# The Hervey Group (Middle-Upper Devonian) on the Grenfell 1:100 000 Sheet Area, NSW (Lachlan Fold Belt)

*by*

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# THE HERVEY GROUP (MIDDLE-UPPER DEVONIAN) ON THE GRENFELL 1:100 000 SHEET AREA, NSW (LACHLAN FOLD BELT)

G.C. Young

## Abstract

The Middle-Late Devonian Hervey Group on the Grenfell 1:100 000 Sheet Area covers approximately 400 km$^2$ in three major areas of outcrop which were remapped in 1995-96. The Peaks and Hunter Formations, which have type sections in the central part of the Hervey Group outcrop on the Grenfell Sheet Area, are recognised for the first time in the Weddin Range in the southeastern corner of the Sheet Area. The Gooloogong Member is a basal marginal marine unit within the Hunter Formation characterised by an association of lingulid brachiopods, plants and fish remains, the lowest of probably four fish assemblages within the Hunter Formation. The overlying major bluff-forming sandstone, previously mapped as 'Mandagery Sandstone', is renamed the Weddin Formation, and correlated with this formation in the upper part of the sequence in the Weddin Range. The Mandagery Formation defined on the Parkes 1:100 000 Sheet Area is considered to be broadly equivalent to the Peaks Formation on the Grenfell 1:100 000 Sheet Area. The basal part of the Weddin Formation is characterised by the trace fossil Skolithos at several localities, which probably indicates a near-shore marine environment. The Culela Member is a fine-grained unit defined near the top of the Weddin Formation, which is characterised by a presumed latest Famennian fish assemblage, commonly associated with the lycopod plant Leptophloeum. This unit is considered to be broadly equivalent to the much thicker fine-grained sequence in the northeastern corner of the Grenfell Sheet Area, which is correlated with the Eurow Formation defined in the Parkes Syncline to the north. The uppermost Wingara Formation in the Parkes Syncline is identified as a massive cross-bedded quartzite unit overlying the Eurow Formation in the northeastern part of the sheet. The term Bumberry Formation is retained for the upper sandstone formation on the northern side of the Lachlan River, where there is continuity of outcrop onto the Parkes sheet where this formation has its type section. A new occurrence of the Grenfellaspis fish fauna near the top of the Bumberry Formation establishes a correlation with the upper part of the Hunter Formation and lower part of the Weddin Formation on the southern side of the Lachlan River. The occurrence of the lycopod plant Leptophloeum in sandstones very close to the top of the Hervey group is considered to indicate that preserved strata do not extend into the Carboniferous. The age of the basal part of the Hervey Group is probably late Middle Devonian (Givetian).

# INTRODUCTION

The Middle-Late Devonian Hervey Group is represented on the Grenfell 1:100 000 sheet in three major areas of outcrop, covering approximately 400 km$^2$, which generally correspond to the areas mapped by Conolly (1965a). In the northeastern corner is a southern extension of the Eugowra Syncline, Nangar Anticline, and intervening folds which crop out in the southeastern corner of the Parkes 1:100 000 sheet (Young 1999b). This outcrop extends as far as the alluvial valley of the Lachlan River, and is exposed in the northern river bank about 1 Km NNW of the village of Gooloogong. A major outcrop of a complexly folded rocks occupies the central eastern portion of the Grenfell 1:100 000 sheet. The major structural features, from W to E, are the Redcliff Syncline, Gooloogong Anticline, Yambira (Sugarloaf) Syncline, Keewong Anticline, Brundah Syncline, Kangarooby Anticline, Conimbla Syncline, and Broula Anticline. Widely separated from this outcrop by Ordovician sediments, Silurian volcanics, Devonian intrusives and alluvium, is the outcrop in the Weddin Range, in the southwestern corner of the Grenfell 1:100 000 sheet.

The rugged sandstone ridges that characterise much of the Hervey Group outcrop tend to be of high relief, with poor or skeletal soils, and generally not cleared of timber except in valleys with appreciable colluvial cover or alluvium. Because of the scenic nature of the sandstone ridges and bluffs, several areas of Hervey Group outcrop have been put aside as reserves or national parks, and on the Grenfell 1:100 000 sheet the Weddin Mountains National Park in the southwest corner is entirely within the Hervey Group outcrop, as is largely the Conimbla National Park on the eastern boundary of the sheet (including the Conimbla Range).

Access to the main folded outcrop in the central eastern portion of the Grenfell 1:100 000 sheet is via the Kangarooby Road from the north, which passes south along the valley of Kangarooby Creek, and connects to the south via the Bumbaldry Fire Trail with the Major West Road which runs down to the Midwestern Highway connecting Cowra and Grenfell. The northern section of the Kangarooby Road also connects to the east with Barryrenie Road which traverses the Conimbla National Park to connect with the Lachlan Valley Way to the east. A separate southern section of the Kangarooby Road runs to the north off the Midwestern Highway to provide access to the core of the Conimbla Syncline between the Conimbla Range and Bumbaldry Hills.

The Grenfell 1:100 000 sheet contains the type sections for three formations of the Hervey Group erected by Conolly (1965a). The restudy of the Hervey Group during fieldwork in 1995-96 under the National Geoscience Mapping Accord was facilitated by modern colour air photos, and provision of radiometric images resulting from airborne geophysical survey of the mapped areas. I acknowledge assistance from AGSO and the NSW Geological Survey in support of fieldwork and map preparation, and amongst others I thank D. Wyborn, D. Wallace, O. Raymond, L. Sherwin, J. Pickett, N. Watson for advice, and assistance in the field, Cathy Brown for advice on stratigraphic nomenclature, and all the landowners on the Grenfell 1:100 000 sheet who allowed access to their properties. In addition R.W.

Brown assisted with palaeontological collection and section measurement, and H.M. Doyle prepared much of the new fossil material. This restudy of the Hervey Group has also benefited from the first systematic examination and collection of fossil fish remains by an experienced vertebrate palaeontologist, which has resulted in the discovery of some 40 new fossil localities at various horizons within the Hervey Group. A full listing of new fossil localities is given elsewhere (Young 1997a), and a preliminary biostratigraphic analysis of the new data is presented by Young (1999a). Information relevant to age control and correlation within the Hervey Group is summarised for individual formations in the new stratigraphic subdivision presented below. Devonian timescale and stage name usage is based on the AGSO Phanerozoic timescale (see Young 1995, 1996, 1997b).

## HERVEY GROUP

*Nomenclature, derivation, type locality and subdivision*
The Hervey Group, as defined by Conolly (1965b), has its type section in the Hervey Range on the Narromine 1:250000 sheet (along Clagger Creek to Caloma trig), where the sequence consists of some 1500 m of quartzose sediments (Conolly et al. 1969; Sherwin 1996). However the type sections for several of the constituent formations were defined elsewhere, and for the Grenfell 1:100 000 sheet Conolly (1965a) erected and defined type sections for three formations: Peaks Formation, Hunter Siltstone and Weddin Sandstone. These are retained in the stratigraphic subdivision presented below. Conolly (1965a) also subdivided the Hervey Group into three subgroups, but this has not been followed here.

Major problems in lithological correlation of the Hervey Group between different areas have been noted by several authors (e.g. Sherwin 1973, 1996; Campbell & Bell 1977; Ritchie et al. 1992; Young 1999a). For the Grenfell 1:100 000 sheet the main difficulties have arisen because of doubtful correlations across the Lachlan River originally proposed by Conolly (1965a), who recognised the Mandagery Sandstone as the major bluff-forming sandstone unit in the main part of Hervey Group outcrop on the Grenfell 1:100 000 sheet. In the stratigraphic subdivision adopted below, the term Weddin Formation is used for this major bluff-forming sandstone unit on the southern side of the Lachlan River, and on the northern side where there is continuity of outcrop onto the Parkes 1:100 000 sheet, the terminology of formations defined in the Mandagery Railway type section of the Parkes Syncline is used (Bumberry, Eurow, Wingara Formations).

### Peaks Formation (Dhp) after Conolly (1965a)

*Previous nomenclature*
Peaks Sandstone of Conolly (1965a)
Bogan Gate Sandstone (in part); Conolly (1965a)

The lower part of the Hervey Group sequence in the Weddin Range was initially identified by Conolly (1965a: 71) as the 'Bogan Gate Sandstone', but the type section for this formation lies far to the north in the Tullamore Syncline. This stratigraphic

subdivision has been followed recently (e.g. Warren et al. 1995, fig. 4), but according to Sherwin (1996: 75) the term 'Bogan Gate Sandstone' as originally defined applies to a composite of sediments and volcanics ranging in age from Late Silurian to Mesozoic, and should no longer be used.

