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

by

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

G.C. Young

Abstract

Remapping of the Middle-Upper Devonian Hervey Group on the Parkes 1:100 000 Sheet Area involved reassessment of type sections of the Mandagery, Bumberry and Eurow Formations exposed in an 8 km section along the Sydney-Broken Hill railway line through the Parkes Syncline. A new formation name (Boulton Formation) is proposed to replace the basal 'Kadina Formation' of previous usage. Radiometrics show that the overlying Mandagery Formation was misidentified in the Bumberry Syncline, and is much less extensive than originally mapped. The overlying Mount Cole Formation (new name) replaces the 'Pipe Formation' of previous usage. A new formation (Wingara Formation) is defined for the sandstone unit at the top of the Eurow Formation in the core of the Parkes Syncline. Based on some 40 new fossil localities documented from various horizons within the Hervey Group, new correlations are proposed with the type area in the Hervey Syncline, and across the Lachlan River to Hervey Group outcrops on the Grenfell 1:100 000 sheet. The age of the Hervey group is considered to range from probable late Middle Devonian (Givetian) to Famennian (late Late Devonian).

INTRODUCTION

The Hervey Group of central NSW is represented on the Parkes 1:100 000 sheet in three major areas of outcrop, as first mapped by Conolly (1965a). The **Parkes** and **Bumberry** Synclines occur to the southeast and east of Parkes, each truncated by major fault systems along their western and eastern margins respectively. The western limb of the **Eugowra** Syncline occurs at the eastern margin of the map sheet northeast of Eugowra. The Parkes Syncline contains the type sections of three formations (Mandagery Sandstone, Bumberry and Eurow Formations) in the stratigraphic subdivision of the Hervey Group proposed by Conolly (1965a). These are exposed in a series of outcrops and cuttings along an 8 km section of the main western railway line to Parkes (Sydney-Broken Hill railway), which passes through the Parkes Syncline between the villages of Mandagery in the east and Cookamidgera in the west. The latter village gives its name to the uppermost 'Cookamidgera Sub-group' in the stratigraphic scheme proposed by Conolly (1965a).

The Hervey Group is generally characterised by timbered country of higher relief formed by sandstone ridges of the Mandagery and Bumberry Formations. On the southeastern flank of the Parkes Syncline the Eurow Mountains formed by the basal

Bumberry Formation reach 644 m, and the same strata form the Bumberry Ridges in the Bumberry Syncline about 20 km east of Parkes, where similar high relief has been utilised in the construction of the Bumberry and Lake Endeavour reservoirs for the Parkes water supply.

Fieldwork during which this restudy of the Hervey Group was undertaken was carried out in 1995 under the National Geoscience Mapping Accord. With the aid of modern colour air photos, and radiometric and gravity maps, and discovery of some 40 new fossil localities at various horizons within the Hervey Group, some significant new correlations are proposed below, with new formations defined and type sections specified. A full listing of new fossil localities on the Parkes 1:100 000 sheet is given in Young (1997a:3-5). However the basic stratigraphic framework originally proposed by Conolly (1965a) is maintained. Information relevant to age control and correlation within the Hervey Group is summarised for individual formations in the stratigraphic subdivision presented below. A preliminary biostratigraphic analysis of new fossil data is presented by Young (1999a), and Devonian timescale and stage name usage is based on the AGSO Phanerozoic timescale (see Young 1995, 1996, 1997b).

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HERVEY GROUP

Nomenclature, derivation, type locality and subdivision

The Hervey Group was named by Conolly (1965b) after its type section in the Hervey Range on the Narromine 1:250 000 sheet (see also Conolly 1965a, 1969; Sherwin 1996). However type sections for several of the constituent formations of the Hervey Group were defined elsewhere, and for the Parkes 1:100 000 sheet Conolly (1965a) erected and defined type sections for the Mandagery Sandstone, and Bumberry and Eurow Formations in the exposures along an 8 km section of the Orange-Broken Hill railway line passing through the Parkes Syncline about 15 km SE of Parkes. In its type section in the Hervey Range a sequence of resistant quartzose sediments at least 1600 m thick is exposed, and this was subdivided by Conolly (1965a) into three subgroups and six formations. However, problems have arisen in attempting lithological correlation of Hervey Group formations between different areas of outcrop, and the suggested equivalence and applicability of formation names over long distances was questioned by various workers (e.g. Sherwin 1973, 1996; Campbell & Bell 1977; Ritchie et al. 1992; Young 1999a). The new stratigraphic terminology presented below is based on type sections through the complete Hervey Group sequence in the Parkes Syncline, with suggested

correlations relying on palaeontological data and event stratigraphy rather than lithology.

