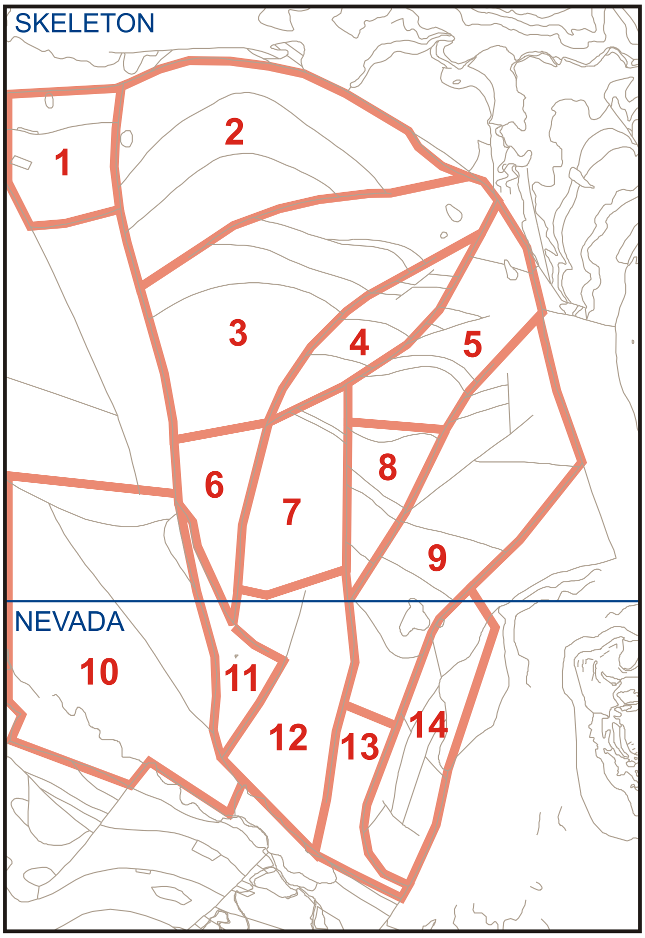


Figure 30

Geological boundaries and domain boundaries for equal area stereoplots, Jubilee Range area (see Figure 32).

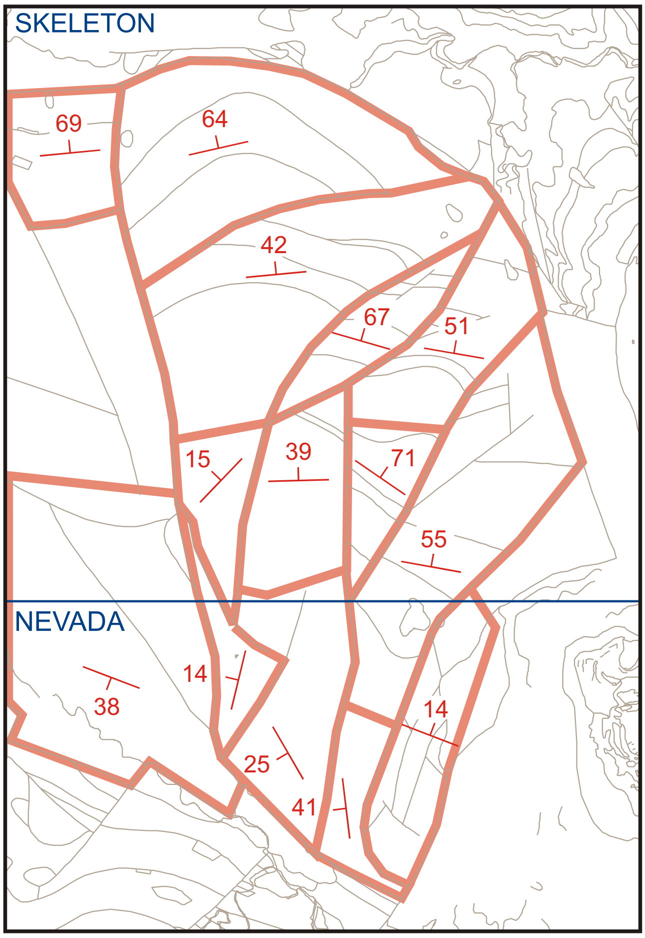


Figure 31

Average bedding orientations in domains, Jubilee Range area.

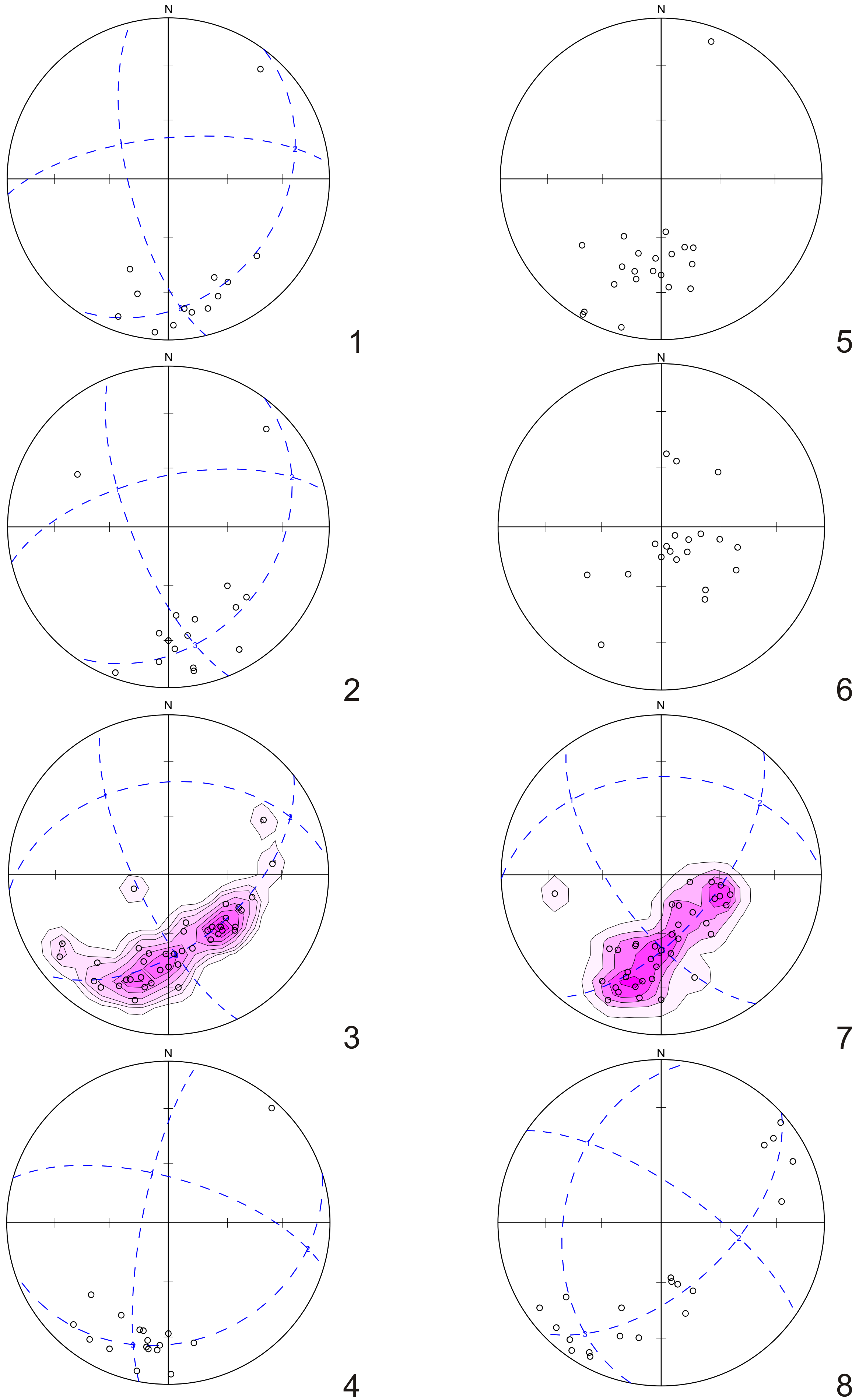


Figure 32a

Equal area plots, Jubilee Range area.

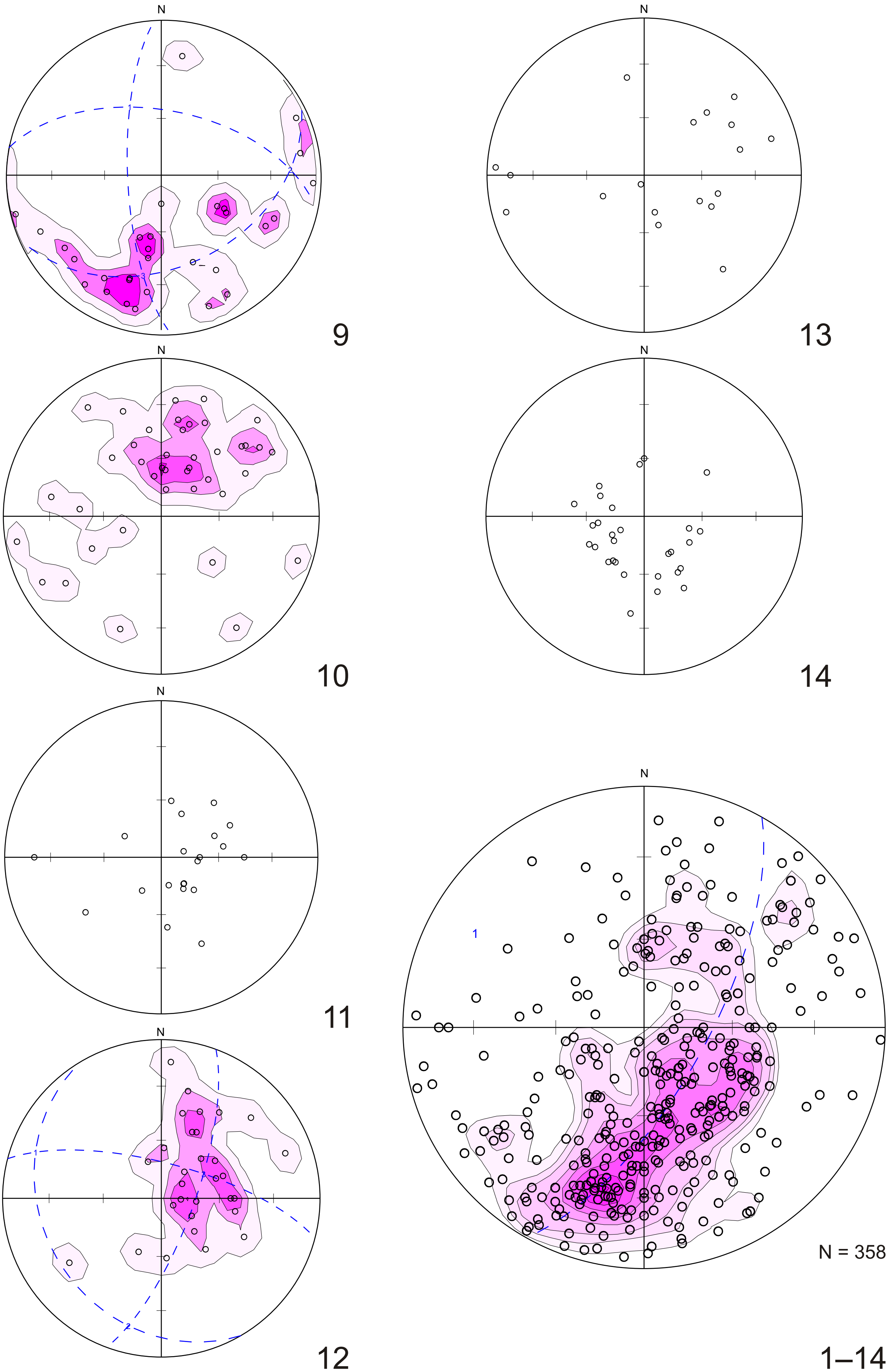


Figure 32b

Equal area plots, Jubilee Range area.

cleavage, outcrop over the whole area appears to be unstrained or only weakly strained. The absence of strain is shown by lack of cleavage and the undeformed state of sedimentary structures such as cross bedding in Pcq, and halite hopper casts, stromatolites and mud cracks in Pcdc and Pcdos (e.g. Plate 3, Plate 5).

Mudstone of Pcd and Pcmm has a weak slaty cleavage, here called S_1, parallel to bedding. This is defined by a preferred orientation of fine-grained (<10 μm) phyllosilicates, and appears as an extinction direction under low magnification and crossed polars. A similar bedding-parallel slaty cleavage was seen in Pcmm in the adjoining area in the Pedder Quadrangle, and is interpreted to be a tectonic fabric rather than merely a compactional fabric (Calver *et al.*, 1990, p.89).

In many places there are minor folds and weak crenulation cleavages. These folds tend to be angular in profile, one to a few metres in wavelength and have interlimb angles around 60 to 90°. Associated axial-planar crenulation cleavages are weak or absent. The most simple interpretation of these features is that they result from two phases of deformation. Possibly the first phase comprises minor folds at four localities, all located on the northern limb of the major anticline. These folds all plunge moderately northwest, and have sinistral (S-) vergence. None has discernible axial planar cleavage. They are roughly coaxial with the major anticline, and may be parasitic structures.

The second phase, which post-dates the major anticline, involves a crenulation (and/or axial planes of minor folds) that dip moderately to steeply west or northwest. Hinge directions and asymmetry of this group of minor folds vary in accord with the position on the first-order anticline, consistent with superimposition on a pre-existing structure. Thus, on the northern limb of the anticline, steep north to northeast plunges and dextral (Z-) vergence are the rule, although in places the vergence is only slight (e.g. 466600/5252000). Nearer the hinge of the major structure at 462300/5256300 minor fold hinges plunge northwest, with steeply northwest-dipping axial planes and dextral vergence, and may belong to this group. On the southern limb of the major structure, upright minor folds with gentle southwest and north plunges (465200/5248100, 466100/5247600) probably also belong to this group. Where present, cleavages are weak crenulation cleavages (crenulating the bedding-parallel slaty cleavage) in mudstone, spaced fracture cleavages, or rough cleavages in siltstone of Pcmm.

A prominent north to northeast-trending family of cross faults transects the Jubilee Range anticline. These faults have a similar orientation (in map view) and a similar apparent vergence to the north to northeast-trending folds and cleavage described above, and may belong to the same phase of deformation.

In the Mt Anne–Mt Bowes area in the Pedder Quadrangle (Calver *et al.*, 1990) major F_1 folds are inclined (with southwest-dipping axial surfaces) to overturned with northwesterly-plunging hinges, and are similar in orientation to the Jubilee Range anticline. F_1 folds in the Pedder Quadrangle have a strong slaty axial planar cleavage. There are also F_3 folds, coaxial with F_1, that also have southwest-dipping axial surfaces. These F_3 folds have an axial-planar crenulation cleavage. It is not certain on present evidence whether the Jubilee Range anticline correlates with D_1 or D_3 of the Mt Anne–Mt Bowes area. The presence of a later fold phase at Jubilee Range, with northeasterly-dipping axial surfaces and crenulation cleavage, which is similar in orientation to D_2 structures in the Mt Anne area, suggests that the Jubilee Range anticline may correlate with D_1. A corollary of this correlation is that the weak bedding-parallel fabric in the Jubilee Range area is pre-D_1 of the Mt Anne area.

Weld Valley (Nevada, Weld map sheets)

The dolostone of the Weld River Group northeast of Mount Weld (northern Weld and southern Nevada map sheets) dips steeply southwest. The abundance of grainstone allows facing to be determined in many places. Both northeast and southwest-younging directions are seen. Bedding at 469000/5240500 is overturned and faces northeast (shown as facing unknown on pre-2001 editions of the map). All but one of the facing determinations in this area could be accommodated by a major isoclinal synclinal fold axis with a steeply southwest-dipping axial surface trending at 305° through 469000/5240600. No fold closures were observed and the rocks are unstrained, as shown by the undeformed nature of sedimentary structures such as ooids.

Further up the Weld Valley, the structure of Proterozoic rocks — mainly Weld River Group — in the western part of the Nevada map sheet is poorly understood, because of sparsity of facing evidence, poor outcrop and difficulty of access, and evident structural complexity.

