DEPARTMENT OF MINERALS AND ENERGY

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

RECORD 1975/147

SILURIAN STRATIGRAPHIC UNITS OF THE SOUTHERN PART OF THE MOLONG HIGH*

by

D.L. Strusz

RECORD 1975/147

SILURIAN STRATIGRAPHIC UNITS OF THE SOUTHERN PART OF THE MOLONG HIGH*

by

D.L. Strusz

*Published with the permission of the Director, Bureau of Mineral Resources, Geology and Geophysics, Canberra, A.C.T.

Table of Contents

This Record is a draft contribution to a forthcoming publication by the Geological Survey of New South Wales, on the Silurian System of the State, which is being edited by Dr J. Pickett. This contribution deals with the Silurian stratigraphic units of the southern part of the Molong High (that part on the Monaro 1:500 000 geological sheet). In this area, the high is developed as a series of horsts and grabens, meridionally oriented; the Goodradigbee Graben and Canberra Graben, and the intervening Cotter Horst, are the subject of this Record.

Each unit is described in terms of lithology, stratigraphic position, fossil content, age, and correlation. For descriptive purposes, the units have been grouped according to structural and geographic criteria. Within each grouping, the units are arranged essentially in order of decreasing age.

The considerable help given by the members of the Tantangara mapping party (M. Owen, D. Wyborn, P. Jell) and R.S. Nicoll, of the BMR, and by J. Pickett and G. Bradley of the Geological Survey of New South Wales is here acknowledged.

NORTHERN PART OF THE CANBERRA GRABEN

CANBERRA AREA

State Circle Shale

The State Circle Shale was defined by Öpik (1954, 1958) as a sequence of shale and sandy shale with interbeds of fine sandstone. He considered that it was conformably underlain by the Camp Hill Sandstone, which it overstepped in places to rest unconformably on Ordovician rocks, and that it passed upwards into the Canberra Group. Recent work by the Engineering Geology Section of the Bureau of Mineral Resources (BMR), and by senior students at the Australian National University (ANU), has led to a reinterpretation of the relationships (Strusz & Henderson, 1971; Crook et al., 1973). It is now thought more likely that the State Circle Shale is conformably overlain by the Black Mountain Sandstone (thought by Öpik to be Ordovician), with the Canberra Group unconformably above that. An unconformable relationship with Ordovician strata is still accepted.

The type locality is the embankment on the northwest part of State Circle, Canberra, east from Darwin Avenue and the South African Embassy (grid reference 8727-928.907)*. Here is exposed a sequence of brown-weathering grey silty mudstone and occasional siltstone beds, about 60 to 65 m thick.

Öpik mapped the formation in the partly fault-bounded block around the type locality, in a narrow strip at the southern foot of Black Mountain, and in a rather larger strip northwest of the mountain. Moore (1957MS) added a small area southeast of Canberra airport, and there are now known to be larger areas of outcrop along the northeast edge of Belconnen (Strusz & Henderson, 1971). Exposure is generally poor, so that thicknesses are difficult to determine, but Henderson (1973aMS) suggests the unit may reach 200 m around Capital Hill. The predominant rock type is a banded moderately fissile dark greenish-grey mudstone, often somewhat silty, which weathers to brown, pale grey, or cream. Slump breccias have been observed, but are not common. Towards the top of the formation there are beds of siltstone and fine to medium-grained arenite.

The evidence for the relationship between the State Circle Shale and the Black Mountain Sandstone is subject to argument. As the age of the latter depends largely on the interpretation of that relationship, it is discussed further under the heading Black Mountain Sandstone.

The only fossils known from the State Circle Shale are graptolites, and these have not been found at every outcrop. Öpik collected from the southern foot of Black Mountain, and from south of the British High Commission (Commonwealth Avenue); specimens have also been collected from a trench behind Parliament House, and from several places northeast of Belconnen town centre, including the Barton Highway at Ginninderra Creek (see Crook et al., 1973). The most common species is <u>Monograptus exiguus</u>, but the fauna also contains <u>M. turriculatus</u>, <u>M. spiralis</u>, and <u>Retiolites</u>. Correlation can be made with the British Zone of <u>M. turriculatus</u> (Fronian Stage, late Llandoverian).

---

*Grid references are to the metric co-ordinates on the 1:100 000 topographic sheets, and are to the nearest 100 metres; the appropriate sheet number is stated first.

From the admittedly limited evidence available, Crook et al. (1973, p.124) suggest that "the unit may have accumulated in deep water in areas remote from sources of coarser terrigenous sediment,..", probably as a distal flysch.

A possible southerly extension of the State Circle Shale has recently been discovered by ANU students.* About seven km south of Michelago, just east of the Monaro Highway (G.R. 8726-959.386), is a small area of shale and quartz arenite from which graptolites have been recovered. The stratigraphic context is uncertain as outcrop is poor, but the rocks seem to be on the western side of the northern end of the Collingwood Fault. The fauna includes Glyptograptus cf. incertus, Monograptus cf. communis communis, M. cf. lobiferus, orthograptids, and Climacograptus. The probable age is middle Llandoverian (Idwian Stage?). Farther south, on the northeast slope of Colinton Hill (ca 8726-990.300) is a band of grey-green shale, poorly outcropping but apparently conformable beneath the Cappanana Beds, from which a single specimen of Monograptus gemmatus was recovered. This again gives a Llandoverian age.

Black Mountain Sandstone

The sandstones on Black Mountain in Canberra were first referred to by Pittman (1911), who commented on the "thick beds of buff-coloured sandstone". However the unit was first defined and named stratigraphically by Öpik (1954, 1958), who described it as a fine-grained quartzose sandstone, with rare thin shaly beds. The formation is unconformably overlain by the Camp Hill Sandstone, but the nature of the lower boundary, and the age of the unit, is subject to argument. Pittman thought the sandstone was conformable on the shale-limestone sequence (the present Canberra Group) east of Black Mountain, while Öpik stated that "..the lower contact... is eliminated by faults". More recently the unit has again been considered as lying conformably on Silurian rocks, namely - the Lower Silurian State Circle Shale (Henderson 1973a & b MS, Strusz & Henderson, 1971; Crook et al., 1973).

---

* Named the Gungoandra Siltstone Member of the Ryrie Formation by Richardson, 1975: Q. Notes geol. Surv. N.S.W., 21:1-7.

The type locality was designated by Öpik as Black Mountain, but a specific section was not mentioned. The thickness here was estimated by him as not less than 460 m. The lower 60 m contains interbedded sandstone and brownish-grey shale, the latter possibly tuffaceous. The shale beds become less frequent upwards, and the greater part of the formation comprises pale grey medium to fine grained quartz greywacke, in thick beds.

Similar arenites are exposed on Capital Hill (where the unconformable boundary with the Camp Hill Sandstone is preserved) and Mount Jerrabomberra, south of Queanbeyan. There is also a band of sandstone extending southwestward for about 3.5 km from the Barton Highway near Ginninderra Creek, which has been mapped as Black Mountain Sandstone. In this faulted block the proportion of shale is much greater than at Black Mountain. The adjacent sediments include the State Circle Shale, and beds which Crook et al. (1973) assigned to the Canberra Group, but which are probably better regarded as the southerly continuation of the Westmead Park Formation. It is possible that the sandstone/shale unit is part of the Upper Llandovery to Wenlock Murrumbateman Creek Formation.

A variety of sedimentary structures are developed, and some can be seen in any outcrop. They include small-scale cross-lamination and occasional ripple marks, some convolute lamination, common slump structures, and sole markings such as load coasts, and flute moulds. Some layers contain clay-pellets, and there are also shale-clast conglomerates. According to Crook et al. (1973) these structures correspond to the typical flysch association.

The only area mapped in detail is that by Scott (1970MS). Öpik had failed to find any fossils in his moderately intensive mapping, and Scott fared no better. Consequently the age assigned to the Black Mountain Sandstone depends on the interpretation of its stratigraphic position. According to Öpik it is pre-Darriwilian (Ordovician), but Strusz & Henderson (1971) and Crook et al. (1973) think a Middle Silurian age more likely. One critical area is at the southern foot of Black Mountain, near the Black Mountain Peninsula. Next to Lady Denman Drive are outcrops of buff to pale olive mudstone containing *Monograptus exiguus* - the State Circle Shale. These beds dip north, towards the mountain.

In a gully above the road are similar mudstones, but lacking graptolites; these extend up the hillside, interbedded with sandstones, and show a gradual passage to the massive Black Mountain Sandstone. The attitude of the mudstone and interbedded sandstone is similar to that of the State Circle Shale outcrops. Öpik interpreted them as the lowest exposed part of the Black Mountain Sandstone, and because of the tectonically disrupted nature of that unit postulated a fault separating them from the graptolitic mudstone. Henderson (1973a MS) and Crook et al. (1973) prefer the simpler interpretation of a completely conformable succession. Until fossils are found in the Black Mountain Sandstone, or an unequivocal exposure of its boundary with the State Circle Shale is made, there can be no certainty regarding its age and stratigraphic position.

Canberra Group

Öpik (1954, 1958) originally defined the Canberra Group as comprising three conformable formations: Turner Mudstone, Riverside Formation, and City Hill Shale. The Group was considered to be conformable on the State Circle Shale, while the St Johns Church Beds were considered to overlie red claystones (exposed only temporarily in a trench) which in turn conformably overlay the City Hill Shale. More recent work, and a reinterpretation of the stratigraphic relationships, has led Henderson (in Strusz & Henderson, 1971) to redefine the Group to include the marine sedimentary and volcanogenic strata northeast of the Deakin Fault in the Canberra city area, which are believed to be unconformable on the State Circle Shale and Black Mountain Sandstone, and unconformably overlain by the Ainslie Volcanics. The full content of the Group is thus: Camp Hill Sandstone, Turner Mudstone, Riverside Formation, City Hill Shale, unnamed claystones (probably best referred to the St Johns Church Beds?), St Johns Church Beds, Mount Pleasant Porphyry? The last could be a volcanic sequence carrying on from the tuffs at the top of the St Johns Church Beds (Öpik's interpretation), or a tectonically disturbed part of the Ainslie Volcanics (as implied by the Canberra map, Strusz & Henderson, 1971). On the former interpretation, it occurs as an inlier within the Ainslie Volcanics.

The base of the Group can be no older than late Llandoverian, since the underlying State Circle Shale contains late Llandoverian (Fronian) graptolites. Link & Druce (in Strusz & Henderson, 1971) recovered conodonts from high in the Riverside Formation which indicate a probable Ludlovian age. It is likely that the greater part of the Group is of Wenlockian age.

The relationship with surrounding sequences is uncertain. The Fairbairn Group is possibly coeval. The sequence is similar, as are the faunas in so far as they are known. The Red Hill Group is almost certainly younger.

Camp Hill Sandstone (Canberra Group)

First recognized and described by Öpik (1954, 1958), the Camp Hill Sandstone is a sequence of interbedded quartzose sandstone and shale. It is known to be unconformable on the Ordovician Pittman Formation, and the Silurian(?) Black Mountain Sandstone, and from mapping since 1970 is also now thought to be unconformable on the Lower Silurian State Circle Shale. Öpik considered that the latter was conformable on the Sandstone. The upper boundary is not exposed, but is thought to be conformable with the Turner Mudstone.

At the type locality (Camp Hill, behind Parliament House, Canberra) Öpik estimated a thickness of twelve metres, but subsequent roadworks in the area suggest it is much greater. Henderson (1973b MS) estimates the total as about 120 m.

The lowermost layers exposed near the flagpole atop Capital Hill comprise a basal grit about 10 cm thick, lying on silicified upturned Black Mountain Sandstone; this is followed by several metres of thinly interbedded shale to fine grained sandstone. The basal unconformity is also well exposed in State Circle, in a deep road cutting into the southwest side of Camp Hill. Here, a thick succession of thin sandstone and shale beds overlies a massive unit of soft mudstone and siltstone considered to be the State Circle Shale. Both units are folded and faulted. Henderson estimates a total of about 60 m for this part of the Camp Hill Sandstone. Higher strata, comprising about 60 m of siltstone, shale, silty mudstone and minor thin sandstone beds, were temporarily exposed in the southeastern sector of Capital Circle and in a sewerage tunnel behind Parliament House (Gardner, 1969 MS). These are thought to pass upwards into the Turner Mudstone southeast of Parliament House. The Camp Hill Sandstone is not developed everywhere, however. It is missing in the 'Westlake Outlier' of Öpik (1958) (now submerged beneath Lake Burley Griffin), where the Turner Mudstone rests directly on the Ordovician.

Crook et al. (1973) ascribe an exposure on the Barton Highway 240 m northwest of Ginninderra Creek to the Camp Hill Sandstone. This consists of a sedimentary breccia containing clasts of State Circle Shale (in which Monograptus exiguus has been found), and lying unconformably upon unfossiliferous quartzose arenite assigned to the Black Mountain Sandstone, which nearby is in apparent stratigraphic conformity with shales containing M. exiguus. The precise value of this area must be evaluated only when the stratigraphic units established by Smith (1964 MS) in the Gundaroo-Nanima area to the northeast have been followed through to the Barton Highway.

Phillips (1956) described a sequence of buff-to-white quartzose sandstone, becoming shaly towards the top, in isolated outcrop belts on the western outskirts of Queanbeyan, faulted against Ordovician rocks of the Cullarin Horst on the east. She estimated a total thickness of 46 m; the top is not exposed. Moore (1957 MS) mapped further similar sandstones in a belt extending north from the Molonglo River to near "Dundee" farmhouse east of Fairbairn RAAF base; he estimated a thickness of 67 m. Henderson (1973aMS) queries his identification of these rocks as Camp Hill Sandstone, and on the Canberra 1:50 000 Sheet (Henderson & Strusz, 1971) they are shown as Pittman Formation.

The Camp Hill Sandstone may be present in the less well known Silurian successions north and south of Canberra, but the presently known distribution is confined to the Canberra-Queanbeyan area.

From the sandstones just above the unconformity on Capital Hill, Öpik collected dissociated valves of the pentamerine brachiopod Rhipidium, moulds of fragmentary rugose and tabulate corals (including Favosites forbesi?, Phaulactis?, Heliolites?, Pycnostylus?), an unidentified rhynchonellacean, gastropods, and trilobites including cheirurids, a proetacean, and an unusual calymenid resembling Liocalymene. Fossils are locally abundant in the shales higher in the succession; those found include brachiopods (in particular a rhynchonellacean, possibly Eatonioides), Encrinurus cf. etheridgei, Onycopyge sp., proetaceans, and odontopleurids. From the outcrops west of Queanbeyan a large smooth pentamerid, possibly Pentamerus, has been collected.

Rhipidium and similar ribbed pentameraceans first appear in the Wenlockian (Berry & Boucot, 1970, p.30; they would restrict Rhipidium to the late Wenlockian, at which level it has been reported near Manildra, N.S.W. by Savage, 1969). Encrinurus etheridgei is known from many levels in the Canberra Silurian, being most common in the Ludlovian Yarralumla Formation. On the other hand, the monospecific calymenid Liocalymene is only known from the late Llandoverian of central and eastern North America (Whittington, 1971). As its phylogenetic relationships are unknown, and the Camp Hill form shows some differences possibly of generic value, this comparison cannot be given great weight. The Camp Hill Sandstone is therefore almost certainly of Wenlockian age, but a more precise correlation is not yet possible.

In nearly all cases, the fossils in the Camp Hill Sandstone have been at least moderately reworked. As well, cross lamination and ripple marks have been observed. It is clear, as already noted by Öpik (1954, 1958) and Crook et al. (1973) that the formation was formed under shallow marine conditions.

Turner Mudstone (Canberra Group)

The Turner Mudstone was named - as 'Shale' in 1954 and 'Mudstone' in 1958- by Öpik, who briefly described it as about 60 m of calcareous mudstone containing thin layers of siltstone, fine grained sometimes tuffaceous sandstone, and impure limestone. The base is nowhere exposed. Öpik thought it conformable on the State Circle Shale (differing essentially in its calcareous content), but on his map the two units are nowhere in close juxtaposition. Strusz & Henderson (1971) and Henderson (1973a MS) consider it more likely that the formation is conformable on the Camp Hill Sandstone, whose upper layers are lithologically similar.

The type locality, Sullivans Creek in the Canberra suburb of Turner, is no longer accessible (the creek has been lined with concrete and stone). Another small area of outcrop, the 'Westlake Outlier' of Öpik (1958), is now submerged by Lake Burley Griffin. There, the Mudstone was unconformable on the Ordovician Pittman Formation, the intervening Camp Hill Sandstone being absent. A third outcrop area in Canberra no longer visible was the former caravan park now occupied by part of Barry Drive. There is a large area in Lyneham, bounded on the west by the Acton Fault and on the east by alluvium. The formation has not been positively identified elsewhere, but there are doubtless equivalent strata in the Silurian north and northwest of Canberra.

Öpik noted that fossils are rare, and listed none. Excavations for the Haydon Allen Building, ANU, yielded a shelly fauna in a leached buff siltstone, within the formational boundaries shown by Öpik. Species have not been identified (preservation is mediocre), but forms present include _Encrinurus_, dalmanitids?, _Brachyprion?_, rhynchonellaceans, an atrypid, _Syringopora_, and _Tryplasma?_. The age is Silurian: further refinement is not yet possible.