BOULTON FORMATION nov.
Bolten Formation - Conolly (1965a)
Kadina Formation (in part) - Conolly (1965a)
Bolton Formation - Brunker (1972)

Previous nomenclature
This name is used for the basal formation of the Hervey Group on the Parkes 1:100 000 sheet, to replace 'Kadina Formation' as used by Conolly (1965a). The Kadina Formation was the only named formation recognised by Conolly within his lower 'Beargamil Sub-Group' for the Parkes-Manildra area (see Conolly 1965a, table 1), but its type section is near Kadina Trig station in the Hervey Range on the Narromine 1:250 000 sheet (Conolly 1965a: 47). Here, the 'Beargamil Sub-Group' includes also the underlying Clagger Sandstone, a coarser-grained red unit including reddish - purple sandstones, conglomerates, and some red shales and siltstones (see Sherwin 1996). Conolly cited as the 'type section for the Beargamil Sub-Group' his measured section 'one half mile due east of Beargamil Dam', where 'two to three hundred feet of basal red conglomerates, red arkoses and lithic sandstones rest with a marked angular unconformity on acid volcanics and tuffs of probable Lower Devonian age' (Conolly 1965a: 45-46). Elsewhere (Conolly 1965a: 55) this type section was also referred to as the 'Kadina Formation immediately west (*sic*) of Beargamil Dam', but since his map shows granite immediately west of the dam, with 'Bolten Formation' immediately to the east, this is assumed to be an error. Remapping east of the dam has shown that the base of the Hervey Group is separated from the dam by both granite and Dulladerry Volcanics, so this should be disregarded as a type section for the 'Beargamil Sub-Group'.

The name 'Kadina Formation' was presumably applied in the Parkes-Manildra area because of an assumed correlation with the type locality, but Conolly's intentions are unclear as published, because the basal formation of the Hervey Group is also named 'Bolten Formation' on his map (Conolly 1965a, fig. 8). This name was derived from the section described as 'red siltstone and shale unconformably overlying older Palaeozoic green shales of probable Silurian age' at 'Mt. Bolten on the eastern limb of the Parkes Syncline' (Conolly 1965a: 55). This informal name, 'Bolten Formation', has priority, but was misspelt 'Bolton Formation' on the 1972 Forbes 1:250 000 sheet, and has been confused with another unit, the 'Boltons beds' (Silurian) in the Tantangara region of NSW (C. Brown, in litt. 1 August 1995), so this spelling has been discontinued.

Here, the correct spelling given on the Parkes 1:50 000 topographic map is adopted to define a new Boulton Formation as the basal formation of the Hervey Group on the Parkes 1:100 000 sheet.

Derivation of name
From Mount Boulton (635 m) on the Parkes 1:50 000 sheet, about 2 km south of the Mandagery crossing on the Orange-Broken Hill railway line, which forms the easternmost exposure of Hervey Group in the Parkes Syncline.

Type locality
Mount Boulton provides the type section of 'red siltstone and shale unconformably overlying older Palaeozoic green shales' as measured by Conolly (1965a: 55) through the basal part of the Hervey Group in the Parkes Syncline.

Thickness
The type section at Mount Boulton was given a thickness of 107 m (350') by Conolly (1965a: 55). In the 'type section for the Beargamil Sub-Group' specified by Conolly (1965a: 45-46), the Boulton Formation ('Kadina Formation') had a measured thickness of 60-90 m.

Distribution and outcrop
The basal part of the Hervey Group is often poorly exposed, mainly because of scree cover from overlying sandstones. The lowermost outcrop of Hervey Group observed to the east of Beargamil Dam on the Bindogandra fire trail at locality GY95/58 is a basal red gritstone with rounded quartz pebbles to 10 mm across, and subrounded lithic fragments up to 20 mm across. Elsewhere in the Bumberry Syncline the basal Hervey Group was observed at locality GY95/16 where similar red grits and conglomerates, plus red siltstones are exposed in association with underlying Moura Formation sediments in a gravel scrape. Along the southern limb at locality GY95/19 a kaolin quarry in deeply weathered red mudstone immediately overlies basal conglomerates, but underlying sediments are covered by alluvium. This quarry lies outside the limits of the radiometrics which here correspond to the base of the Mandagery Formation, whereas in the type area at Mount Boulton this is not the case (see below).