In the southwestern part of this area, in the upper Snake River valley, dolostone of the lower part of the Weld River Group (Pwt) mostly dips and faces northeast, and in places dips west to southwest and is overturned (400603/5242300). The dolostone is inferred to overlie Annakananda Formation (Pwa) and Humboldt Formation (Pcmm) correlates. This stratigraphy is considerably disrupted by major faults that trend northwest. In the southwest corner of the Nevada map sheet (460700/5240300), a slaty cleavage in mudstone of unit Puhcm dips moderately southwest, and nearby bedding readings are consistent with F_1 folds that plunge gently northwest and are overturned to the northeast. This is consistent with D_1 orientations in the Mt Anne–Mt Bowes area in the Pedder Quadrangle. Further northeast, in a separate inlier of Pcmm, a weak slaty cleavage is parallel to bedding, and a weak crenulation cleavage is axial-planar to upright, NNW-trending folds (463000/5242300), orientated similarly to F_3 of the Mt Anne–Mt Bowes area.

Still further northeast lies a broad (3 km) belt of Cotcase Creek Formation (Pwc) that extends along the Weld

Valley, and continues northwest into the Pedder Quadrangle (Calver *et al*., 1990). The Cotcase Creek Formation has faulted contacts with all other units, including Pwt and the Clark Group. Its structure and stratigraphy is poorly understood. The northeastern boundary is a northwest-trending major fault against Clark Group rocks, coinciding roughly with the prominent regional linear followed by the Weld River. A cataclastic foliation in this fault zone (at 462900/5246900) is vertical. The western boundary is an inferred major fault against Pwt north of the Snake River, this fault being probably continuous with the observed fault at 455700/5248000 in the Pedder Quadrangle. This fault was not observed but cataclastic foliation in nearby mudstone of Pwcm at 459500/5245100 (just west of the western boundary of the Nevada map sheet) dips steeply east.

Some lithological contacts within the Cotcase Creek Formation are observed faults. For example, diamictite (Pwcx) is faulted against dolostone (Pwcd) at 462350/5245500, with the fault dipping 54° north. Pwcd is faulted against Pwcm at 464300/5245800, and a cataclastic foliation is subvertical and trends northwest. Black shale within Pwcm carries a cataclastic foliation in many places. This is an anastomosing foliation marked by glossy cleavage surfaces and lenticular bodies of more competent dolostone or quartzite. A narrow (10 m) belt of sheared black shale (cataclasite) trends northwest along the Weld River at 465050/5245100, with massive dolostone on either side. The shear foliation dips steeply northeast, and the vergence of minor folds suggests east-side-up movement.

A fault block of Cotcase Creek Formation extends south from the Snake–Weld junction (464500/5245500) as far as the outcrops of Pwcg around 465000/5242000. Bedding within this fault block mainly dips moderately southwest, and (on sparse evidence) is predominantly right-way-up. The predominant cleavage is a slaty cleavage of variable intensity, that also dips southwest, and is steeper than bedding (e.g. 464075/5244600). The slaty cleavage is best developed in the mudstone of Pwcm, and in the more pelitic layers within Pwcg. It is only locally developed in diamictite (Pwcx), and there is no cleavage in dolostone (Pwcd). In some cases, clasts in diamictites are stretched, and have transverse brittle fractures (veins). The southwest-dipping slaty cleavage of this fault block probably correlates with S_1 of the Mt Anne–Mt Bowes area of the Pedder Quadrangle.

Data are too sparse to deduce a coherent concept of the structure elsewhere in the Cotcase Creek Formation on the Nevada map sheet. Pwcg recurs around 460800/5246300, where it dips moderately north and is right-way-up. A weak slaty cleavage dips moderately west here.

Devonian deformation, The Needles–Maydena area

The Tim Shea Anticline is flanked to the west by the Tiger Syncline, and to the east by the Westfield Syncline. These folds plunge gently northwest, and in the Tiger Range–Florentine Valley area to the north of The Needles–Maydena area, these folds are parallel and trend NNW. Southwards, the Tiger and Westfield synclines diverge strongly about the exposed northern end of the Jubilee Region, so that the Tiger Syncline is NNE-trending in the upper Florentine Valley–Frodshams Pass area (southwest of The Needles), and the southern extension of the Westfield Syncline is northwest-trending on the Maydena map sheet. This divergence in Devonian fold trends is attributed to refraction of a single fold phase. Consistent with this, the axial planes of the Tiger Syncline and Westfield Syncline are not vertical but dip steeply away from the Jubilee Region. This suggests that the presently exposed Proterozoic to Cambrian rocks of the Jubilee Region were relatively resistant to deformation in the Devonian.

An enigma is posed by the broad area of concealed Cambrian and Ordovician rocks under the alluvial flats of the upper Tyenna River (around 464000/5266000) in the western part of the Maydena map sheet. To the north and south, the flats are flanked by strike ridges of north-dipping Tim Shea Sandstone overlying Ragged Basin Complex (on Pine Hill at 465000/5264400 and Nicholls Spur at 464000/5267700). This structural repetition is presumably due to faulting, since there is no evidence of a southwest-dipping fold limb. Four short drill holes to basement (Styx 5, 6, 8 and 9) were drilled in an attempt to better constrain the concealed structure of this area, and are shown on the map. Two or more major south-side-down faults are inferred for this area. Two faults are required by the additional structural repetition implied by the presence of Cambrian chert float at 462700/5266300 and Gordon Group limestone in Styx 6 at 463000/5266700. The more southerly fault could trend more southwesterly towards the west, to cause the offset of the Cals–Ccwl contact between 460500/5267000 and 460500/5263500.

East of the river flats, a major fault of post-Parmeener Supergroup age is of a suitable orientation, but the movement of this fault is north-side-down, with a displacement of about 300 m seen in the Parmeener Supergroup stratigraphy.

Jurassic dolerite (SMF)

Dolerite occurs extensively in the eastern parts of the Maydena–Picton area and normally takes the form of a single massive sheet several hundred metres thick that intrudes the Parmeener Supergroup and caps the mountain ranges and plateaux. The horizon intruded is commonly within the Upper Parmeener Supergroup. This is the case at the Maydena Range, Mount Styx and the adjacent plateau area, and the crests of the Snowy Range where the intruded horizon is within the quartz sandstone sequence (Trp). On the western spur of Mount Picton the base of the intrusion is in the Cygnet Coal Measures correlate, but immediately east it transgresses to slightly lower levels in the Abels Bay Formation. At Weld Ridge the stratigraphic level of intrusion is unknown, but it is probably no lower than the upper parts of the Abels Bay Formation correlate. The extreme exception to this pattern is in the Glovers Bluff area, where dolerite intrudes both beneath the Parmeener Supergroup and in the basal glacigene rocks (Ptx) of the Lower Parmeener Supergroup. In a broad asymmetric zone around Glovers Bluff, extending about ten kilometres to the northeast, dolerite intrudes various horizons within the Parmeener Supergroup.

The Cambrian and Proterozoic rocks and the overlying Truro Tillite correlate in the Glovers Bluff area are considered to have undergone uplift caused by the dilatation effects of an underlying dolerite intrusion fed from a feeder structure.

At the northwest end of the Proterozoic rocks the upper surface of the underlying dolerite rises at an angle of 20–25°, and about 1.5 km further northwest the base of the intrusion is apparent. A comparison of the topographic heights of Parmeener horizons across the dolerite intrusion enables an estimation of the dolerite sheet thickness to be made. In this case only the irregular position of the basal Parmeener unconformity can be compared to derive an estimate of >300–400 m dilation without correction for tectonic dip. A similar consideration of the Abels Bay Formation correlate exposed on Edwards Road, and the Truro Tillite correlate on the northern side of the Huon River, suggests a minimum dilation of 300 metres. The occurrence of unit Pwm southwest from Glovers Bluff indicates that the sheet transgresses to younger horizons in a southwesterly direction.

Three kilometres north of the northernmost Proterozoic rocks, an erosional window through the dolerite in the Snowy Range clearly shows that the northerly transgression reaches Upper Parmeener horizons. Scattered intrusive contacts between dolerite and the Upper Parmeener unit (Trqp) are found for a further ten kilometres northward, but further east intrusive contacts are mostly with Lower Parmeener rocks.

Near Denison Ridge, the top of a major dolerite sheet that intrudes low in the Abels Bay Formation correlate is exposed in Falls Creek. Closer to Russell River, in the adjacent Lonnavale map sheet, the intrusion also shows contacts with the Risdon Sandstone correlate and Minnie Point Formation correlate. A curved but generally northeast-trending contact occurs between the Abels Bay Formation correlate and dolerite forming Compton Hill. This intrusive boundary has been interpreted as a steeply transgressive segment of the sheet beneath Denison Ridge. The magnitude of the transgressive segment step could be expected to result in intrusion within the upper parts of unit Trqp at Compton Hill. The intrusive contacts west of Compton Hill conform to this expectation. Several of these boundaries are with the top of the dolerite sheet and all may be of this type.

The eastern margin of the strata exposed in the dolerite window at the Little Denison River is not exposed but the distribution of outcrops and the fine grain size of the dolerite indicate a steep intrusive contact. Projection of the strata, based on accurately measured dip, suggests that a sequence with Risdon Sandstone correlate exposed downstream is 150–200 m higher than expected. The steep intrusive contact has been interpreted as an elbow in the base of the intrusion and the uplift of the Risdon Sandstone correlate as, in part, the result of dilation caused by continuation of a sheet beneath the Risdon Sandstone correlate.

Further downstream, thermally metamorphosed rocks of unit Puh and fine-grained dolerite indicate that an intrusive boundary crosses the creek (478700/5241600). The regional trend of the boundary is 47°. This boundary is in alignment with a second boundary (trend 45°) between Proterozoic rocks and dolerite north of Glovers Bluff. Minnie Point Formation correlate overlies dolerite one kilometre to the southwest (478300/5240700). The rock distribution suggests that dolerite underlies unit Puh in the Little Denison River and extends subsurface to underlie the Parmeener sequence at Barn Back, east of the Glovers Bluff area. This interpretation suggests that the sheet underlying Barn Back is thinner than that at Glovers Bluff or alternatively that the Barn Back area is down faulted with respect to the area to the west.

If instead the Glovers Bluff dolerite transgresses over the top of the Abels Bay Formation correlate to the east, this would imply a reversed sense of transgression of dolerite through unit Puh in the Little Denison River to that discussed above.

At the Huon River the southern transgressive segment of the Glovers Bluff centre has a strike of about 50°. In the Picton map sheet a steeply transgressive dolerite boundary, which may be related to a possible dolerite centre further south, has a strike of 55°.

The Jurassic dolerite intrusive margins with trends of 45 to 55° parallel other lineaments and physiographic features, but faults displacing dolerite do not appear to share this trend.

The base of the dolerite sheet forming the Mount Styx plateau area lies between Dolerite Road and Russell Road. A fault could be inferred to downthrow the sheet into the Russell River valley to the southwest, although some of the exposed contacts between the sandstone and dolerite near the location of such a fault are intrusive. This may indicate an elbow in the base of the sheet rather than faulting alone, or a rotated and downthrown block enclosing the contact between the sandstone and the sheet base.

Picton map sheet (JLE)

The major dolerite intrusion around Loop Hill in the southeastern part of the Picton map sheet extends south for 20 km along Devils Backbone, to form the spine of the Hartz Mountains. North of Loop Hill the intrusion abruptly narrows to a sub-vertical dyke, locally less than 100 m wide, which is exposed in Arve Road (478900/5227900) and extends at least as far as near Piners Eddy (479000/5229700) on the Huon River. It probably continues beneath alluvium to join another major intrusion on the Weld map sheet. The dolerite near the dyke contacts is chilled to a fine grain size, but rapidly coarsens towards the dyke interior.

The transgressive northwest margin of the Loop Hill intrusion corresponds to a strong topographic lineament extending southwest from the Picton River at 476600/5224400. Although no chilled dolerite was found near the contact, this is probably also a steep intrusive contact. The contact rises between the river and Loop Hill, exposing Upper Parmeener Supergroup rocks beneath it, before steepening again and heading north to form the western margin of the dyke. As noted above, the higher stratigraphic level of the Parmeener Supergroup rocks northeast of Loop Hill indicates relative uplift of 250 m, probably by an underlying dolerite sill extending eastward from the dyke. The small dolerite area capping a hill near the sheet edge (479900/5227300) may represent the remnant of a similar smaller sill.

The dolerite at Pear Hill probably represents the down-faulted extension of the Mt Picton–Mt Riveaux intrusion. The latter is probably continuous with the Loop Hill intrusion, although the area east of Lake Picton was interpreted from aerial photographs. Small Parmeener Supergroup outcrops near the southern margin of the Picton map sheet (around 474100/5220300) suggest that the dolerite intrusion bifurcates southward.

Further mapping of areas to the south and east of the Picton map sheet is required, as a minimum, before the regional geometry of the dolerite intrusions can be fully understood.

Minor intrusions

Apart from dolerite dykes intruding rocks overlying the dolerite centre near Glovers Bluff, minor intrusions were seldom found. A small area of fine-grained dolerite intrudes Abels Bay Formation correlate on Denison Ridge about 90 m above a major dolerite intrusion; presumably the sheet has acted as a source for the minor intrusion. Three other examples occur in sections in which there is no known underlying dolerite within the Parmeener sequence and the nearest known dolerite occurs several hundred metres higher in the succession. These occur in unit Puh at Humboldt Ridge (468800/5268950), and in the Abels Bay Formation correlate as a dyke several metres wide exposed in road cuttings near Gee Creek (475800/5257500), and as a thin (150 mm) dyke exposed in a creek (574200/5256300) west of Gee Creek. The dykes may be related to nearby faults.

There are isolated small outcrops, distant from the main intrusions, north of the Jubilee Range at 462250/5256500 and 466050/5257050.

Glovers Bluff cone sheet (Weld map sheet) (CRC)

Jurassic dolerite surrounds the Proterozoic to Cambrian rocks of the Glovers Bluff inlier and Truro Tillite correlate (Ptx) in the eastern part of the Weld map sheet. Observed contacts (e.g. at 476300/5234300) are intrusive, and dip gently to moderately inwards, under the inlier. The lower contact of the dolerite is inferred to similarly dip gently towards the inlier. The intrusion is in the form of a large irregular cone sheet with the Glovers Bluff inlier comprising the eroded remnant of the uplifted roof rocks in the centre of the cone (fig. 33). The area of contact-metamorphosed Permian mudstone at higher elevations southwest of the Glovers Bluff inlier (475500/5232500) is another roof-rock remnant, inferred to be shallowly underlain by dolerite. The limbs of the cone sheet flatten out while rising gently away from the inlier, merging with the high-level horizontal sills capping Weld Ridge to the west and Snowy Range to the north. The southeastern side of the cone sheet is locally narrower, more steeply intrusive and partly faulted (fig. 33). A thickness of about 500 m may be inferred for most of the intrusion. A major dolerite feeder is inferred to underlie the inlier. The form and exact location of the feeder are a matter of conjecture, but there are large subcircular aeromagnetic anomalies at 476700/5236300 (near the centre of the inlier) and at 474900/5237200 at the northwestern side of the inlier that may indicate the locations of large, vertical, pipe-like feeders at depth.

A number of smaller dolerite intrusions occur within the inlier. In the Weld River, exposures of Clark Group and Cambrian rocks are intruded by dykes of dolerite 100 mm to a few metres wide. Dykes, and the chilled margins of larger intrusions, are characteristically fine grained and contain small (<1 mm) phenocrysts of green orthopyroxene. A large (1 km^2) irregular area of dolerite occurs north of the Weld River in the approximate centre of the inlier. The form of this body at depth is unknown — it is presumably continuous with the main cone sheet — but it is fine grained close to contacts, suggesting an intrusive rather than faulted relationship with the surrounding Proterozoic rocks.

The narrower dolerite body on the southern part of the ridge east of Eddy Creek is interpreted to be the eastern side of the cone sheet and has a steep contact (probably a normal fault) on its eastern side. The limits of this body, and attitudes of contacts (mostly concealed by soil and talus) are constrained, in part, by ground magnetic traverses (Appendix 2). This body is interpreted to dip gently west under the contact-metamorphosed Weld River Group carbonates (the 'western marble/skarn unit') to the west, and is probably continuous with the fine-grained dolerite outcrop at Fletchers Eddy. The ridge east of the Eddy Creek dolerite body bifurcates to the south, with silicified and skarn-altered rocks of the Weld River Group (the 'eastern marble/skarn unit' and the Hogsback Hill quartzite) lying between the two 'arms'. The eastern arm extends south of the Weld River, where drill-hole data show that the dolerite dips gently west to underlie the eastern marble/skarn unit at depths of up to 80 m, as far south as the Fletcher Road–Forster Road junction.