*Derivation of name*
From Peaks Creek, which forms the alluvial fill of the valley of the Gooloogong Anticline northeast of Adelargo.

*Type locality*
The type section of the Peaks Formation was defined by Conolly (1965a) along Peaks Creek on the western limb of the Goolooogong Anticline at GR 623000, 6263000.

*Thickness*
Conolly (1965a) recorded the following sequence in the type section:

| | |
|---|---|
| TOP | |
| white and red coarse/medium grained sandstones and red siltstones | 46 m |
| red siltstones | 9 m |
| red coarse-grained sandstones and red siltstones and shale | 58 m |
| red siltstones and shale | 15 m |
| TOTAL | 128 m |

Conolly (1965a) estimated a maximum thickness of some 1500′ (450 m) in the Gooloogong Anticline, but Colwell (1974) revised this to 250 m. The thickness of bluff-forming coarse sandstones can vary considerably along strike, mainly due to facies change, for example in the Bumbaldry Hills along the eastern limb of the Conimbla Syncline, and at the southern end of the Keewong Anticline, where the Mogongong Conglomerate Member is developed (see below). Jones (1984) recorded a thickness of 860 m in this area, whilst in the SE part of the Weddin Range a thickness of about 170 m is estimated.

*Distribution and outcrop*
As is the case on the Parkes 1:100 000 sheet, the basal part of the Hervey Group is often poorly exposed, mainly because of scree cover from overlying sandstones. In the type area the Peaks Formation consists of a sequence of poorly sorted red and white lithic sandstones interbedded with red siltstones and shales, the sandstone units being generally 1-3 m in thickness, and lensing out over distances of up to 400 m along strike (Colwell 1974). Locality GY96/165 is a reported contact with the underlying Loch Lomond Granite (Conolly 1965a; illustrated by Colwell 1974, pl. 8). Here the Peaks Formation forms a low bluff of massive red gritstone, beneath which a single granite boulder was observed in the float of large blocks which had rolled down onto the soil cover. The adjacent road cutting 1.5 km to the south exposes the type section of the 'Gooloogong Beds' of Colwell (1974). As noted below, outcrop of Peaks Formation immediately to the north of this road cutting, which is well exposed by a recent Telstra cable line, indicates that the lower 20 m of

coarser red sediments in the road cutting should be included within the upper part of the Peaks Formation.

In the valley of Warrumba Creek, the eastern flank of the Warrumba Range contains westerly dipping sandstones in the gullies west of the track at GY96/2, but an easterly dipping ridge-forming white and red sandstone unit occurs east of the creek. This presumably is the Peaks Formation on the western limb of the adjacent Warrumba Syncline, rather than a sandstone unit within the Hunter Formation as was suggested by Colwell (1974).

In many places the Peaks Formation outcrops as thick bluff-forming coarse sandstones which result in conspicuous ridges, for example the Bumbaldry Hills along the eastern limb of the Conimbla Syncline. In other sections the ridge-forming sandstones may be reduced or absent, and in the Keewong/Brundah fold system of the Yambira Syncline area, as mapped by Jones (1984), the basal Hervey Group contact is apparently between the Hunter Formation and the underlying volcanics.

Along the eastern limb of the Conimbla Syncline coarse pebbly sandstones form the main ridge, but massive sandstones crop out right through the fold axis (e.g. localities GY96/257-265), and the Hunter Formation is not evident as a valley within the sandstone sequence. It is possible that the Hunter Formation is missing, with the Peaks Formation grading into higher sandstones assigned to the Weddin Formation which occupy the core of the fold, these two formations having similar lithologies. Alternatively, there could be a faulted contact between the two formations, or else the Peaks Formation could lie further east, and the basal contact with volcanics has been misidentified. Field checking is required to clarify this. Also possible is the wedging out of sandstone lithology to the south, such that the basal contact is between the Hunter Formation and underlying volcanics, as mapped by Jones (1984) in the Keewong/Brundah fold system to the west. A lithological change was noted to the south along strike, and at GY96/255 lithology typical of the Gooloogong Member of the Hunter Formation is seen above a much thinner coarse sandstone unit. These possibilities cannot be resolved without further field work.

In the region south of Keewong Creek, where Conolly (1965a) identified the Mogongong Conglomerate Member, Jones (1984) mapped a variety of lithologies including lower red bed and debris flow units. In the core of the Keewong Anticline much of the Peaks Formation shows up on air photos as more finely bedded that the more typical massive coarse sandstone units of other localities.

In the Weddin Range good sections are seen in the foothills at the southeastern end, separated from the main Range by recessive outcrop of Hunter Formation. The basal contact with underlying Early Palaeozoic strata, which dip to the east, is well displayed at several localities (GY96/5, 35, 20). Prominent strike ridges of pebbly sandstone are evident on air photos; at GY96/20 the basal unit, and at GY96/4-5 a higher sandstone unit at the top of the formation are the main ridge-formers. At

GY96/16 vein quartz suggests faulted truncation of the Peaks Formation, but higher in the section in the Weddin Formation at the eastern extremity of the Weddin Range there is no evidence of faulting. Any major faulting must therefore lie farther east beneath alluvial cover.

*Description*

The lithology of the basal beds of the Peaks Formation is variable. At GY96/40 on the nose of the Redcliff Syncline a brick-red mudstone forms the basal unit, overlain by a felspathic red sandstone with rounded outcrop and occasional pebbles, but the actual contact is not exposed. At GY96/25 just north of the type section a ridge-forming red siltstone with abundant burrowing at the tree line represents the basal unit, with the cleared country to the east being an outcrop tract of the Illunie Volcanics (Adelargo Member). In the type area, Colwell (1974) noted a basal 15 m thick unit of red siltstone and shale mappable on both sides of the Gooloogong Anticline, which thickens to the SE to reach about 50 m thickness east of 'Adelargo' property. On the eastern side of the Redcliff Syncline this basal unit beneath the first sandstone outcrop is about 20 m thick at GY96/44. 5 km to the south of the type area, in the vicinity of Mogongong-Bumbaldry, the basal beds are represented by the Mogongong Conglomerate Member up to 120 m thick, above which the red mudstone unit reaches a thickness of some 90 m (Jones 1984, fig. 6.6). At the NW end of the outcrop across the Gooloogong Road, the Peaks Formation forms a low bluff of massive arkosic red gritstone, close to the contact with underlying granite.

In the Weddin Range the basal unit is unconformable on underlying Early Palaeozoic strata at GY96/5, as a reddish quartz pebble sandstone/conglomerate about 3 m thick, with angular pebbles up to 20 mm across. The 'small lenses of reworked limestones' said by Conolly (1965a: 71) to occur in the 'Bogan Gate Sandstone' in the Weddin Range were not observed at any locality. At GY96/30 the unconformity is well seen in the gully on the west side of the track, where the pebbly sandstone unit is underlain by a basal red shale only 1 m thick. The section at GY96/5 comprises an estimated 170 m of thickness to the top of the second ridge-forming pebbly sandstone, which itself is about 10 m thick. This is taken to represent the top of the Peaks Formation, and is the highest sandstone outcrop in the section before the Weddin Formation is encountered on the main escarpment. The intervening strata, representing the lower part of the Hunter Formation, are seen only as float of small pieces of laminated micaceous red siltstones. The middle 150 m of the Peaks Formation at this locality comprises interbedded red/buff siltstones and lesser mudstone (at least in outcrop), often as platey outcrop, and sometimes showing bioturbation and burrows.

*Depositional environment*

A fluvial environment with both high and low energy regimes is indicated for the Peaks Formation. Palaeocurrent direction was from the west (Conolly (1965a)) or southwest (Colwell 1974). A local igneous source for clastic constituents is indicated (Jones 1984).

*Palaeontology*
A placoderm fish assemblage was found by John Pickett in 1994 (locality GY94/7) in a 40 cm thick red sandstone unit at the western end of the Gooloogong road cut section of Colwell (1974), which is close to the top of the formation. Identified taxa are *Bothriolepis* sp. and *Remigolepis* sp. In addition Jones (1984) noted plant remains provisionally identified as *Protolepidodendron* in the Brundah Creek region.