Riverside Formation (Canberra Group)

Öpik (1954) defined the Riverside Formation as a sequence of "calcareous shales and mudstones, current-bedded, fine-grained sandstones, prominent limestone lenses, tuffaceous sediments, tuffs, and acid flows (rhyolites)". The formation is apparently conformable on the Turner Mudstone, and is in turn conformably overlain by the City Hill Shale (there are now no exposures of either boundary). Öpik noted a change in the weathering characteristics of the rocks as one traced the sequence into the City Hill Shale. The Riverside Formation shale and siltstone weathers deeply to a yellow or brown colour, whereas that in the City Hill Shale is usually less weathered, often retaining the dark grey colour of fresh rock. This change may reflect the absence of tuffaceous material in the City Hill Shale.

The type locality of the Riverside Formation is on the southern shore of Lake Burley Griffin, north of Brisbane Avenue, Barton. Öpik estimated a thickness in the vicinity of 180 m; the exposed rocks are mainly khakhi siltstones.

The known extent of the formation is confined to the area east of the Acton Fault, and, apart from small outcrops in Woolshed Creek near Canberra airport, is west of the Ainslie-Majura ridge. Near Parliament House and the National Library, less than a kilometre northwest of the type locality, detailed mapping of foundations has revealed a sequence totalling about 180-190 m, which probably does not contain the full thickness of the formation (Gardner, 1969 MS; Henderson, 1973b MS; Best & Henderson, 1968 MS). Here, 65 m or more of calcareous shale, mudstone and thinly bedded limestones are followed by 60-65 m of fine-grained calcareous sandstone and interbedded calcareous siltstone, then about 60 m of calcareous shale and mudstone with fairly prominent limestone lenses and common tuffaceous beds. A few rhyolite flows were also found. In a sewerage tunnel southeast of Parliament House, a rather confused area may include a transition from massive Turner Mudstone into calcareous shale of the Riverside Formation. Limestone lenses or layers have also been found in drill cores near the Albert Hall (west of the National Library), and in foundation excavations on Northbourne Avenue north of Civic Centre. However, most exposures (nearly all temporary) north of Lake Burley Griffin are of siltstone and shale. Those in Woolshed Creek to the east are of cleaved calcareous siltstone.

Fossils were first collected from the Riverside Formation by Clarke (1848ff), and described by de Koninck (1876); later descriptions are in Etheridge & Mitchell (1916) and Mitchell & Dun (1920). No further palaeontological work was published until Link (1970 and in Strusz & Henderson, 1971) reported conodonts from limestones north of Civic Centre. Holloway (1972 MS) has studied faunas from Woolshed Creek and the foundations of St Edmunds College, Griffith. The BMR holds collections from a number of localities; most have not yet been properly studied.

From south of Lake Burley Griffin, both siltstones and silty limestones have yielded a diverse fauna; tetracorals such as *Tryplasma lonsdalei?*, *Cystiphyllum* sp., cf. *Holmophyllum multiseptatum*, *?Entelophyllum latum*, and pyriform halysitids and various other tabulate corals are mostly found in the limestones. The remaining corals also occur in the less calcareous beds, together with the shelly fossils. Forms recognized include the corals *Phaulactis shearsbyi* (Sussmilch), *Mucophyllum crateroides* (Eth.), *M. liliiforme*, *Tryplasma derrengullenense*, *Rhizophyllum interpunctatum* de Koninck, trilobites including Encrinurus cf. mitchelli Foerste, E. of. etheridgei Mitchell, Onycopyge n. sp., Gravicalymene sp., Leonaspis? sp., scutelluids, proetids, dalmanitids and lichids, numerous brachiopods, especially Atrypa duntroonensis and Howellella but also including Plectodonta minuta, Brachyprion, Leptostrophia and Macropleura?.

This fauna would suggest correlation with the Yass Subgroup and the Silverdale Formation of the Yass Basin, and thus an early Ludlovian age. However the abundance of halysitids (which do not occur at Yass above the Bango Limestone Member of the Hawkins Formation, and which are not often found above the Wenlockian anywhere) would suggest a more probable late Wenlockian age.

The outcrops in and north of the Canberra city centre have produced a smaller fauna, but there are no obvious differences. However, two limestone lenses yielded a small conodont fauna including Spathognathodus inclinatus s.s. and Kockelella variabilis, which Link & Druce (in Strusz & Henderson, 1971) consider to indicate a Ludlovian age. These limestones appear to be high in the sequence - in fact Henderson (1973a MS) suggest they may be above the City Hill Shale.

It would appear that the Riverside Formation ranges in age from late Wenlockian to early Ludlovian, but greater precision will follow only if conodonts can be recovered from limestones near the type locality (not very successful so far), or if graptolites can be found in the shales.

The lateral and vertical variation of rock types, which include coralline limestones, suggests that the formation was deposited in shallow seawater. The patchy distribution of the shelly fossils in the siltstones, and the general dissociation but not destruction of the brachiopod valves and trilobite exuviae, suggests that the sea floor was close to, but not above, wave base. The sedimentary structures recorded by Öpik would support that interpretation.

City Hill Shale (Canberra Group)

According to Öpik (1954, 1958), the City Hill Shale is a sequence of calcareous shale with limestone layers and lenses, lacking volcanic detritus; it is conformable on the Riverside Formation. Öpik considered a diagnostic feature to be the change in colour of the outcropping rocks, from brown or yellow and deeply weathered in the Riverside Formation to dark grey in the City Hill Shale. An apparently conformable passage upwards through buff and red weathered shales into the St Johns Church Beds was temporarily exposed in a sewerage trench along Constitution Avenue.

Öpik did not designate a type locality, but it is presumably the eastern side of City Hill, where there are some 110 m of dark grey calcareous shale. Similar shale is known along the east side of the Acton Peninsula, where the formation contains a prominent lens of fossiliferous limestone. Öpik also mapped exposures of calcareous shale along the southern side of Lake Burley Griffin in Barton and Kingston, but these are no longer visible.

Recent work by the Engineering Geology group of the BMR, based on temporary exposures and shallow drilling, has shown that the grey little-weathered shales of City Hill extend northwestward along strike, across Northbourne Avenue. Consequently, the deeply weathered shales (and associated limestone lenses) north of Civic Centre, placed in the Riverside Formation by Öpik, would appear to be above the City Hill Shale. Possibly they are at the same stratigraphic level as the unnamed shales on Constitution Avenue (which are very similar to the leached calcareous shales occasionally exposed in the southern outcrop area of the Riverside Formation, such as near the Kingston shopping centre). These observations, taken together with the rather limited extent of the City Hill Shale, suggest that the latter may represent a geographically restricted sequence of non-tuffaceous calcareous shale within the rather more variable Riverside Formation. However until this is investigated further the nomenclature now used is retained.

A small collection of fossils is available from the east side of City Hill. Amongst others this contains the trilobites Odontopleura cf. bowningensis, ?Otarion yassensis, ?Proetus bowningensis, Encrinurus sp., and brachiopods including "?Plectodonta" minuta, Atrypa, and Dicoelosia?. At Yass, such a collection would suggest the Black Bog Shale, which Link (1970) correlates with the middle-to-late Ludlovian. The calcareous shales southeast of City Hill, along Constitution Avenue, have yielded halysitids, Tryplasma and other corals, Encrinurus, Brachyprion, Atrypa, and other undetermined shelly fossils. There is no detectible difference from the faunas of the Riverside Formation. Excavations at several localities along the northeast margin of the Civic area of outcrop (as mapped by Öpik) have revealed grey-green and buff calcareous siltstone to claystone, often deeply weathered, from which some fossils have been recovered. These include Encrinurus, Brachyprion, Atrypa, Howellella?, halysitids and other tabulates, Tryplasma and Pisocrinus.

There are no fossils sufficiently diagnostic for precise correlation, but the City Hill Shale is probably of late Wenlockian to early Ludlovian age on the basis of available information. The conditions of deposition would have differed little from those for the Riverside Formation - shallow marine.

St Johns Church Beds (Canberra Group)

Öpik (1954) defined the St Johns Church Beds as a succession of acid flows and tuffs interbedded with more or less tuffaceous mudstone, sandstone and limestone (mostly nodular). His information was insufficient to recognize a complete sequence or to show the place of the unit within the overall Silurian sequence, but on structural grounds he concluded that it conformably followed the City Hill Shale. Its top was, and remains, unknown, concealed by the Ainslie Volcanics.

The type locality was defined as 'just south of St Johns Church', where there are now only very restricted outcrops of siltstone. Deeply weathered yellow to mauve mudstone and siltstone were exposed in the foundations of the nearby BMR Building and Jamieson House. The unit was also mapped by Öpik in several inliers in and around the southern end of the Majura-Ainslie ridge, overlain unconformably by the Ainslie Volcanics or alluvium. Another mapped area is southwest of the suburb of Hackett; here the Beds are downfaulted against the Riverside Formation on the west, and overlain by the Ainslie Volcanics on the east.

By 1958, excavations west of St John's Church had shown a sequence of mudstones conformably between the St Johns Church Beds and the City Hill Shale (Öpik, 1958, p.75). As mentioned in the account of the latter unit, it is possible that these beds are a part of the Riverside Formation which actually overlies the City Hill Shale, but in any case they establish the relative position of the St Johns Church Beds in the Canberra Group. Similar reddish buff weathered mudstone has more recently been exposed in excavations for extensions to the Canberra Technical College northwest of the church.

Öpik estimated a thickness of about 90 m for the unit. He also suggested that the Mount Pleasant Porphyry, an inlier within the Ainslie Volcanics, was probably equivalent to part of the St Johns Church Beds.

Fossils had been noted by Öpik, but he did not list the fauna; the small available collections contain brachiopods including Howellella?, spiriferids and pentamerids, and a proetacean trilobite. None is diagnostic of age. From its stratigraphic position the unit is most likely to be of early to middle Ludlovian age.

Mount Pleasant Porphyry (Canberra Group)

Originally called the Mount Pleasant Rhyolite by Öpik (1954), and first recognized (as felsite) by Pittman (1911), the Mount Pleasant Porphyry was described by Öpik (1954, 1958) as a suite of altered acid volcanic rocks - dacite and rhyolite - occurring as a Silurian inlier within the Ainslie Volcanics. Öpik differentiated the Porphyry on its greater degree of tectonic disturbance, and also noted that it, and a quartz reef cutting it, were overlapped by the Ainslie Volcanics. He considered the Porphyry to be most likely a part of the St Johns Church Beds, and compared it petrographically with the Deakin Volcanics.

On Öpik's maps the Porphyry is shown as occupying the ridge north of the Royal Military College at Duntroon, joining Mount Pleasant to Mount Ainslie. It is not shown on the Canberra 1:50 000 geological map, and is not mentioned by Henderson (1973a MS). If Öpik was correct in distinguishing the unit, and in estimating its stratigraphic position, it is definitely of Late Silurian (Ludlovian) age; if the outcrops are part of the Ainslie Volcanics the age is as likely to be Early Devonian. There is no direct evidence.

Fairbairn Group

The Fairbairn Group was defined by Öpik (1954) as comprising the Molonglo Ford Hornfels, the Molonglo Village Sandstone, the Molonglo River Formation, and the Mahon Formation. The upper part of the Molonglo River Formation, as originally defined, contained acid volcanics which were extensively developed north of Canberra airport at Fairbairn. These have since been separated out as the Gladefield Volcanics (Moore, 1957 MS; Best et al. 1964).

The Group is developed in the Fyshwick area between Canberra and Queanbeyan, and in the Woolshed Creek valley north of Canberra airport. Moore (1957 MS) extended the Group northwards across the Federal Highway, and Öpik's maps also include rocks at the northeastern outskirts of Canberra in the Group. On the east, it is faulted down against the Ordovician rocks of the Cullarin Horst. The southern margin, where not obscured by the Ainslie Volcanics, is a faulted contact with volcanics of the Red Hill Group. Much of the western margin is obscured by the Ainslie Volcanics, the rest by alluvium or (in northern Canberra) colluvium. Consequently the relationship of the Fairbairn Group to the Canberra Group is unknown. Öpik presumed that the Fairbairn Group followed the Canberra Group, but there is no definite evidence for this, and the faunas at present do not appear dissimilar. The depositional environment also appears to have been much the same: probably open shelf, with fairly shallow water but mostly below wave base.

At Fyshwick, the three first-mentioned component formations are in sequence; they are overlain by the Gladefield Volcanics north of Canberra Airport. Öpik noted that the Mahon Formation is separated from the remaining units by faults or the overlying Ainslie Volcanics, but by his order of listing the units it could be assumed that he considered it younger than the Molonglo River Formation - a position occupied by the Gladefield Volcanics, which are quite thick. The position of the Mahon Formation is thus unknown; it could be the oldest member of the Fairbairn Group.

North of Canberra airport Moore (1957 MS) could not find the Molonglo Village Sandstone, and placed the whole succession in the Molonglo River Formation. In fact, apart from the effects of thermal metamorphism the Molonglo Ford Hornfels does not significantly differ lithologically from the Molonglo River Formation. At Fyshwick, the total thickness of the three successive units was estimated by Opik to be 145 m. Moore estimated the thickness of the succession north of the airport as 120 m or more. It seems likely, therefore, that the Molonglo Village Sandstone is a lens within a sequence of calcareous shale, mudstone, and occasional limestones, which can only be subdivided stratigraphically where the sandstone is present. If this is the case (and it remains to be proved) then the Molonglo Ford Hornfels is probably best treated as the locally distinguishable and hornfelsed lower part of the Molonglo River Formation. Nomenclatural changes must however await proof of the suggestion.

Molonglo Ford Hornfels (Fairbairn Group)

The Molonglo Ford Hornfels was defined by Öpik (1954) as a calcareous hornfels, with bands of impure marble, having a visible thickness of about 75 m. The base is faulted out against the North Fyshwick Fault (Öpik, 1958), while the top is conformable with the Molonglo Village Sandstone. The formation is only known in its type area, the northern end of the industrial suburb of Fyshwick, on a hill above the Molonglo River. It forms the core of an anticline. From the occurrence, within the formation, of several porphyry dykes, Öpik postulated that the metamorphism of the unit was caused by a near-surface intrusion into the core of the anticline. The formation must originally have been a calcareous siltstone with limestone lenses.

No fossils were listed by Öpik, and no collections are available to the writer. From its stratigraphic position, the formation is presumably of Ludlovian age.

Molonglo Village Sandstone (Fairbairn Group)

The Molonglo Village Sandstone was briefly described by Öpik (1954, 1958) as a flaggy, quartzose, leached calcareous sandstone overlying conformably the Molonglo Ford Hornfels. He did not cite a type locality, but from his map and the origin of the name (see Strusz & Henderson, 1971) it can be presumed to be the northeastern part of Fyshwick (the central section of Gladstone Street). The thickness was estimated to be 45 m.

Öpik also mapped two isolated areas on or near the railway line at Fyshwick, and a smaller one northwest of Fyshwick, near 'Golden Home' farmhouse, as belonging to the Sandstone. Moore (1957 MS) could not find the Sandstone in the outcrops of the Fairbairn Group north of Canberra airport.

While he noted that the unit is fossiliferous, Öpik did not cite any species; no collections are available, and the outcrops are no longer accessible. From stratigraphic position, the unit is presumed to be of Ludlovian age.

Molonglo River Formation (Fairbairn Group)

Conformably overlying the Molonglo Village Sandstone is the Molonglo River Formation, originally defined by Öpik (1954, as the Molonglo Formation) as about 25 m of calcareous shale and limestone, followed by tuffaceous sediments, tuffs and porphyries. Only the lower, non-volcanic, part occurs in the Fyshwick area, on the eastern and western flanks of the Fyshwick Dome (Öpik, 1958). No type locality was designated.

As well as the two Fyshwick outcrop areas, Öpik identified the sediments of the Molonglo River Formation in two small areas east of Kingston (that near The Causeway is shown as Canberra Group by Strusz & Henderson, 1971), and several in the northeastern suburb of Hackett, west of or as inliers within the Ainslie Volcanics. The inliers are not shown on the Canberra 1:50 000 Sheet. According to Öpik, the upper volcanic part occurs east of the Majura-Ainslie ridge. Moore (1957 MS) mapped this area - the Woolshed Creek Valley - in detail. He identified outcrops of shale and sporadic limestone, occurring in a belt for about 4 km north and south from the Federal Highway at Ginns Gap, as the Molonglo River Formation, and estimated a total thickness of at least 120 m. However, he also distinguished, as a separate unit, the Gladefield Volcanics, a tuffaceous sequence overlying the shales, which presumably is Öpik's upper Molonglo River Formation. The boundary mapped by Moore is gradational.

Moore's work implied, but did not explicitly state, restriction of Öpik's Molonglo River Formation to the sequence of shale and limestone such as occurs in the Fyshwick area. This restriction is accepted here. The implications of Moore's failure to find the Molonglo Village Sandstone have already been discussed in the description of the Fairbairn Group.

As pointed out by Öpik, fossils have been known from what is now the Molonglo River Formation for some time. Mahoney & Taylor (1913) recorded Phaulactis shearsbyi, Favosites gothlandica, F. cf. basaltica, Syringopora sp., from the 'Old Mill' (the western margin of Fyshwick), and Atrypa and Encrinurus from 'Miss Cameron's Farm, Majura' (Woolshed Creek about 3.5 km south of the Federal Highway), both of which are east of the Ainslie-Majura ridge. From a locality west of Mt Majura they recorded Alveolites?, Acanthohalysites gamboolicus, Heliolites spp., Atrypa cf. reticularis, and Encrinurus. The age correlations cannot be precise, but the presence of halysitids (which are probably the same species as is common in the Riverside Formation) would favour a late Wenlockian age, or earliest Ludlovian at the youngest.