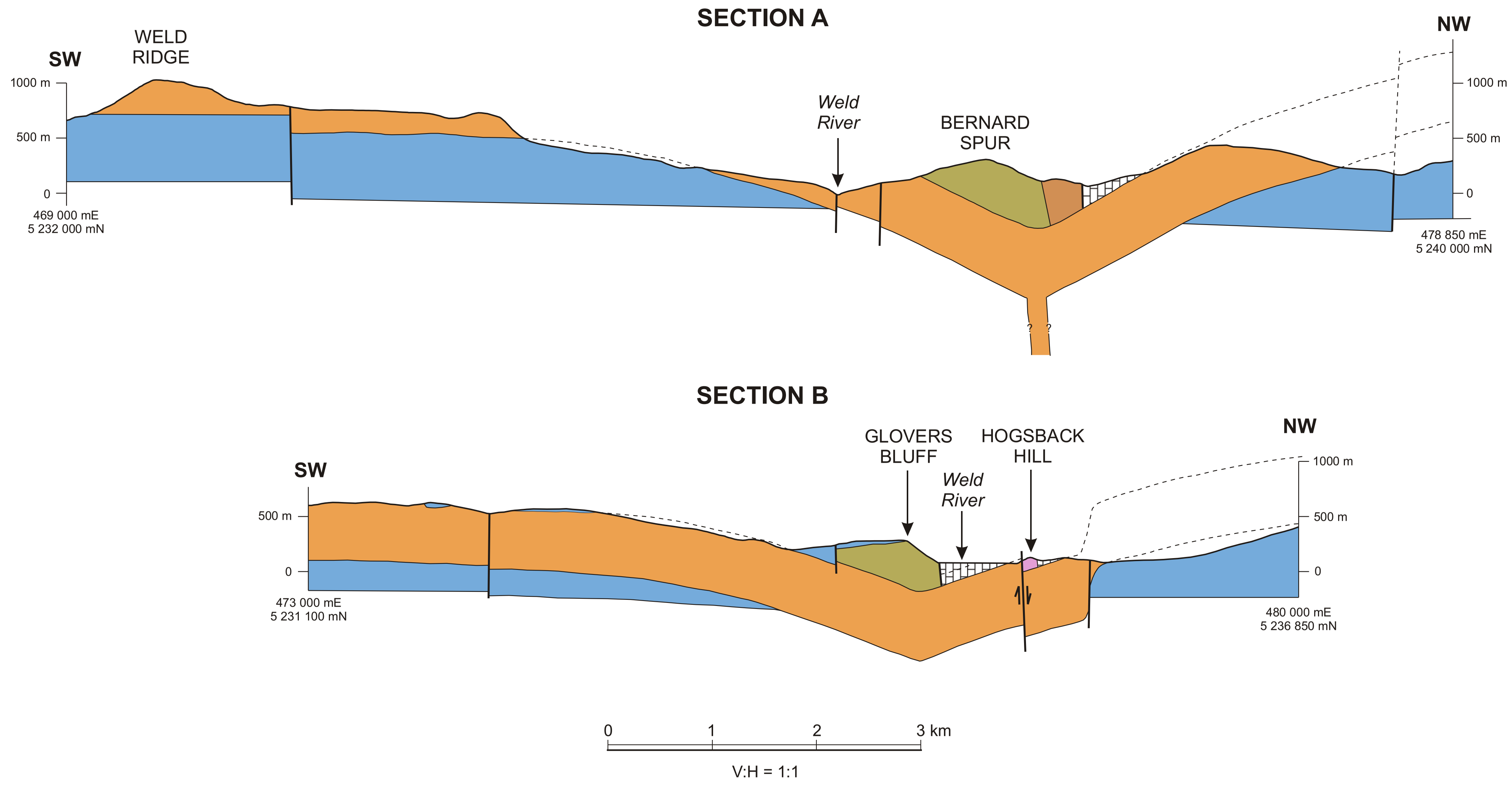


Figure 33

SW–NE cross sections of Glovers Bluff inlier, showing interpreted cone sheet geometry of Jurassic dolerite intrusion.

The cone sheet geometry of the dolerite surrounding the Glovers Bluff inlier explains the elevation of the Proterozoic to Cambrian basement rocks to relatively high levels within the Tasmania Basin, without the need for major faults. This geometry is also consistent with the strong alteration and high-temperature, low-pressure metamorphism seen in the reactive siliceous dolomite and conglomerate in the eastern part of the inlier (Bottrill *et al.*, 1999), which is predicted to be shallowly underlain by several hundred metres of dolerite (fig. 33). The inlier, surrounded and underlain by dolerite and close to a major feeder, would have been the focus of an unusually large heat flux at the time of intrusion.

Parmeener Supergroup (SMF)

The Parmeener Supergroup is intruded by thick transgressive dolerite intrusions and is block faulted. The strata commonly dip to the northeast or southeast at low angles and an easterly dip component is typical for most of the area. Locally the strike of bedding tends to parallel fault trends and the dip may steepen near the faults. In some areas pairs of subparallel faults delimit more steeply dipping strata. Downthrown strata are usually found on the eastern side of faults, but exceptions occur.

The trend distribution of faults affecting the Parmeener Supergroup is not uniform and no faults were mapped with trends between 45° and 80°. Only two faults with trends between 80° and 90° were mapped. These faults occur west of the Maydena Range and downthrow Truro Tillite correlate into pre-Parmeener rocks. A fault of similar trend, between Cambrian and Proterozoic rocks, occurs nearby. For the remainder of the map sheets the gap in fault trends extends to 45° to 100°. The only fault of trend 45° displaces Parmeener rocks at Weld Ridge, but does not seem to displace overlying dolerite to the same extent.

In most areas the Parmeener Supergroup occurs beneath a thick dolerite intrusion and the effects of intrusive dilation are no longer visible. In the Glovers Bluff–Compton Hill–Barn Back area, and possibly part of the Picton Road area, the Parmeener Supergroup and older rocks are underlain by dolerite and the effects of dilation are apparent.

In some areas it is difficult to determine if the basal Parmeener unconformity is faulted or merely has steep basement relief.

The combination of an easterly dip component and east-side-down fault movements results in the strata occurring at lower altitudes in the east compared to the west. The fall is about 900 m west to east cross the map sheets. The Upper–Lower Parmeener boundary, or the inferred former position of the boundary in areas from which it has been eroded, makes a convenient datum to compare vertical displacements of the strata. The datum is highest (1200 m) in the southwest corner of the Maydena map sheet. It is lower at the western limit of Mount Picton (1060 m) and at least that height at Mount Weld. It may well have been higher further west, but trends in thickness variations of the Lower Parmeener are too poorly known to undertake reliable restoration of the missing sequence in that area.

The Parmeener Supergroup rocks are quite commonly down faulted at the contact with older rocks. This results in relatively steep dips (10–23°) in Parmeener Supergroup rocks near the South Styx River northwest of Snowy North. For a significant distance west of the Snowy Range the nature of the contact, i.e. faulted versus unconformable, is unknown, but it is likely that if the boundary is not faulted then part of the overlying Parmeener sequence is faulted out along the flanks of the range.

In the Snowy Range the datum is probably highest near The Wart (~950–1000 m), but falls from 470 m to 420 m at the dolerite window in the Little Denison River. Dips of 10–16° to the southeast in Sandy Creek may indicate the initial dip direction accounting for this drop, but a northeasterly dip of about 5° is also involved.

From Scrivens Cone to Snowy North the datum falls from 900 to 800 m and then continues to fall to 650 m across the northern side of Snowy North. The datum maintains a height of about 950 m for a few kilometres along the crest of the Maydena Range west of the Pillinger Fault as the dip is directed south-south-east. The beds are more steeply inclined east of Pillinger Fault (14–38°) and the combined effect of throw and faulting lowers the datum to 620 metres. Dips of 4° to 9°, initially to the south and east, then swing to the northeast and become more consistent down the Tyenna Valley and on Humboldt Ridge (3–8°) as the datum continues to fall to 300 m north of Marriotts Lookout. A concealed fault with a throw of 60 m may extend down the Tyenna Valley, but evidence for the Roberts Fault (Lewis, 1940; Jago, 1972) is now considered less compelling as the juxtaposition of the Lower Parmeener rocks and the Tim Shea Sandstone could be partly caused by variations of the basement relief.

Further down the Tyenna Valley the datum is uplifted to 520 m north of Lorkins Lookout and to a similar height (560 m) north of Mt Styx in the Styx Valley. In the Styx Valley, consistent northeast dips of 5° to 7° east of the fault zone lower the datum to 430 m at the edge of the map and to 300 m further east. The uplift near the fault zone is sufficient to expose the Bundella Formation correlate dipping away at 12° in the Styx Valley. In the Tyenna Valley, moderately steep dips occur within the fault zone that consists of at least two main faults 500 m apart separated by a rotated horst. The fault zone was not mapped, but is assumed to run through the saddle between Lorkins Lookout and Marriotts Lookout and to be responsible for the anomalous northwest-dipping strata of moderate dip (14–35° and steeper near faults) that occur in the Styx Valley. Bundella Formation correlate and Woody Island Formation correlate occur within the fault complex.

Before intersecting this fault zone, the Pillinger Fault appears to bifurcate to enclose sag blocks dipping southwest at 20°. The combined fault systems result in graben blocks, but the overall throw across the combined system is quite small and less than 50 metres. The combined systems trend south between the Mount Styx plateau area and Snowy North, but some small faults of the Pillinger Fault trend continue southeast. Their extensions may be indicated by physiographic features on the Mount Styx plateau, but detailed examination of the basal boundaries of the Upper Parmeener and of the dolerite intrusion would be needed before faulting could be confidently interpreted on the plateau. Small dolerite intrusions near some faults may be related to the fault system.

The graben structure could widen in the Russell River catchment, with one bounding fault taking the course of the mapped linear between Dolerite Road and North Russell Road and another bounding fault located between Lake Skinner and Compton Hill. With the present information it is difficult to distinguish between the effects of dolerite transgression, tilted dolerite and faulting, and these possible faults have not been indicated on the map. The southernmost extent of the sandstone in the upper Russell River (south of 5 253 000 mN) is interpreted from aerial photographs and cannot be relied upon in comparing structure models. Faults could extend south to the valley west of Barn Back and also trend southeast near the boundary between dolerite and undifferentiated Upper Parmeener rocks on McDougalls Road (479000/5244200). The datum lies below 400 m in the southeast corner of the Skeleton map sheet. On Denison Ridge the datum is approximately 400 m, on Barn Back 500 m and north of Denison Road (477900/5241800) about 460 m, but all three areas are considered to overlie a dolerite intrusion and the datum height could be reduced by 300 to 400 m if dolerite was not present. The datum is below 60 m east of Piners Eddy on the Huon River, 240 m west of Loop Hill, and is about 460 m across a nearby dolerite dyke.

Magnetic anomalies

The geological mapping has more precisely defined the surface boundaries of Jurassic dolerite intrusions and provided information about the dilation effects of underlying dolerite intrusions. In addition to the western parts of the map sheets, the Tyenna and Styx valleys provide opportunities to observe the magnetic anomalies caused by pre-Parmeener rocks free from the effects caused by surface exposures of Jurassic dolerite. Unless blind feeder structures are present the subsurface rocks are considered not to include Jurassic dolerite.

A broad positive anomaly with second-order rounded highs is found in the Styx Valley (Curtis and Hartman, 1966). This arises near the confluence of the South Styx and Styx rivers and reaches one of several local maxima about two kilometres to the east, but extends with decreasing magnitude to near the eastern edge of the map sheets. The maximum gradients of the field occur in the west and the trend of contours is relatively linear along the southwest margin. This trend, with only slight deflection, can be followed through an area with sharper, smaller wavelength anomalies attributed to dolerite near the crest of the Snowy Range and across the eastern flanks of the Snowy Range towards Compton Hill. Although the dolerite may be thin or absent along sections of the eastern flank of the Snowy Range, in the area closer to Compton Hill the dolerite is thick and may be faulted along its western margin. Thus the interpretation of the origin of the anomalies becomes more ambiguous near Compton Hill.

In the north the anomaly undergoes a substantial reduction between the Styx River and the crest of the Maydena Range and possibly disappears altogether. Five kilometres further northwest along strike, a similar strong asymmetric anomaly is developed. The anomaly is sharply defined on the southwest side, but gradually decreases to background levels down the Tyenna Valley. Several anomalies of more restricted area are caused by rocks beneath the Parmeener Supergroup near Mueller Road.

In contrast Proterozoic rocks in the Jubilee Range area do not give rise to similar abrupt-edged anomalies, but are associated with uniform, very low gradients that reach a maxima at a persistent, but subdued weak positive anomaly approximately coincident with the Weld River. This anomaly extends across the boundary between the Nevada and Skeleton map sheets and may be related to a sequence of Cambrian rocks that is exposed in this area.

References

ANON. 1981. *Exploration Licence 37/79 Styx River, Tasmania. Report for the six months ending 1 November, 1981*. Broken Hill Proprietary Co. Ltd [TCR 81-1657].

BACON, C. A. 1992. Notes on the history of mining and exploration at Adamsfield. *Report Mineral Resources Tasmania* 1992/20.

BACON, C. A.; CALVER, C. R.; BOREHAM, C. J.; LEAMAN, D. E.; MORRISON, K. C.; REVILL, A. T.; VOLKMAN, J. K. 2000. The petroleum potential of onshore Tasmania: a review. *Bulletin Geological Survey Tasmania* 71.

BAILLIE, P. W. 1989. Carboniferous–Triassic(?) (Parmeener Supergroup), *in:* BROWN, A. V.; MCCLENAGHAN, M. P.; TURNER, N. J.; BAILLIE, P. W.; MCCLENAGHAN, J.; CALVER, C. R. Geological Atlas 1:50 000 series. Sheet 73 (8112N). Huntley. *Explanatory Report Geological Survey Tasmania* 58–59.

BAILLIE, P. W.; SUTHERLAND, F. L. 1992. Devonian lamprophyres from Mt Lyell, western Tasmania. *Papers and Proceedings Royal Society of Tasmania* 126:19–22.

BANKS, M. R. 1962. Permian, *in:* SPRY, A.; BANKS, M. R. (ed.). The geology of Tasmania. *Journal Geological Society of Australia* 9(2):189–216.

BANKS, M. R. 1973. General geology, *in:* BANKS, M. R. (ed.). *The Lake Country of Tasmania*. 25–33. Royal Society of Tasmania.

BANKS, M. R.; BAILLIE, P. W. 1989. Late Cambrian to Devonian, *in:* BURRETT, C. F.; MARTIN, E. L. (ed.). 1989. Geology and Mineral Resources of Tasmania. *Special Publication Geological Society of Australia* 15:182–237.

BANKS, M. R.; BURRETT, C. F. 1980. A preliminary Ordovician biostratigraphy of Tasmania. *Journal Geological Society of Australia* 26:363–376.

BANKS, M. R.; CLARKE, M. J. 1987. Changes in the geography of the Tasmania Basin in the Late Paleozoic, *in:* MCKENZIE, G. D. (ed.). Gondwana Six: Stratigraphy, sedimentology and paleontology. *Geophysical Monograph American Geophysical Union* 41:1–14.

BANKS, M. R.; GREEN, D. H.; HERGT, J. M.; MCDOUGALL, I. 1989. Jurassic dolerite. Introduction, *in:* BURRETT, C. F.; MARTIN, E. L. (ed.). Geology and Mineral Resources of Tasmania. *Special Publication Geological Society of Australia* 15:375–378.

BANKS, M. R.; HALE, G. E. A. 1957. A type section of the Permian System in the Hobart area, Tasmania. *Papers and Proceedings Royal Society of Tasmania* 91:41–64.

BANKS, M. R.; HALE, G. E. A.; YAXLEY, M. L. 1955. The Permian rocks of Woody Island, Tasmania. *Papers and Proceedings Royal Society of Tasmania* 89:219–229.

BANKS, M. R.; READ, D. E. 1962. The Malbina Siltstone and Sandstone. *Papers and Proceedings Royal Society of Tasmania* 96:19–31.

BAU, M. 1996. Controls on the fractionation of isovalent trace elements in magmatic and aqueous systems: evidence from Y/Ho, Zr/Hf and lanthanide tetrad effect. *Contributions to Mineralogy and Petrology* 123:323–333.

BERRY, R. F.; CRAWFORD, A. J. 1988. The tectonic significance of Cambrian allochthonous mafic-ultramafic complexes in Tasmania. *Australian Journal of Earth Sciences* 35:523–533.