At the Telecom line south of the Dungeons road cut the basal beds of the Hervey Group are covered by sandstone scree, as on the eastern limb of the Parkes Syncline at locality GY95/15, and travelling west along the road following the Sydney-Broken Hill railway line the first good outcrop of Hervey Group sediments is a grey quartzite. However radiometrics indicate that the outcrop extends north to the road from Mount Boulton, and at locality GY95/14 buff mudstone exposed on the south side of the road 2.1 km west of the Mandagery turnoff dipping to the west is assumed to represent the Boulton Formation. At locality GY95/15 above a Moura Formation quarry exposure scree from the sandstone ridge covers a recessive unit of reddish-brown mudstone (excavated from rabbit burrows). The ridge-forming unit comprises yellowish brown siltstones and fine sandstones (light grey when fresh), which is assumed to correspond to the basal sandstone unit of the Mandagery Formation in its type section (see below). Radiometrics indicate that this unit (and presumably the underlying Boulton Formation) pinch out about 5 km along strike north of the railway line. To the north of this the base of the Hervey Group is a unit which can be traced to the south in apparent continuity with a sandstone horizon

within the type section of the Mandagery Formation. At the northern extremity, on the Parkes-Orange road, only light grey quartz sandstones are exposed, although outcrop pattern on air photos suggests another recessive middle unit in the ridge to the south of the road. Following previous mapping, a basal equivalent of the Boulton Formation is inferred along the northern half of this northern limb of the Parkes Syncline, but without age control it could equally well be considered a lateral equivalent of the finer grained interval noted below within the type section of the Mandagery Formation (see below).

Good exposures of the basal Hervey Group and marked angular unconformity with underlying Moura Formation are seen at Mount Boulton, where readings of 10/335° above and 43/320° below the unconformity at locality GY95/64 compare with those previously published (Powell et al. 1980, fig. 7). Down the dip slope to the west of Mount Boulton the radiometrics suggest discontinuous Hervey Group outcrop, with the Mt Boulton exposure forming an outlier from the main outcrop of the Parkes Syncline. However, although outcrop is poor, exposures of Boulton Formation were observed at locality GY95/86 and 89, with colluvium with sandstone float to the north, and outcrops of sandstone at locality GY95/87 and green siltstone at locality GY95/88. It is presumed therefore that the basal Hervey Group has been eroded to a very thin or colluvial cover over the volcanics in this area (i.e. transparent on the radiometrics).

Description

In the type area, the basal 10 m of the Boulton Formation is exposed in the gully at locality GY95/64. The basal unit comprises about 3 m thickness of dark grey pebble conglomerate with angular pebbles and shale and mudstone clasts up to 25 mm across, overlain by lithic sands and grits in 150-300 mm thick beds interbedded with maroon mudstones (1-2 m thick). Above this is some 5 m of friable red mudstone, at the top of which is another dark grey/maroon unit which contains few bands of calcareous nodules. At 95/62 the lowest exposure at the top of the gully is friable red mudstone, overlain by massive red/purple siltstones which in outcrop form large blocks. Some beds are mottled and much bioturbation. Small channel fills 150 mm deep by .5 m wide are the only sandstones in this unit, which is overlain by a fine sandstone forming the ridge, the same lithology as observed at 95/15 above the Symington quarry.

Depositional environment

A low energy fine-grained tidal flat or overbank depositional setting is suggested, with minor stream channels.

Palaeontology

No fossils have been recorded from this formation, although there is some evidence of biological activity in the form of worm burrows and other minor bioturbation. Limestone pebbles from just above the unconformity at Mount Boulton were submitted to AGSO acid laboratory for microfossil processing, but no results are available. Previously, Conolly (1965a: 55) mentioned a fossil locality on the eastern limb of the Parkes Syncline where 'basal red sandstones of the Kadina Formation

thin onto boulders of granite basement'. This is presumably the locality illustrated by Williams (1977, fig. 1) as a fossiliferous marine unit beneath the Mandagery Formation. However remapping indicates that these fossiliferous horizons represent the lower part of the overlying Mount Cole Formation (previously 'Pipe Formation'; see below).

Age and relationships
The age of this basal formation of the Hervey Group in the Parkes Syncline is probably constrained to the Givetian-Frasnian interval (Middle-Late Devonian). To the south, on the Cowra 1:100 000 sheet, the Merriganowry Beds (included in the top of the Dulladerry Volcanics beneath the Hervey Group by Pogson & Watkins 1998) contain a late Givetian fish and plant assemblage (Pickett 1993b; Young 1994, 1999a), providing an older age limit to the Boulton Formation. The Canowindra fish fauna in the top of the Mandagery Formation was previously assessed as Famennian in age (e.g. Young 1993), but new evidence of marine influence indicates that it may be late Frasnian (Young 1997a, 1999a; Young & Turner in press).