*Age and relationships*
The equivalent basal formation of the Hervey Group on the Parkes 1:100 000 sheet was identified by Conolly (1965a) as the Kadina Formation, the name derived from the type section defined near Kadina Trig station in the Hervey Range on the Narromine sheet (Conolly 1965a, p. 47). The Kadina Formation was the only named formation within Conolly's (1965a) 'Beargamil Sub-Group' in the Parkes-Manildra area (Conolly 1965a, table 1), whereas in the type area of the Hervey Range Conolly included in this sub-group the underlying Clagger Sandstone, a coarser-grained red unit including reddish - purple sandstones, conglomerates, and some red shales and siltstones (see Sherwin 1996). It is evident that on the Grenfell 1:100 000 sheet there is often a similar sequence of lower red mudstones overlain by sandstones, both of which have been included here within the Peaks Formation. A broad correlation can therefore be proposed between the Peaks Formation and both the Kadina and Clagger Formations in the type area of the Hervey Range.

Broad correlation with the Mandagery Formation is also likely, as previously proposed (e.g. Young 1994, 1999a, fig. 3), based on revised correlations of the Mandagery Sandstone across the Lachlan River as discussed by Ritchie *et al.* (1992) and Pickett (1993a). Palaeontological evidence supports the correlation of the Peaks and Mandagery Formations, and the age of the latter, as indicated by the Canowindra fish fauna, might be older than the Famennian age previously suggested by Young (1993). A late Frasnian age for this fauna was proposed by Young (1997a, 1999a), and the fish assemblage from the upper part of the Peaks Formation may represent the same fauna. The same may apply to the fish fauna from Gingham Gap in the Hervey Range described by Hills (1936), which probably derives from the Clagger Sandstone (Sherwin 1996).

The occurrence of plant remains provisionally identified as *Protolepidodendron* by Jones (1984) from the basal part of the formation suggests a possible correlation with the Merriganowry Member of the Dulladerry Volcanics on the Cowra 1:100 000 sheet, which also contains this plant, and has been assigned a probable late Middle Devonian (Givetian) age (Pickett 1993b; Young 1994, 1999a).

## Mogongong Conglomerate Member (Dhpm) Conolly (1965a)

*Previous nomenclature*
This member was defined by Conolly (1965a: 60). Jones (1984) further subdivided this member into mappable lower 'Debris Flow', and upper 'Fluviatile Conglomerate' units, reflecting different modes of deposition. This subdivision is not used here.

*Derivation of name*
After Mogongong railway siding and Mogongong Spring, just south of the Mid Western Highway about 15 km east of Grenfell.

*Type locality*
The type section of Conolly (1965a: 60) is just north of the Mid Western Highway about 15 km east of Grenfell.

*Thickness*
Conolly (1965a) measured a sequence of 98 m (320'), comprising 37 m of massive red conglomerate, overlain by coarse pebbly sandstones, thin conglomerates and red siltstones (61 m). Jones (1984, fig. 6.6) recorded a thickness of 120 m, with the unit thinning to the south. About 20 m of fluviatile conglomerate occurs at the southern end of the Yambira Syncline.

*Distribution and outcrop*
This member is restricted to the southern part of the Yambira Syncline, with the main outcrop on the northern side of the Mid Western Highway in the Brundah Falls area, and on the southern side in outcrops on both sides of Bungalong Creek. An outlier of fluviatile conglomerate, in unconformable contact with underlying Ordovician sediments, occurs at the summit of Mount Lively south of the Grenfell-Koorawatha railway line (Jones 1984). A significant proportion of clasts from the underlying Ordovician sediments were reported by Jones (1984) from this locality.

*Description*
Conolly (1965a) described a thick massive conglomerate member with poor and indistinct bedding at the base, overlain by well bedded conglomerates and sandstones. Pebbles vary in size from 12 to 75 mm diameter. Jones (1984) recorded angular immature clasts set in a fine red matrix in lower beds, identified as debris flow deposits, and an upper 'Fluviatile Conglomerate' units, with well-rounded gravel and pebbles which are not clast-supported, indicating shallow water high energy deposition. Above this his 'red-bed sequence' up to 20 m thick comprises massive mudrock with some silty and fine sand interbeds.

*Depositional environment*
The angular immature clast-supported sediments recorded by Jones (1984), which conform with the 'massive matrix supported gravel lithofacies' of Miall (1978), were interpreted as debris flow deposits. Fluvial deposition (shallow water high energy) in the upper 'Fluviatile Conglomerate' unit is indicated by the well-rounded gravel and pebbles which are not clast-supported, with the massive mudrock probably representing overbank deposits in which Jones (1984) identified well developed pedotubules at some horizons, indicating subaerial exposure.

*Palaeontology*
At Brundah Falls Jones (1984) recorded plant impressions identified as *Cordaites* sp. cf. *C. australis*, and *Protolepidodendron* sp.

*Age and relationships*
See comments above for the Peaks Formation.

## Hunter Formation (Dhh) after Conolly (1965a)

*Previous nomenclature*
Hunter Siltstone of Conolly (1965a)
Bogan Gate Sandstone (in part); Conolly (1965a)

*Derivation of name*
From Hunter Creek, where Conolly (1965a) defined the type section.

*Type locality*
The type section of Conolly (1965a) was measured on the eastern limb of the Gooloogong Anticline in the valley of Hunter Creek.

*Thickness*
Conolly (1965a) calculated a thickness of about 330 m ('one thousand feet of red siltstone with occasional fine-grained red sandstone and shale members') from width of outcrop and average dip, and a maximum thickness of 525 m (1600') was estimated (Conolly 1965a: fig. 4, col K) in the section near the Lachlan River just off the NE corner of the Grenfell 1:100 000 sheet. In the region of the Redcliff Syncline and Gooloogong Anticline the Hunter Formation maintains a thickness of at least 150 m (Colwell 1974), whereas in the southern part of the Yambira Syncline it reaches some 450 m thickness (Jones 1984).

At the SE end of the Weddin Range, width across the recessive valley between the Peaks and Weddin Formations suggests a thickness of Hunter Formation of some 200 m, based on dip measurements varying from about 35° to 20° up the sequence. Previously, Conolly (1965a) recorded a thickness of some 248 m of 'Bogan Gate Sandstone' beneath the Weddin Formation in this area, which presumably includes both the Peaks Formation and Hunter Formation as recognised here.

*Distribution and outcrop*
The 'Hunter Siltstone' was identified and mapped by Conolly (1965a), as a thick sequence of red siltstones and shales which 'forms prominent valleys between the strike ridges of the Peaks and Mandagery Sandstones'. As such it is rarely observed, except when capped and preserved by overlying sandstones when it can form prominent outcrops. Thus, the red colour of the northwest facing escarpment at Redcliff Mountain is due to an extensive exposure of Hunter Formation, here protected from erosion by the overlying cliffs of Weddin Formation. Immediately to the north, where the overlying sandstones have been lost, the Hunter Formation outcrop is represented by a wide valley with little exposure, which occurs mainly as scattered float derived from the more resistant siltstone interbeds. It is noteworthy

that the radiometrics indicate a high radiogenic mineral content for this formation, which is clearly defined within the Hervey Group sequence by its light colour, although sometimes difficult to distinguish from underlying volcanics.

The Hunter Formation forms extensive but mainly recessive outcrops capped by Weddin Formation in the cores of the Redcliff, Yambira and Brundah Synclines. Farther east it forms a conspicuous valley around the axis of the Broula Anticline. On the western limb of the Conimbla Syncline the Hunter Formation apparently thins to the south, although lithology typical of the Gooloogong Member is seen at locality GY96/253. Up the eastern limb of this syncline the entire outcrop from the base of the sequence to the fold axis is of sandstone lithology, so the Hunter Formation may be missing due to facies changes. However faulting, or an incorrect contact with underlying volcanics are alternative interpretations for which field checking is required. According to Jones (1984), in the Yambira Syncline area the Hunter Formation overlies the Peaks Formation conformably on the western side, but to the east extends out over the basal debris flow unit (mcm) to lie directly on the underlying volcanics. It is possible therefore that the same applies along the southeastern flank of the Bumbaldry Hills, where the Peaks Formation may be absent because the sandstone lithology wedges out to the south. However further east, on the eastern limb of the Broula Anticline, the Hunter Formation is readily identified as another distinctive valley between the Peaks and Weddin Formations, this sequence apparently truncated around the fold axis by faulting. As noted above, the position of the basal Hervey Group contact needs field checking in this area.