BERRY, R. F.; HARLEY, S. 1983. Pre-Devonian stratigraphy and structure of the Prion Beach–Rocky Boat Inlet–Osmiridium Beach coastal section, southern Tasmania. *Papers and Proceedings Royal Society of Tasmania* 117:59–75.

BLACK, L. P.; CALVER, C. R.; SEYMOUR, D. B.; REED, A. 2004. SHRIMP U-Pb detrital zircon ages from Proterozoic and early Palaeozoic sandstones and their bearing on the early geological evolution of Tasmania. *Australian Journal of Earth Sciences* 51:885–900.

BLACK, L. P.; SEYMOUR, D. B.; CORBETT, K. D.; COX, S. E.; STREIT, J. E.; BOTTRILL, R. S.; CALVER, C. R.; EVERARD, J. L.; GREEN, G. R.; MCCLENAGHAN, M. P.; PEMBERTON, J.; TAHERI, J.; TURNER, N. J. 1997. Dating Tasmania's oldest geological events. *Record Australian Geological Survey Organisation* 1997/15.

BLAKE, F. 1935. Report on country along route of Cracroft Track from Glen Huon to Frankland Range. *Unpublished Report Department of Mines Tasmania* 1935:30–35.

BLEVIN, P. L.; CHAPPELL, B. W. 1992. The role of magma sources, oxidation states and fractionation in determining the granite metallogeny of eastern Australia. *Transactions Royal Society of Edinburgh (Earth Sciences)* 83:305–316.

BLEVIN, P. L.; CHAPPELL, B. W. 1995. Chemistry, origin and evolution of mineralized granites in the Lachlan Fold Belt, Australia: the metallogeny of I- and S-type granites. *Economic Geology* 90:1604–1619.

BOTTRILL, R. S.; TAHERI, J.; CALVER, C. R. 1999. The nature and origin of gold mineralisation at the Forster Prospect, Glovers Bluff/Weld River area. *Record Tasmanian Geological Survey* 1999/06.

BOTTRILL, R. S.; WOOLLEY, R. N. 1996. Mineralogy and petrography of some rocks from the Glovers Bluff/Weld River area. *Record Geological Survey Tasmania* 1996/15.

BOYD, D. 1996. *The origin and timing of silica and skarn alteration in the Weld River, southern Tasmania*. B.Sc. (Hons) thesis, University of Tasmania.

BOYNTON, W. V. 1984. Cosmochemistry of the rare earth elements: meteorite studies, *in:* HENDERSON, P. (ed.). *Rare earth element geochemistry*. 63-114. Elsevier.

BROWN, A. V. 1986. Geology of the Dundas–Mt Lindsay–Mt Youngbuck region. *Bulletin Geological Survey Tasmania* 62.

BROWN, A. V. 1989*a*. Geological Atlas 1:50 000 Series. Sheet 21 (7916S). Smithton. *Explanatory Report Geological Survey Tasmania*.

BROWN, A. V. 1989*b*. Eo-Cambrian–Middle Cambrian mafic volcanic rocks, *in:* BURRETT, C. F.; MARTIN, E. L. (ed.). Geology and Mineral Resources of Tasmania. *Special Publication Geological Society of Australia* 15:61–69.

BROWN, A. V.; JENNER, G. A. 1988. Geological setting, petrology and chemistry of Cambrian boninite and low-Ti tholeiite lavas in western Tasmania, *in:* CRAWFORD, A. J. (ed.). *Boninites and related rocks*. Unwin Hyman.

BROWN, A. V.; MCCLENAGHAN, M. P.; TURNER, N. J.; BAILLIE, P. W.; MCCLENAGHAN, J.; LENNOX, P.; WILLIAMS, P. R. 1982. *Geological Atlas 1:50 000 series. Sheet 73 (8112N). Huntley*. Department of Mines, Tasmania.

BROWN, A. V.; MCCLENAGHAN, M. P.; TURNER, N. J.; BAILLIE, P.W.; MCCLENAGHAN, J.; CALVER, C. R. 1989. Geological Atlas 1:50 000 series. Sheet 73 (8112N). Huntley. *Explanatory Report Geological Survey Tasmania*.

BURRETT, C. F.; MARTIN, E. L. (ed.). 1989. Geology and Mineral Resources of Tasmania. *Special Publication Geological Society of Australia* 15.

CABANIS, B.; LECOLLE, M. 1989. Le diagramme La/10-Y/15-Nb/8: un outil pour la discrimination des séries volcaniques et la mise en évidence des processus de mélange et/ou de contamination crustale. *Comptes rendus de l'Académie des sciences. Série 2* 309:2023–2029.

CALVER, C. R. 1977. *Palaeoecology of the Lower Limestone Member, Benjamin Limestone, Florentine Valley*. B.Sc. (Hons) Thesis, University of Tasmania.

CALVER, C. R. 1989. The Weld River Group: A major Upper Precambrian dolomite sequence in southern Tasmania. *Papers and Proceedings Royal Society of Tasmania* 123:43–53.

CALVER, C. R. 1990*a*. *Lower Palaeozoic stratigraphy of the Florentine Valley*. Geological Society of Australia, Tasmania Division.

CALVER, C. R. 1990*b*. Limestone resources of the Maydena–Florentine Valley area. *Report Division of Mines and Mineral Resources Tasmania* 1990/06.

CALVER, C. R. 1992. Maydena DDH 1: Appraisal of the limestone resource at Risbys Basin. *Report Department of Mines Tasmania* 1992/03.

CALVER, C. R. 1995. *Ediacarian isotope stratigraphy of Australia*. Ph.D. thesis, Macquarie University, Sydney.

CALVER, C. R. 1997. *Digital Geological Atlas 1:25 000 Scale Series. Sheet 4623. Weld*. Mineral Resources Tasmania.

CALVER, C. R. 1998. Isotope stratigraphy of the Neoproterozoic Togari Group, Tasmania. *Australian Journal of Earth Sciences* 45:865–874.

CALVER, C. R.; BAILLIE, P. W. 1990. Early diagenetic concretions associated with intrastratal shrinkage cracks in an upper Proterozoic dolomite, Tasmania, Australia. *Journal of Sedimentary Petrology* 60:293–305.

CALVER, C. R.; FORSYTH, S. M.; EVERARD, J. L. 2006. Explanatory report for the Maydena, Skeleton, Nevada, Weld and Picton geological map sheets. *Explanatory Report 1:25 000 Scale Digital Geological Map Series* 1.

CALVER, C. R.; MCCLENAGHAN, M. P.; MCCLENAGHAN, J. 1990. Geological Atlas 1:50 000 series. Sheet 80 (8112S). Pedder. *Explanatory Report Geological Survey Tasmania*.

CAREY, S. W.; AHMAD, N. 1961. Glacial marine sedimentation, *in:* RAASCH, G. E. (ed.). Geology of the Arctic. *Proceedings of the First Arctic Geology Symposium* 2:865–894.

CAREY, S. W.; BANKS, M. R. 1954. Lower Palaeozoic unconformities in Tasmania. *Papers and Proceedings Royal Society of Tasmania* 88:245–270.

CARTHEW, S.; POLTOCK, R.; BELLAIRS, P. 1988. *Weld River, South West Tasmania, EL11/84. Annual report for the period ending 27 September, 1988*. Metals Exploration Limited [TCR 88-2855].

CHAPPELL, B. W.; ENGLISH, P. M.; KING, P. L.; WHITE, A. J. R.; WYBORN, D. 1991. Granites and related rocks of the Lachlan Fold Belt (1:2 500 000 scale map). *Bureau of Mineral Resources, Geology and Geophysics, Canberra*.

CHAPPELL, B. W.; WHITE, A. J. R. 1992. I- and S-type granites in the Lachlan Fold Belt. *Transactions of the Royal Society of Edinburgh (Earth Sciences)* 83:1–26.

CLARKE, M. J. 1987. Late Permian (late Lymingtonian = ?Kazanian) brachiopods from Tasmania. *Alcheringa* 11:261–289.

CLARKE, M. J. 1989. Lower Parmeener Supergroup, *in:* BURRETT, C. F.; MARTIN, E. L. (ed.). 1989. Geology and Mineral Resources of Tasmania. *Special Publication Geological Society of Australia* 15:295–309.

CLARKE, M. J. 1992. Hellyerian and Tamarian (Late Carboniferous–Lower Permian) invertebrate faunas from Tasmania. *Bulletin Geological Survey Tasmania* 69.

CLARKE, M. J.; BANKS. M. R. 1975. The stratigraphy of the lower (Permo-Carboniferous) parts of the Parmeener Super-Group, Tasmania, *in:* CAMPBELL, K. S. W. (ed.). *Gondwana geology: Papers presented at the 3rd Gondwana Symposium, Canberra, Australia, 1973*. 453–467. Australian National University Press : Canberra.

CLARKE, M. J.; FARMER, N. 1976. Biostratigraphic nomenclature for Late Palaeozoic rocks in Tasmania. *Papers and Proceedings Royal Society of Tasmania* 110:91–109.

CLARKE, M. J.; FARMER, N. 1982. A diamond drill hole at Mt Nassau, near Granton. *Unpublished Report Department of Mines Tasmania* 1982/29.

COLHOUN, E. A.; GOEDE, A. 1979. The late Quaternary deposits of Blakes Opening and the middle Huon Valley. *Philosophical Transactions Royal Society of London. Series B, Biological Sciences* 286:371–395.

COLLINS, P. L. F. 1983. *Geology and mineralisation at the Cleveland mine, western Tasmania*. Ph.D. thesis, University of Tasmania.

CONSOLIDATED GOLD FIELDS, 1974. *Glovers Bluff silica. Monthly report. Mineral leases*. Consolidated Gold Fields Australia Ltd [TCR 74-1030].

CONSOLIDATED GOLD FIELDS, 1975. *Final report, Glovers Bluff quartzite mineral leases*. Consolidated Gold Fields Australia Ltd [TCR 75-1088].

CORBETT, K. D. 1970. *Sedimentology of an upper Cambrian flysch-paralic sequence (Denison Group) on the Denison Range, southwest Tasmania*. Ph.D. thesis, University of Tasmania.

CORBETT, K. D.; BANKS, M. R. 1974. Ordovician stratigraphy of the Florentine Synclinorium, southwest Tasmania. *Papers and Proceedings Royal Society of Tasmania* 107:207–238.

COWAN, C. A.; JAMES, N. P. 1992. Diastasis cracks: mechanically generated synaeresis-like cracks in Upper Cambrian shallow water oolite and ribbon carbonates. *Sedimentology* 39:1101–1118.

CRAWFORD, A. J.; CORBETT, K. D.; EVERARD, J. L. 1992. Geochemistry of the Cambrian volcanic-hosted massive sulfide-rich Mount Read Volcanics, Tasmania, and some tectonic implications. *Economic Geology* 87:597–619.

CURTIS, C. E.; HARTMAN. R. R. 1966. *Interpretation report, airborne magnetometer survey in southwest Tasmania*. Broken Hill Proprietary Company Limited [TCR66-0445].

DAVIES, J. L. 1965. Landforms, *in:* DAVIES, J. L. (ed.). *Atlas of Tasmania*. 19–23. Lands and Surveys Department : Hobart.

DOMACK, E. W.; BURKLEY, L. A.; DOMACK, C. R.; BANKS, M. R. 1993. Facies analysis of glacial marine pebbly mudstones in the Tasmania Basin: Implications for regional paleoclimates during the late Paleozoic, *in:* FINDLAY, R. H.; UNRUG, R.; BANKS, M. R.; VEEVERS, J. J. (ed.). *Gondwana Eight: Assembly, Evolution and Dispersal*. 471–484. Balkema : Rotterdam.

EDWARDS, A. B. 1942. Differentiation of the dolerites of Tasmania. *Journal of Geology* 50:451–480, 579–610.

EVERARD, G. B. 1976. Chapel St Borehole. Appendix 3 *in:* LEAMAN, D. E. 1976. Geological Atlas 1:50 000 Series. Sheet 82 (8312S). Hobart. *Explanatory Report Geological Survey Tasmania*.

EVERARD, J. L. 1999. Petrology of an aplite from the Weld River, southern Tasmania. Appendix 6 *in:* BOTTRILL, R. S.; TAHERI, J.; CALVER, C. R. 1999. The nature and origin of gold mineralisation at the Forster Prospect, Glovers Bluff/Weld River area. *Record Tasmanian Geological Survey* 1999/06.

EVERARD, J. L.; SEYMOUR, D. B.; BROWN, A. V. 1996. *Geological Atlas 1:50 000 Series. Sheet 27 (7915N). Trowutta*. Mineral Resources Tasmania.

EVERARD, J. L.; SEYMOUR, D. B.; REED, A. R.; MCCLENAGHAN, M. P.; GREEN, D. C.; CALVER, C. R. 2001. *Geology of the southern Smithton synclinorium. Explanatory report for the Roger, Sumac and Dempster 1:25 000 map sheets, far northwestern Tasmania*. Mineral Resources Tasmania [unpublished].

FARMER, N. 1985. Geological Atlas 1:50 000 Series. Sheet 88 (8311N). Kingborough. *Explanatory Report Geological Survey Tasmania*.

FLOYD, P. A.; WINCHESTER, J. A. 1975. Magma type and tectonic setting discrimination using immobile elements. *Earth and Planetary Science Letters* 27:211–218.

FORD, R. J. 1956. The geology of the Upper Huon–Arve River area. *Papers and Proceedings Royal Society of Tasmania* 90:147–156.

FORD, R. J. 1983. *The alkaline rocks of Port Cygnet, Tasmania*. Ph.D. thesis, University of Tasmania.

FORSTER, M. C. 1973. *Proposed silicon-ferrosilicon-magnesium industry in southern Tasmania*. M. C. Forster [TCR 97-3986].

FORSTER, M. C. 1992*a*. *EL11/84 Borril Creek–Weld River. Annual report — year 7, 28/9/1990 to 27/9/91*. M. C. Forster [TCR 92-3339].

FORSTER, M. C. 1992*b*. *EL14/88 Maydena. Annual report — year 4, 5th August 1991 to 4th August 1992*. Northwest Bay Co. Pty Ltd [TCR 92-3397].

FORSTER, M. C. 1993*a*. *EL11/84 Borril Creek–Weld River. Annual report — year 8, 28/9/1991 to 27/9/92*. M. C. Forster [TCR 93-3412].

FORSTER, M. C. 1993*b*. *EL11/84 Borril Creek–Weld River. Annual report — year 9, 28/9/1992 to 27/9/93*. Northwest Bay Co. Pty Ltd [TCR 93-3503].

FORSTER, M. C. 1994. *EL14/88 Maydena. Annual report — year 5, 5/8/92 to 4/8/93*. Northwest Bay Co. Pty Ltd [TCR 94-3534].

FORSYTH, S. M. 1984. Geological Atlas 1:50 000 series. Sheet 68 (8313S). Oatlands. *Explanatory Report Geological Survey Tasmania*.

FORSYTH, S. M. 1989*a*. Geological Atlas 1:50 000 series. Sheet 61 (8313N). Interlaken. *Explanatory Report Geological Survey Tasmania*.

FORSYTH, S. M. 1989*b*. Upper Parmeener Supergroup, *in:* BURRETT, C. F.; MARTIN, E. L. (ed.). Geology and Mineral Resources of Tasmania. *Special Publication Geological Society of Australia* 15:309–333.

FORSYTH, S. M.; FARMER, N.; GULLINE, A. B.; BANKS, M. R.; WILLIAMS, E.; CLARKE, M. J. 1974. Status and subdivision of the Parmeener Super-Group. *Papers and Proceedings Royal Society of Tasmania* 108:107–109.

GEE, R. D. 1963. Structure and petrology of the Raglan Range. *Bulletin Geological Survey Tasmania* 47.

GEE, R. D. 1968. A revised stratigraphy of the Precambrian in north-west Tasmania. *Papers and Proceedings Royal Society of Tasmania* 102:7–10.

GULLINE, A. B. 1967. The first proved Carboniferous deposits in Tasmania. *Australian Journal of Science* 29:332–333.

HASSEL, D. J. 1981. *Report on Exploration Licence 35/79 for six months ended 14 December 1981*. Tasmanian Electro-Metallurgical Co. [TCR 82-1668].

HERGT, J. M. 1987. *The origin and evolution of the Tasmanian dolerites*. Ph.D. thesis, Australian National University.

HERGT, J. M.; MCDOUGALL, I. 1989. Jurassic dolerite. Petrography, *in:* BURRETT, C. F.; MARTIN, E. L. (ed.). Geology and Mineral Resources of Tasmania. *Special Publication Geological Society of Australia* 15:378–381.