The Boulton Formation can be considered broadly equivalent to other basal Hervey Group formations - the Clagger Sandstone and Kadina Formation in the Hervey Range on the Narromine sheet, and the Peaks Formation on the Grenfell 1:100 000 sheet (Young 1999b). Sherwin (1996) has recently noted a locality at the southern end of the Hervey Syncline where crinoid debris in a recessive outcrop characteristic of the Kadina Formation indicates a marine environment of deposition. In the Hervey Syncline the base of the Hervey Group is represented by the Clagger Sandstone, which contrary to Conolly's (1965a) interpretation, is not confined to the northern part of the syncline, but extends to the southern end, where it forms prominent dip scarps (Sherwin 1996). Assuming that evidence for marine deposition in the Parkes and Hervey Synclines represent a transgressive event, and can therefore be correlated, the Kadina Formation in its type area might relate to a higher horizon (Mandagery/Mount Cole Formation transition) in the Parkes Syncline (see below), in which case the Boulton Formation would be equivalent only to the basal Clagger Sandstone of the Hervey Group type section.

MANDAGERY FORMATION (Dhm) after Conolly (1965a)

Previous nomenclature
Mandagery Sandstone of Conolly (1965a)

Derivation of name
Mandagery is an aboriginal word widely used in the area, applied to the vicinity immediately east of the Parkes Syncline, to a major sandstone ridge on the adjacent Molong 1:100 000 sheet to the east, and to Mandagery Creek which flows in a southwesterly direction across the southeastern part of the Parkes 1:100 000 sheet, and through the town of Eugowra.

Type locality
The type locality of the Mandagery Formation is within in the Parkes Syncline, about 4 km to the west of the Mandagery railway crossing. Conolly (1965a: 55) stated that the type section 'was measured along the main western railway line to Parkes, near Mandagery Railway Station'. The base and top of the Mandagery Formation were defined respectively by the first and last white sandstones above the underlying formation ('Kadina Formation' of Conolly; see above), and below the overlying formation ('Pipe Formation' of Conolly; see below).

Thickness
Conolly (1965a: 55) recorded a measured thickness in the type section of 686 m (2250'), comprising interbedded white sandstones, red siltstones and green shales. However, as mapped here, assuming an average dip of 20°, the formation seems thicker than measured by Conolly, at least along the road, where dips have been measured in the 20-30° range (cf. 25° from Conolly 1965a; 21° given by Powell et al.1980). The upper part of the formation is exposed in the creek just south of the railway line at GY95/12. From the published map (Conolly (1965a), fig. 8), the upper boundary crosses the road at about GR260236, where the road descends to the flats of the recessive Mount Cole Formation, but radiometrics show a distinct change further east, at about 267236, by which the Mount Cole Formation is readily recognised. Within these limits, a thickness of up to 900 m is indicated.

Conolly (1965a: 55) also noted that this formation thins to the north, south and east away from the type area, but these thickness comparisons are not reliable, because radiometrics show that the formation was misidentified in the adjacent Bumberry Syncline, which, at its closest, is less than 5 km east of the type section. The original maps (Conolly 1965a, fig. 8) show most of the core of the Bumberry Syncline to comprise an extensive outcrop of Mandagery Formation. However it is clear from radiometrics that the mapped area includes three formations, (Mandagery, Mount Cole, and Bumberry), and much of the thickness attributed to the Mandagery is in fact Bumberry Formation. Along the southern extremity of the Parkes Syncline however there is evidence that the Mandagery Formation thins out against the underlying granite.

Distribution and outcrop
In the type locality the Mandagery Formation is well exposed in railway cuttings, and along the road between Cookamidgera and Mandagery just south of the railway line, where it forms dominant strike ridges which are readily identified on the radiometrics. It can be traced as a strike ridge to the north and south in the Parkes Syncline, where at the southern extremity it is clearly exposed and appears to thin out against the underlying granite, with facies change to finer siltstones making it difficult to distinguish from the overlying and underlying finer-grained units (Boulton and Pipe Formations). As noted above, the formation was misidentified in the original maps in the Bumberry Syncline, and is much narrower in outcrop than shown by Conolly (1965a, fig. 8; also Brunker 1972), but still readily identified in outcrop and on the radiometrics. The Mandagery Formation is also less clearly developed in the Eugowra Syncline, where the Bumberry Formation tends

to be the main bluff-forming sandstone, although originally it was mapped in this area (Conolly 1965a, fig. 8). Remapping of this area was not completed in 1995, and further fieldwork is necessary to tie in the radiometrics with outcrop pattern.