The Hunter Formation has not previously been identified in the Weddin Range, although the lower part of the sequence initially identified by Conolly (1965a: 71) as the 'Bogan Gate Sandstone' presumably included the strata assigned here to this formation. The Hunter Formation is generally difficult to observe because of its recessive outcrop, and the extensive sandstone scree from the overlying Weddin Formation. However the valley between the foothills at the southeastern end and the main range is typical of the often recessive outcrop of Hunter Formation at other localities. At GY96/5 the top of the Peaks Formation is a ridge-forming pebbly sandstone, which is overlain by scattered float of small pieces of laminated micaceous red siltstone on a shallow dip slope leading down into the valley, formed in the fine grained sediments of the lower part of the Hunter Formation. The resistant sandstones and conglomerates of the Weddin Formation form the steep cliffs capping the main range, but the lower flanks and even the steeper middle parts of the NE facing escarpment are also formed by fine friable red and green mudstones typical of the Hunter Formation at other localities. These outcrops are almost completely obscured by a scree cover of sandstone and conglomerate, including many large blocks and boulders. Actual outcrops occur in erosion gullies at least half way up the scarp and near the base of the overlying Weddin Formation at localities GY96/7, 8, and 21. Elsewhere the friable mudstone typical of the Hunter Formation may be rarely observed well up the scree slope in the excavations of rabbit burrows, attached to roots of fallen trees, etc.

*Description*
This formation was originally described by Conolly (1965a : 61) as follows:

> 'The Hunter Siltstone is a thick sequence of red siltstones and shales and a lesser proportion of fine-grained red sandstones conformably overlying the Peaks Sandstone and underlying the Mandagery Sandstone. It forms prominent valleys between the strike ridges of the Peaks and Mandagery Sandstones.'

Because the unit tends to be recessive lithologies are often not discernable, but finer grained sediments predominate. In the core of the Redcliff Syncline on 'Arkingarrie' property at locality GY96/42 are typical Hunter Formation lithologies with red mudstones containing abundant burrows, and minor buff siltstone interbeds. 1-2 km to the north the extensive exposure and float of fine siltstone/mudstone is interrupted by a low ridge of fossiliferous arkosic fine sandstones at locality GY96/41, which contain fish remains (see below). Further north at locality GY96/43 this sandstone is seen to lie on the fold axis, with two dip measurements in the same outcrop about 7 m apart of 28° to the east and 48° to the west (both striking at 040°). Because of its position in the fold axis the stratigraphic level of this fossiliferous sandstone unit is difficult to estimate. Similar lithology was observed at locality GY96/237 on the axis of the Yambira Syncline, and at locality GY95/144 on the Yambira Road in the valley of Hunter Creek (type locality). Generally the red siltstone lithology in beds up to .5 m thick are most typical. Yellow and olive-grey siltstones occur near the top of the sequence in the vicinity of Redcliff Mountain, and were separated out as a separate member by Jones (1984), although this subdivision is not followed here.

An extensive exposure of Hunter Formation is seen on the northwest facing escarpment at Redcliff Mountain (e.g. localities GY96/53-55). This outcrop extends to the north into the valley of the headwaters of Warrumba Creek. A more resistant white and red sandstone unit identified by Colwell (1974) to the east of this creek is reinterpreted here as the basal Peaks Formation on the western limb of the adjacent Warrumba Syncline (it dips to the east), which is juxtaposed against the same formation dipping to the west in a probable faulted contact.

*Depositional environment*
A low energy shallow water environment is indicated by the fine-grained sediments, presumably overbank or lacustrine deposits as suggested by Colwell (1974). The presence of lingulid brachiopods associated with fish and plant remains in the Gooloogong Member (see below) might indicate brackish water, perhaps related to marine transgression into a coastal flood plain environment. Circumstantial evidence of a second phase of marine influence at the top of the Hunter Formation (also with abundant fish remains) might be suggested on the basis of a sandy shore environment indicated by the *Skolithos* ichnofacies identified in basal beds of the overlying Weddin Formation (see below).

*Palaeontology*
Fossil assemblages have been found at the base, near the middle, and at the top of the Hunter Formation, as summarised by Young (1997a). Four assemblages may be present (A-D).

**Assemblage A.** The lowest occurrence (locality GY96/57 in the Gooloogong Member type section), first reported by Colwell (1974), includes lingulid brachiopods (first reported by Jones 1984), plant remains, and fish plates referred to the placoderm *Groenlandaspis* sp. The latter have tubercular ornament, so are not conspecific with those from the higher *Grenfellaspis* horizon described by Ritchie et al. (1992).

**Assemblage B.** From the middle part of the Hunter Formation at GY96/41 *Bothriolepis* sp.and a phyllolepid indet. occur about 2 km south of the original *Grenfellaspis* locality at Redcliff Mountain. Of biostratigraphic significance is the phyllolepid plate, a taxon not recorded in the higher *Grenfellaspis* horizon. This is fauna 3 of Young (1999a, fig. 5). Locality GY96/237 in theYambira Syncline may be another occurrence of this fauna (Young 1997a). A new fossil fish locality at GY96/145 in the Weddin Range may belong here, or in Assemblage C below. *Bothriolepis* sp. is the only genus identified at this locality so far (Young 1997a).

**Assemblage C.** This is a poorly known occurrence from the middle part of the Hunter Formation, from where Colwell (1974, pl. 15) illustrated an ADL plate of *Groenlandaspis* sp. which lacks tubercular ornament, and therefore may be conspecific with the species from the *Grenfellaspis* fauna at the top of the formation. It is assumed therefore to be a younger horizon than Assemblage B above.

**Assemblage D.** From the upper part of Hunter Siltstone comes the *Grenfellaspis* fish fauna of Ritchie et al. (1992), recorded from various localities on the Grenfell 1:100 000 sheet. Locality GY96/1 represents new material collected from the 'Eagle's Nest' locality of Ritchie et al. (1992). The faunal list given below, modified from Young (1993: 251), is based on collections from this and other localities, including the original locality at the southern end of Redcliff Mountain. The *Bothriolepis* and *Remigolepis* from the *Grenfellaspis* fauna were described by Johanson (1997).

**Acanthodii:** ischnacanthid gen. nov.
**Placodermi:** *Grenfellaspis branagani* Ritchie *et al.* 1992
*Bothriolepis grenfellensis* Johanson 1997
*Remigolepis redcliffensis* Johanson 1997
*Groenlandaspis* spp.
**Osteichthyes:** ?*Eusthenodon* sp.
?*Ctenodus* sp.
porolepiform gen. nov.

*Age and relationships*
Correlation with the Mount Cole Formation on the Parkes 1:100 000 sheet (previously Pipe Formation; Young 1999b) has been proposed for the lower part of

the Hunter Formation. Young (1999a) suggested that the change to fine-grained deposition in both sequences may have resulted from a the marine flooding event, which caused brackish water conditions indicated by the lingulid brachiopod assemblages found at various localities including the Gooloogong Member type section (Assemblage A above). Also possible is correlation with the Kadina Formation in the Hervey Syncline, from which Sherwin (1996) has recorded crinoid ossicles which indicate marine conditions. Assemblage B above is fauna 3 of Young (1999a, fig. 5), assigned to the early Famennian, and Assemblage D above has been assigned to the late Famennian (Young 1993, 1999a, fig. 5). the latter is correlated with uppermost part of the Bumberry Formation (see below), where locality GY96/174 on the western limb of the southern part of the Eugowra Syncline has yielded the only known articulated specimen of *Grenfellaspis branagani.*

## Gooloogong Member (Dhhg) after Colwell (1974)

*Previous nomenclature*
'Gooloogong Beds' of Colwell (1974, p.28)

*Derivation of name*
From the town of Gooloogong in the north-central part of the Grenfell 1:100 000 sheet.

*Type locality*
The type section was defined by Colwell (1974: fig. 13) in the road cutting on the Gooloogong-Grenfell Road, 7 km west of the town of Gooloogong.

*Thickness*
Colwell (1974) assigned the complete exposed section in the road cutting on the northern side of the road to the 'Gooloogong Beds'. The 96 m exposure is delimited by non outcrop at both ends. However it is evident from normal field outcrop immediately to the north of the road cutting that the lower 20 m of coarser sediments, which are predominantly of reddish colour, should be included within the upper part of the Peaks Formation. Consequently the type section of the Gooloogong Member is here restricted to the upper 80 m of Colwell's (1974, fig. 13) stratigraphic section.

*Distribution and outcrop*
The type section is a good exposure of some 80 m of easterly dipping buff sandstones and siltstones, with minor components of red siltstone, shale and fine-grained sandstone. Generally these beds are poorly outcropping and difficult to observe, and they were recognised only after the road cutting was constructed in the early 1970's. Colwell (1974) considered the unit to lense out rapidly to the south along the Redcliff Syncline, but the poor outcropping characteristics mean that this assessment may not be reliable over large areas. A considerable thickness (possibly partly due to faulted repetition) of typical buff sandstones/siltstones identified as the Gooloogong Member occurs immediately above the Peaks Formation in roadside exposures and gravel scrapes along the Bumbaldry Fire Trail at GR 132.