HOFFMAN, P. F.; KAUFMAN, A. J.; HALVERSON, G. P.; SCHRAG, D. P. 1998. A Neoproterozoic snowball Earth. *Science* 281:1342–1346.

HOLM, P. E. 1982. Non-recognition of continental tholeiites using the Ti-Y-Zr diagram. *Contributions to Mineralogy and Petrology* 79:308–310.

HUGHES, T. D. 1957. Limestones in Tasmania. *Mineral Resources Geological Survey Tasmania* 10.

IRVINE, T. N.; BARAGAR, W. R. A. 1971. A guide to the chemical classification of the common volcanic rocks. *Canadian Journal of Earth Sciences* 8:523–548.

JAGO, J. B. 1966. *Geology of the Maydena Range*. B.Sc. (Hons) thesis, University of Tasmania.

JAGO, J. B. 1972. Geology of the Maydena Range. *Papers and Proceedings Royal Society of Tasmania* 106:45–57.

JAMES, N. P.; NARBONNE, G. M.; SHERMAN, A. G. 1998. Molar-tooth carbonates: Shallow subtidal facies of the Mid- to Late Proterozoic. *Journal of Sedimentary Research* 68:716–722.

JENNINGS, I. B. 1965. Geological report on the Risdon Brook damsite. *Technical Reports Department of Mines Tasmania*. 9:112–120.

JONES, P. A. 1989. *Exploration Licence No. 14/88 – Maydena. Progress report on exploration activity 5 August 1988 to 5 July 1989*. Phil Jones & Associates Pty Ltd [TCR 89-2982].

KIERNAN, K. 1995. An atlas of Tasmanian karst. *Research Report Tasmanian Forest Research Council* 10.

KNOLL, A. H.; WALTER, M. R. 1992. Latest Proterozoic stratigraphy and Earth history. *Nature* 356:673–678.

KUNO, H. 1968. Differentiation of basalt magmas, *in:* HESS, H. H.; POLDERVAART, A. (ed.). *Basalts: The Poldervaart treatise on rocks of basaltic composition*. 2:623–688. Interscience, New York.

LEAMAN, D. E. 1975. Form, mechanism and control of dolerite intrusion near Hobart, Tasmania. *Journal Geological Society of Australia* 22:175–186.

LEAMAN, D. E. 1976. Geological atlas 1:50 000 series. Sheet 82 (8312S). Hobart. *Explanatory Report Geological Survey Tasmania*.

LEAMAN, D. E. 1999. The nature of jointing, Tasman Peninsula, southern Tasmania. *Papers and Proceedings Royal Society of Tasmania* 133:65–76.

LEAMAN, D. E. 2002. *The rock which makes Tasmania*. Leaman Geophysics : Hobart.

LEAMAN, D. E.; RICHARDSON, R. G. 1989. The granites of west and north-west Tasmania: A geophysical interpretation. *Bulletin Geological Survey Tasmania* 66.

LE MAITRE, R. W.; *et al*. 1989. *A classification of igneous rocks and a glossary of terms*. Blackwell : Oxford.

LEWIS, A. N. 1924. Notes on a geological reconnaissance of Mt Anne and the Weld River valley, south-western Tasmania. *Papers and Proceedings Royal Society of Tasmania* 1923:9–42.

LEWIS, A. N. 1940. Geology of the Tyenna valley. *Papers and Proceedings Royal Society of Tasmania* 1939:33–60.

LUTH, W. C.; JAHNS, R. H.; TUTTLE, O. F. 1964. The granite system at pressures of 4 to 10 kilobars. *Journal of Geophysical Research* 69:759–773.

MACDONALD, G. A.; KATSURA, T. 1964. Chemical composition of Hawaiian lavas. *Journal of Petrology* 5:82–133.

MANNING, D. A. C. 1981. The effect of fluorine on liquidus phase relationships in the system Qz-Ab-Or with excess water at 1 kb. *Contributions to Mineralogy and Petrology* 76:206–215.

MARTINI, I. P.; BANKS, M. R. 1989. Sedimentology of the cold-climate, coal-bearing, Lower Permian "Lower Freshwater Sequence" of Tasmania. *Sedimentary Geology* 64:25–41.

MCCLENAGHAN, M. P.; FINDLAY, R. H. 1993. Geological Atlas 1:50 000 Series. Sheet 64 (7913S). Macquarie Harbour. *Explanatory Report Geological Survey Tasmania*.

MCCLENAGHAN, M. P.; SEYMOUR, D. B.; VILLA, I. M. 1994. Lamprophyre dyke suites from western Tasmania, their radiometric dating and age of thrust faulting in the Point Hibbs area. *Australian Journal of Earth Sciences* 41:47–54.

McDougall, I. 1962. Differentiation of Tasmanian dolerites: Red Hill dolerite-granophyre association. *Bulletin Geological Society of America* 73:279–315.

McDougall, I. 1964. Differentiation of the Great Lake dolerite sheet, Tasmania. *Journal Geological Society of Australia* 11:107–132.

Meschede, M. 1986. A method of discriminating between different types of mid-ocean ridge basalts and continental tholeiites with the Nb-Zr-Y diagram. *Chemical Geology* 56:207–218.

Middlemost, E. A. K. 1975. The basalt clan. *Earth Science Reviews* 11:337–364.

Morrison, K. C. 1990. *EL11/84 Borill Creek. Annual report — year 6, 28/9/1989 to 27/9/1990*. Pegasus Gold Australia Ltd [TCR 90-3166].

Morrison, K. C.; Baillie, P. W.; Davidson, J. K.; Quilty, P. G. 1989. Tectonic and depositional framework, *in:* Burrett, C. F.; Martin, E. L. (ed.). Geology and Mineral Resources of Tasmania. *Special Publication Geological Society of Australia* 15:341–347.

Mullen, E. D. 1983. MnO/TiO_2/P_2O_5: a minor element discriminant for basaltic rocks of oceanic environments and its implications for petrogenesis. *Earth and Planetary Science Letters* 62:53–62.

Paterson, W. 1990. *Exploration Licence 14/88 — Maydena. Annual report on exploration activities, 6th July 1989 to 4th August 1990*. Pioneer Silicon Industries Pty Ltd [TCR 90-3202].

Pearce, J. A. 1976. Statistical analysis of major element patterns in basalts. *Journal of Petrology* 17:15–43.

Pearce, J. A. 1982. Trace element characteristics of lavas from destructive plate boundaries, *in:* Thorpe, R. S. (ed.). *Orogenic andesites*. 525–548. John Wiley : Chichester.

Pearce, J. A. 1983. Role of the sub-continental lithosphere in magma genesis at active continental margins, *in:* Hawkesworth, C. J.; Norry, M. J. (ed.). *Continental basalts and mantle xenoliths*. 230–249. Shiva, Nantwich.

Pearce, J. A.; Cann, J. R. 1973. Tectonic setting of basic volcanic rocks determined using trace element analyses. *Earth and Planetary Science Letters* 19:290–300.

Pearce, J. A.; Gale, G. H. 1977. Identification of ore-deposition environment from trace element geochemistry of associated igneous host rocks. *Special Publication Geological Society of London* 7:14–24.

Pearce, T. H.; Gorman, B. E.; Birkett, T. C. 1975. The TiO_2-K_2O-P_2O_5 diagram: a method for discriminating between oceanic and non-oceanic basalts. *Earth and Planetary Science Letters* 24:419–426.

Pearce, T. H.; Gorman, B. E.; Birkett, T. C. 1977. The relationship between major element chemistry and tectonic environment of basic and intermediate volcanic rocks. *Earth and Planetary Science Letters* 36:121–132.

Pearce, J. A.; Norry, M. J. 1979. Petrogenetic implications of Ti, Zr, Y and Nb variations in volcanic rocks. *Contributions to Mineralogy and Petrology* 69:33–47.

Peccerillo, A.; Taylor, S. R. 1976. Geochemistry of Eocene calc-alkaline volcanic rocks from the Kastamonu area, northern Turkey. *Contributions to Mineralogy and Petrology* 58:63–81.

Plumb, K. A. 1991. New Precambrian time scale. *Episodes* 14:139–140.

Plummer, P. S.; Gostin, V. A. 1981. Shrinkage cracks: desiccation or synaeresis? *Journal of Sedimentary Petrology* 51:1147–1156.

Public Land Use Commission, 1996. *Tasmania–Commonwealth Regional Forest Agreement. Social and Economic Report Vol. III. Background Report, Part D.* Tasmanian Public Land Use Commission.

Radke, B. H.; Mathis, R. L. 1980. On the formation and occurrence of saddle dolomite. *Journal of Sedimentary Petrology* 50:1149–1168.

Riek, E. F. 1976. Neosecoptera, a new insect suborder based on a specimen discovered in the Late Carboniferous of Tasmania. *Alcheringa* 1:227–234.

Rock, N. M. S. 1991. *Lamprophyres*. Blackie and Sons, Glasgow.

Rollinson, H. R. 1993. *Using geochemical data: evaluation, presentation, interpretation*. Longman Scientific and Technical.

Runnegar, B. N. 1969. The Permian faunal succession in eastern Australia. *Special Publication Geological Society of Australia* 2:73–98.

Schmidt, P. W.; McDougall, I. 1977. Palaeomagnetic and potassium-argon dating studies of the Tasmanian dolerites. *Journal Geological Society of Australia* 25:321–328.

Seymour, D. B.; Calver, C. R. 1995. Explanatory notes for the Time-Space Diagram and Stratotectonic Elements Map of Tasmania. *Report Mineral Resources Tasmania* 1995/01.

Sharples, C. 1998. *Geomorphic assessment: Coupes TN040A & E. Report to Forestry Tasmania.* (unpublished).

Shervais, J. W. 1982. Ti-V plots and the petrogenesis of modern and ophiolitic lavas. *Earth and Planetary Science Letters* 59:101–118.

Smith, A. G. 1968. The origin and deformation of some 'molar-tooth' structures in the Precambrian Belt-Purcell Supergroup. *Journal of Geology* 76:426–443.

Sproule, R. A. 1994. *Stratigraphy and geochemistry of the Dial Range Trough, NW Tasmania*. B.Sc. (Hons) Thesis, University of Tasmania.

Spry, A. 1962. The Precambrian rocks, *in:* Spry, A.; Banks, M. R. (ed.). The geology of Tasmania. *Journal Geological Society of Australia* 9:107–126.

Stait, B.; Laurie, J. 1980. Lithostratigraphy and biostratigraphy of the Florentine Valley Formation in the Tim Shea area, southwest Tasmania. *Papers and Proceedings Royal Society of Tasmania* 114:201–208.

Steiner, J. C.; Jahns, R. H.; Luth, W. C. 1975. Crystallization of alkali feldspars and quartz in the haplogranite system $NaAlSi_3O_8$-$KAlSi_3O_8$-SiO_2-H_2O at 4 kb. *Bulletin Geological Society of America* 86:83-97.

Summons, T. G. 1986*a*. Pyramid Hill, Weld River, southern Tasmania (CML39M/77 – M. C. Forster). Appendix 1 *in: Annual report, Weld River area, south eastern Tasmania, EL 11/84. Period 27 September, 1985 to 26 September, 1986*. Queensland Mines Limited [TCR 86-2590].

Summons, T. G. 1986*b*. Hogsback Hill, Weld River, southern Tasmania (EL 11/84 – M. C. Forster). Appendix 2 *in: Annual report, Weld River area, south eastern Tasmania, EL 11/84. Period 27 September, 1985 to 26 September, 1986*. Queensland Mines Limited [TCR 86-2590].

Summons, T. G. 1988. *Weld River, South West Tasmania, EL 11/84. Annual report for the period ending 27th September, 1987*. Metals Exploration Limited [TCR 88-2806].

Summons, T. G. 1997. *Exploration Licences 11/84 & 3/94. Forster Project. Combined annual report for the period ended September 1996*. Sedimentary Holdings NL [TCR 97-3993].

Summons, T. G. 1999. *Annual report for the Forster Project Southern Tasmania. RL9803, EL's 3/94 and 33/96*. Sedimentary Holdings NL [TCR 99-4409].

Sun, S. -S.; McDonough, W. F. 1989. Chemical and isotopic systematics of oceanic basalts: implications for mantle composition and processes. *Special Publication Geological Society of London* 42:313–345.

Sutherland, F. L. 1964. The geology of the Collinsvale area. *Papers and Proceedings Royal Society of Tasmania* 98:119–133.

SUTHERLAND, F. L.; CORBETT, E. B. 1974. The extent of Upper Mesozoic igneous activity in relation to lamprophyric intrusions in Tasmania. *Papers and Proceedings Royal Society of Tasmania* 107:175–190.

TAHERI, J. 1989. Preliminary fluid inclusion and petrographic studies on samples SW1-1 and SW1-2, Weld river area, south-west Tasmania. Appendix *in:* MORRISON, K. C.; SUMMONS, T. G. 1989. *EL 11/84 Borril Creek. Annual report – year 5, 28/9/1988 to 27/9/1989*. Pegasus Gold Australia Ltd [TCR 89-3027].

TAHERI, J. 1990. Petrographic, oxygen isotope and fluid inclusion studies, and the clay mineralogy of core samples from DDH BC15 and sample BCF8, Weld River area. Appendix *in:* MORRISON, K. C. 1990. *EL11/84 Borill Creek. Annual report — year 6, 28/9/1989 to 27/9/1990*. Pegasus Gold Australia Ltd [TCR 90-3166].

TUTTLE, O. F.; BOWEN, N. L. 1958. The origin of granite in the light of experimental studies in the system $NaAlSi_3O_8$-$KAlSi_3O_8$-SiO_2-H_2O. *Memoir Geological Society of America* 74.

TURNER, N. J. 1989. The Adamsfield district, *in:* BURRETT, C. F.; MARTIN, E. L. (ed.). Geology and Mineral Resources of Tasmania. *Special Publication Geological Society of Australia* 15:168–174.

TURNER, N. J.; CALVER, C. R.; MCCLENAGHAN, M. P.; MCCLENAGHAN, J.; BROWN, A. V.; LENNOX, P. G. 1985. *Geological Atlas 1:50 000 series. Sheet 80 (8112S). Pedder*. Department of Mines, Tasmania.

WHITE, N. C. 1975. *Cambrian volcanism and mineralization, south-west Tasmania*. Ph.D. thesis, University of Tasmania.

WHYTE, R. K. 1974. *Stratigraphic, structural and sedimentologic investigations of Cambro-Ordovician rocks between Maydena and Frodsham's Gap*. B.Sc. (Hons) Thesis, University of Tasmania.

WILSON, M. 1989. *Igneous petrogenesis*. Chapman and Hall, London.

WINCHESTER, J. A.; FLOYD, P. A. 1976. Geochemical magma type discrimination: application to altered and metamorphosed basic igneous rocks. *Earth and Planetary Science Letters* 28:459–469.

WRIGLEY, P. K. 1992. Surface exploration of the limestone resource at Roberts Hill, Maydena. *Report Department of Mines Tasmania* 1992/32.

WRIGLEY, P. K. 1993. Evaluation of the limestone resources at Roberts Hill, Maydena. *Report Division of Mines Tasmania* 1993/03.

YOUNG, S. 1997. *1996-97 Annual Report for the Forster Project, southern Tasmania. EL's 11/84, 3/94 & 33/96*. Sedimentary Holdings NL [TCR 97-4081].

[31 July 2007]

APPENDIX 1

The geology of The Needles area and some revisions to the stratigraphy of the Clark Group

C. R. Calver

Abstract

New mapping has elucidated the stratigraphy and structural setting of the type area of the late Mesoproterozoic to early Neoproterozoic Clark Group, at The Needles in central–south Tasmania. The Clark Group consists of a basal formation of quartz siltstone, conformably followed by the Needles Quartzite, and then the Humboldt Formation of dolostone and mudstone. The lower, more dolomitic part of the Humboldt Formation contains a distinctive suite of sedimentary structures, some indicative of deposition in very shallow marine environments; stromatolites, oolites, evaporite indicators and molar-tooth structures. The base and top of the Clark Group are not exposed. To the north, the Clark Group is faulted against dolostone of the Weld River Group which crops out on the south flank of Tim Shea. Major faults subparallel to bedding separate the Clark Group from areas of probably-Cambrian lithicwacke to the south and east, indicating an important phase of thrust faulting followed by folding, during the Cambrian. Correlates of the Clark Group crop out in the Jubilee Range and Mt Anne areas, where they are overlain with low-angle unconformity and paraconformity by the dolomitic, Neoproterozoic Weld River Group.