Description
The described type section begins with a unit of 'massive white and red sandstones' 45 m thick, overlain by 'fine-grained white sandstones and siltstones' (90 m), and 'green and red siltstones and shales with some white sandstones' (73 m). From the published map (Conolly (1965a), fig. 8), the base of the Mandagery Formation can be assumed to be represented by the massive finely laminated light grey quartzites exposed beside the road just east of the cattle grid at GR276237. About 500 m west, friable red mudstone exposed in a gravel excavation on the south side the road, presumably represents a level within the finer sediments of the overlying 163 m interval recorded for the type section (of which red siltstones form only a minor part; see Conolly (1965a), fig. 6). Radiometrics clearly show this fine-grained unit, which can be traced along the northern limb, the outcrop decreasing in thickness (presumably due partly to steepening of the dip), as does the underlying sandstone unit, which pinches out about 5 km along strike north of the road. It appears from the radiometrics that the basal Hervey Group unit along the northern half of the northern limb is continuous to the south with a sandstone horizon within the type section of the mdst, but as noted above a basal equivalent of the Boulton Formation is inferred, following previous mapping. The approximate base of the Mandagery on Conolly's map (Conolly (1965a), fig. 8) on the road 4 km west of Mandagery railway crossing is a hard grey quartzite with small mudclasts. The radiometrics show a unit within the Mandagery Formation with a similar colour intensity to the overlying Mount Cole Formation in outcrop seen to the west around the bend in the road where it swings to the northwest, with red/green mudstones exposed on the road edge.

Towards the southern end of the Parkes Syncline the Mandagery Formation is clearly exposed and appears to thin out against the underlying granite, with facies change to finer siltstones making it difficult to distinguish from the overlying and underlying finer-grained units (Boulton and Mount Cole Formations). This is the area where Williams (1975) identified a fossiliferous lithological 'subunit A' of the Boulton Formation resting unconformably on the granite, which was considered to underlie typical Mandagery Sandstone. The section at GR 201115 shows this finegrained unit in contact with the granite, but above there is a finegrained and recessive sequence right across the valley, with no marked sandstone outcrop until the slope of the Eurow Range to the west, which is formed by the overlying Bumberry Formation. The basal Bumberry slope can be traced continuously to the north to the Mandagery railway type section. The Mandagery Formation is therefore interpreted to be absent in this section, with the basal fossiliferous unit considered instead to be equivalent to the lower part of the Mount Cole Formation (see below).

In the Bumberry Syncline there are exposures in The Dungeons road cuttings, and to the south. The lowest exposure just above Bindogundra Creek is a massive sst. in

the road gutter. At locality GY95/4 (telecom section) the last steep slope down to the bottom of the outcrop shows yellow blocks of sandstone, grey when fresh, and the Boulton Formation is apparently missing or covered by scree. Above this massive unit (forming a 'waterfall' in the gully), is a more reddish unit; with some cross-bedding, and large load casts 2/3 way down. locality GY95/5 in the telecom section shows a fish bed assumed to approximate the top of the Mandagery, because it coincides with the radiometrics boundary.

Depositional environment
A high energy fluvial environment is indicated, presumably in a coastal plain setting. There is also some circumstantial evidence from the overlying Mount Cole Formation for a marine influence at the top of the formation (see below).

Palaeontology
Bothriolepis and *Remigolepis* plates were found at locality GY95/5, which according to the radiometrics approximates to the top of the Mandagery Formation. Both genera are well known from the Canowindra fossil fish fauna on the Cowra 1:100 000 sheet, which also occurs near the top of the Mandagery Formation.

Age and relationships
A late Frasnian age has been proposed for the Canowindra fish fauna (Young 1999a), which would place the Mandagery Formation in the Frasnian. Possible equivalents are the Clagger Sandstone in the Hervey Range (but a higher sandstone has been identified as Mandagery Formation in that sequence, although the correlation is questionable; Sherwin 1996), and the Peaks Formation on the Grenfell 1:100 000 sheet (Young 1999b).

MOUNT COLE FORMATION nov.

Previous nomenclature
'Pipe Formation'; Conolly (1965a)
'Nyrang Formation'; Conolly (1965a)

Conolly (1965a: 56) described a measured section (480 m thickness) of 'Pipe Formation' north of Nyrang Creek near Mount Cole trig. (Mount Cole), which he once also referred to (p. 57) as 'Nyrang Formation'. However this name is preoccupied, having already been used as the 'Nyrang Sandstone Member' by Pickett (1982) for a member of the Silurian Wallace Shale in the Cheesemans Creek district (C. Brown, in litt. 1 Aug, 1995).