To the west of the Conimbla Syncline along the Major West Road (e.g. localities GY95/142C-D, 96/251-252), fine buff sandstones/siltstones and red mudstones are observed in the core of a small syncline which may be faulted against the underlying Warrumba Volcanics to the west. However the map of Jones (1984) interpreted the Hunter Formation to lie in unconformable contact with the volcanics around the axis of the Kangarooby Anticline, and further field work is required to check this contact. Similar lithology is seen as far south along strike as locality GY96/255, where lithology typical of the Gooloogong Member was observed in a dam excavation.

*Description*
The type sequence includes buff sandstones and siltstones, with minor components of red siltstone, shale and fine-grained sandstone. Sandstone interbeds are less than 2 m thick, and coarser sandstones such as seen in the underlying Peaks Formation are completely absent. Ripple marks, medium scale cross-stratification, fine laminations, and burrowing an other evidence of bioturbation (tracks and trails) are displayed in the predominantly buff-coloured central part of the type section, and along the Bumbaldry Fire Trail (GR 132, 133).

*Depositional environment*
The fine laminations and ripple marks, tracks and trails and extensive burrowing in some layers suggests a shallow water environment, presumably an estuarine brackish water on the evidence of the lingulid brachiopods. The association of lingulids with plant remains and placoderm plates also occurs in the southern part of the Parkes Syncline (Parkes 1:100 000 sheet) and at Nyrang Creek (Cowra 1:100 000 sheet).

*Palaeontology*
Lingulid brachiopods, plant stems, and fish plates occur in the type locality (Young 1997a).

*Age and relationships*
See discussion above for the Hunter Formation. The similar lingulid/plant/ placoderm association which occurs in the southern part of the Parkes Syncline (Parkes 1:100 000 sheet) and at Nyrang Creek (Cowra 1:100 000 sheet), suggests correlation with the lower part of the Mount Cole Formation of Young (1999b). The fish remains are assumed to indicate a Frasnian (Late Devonian) age, and this horizon possibly relates to the late Frasnian marine transgression identified in other areas (Young 1999a; Young & Turner, in press).

## **Weddin Formation (Dhw)** after Conolly (1965a)

*Previous nomenclature*
Weddin Sandstone of Conolly (1965a)
Mandagery Sandstone (in part); Conolly (1965a)
Bumberry Formation (in part); Conolly (1965a)

Eurow Formation (in part); Conolly (1965a)

In addition to its type locality (Weddin Range), this formation name is applied to a considerable thickness of strata which occur widely within the eastern part of Hervey Group outcrop on the Grenfell 1:100 000 sheet south of the Lachlan River, the base of which is the major bluff-forming sandstone unit in the area. This basal unit was previously identified by Conolly (1965a) as the 'Mandagery Sandstone', but the type section of the Mandagery Formation occurs in the Parkes Syncline, some 40 km to the north on the Parkes 1:100 000 sheet. There is no reliable ground for correlation across this distance, and as noted above, the Mandagery Formation is considered instead to broadly correlate with the other major sandstone interval lower in the sequence on the Grenfell 1:100 000 sheet (the Peaks Formation). Some close lithological similarities have been noted between the upper bluff-forming sandstones in the Redcliff Syncline - Broula Anticline region, and those forming the main escarpment in the Weddin Range, suggesting that the term 'Weddin Formation' is better applied to these upper sandstone strata, a conclusion supported by a small number of relevant palaeontological data points (see below). As a result of this revision, the term 'Mandagery Formation' has not been used anywhere on the Grenfell 1:100 000 sheet.

Similarly, the 'Bumberry' and 'Eurow' Formations recognised in the Gooloogong-Grenfell region by Conolly (1965a, fig. 11) are here included within the Weddin Formation, since these formations also have their type sections in the Parkes Syncline. There is little point in attempting subdivision of the Weddin Formation based on lithology, but the one constituent member defined below can be identified by its distinctive fossil fish fauna.

*Derivation of name*
From the Weddin Range, in the SW corner of the Grenfell 1:100 000 sheet. In the language of the Wiradjuri tribe which inhabited the Lachlan River basin, the word *weedin* means 'a place to sit, stay or remain' (Kabaila 1996).

*Type locality*
Conolly (1965a: 72) defined the type section of the Weddin Sandstone as a sequence which 'forms rugged sandstone cliffs 800 feet high ... near Black Spring Mountain in the Weddin Range'. He stated that 'the Nangar Sub-Group cannot be subdivided into individual formations in the Weddin Range', but as noted above equivalents of both the Peaks and Hunter Formations can be recognised in this sequence. The type section thus needs to be limited to the upper part of Conolly's measured section, presumably including the upper 1050' which was said to include 'several 10' to 20' thick conglomerate layers'. Conolly gave a total thickness of 1500' (457 m) for the type section, but the sequence continues for some 5 km to the south of Black Spring Mountain, with upper strata observed on the adjacent Young 1:100 000 sheet (GY96/23). A section examined at locality GY96/21 (gully 3 km SE of Black Spring Mountain) is summarised below. Conolly's type section was given as follows:

TOP

Fine and medium-grained white and buff sandstones with interbedded green and white siltstones .....
122 m

Medium white sandstones, coarse sandstones interbedded with several 10′ to 20′ thick conglomerate layers .....
198 m

BASE

White and red sandstones, conglomerate, but many fine red and white sandstones and siltstones .....
137 m

TOTAL THICKNESS 457 m

However estimation from air photo interpretation suggests a considerably greater thickness than this, and it is not clear precisely where the above type section was measured, although apparently it did not go right through the range (e.g. Conolly 1965b, fig. 2). If through the Weddin Gap (about 3 km NW of Black Spring Mountain) then the section may not be reliable since faulting is evident in this vicinity. Furthermore the structure was misinterpreted by Conolly, being a shallow syncline with axis trending at about 330°, with the uppermost preserved strata occurring only in the core of the syncline on the adjacent Marsden 1:100 000 sheet. An auxiliary section in the type locality is proposed here from the eastern escarpment at GR593450 624410, running across strike SW at about 240° across the range and down Guinea Hen Creek to locality GY96/149 on the Marsden 1:100 000 sheet, where the highest strata are preserved.

*Thickness*

The 457 m thickness in the type locality given by Conolly (1965a) seems to be a considerable underestimate. Air photo estimation of thickness of a section across strike from the escarpment near Black Spring Mountain to the uppermost preserved strata to the SW in the vicinity of locality GY96/23 (Young 1:100 000 sheet), suggests a thickness of 1000-1200 m, using measured dips at both ends of the section in the range 16-20°. The auxiliary and more complete section to the north, crossing the range and running approximately along the gully of Guinea Hen Creek, gives an estimated thickness of about 1150 m using a dip of 15° (measured at the eastern end), or about 800 m using a dip of 10° (measured at the western end). The formation is much thinner in some parts of the Grenfell 1:100 000 sheet, where the upper part is largely removed by erosion. It is 100-400 m thick in the Warrumba Range area (Colwell 1974), and at Mt Yambira forms a thin cap of about 20 m section above the Hunter Formation (Jones 1984). Conolly (1965a :61-62) mentioned thicknesses of the 'Mandagery Sandstone' of 165-224 m in the Gooloogong - Grenfell region, and some 980-1050 m thickness of 'Bumberry Formation' to the east of the Kangarooby Anticline, both formations included here in the Weddin Formation. Thus, total thickness in the east would compare with or perhaps exceed that of the type section. No detailed new sections have been measured because structural complications mean repetition of strata is difficult to detect.

*Distribution and outcrop*

The Weddin Formation forms an impressive series of rugged cliffs in the type area of the Weddin Range, reaching a height of 712 m at Weddin Mountain. As noted above, the lower flanks and steeper middle parts of the NE facing escarpment are actually formed by finer sediments of the Hunter Formation, which are mostly obscured by a scree cover of sandstone and conglomerate blocks and boulders. At the eastern extremity of the Weddin Range (locality GY96/37), the edge of the outcrop is pipe rock, elsewhere seen near the base of the Weddin Formation. To the NE, the Weddin Formation forms the bluffs capping Redcliff and Yambira Mountains although the thickness is considerably less in the flat-lying strata in the cores of the Redcliff and Yambira Synclines because much of the upper part has been lost to erosion. To the east the Weddin Formation forms the sandstone ridges of the Conimbla Range, and occupies the core of the Conimbla Syncline. In the NE in the region of Pipe Clay Creek and N of Barryrenie Road, the Weddin Formation contains a much higher proportion of finer siltstones and mudstones than in the Weddin Range, thus resembling the correlative units on the northern side of the Lachlan River, the Bumberry and Eurow Formations.