Introduction

The folded sedimentary succession in The Needles area was mapped and named the Clark Group by Carey and Banks (1954), who divided the succession into an undifferentiated unit, followed by the Needles Quartzite, overlain in turn by the Stephens Dolomite. The Stephens Dolomite was shown as enclosing a relatively thin 'Humboldt Slate' (their Figure 3), and to be unconformably overlain by the Late Cambrian to Early Ordovician Tim Shea Sandstone on the south flank of Tim Shea. Carey and Banks (1954) considered the succession to be pre-Dundas Group (i.e. pre-Middle Cambrian) in age. Spry (1962) classed the rocks as 'younger Precambrian' and gave the succession as (from the base) Green Greywacke Sandstone (500′+), quartzite and dolomite (300′), Needles Quartzite (1500′), Humboldt Slate and Dolomite (1800′), and Stevens Dolomite (4000′+). On the Huntley 1:50 000 scale geological map (Brown *et al*., 1982), units below the Needles Quartzite are not differentiated, and the extensive dolostone outcrops on the south flank of Tim Shea are wrongly indicated as quartzite. Brown *et al*. (1982, 1989) considered the succession to be Eocambrian to Early Cambrian because of its very low tectonic and metamorphic grade.

Additional traverses by the writer in the 1987 to 1990 period have added significantly to the knowledge of the stratigraphy and structure of the area (fig. 34). Stratigraphy of the Clark Group can now be revised and its constituent formations formally redefined. The basal 'Green Greywacke Sandstone' of Spry (1962), while broadly structurally conformable with the Needles Quartzite, is probably Cambrian (unit Cals, see below) and is separated from the Clark Group by a major fault at a low angle to bedding. The 'Stevens Dolomite' on the south flank of Tim Shea belongs to the Weld River Group (Calver, 1989), and is faulted against the Clark Group. The revised Clark Group therefore consists of a basal formation of quartz siltstone, conformably followed by the Needles Quartzite, and then the Humboldt Formation of dolostone and mudstone. Major faults subparallel to bedding separate the Clark Group from areas of Cambrian rocks to the south and east, suggesting an important phase of thrust faulting, followed by folding, during the (?late) Cambrian.

Recent mapping has also shown that lithostratigraphic correlates of the Clark Group underlie the Weld River Group with low-angle unconformity or paraconformity in the Weld Valley, Jubilee Range and Glovers Bluff areas. The Weld River Group is probably middle to upper Neoproterozoic in age (Calver, 1989; Seymour and Calver, 1995; this report). Radiometric dating of detrital zircon from a correlate of the Needles Quartzite at Glovers Bluff shows ages ranging from Archaean to 1400 Ma (Black *et al*., 2004). Similarities in the distribution of detrital zircon ages, and general lithological similarities, suggest that the Clark Group is a correlate of the Rocky Cape Group of northwest Tasmania, which is considered to be of early Neoproterozoic age (1000–750 Ma: Black *et al*., 2004).

Correlates of the Clark Group are widespread in the Jubilee region, cropping out as broadly anticlinal inliers at Jubilee Range, Mt Anne, and possibly Schnells Ridge. Probable correlates of different parts of the Clark Group near Mt Anne were named 'Mt Anne Group' and 'Pandani Group' by Calver *et al*. (1990), but the name 'Clark Group' has priority as a general term for this succession in south–central Tasmania.

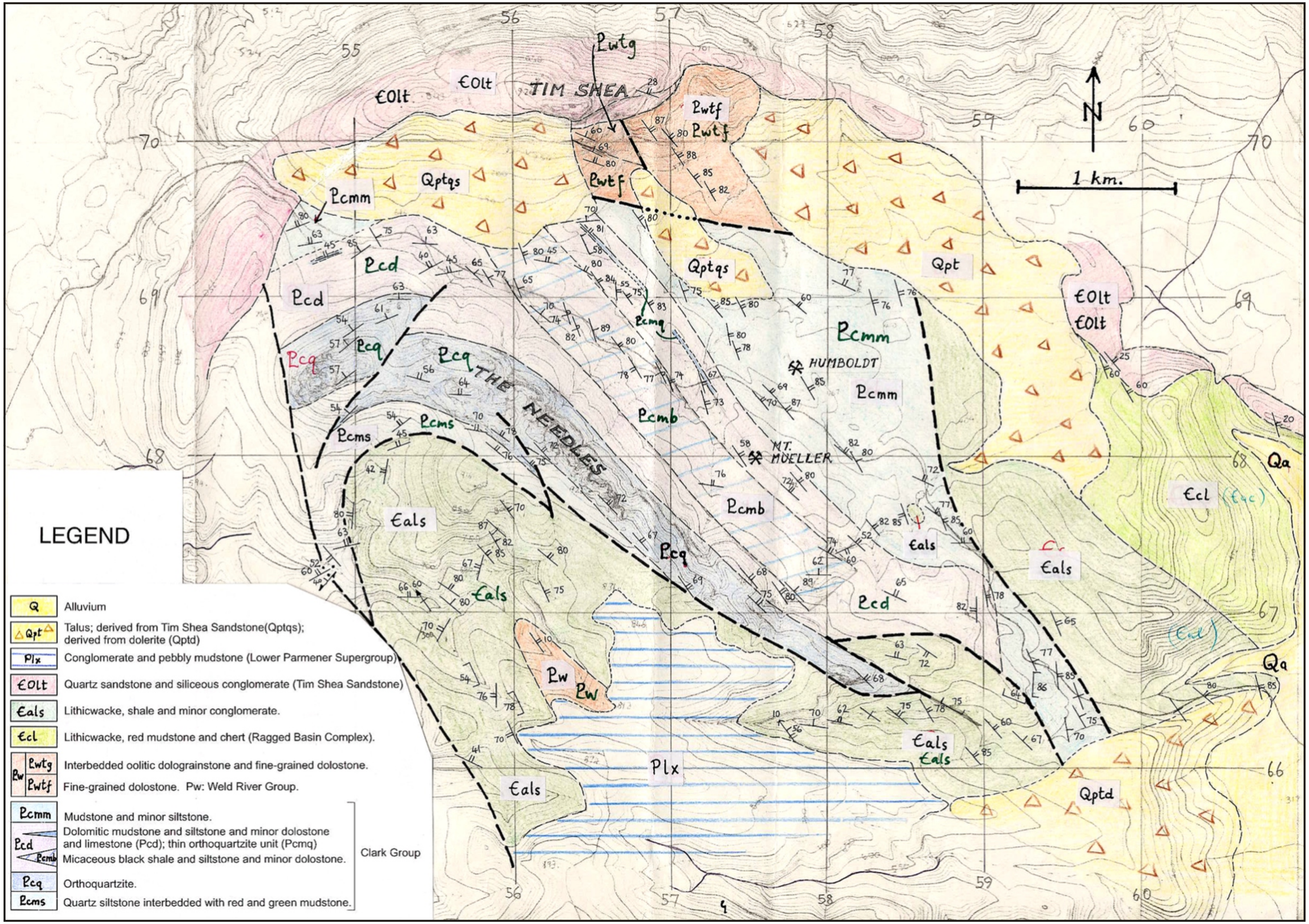


Figure 34
Geological map of The Needles area.

Stratigraphy

Clark Group

Carey and Banks (1954) provided no formal definition of the Clark Group. Their maps show essentially the entire area between the Permian rocks on the northern slopes of Mt Mueller, and lower Ordovician conglomerate on Tim Shea, as Clark Group. The new mapping (fig. 34) shows that much of this area belongs to other, younger successions. Here, the original concept of the Clark Group — the sequence consisting of the Needles Quartzite and units conformably enclosing it — is retained. The Clark Group is here redefined as the unit consisting of unnamed siltstone, Needles Quartzite and Humboldt Formation, as described below.

Siltstone underlying Needles Quartzite

A poorly-exposed unit of quartz siltstone and mudstone, similar to the Humboldt Formation, underlies the Needles Quartzite. The base of this unit is not exposed. It is inferred to be faulted against probably-Cambrian lithicwacke to the south. Creek exposures around 454900/5267300 are thinly interbedded quartzitic siltstone and green and red shale, with some micaceous black silty shale. Near the top of this unit, within 50 m of the base of the Needles Quartzite (at 455775/5268175) is pale grey dolomitic quartz siltstone with low-angle trough cross-lamination, thinly interbedded with black mudstone. Clastic dykes of siltstone are common in many of the mudstone beds. Nearby, there is a conformable, gradational transition, through thin-bedded, fine-grained quartz sandstone and siltstone, up into the Needles Quartzite.

This unit (Pcms of fig. 34) is not formally named because its base is unknown and its regional significance is uncertain. Correlates of the Needles Quartzite at Jubilee Range, Mt Anne, Glovers Bluff and elsewhere are much thicker (>1 km) than the type Needles Quartzite, so Pcms may be merely a siltstone lens within a thick orthoquartzite succession, truncated at The Needles by faulting. Alternatively, Pcms could be equivalent to the Twin Creeks Formation, a lithologically similar unit that underlies the probable Needles Quartzite correlative southwest of Mt Anne (Calver *et al.*, 1990).

Needles Quartzite

The Needles Quartzite (Carey and Banks, 1954) consists of fine to medium-grained (0.125–0.5 mm) orthoquartzite (i.e. texturally and compositionally supermature quartzarenite). The formation is erosionally resistant, about 300 m thick, and forms the prominent strike ridge known as The Needles. The quartzite is white to pale pink, thin to medium bedded, with common cross bedding, in sets 50–100 mm thick. Locally there are shaly interbeds, and intraclast conglomerate horizons consisting of flakes of shale in quartzite. Clastic dykes of orthoquartzite in a thin green mudstone bed, forming a polygonal network in plan view (possibly desiccation cracks), were seen at one locality near the base of the formation (455900/5268125).

No type section or area has been nominated by earlier authors. The basal transition is exposed around 455800/5268100 and intermittent exposure of an upward conformable transition into Humboldt Formation is seen in a creek around 457600/5267100. It is proposed that the area between these two localities, encompassing the boldly outcropping strike ridge of quartzite, be taken as the type area of the Needles Quartzite.

Restored palaeocurrent directions, derived from cross bedding, were determined from localities near the base and top of the formation. Near the base, palaeocurrents show a very broad southeasterly mode, and near the top, a broad easterly mode (fig. 4).

Humboldt Formation

The terms 'Humboldt Slate' (Carey and Banks, 1954) and 'Humboldt Slate and Dolomite' (Spry, 1962) were not formally defined and were applied to different (although overlapping) rock units. To clarify the stratigraphic nomenclature, the Humboldt Formation is here defined as the unit of mudstone and impure fine-grained dolostone, about 2000 m thick, overlying the Needles Quartzite. The formation is well exposed in cuttings on the Gordon River Road between 459600/5266400 and 454700/5269400, and in creeks flowing east off The Needles. The formation dips steeply and faces northeast. The youngest exposed beds crop out in the Tyenna River around 458300/5269000. This area, between The Needles and the Tyenna River, is nominated as the type area, as no single well-exposed section exists. The top of the formation is not exposed: it is in faulted contact with a correlative of the Neoproterozoic Weld River Group and with Cambrian sandstone (unit Cals). In complete sections in the Jubilee Range area, a correlate of the Humboldt Formation is overlain with paraconformity or low angle unconformity by the Weld River Group. Probably not much of the formation is missing in The Needles area.

A bedding-parallel fault may transect the upper part of the Humboldt Formation (see below). However unfaulted correlatives in the Jubilee Range area are broadly similar, suggesting no significant disruption to the lithostratigraphy of the type area.

The Humboldt Formation can be subdivided into two main mappable units; a lower half of interbedded dolostone and mudstone (unit Pcd), and an upper half of mudstone (Pcmm). This subdivision can also be recognised in the Jubilee Range area, around Mt Anne (Pedder Quadrangle), and probably elsewhere.

Unit Pcd

This is a variable succession of interlaminated and interbedded, impure fine-grained dolostone and mudstone, with minor limestone and quartzarenite.

Intermittent outcrop in a creek at 457600/5267100 exposes an apparently conformable upward transition from the Needles Quartzite into unit Pcd. Thin-bedded, ripple-marked, very fine-grained quartzarenite and quartz siltstone, with partings of red mudstone, comprise the transitional beds, which are included in unit Pcd.

Stratigraphically higher beds are well exposed on the Gordon River Road, 0–600 m east of Humboldt Divide. These are thin-bedded to laminated, leached (puggy) dolomitic mudstone and impure dolomite, mostly white to yellow-orange in colour, with horizons of red mudstone. Well-preserved halite hopper casts are present in leached dolomitic mudstone just east of Humboldt Divide (Plate 14). There are thin beds of dolomitic siltstone; some are graded, others cross laminated. Molar-tooth structures are present in some beds (these are thin, bedding-perpendicular carbonate veins of early diagenetic origin, that have usually been buckled by compaction: Plate 15; Smith, 1968; James *et al*., 1998). In common with molar-tooth structures described elsewhere (e.g. Smith, 1968), those of the Humboldt Formation are composed of uniform, even-grained calcite microspar of 10 µm grain size (e.g. thin section R002673). Some examples have been replaced by somewhat coarser dolomite (thin section R002668).

Beds of dolostone with stromatolites, mostly as low domes 0.3 to 1.0 m across and locally as columns (Plate 16), occur about 500 m east of Humboldt Divide. The dolostone includes minor thin, graded beds of grainstone with abundant platy intraclasts (flat-pebble conglomerate). One mudstone interbed preserves probable desiccation cracks.

Stratigraphically higher exposures on the Gordon River Road, between 0.7 and 2.0 km east of Humboldt Divide, consist of black micaceous pyritic shale and dolostone, and comprise a mappable unit (Pcmb) within Pcd. Black micaceous shale or silty shale is predominant, and there are common thin graded beds of quartzose siltstone and beds of impure, dark grey, fine-grained dolostone or limey dolostone. Stratiform to domical, stromatolitic lamination is present in some of the dolostone beds. Dolostone beds commonly contain blebs of calcite microspar, probably remnants of an original limestone precursor (thin section R002642). Abundant, randomly orientated lenticular bodies or radiating aggregates of coarse, bladed, inclusion-rich dolomite spar, 10–20 mm long (thin

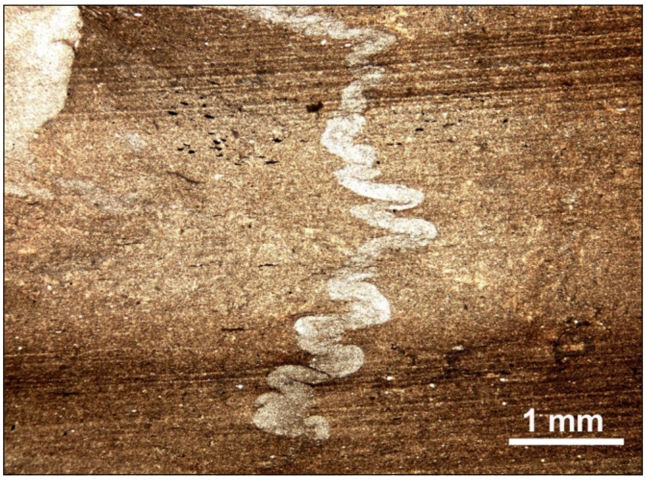


Plate 15

Photomicrograph of small molar-tooth structure in mudstone of Humboldt Formation. Sample R002673 (457525/5267950).

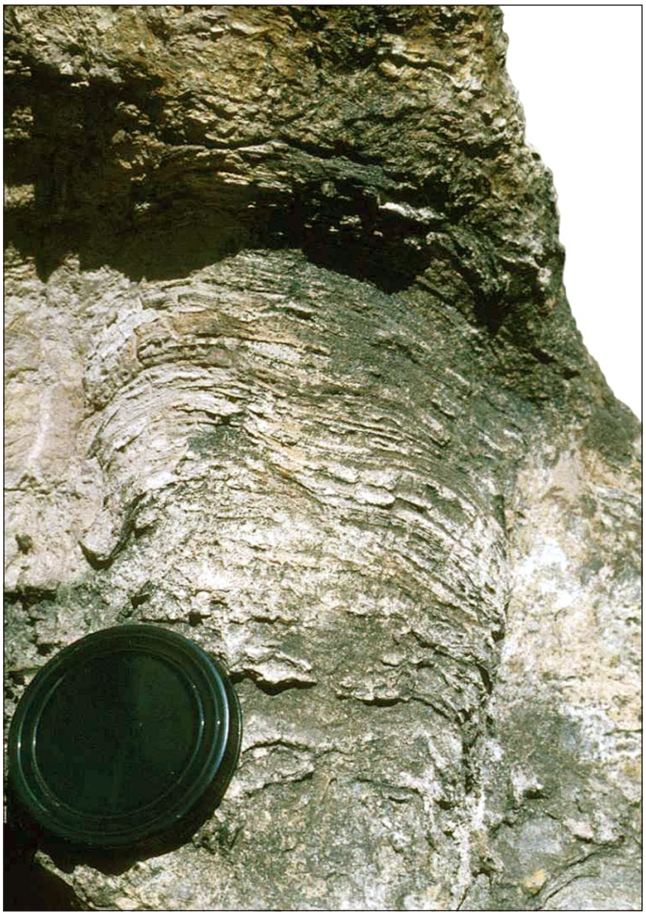


Plate 16

Columnar stromatolite, Humboldt Formation, Gordon River Road (455700/5269200).