Conolly's usage of the term 'Pipe Formation' was based on the assumption that this often recessive formation on the Parkes 1:100 000 sheet is a correlative of the Pipe Formation in its type locality in the Hervey Syncline. Similarly, he applied the term 'Kadina Formation' (defined in the Hervey Syncline) to the basal formation of the Hervey Group in the Parkes-Manildra area, and the term 'Mandagery Sandstone' (defined in the Parkes Syncline) to a similar prominent sandstone unit in the Hervey Syncline. As noted by Sherwin (1996), it is uncertain how reliable such

correlations are over long distances. Whilst there is little reason to proliferate stratigraphic names when lithological correlations are uncertain, there is some palaeontological evidence that they are in fact incorrect (see below), so it is appropriate to propose a new formation name with its type locality in the Manildra-Parkes area.

Derivation of name
After the Mount Cole district, Mount Cole River, and Mount Cole trig. on Mt Cole north of Nyrang Creek (Cowra 1:100 000 sheet), where Conolly (1965a) recorded a well exposed section of the Mount Cole Formation.

Type locality
The nominated type section is the 344m (1050') interval of red siltstone and green/buff shale with minor white sandstone in the Mandagery Railway section of Conolly (1965a) fig. 10A, which he identified as 'Pipe Formation'. The Nyrang Creek section (Conolly (1965a), fig. 10B) is thicker, but it is appropriate to specify a type section which has a demonstrable field/stratigraphic relationship to the type sections of overlying and underlying formations defined in this area.

Thickness
The 344 m thick type section may be compared with the 250 m (820') type section of the Pipe Formation measured near Caloma trig in the northern end of the Hervey Syncline (Narromine 1:250,000 sheet). Conolly (1965a) recorded a maximum thickness near Goimbla trig. of some 650 m.

Distribution and outcrop
Conolly (1965a: 50) identified this poorly outcropping formation as being 'easily traced on air photographs' by forming 'valleys between Mandagery Sandstone and Bumberry Formation ridges'. However, the 'Pipe Formation' was overlooked in the Bumberry Syncline in Conolly's (1965a) original mapping, with higher relief resulting in a 'single ridge' type of outcrop, as illustrated by Sherwin (1973, fig. 7), so topographic relief is not always reliable, even over short distances. On the original maps the whole sequence in the Bumberry Syncline was erroneously interpreted to represent only the Mandagery Sandstone and Pipe Formation. However, radiometrics clearly show within this outcrop the presence of an equivalent unit to the recessive 'Pipe Formation' which in the Parkes Syncline forms the deep valley of poor outcrop between the type sections of Mandagery and Bumberry Formations. The recessive unit identified by Conolly (1965a) as 'Pipe Formation' is in fact the Eurow Formation, which overlies the Bumberry Formation as in the Parkes Syncline (see below).

On the northeastern limb of the Parkes Syncline the Mount Cole Formation forms a valley of poor outcrop between sandstones of the underlying Mandagery and overlying Bumberry Formations, which shows up clearly on the radiometrics. On the road south of the railway line between the Mandagery and Bumberry type sections the Mount Cole Formation forms a broad valley. The colour change in radiometrics on the road occurs slightly lower in the sequence than the uppermost

conspicuous sandstones, mapped by Conolly as the top of the Mandagery. Massive sandstones are also exposed in a gully at 95/67, with the colour change in the radiometrics located about 200 m to the east, suggesting that the geochemical change (reduction in radiogenic minerals) occurred within the upper Mandagery. Generally the radiometrics approximate to the Mandagery-Pipe boundary, but poor outcrop often limits the precise location of lithological change.

Good exposures of the Mount Cole Formation in the Parkes Syncline are generally limited to some of the creeks and gullies, but the formation is traceable on radiometrics and as a valley from the type section to the extremity of the southeastern limb, where it apparently lies directly on the granite, at a locality first mapped by Conolly (1965a) to have a complete section with Mandagery Sandstone overlying Kadina Formation in unconformable contact with the granite (see below).

The upper part of the Mount Cole Formation is often obscured by scree from the basal Bumberry, which is clearly seen on the radiometrics as a prominent marker well up the slope. The Mount Cole/Bumberry Formation transition is well seen at locality GY95/66, in the cleared slope adjacent to the northern side of the railway line, where about 15 m of interbedded green and red mudstones forms a sharp contact with the first massive sandstone of the basal Bumberry Formation.

In the Bumberry Syncline the Mount Cole Formation is less obvious in air photos, but again very clear on the radiometrics, extending the length of the northern and eastern limbs. Good exposures are encountered in the Dungeons road cuttings on the main Parkes-Orange road, and in the telecom cable line to the south (locality GY95/4-5).

Description

In the headwaters of Bartleys Creek, immediately south of the type section, the basal strata of the Mount Cole Formation are poorly exposed, but the middle part has good outcrops of red mudstone (locality GY95/65-66) with calcareous bands and common fish remains as described by Williams (1975).