Mahon Formation (Fairbairn Group)

The sedimentary rocks cropping out on either side of Jerrabomberra Creek south of the Queanbeyan-Canberra railway line were placed by Öpik (1954, 1958) in the Mahon Formation. The unit is essentially a gently folded sequence of calcareous shale and limestone, dipping westward at no more than 15°. The base of the formation is obscured by the Ainslie Volcanics, or truncated by the South Fyshwick Fault (Öpik, 1958); the top is obscured by the same volcanics or alluvium, or cut off by the Deakin Fault. Öpik showed one other small outcrop, isolated within the extensive alluvial flats northwest of Fyshwick, as Mahon Formation. The formation has not been recognized away from the Fyshwick area.

The type locality is the western slope of Mahon Hill, south of Canberra Avenue (grid ref. 8727-974,867). Öpik estimated the exposed thickness as about 60 m.

As described by Mahoney & Taylor (1913, p.26) and Öpik, the Mahon Formation comprises thin-bedded calcareous shale and more or less impure limestone, with sporadic limestone lenses up to 1.5 m thick, and layers of tuff. Brachiopods, not yet identified, have been collected from the formation; as yet, they do not allow a precise age within the Silurian to be assigned.

The relative position of the formation in the Fairbairn Group has already been discussed. It may be significant that the combination of shale, limestone and tuff is reminiscent of the Riverside Formation and St Johns Church Beds on the one hand, and the Yarralumla Formation on the other.

Gladefield Volcanics (Fairbairn Group)

The Gladefield Volcanics were described by Moore (1957 MS), and the name published by Best et al. (1964). The formation consists of a thick series of acid lavas tuffs and ashstones with some interbedded shale. It is conformable on the Molonglo River Formation (as implicitly restricted by Moore); there is an interfingering boundary north of Ginns Gap on the Federal Highway. The top of the formation is cut off by the Sullivans Fault, which has brought up the Ordovician of the Gullarin Horst.

The type section, in which the base is not exposed, is along a tributary of Woolshed Creek, just south of 'Gladefield' farmhouse (grid. ref. 8727-007.951).

Moore could find no evidence of folding, and estimated the thickness at some 1500 m or more. The formation is confined to the eastern margin of the Canberra Graben, against the Cullarin Horst, and occupies a meridional belt about 18 km x 2.5 km.

No fossils have been reported from the Gladefield Volcanics, whose age therefore depends on the age assigned to the underlying sediments. An early Ludlovian age seems likely.

Recent mapping and geochemical studies suggest that the Ainslie Volcanics, thought by Öpik (1958) to be of Early Devonian age, may in fact be less-sheared equivalents of the Gladefield Volcanics, and so of Late Silurian age.

NORTH AND WEST OF THE CANBERRA AREA

Murrumbateman Creek Formation

The name Murrumbateman Creek Formation was first published by Best et al. (1964), and is taken from preliminary work subsequently incorporated in Smith (1964 MS). Smith defined the formation as slate, with arenite beds in the upper part of the succession. The base is unconformable on Upper Ordovician slates and arenites (the relationship is particularly clear between 'Glenlee' and 'Glengyle' homesteads, at about 8727-942.222 to 950.215), and the top is conformable with the Westmead Park Formation. The top of the formation is defined as the top of the highest arenite bed. Bedding is generally obscured by a strong cleavage, but there is evidence for close (but not isoclinal) folding about northeast-trending axes. The area of outcrop mapped by Smith is triangular, and lies between Hall and Gundaroo, north of Canberra. The western boundary seems to be in contact, either faulted or unconformable, with north-northwest-trending dacites of probably late Wenlockian age (the Hawkins Tuff?); it lies about 5 km east of the Barton Highway. The extent of this area has been increased a little by more recent mapping northeast of Hall.

The type area (no section was designated) lies east and west of 'Glencoe' homestead, grid ref. c. 8727-937.180. Because of the generally sparse outcrop and the obscurity of the bedding, Smith could not be certain of the thickness of the unit, but estimated it to be about 900 m.

The slate which makes up the bulk of the formation is generally buff, but may be grey, greenish grey, or pink; most outcrops are moderately to deeply weathered. There is evidence in a few places that some of the rock could have been a calcareous mudstone, but most seems to have been non-calcareous. The minerals present are quartz, sericite, chlorite, and minor pyrite (weathering to haematite). The arenite beds vary from 0.6 to 4.6 m thick, and form flaggy, relatively resistent outcrops; there are no visible sedimentary structures. The grains are of quartz, with lesser rock fragments, mica, feldspar, and opaque minerals. The rock fragments are derived from low grade metasediments such as slate, phyllite, fine-grained quartzite, etc., similar to rocks which have been described from the Ordovician near Captains Flat for instance (Oldershaw, 1965). The presence of these rock fragments, which are characteristic of the formation, provides a useful criterion for distinguishing it from the underlying Ordovician quartz greywackes. The arenites in the Murrumbateman Creek Formation are probably best regarded as being quartzose to sublabile sandstones.

Mapping northeast of Hall, by students of ANU and by geologists from the BMR Engineering Geology Section, has extended the limits of Smith's mapped outcrop area southwestwards to within about 3 km of Hall. The formation has not yet been recognized elsewhere, although the work is not complete. Its relationship to the Canberra succession is not yet known.

Smith collected small faunas from two localities low in the formation. In one he found a dalmanatid and a phacopid, in the other Atrypa, gastropods and bivalves, and Monograptus cf. priodon. This is not enough for a precise age, but it is more likely to be Wenlockian than late Llandoverian, especially as the overlying Westmead Park Formation contains a late Wenlockian graptolite fauna.

The dearth of appropriate sedimentary structures and the presence of shelly fossils led Smith to consider a shallow marine environment as being the most likely for deposition of this formation.

Westmead Park Formation

The Westmead Park Formation was described from around Nobby Hill, southwest of Gundaroo and about 16 km north of Canberra, by Smith (1964 MS), the name having been published by Best et al. (1964) on the basis of Smith's preliminary work. It was defined by Smith as a varied sequence of dacitic volcanics, terrigenous and calcareous sediments, conformably overlying the Murrumbateman Creek Formation. The base of the formation is at the top of the last sandstone bed of the latter. The highest beds form the core of a syncline, and so the relationship of the formation to younger units is not known. If the volcanic rocks along the Barton Highway are in fact unconformable on the Murrumbateman Creek Formation, as suggested by Smith, they would also be unconformable on the Westmead Park Formation.

Smith did not designate a type section or area, but noted that the best exposures are west of 'Kia-Ora' homestead (grid ref. c. 8727-980.145), and that area is here designated the type area for the formation. It forms the western limb of a syncline, separated from the axis by a longitudinal fault. On this limb, Smith estimated a total exposed thickness of 1800 m, of which the lower 1000 m is essentially a sequence of shale and calcareous shale. The sequence on the eastern limb differs in detail (some beds can be correlated), and the base is cut off by the Sullivans Line Fault. About 1000 m is preserved, mostly shale. The sequences as measured and correlated by Smith are:

WEST	EAST
350 m tuff and shale	= 330 m shale
105 m dacite	= 230 m tuff overlying dacite
90 m tuff, shale, and calcareous shale	
45 m flaggy fossiliferous siltstone, plus minor sandstone, limestone, tuff, mudstone	90 m shale ?= 25 m dacite
130 m shale and calcareous shale	310 m shale, minor calcareous shale
25 m tuff, minor shale	
435 m shale	
650 m shale, calcareous shale, minor dacite	-

Reconnaissance mapping incorporated in the Canberra 1:250 000 Sheet (Best et al., 1964) extended Smith's mapped boundaries southwestward towards Hall, with an indefinite boundary against acid volcanics and the Canberra Group. Some detailed mapping has since been done around Hall and southeastward towards Canberra, but unfortunately not in the intervening area between there and Smith's original mapping, i.e. at the heads of Murrumbateman and Ginninderra Creeks. However, the work done along the Barton Highway (some of the results of which are incorporated in the Canberra 1:50 000 Sheet, Strusz & Henderson, 1971) indicates extensive northeast-trending faulting. Thus there is a major fault which diverges from the Sullivans Fault (where it brings the Westmead Park Formation against the Ordovician Pittman Formation, near Nobby Hill), and extends southwestwards to cross the Barton Highway south of Gungahline Hill (at approximately 8727-926.005). Between this fault and the Gundaroo Road the Silurian is represented by mudstones and dacitic volcanics, similar to the Westmead Park Formation in its type area. Therefore the outcrops near Ginninderra assigned by Crook et al. (1973) to the Canberra Group should really be considered part of the Westmead Park Formation, since they are almost certainly in continuity with that unit, but are certainly not in continuity with the Canberra Group.

The geology at this point, where the Barton Highway crosses Ginninderra Creek, is subject to argument (compare Crook et al., with Öpik, 1958). It is clear that there is an interbedded shale-sandstone sequence containing *Monograptus exiguus*, which is an extension of the State Circle Shale. Gradational above this is a thick sequence of quartzose sandstone and shale, apparently unfossiliferous, which Öpik tentatively and Crook et al. definitely assigned to the Black Mountain Sandstone. Surrounding this essentially Lower Silurian sequence are shales and fine-grained sandstones; the contact is shown as unconformable by Crook et al., but at least in places could be faulted. At one locality on the highway shale clasts in a conglomeratic layer have yielded *M. exiguus*. Crook et al. have assigned these shales, sandstones, and conglomerate to the Canberra Group, but as noted above they are more likely a continuation of the Westmead Park Formation, whose relationship with the former is unknown.

Smith collected a relatively limited fauna from the fossiliferous siltstone in the type area, including Encrinurus, a sowerbyellid brachiopod, strophomenaceans, Pisocrinus, Favosites, and indeterminable monograptids. This fauna gives a general Silurian age, but a graptolite fauna collected by Sherrard (1952) from mudstones northeast of One Tree Hill, which are almost certainly a continuation of the formation, are of late Wenlockian age. The fauna as identified by Sherrard is Monograptus flemingii var. elegans, M. flemingii var. compactus, M. vomerinus, and M. testis var. inornatus.

Northwest of One Tree Hill, on the Spring Range road (Sherrard, 1952) and around 'Braeside' and 'Glenbower' homesteads, lenticular limestones have yielded halysitids, Phaulactis, Mucophyllum, Spirinella?, spiriferids, and Encrinurus (Bell, 1971 MS; Ozimic, 1971 MS). Interbedded calcareous shale and tuffaceous limestone southeast of One Tree Hill contain Atrypa, Howellella, eospiriferids, Phaulactis, and Encrinurus (Ceplecha 1972 MS). While such shelly faunas, whose identifications are only preliminary, cannot give a precise and reliable age, they do support the age provided by Sherrard's graptolites, and also show some similarity with the faunas of the Canberra and Fairbairn Groups.

The laterally and vertically variable nature of the unit, the lithology of the dominant rock types, and the predominance of shelly fossils including corals in limestone lenses, all point to shallow marine conditions of sedimentation, probably below wave base and somewhat offshore. There was probably significant fluctuation in water depth and distance to shoreline.

Glenesk Volcanics

Along the Hall-Nanima road between Jobbins Hill (grid ref. 8727-930.206) and Mount Spring (899.144), Smith (1964 MS) mapped the eastern edge of an extensive body of acid igneous rocks which had first been described by Sherrard (1952) in reconnaissance fashion. To the rocks he actually examined - about 240 m of porphyritic rhyodacite, coarse tuff and tuffaceous shale, and agglomerate - Smith gave the name Glenesk Volcanics. He concluded that the rocks are extrusive (the nature of the porphyritic rocks in the general area has been subject to argument for at least 50 years) and probably unconformable on the Murrumbateman Creek Formation. No type area or section was proposed, and the mapping did not extend far into the belt of volcanics. It is probably best to regard the unit as an informal local one, useful until the already named units around Yass and Canberra have been extended into the Hall-Murrumbateman area. A start on this has already been made, with Hughes' mapping of the Mundoonen Sandstone and Hawkins Tuff to the north (in Crook et al., 1973), and mapping by BMR geologists west of the Barton Highway. Thus the Laidlaw Formation is now known to extend south to Belconnnen, while the sedimentary rocks along the highway (mapped generally by Sherrard (1952) and shown by Best et al. (1964) are now recognized as a continuation of the Yass Subgroup. Until the effects of probable faulting are worked out, precise correlation cannot be made, but it is likely that the acid volcanics of which Smith's Glenesk Volcanics are a part, east of the highway, are partly or wholly to be included in the Hawkins Tuff.

Glen Bower Formation

The presence of Silurian rocks on the Murrumbidgee River near the Boambolo crossing above 'Cavan' homestead was first demonstrated clearly by Shearsby (1905), who named the Glen Bower Anticline, provided a geological sketch-map of the exposures, briefly described the succession, and listed the fauna. Harper (1909) included the whole area of outcrop of these beds in his detailed mapping. He and Shearsby collected many fossils, which were identified by W.S. Dun. However, the only fossils described so far are corals. Hill (1940) included material from the Boambolo area in her descriptions of *Phaulactis shearsbyi*, *Entelophyllum latum* (the Glen Bower Anticline is the type locality), and *Tryplasma lonsdalei*. The name 'Glen Bower Series' was used for part of the sequence by Harper; on the Canberra 1:250 000 Sheet (Best et al., 1964) the complete sedimentary succession was termed the 'Glen Bower Beds'. The only work subsequent to that of Harper (Bell, 1963 MS; Moignard, 1970 MS; various ANU student mapping projects) has not been published, and the various maps produced are not in close agreement. Moignard's work, being the most comprehensive and recent, is followed in this account.

The Glen Bower Formation is a thick sequence of laterally variable shallow-water marine and possibly estuarine sedimentary rocks, mainly siltstone but including sandstone and limestone. Most of the outcrop is on the north side of the Murrumbidgee River, east of Clear Hill ("Cavan" property, about 15 km south of Yass) but there is also a narrow strip on the south bank, near the ruined 'Glen Bower' homestead. In Sapling Point Creek (grid ref. c. 8628-710.260) the formation is conformable on tuffaceous dacites to rhyolites of the Douro Group (Hawkins Volcanics?). On the eastern side it is overlain, possibly unconformably, by the Boambolo Formation, and both units are unconformably overlain by the volcanics of the Laidlow Formation. The whole sedimentary sequence forms an inlier within the Douro Group, and has not been recognized with any degree of confidence away from the Boambolo area.

Moignard divided the succession into three successive members, but there is some uncertainty about aspects of their detailed delineation, so they are better put aside. He designated type sections for the lower and upper members only. There is no single section which adequately represents the whole formation, although it may be possible to obtain enough information along the line of Harper's section J-K. This extends from the north bank of the river, opposite the 'Glen Bower' ruins (grid ref. c. 8627-710.226), east through 'Boambolo' property to the southwest foothills of Mount Boambolo (c. 735.227). At the moment a formal type section is not designated.

The lower part of the succession is exposed in Sapling Point Creek, in the northwest part of the inlier. Here, Moignard measured about 326 m of sediments; a summary of the sequence, from the top, is:

- 29 m - incompletely exposed current-bedded quartzose sandstone, muddy sandstone, detrital limestone, and fossilierous shale.
- 51 m - incompletely exposed silty sandstone with sporadic layers containing limestone clasts and reworked shells, and 0.5 m - 5 m beds of stromatolitic and intraclast limestone.
- 2.5 m - impure pebbly calcarenite.
- 82 m - fine-grained volcanolithic quartzose sandstone, becoming increasingly argillaceous upwards.
- 5 m - silty calcirudite (with oncolites, and overturned colonies of *Heliolites* and stromatoporoids).
- 61 m - coarse-to medium-grained cross-bedded quartzose sandstone.
- 93 m - dark to olive brown volcanolithic quartzose siltstone and sandstone.

Dark olive siltstones and shales, calcareous shales, and thin impersistent biostromal limestones appear to make up the bulk of the remainder of the formation. They do no crop out well, and are much the same lithologically as the siltstones which Moignard included in his lower and upper members. Consequently it is difficult to place such beds in correct stratigraphic sequence, in the presence of the extensive faulting which is undoubtedly developed in the inlier. Both Harper and Moignard experienced this difficulty. These rocks crop out along the south bank of the Murrumbidgee River near 'Glen Bower'. Harper estimated the thickness in this place to be about 250 m, the rocks being olive shale with bands of coarse-grained sandstone and limestone. For the same outcrop Moignard suggested a thickness of at least 800 m, and possibly more than 1000 m; on the opposite bank, however, he estimated it at only 500 m; these estimates do not seem reliable.

The uppermost part of the formation is well exposed in the earliest-recognized locality, the Glen Bower Anticline on the south bank of the Murrumbidgee River below the Boambolo Crossing. There are also good exposures east of 'Boambolo' homestead, but north from there outcrops become poorer and less easy to interpret. In the anticlihe, Moignard measured a sequence, from the top -

69 m - poorly exposed silty sandstone with sporadic limestone lenses, containing reworked shells and abundant crinoid ossicles; becoming sandier upwards, with cross-bedding developed towards the top.

7.5 m - massive bioclastic to algal limestone.

c. 18 m calcareous mudstone to fine-grained sandstone, with thin silty and sometimes stromatolitic calcarenites.

c. 11 m stromatolitic limestone, with infilled channels.

12 m - coarse-grained quartzose sandstone with prominent cross-ripple bedding and occasional clasts of red-stained limestone.