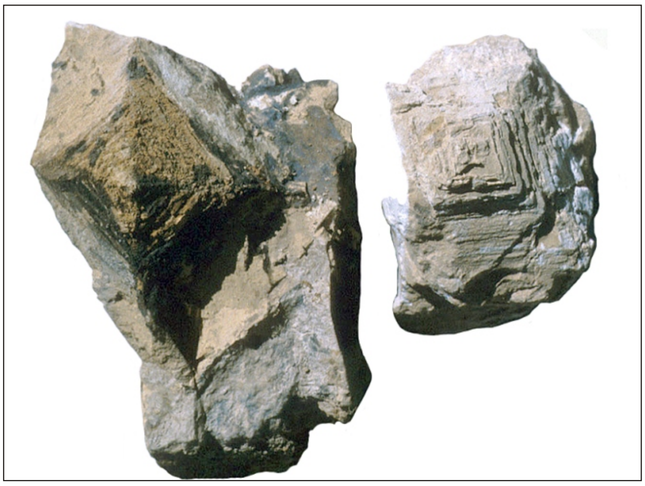


Plate 14

Halite 'hopper casts' in weathered dolomitic mudstone of lower Humboldt Formation (Unit Pcd), Gordon River Road east of Humboldt Divide (455500/5269300).

section R002662) occur in black dolomitic mudstone at 456300/5269200 and in black cherty mudstone at 458125/5267400. These appear to have grown in soft sediment, and may be pseudomorphs after an evaporite mineral.

The uppermost part of unit Pcd, as exposed in road cuts 2.0–2.3 km east of Humboldt Divide, consists of quartz sandstone and orthoquartzite passing up into thinly interbedded dolomitic mudstone, mudstone and siltstone, mostly pink to brown in colour, with minor chert nodules. Molar-tooth structures are present in some mudstone beds. There is a conformable contact with overlying hackly red mudstone of Pcmm.

An impersistent unit of orthoquartzite, lithologically similar to the Needles Quartzite and up to six metres thick, is present in places near the top of unit Pcd. This crops out along the crest of a ridge (456600/5269300 to 457100/5268700), in a cutting on the Gordon River Road (457300/5268500) and west of Humboldt Divide (454800/5269300). It is only moderately sorted in places, of fine to very coarse (0.25–1.5 mm) grain size, with very well-rounded quartz grains.

The Mt Mueller mine (457525/5267950) was developed on vein mineralisation (see previous section) hosted by the upper part of unit Pcd. The host rocks consist of interbedded black shale and impure, fine-grained, grey limestone, with common molar-tooth structures. Partly chertified dolomite oolite is present nearby. Some limestone beds are seen in thin section to contain an abundance of small (100 µm), authigenic prismatic crystals of inclusion-rich quartz (thin section R002672).

A relatively pure, thick-bedded to massive, pale grey, fine-grained dolostone unit, in part a sedimentary breccia (thin section R002636) and perhaps a few tens of metres thick, is present near the top of unit Pcd east of the Mt Mueller mine (457900/5267700), and extends at least as far south as the creek at 458150/5267400.

Interbedded dark grey impure limestone and shale near the top of unit Pcd is exposed in a road cutting at 459000/5267100. This is probably the same interval that hosts the Mt Mueller mine. Stromatolitic lamination, of stratiform, wavy and domical configuration, is present in some of the limestone beds. Near a culvert at the southern end of the cutting, an exposure of several metres of limestone consists of interbedded flat-pebble breccia, nodular limestone and stromatolitic limestone. The nodules in the nodular limestone consist of ellipsoidal concretions of impure fine-grained limestone in a black, limey mudstone matrix. Some concretions are orientated parallel to bedding; others, which appear to have developed along molar-tooth structures, are at a high angle to bedding (Plate 17). This unusual fabric has been previously described from the Irby Siltstone of the Rocky Cape Group in northwest Tasmania (Calver and Baillie, 1990).

Good outcrop of impure dark grey limestone and shale persists for 200 m up a small creek to the west of the last-mentioned road cutting (stratigraphically down section), and includes chertified oolite (R007655: Plate 18).

Plate 17

Impure nodular limestone from unit Pcd of the Humboldt Formation, Gordon River Road (459050/5267050). Etched slab. Most nodules are parallel to bedding (horizontal), but some nodules at a steep angle to bedding have nucleated on molar-tooth structures.

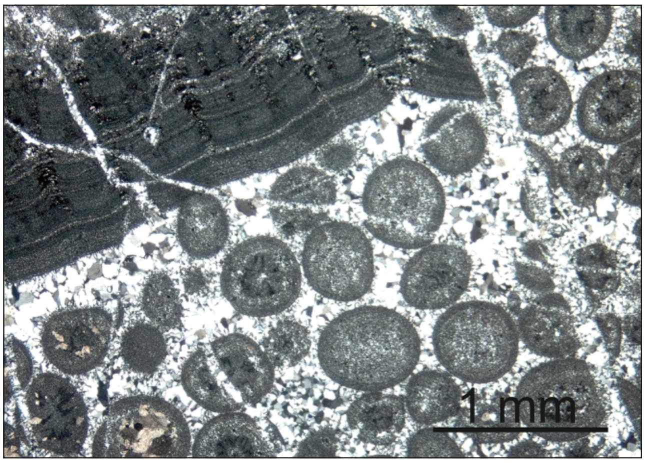


Plate 18

Photomicrograph of silicified oolite, from unit Pcd of the Humboldt Formation (458700/5266900). Crossed polars. Sample R007655.

Unit Pcmm

This unit, the upper part of the Humboldt Formation, consists almost entirely of brittle, uniform claystone, red, brown or grey-green in colour. It is well exposed in cuttings along the Gordon River Road. In many outcrops there are minor, thin (0.1–5 mm), planar, graded laminae of fine-grained siltstone. There are rare beds of very fine-grained, well-sorted muscovitic quartz sandstone and siltstone with micaceous partings and pale grey, limey, impure dolostone. Brown, puggy leached dolomitic mudstone crops out in the Tyenna River around 458400/5269000.

Fissile brown shale near the Humboldt mine (at 458000/5268300) contains nodules of fine-grained quartz around 100 mm in size. There are disseminated sulphide minerals in the nodules. In thin section (R007619) the quartz consists of displacive masses within mudstone, a texture suggesting replacement of evaporites.

Weld River Group

Dolostone crops out boldly on the three southeastern spurs of Tim Shea (456400/5270000 to 457400/5270200). On the westernmost spur, below the summit of Tim Shea, outcrop is predominantly well-bedded, oolitic grainstone, cross bedded in places and dipping NNE, right way up. On the next spur east, outcrop is of massive to thin-bedded, fine-grained, pale grey dolostone, dipping steeply northeast. Discordance of bedding and lithology requires a fault in the intervening gully. The easternmost spur is massive, pale grey dolostone. These occurrences are dissimilar to the dolostones of the Humboldt Formation in their total lack of argillaceous or sandy, detrital impurities. They are identical in outcrop appearance and texture (e.g. thin section 002512) to dolostones of the Weld River Group (Calver, 1989; Calver *et al*., 1990) with which they are correlated. The disposition of bedding requires a fault between these outcrops and the Humboldt Formation.

The term 'Stephens Dolomite' or 'Stevens Dolomite' has been applied to these outcrops by Carey and Banks (1954) and Spry (1962). However these authors also included much (Spry, 1962) or all (Carey and Banks, 1954) of the Humboldt Formation in the Stephens Dolomite. It is recommended that this term be discontinued.

Cambrian

The Clark Group is faulted to the south and east against turbiditic lithic sandstone, mudstone and minor conglomerate, shown as Cals on Figure 34. These rocks are composed of detritus derived from a metasedimentary terrain similar to the Tyennan region, from unmetamorphosed sedimentary rocks including dolostones similar to the Weld River Group, and there is also mafic volcanic detritus and rare ultramafic detritus. This diversity of source materials is unknown in the Tasmanian Proterozoic, and is taken as indicating a Cambrian age. These rocks are continuous with an area shown as Cals on the Pedder 1:50 000 scale geological map and described by Calver *et al*. (1990). These rocks are unfossiliferous, and a middle Cambrian age is inferred from their similarity to fossiliferous, middle Cambrian successions (Island Road Formation, Trial Ridge Beds) in the Pedder and Huntley quadrangles (Brown *et al*., 1989). The presence of rare ultramafic detritus and chromite in rocks of units Cals and Calc suggests that these rocks are younger than the ultramafic complexes. The presence of dolostone clasts suggests the rocks are younger than the Weld River Group, of probable middle to upper Neoproterozoic age.

The area of unit Cals lying south of The Needles forms a major northwest-plunging anticline, broadly concordant with the Needles Anticline (fig. 34). Unit Cals is here inferred to be separated from the structurally overlying Proterozoic rocks by a major folded thrust. In the core of the anticline is an area of dolostone correlated with the Weld River Group, which may unconformably underlie unit Cals, or be faulted against it. To the south, these rocks are unconformably overlain by the Parmeener Supergroup. The eastern limb of the anticline may be continuous (under Parmeener Supergroup cover) with the northeast-dipping tract of Cals on the eastern slopes of Mt Mueller, on the eastern part of the Maydena 1:25 000 scale map sheet (see previous section).

The area of unit Cals south of The Needles is dominated by tough, slightly micaceous, fine-grained sublithic quartzose sandstone that tends to be white on well-weathered outcrops but is dark grey to grey-green on fresher exposures. The sandstone tends to be thick-bedded to massive, but well-bedded intervals with interlayered dark grey mudstone and siltstone are common.

There are rare, medium to coarse-grained sandstone beds. Sandstone beds tend to be internally structureless, but grading, plane lamination and cross-lamination are occasionally seen. In a few places, irregular inclusions of sandstone within shale attest to syn-sedimentary slumping.

Thin sections of medium to coarse-grained sandstone (R007665, R007669) show these rocks to be lithicwackes dominated by ill-sorted angular quartz and metamorphic rock fragments, detrital dolostone fragments, chert, other sedimentary rock fragments and minor mafic volcanic rock fragments. Detrital muscovite, K-feldspar, plagioclase and chlorite are present. Metamorphic rock fragments consist of foliated metaquartzite and quartz-mica schist. Dolostone fragments are variable in texture (coarsely to finely crystalline), sometimes rounded, with recrystallisation pre-dating incorporation into the sediment. Mafic volcanic fragments consist of felty textured plagioclase in a turbid, brown or green chloritic groundmass.

The fine-grained sandstone is sublithic quartzwacke, dominated by ill-sorted angular quartz grains and fewer lithic grains than the medium to coarse-grained sandstone. The more labile grains (dolostone, volcanics) are absent or rare.

In a creek just south of Gordon River Road, east of The Needles (458600/5267600), is a small area of outcrop of unit Cals, entirely surrounded by Proterozoic Humboldt Formation. This outlier is inferred to be fault bounded, and could be a thrust window (see below).

The outlier consists of two outcrops in the creek bed about 30 m apart. These consist of massive, dark grey-green quartz siltstone, sandstone and foliated pelite. The upstream outcrop consists of pods of siltstone and lithic sandstone in sheared mudstone, with a steeply northeast-dipping shear foliation. The sandstone in thin section (R002634) is moderately sorted, of medium (0.25–0.5 mm) grain size, and is dominated by quartz, sedimentary rock fragments (chert, mudstone, siltstone), metamorphic rock fragments (quartz-mica schist), with some feldspar (including sodic plagioclase), minor chlorite, biotite and muscovite, and rare ?mafic volcanic rock fragments.

Structure

The Proterozoic and Cambrian rocks lie in the hinge and eastern limb of a major fold, the Needles Anticline, which plunges 60° to the northwest, with a subvertical axial surface. The older rocks are unconformably overlain to the north by the Wurawina Supergroup, and bedding in the younger succession lies in a broad, relatively open, major anticline (the Tim Shea Anticline) that is nearly coaxial with the Needles Anticline. The Tim Shea Anticline is one of a number of major Devonian folds in the Wurawina Supergroup that plunge gently NNW and comprise the Florentine Synclinorium (Corbett and Banks, 1974). Lennox (*in* Brown *et al*., 1989) described the geometry of the Needles Anticline, and indicated that it pre-dates the Devonian deformation, but was tightened in the Devonian.

The remapping has shown that south of The Needles, the Clark Group is structurally underlain by Cambrian lithicwacke (Cals), folded in harmony with the Needles Anticline. A major, folded fault — probably a thrust — separates the Cambrian rocks from the Clark Group (fig. 34). A small area of Weld River Group dolostone lies in the core of the anticline, but it is uncertain whether the dolostone-lithicwacke contact is an unconformity or another fault.

A number of other, less significant faults at a low angle to bedding were also mapped, and are probably related to the main thrust, for example, offsetting the base of the Needles Quartzite (456150/5267950). A cataclastic foliation at 458800/5266400 dips 75° northeast, parallel to regional bedding, and is probably associated with an inferred fault that displaces the main thrust (fig. 34). A small outlier of ?Cambrian lithicwacke within Clark Group near the Gordon River Road (458600/5267600) may be a thrust window. This lies adjacent to a linear, parallel to regional bedding, which extends northwest through the Humboldt prospect.

If the limbs of the Needles Anticline are rotated back by an amount equivalent to the dip on the limbs of the Tim Shea Anticline, the approximate geometry of the fold that pre-dated the deposition of the Wurawina Supergroup (and Devonian tightening) is obtained. This was an open, upright fold plunging gently to the northwest. The thrust and this fold are probably Cambrian in age as these structures involve lithicwacke (Cals) of inferred Cambrian age, and pre-date the Late Cambrian to Early Ordovician Tim Shea Sandstone.

The direction of transport on the Needles thrust is uncertain. South and east of The Needles, it appears to ramp upwards through the Clark Group stratigraphy in a southeasterly direction, suggesting a component of southeast transport.

As in the Jubilee Range area, rocks of the Clark Group in The Needles area are unstrained or only weakly strained, as shown by the undeformed state of sedimentary structures. There is a weak slaty cleavage parallel to bedding in mudstone, most easily discerned in thin section as an extinction direction under crossed nicols (e.g. thin section R002668). In places, a crenulation cleavage is observed in the Clark Group that is approximately parallel to the axial plane of the Needles Anticline (e.g. Lennox *in* Brown *et al*., 1989, p.95). A minor fold in lithicwacke at 455400/5267100 is parallel to the Needles Anticline, and has an axial planar cleavage that crenulates a weak, bedding-parallel slaty cleavage in mudstone (thin section R002679).

Correlation of the major thrust and anticline at The Needles with deformation elsewhere in the Jubilee Region is uncertain. The lithic sandstone succession (Cals) is tentatively correlated with a lithic sandstone–conglomerate succession north of Mt Bowes that contains rotated, cleaved clasts of Clark Group correlate (Calver *et al*., 1990, p.49). The thrust and anticline therefore probably post-D_1 of the Mt Anne–Mt Bowes area. The thrust may correlate with ?D_2 faults in the Jubilee Range area. The fold may correlate with D_3 of the Mt Anne–Mt Bowes area, which is associated with upright northwest-plunging major folds and axial planar crenulation in that area (Calver *et al*., 1990).

APPENDIX 2

Interpretation of ground magnetic traverses in the Glovers Bluff (Forster Prospect) area

C. R. Calver and A. R. Ezzy

In order to better constrain the distribution of poorly outcropping Proterozoic to Cambrian units and Jurassic dolerite in the Glovers Bluff–Forster Prospect area, six ground magnetic traverses (4, 5, 10, 11, 12 and 13 on fig. 35) and about 400 magnetic susceptibility determinations were undertaken. Seven profiles from Carthew *et al*. (1988) (1, 2, 3, 6, 7, 8 and 9) are also shown on Figure 35.