The basal beds are seen at the southern end of the Parkes Syncline, where they lie directly on the granite. Williams (1975, 1977) followed Conolly's (1965a) interpretation that this was a complete section with Mandagery Sandstone overlying Kadina Formation in unconformable contact with the granite. However Williams (1975: 33) identified a distinct lithological 'subunit A' of buff-green siltstones, which he considered to underlie typical Mandagery Sandstone, and unconformably overlie the adjacent granite contact. This unit contains a faunal assemblage of plants, bivalve molluscs, and lingulid brachiopods indicating a brackish or marginal marine environment (see below). At GR 201115 there is a granite contact with this finegrained unit, which has many trace fossils in a lithology similar to the lower part of the Mount Cole Formation observed in The Dungeons road cutting through the Bumberry Syncline. This section displays red bioturbated mudstone (worm burrows, etc.) near the base, overlain by finely bedded red siltstone with small scale cross bedding, and large (20x10 mm) patches

of fine mudclasts, with some soft interbedded mudstones, which are considered to be transitional beds from the upper Mandagery. Above are greenish mudstones and shales, displaying some good ripple marks etc., as seen also at locality GY95/3, although here exposures are obscured by sandstone scree and float from the overlying formation. However, in gullies the green siltstones, with sandy interbeds beds up to 100 mm thick can be observed.

At locality GY95/4 the upper Mount Cole Formation is exposed as slabs of bedded siltstone, some with tracks and traces, interbedded with reddish silstone and shale. This may be compared with the uppermost beds exposed in the vicinity of locality GY95/66 at the type locality. An atypical 1 m thick hard quartzite is exposed in the gully south of the road about 50 m from the culvert, but above this are at least three exposures of red mudstone in the gully (about 5 m apart), separated by alluvium. The highest outcrop is scree adjacent to the northern side of the railway line, where about 4 m thick unit of very friable red mudstone lies immediately beneath the first massive sandstone through the fence representing the base of the Bumberry Formation. The mudstone is interbedded and underlain by green siltstones up to 50 cm thick, with sole marks, and various red/green siltstones and shales. Plant fragments, bioturbation, and fish remains occur near the base of this exposure, representing about 15 m of section at the top of the Mount Cole Formation.

Depositional environment
Fossil evidence indicates a brackish water/marine influence for the lower part of the Mount Cole Formation, and an estuarine or tidal flat environment can be suggested.

Palaeontology
Conolly (1965a: 56) reported lepidodendroid plant remains as the only fossils from his 'Pipe Formation', but the horseshoe crab *Kasibelinurus amicorum* Pickett 1993 came from this formation in The Dungeons roadcut. This locality, assumed by Pickett following Conolly mapping to belong to the Mandagery Sandstone, has also yielded plant remains, including *Leptophloeum australe* (Pickett 1993a: 281). Plant remains including *Leptophloeum australe,* fish plates, bivalve molluscs, and the inarticulate brachiopod *Apsilingula parkesensis* Williams 1977 are recorded from the southern extremity of the Parkes Syncline, in the lower part of the section resting unconformably on granite. Williams (1975) considered broken fish plates to be ubiquitous within the 'Pipe Formation', and many horizons in the valley south of the type section contain bone fragments. Locality GY95/65 has yielded osteolepid and holoptychiid crossopterygian scales, and bones of the placoderms *Groenlandaspis, Remigolepis, Bothriolepis,* and a phyllolepid. At locality GY95/66, near the top of the formation (about 15 m stratigraphically below the basal Bumberry) plant stems and burrowed horizons are associated with large antiarch remains (probably *Remigolepis*), fragments of *Groenlandaspis, Bothriolepis,* a phyllolepid, and crossopterygian remains.

Age and relationships

Young (1999a; Young & Turner in press) proposed a late Frasnian age for the fossiliferous interval representing the Mandagery/Mount Cole transition on the Parkes 1:100 000 sheet, on the assumption that it representes the late Frasnian maximum transgression identified on conodont and other evidence frome elsewhere in eastern Australia (e.g. Pickett 1972; Young 1995). Rather than the Pipe Formation in the Hervey Syncline, a correlation with the Clagger Sandstone/Kadina Formation transition can be proposed, on the evidence of marine fossils in the latter (Sherwin 1996). To the south on the Grenfell 1:100 000 sheet, correlation with the Peaks/Hunter transition is supported by fossil content of the Gooloogong Member (Young 1999b).

BUMBERRY FORMATION Conolly (1965a)

Derivation of name
From the Bumberry Ridges and Bumberry Syncline, about 20 km E of Parkes.