6 m - very thick-bedded rubbly to nodular silty limestone, of which the top 30 cm is stromatolitic and contains a good silicified shelly fauna.

1 m - calcareous siltstone with abundant Parastriatopora.

13 m+ - medium-grained argillaceous quart sandstone with some cross-ripple bedding.

The base of the section is below water level, and the top is unconformably overlain by the Laidlaw Volcanics.

The same unconformable relationship occurs east of 'Boambolo'. However, a little farther north, on the western slopes of Mount Boambolo, sandstones, siltstones and shales of the Glen Bower Formation are overlain by the Boambolo Formation. Moignard has assigned the former a position low in the sequence, and deduced an unconformity between the two formations. However outcrop is poor, so this relationship is not proven. Farther north again, towards 'Ravenswood' homestead, the two could easily be considered conformable; the interpretation hinges on the stratigraphic position assigned to the siltstones, and on the structural interpretation in key areas of a closely faulted sequence. Both Harper and Moignard mapped numerous faults, some of which they agree on; many are clearly demonstrable by the offsetting of marker beds, or by shear zones and quartz veins.

The faunas listed by Harper, unsupported by illustrations or detailed locality information, were identified by Dun. They have not been re-examined since, and in most cases cannot be related to the succession as proposed by Moignard.

According to Moignard, the lower part of the formation (such as the sandstones exposed in Sapling Point Creek, and their equivalents) has few fossils. In the lowest limestone there are *Heliolites*, stromatoporoids and gastropods, and higher limestones have yielded a limited reworked shelly fauna. These sediments are interpreted as being fluivatile or deltaic, with sporadic subtidal marine incursions. With the incoming of fossiliferous shales and limestones (above 240 m in the Sapling Point Creek section), more normal marine conditions prevailed, though still shallow-water, and the fauna is larger. Moignard described some of it, including the corals *Phaulactis shearsbyi*, *Tryplasma derrengullenense?*, *Rhizophyllum interpunctatum*, *Heliolites daintreei*, and *Parastriatopora* sp. (Hill & Jones, 1940), the brachiopods *Atrypa*, *Spinatrypa?*, and *Mesopholidostrophia?*, the *tentaculitid* *Paranowakia* sp. cf. *intermedia* (Barrande, 1867), the trilobite *Encrinurus* sp. cf. *mitchelli*, and a new species of the ostracode *Vellibeyrichia*. To this, from the outcrops in and near the Glen Bower Anticline, can be added *Phacops*, *Antirhynchonella*, *Entelophyllum latum* Hill, 1940, *?E. yassense*, *Tryplasma lonsdalei*, *Pycnostylus dendroides*, *Favosites gothlandica*, *Alveolites*, and *Syringopora* (Harper, 1909; Hill, 1940). The fauna seems most like that of the Yass Subgroup.

Several of the limestone beds yielded conodonts, but unfortunately mostly long-ranging species. From one horizon in the formation Moignard recovered a good fauna which included *Hindeodella equidentata*, *Lonchodina walliseri*, *Ozarkodina* sp. cf. *fundamentata* and *ortus*, *O ziegleri*, *?O. media*, *Panderodus unicostatus*, and *Spathognathodus inclinatus* subsp. cf. *inclinatus*. This fauna correlates with the middle Wenlockian to early Ludlovian.

Boambolo Formation

The Boambolo Formation was first recognized and named by Moignard (1970 MS), and corresponds reasonably closely to unit 'g' of Harper (1909). It consists of shale and siltstone, overlain by calcareous sandstone and sandy conglomerate, and is best exposed on the western slope of Mount Boambolo. The formation is confined to the eastern margin of the Boambolo Inlier, where it is unconformably overlain by the Laidlaw Formation. According to Moignard it is also unconformable on the Glen Bower Formation, but as already discussed under that unit, this is not yet proven.

The lower part of the formation is poorly exposed, but is estimated to be from 20 to 40 m thick. The rocks are finely laminated and usually cleaved shale and siltstone, sparsely fossiliferous. Moignard reported lingulids, *Girvanella?*, and various marine fossils including *Tryplasma lonsdalei*, *Cladopora?*, and *Encrinurus*. He suggested an estuarine environment.

The upper part is thicker (60-70 m) and more resistant, consisting of medium to coarse grained calcareous sandstone, pebbly sandstone and sandy conglomerate. The sand grains are generally rounded and fairly well sorted, while the clasts in the pebbly beds include red-stained (sub-aerially weathered) limestone containing tabulate corals such as *Heliolites* and *Favosites*. Sedimentary structures include slumping and ripple cross bedding. Moignard suggested that the deposits may have been formed as beach ridges.

Yass Subgroup (Douro Group)

Outcrops of Silurian sedimentary rocks along the Canberra-Yass road northwest of Hall were first reported by Carne & Jones (1919, p.289), who described poor outcrops of limestone and shale at three places: near 'The Kurrajong' and 'Jier' homesteads, and on Gooda Creek near Morrison trig. station. He noted the presence of Silurian fossils (corals and brachiopods) in the most northerly of these outcrops, but did not list the species.

Sherrard (1952) further examined these rocks in a study of the Nanima-Bedulluck district. At Gooda Creek she described the sequence as sandstone and siltstone overlain by fossiliferous limestone, the whole contained within porphyritic dacites. Fossils found in the limestone included Heliolites daintreei, Phaulactis shearsbyi and Howellella. Farther north, she recorded a brachiopod fauna from a sandstone, with (amongst others) Howellella, Parmorthis? and Leptaena, and beneath that a quartzite containing Acanthohalysites pycnoblastoides.

The strip of sediments has been mapped recently, between Gooromon Ponds Creek and Gooda Creek, by BMR geologists. Fossils have been collected from near 'The Kurrajong' (c. 8727-850.160; the most southerly locality of Carne & Jones), and include Entelophyllum latum, Phaulactis shearsbyi, Rhizophyllum interpunctatum, Tryplasma, Favosites, Heliolites, Propora, Encrinurus sp. cf. etheridgei, Eobronteus? and Atrypoides. In this locality the limestone is a medium-bedded algal micrite with bioclastic layers, surrounded by olive-brown shale, and is overlain by ferruginous quartzose sandstone. The BMR mapping suggests a possibly faulted contact with dacitic volcanics in the east, while purple rhyodacite of the Laidlaw Formation forms outcrops on the ridge immediately to the west. The boundaries are not exposed and structural information is sparse, but the outcrop pattern near 'Jier' (c. 8727-830.200) suggests there may be a low-angle unconformity beneath the Laidlaw Formation.

Correlating Sherrard's and Link's mapping, and that by the BMR, shows that the outcrops in the Barton Highway belt definitely extend northwards to join the southern limit of the Yass Subgroup as mapped by Link (1970). The fossils so far found in the Barton Highway belt resemble most closely those of the Yass Subgroup, of all the levels at Yass (although Sherrard's halysitid is anomalous), and the lithologies are comparable. So, although the individual formations have not been distinguished, it seems logical to refer to the Barton Highway belt as an undivided part of the Yass Subgroup. In this way the southern limit of that unit is brought to just north of Gooromon Ponds Creek, 7 km north-northwest of Hall.

Paddys River Volcanics

The Paddys River Volcanics have been shown on the Canberra 1:250 000 Sheet (Best et al., 1964), but a definition has not been published. The name was introduced by Malcolm (1954 MS), who described the unit from the northern end of the Murrumbidgee Batholith, west of Canberra. The dominant rock types are grey predominantly dacitic lavas and fine to coarse grained tuffs, within which are intercalated thin lenses of pure and impure limestone, calcareous shale, and siltstone. The rocks are strongly sheared, and have been steeply folded. In the Paddys River area the Volcanics are apparently disconformable on Upper Ordovician greywackes (which lie between them and the Murrumbidgee Fault which forms the eastern margin of the Cotter Horst). The western margin of the Volcanics is an intrusive contact with the Shannons Flat Granodiorite, whereby metasomatic replacement of calcareous beds has produced several mineral deposits. These consist of magnetite with minor galena, chalcopyrite and sphalerite.

The type area was designated by Malcolm as 'the lower reaches of Paddys River immediately above the Cotter River Junction' - i.e. approx. grid refs 8627-773.860 to 761.884. The thickness is unknown.

Acid volcanics in a fault block north of the Murrumbidgee Batholith, between the Cotter and Pig Hill Faults, have also been referred to the unit. This is a larger area of outcrop than in the type area, but exposure is poor and folding severe, so Malcolm's estimated thickness of over 1500 m is very unreliable. The rocks are apparently steeply overturned to the west, where they are faulted against the Upper Ordovician; to the east they are upthrown against the Uriarra Volcanics by the Pig Hill Fault. They unconformably overlie the Upper Ordovician arenites west of Uriarra Crossing. Recent work by Owen & Wyborn (in prep.) suggests this block may be part of the Uriarra Volcanics sequence, distinguished mainly by the development of a severe foliation.

No identifiable fossils have been found, but the relationship with the Ordovician indicates that they are Silurian or younger. As the Uriarra Volcanics are thought most likely to be of late Wenlockian age, the presumably older Paddys River Volcanics are thought to be early Wenlockian.

Uriarra Volcanics

The Uriarra Volcanics were recognized and mapped as a separate unit by Malcolm (1954 MS), some of whose results were included in the second edition of the Canberra 1:250 000 Geological Sheet (Best et al., 1964). Recent mapping by BMR geologists has confirmed the validity of his work, while allowing finer subdivision of parts of the sequence. This work is to be published later (Owen & Wyborn, in prep.), and in the meantime Malcolm's succession is described here.

The formation was defined as a thick sequence of dacitic lava and tuff, occurring in the Cotter Dam/Uriarra Crossing area 15-20 km west of Canberra. The type area chosen by Malcolm is around 'Uriarra' homestead (c. 8627-740.930) and the nearby Uriarra forestry settlement (c. 750.920), but is an area of poor outcrop. Final selection of a publishable type section will follow from the work of Owen & Wyborn. Dips where visible are westerly at 20°-40°. The unit occupies a downfaulted wedge at the northern end of the Cotter Horst, and is gently folded but cut by faults trending northwesterly and northeasterly. Malcolm did not map the base (the line shown on the Canberra sheet is not a stratigraphic boundary), and the recent mapping has not progressed to the stage of showing where that base lies.

In the southeast the Uriarra Volcanics are downthrown by the Winslade Fault against the Murrumbidgee Batholith and unnamed porphyritic rocks west of Mount Stromlo. The highest parts of the unit are faulted against the earlier Paddys River Volcanics and the Lower Devonian Mountain Creek Volcanics in the west. There is a partly faulted and partly intrusive contact with a porphyry body near the confluence of Ginninderra Creek and the Murrumbidgee River in the north.

The total thickness estimated by Malcolm is of the order of 3300 m.

Malcolm divided the Volcanics into four conformable members (of which only one is shown separately on the Canberra 1:250 000 Sheet). The lowest (and thickest) is the Walker Member, followed by the Tarpaulin Creek Ashstone Member, the Swamp Creek Member, and the Vanity Member. The relationship between the last two is uncertain - recent mapping suggests that they may be laterally equivalent.

Walker Member (Uriarra Volcanics)

The lowest subidivision of the Uriarra Volcanics mapped by Malcolm (1954 MS), the Walker Member is essentially a massive medium-grained dacite; it was named from Walker trig. station (8627-779.950). The type area is around the Uriarra Crossing of the Murrumbidgee River, on the Canberra/Wee Jasper road at about 8627-780.980. In this area the massive dacite is rich in chlorite (replacing amphibole), and is underlain by a band of shale 6 m thick, then a medium-grained massive dacitic tuff which weathers a distinctive reddish-brown. In the Cotter Dam area (8627-760.900) some of the dacite is biotite-rich rather than amphibole-rich, and the brown-weathering dacitic tuff is underlain by a dacite flow containing abundant pink feldspar laths.

Malcolm estimated the minimum thickness of the member to be about 1500 m; he did not establish the base of the unit.

A lens of coarse bioclastic limestone in the dacites close to Uriarra Crossing has yielded a coral-brachiopod fauna which includes *Tryplasma lonsdalei?*, *Phaulactis?*, halysitids, and a large smooth pentamerid (possibly *Pentamerus*). About 2 km northeast of the crossing is a 4 m-thick lens of bedded limestone above almost unfossiliferous slumped siltstone, all enclosed within the volcanics. The limestone is partly stromatolitic, partly clastic, and contains a shelly fauna including halysitids, *Rhizophyllum*, *Tryplasma*, *Entelophyllum?*, *Holmophyllum multiseptatum*, *Cystiphyllum*, *Encrinurus*, calymenids and pentamerids. The greatest similarity is with the fauna of the Yass Subgroup, the presence of common halysitids perhaps favouring a late Wenlockian age rather than early Ludlovian.

Tarpaulin Creek Ashstone Member (Uriarra Volcanics)

Named from Tarpaulin Creek, near the type locality on the Uriarra Road at 8627-754.949, this member is a distinctive massive purple to dark grey very fine-grained dacitic ashstone with sparse orthoclase phenocrysts, in places prominently banded, and weathering to a very pale grey. Southwest of Uriarra Crossing it is locally only a metre thick, but generally it varies from 6 m in the Cotter area to 15 m in Uriarra Creek. This ashstone has proved a very useful marker, and is the only member shown on the Canberra 1:250 000 Sheet.

Swamp Creek Member (Uriarra Volcanics)

Malcolm suggested as type area of this member the middle course of Swamp Creek (c. 8627-740.980), from which it takes its name,but this is being reconsidered by Owen & Wyborn (in prep.). It is a relatively uniform sequence of massive medium to coarse dacitic ashfall tuff, with lesser lava, and is characterised by the presence of abundant reddish feldspar phenocrysts and large blotches of chlorite in the matrix. Malcolm estimated a maximum thickness of about 900 m.

Vanity Member (Uriarra Volcanics)

According to Malcolm the Vanity Member is the highest part of the Uriarra Volcanics, but he did not have as much information for this as for the other members. It occurs in rough country, in the Cotter Valley southwest of the Cotter Dam. The type locality was designated as Vanity Crossing (8627-716.867) on the Cotter River. Malcolm defined the member as a succession of medium to fine-grained dacitic lavas and fine-grained tuffs, possibly thicker than 900 m. It is contained between the Pig Hill Fault on the west and the Winslade Fault on the southeast. Recent work, not yet completed, suggests that it may in fact be laterally equivalent to the Swamp Creek Member.

Not mapped by Malcolm in 1954, but almost certainly part of the Walker Member, is an irregular area of volcanics shown on the Canberra 1:50 000 Sheet as unnamed grey-green porphyritic dacite southwest of Belconnen. These rocks are northwest of the Winslade Fault, and extend southwest from the southeastern suburbs of Belconnen, across the Molonglo River, to join the area mapped by Malcolm west of the Uriarra Road. The boundary with the Laidlaw Formation to the north (shown on the Canberra Sheet as Deakin Volcanics) is poorly exposed, but could be an unconformity.

Where these volcanics cross the Molonglo River, about 2 km northwest of Coppins Crossing, there are outcrops of limestone and siltstone. Temporary exposures in a main sewer trench in 1974 showed that the limestone, which is lenticular, nodular, and up to 4 m thick, rests conformably on volcanics, and is overlain by or passes laterally into tuffaceous and partly calcareous siltstone and mudstone. The limestones contain a coral-brachiopod fauna which includes Tryplasma, Rhizophyllum and halysitids. There is a very rich fauna in some layers of calcareous tuffaceous siltstone. Most of the species have not yet been identified, but include Encrinurus sp. cf. mitchelli,

E. n.sp? cf. inusitatus Kolobova, Otarion, Gravicalymene, scutelluids, illaenids, odontopleurids, proetids, dalmanitids, harpids, Eospirifer?and other spiriferids, sowerbyellids, atrypids, dalmanellids, and others. Although far richer, the fauna seems close to that found near Uriarra Crossing. A late Wenlockian age is probable, but must be confirmed by faunal studies.

Laidlaw Formation

The Laidlaw Formation, originally defined from the vicinity of Yass, can now be recognized as far south as the urban area of Belconnen, northwest of Canberra City. It may well correlate with the Deakin Volcanics in the Canberra-Woden area, but this cannot be proved, and extension south from there is highly uncertain.

Moignard (1970 MS) has demonstrated the extension of the formation to the Boambolo area, by continuity of outcrop. Here, the outcrops are generally in the form of tors, although cliffs on the Murrumbidgee River south of Mount Boambolo expose a 50 m - section in strongly jointed ash-flow tuff. Most outcrops are of grey tuffaceous rock, porphyritic in quartz and feldspar, and very silica-rich. The composition is probably in the rhyodacite-rhyolite range.

BMR geologists have extended Moignard's mapping southward, to link up with existing mapping in Belconnen (Strusz & Henderson, 1971). Although the work is incomplete, and the boundaries in Belconnen are only tentative, enough is known to allow definite correlation of the dacites, rhyodacites and rhyolites on either side of the Deakin Fault, west of the Barton Highway, with the Laidlaw Formation. The southern limit extends west from the Deakin Fault in the town centre, through the suburbs of Scullin, Higgins and Holt. The nature of this boundary is uncertain, but it could be an unconformity against the probably older Uriarra Volcanics. At this southern end, the formation is faulted on the east against probable extensions of the Westmead Park and Murrumbateman Creek Formations - mapping northeast of the Deakin Fault is incomplete. There is a wedge of tuffaceous sediments south of the suburb of Melba, probably a continuation of the Yarralumla Formation; it appears to be in faulted contact with the Laidlaw Formation.