The magnetic susceptibility (MS) of Jurassic dolerite was found to be highly variable from place to place, from a maximum of $22.4 \pm 6.5 \times 10^{-3}$ SI units (n = 13) in Eddy Creek (477280/5436650) to a minimum of 0.41 ± 0.04 (n = 12) on the ridge east of Fletchers Eddy (478350/5435800). In general, dolerite MS values required to model the profiles were considerably higher than the values measured in the field (up to 40×10^{-3} SI units, see fig. 37), probably because of remanence (Leaman, 2002, p.144).

Dolostone, skarn-altered dolostone and silica are essentially non-magnetic (MS $<0.05 \times 10^{-3}$ SI units). Float of ?Cambrian lamprophyre and altered volcaniclastic sandstone on the ridge east of Eddy Creek (478780/5237500) is highly variable ($0.06–19.7 \times 10^{-3}$ SI units). No determinations were made of Cambrian units in the Forster Prospect area, but the strong response on the profiles indicates the presence of some highly magnetic units (with modelled MS up to 300×10^{-3} SI units).

Four profiles modelled using ModelVisionPro are shown (fig. 36, 37). The main conclusions that can be drawn from the modelled profiles are as follows.

1. Modelling of profiles 2 and 3 suggests that the Cambrian units, here dominantly conglomerate of mafic and ultramafic provenance, are weakly to very strongly magnetic units dipping steeply west, including a highly magnetic unit about 30 m thick near the faulted contact with non-magnetic, dolomitic skarn. The depth extent of the Cambrian units is very approximately 100 m or more.

2. Drill-hole data show that Jurassic dolerite underlies the skarn at depths of 30 to 40 m in profile 3, and probably at somewhat greater depths in profile 2 (see fig. 7). Dolerite cropping out near the eastern end of profile 3 is relatively weakly magnetic ($3.0 \pm 1.1 \times 10^{-3}$ SI units (n=36)). The modelled depth of the dolerite in lines 2 and 3 (fig. 36) is very sensitive to the selection of the regional field, and is poorly constrained by the magnetic data. The thickness of the dolerite (more than 100 m from drilling evidence) cannot be determined from the magnetic data.

3. There is an outcropping belt of weakly magnetic dolerite, roughly 100–200 m wide and three kilometres long, that extends from just east of Forster Prospect (near the eastern end of Profile 3) northwards along the crest of the ridge that lies east of Eddy Creek (fig. 6). This belt is characterised by low MS readings in the field ($<3 \times 10^{-3}$ SI units), and on the magnetic profiles it is represented by subdued sections that are modelled as underlain by dolerite with MS of 8×10^{-3} SI units or less (e.g. eastern end of Profile 10, fig. 37). A polished thin section (R008107) from this zone shows no magnetite; the opaque minerals are dominantly ilmenite and pyrite with minor chalcopyrite and pyrrhotite (R. S. Bottrill, pers. comm.). The weakly magnetic belt may be a zone of subtle alteration genetically related to the mineralisation at Forster Prospect. It adjoins Forster Prospect to the east and possibly underlies it. Further north (Profile 10) the weakly magnetic dolerite zone is faulted against Permian rocks on the eastern side; still further north (Profile 11) it is enclosed by more strongly magnetic dolerite, apparently with steep boundaries.

4. Outside the weakly magnetic zone, dolerite is characterised by erratic, spiky profiles modelled by strong lateral variations in magnetic susceptibility (5 to 60×10^{-3} SI units).

5. Profile 10 was intended to test whether Proterozoic or Cambrian units underlie the areas of no outcrop west and east of dolerite outcrop at Fletchers Eddy. Fletchers Eddy is situated at 800 m on Profile 10. The profile suggests the presence of near-surface dolerite for 150 m east and west of Fletchers Eddy, and there is a broad magnetic low to the west of this zone and a narrower low to the east. The modelling of these lows is uncertain, being dependent on the selection of the regional field, the MS attributed to dolerite, and the unknown thickness of surficial cover. The presence of predominantly non-magnetic rocks (such as Proterozoic– Cambrian units) up to about 200 m in vertical extent is probable (fig. 37). Short wavelength maxima within these broad lows could be Jurassic dolerite dykes (as seen intruding Proterozoic rocks in the Weld River, just to the south) or surficial boulders. Because of the short wavelength spikiness of the ground magnetic profile, modelling of line 10 was carried out mainly with reference to the 50 m upward continuation (fig. 37).

6. The northernmost line (Profile 13) suggests that the ?Cambrian lamprophyre/basalt float band on the ridge east of Eddy Creek is related to a 25 m thick tabular magnetic unit that dips about 70° west. Weaker anomalies 100–200 m to the east can be modelled as more weakly magnetic, steeply east-dipping units under 10–20 m of non-magnetic cover. The origin of these anomalies is unknown. Only sparse silica fragments are present as float.

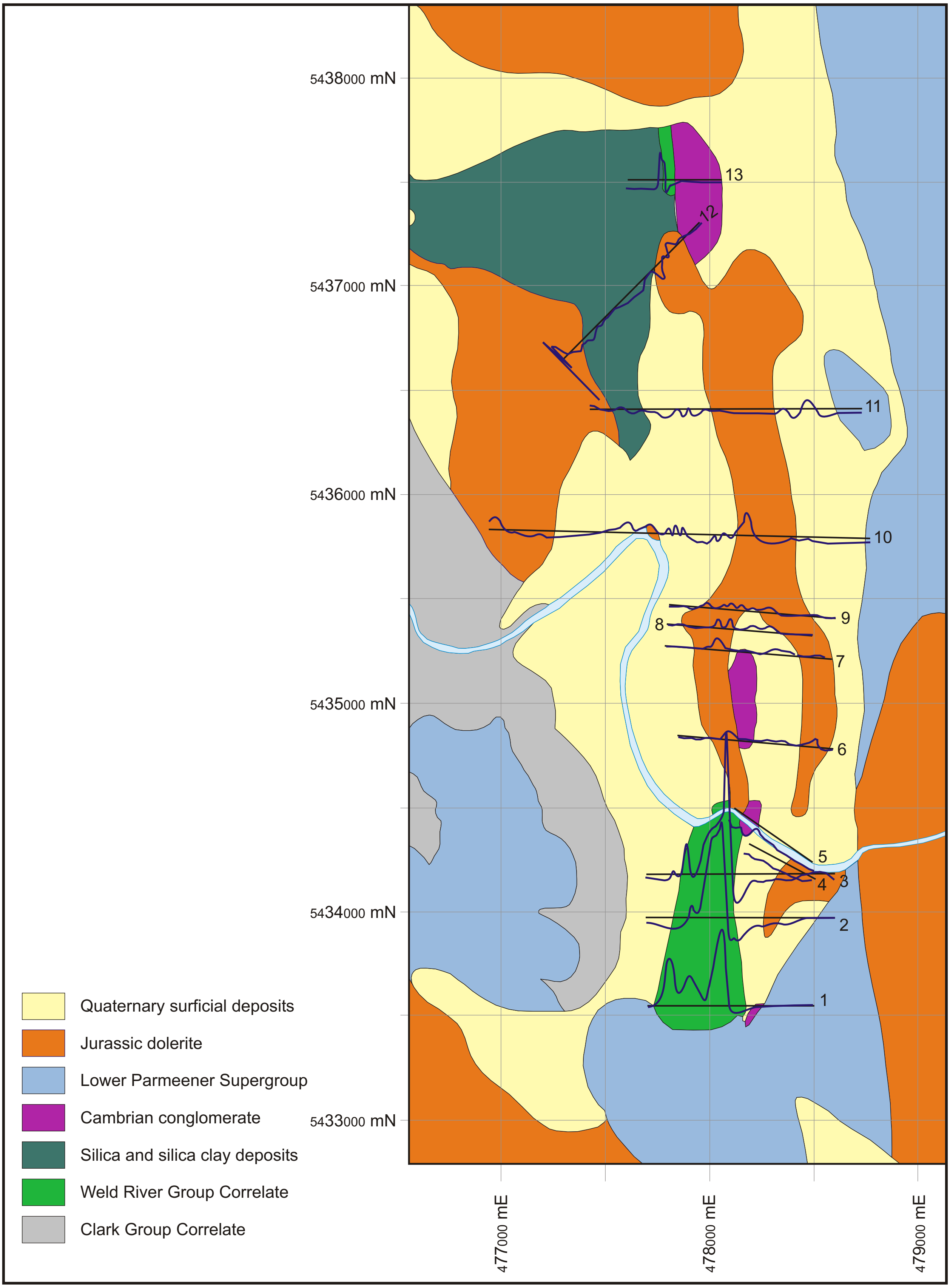


Figure 35

Simplified bedrock geology and ground magnetic profiles, Glovers Bluff inlier.

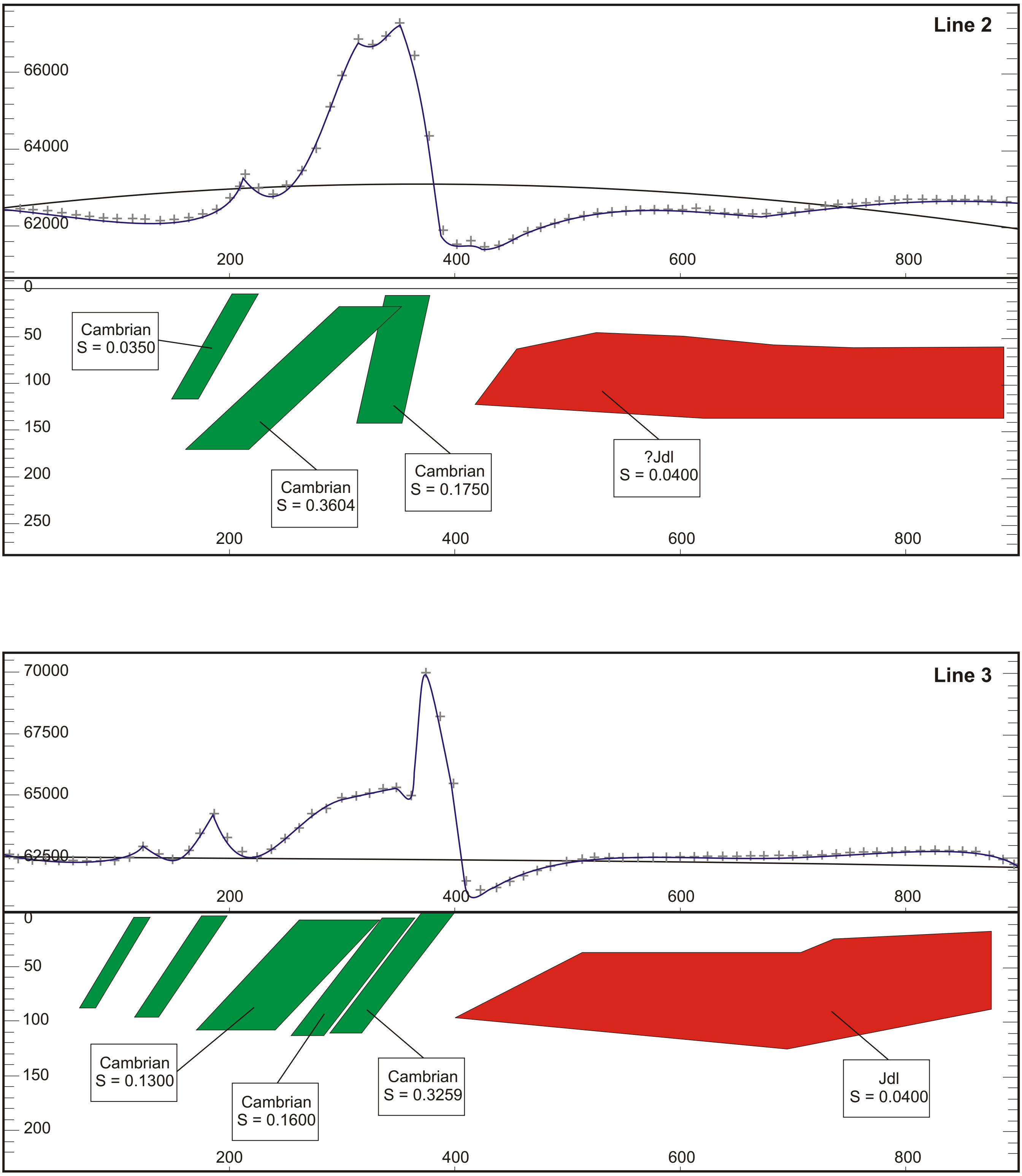


Figure 36

Modelled ground magnetic profiles (Lines 2 and 3), Glovers Bluff inlier.

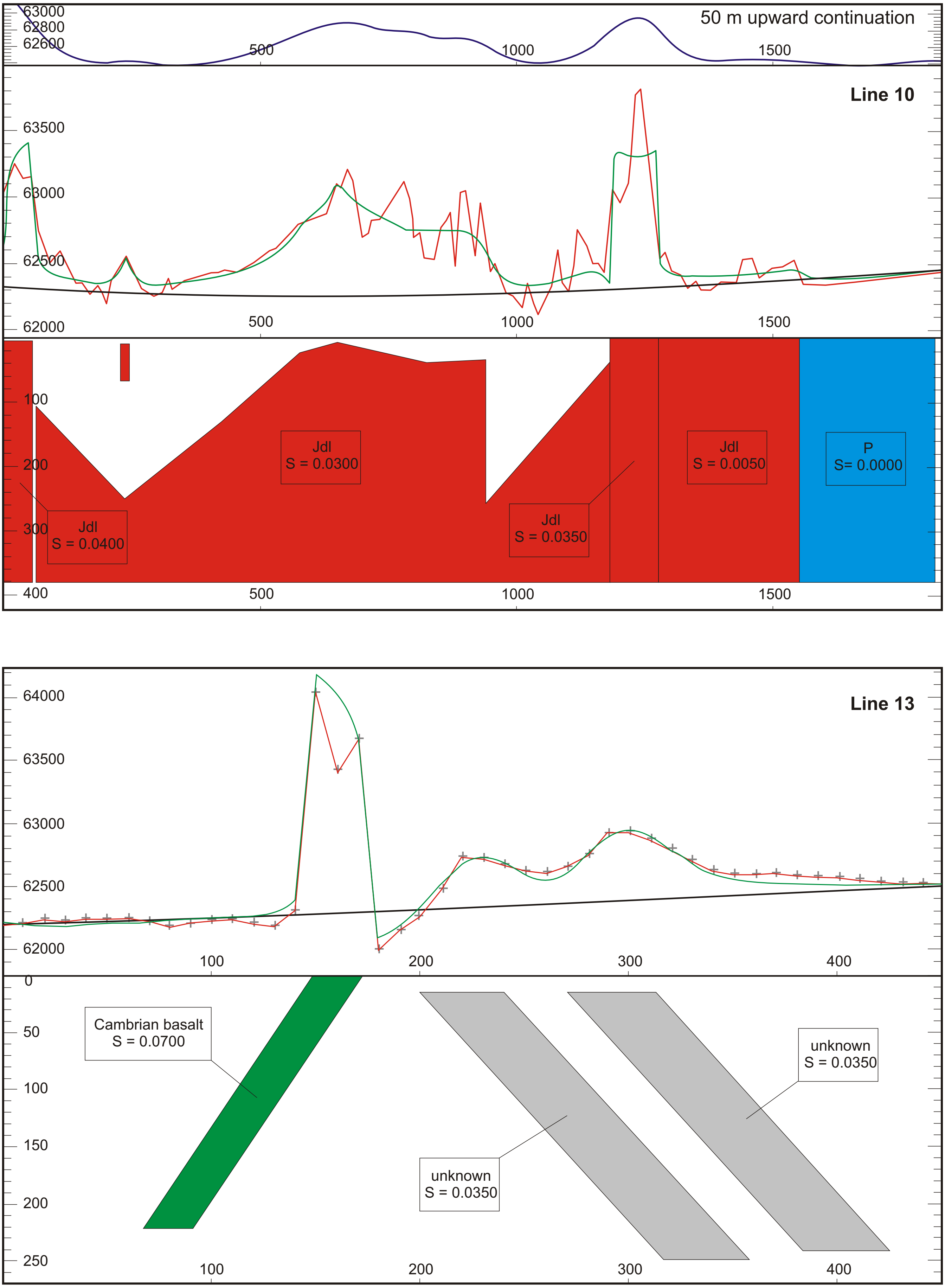


Figure 37

Modelled ground magnetic profiles (Lines 10 and 13), Glovers Bluff inlier.