*Description*

A good section was observed at locality GY96/21 up the gully on the eastern escarpment beneath Weddin Mountain, where the first sandstone outcrop occurs some 30 m above one of the few high exposures of the Hunter Formation. Lithology of the basal beds of the Weddin Formation is a massive grey-buff quartzite in 40-50 cm thick beds, some with abundant rounded mudclast horizons (up to 10 cm across), and 'pipe rock' with *Skolithos* burrows is common. This is some 30-40 m beneath the first cliff-forming sandstone, also observed further east at

locality GY96/9, which is characterised by a basal scour fill with abundant mudclast impressions, overlain by a massive yellow/buff fine orthoquartzite with bedding between 1 m and 40 cm thickness, some tabular cross-beds, and parting lineations, but above the basal scour fill few if any pebble or mudclast inclusions. This is in contrast to the two higher bluffs forming the top of the escarpment, each separated by some 20-30 m of scree, which comprise small cliffs of massive pebbly sandstone and conglomerate each 2-3 m thick. The lower part of the Weddin Formation was also observed at the eastern extremity of the range (GY36-37), again displaying cross-bedded sandstone and pipe rock lithologies. The lithology of the upper part of the Weddin Formation in this section was observed at locality GY96/23 on the southern side of the Weddin Range, where buff/yellow cross-bedded sandstones with some small pebble layers crop out right to the National Park boundary.

Lithologies in the northern part of the range were observed at locality GY96/143-144 (base), and locality GY96/147-51 on the Marsden 1:100 000 sheet (uppermost preserved strata). At locality GY96/143 the lowest sandstone exposure is a light buff quartzite, with large tabular cross-beds at some horizons, but otherwise massive in outcrop. Again, pipe rock was observed in the scree. The top of the sequence at locality GY96/149 is a massive cross-bedded sandstone unit some 6 m thick which forms a conspicuous bluff in the core of the syncline, delimiting a small plateau of flat-lying bedded sandstones with platey outcrop which are not well exposed, comprising the uppermost preserved strata with an estimated thickness of 10-20 m. Beneath the bluff the scree contains much evidence of bioturbation (worm burrows etc.), and although poorly exposed, the valley is apparently the result of a fine-grained interval observed to the south at localities GY96/ 150-51 as washouts of very friable red/green mudstone gravel.

Elsewhere the basal beds of the Weddin Formation were observed to show similar lithologies to the type area. At Redcliff Mountain (..45) the first sandstone outcrop about 5 m above the highest exposure of the Hunter Formation is a bluff-forming massive cross-bedded sandstone, again lacking pebbles, which is succeeded some 30 m up section by a thicker massive unit (10-12 m) forming the cliff at the top of the western slope. This is characterised by cross-beds in tabular sets 40-50 cm thick, and a few pebble layers. Proceeding east towards the core of the Redcliff Syncline the distinctive pebbly sandstones with low angle cross-beds are encountered up sequence, as in the Weddin Range. In the Conimbla Range east of Kangarooby Creek the basal Weddin Formation was observed at locality GY96/115, again a massive cross-bedded sandstone with few pebbles overlying scree-covered slopes of Hunter Formation.

A distinctive by 'pipe rock' lithology with abundant *Skolithos* burrows ranging in diameter from 10-20 mm was observed in outcrop and scree at several localities along the Weddin escarpment, and apparently characterises the basal part of the Weddin Formation, since it disappears consistently from the scree at about the same level as one proceeds up the gullies. The same facies was observed in the core of the Conimbla Syncline (GY96/261), and also in an outcrop assigned to the basal

part of the equivalent Bumberry Formation north of the Lachlan River at locality GY96/213, and in scree at GY96/212.

In the NE part of the main Hervey Group outcrop, to the east of the Conimbla Range, the Weddin Formation contains more fine-grained units (siltstones and mudstones) and less sandstone and conglomerate than in the type area of the Weddin Range.

*Depositional environment*
A fluvial environment has been proposed, and Conolly (1965a: 73) stated that palaeocurrent indicators were consistently from the north in the Weddin Range area. The basal part of the unit, characterised by 'pipe rock' of medium-grained sandstone or quartzite with abundant *Skolithos* burrows ranging in diameter from 10-20 mm, is an uncommon lithology within the Hervey Group. The *Skolithos* ichnofacies is widely regarded as indicative of a sandy shore environment (e.g. Frey 1975; Howard & Frey 1984; Bjerstedt 1987). The initiation of coarser sedimentation at the Hunter/Weddin transition may therefore have resulted from a sea level rise.

*Palaeontology*
According to Conolly (1965a: 73), in his 'Weddin Sandstone ...fish plates ... are fairly abundant and similar to types described by Hills (1932, 1936) from the Hervey Range', but this has not been confirmed on the Grenfell 1:100 000 sheet, with the exception of the Culela Member (see below). Otherwise, only two small fragments of possible fish plates have been identified after extensive examination of outcrop including abundant broken blocks, many with mudclast horizons which would normally reveal fish remains if present. Conolly (1965a) also noted traces of fish and plant impressions attributed to both the Mandagery and Bumberry Formations in the Gooloogong-Grenfell region. Impressions of the lycopod plant *Leptophloeum australe* were found in the measured section at Yarrabunda (GY96/85) some 36 m above the Culela fish fauna (see below), and small invertebrates occur at locality GY96/87. At locality GY96/148 (Marsden 1:100 000 sheet) an impression of *Leptophloeum australe* was found in sandstone scree near the axis of the syncline, and derived from the uppermost 50 m (estimate) of the preserved section in the Weddin Range (abundant evidence of bioturbation also occurs at this locality).

*Age and relationships*
The Culela fish fauna (see below) is assigned a provisional latest Famennian age in the new macrovertebrate biostratigraphic scheme of Young (1999a, fig. 5, assemblage 6). Evidence from the Bumberry Formation north of the Lachlan River confirms a close association with abundant lycopod remains (*Leptophloeum australe*; see below). The occurrence of this plant very close to the preserved top of the Hervey Group in the southern part of the Weddin Range is significant, since the upper limit of *L. australe* approximates to the late Famennian *praesulcata* or *costatus* conodont zones (Mory 1981; Pickett, 1993b: 281), and is not considered to extend across the Devonian-Carboniferous boundary (Young 1995, 1996). This would

suggest that the Weddin Formation is confined to the Late Devonian (Famennian) rather than extending into the Carboniferous, at least in its preserved part.

The Weddin Formation as interpreted here is considered to broadly correlate with part or all of the Bumberry, Eurow, and Wingara Formations on the Parkes 1:100 000 sheet (see below).

## Culela Member (Dhwc) *nov.*

*Derivation of name*
From 'Culela' property, whose owner Neville Fragar was the first to discover the Culela fish fauna which occurs in this member.

*Type locality*
The type section is included in a measured section across the eastern limb of the northern extension of the Conimbla Syncline on 'Yarrabunda' property (section base at locality GY96/159; section top at GY96/161).

*Thickness*
113 m of interbedded green/red siltstones, fine buff sandstones and red mudstones form a recessive unit between ridge-forming sandstones which define the base and top of the member. The fish assemblage comes from the top of a 10 m interval of red mudstone 77 m above the base of the member (top of the underlying sandstone).

*Distribution and outcrop*
This is a distinctive fine grained unit with recessive outcrop which tends to form valleys within the sandstones that predominate in the Weddin Formation. Part of the valley of Barryrenie Road is formed by the Culela Member, and its non-outcrop apparently delimits the eastern margin of Hervey Group outcrop in the Broula Anticline (off the eastern margin of the Grenfell 1:100 000 sheet). It crops out to the north on Yarrabunda and Culela properties, where it is extensively folded. From the type section it can be traced on air photos to the north into the valley of Pipe Clay Creek, where the distinctive Culela fish fauna has also been identified. It is evident that this member occurs close to the top of the Weddin Formation sequence in this area. On both sides of the northern extension of the Conimbla Syncline the Culela Member can be traced on air photos as a more recessive unit, but with the steeper dips its topographic definition is sometimes uncertain. In general, this uppermost part of the Weddin Formation sequence in the northeastern part of the outcrop on the southern side of the Lachlan River contains more fine-grained units interbedded with thinner sandstones than in the Weddin Range, as in the equivalent strata north of the Lachlan River (Bumberry and Eurow Formations). Where the Culela Member crosses the Barryrenie Road (between GY96/67-68) the radiometric image indicates high K, U and Th levels as in the Hunter Formation, but to the east and north of this point radiometrics are difficult to relate to the geological structure of the area as previously mapped by Conolly (1965a). This area

is complexly folded and faulted, and more detailed fieldwork is necessary to clarify the provisional outcrop pattern shown on the map.