The rocks northwest of Hall are predominantly ignimbrites, including grey to purple rhyodacite and dacite, and purple rhyolite. In Belconnen there are purple and grey rhyodacite and pink to cream rhyolite tuffs (Henderson, 1970 MS, 1973 MS).

SOUTHERN PART OF THE CANBERRA GRABEN

Cappanana Beds (= London Bridge Formation)

The name Cappanana Beds was first published by Best et al. (1964), incorrectly spelt 'Cappanama', and without supporting definition. The unit was mentioned by Packham (1969), and shown on the Monaro 1:500 000 Sheet (Brunker et al., 1970); it was briefly discussed by Strusz (1971), who noted that the London Bridge Formation, also published by Best et al., is a probable synonym. Additional work since, by both the NSW Geological Survey and the BMR, has made it quite clear that only one unit is involved, for which the name Cappanana Beds will be used.

The unit takes its name from Cappanana Creek, which flows into the Bredbo River east of Bredbo (about 149°15'E, 35°55'S). The western side of this valley contains the best exposures of the unit so far known. The principal lithology is cleaved olive to brown mudstone and siltstone, with lesser amounts of quartzose sandstone (particularly near the base), bedded and lenticular limestone, and tuffaceous sandstone (towards the top). The lower boundary is poorly exposed. Mostly it is an apparently faulted contact with Upper Ordovician greywackes and graptolitic slates, although in places this could be an unconformable depositional contact. Near Colinton Hill northeast of Bredbo a band of grey-green shale has been found apparently conformably beneath the Cappanana Beds, and has yielded a single Llandoverian graptolite[*1]. A similar shale, with more abundant Llandoverian graptolites, occurs south of Michelago, but the stratigraphic context is obscure.[*2] Details are given in the description of the State Circle Shale.

The upper boundary is marked by a considerable increase in the proportion of dacitic volcanic rocks and tuffaceous sandstones, showing a gradational and probably diachronous passage into the Colinton Volcanics.

*1 : See Sherwin 1975: Q. Notes geol. Surv. N.S.W., 21
*2 : Richardson 1975: ibid

The Cappanana Beds are known in a long strip on the eastern side of the Canberra Graben, downfaulted by the Queanbeyan Fault against the Ordovician of the Cullarin Horst over most if not all of its length (details are lacking for the area east of Cooma). The northern end of this strip is southeast of Queanbeyan; there is continuous outcrop southwards from Queanbeyan for about 20 km, whereupon the unit is completely cut out between the Queanbeyan Fault and the Keewong Porphyry. There is an isolated sliver at 'Spring Valley' northeast of Michelago (ca 8726-000.530), and continuous outcrop resumes from Colinton Hill (8726-980.285). West of the Queanbeyan Fault outcrop ceases beneath the Tertiary basalts southeast of Cooma, on the Kydra road, but there are also outcrops east of the fault between the Countegany road and where the Kydra road crosses Tom Groggans Creek (ca 8725-040.695). The total distance south from Queanbeyan is about 110 km.

Outcrop of the mudstone and siltstone is generally poor, and dips are steep. It is therefore likely that there is some undetected small-scale folding, rendering thickness estimates unreliable. Detailed mapping was done in the Bredbo area by the BMR in 1967 and 1968, which has enabled a general succession to be drawn up. The lower part of the unit, probably about 150 m thick, comprises poorly outcropping olive-green cleaved mudstone with scattered small limestone lenses. Above that is a more resistant layer, again about 150 m thick, of fine to medium-grained quartzose sandstone, which is often ferruginous and sometimes argillaceous. Some current bedding is developed. Above the sandstone are about 400 m of olive to brown siltstone, mudstone and shale, grey calcareous shale, limestone lenses and beds, and thin sandstone beds, with some tuff beds near the top.

Near London Bridge (Queanbeyan River about 12 km south of the town) Veevers (1953 MS) reported some 450 m of limestone, calcareous slate and greywacke, and sandstone. This is reduced to about 60 m near Burra, 5 km farther south, by faulting.

All the rocks are strongly cleaved, the usual direction being meridional with a steep dip, not very different from the bedding attitude. The limestone near London Bridge, and east to southeast of Cooma, is recrystallized and foliated, so that fossils are sparse and poorly preserved. The fossils in the mudstones are distorted but usually identifiable.

The basal beds at Bredbo contain a small fauna, including brachiopods, corals such as Favosites, Striatopora?, Romingerella? and Tryplasma, Encrinurus and Onycopyge. A few fossils have also been found in the sandstone: Encrinurus, Favosites and Heliolites. The upper sequence of mudstone and limestone is more fossiliferous. Encrinurus, Brachyprion, Rhizophyllum interpunctatum (whose type locality is within the unit near Cooma) and halysitids including Falsicatenipora chillagoensis are common. Other forms recognized include Favosites, Cystiphyllum, Tryplasma spp. cf. lonsdalei and derrengullenense, Phaulactis shearsbyi, Syringopora, Heliolites, Howellella, Atrypa, Leptaena, Atrypoidea?, and Otarion.

Precise correlation is not possible until identifications have been carried to specific level for as many forms as possible, but the overall aspect of the fauna resembles most closely that of the Canberra Group, and it is most likely to be of Wenlockian or at youngest early Ludlovian age.

Some fossils have been collected from outcrops in the Cooma region, where the limestones have also been sampled for conodonts by R.S. Nicoll. At the Rosebrook Caves the massive limestones have yielded Tryplasma, Favosites, and Pelekysgnathus? n.sp. From limestone interbedded with cleaved mudstone at Rock Flat Creek on the Umeralla-Kybean road have come Tryplasma, Favosites, Thaumatolites?, and the Ludlovian conodonts Spathognathodus snajdri and S. inclinatus hamatus. Limestone at 'Dangelong' (8725-056.746) contains Favosites, Phaulactis and others, while more limestone beside the Cooma-Kybean road near the Numeralla River (8725-063.826) contains pentamerids, Favosites, and Parastriatopora.

It would seem likely that an interval of time including both Wenlockian and part of the Ludlovian may be represented by the Cappanana Beds, as is the case with the Canberra Group. Certainly both units can be no older than the underlying late Llandoverian graptolitic shales.

Colinton Volcanics

The name Colinton Volcanics was first given to the thick sequence of acid volcanics along the east side of the Murrumbidgee Valley south of Canberra by Best et al. (1964), but the unit has not been defined. Browne (1944) provided some information about the rocks, but even the unpublished information is less than adequate, and patchily distributed.

The unit contains volcanic rocks of dacitic and rhyodacitic composition, with some minor rhyolites, in a thick sequence of flows, tuffs, welded tuffs and agglomerates, interbedded with marine mudstone, siltstone and sandstone, and rare small limestone lenses. In the Colinton-Bredbo area (and presumably south from there to beyond Cooma) these rocks overlie the Cappanana Beds, the boundary being gradational and interfingering. A similar relationship exists near Queanbeyan, while near Michelago there can be seen a conformable boundary with the overlying Bransby (= Goosoon) Beds.

The most complete succession appears to be in the Colinton-Bredbo area. Mayo (1967 MS) has mapped an incomplete section northwest of Colinton which appears to be at least 2600 m thick, while Goldsmith (1972 MS) provided evidence from north of Michelago for a thickness of some 3000 m. In general, however, the thickness estimates are unreliable because bedding in the volcanics is difficult to detect, and so therefore is also possible folding or faulting. The rather poorly outcropping rocks are mostly strongly cleaved (probably parallel to bedding), and the abundance of quartz reefs or gossan deposits, together with occasional mappable offsets, indicates extensive faulting in several directions.

The only detailed mapping is that of Baczynski (1970 MS), in the Bredbo area. He could not provide a reliable general succession, but did map a number of individual lithological units of variable extent. Most of the rocks are tuffs, often porphyritic in quartz and feldspar, and generally grey to green in colour. They include welded tuff, ash-flow tuff, and agglomerate. Amongst these volcanic units he mapped lenticular mudstone and siltstone beds, at times cutting across the general strike in a way suggestive of the effects of faulting. These sedimentary layers contain a shelly fauna of brachiopods, trilobites and occasional corals. The fossils are usually considerably distorted.

Between Colinton and 'Spring Valley' (c. 8726-000.530) the eastern margin of the unit is brought against Upper Ordovician rocks of the Cullarin Horst by part of the Queanbeyan Fault. North of Michelago, where the Canberra Graben widens, the Colinton Volcanics are intruded by a large dacitic porphyry along their eastern side (see Vallance, 1966).

At the northern end of the outcrop belt, southeast of Queanbeyan, the unit is intruded by two small adamellite stocks, and overthrust by the Ordovician Pittman Formation (Stauffer & Rickard, 1966). The relationship with the large area of undifferentiated volcanics west of the Monaro Highway in the Naas-Tharwa-Tuggeranong area south of Canberra is still not known.

Fossils found in the Bredbo area include Atrypa, Howellella and Encrinurus. Browne (1944, p.161) recorded Encrinurus mitchelli, Alveolites, Favosites, Heliolites and Phaulactis? from shales at Billilingra Siding, south of Bredbo - probably low in the Colinton Volcanics. And from a limestone in Gungoandra Creek south of Colinton he collected Phaulactis shearsbyi, Cystiphyllum, Mucophyllum crateroides and Favosites allani. The fauna is limited, but suggestive of correlation with that of the Silverdale Formation at Yass, which is of early Ludlovian (Late Silurian) age.

The combination of marine sediments containing shallow-water shelly fossils, and extensive volcanic rocks many of which are ash-flow tuffs, suggests that the unit was deposited under alternate shallow marine and subaerial conditions, probably during continuous subsidence of the graben.

Bransby Beds (= Goosoon Beds)

Joplin (1943) introduced the name Bransby Beds for a sequence consisting 'largely of volcanic and pyroclastic material, although pelites occasionally occur, thinly bedded limestones alternate with tuffs near the base and lenses of limestone occur near the top'. The volcanics are of dacitic to rhyolitic composition. Joplin, and Browne (1944), thought that these volcanics conformably overlay the Ordovician sequence in the Cooma region, and were themselves of Ordovician age, being overlain by the Silurian (Colinton Volcanics and Cappanana Beds). It is now known that the Bransby Beds in fact are conformable on the Colinton Volcanics, and are of Late Silurian age. The boundary with the Ordovician is faulted.

Best et al. (1964) introduced the name 'Goosoon Beds' for the same unit, but no definition was provided. Joplin's name has clear priority.

The Bransby Beds occupy the western side of the Canberra Graben south from Tharwa. They have not been differentiated on the Bega 1:250 000 Sheet, but are probably cut out by faulting a little north of Bunyan. The outcrops nowhere extend over a width greater than about 1.5 km. The upper boundary is generally faulted against the Murrumbidgee Batholith. At the northern end, near Tharwa, the Bransby Beds are unconformably overlain by a small area of sedimentary rock containing probably earliest Devonian fossils, which is overlapped by a thick sheet of dacitic welded tuff (see Strusz, 1971).

The type area nominated by Joplin is the Parish of Bransby, south of Michelago. Limestone lenses seem to be most common in this area.

The commonest rock types appear to be dacitic to rhyodacitic porphyritic tuff, welded tuff, and possibly lava; Joplin listed analyses of rocks from the southern outcrops which are in the rhyolite range. Interbedded with these volcanic rocks are brown mudstone, some sandstone, and irregular limestone lenses. As noted by Joplin, the sedimentary rocks seem to be most abundant at the bottom and top of the known sequence. All of the rocks have been strongly sheared and altered, especially near the Murrumbidgee Fault. The more westerly limestones have been altered to foliated marble, often showing extensive distortion.

Best et al. (1964) show a number of porphyry bodies apparently intruded into the Bransby Beds. They have been described by Joplin, who noted their affinity with the enclosing tuffs; the most striking difference is their lack of significant shearing. It is most likely that they are massive sheets of dacitic welded tuff sufficiently large and cohesive as to have avoided internal deformation.

Few fossils have been reported from the Bransby Beds. Some of the limestones have yielded distorted specimens of Favosites, Phaulactis shearsbyi, Cystiphyllum and Tryplasma, while indeterminable large pentamerids have been seen but not collected. This fauna does not permit precise correlation, but from their position above the Ludlovian Colinton Volcanics and Wenlockian-Ludlovian Cappanana Beds, the Bransby Beds must be of Ludlovian age.

The unit must have been deposited in much the same sort of environment as the Colinton Volcanics, but with a greater chance for normal marine conditions to develop.

Deakin Volcanics (Red Hill Group)

The Deakin Volcanics were defined by Öpik (1954) as 'a formation of acid volcanic rocks (tuffs, rhyolites) interbedded with tuffaceous sandstones and in places tuffaceous shales with limestone bands'. The unit as defined is the lowest in the Red Hill Group. The stratigraphic relationship with the Canberra Group is unknown, as the base of the Volcanics is everywhere either cut off by the Deakin Fault, or intruded by the Mount Painter Porphyry. Conformably above the rocks originally included in the unit by Öpik is the Yarralumla Formation. However, subsequent mapping of the geology of the Woden Valley/Weston Creek area has led Henderson (in Strusz & Henderson, 1971; 1973 MS) to propose a redefinition of the Deakin Volcanics to include volcanic rocks which overlie the Yarralumla Formation. Following such a definition, the top of the unit would be uncertain, as the boundary with the various volcanic rocks close to the Murrumbidgee Fault has not been mapped in detail.

The type area designated by Öpik is the Canberra suburb of Deakin, where the unit crops out north of Latrobe Park (c. 8727-920.900). In this area the only boundaries are intrusive ones against the Mount Painter Porphyry, but just to the north there is a depositional contact with the Yarralumla Formation. Öpik estimated a thickness of about 100 m in this area.

Wilson & Newstead (1967 MS) mapped the rather sparse outcrops in the eastern part of the Weston Creek area, while Gardner compiled much information from excavations in the northern Woden Valley suburbs. Wilson & Newstead estimated that there were about 130 m of dacitic tuff and ashstone below the Yarralumla Formation west of the suburb of Curtin, and about 1600 m of similar rocks above that formation. In the absence of the Yarralumla Formation, it is not possible to reliably distinguish between the volcanics above and below it - this is essentially the basis of Henderson's proposed redefinition. The rocks examined by Wilson & Newstead are green to grey, purple, and cream porphyritic dacitic and rhyodacitic tuffs, generally too altered for precise identification. The phenocrysts are quartz (often corroded) and plagioclase, and sometimes altered mica. The groundmass in most cases is apparently a devitrified glass. It is likely that both ash-fall and ash-flow tuffs are represented.

The Canberra 1:50 000 Sheet (Henderson & Strusz, 1971) shows an extensive area of acid volcanic rock in the Belconnen district, northwest of Canberra, as belonging to the Deakin Volcanics. This outcrop area is separated from the typical Deakin Volcanics by the Winslade Fault and a belt of Uriarra Volcanics. Henderson (1970 MS) compiled the results of detailed mapping in the region, which revealed a complex sequence of grey, green, purple and pink porphyritic dacite to rhyodacite. These he found to be very similar to the Deakin Volcanics, although the detailed sequences could not be matched. Moreover one fault wedge contains siltstone etc. very similar lithologically and faunally to the Yarralumla Formation, with a suggestion that it is conformable beneath the acid volcanics. It is now known that the volcanics are the southernmost part of the continuously outcropping Laidlaw Formation. It cannot be shown that the Deakin Volcanics are the precise equivalent of the Laidlaw Formation, although they are probably coeval, so the name Deakin Volcanics should be retained for the rocks south of the Winslade Fault and west of the Deakin Fault. Whether Henderson's proposed redefinition should be maintained depends in part on the relationships, as yet uncertain, with the volcanics near the Murrumbidgee Fault west of Weston Creek.

There are no fossil localities which can definitely be assigned to the Deakin Volcanics, whose age therefore depends on that assigned to the Yarralumla Formation. On present knowledge, this is Ludlovian. Similarly, the environmental evidence is sparse. Many of the tuffs have an altered glassy groundmass, which strongly suggests subaerial eruption, and the lack of marine fossils in the interbedded sandstones and siltstones would lend some support to that interpretation.

Yarralumla Formation (Red Hill Group)

Öpik (1954) defined the Yarralumla Formation as a succession of calcareous shale and sandstone with limestone beds, all more or less tuffaceous, and conformable with the Deakin Volcanics. Both units have been intruded by the Mount Painter Porphyry.

The type locality is in the suburb of Yarralumla, in and around the old brickpits (c. 8727-900.905). Exposed here is about 150 m of cleaved olive-green mudstone, calcareous mudstone, tuffaceous and calcareous siltstone, and nodular impure limestone.

The formation occurs in two main outcrop belts: one extending northwest across Red Hill as far as Lake Burley Griffin north of Yarralumla, and the other extending west from the Woden Valley suburb of Hughes to Lyons, then north-northwest across the Molonglo River to the Green Hills Pine Plantation. The two belts are separated by a strike fault, along which are two smaller outcrop areas. There is also a very poorly exposed area of the formation north of the Belconnen town centre, against the Deakin Fault.

On the Red Hill ridge the rocks have been metamorphosed by the Mount Painter and possibly Mugga Mugga Porphyries to a hard calcareous hornfels. Elsewhere a steep-dipping regional cleavage is the dominant feature, and outcrop is much poorer. In the Woden Valley, the formation forms the nose and western limb of a south-plunging anticlinorium. Wilson & Newstead (1967 MS) estimated a thickness of about 300 m south of the Cotter Road, while Henderson (1973a MS) suggests that there are about 450 m of tuffaceous, sandstone, calcareous sandstone, and olive mudstone and shale in the Woden Valley, showing a complex interfingering relationship with the overlying and underlying volcanics. The thickness in Belconnen is unknown; the rocks include brown and olive-green mudstone, tuffaceous and calcareous siltstone, and impure limestone.

On the Canberra 1:250 000 Sheet (Best et al., 1964) some isolated outcrops of sedimentary rock within undifferentiated volcanic rock along the Murrumbidgee River near 'Lambrigg' and the Poiht Hut Crossing have been assigned to the Yarralumla Formation, but are probably better regarded as northerly inliers of the Bransby Beds. There has been some detailed mapping in the area by MacKenzie (1966 MS) and the BMR Engineering Geology Group. Near Tharwa, the rocks are sandstone and shale within a sequence of acid volcanics, while near Point Hut Crossing they are small outcrops of shale. In both instances the rocks are unconformably overlain by a rhyolite breccia which is thought likely to be of earliest Devonian age (see Strusz (1971) for further discussion of the succession at Tharwa).

Fossils are common in localities south of the Molonglo River, especially in the calcareous siltstones and limestones. Unfortunately those in the siltstones (mostly brachiopods and trilobites) are often strongly distorted, making identification difficult. Some species have already been described, by de Koninck (1876) and Etheridge & Mitchell (1916), but most remain to be described. The commonest forms are the trilobite Encrinurus etheridgei and the brachiopods Howellella, Atrypella (= ?Atrypoidea), and Atrypa. Also known are various other brachiopods, including Protochonetes?, trilobites such as Otarion, odontopleurids, scutelluids and proetids, and (especially in the limestones) corals such as Phaulactis shearsbyi, Entelophyllum, Favosites, Heliolites, Syringopora and Aulopora. The microcrinoid Pisocrinus is commonly found. Öpik (1958, pp. 43, 89) suggested approximate correlation with the Barrandella Shale (upper Silverdale Formation) fauna of Yass, which Link (1970) and Link & Druce (1972) on conodont and graptolite evidence consider to be of Middle Ludlovian (late Eltonian) age. A few conodonts have been recovered from limestone in the Yarralumla Formation, but are all long-ranging forms.

A similar fauna to that listed has been found in the probable outcrops of Yarralumla Formation in Belconnen.

The only positive evidence on water depth comes from the Belconnen exposures: in one excavation it could be seen that laminar stromatoporoids were in growth position, suggesting fairly shallow water. The tuffaceous calcirudite at a sewer vent near the Cotter Road (c. 8727-875.893), and a limestone-tuff conglomerate west of Curtin could also represent areas of shallow-water deposition.

Mugga Mugga Porphyry

The presence of porphyritic igneous rock on Mount Mugga Mugga (on the southern edge of Canberra) was first recorded by Pittman (1911), who referred to it as a 'massif' of quartz porphyry, and suggested an intrusive origin. Öpik (1954, 1958) formally named the unit, and defined it as a medium-grained dark massive porphyry forming the bulk of the Mugga Mugga ridge. From textural and structural evidence he concluded that it intruded the Red Hill Group shortly after the intrusion and folding of the sill-like Mount Painter Porphyry, and at about the same time as initiation of movement on the Deakin Fault.

No specific type locality has been designated. There are good accessible outcrops in road cuttings in Hindmarsh Drive at the crest of the ridge, which would serve that purpose.

The commonest rock type is a dark brown to purple dacite, with greenish feldspar and clear quartz phenocrysts. Mapping since 1958 has extended the outcrop area southeastward across Jerrabomberra Creek near the A.C.T. border (see Henderson & Strusz, 1971). Öpik (1954) argued, against Mahoney & Taylor (1913), in support of the intrusive nature of the body, citing the existence of chilled margins on the western side, and roof pendants of metamorphosed Yarralumla Formation on the crest of the ridge. He pressed the argument in 1958, identifying the roof pendants as the strip of Red Hill Group forming the Red Hill ridge, between the Mugga Mugga and Mount Painter Porphyries. His map does not show the 'rafts of metamorphosed sediment' on the crest of the Mugga Mugga ridge - the hornfelsed Yarralumla Formation on the saddle between the Red Hill and Mugga Mugga ridges could be meant. Henderson (1973, MS) has commented on the difficulty of distinguishing between intrusive and extrusive rocks, because of the general alteration of the igneous rocks of the Canberra region, which frequently obliterates critical evidence. Nevertheless he suggests that the Porphyry is more likely to be a flow. Thin sections of specimens from Mugga Quarry (8727.931.855) show textures suggesting an ash-flow tuff. Öpik concluded that the Porphyry is of Late Silurian age. A radiometric date of 423 ± 9 m.y. has been obtained, which is Late Silurian (Bofinger et al., 1970).

Mount Painter Porphyry

The Mount Painter Porphyry was defined by Öpik (1954, 1958) as a dark, massive porphyry, intruding as a sill the Red Hill Group west of the Deakin Fault. The northeast margin of the body ends abruptly against that fault.

The type locality is Mount Painter, immediately south of the Belconnen suburb of Cook, west of Black Mountain. However, Öpik seems to have deduced the sill-like shape of the body from the outcrop pattern south of Lake Burley Griffin. He estimated a thickness of over 200 m.

The rock is a porphyritic dacite to rhyodacite, containing besides quartz and feldspar phenocrysts also numerous xenoliths of both sedimentary and igneous origin. Intrusive contacts have been exposed at several places: Öpik commented on one in a quarry at the northwestern end of Red Hill, and others east of Red Hill and in Yarralumla. Henderson (1973, MS) added others near Mount Stromlo, and at the Lake Ginninderra (Belconnen) dam site. As now mapped (Strusz & Henderson, 1971), the Porphyry occupies a southeast-trending triangular region 7 x 17.5 km. It is confined by the Winslade Fault on the northwest, near Belconnen, another fault on the west (west of Mount Stromlo), the Deakin Fault on the northeast, and is in contact with the Red Hill Group in the southwest and south.

The precise nature of all localities within that area is at times still uncertain. Some specimens have the texture of welded tuff in thin section. These could be from unmetamorphosed pendants of the Deakin Volcanics, such as those shown south of Mount Painter on the Canberra 1:50 000 Sheet. Öpik (1958, p.46) has already noted the existence of a number of unmapped, and now inaccessible, pendants.

Specimens from the Red Hill area are often very coarse-grained, which would agree with the unit being an intrusive mass. Perhaps the Mount Painter Porphyry as mapped includes several disparate rock bodies.

The Porphyry intrudes rocks of Ludlovian (late Silurian) age, and Öpik has argued on tectonic grounds for a pre-Devonian age, suggesting that the Porphyry and the dacitic volcanics which it intrudes are probably co-genetic. A radiometric date of 438 ± 4 m.y. (late Llandoverian or Wenlockian) has been obtained from rocks at Mount Painter (Bofinger et al., 1970).

COTTER HORST

Tidbinbilla Quartzite

Noakes (1946 MS) named and described the Tidbinbilla Quartzite in a report on possible damsites in the upper Cotter Valley, southwest of Canberra. The greatest geographic extent postulated for the formation is that shown by Best et al. (1964), but recent more detailed mapping (Owen et al., in prep.) has restricted this to the area between the Bendora Reservoir and

Tidbinbilla Mountain. The formation is essentially a gently west-dipping sheet of orthoquartzite, unconformably overlying Upper Ordovician quartzose greywackes and graptolitic black slates. The top is truncated by the Cotter Fault, leaving a total preserved thickness of about 300 m.

Noakes did not designate a type locality or section. Owen et al. (in prep.) propose to designate as type section one extending south-southwest from the summit of Tidbinbilla Mountain (8627-693.757) to a steep gully, ending at 692.755. At the base of this section, overlying the Ordovician rocks, is a conglomerate a few metres thick, containing tabular mudstone clasts in a coarse matrix of quartz and chert grains. Above this basal conglomerate the section exposes about 100 m of orthoquartzite. This occurs in massive beds, sometimes cross-bedded, up to 4 m thick.

The massive orthoquartzites are about 250 m thick. The remaining 50 m consists of interbedded quartzite and siltstone to mudstone. The grains making up the quartzites are moderately to well rounded, and include unstrained quartz, quartzite, mudstone, and chert, and the general appearance of the rock is quite similar to the Black Mountain Sandstone as exposed on the road to the Black Mountain lookout. The clasts in the conglomerate are generally 20-40 mm across, and are mainly mudstone, with lesser and much smaller chert. The rock types can be matched in the Upper Ordovician rocks of the region. There is extensive silica overgrowth on the quartz grains.

A single incomplete graptolite was discovered on the line of the Bendora water main, in shales that are now considered to be within the upper part of the Tidbinbilla Quartzite. Strusz (1971) suggested the graptolite could be Monograptus flemingi or M. chimaera var. salweyi, but this is not certain, as the proximal end is missing. If correct, the age would be early Ludlovian.

The lower part of the formation is possibly a deltaic deposit. The upper part, with interbedded shales and at least one marine fossil, could have been deposited in somewhat deeper water, or in front of a regrading delta.

Tantangara Beds

The name Tantangara Beds was introduced by Best et al. (1964), without definition, for sedimentary rocks on Nungar Ridge north and south of Tantangara Dam (8626-502.372). The unit was assigned a Silurian age, and was listed as "shales, sandstones, greywackes and volcanics". Crook et al. (1973), using work done by Bein (1968 MS), noted the occurrence of Late Ordovician graptolites at Tantangara Dam, and concluded that they could not separate the Tantangara Beds from the Nungar Beds. However, detailed mapping by the BMR party in 1971-72 provided evidence for separating the two; a full account will appear elsewhere (Owen et al., in prep. a), but a summary follows.

The Tantangara Beds comprise a sequence of dark coarse-grained sandstone, siltstone and shale, which in the upper part of the unit become interbedded with, and subordinate to, brown shale, siltstone and fine-grained sandstone. The Beds occur in a block bounded on the west by the Boggy Plain Fault (a meridional fault which crosses the Snowy Mountains Highway on the east slope on Connors Hill, northwest of Lake Eucumbene), and on the east by the Cotter Fault. The southern limit has not been mapped, but is presumed to be an intrusive contact with the granite south of Lake Eucumbene. In the northeast the outcrops end against the Goodradigbee Fault. All these faults bring the unit into contact with Ordovician rocks or granite. North and west of Tantangara Reservoir the Beds are unconformably overlain by the Upper Llandoverian Peppercorn Beds and Pridolian Kellys Plain Volcanics.

The overall outcrop width at Tantangara Dam is about 22 km, and at the southern margin of the Canberra 1:250 000 Sheet at least 16 km (if the rocks between the two arms of the Cotter Fault at Adaminaby are part of the unit, this is increased to about 20 km). The meridional extent is over 40 km. This is a considerable increase over the extent shown on the Canberra Sheet, and includes rocks previously thought to be Ordovician (on lithological grounds, in the absence of fossils: the sandstones are fairly similar, and the shales do not crop out well).

Within the outcrop area exposure is generally poor. There are numerous inliers of the Upper Ordovician Nungar Beds and (in the west) Temperance Chert. The boundary is nowhere exposed, but is almost certainly mildly unconformable. The Beds have been intruded by the Gingera Granite in the north, and by other smaller granite bodies, probably apophyses of a larger unexposed massif, elsewhere.

Both lower and upper parts of the sequence are incompletely exposed in a section at Tantangara Dam, which Crook et al. (1973) chose as a reference section for the 'Nungar Beds'. This extends east along the road from the tunnel inlet valve station (above the south abutment, 8626-500.371), with almost continuous exposure of the lower part as far as the bridge over the Murrumbidgee River at 513.368. The section continues east along the edge of an area of severe erosion on the south bank, as far as 520.370 at a bend in the river, and provides exposures of the softer upper part of the unit. The total distance is 2 km, across beds dipping generally at 70° to 80° to the west-northwest. The lower beds are massive dark grey coarse-grained sublitharenite, generally in graded beds, with interbeds of dark grey to brown siltstone and shale. East of the road bridge exposure is less complete. The rocks are interbedded light to medium brown fine-grained arenite, siltstone and shale, in which graded beds are uncommon.

Rocks probably higher in the sequence are exposed in a road cut on the Snowy Mountains Highway, on the eastern side of the Monaro Range from 8626-486.218 to 496.220. These beds are brown fine-grained arenite, siltstone and shale, 0.5-30 m thick, and only sporadically showing grading.

The most distinctive rock type in the lower part of the Tantangara Beds is a coarse to very coarse sublitharenite in beds up to 20 m thick, commonly graded, and forming large tor-like outcrops in which the bedding is usually indistinct. The rock is brown to very dark grey in colour, which conspicuous well-rounded quartz grains up to 2 mm across, and generally iron-stained feldspar. Black mudstone clasts, usually tabular and up to 250 mm across, are found at the bottom of many graded units, and rock fragments also occur in the arenite - black mudstone, chert, and andesitic volcanics. The obvious source of all these is the underlying Ordovician in the west - the Nine Mile Volcanics and Temperance Chert.

The arenites in the upper part of the sequence are generally brown and fine-grained, less resistant to weathering, and consist of quartz grains with minor chert and shale fragments, in a silt or clay matrix. The associated shales may be part of graded units, or may form individual beds up to 50 m thick.

No accurate estimate of thickness can be made because of poor exposure and complex structure. The section at the Tantangara Dam is at least 1000 m thick, and that on the Snowy Mountains Highway is about the same, so a minimum thickness of 2000 m is likely.

Fossils were collected from a coarse sublitharenite on the northern edge of the Nungar Plain, at 8626-491.297. They are poorly preserved and fragmentary; most are tabulate corals, but some of the brachiopod fragments are probably Eospirifer (which appears in the Llandoverian and is widespread throughout the Silurian). There is a fasciculate species of Tryplasma (Late Ordovician to Devonian) and a probably Angopora (Silurian). The fauna therefore indicates a Silurian age. It is known that the unconformably overlying Peppercorn Beds are of Late Llandoverian age, so the age of the Tantangara Beds must be Early Llandoverian.

The widespread presence of graded beds indicates a turbidite depositional regime. No direct evidence could be found for the palaeo-slope direction, but the existing outcrops of the source of many of the rock fragments - the Nine Mile Volcanics and Temperance Chert - are on the western side of the Tantangara Beds, suggesting an easterly slope. On the other hand, there was almost certainly land to the east, resulting from the recumbent and isoclinal folding of the Ordovician in the Cullarin Horst, reported from the Queanbeyan area by Stauffer & Rickard (1966) and known also from the Bredbo area.

GOODRADIGBEE GRABEN

Peppercorn Beds

The Peppercorn Beds occur in the source area of the Murrumbidgee River - the Long Plain area north of Kiandra. The name was introduced by Walpole (1964), whose sketch-map (p. 37) showed a fairly limited area at the northern end of the Plain; he noted several outcrop localities, but did not define the unit. Best et al. (1964) also incorporated a large area of volcanic rock west of the Long Plain Fault into the unit. This region has recently been revised as part of a BMR mapping project, whose full results will appear elsewhere (Owen et al., in press); a summary follows.

The Peppercorn Beds as now understood display a fairly constant lithology. There is a basal chert conglomerate and sandstone layer, followed by interbedded fine-grained sandstone, siltstone and mudstone. Fossils occur in isolated pockets in the finer beds, being commonest in sandstone and siltstone just above the basal conglomerate. There are a few small lenses of fossiliferous limestone and calcareous shale. The unit is unconformable above the Ordovician Nine Mile Volcanics (in the Long Plain Fault zone) and Temperance Chert (northwest of Tantangara Reservoir), and the Lower Silurian Tantangara Beds (west of the Reservoir). The top is faulted out, or unconformably overlain by the Upper Silurian Kellys Plain Volcanics. The relationship with the Cooleman Plain sequence is obscured by these volcanics, but it is thought probable that the Peppercorn Beds are the lateral equivalent of the lower Pocket Beds, and are conformably overlain by the Cooleman Limestone.

The extensive area west of the Long Plain, included in the Peppercorn Beds by Best et al. (1964) contains only dacitic to rhyodacitic volcanics, and is now recognized as the eastern extension of the Goobarragandra Beds. On the other hand, outcrops of Silurian rock in the Nungar Creek valley, mapped but not named by Stevens (1958a), are included in the Peppercorn Beds. Moreover, the Currango Beds, defined by Crook et al. (1973) because of uncertain correlation in the Peppercorn Creek area, can now confidently be equated with the Peppercorn Beds, and their name can be allowed to lapse. Similarly included in the Peppercorn Beds are Silurian rocks in the Brindabella Valley farther north, separately recognized as the Brindabella Beds by Best et al. (1964).

A section representative of the Peppercorn Beds is in the valley of Little Peppercorn Creek. It starts at 8626-489.637, about 200 m northeast of the creek-crossing of an old track from Little Peppercorn Plain to Peppercorn Hut, and extends northwest for some 800 m to the base of the overlying Kellys Plain Volcanics at 476.642. Although the contact with the Nine Mile Volcanics is not exposed, mapping in the area shows it to be unconformable. The basal Silurian bed here is a coarse sandstone, known only from float, and estimated to be about 5 m thick; it contains reworked fragments of the underlying tuffs. Above it is 65 m of poorly bedded conglomerate containing well rounded chert pebbles up to 30 mm across, interbedded with coarse to pebbly sandstone; this layer is resistant to weathering. There is then a gradual passage into coarse, then finer, poorly outcropping sandstone about 25 m thick, which gives way to very poorly exposed strongly cleaved brown siltstone which could be over 500 m thick. The total thickness preserved in this section is estimated at about 600 m.