*Description*
Typical lithologies in this unit are red/green mudstones and siltstones and interbedded fine sandstones. Lithologies and outcrop pattern are generally similar to the Hunter Formation, but the member is clearly much higher in the sequence, and contains a different vertebrate fauna.

*Depositional environment*
A low energy shallow water environment is indicated by the fine-grained sediments, which were presumably laid down as overbank or lacustrine deposits.

*Palaeontology*
The Culela fish fauna has been identified at localities GY 96/79, 85, 103, 104 and 270.
A preliminary list of identified taxa is as follows:

| | |
|---|---|
| Placodermi: | large remigolepid antiarch |
| | *Bothriolepis* sp. |
| | *Groenlandaspis* sp. |
| Osteichthyes: | scales and bones (crossopterygian; ?actinopterygian) |
| Plantae: | plant remains (incl. *Leptophloeum* in a higher horizon) |

*Age and relationships*
The Culela fish fauna is Assemblage 6 in the new macrovertebrate biostratigraphic scheme of Young (1999a, fig. 5), which has been assigned a provisional latest Famennian age. The Culela Member, as a recessive member near the top of the Weddin Formation, may be equivalent to the recessive unit near the top of the Weddin Range sequence identified near the axis of the syncline on the Marsden 1:100 000 sheet as a recessive valley beneath the uppermost preserved sandstone unit (localities GY96/148-151). As noted above, the lycopod *Leptophloeum australe* has been found at both localities. It is noteworthy that this lycopod is also common in the upper part of the Eurow Formation at locality GY96/187 north of the Lachlan River, which has also yielded the Culela fish fauna, and again is overlain by a sandstone unit close to the preserved top of the sequence (interpreted below as equivalent to the Wingara Formation on the Parkes 1:100 000 sheet). On this basis a provisional correlation is proposed with the uppermost part of the Eurow Formation on the Parkes 1:100 000 sheet.

## **Bumberry Formation (Dhb)** after Conolly (1965a)

*Previous nomenclature*
Conolly (1965a) applied this term to all the sections of the Hervey Group on the Grenfell 1:100 000 sheet with the exception of the Weddin Range, but with some difficulty. The two lithologically similar sandstone units (Mandagery, Bumberry) were supposedly distinguished in the type section through the Parkes Syncline by the intervening valley of recessive 'Pipe Formation'. However, in the Gooloogong-

Grenfell region the Bumberry was mapped as lying directly above the Mandagery, so criteria for distinguishing these two lithologically similar formations is unclear. These sequences were reinterpreted above to be equivalent to the Weddin Formation.

In this revision of Hervey Group stratigraphy for the Grenfell 1:100 000 sheet, the term Bumberry Formation is used only on the northern side of the Lachlan River, where there is continuity of outcrop onto the Parkes 1:100 000 sheet to the north.

*Derivation of name*
From the Bumberry Syncline, about 20 km E of Parkes on the Parkes 1:100 000 sheet.

*Type locality*
The type section of the Bumberry Formation occurs on the Parkes 1:100 000 sheet in the Mandagery railway section of Conolly (1965a: 57). The type section is a sequence of four fining-upward cycles, each with pebbly white sandstones at the base, interbedded red siltstones and white sandstones in the middle part, and fine red siltstones and shales at the top (Conolly 1965a, fig. 10).

*Thickness*
Conolly (1965a: 57) recorded a measured thickness of 707 m in the type section, and commented that in the Nyrang Creek section the uppermost of the four cycles was 'so thick it must be considered as part of the Cookamidgera Sub-Group'. Thus the definition of the boundary with the overlying Eurow Formation is unclear. No section has been measured in the Grenfell sheet outcrop on the northern side of the Lachlan River. As noted above, the thicknesses of up to 1050 m attributed by Conolly (1965a) to the Bumberry Formation in the Kangarooby Anticline area to the south are now included within the Weddin Formation.

*Distribution and outcrop*
On the Grenfell 1:100 000 sheet the Bumberry Formation is identified on the northern side of the Lachlan River by extension from the southern edge of the Parkes 1:100 000 sheet.. It flanks both sides of the valley of Nanami Creek, as a southern extension of the Eugowra Syncline. Along the western limb of this syncline the formation forms the prominent outcrop of the Barwigie Hills, which is truncated to the west by faulting against the Milandra Granite (e.g. locality GY96/171). Along the eastern limb it forms another row of hills extending from just north of the Cowra-Eugowra Railway line to the Canowindra-Eugowra Road, where it occupies the core of a major anticlinal structure. Further east it is overlain by the more fine-grained strata of the Eurow Formation.

*Description*
The Bumberry Formation is predominantly a coarse grained unit on the Grenfell 1:100 000 sheet, and the four fining-upward cycles identified by Conolly (1965a) in the type section are not evident this far to the south. The lowest beds observed at locality GY96/171 (faulted to the west) are laminated buff siltstones with festoon cross-bedding, which are lithologically similar to the Gooloogong Member of the

Hunter Formation to the south. These are interpreted as a finer-grained interval near the base of the Bumberry Formation. Higher in the section through the Barwigie Hills lithologies include coarse cross-bedded feldspathic gritstone (GY96/169), and laminated cross-bedded sandstones (GY96/168), the former resembling lithologies in the Peaks Formation, and the latter lithologies in the Weddin Formation, the assumed broad correlative of the Bumberry Formation across the Lachlan River. At some localities higher in the sequence (e.g. locality GY96/173) laminated cross-bedded sandstones are interbedded with burrowed red mudstones (generally rercessive; observed only as chips in the soil). Conolly (1965a) identified a small outcrop of basal Eurow Formation at the top of the Barwigie Hills sequence, but this section is interpreted here to represent the uppermost fine cycle of the Bumberry Formation. At these localities (GY96/174-175) are quarries in a red mudstone unit (containing fish, plant remains, and abundant burrowing; see below) which is overlain by a 40 m thick section comprising two prominant sandstone horizons separated by another fine-grained interval (no outcrop). The upper bed of coarse red sandstone (7.5 m thick) is the highest outcrop in this valley, and is assumed therefore to represent the top of the Bumberry Formation. Exactly the same sequence is seen at locality GY96/176 on the eastern limb of the Eugowra Syncline, the intervening valley occupied by the overlying recessive Eurow Formation being devoid of outcrop. Further south along the eastern limb, a lower fine-grained interval of the Bumberry Formation is exposed in the core of the Nanami Anticline at locality GY96/226 (red mudstone), with overlying laminated cross-bedded quartzites observed at locality GY96/227. Interbedded sandstones and siltstones crop out along the northern bank of the Lachlan River (GY96/220-221), faulted out the the west. This folded and faulted section is assumed to represent the more fine-grained upper part of the Bumberry Formation. At GY96/213 a syncline axis is observed in a pipe rock lithology (*Skolithos*) resembling this ichnofacies in the basal part of the Weddin Formation.

On the eastern limb of the Nanami Anticline at locality GY96/177-180 interbedded cross-bedded laminated sandstone and red mudstone units (the latter non-outcropping) aparently represent the gradational upper boundary of the Bumberry Formation. At locality GY96/181 a highly cleaved phyllitic mudstone was observed in a dam-wall excavation, and farther east the sequence is dominated by similar highly cleaved fine-grained sediments, assigned below to the Eurow Formation.

*Depositional environment*

A fluvial/coastal plain or near shore moderate energy environment is indicated by the predominant cross-bedded sandstone lithologies.

*Palaeontology*

A new locality of the *Grenfellaspis* fish fauna first described by Ritchie et al. (1992) was discovered in red mudstone forming an upper recessive unit near the top of the Bumberry Formation at locality GY96/174, a gravel quarry on the western limb of the Eugowra Syncline. Continuity of outcrop along strike to the north establishes the stratigraphic position of this new fish horizon as approximating the upper Bumberry-lower Eurow interval as mapped on the Parkes 1:100 000 sheet.