The overall meridional extent of the Peppercorn Beds is considerable: about 55 km from Nungar Creek southwest of Tantangara Dam to near McDonalds Flat in the Goodradigbee valley northeast of Brindabella Mountain. For most of this distance the Beds occur as a series of small to medium-sized fault blocks, forming a belt no more than 3 km, and generally less than 1 km, wide. The main development is at the northern end of the Long Plain, from "Cooinbil" ruin (8626-444.556) to Little Peppercorn Creek (c. 640.480).

The basal conglomerate is very distinctive; its pebbles are generally rounded, with rather high sphericity, and are mostly chert. The lithology also reflects the underlying geology, however: over the Nine Mile Volcanics there are common andesite pebbles, while above the Tantangara Beds the pebbles include quartz and sublitharenites. Mostly the pebbles are 10-50 mm across, but south of the lower Nungar valley they are often 100 mm and occasionally up to 200 mm across. The rather sparse matrix is a well rounded very fine to very coarse-grained sand, which also forms small crossbedded lenses within the conglomerate. The layer is generally less than 25 m thick, but may be as much as 70 m; lateral variation can be rapid. In places (as in the Little Peppercorn Creek section) the conglomerate is underlain by up to 10 m of medium to coarse-grained sublitharenite; there are also usually 2-3 m at least of coarse to fine-grained sandstone above the conglomerate. This generally passes quickly up into light brown sandy siltstone or fine-grained sandstone, in which fossils are commonly found (especially near the base). On the Long Plain there are beds of fine conglomerate up to 0.5 m thick within this siltstone. Sedimentary structures are uncommon, apart from minor lamination and small scale cross-bedding; slumping has been seen in the Nungar Creek valley. There are small lenses of limestone and calcareous shale within the siltstone on the Long Plain, the largest limestone being close to 'Cooinbil'.

The sandy siltstone passes up into medium brown to dark grey fine-grained siltstone or mudstone, commonly cleaved and poorly outcropping. The outcrops in the Brindabella Valley are of this type.

Shelly marine fossils are most commonly found in sandy siltstone just above the basal conglomerate, especially in the Nungar and Peppercorn Creek areas. They are also sometimes found high in the sequence, and some have been described from the 'Cooinbil' limestone lens. Hill (1954) recognized amongst others from 'Cooinbil' the tabulate corals Acanthohalysites cf. australis, Hexismia? brevicatenatus, Coenites cf. seriatopora, and Diploepora cf. grayi, and deduced a Wenlockian or Ludlovian age. A shelly fauna in siltstone from the Nungar Creek valley at 8626-470.411 includes Encrinurus cf. etheridgei, Rhizophyllum sp., and Nucleospira? sp., which do not disagree with Hill's dating. More recently, R.S. Nicoll has recovered a good conodont fauna from the limestone at 'Cooinbil', of which the main elements are Ambalodus galerus, Apsidognathus tuberculatus, Astrognathus cf. tetractis, Neospathognathodus pennatus, Ozarkodina gaertneri, Pterospathodus amorphognathoides, and Pygodus lyra. This fauna correlates closely with that of the Telychian Stage (Late Llandoverian) of the Welsh Borderlands (Aldridge, 1972).

The Peppercorn Beds represent the marine transgression which followed the severe folding of the basal Silurian Tantangara Beds and the Ordovician on which they rest. The basal conglomerate of the Peppercorn Beds may be deltaic or intertidal - evidence in favour of one or the other is lacking.

Pocket Beds

The Pocket Beds are a sequence of quartzite, slate, lenticular limestone and tuff in and near the Goodradigbee Valley from Pocket Saddle (8626-560.520) to Cave Creek, east of the Cooleman Plains (c. 550.570). The name was introduced by Newberry (1956 MS), and published by Stevens (1958b); the Mount Murray Branch Formation of Walpole (1964) and Best et al. (1964) is a junior synonym. The area was mapped in detail by Legg (1968 MS), and further work was done by P.A. Jell and M. Owen in 1972 and D. Wyborn in 1973, as part of a BMR mapping project. A detailed account of this work will appear later (Owen et al., in press); what follows is a summary of the essential features.

The base of the unit is either concealed by alluvium or the Pridolian Kellys Plain Volcanics, or is faulted out. The Beds are conformably overlain by the Blue Waterhole Beds.

The best-exposed section is along the Goodradigbee River. The base of the section is at 8626-553.555, about 1.5 km above the mouth of Cave Creek, where the sediments are intruded by a dyke from the Gurrangorambla Granophyre. The sequence is about 750 m thick, its top being about 400 m above the mouth of Cave Creek, at 553.565. From the top, the succession is -

Blue Waterhole Beds: black chert with fossils

75 m - brown shale, sporadically fossiliferous.

11 m - impure limestone.

115 m - brown shale, sporadically fossiliferous.

140 m - impure grey limestone, locally very fossiliferous, with thin shale interbeds.

115 m - cleaved brown shale and minor sandstone, sparsely fossiliferous.

32 m - impure grey limestone, strongly cleaved.

135 m - strongly cleaved brown shale and minor sandstone.

15 m - coarse tuff.

24 m - brown fossiliferous shale.

21 m - grey slightly tuffaceous lithic sandstone.

15 m - coarse tuff.

felsite dyke.

32 m+ - very cleaved brown shale.

The dominant rock type is cleaved grey, brown-weathering massive mudstone with interbeds of impure limestone and, locally, thin sandy siltstone and tuffaceous sandstone. Fossils are common. The cleavage and consequent distortion of the fossils increase southwards until the rocks become apparently unfossiliferous slate. The limestones are commonly lenticular and 1-3 m thick, but some reach as much as 140 m. They are impure, grey, usually fossiliferous biomicrites or biosparites, and mostly contain thin shale interbeds. Their boundaries with the surrounding mudstones and usually gradational.

The Pocket Beds crop out in two areas, separated by the Kellys Plain Volcanics and the Gurrangorambla Granophyre. The northern area lies on the south side of Cave Creek, and extends some way up the Goodradigbee River; it is bounded on the west by the Black Mountain Fault, on the north by the Blue Waterhole Beds, and elsewhere by igneous rocks. The southern area is in a fault block, between the Mount Black Fault, the Tantangara Fault, and splays of the Goodradigbee Fault; it occupies the Pocket Saddle, extending down from there into the Goodradigbee Valley. Overall, the total area of outcrop is about 6.5 x 2 km.

Legg (1968 MS) collected and identified fossils from the Pocket Beds, especially in the north. In the mudstones he found brachiopods including Molongia elegans Mitchell, Atrypoidea angustans Mitchell & Dun, Howellella nucula Barrande, Atrypa, and Pholidostrophia sp. cf. nitens Williams, together with the trilobite Encrinurus sp. cf. mitchelli. The limestones yielded amongst other Phaulactis shearsby (Süssmilch), Tryplasma lonsdalei Etheridge, Pyonostylus dendroides Eth., Favosites gothlandica Lamarck, Heliolites daintreei Nicholson & Eth., Plasmopora heliolitoides Lindström, and the brachiopod Conchidium.

A few conodonts have so far been recovered by R.S. Nicoll, but they are all simple cones of little stratigraphic value.

The fauna is most likely to be of late Wenlockian of early Ludlovian age, and was probably deposited in shallow marine waters subject to significant sediment supply.

Cooleman Limestone

The name Cooleman Limestone was published by Leight & Etheridge (1894), who briefly described the limestones of the Cooleman Plains area, northeast of Kiandra. Of several subsequent investigations (Walpole, 1952; Stevens, 1957, 1958b; Legg, 1968), only the second of Stevens has been published. P.A. Jell and M. Owen remapped the Plains in 1972, as part of a BMR mapping project, and their results, to be published in full elsewhere (Owen et al., in press) are summarized here.

The Cooleman Limestone is a massive or bedded generally light grey limestone, often extensively recrystallized, and mostly only sparsely fossiliferous. Dolomitization, controlled by jointing, is widespread but seldom complete. The boundaries of the limestone are clearly diachronous. In the outcrop area west of the Black Mountain Fault (the Cooleman Plains outcrops) the formation is thick. Its lower boundary is concealed by the Kelly Plain Volcanics or intruded by the Gurrangorambla Granophyre, but is thought most likely to be conformable with the Peppercorn Beds towards the Long Plain, and the Pocket Beds in the south. East of the Fault, in the Cave Creek gorge and the Goodradigbee Valley, the limestone occurs as tongues extending into the Pocket Beds and the chert facies of the Blue Waterhole Beds. The upper boundary in the western outcrops is not well exposed, but there seems to be a well-developed karst surface on which the siltstone of the Blue Waterhole Beds was deposited - although without structural unconformity. In the east the upper boundary is conformable with the Blue Waterhole Beds. The maximum thickness is at least 480 m, but probably is closer to 700 m; thickness is however extremely variable, being reduced to less than 70 m in exposures north of Harris' Hut (c. 8626-490.560).

Although recognizing that the limestones east and west of the Mount Black Fault show complex interrelationships, Stevens (1958b) chose to express these relationships, as he understood them, by introducing the name Wilkinson Limestone for the higher of the two main limestone tongues east of the fault. The name was also used by Best et al. (1964) - but for all of the limestone; they used 'Cooleman' for the whole Silurian sequence. Walpole (1964) altered the name to Wilkinson Cliff Limestone (but with the same sense as Best et al.), presumably because 'Wilkinson' had already been used by Andrews (1922) in the Broken Hill region. BMR mapping has demonstrated the continuity of all the limestones, to which the earliest (and most familiar) name is applied.

Owen et al. (in press) have designated a type section which exposes the upper part of the Limestone near the Blue Waterholes, on the west side of the Mount Black Fault. The section begins on the west side of Cave Creek southwest of the Blue Waterholes, at the base of a steep bluff about 600 m above the southern crossing of Cave Creek by the Blue Waterhole Trail (8626-518.560). It extends northeast along Cave Creek for about 150 m, then turns east up a steep gully; from the gully's top, the section bears at 110° to an exposure of the boundary of the Limestone with the Blue Waterhole Beds at 522.559. The exposed thickness totals 257 m; the succession from the top is -

Blue Waterhole Beds

c. 75 m - poorly exposed massive limestone.

40 m - dark grey limestone; thin wavy beds below, thicker more even beds above.

5 m - pale grey bedded medium-grained recrystallized limestone.

37 m - coarse grey micrite, bedding very thick or absent; layer with blocks of cherty siltstone (Blue Waterhole Beds?) about 12 m above base.

12 m - pale cream massive medium-grained recrystallized limestone.

7 - gap.

23 m - poorly bedded sparsely fossiliferous cream limestone, partly recrystallized.

6 m - massive coarsely recrystallized limestone.

8 - medium to thin-bedded partly dolomitized limestone with poorly preserved fossils.

1 m - probable pelletal limestone.

0.5 m - single layer crowed with brachiopods

3.5 m - white moderately recrystallized limestone with bivalves, brachiopods.

39 m - poorly bedded to massive recrystallized limestone; rare bivalves.

A second section has been singled out as representative of the lower part of the formation. It is on the Cooleman Plain, on the north side of the Gurrangorambla Range below Blue Waterhole Saddle, and contains about 210 m of limestone. The interval between the top of this section and the bottom of the type section is unknown. The section starts in a shallow doline at 8626-514.533, and bears at 020° for 260 m, where it reaches a 50 m-wide gully. It then follows the west bank of this shallow gully north for about 170 m to the south branch of Cave Creek, which it crosses and continues north for a short distance. The bottom of the section is in Gurrangorambla Granophyre, the top in colluvium derived from the Rolling Grounds Latite, on a low hill at 516.538. From the top, the succession is -

colluvium with latite float

2 m - pale cream sparry limestone.

5 m - buff dolomite.

80 m - well bedded moderately to very fossiliferous grey biomicrite, with a 15 m gap near the top; fossils include brachiopods, bivalves, gastropods, nautiloids, stromatoporoids, rare corals; base transitional from -

70 m - discontinuously outcropping massive to thickly bedded dark grey limestone, sparsely fossiliferous (mainly brachiopods).
40 m - gap.
10 m - massive grey fossiliferous limestone with brachiopods, bivalves, crinoids, corals.
Gurrangorambla Granophyre

The total area occupied by the Cooleman Limestone is 20.7 km^2. The main outcrop area is Cooleman Plains, where the limestone forms a semi-circular area on the west side of the Mount Black Fault. This area is divided by an east-west band of the Blue Waterhole Beds, and is also partly covered by scattered outcrops of the Devonian Rolling Grounds Latite. The outer boundary is against Blue Waterhole Beds in the north and east (where the limestone is also locally covered by the Mountain Creek Volcanics), or intruded by the Gurrangorambla Granophyre, Jackson Granite, or members of the 'Coolamine Igneous Complex'.

East of the Mount Black Fault, there is an elongate outcrop belt along lower Cave Creek to the Goodradigbee River, then in a faulted zone extending north along the west side of the Goodradigbee Valley as far as Dunn's Flat (8626-567.621). The limestone in the Cave Creek area differs from the main Cooleman Plains mass in that there are cherty beds near its base, showing a transition from underlying cherts of the Blue Waterhole Beds. These cherty beds outline slump structures in the limestone near Cooleman Falls.

The Peppercorn Creek valley also contains two small outcrops of the Cooleman Limestone. One, at 539.668, is a roof pendant in a diorite of the Coolamine Igneous Complex, while the other, at 630.518, is apparently a lens within the Blue Waterhole Beds.

Despite the widespread recrystallization and dolomitization, well preserved fossils can be collected. Legg (1968 MS) recorded amongst others _Favosites gothlandica_ Lam., _Heliolites daintreei_ Nicholson & Etheridge, _Parastriatopora_, _Phaulactis shearsbyi_ (Süssmilch), _Tryplasma lonsdalei_ Eth., _Pycnostylus_, _Actinostroma_, _Kirkidium_, and _Pentamerus?_, as well as algae. This fauna would suggest a late Wenlockian or Ludlovian age.

R.S. Nicoll has obtained conodonts from several localities; they are few in number and often poorly preserved, but in some cases provide an accurate assessment of age. From 147 m above the base of the type section have come Spathognathodus sagitta and Ozarkodina media: they indicate a probable Wenlockian age. 179 m above the base Nicoll found S. sp. cf. remscheidensis, which would suggest Ludlovian or possibly Pridolian. Samples elsewhere suggest a similar overall range: possibly Wenlockian to Ludlovian or possibly Pridolian.

The best fauna so far has come from allochthonous blocks, thought to be of the Cooleman Limestone, within the Blue Waterhole Beds 900 m north-northeast of Harris Dam, at 495.569. Forms recovered include Spathognathodus remscheidensis, S. inclinatus, Ozarkodina media, O. typica, Neoprioniodus multiformis, and indicate a Ludlovian or possibly Pridolian age.

The limestone very probably formed as a shallow water bank deposit. The presence of oncolites, numerous stromatoporoids, algae, thick-walled bivalves and brachiopods, and the common bioturbation of the limestone all indicate shallow water, while the absence of visible coralline framework structures suggests a bank deposit rather than a reef complex.

Blue Waterhole Beds

The name Blue Waterhole Beds was first used by Stevens (1958 MS) and subsequently published by him (1958b). Best et al. (1964) used the name Marys Hill Beds for essentially the same unit. The Beds have been discussed in detail by Owen et al. (in press). They contain two basic lithological associations: mudstone to fine-grained sandstone in the west, passing eastwards into black chert and siliceous siltstone. The succession appears to be thicker in the east, where the unit lies conformably on the Pocket Beds, and interfingers laterally with the Cooleman Limestone. West of the Mount Black Fault it is disconformable on the Cooleman Limestone, whose upper surface had previously developed karst-type relief. In the Peppercorn Creek Valley north of the Cooleman Mountains there appears to be a gradational passage from the Peppercorn Beds up into the Blue Waterhole Beds. The top of the unit has been faulted out in several places, but elsewhere it is overlain unconformably by the Pridolian Kellys Plain Volcanics and the Lochkovian (Lower Devonian) Mountain Creek Volcanics and Rolling Grounds Latite. The Beds have been intruded by the Coolamine Igneous Complex and the Jackson Granite.

About 190 m of the unit is exposed in a section on the left side of the north branch of Cave Creek, east of Harris' Hut; it lies between the Cooleman Limestone and the Rolling Grounds Latite. One end is at the mouth of a tributary gully at 8626-501.557; the section extends north to 501.562, a point on the hillside north of a sharp bend in Cave Creek from easterly to southerly. The contact with the underlying Cooleman Limestone is not exposed, but evidence from the surrounding area indicates the development of karst relief. From the top, the sequence is -

Rolling Grounds Latite.

40 m - Thick bedded dark grey mudstone, with minor interbeds of finely banded siltstone, and thin bands of chert near the top.

10 m - fine-grained sandstone, siltstone, and minor mudstone; slumping common; layer containing large allochthonous blocks of limestone 3 m from the base.

51 m - finely banded thin-bedded siltstone with dark grey mudstone interbeds; 7 m unexposed towards the top.

53 m - gap

3 m - weathered brown siltstone.