*Age and relationships*
The *Grenfellaspis* fish fauna is assigned a late Famennian age by Young (1999a, fig. 5, Assemblage 5), and the new occurrence near the top of the Bumberry Formation at locality GY96/174 suggests that the formation may be equivalent to the upper part of the Hunter Formation and lower part of the Weddin Formation in the Hervey Group outcrops south of the Lachlan River.

## Eurow Formation (Dhe) after Conolly (1965a)

*Previous nomenclature*
The Eurow Formation was the only named formation within the 'Cookamidgera Sub-Group' of Conolly (1965a), above which in excess of 230 m of undifferentiated sediments were estimated in the Mandagery Railway section on the Parkes 1:100 000 sheet (Conolly 1965a: fig. 10). Although Pogson & Watkins (1998) proposed a 'Cookamidgera Formation' containing a lower 'Eurow Member', the name Eurow Formation was retained as a formation by Young (1999b), as seems appropriate for a sequence some 680 m thick.

*Derivation of name*
The type area near Cookamidgera on the Parkes 1:100 000 sheet was said to form the headwaters of Eurow Creek (Conolly 1965a), and the name is also used for the Eurow Mountains which form the southeastern flank of the Parks Syncline.

*Type locality*
There has been confusion about the type locality of the Eurow Formation (see Young 1999b). It seems that Conolly (1965a: 57) erroneously gave 'Bumberry Syncline' as the type area, when he should have referred to the Parkes Syncline, which is also the type section for the Cookamidgera Sub-Group, of which the Eurow Formation was the only named unit in this section (Conolly 1965a, table 1).

*Thickness*
Conolly (1965a) estimated a thickness of at least 680 m in the type section, and at least 650 m 'where the Nangar Anticline pitches to the south near Gooloogong'. This is the main outcrop mapped on the Grenfell 1:100 000 sheet.

*Distribution and outcrop*
The Eurow Formation on the Grenfell 1:100 000 sheet is identified only on the northern side of the Lachlan River, in basically the same outcrop tract as originally mapped by Conolly (1965a, fig. 8). It also occupies the core of the Eugowra Syncline in the valley of Nanami Creek, but there are no exposures in the mapped part of this valley, although they are recorded farther north in the extension of the Eugowra Syncline onto the Parkes 1:100 000 sheet. The Eurow Formation is generally recessive, and exposed only in small outcrops through the alluvial cover. Conolly (1965a) identified a small outcrop of basal Eurow Formation on the western side of the Nanami Road, but as noted above this section is considered to represent the uppermost fine cycle of the Bumberry Formation.

To the east of the Nanami Anticline, the Eurow Formation forms extensive outcrops on Mount Gooloogong and Namani Sugarloaf, where the prominence of outcrop seems partly due to the strong vertical cleavage, which has apparently rendered the fine siltstone and mudstone lithologies more resistant to weathering.

*Description*
Massive redbeds comprising dark grey/maroon siltstones and red mudstone/shale are the dominant lithologies, as seen in the gravel quarries at locality GY96/187-188. Because of the massive lithology bedding may be difficult to distinguish from cleavage. Worm burrows are abundant at some horizons in these quarries. In many areas there is little or no outcrop, with only red mudchips in the soil, or friable shale observed in gullies and washouts. At locality GY96/182-184 good outcrop was observed due to the strongly developed axial plane cleavage which on air photos suggests steeply dipping strata. These massive dark maroon siltstones/mudstones contain little evidence of bedding, but burrowing may be common at some levels. Ripple marks and dessication cracks were observed at a few localities.

*Depositional environment*
A low energy shallow water environment as alluvial plain, overbank or lacustrine deposits is suggested, with occasional subaerial exposure, probably in a coastal plain setting.

*Palaeontology*
The Culela fish fauna was identified near the top of the Eurow Formation at locality GY96/187, again associated with the lycopod *Leptophloeum australe* which has apparently been commonly found in the local area (N. Campbell, pers. comm.). *Leptophloeum* is also recorded from a quarry within the Eurow Formation at locality GY96/210, on the eastern slope of Mount Gooloogong.

*Age and relationships*
The identification of the Culela fish fauna near the top of the Eurow Formation indicates correlation with the Culela Member, defined above as a recessive member near the top of the Weddin Formation in the outcrops south of the Lachlan River. As noted above the lycopod *Leptophloeum australe* is associated in both sequences, and was also found immediately above the recessive unit forming the valley beneath the uppermost preserved sandstone unit of the Weddin Formation in the southern part of the Weddin Range on the Marsden 1:100 000 sheet. *Leptophloeum* impressions may fortuitously be found at various levels within the Hervey Group, but the predominance of lycopod remains at the horizons discussed here suggests some significant vegetation change, perhaps caused by climatic change, or some other 'event' of potential correlation value.

A provisional latest Famennian age is indicated for the Eurow Formation, on the evidence of the Culela fish fauna (see Young 1999a, fig. 5).

## Wingara Formation (Dhw) after Young (1999b)

*Previous nomenclature*
Conolly (1965a) named only the Eurow Formation within his 'Cookamidgera Sub-Group', and the overlying 330 m of undifferentiated sediments in the type section through the Parkes Syncline Railway section was named the Wingara Formation by Young (1999b).

Since this formation in the type area comprises a basal sandstone unit with overlying the fine-grained sediments, which sits above the Eurow Formation, the name can be applied to an equivalent cross-bedded quartzite unit observed to overlie the red beds of the Eurow Formation in the hills to the north and east of Namani Sugarloaf and near the top of Mount Gooloogong.

*Derivation of name*
From 'Wingara' property about 9 km south of the village of Cookamidgera (Parkes 1:100 000 sheet).

*Type locality*
The type section was defined in the core of the southern part of the Parkes Syncline, just north of Wingara homestead, where a sequence of 150-200 m of is exposed.

*Thickness*
A measured section in folded sediments at Gooloogong trig. (GY96/202) passed through about 50 m of interbedded lithic siltstones and fine sandstones above a light grey/buff cross-bedded quartzite some 10 m thick (estimate), which is considered to represent the basal part of the Wingara Formation capping the Eurow Formation at this locality.

*Distribution and outcrop*
This name is applied to a massive cross-bedded quartzite unit observed to overlie the red mudstones of the Eurow Formation in the hills to the north and east of Namani Sugarloaf. This formation is also identified near the top of Mount Gooloogong, with sandstones assigned to forming ridges extending to the north of Gooloogong trig towards the Cowra-Eugowra Railway line, and no doubt contributing to the preservation of the normally recessive underlying Eurow Formation in this area. This formation is at the top of the Hervey Group succession, and at all localities the upper part is lost to erosion.

*Description*
Above the gravel quarry in Eurow Formation at locality GY96/187 is a light buff to grey sandstone unit 3-5 m thick, with a characteristic massive boulder-like outcrop. This coarser-grained sequence is observed to the south at locality GY96/190, where it is more laminar and cross-bedded, with blocky outcrop and some high angle foresets in beds up to 1 m thick. Interbedded are some thin recessive units, which are entirely scree-covered intervals. The sandstones extend south along this ridge to locality GY96/192. To the west at locality GY96/189, the same massive unit

forms a resistant cap to the hill behind the gravel quarry at locality GY96/188, and also apparently crops out across the top of Namani Sugarloaf (air photo interpretation; field checking required). South of the Cowra-Eugowra Railway line the same lithologies were observed in the resistant ridges at locality GY96/214-218. At Gooloogong trig. a sequence of about 50 m of interbedded recessive friable red mudstones and red/purple lithic siltstones with a lumpy bedded outcrop forms the axis of a syncline flanked downslope on both sides by a much cleaner massive cross-bedded quartzite. Since quarries beneath this horizon at the lower southeast flank of the mountain on the Gooloogong Canowindra Road (GY96/212) reveal red mudstone lithologies typical of the Eurow Formation, the overlying strata are interpreted as Wingara Formation.

*Depositional environment*
The coarser sandstone lithology suggests a return to a higher energy fluvial and/or sandy shore environment.

*Palaeontology*
No fossils have been found in this formation, but as noted above the gravel quarry at locality GY96/187 contains fish remains associated with the lycopod *Leptophloeum* in the mudstones immediately beneath the Wingara Formation.

*Age and relationships*
This formation represents the eroded top of the Hervey Group sequence for the Grenfell 1:100 000 sheet on the northern side of the Lachlan River, and is therefore assumed to correspond broadly to the uppermost beds of the Hervey Group south of the river. As noted above, the occurrence of the lycopod *Leptophloeum* near the eroded top of the Weddin Formation in the southern flank of the Weddin Range suggests a latest Devonian age for these strata, and a similar age is assumed for the Wingara Formation.

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