30 m - gap

Cooleman Limestone

West of the Mount Black Fault, there are two distinct areas of outcrop. Around "Coolamine" homestead the unit contains mainly rhythmically interbedded siltstone to fine-grained sandstone, and mudstone, in beds 50-100 mm and 100-250 mm thick. The coarser, thinner-bedded rock is mostly a muddy quartzose siltstone. Some small-scale cross-bedding is developed, and dessication cracks have been seen on the upper surfaces of some of the mudstone beds near the base of the succession. Near Cliff Cave (8626-497.556, east of Harris Hut) some 40 m or more of dark brown micaceous siltstone, apparently deposited on an irregular surface of Cooleman Limestone, underlie the typical mudstone - siltstone sequence. High in the succession there appear thin beds of dark blue-grey chert, generally interbedded with dark grey siltstone; these are followed by the entry of fine-grained micaceous sandstone.

The zone of slumping in the upper part of the sequence, seen in the above-mentioned section, is fairly widespread. It contains numerous allochthonous blocks of limestone, particularly at 495.569 (the conodont fauna obtained here is dealt with under the Cooleman Limestone). These blocks almost certainly were derived from penecontemporaneously deposited and lithified Cooleman Limestone.

In the Blue Waterholes area (ca 520.560), brown micaceous siltstone overlying the Cooleman Limestone near Mount Black mine passes up into dark grey to black fine-grained siliceous siltstone near Spencers Hut. The latter siltstone, which often contains abundant leached fossils, rests directly on a seemingly irregular surface of Cooleman Limestone above Clarks Gorge (530.561). West of Spencers Hut the siliceous siltstone is overlain by fine-grained quartzite, which has been intruded by several sills of the Gurrangorambla Granophyre. The lithologies in this area are transitional between rocks near 'Coolamine' and those east of the Mount Black Fault.

Along Cave Creek below the Mount Black Fault, and extending down the Goodradigbee Valley to Dunns Flat (8626-570.620), the Blue Waterhole Beds comprise black bedded pyritic chert and dark grey fossiliferous siliceous siltstone (like that near Spencers Hut), with some limestone lenses; slumping is common. Along Cave Creek they rest with apparent conformity on the Pocket Beds, and are conformably overlain by the tongue of Cooleman Limestone to which Stevens (1958) gave the name Wilkinson Limestone. Farther north, that limestone can be seen to be a tongue within the Blue Waterhole Beds, wedging out in cherts near Dunns Flat. Along the Goodradigbee Valley the Blue Waterhole Beds are overlain by younger volcanic rocks or are downfaulted against the Ordovician by the Goodradigbee Fault.

Outcrops of the Blue Waterhole Belds also occur in a belt, about 1.5 km wide, extending north-northeast along the east side of the Peppercorn Creek valley, from northwest of Jackson Mountain to beyond the northern end of McLeods Ridge (west of Mount Franklin). On the west they overlie the Peppercorn Beds, apparently conformably,or are faulted against or covered by the Kellys Plain Volcanics. The eastern margin of the belt is either intruded by the Jackson Granite or overlain by the Rolling Grounds Latite and the Mountain Creek Volcanics (both Early Devonian). The more southerly of these outcrops are of well bedded siliceous siltstone, fine-grained sandstone, and mudstone, with a few limestone lenses. These give way northwards (and upwards?) to poorly bedded brown micaceous siltstone and lithic sandstone. At the northern end of the belt there are chert and bedded siliceous siltstone, similar to those in the Goodradigbee Valley farther southeast, and limestone lenses. These rocks are probably equivalent to the lower beds, at the southern end of the outcrop belt.

South of 'Coolamine' the Blue Waterhole Beds have an estimated thickness of about 600 m. Where they overlie the Pocket Beds east of the Cooleman Plains they are only about 70 m thick, but this increases northwards to at least 500 m near Dunn's Flat. The lower Peppercorn Creek valley exposures are also at least 500 m thick.

The fauna of the Blue Waterhole Beds is extensive, but seldom well preserved. Fossils are usually present in the siliceous siltstone, being particularly common in the lower valley of Cave Creek. Legg (1968 MS) collected many, including Heliolites daintreei Nicholson & Etheridge, Favosites gothlandica Lam., Plasmopora heliolitoides Lindström, Alveolites, Mucophyllum, Entelophyllum, Tryplasma lonsdalei Eth., Mazaphyllum, Rhizophyllum, Encrinurus sp. cf. mitchelli Foerste, Calymene, and atrypoids. The only conodonts are those recovered by Nicoll from allochthonous blocks probably derived from the Cooleman Limestone (q.v.) which indicate that the Blue Waterhole Beds on Cooleman Plain are no older than Ludlovian. The shelly fauna is not very specific, indicating a Wenlockian or Ludlovian age for the beds in Cave Creek, which are probably laterally equivalent to the upper part of the Cooleman Limestone.

Kellys Plain Volcanics

The Kelly Plain Volcanics are widely distrubuted in the Tantangara-Cooleman area, with continuous outcrop extending from the Nungar Creek valley near Blackfellows Hill (south of Tantangara Reservoir) northwards to the lower Peppercorn Creek valley west of Mount Ginini, a total distance of 35 km. Outcrops of the unit were first recorded by Ivanac & Glover (1949 MS) and Walpole (1952, MS), who thought it to be an intrusive porphyry. The extensive character was first recognized by Newberry (1956 MS), who coined the name Kellys Plain Dacite; the first published description was that of Stevens (1958b). Best et al., followed by Packham (1969), referred to the unit as the Kelly Plain Porphyry, and assigned a Devonian age.

The chief lithology is porphyritic rhyodacite to dacite. The phenocrysts are quartz and plagioclase, with lesser potassium feldspar, while the groundmass is predominantly quartz and potassium feldspar. Features typical of flows are lacking, and it seems that all the rocks formed as ash-fall and ash-flow tuffs or ignimbrites, probably in very thick individual cooling-units.

The Volcanics unconformably overlie the Ordovician Temperance Chert and Nine Mile Volcanics in the Dairymans Plain area north of Tantangara Reservoir. Elsewhere they are unconformable on the Silurian Tantangara Beds (a contact is exposed in Nungar Creek valley at 8626-468.349), Peppercorn Beds (rhyodacite tuff rests on dark grey mudstone on the west side of Smiths Range, at 478.394), and all components of the Cooleman Plains sequence. The surface on which the volcanics rest appears to be irregular. Inliers of Tantangara and Peppercorn Beds are common, especially between Currango Plain and Smiths Range. A local relief of at least 50 m is suggested by inliers of the Peppercorn Beds in the upper Mosquito Creek valley. The relationship of the Volcanics to the Rolling Grounds Latite is uncertain, but strong arguments can be adduced for the Latite's (and the overlying Mountain Creek Volcanics) being unconformable on the Kellys Plain Volcanics.

The formation takes its name from Kellys Plain, about 1 km west of Tantangara Dam. Stevens did not designate a type locality or section; Owen et al. (in press) propose that the large disused quarry at Traces Knob (8626-488.366), 1500 m southwest of the dame, be so designated. This is the only significant artificial exposure of the Volcanics, and as such is one of the few places from which unweathered rock may be obtained. The quarry exposes about 25 m of massive dark bluish-grey quartz-feldspar porphyry, typical of much of the southern part of the formation.

As already noted, the formation has a continuous meridional extent of 35 km; the width in the Currango Plain area is 12 km. North of the Murrumbidgee River the volcanics crop out over much of the Tantangara Reservoir and the Currango Plain. From there the main belt extends to Skains Hill and the eastern edge of the Long Plain, which it follows, separating the sedimentary sequence there from that of the Cooleman Plains. The formation also crops out in a faulted belt extending from Currango Plain along Pocket Creek to the Rolling Grounds Spur (east of the Cooleman Plains).

Several different rock types have been observed, but they could not be mapped as distinct stratigraphic units. The commonest type in the south, exposed at the type locality, is a dark blue-grey rock, coarsely porphyritic in quartz, plagioclase, lesser potassium feldspar, and biotite altered to chlorite. Widely distributed from Currango Plain northwestward, but rare in the south, is a pale grey rock with fewer and smaller phenocrysts of plagioclase, perthite, biotite and rare ?augite (altered to chlorite). Local varieties of this differ only in the groundmass colour: pink is common on Smiths Range near Traces Hut, and in the north; dark green (due to more extensive chloritization?) is fairly widespread. A pale cream porphyry with scattered small quartz, feldspar and biotite phenocrysts occurs east of 'Currango' homestead. Definite ash-flow tuff, in which the original texture is still visible despite alteration, has been detected in at least two places, and an agglomeratic porphyry is widespread along the western side of the Kellys Plain Volcanics south from Currango Plain. The ignimbrite sheets must have been quite thick - the type locality appears to be within one cooling unit at least 25 m thick. Columnar jointing is common, especially in the south. On Currango Plain north of the 'Old Currango' ruin the columns are up to 2.5 m long and 150 mm across. Banding also is common, again particularly in the south, and generally consists of alternating quartz-rich and feldspar-rich layers about 10 mm thick.

The thickness is probably quite variable, depending on the irregular underlying relief. In the Skains Hill area it is at least 300 m, while in the south, on Smiths Range, a probable gentle easterly dip would give a thickness of about 150 m. An unknown amount has been removed by erosion, so these figures are minima.

There is no direct evidence of age, and so far samples sufficiently unaltered for isotopic age determination have not been collected. Stevens (1958b) argued on topographic and structural grounds that the Kellys Plain Volcanics were older than the Rolling Grounds Latite, but Best et al. (1964) considered that the reverse was true, because they regarded the formation as being essentially an intrusive prophyry, intruding amongst others the Lower Devonian Mountain Creek Volcanics, and so of Middle or Late Devonian age. There is now definite petrographic evidence of the extrusive character of the formation. Geochemically, the Kellys Plain Volcanics are related to, and could well be extrusive derivatives of, the Gingera Granite. That body is intruded by dykes apparently originating from the Coolamine Igneous Complex, to which the Rolling Grounds Latite is closely related. From this it follows that the Kellys Plain Volcanics are older than the Rolling Grounds Latite, which underlies the Mountain Creek Volcanics, of known Lochkovian (Early Devonian) age. The Gingera Granite is related to the Murrumbidgee Batholith; Pidgeon & Compston (1965) provided a Rb/Sr date of cooling of 417 m.y. for the Shannons Flat Adamellite, - which recent revision of the decay constants would increase to over 420 m.y. From this, and the most recent estimates of the age of the Silurian/Devonian boundary (Lambert, 1971), a late Pridolian age for the Kellys Plain Volcanics is almost certain.

Micalong Creek Beds

Caught up in fault slices along the Goodradigbee River north of the Brindabella Valley, where the Goodradigbee and Long Plain Fault Zones merge, are cleaved shales and siltstones with limestone lenses. Edgell (1949 MS) described these, giving names to the three main limestones. The northernmost of these, the 'Micalong Creek Limestone', has also been mentioned by Brown (1964), who lists the fauna. Best et al. (1964) placed the beds on the west side of the fault zone in their interpretation of the Peppercorn Beds (q.v.), but the rocks in that position are now recognized as part of the Goobarragandra Beds.

Recent mapping by a BMR party has clarified the relationships of these rocks. The limestones and associated sedimentary rocks are everywhere in faulted contact with the surrounding units, and seem to be fragments of the one unit. It is therefore proposed to refer to them all as the Micalong Creek Beds, after the outcrops along Micalong Creek about 2 km south of Wee Jasper village. The other main outcrops are at Limestone Creek (8627-560.985) and Sandy Flat Creek (or Dinnertime Creek - 580.930).

The noncalcareous rocks are shale and siltstone; they are generally cleaved, especially strongly close to the faults, and do not contain well preserved fossils. The limestone is dark blue-grey, slightly impure, with thin olive shale interbeds; it is generally recrystallized, but fossils have been collected from the Micalong Creek outcrops.

The relationship to the Silurian sequence farther up the Goodradigbee Valley are uncertain, but lithological similarities suggest that the Micalong Creek Beds are most likely to be a continuation of the Blue Waterhole Beds.

Edgell (1949 MS, and in Brown, 1964) reported amongst others the corals *Phaulactis shearsbyi* and *Tryplasma lonsdalei*, brachiopods including *Howellella*, *Conchidium* and other pentamerids, and the trilobites *Otarion yassensis* and *Encrinurus* sp. cf. *mitchelli*. A general, but not precise, correlation with the latest Wenlockian to early Ludlovian part of the Yass sequence is indicated.

REFERENCE LIST

Only those references not found in Strusz (1971) or Strusz & Henderson (1971) are listed here.

ALDRIDGE, R.J., 1972 - Llandovery conodonts from the Welsh Borderland. Bull. Brit. Mus. Nat. Hist. (Geol.), 22(2).

ANDREWS, E.C., 1922 - The geology of the Broken Hill district. Mem. geol. Surv. N.S.W., Geol., 8.

BACZYNSKI, N.R.P., 1970 - Geology east of Bredbo, N.S.W. B.Sc. (Hons) Thesis, Aust. Nat. Univ. (unpubl.).

BELL, M.W., 1971 - The geology of the Ginninderra-Bedulluck area. Geol. III mapping rep., Aust. Nat. Univ. (unpubl.).

BERRY, W.B.N., & BOUCOT, A.J., (eds), 1970 - Correlation of the North American Silurian rocks. Spec. Pap. geol. Soc. Am., 102.

BOFINGER, V.M., COMPSTON, W., & GULSON, B.L., 1970 - A Rb-Sr study of the Lower Silurian Stage Circle Shale, Canberra, Australia. Geochem. Cosmochim. Acta 34(4):433-445.

BRUNKER, R.L., OFFENBERG, A.C., & WEST, J.L., 1970 - Monaro 1:500,000 geological Sheet. Geol. Surv. N.S.W.
(alternative reference: "1:500 000 geological series, Monaro sheet").

CEPLECHA, J.P., 1972 - The geology of the East Hall district, A.C.T. Geol. III mapping rep. Aust. Nat. Univ. (unpubl.).

CROOK, K.A.W., BEIN, J., HUGHES, R.J., & SCOTT, P.A., 1973 - Ordovician and Silurian history of the southeastern part of the Lachlan Geosyncline. J. geol. Soc. Aust. 20(2); 113-138, 1-3.

GOLDSMITH, R.C.M., 1972 - The geology of an area north of Michelago. Geol. III mapping rep., Aust. Nat. Univ. (unpubl.).

HENDERSON, G.A.M., 1970 - Geological investigations, Belconnen sheets G4C, G4D, G5A, G5B, G5C, GBC, Australian Capital Territory 1965-67. Bur. Miner. Resour. Aust. Rec. 1970/60 (unpubl.).

______________ 1973a - Stratigraphy and structure, Canberra 1:50 000 geological map area. Ibid. 1973/11 (unpubl.).

______________ 1973b - Geology af the Capital Hill area, Canberra, A.C.T. Ibid. 1973/35 (unpubl.).

HILL, D., 1954 - Coral faunas from the Silurian of New South Wales and the Devonian of Western Australia. Bur. Miner. Resour. Aust. Bull. 23.

HOLLOWAY, D.J., 1972 - The fauna of the Riverside Formation (Upper Silurian) of Canberra. B. Sc. (Hons) thesis, Aust. Nat. Univ.

LAMBERT, R. St. J., 1971 - The pre-Pleistocene Phanerozoic time-scale - a review. Geol. Soc. (Lond.) spec. Publ. No. 5, 9-31.

LINK, A.G., & DRUCE, E.C., 1972 - Ludlovian and Gedinnian conodont stratigraphy of the Yass Basin, New South Wales. Bur. Miner. Resour. Aust. Bull. 134.

MACKENZIE, D.E., 1966 - Geology of the Tharwa area, A.C.T. Geol. III mapping rep. Aust. Nat. Univ. (unpubl.).

MAYO, W., 1967 - The geology of an area N.W. of Colinton (between Michelago and Bredbo). Ibid. (unpubl.).

MOIGNARD, P.S., 1970 - The geology of the Boambolo district, New South Wales. B.Sc. (Hons) thesis, Aust. Nat. Univ. (unpubl.).

NEWBERRY, J., 1956 - Murrumbidgee-Eucumbene diversion. Eng. geol. Rep. Snowy Mts Auth. S.G. 69 (unpubl.).

OWEN, M., GARDNER, D.E., WYBORN, D., SALTET, J., & SHACKLETON, M.S., in press - Geology of the Tantangara 1:100 000 sheet, Australian Capital Territory and New South Wales. Bur. Miner. Resour. Aust. Rec. 74/176 (unpubl.).

OWEN, M., & WYBORN, D., in prep. - Geology and geochemistry of the Tantangara and Brindabella 1:100 000 sheets. Bur. Miner. Resour. Aust. Bull.

OZIMIC, S., 1971 - The geology of the Ginninderra Creek area, east of Barton Highway, A.C.T. & N.S.W. Geol. III mapping rep., Aust. Nat. Univ. (unpubl.).

SCOTT, P.A., 1970 - Geology of the Black Mountain area. Geol. III mapping rep., Aust. Nat. Univ. (unpubl.).

STRUSZ, D.L., 1971 - Canberra, A.C.T. and N.S.W. 1:250 000 geological series. Bur. Miner. Resour. Aust. explan. Notes. SI/55-16.

STRUSZ, D.L. & HENDERSON, G.A.M., 1971 - Canberra City, A.C.T. 1:50:000 geological map and explanatory notes. Bur. Miner. Resour. Aust.

WHITTINGTON, H.B., 1971 - Silurian calymenid trilobites from United States, Norway, and Sweden. Palaeontology 14(3): 455-477, 83-89.