Type locality
The type section of the Bumberry Formation is in the Mandagery railway section of the Parkes Syncline (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). More detail on the lower part of this section and its sedimentary petrology was given by Conolly (1965b, fig. 7).

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. The sequence in the Bumberry Syncline apparently has a comparable thickness, taking into account the steeper dip in this section.

Distribution and outcrop
This formation produces the prominent sandstone ridges which lie stratigraphically above the recessive valleys of Mount Cole Formation. The base of the Bumberry Formation is well defined on the radiometrics in the type area, and in outcrop. The basal sandstone forms a prominent marker on the radiometrics along the southeastern limb of the Parkes Syncline, traceable to the south from the type section, and placed well up the slope on the western side of the valley formed by the Mount Cole Formation. Of the four fining-upward cycles identified by Conolly (1965a), fig. 10) in the type section of the Bumberry Formation only the lower one is evident on the radiometrics, which show a distinct marker horizon representing the finer upper part of the first cycle. The transition to the Eurow Formation is also unclear on the radiometrics. On the radiometrics the finer upper part of the lowest cycle can be seen as a distinct marker horizon which can be traced along the northern limb, and also to the south. Exposures of the Bumberry Formation are more extensive near the fault offset on the southeastern flank, due to shallower dip and/or thickening of the unit. South of the fault the lower fine-grained interval is unclear on the radiometrics, as are the higher cycles of the Bumberry Formation, including the transition to the overlying Eurow Formation.

At the southern end of the Parkes syncline the nose of the fold is faulted out in the Bumberry Formation as shown by Powell et al. (1980). A shallow northwesterly dip is evident from air photos adjacent to the fault contact with the steep easterly dipping western limb of the syncline. Powell et al. (1980, fig. 5) show the whole of the Upper Devonian sequence truncated to the west by another fault, but radiometrics indicate that Hervey Group seds extend almost to the Parkes-Eugowra Road immediately south and around 'Ferndale Homestead', where they are

obscured by alluvium. This implies that the strong fault scarp forming the western boundary of the Eurow Range is a normal fault within the Upper Devonian, rather than a reverse fault separating Devonian from Ordovician as interpreted by Powell et al. (1980)

As noted above, Conolly (1965a: 55) misidentified the Mandagery Formation in the Bumberry Syncline, which, at its closest, is less than 5 km from the Mandagery Formation type section. The original maps (Conolly 1965a, fig. 8) show most of the core of the Bumberry Syncline to comprise an extensive outcrop of Mandagery Formation. However the Mount Cole Formation is very clear on the radiometrics, overlain by an extensive outcrop tract of Bumberry Formation. Thus, the sedimentary structures and palaeocurrent information ascribed to the Mandagery Formation which were described and illustrated by Conolly (1965a, p. 56; pl. 2, pl. 3, figs. 2-3), are in fact all within the Bumberry Formation.

On the western limb of the Bumberry Syncline the basal Bumberry Formation forms the highest relief as the ridge-forming unit of the main range (Bumberry and Billygoat Ridges, including Bindogundra trig. at over 640 m). Air photo interpretation of outcrop suggests four cycles as in the type section, with the spillway of Lake Endeavour Dam approximating to the top of cycle 2, and the middle and upper reaches of the lake approximating to cycles 3 and 4. Cycle 4 is distinguishable on the radiometrics by its lighter colour. Similar lithology of the basal Bunberry is observed at GR 311 264, where the upper Mount Cole Formation has extensive exposure in the valley eroded out of the core of the syncline. The four cycles are not evident in outcrop pattern south of Route 90 because of the shallow dip near the fold axis.

Description

At 95/66 is a good exposure of the base of the type section in the cleared slope adjacent to the northern side of the railway line,where the upper 15 m of interbedded green and red mudstones at the top of the Mount Cole Formation is exposed. The basal Bumberry first massive sandstone is well exposed through the fence. It is a well bedded quartzite (5-10 cm beds) with some cross-beds, which forms large blocks in outcrop. The finer upper part of the lowest cycle in the type section can be seen as recessive outcrop on the eastern slope of the hill when viewed to the north across the railway line. Lithologies can be observed to the south at locality GY95/1, an exposure in a gravel scrape on the western side of the road, where friable red mudstone with some less weathered larger blocks are overlain by flat slabs of yellow/buff sandstones with sedimentary structures including cross-bedding, and parting lineation. Typical lithology of associated massive quartzites showing parting lineation and other sedimentary structures is seen at locality GY95/1 in blocks unearthed along a Telstra underground cable line. The same lithology was observed at locality GY95/3B higher in the sequence. Interbedded fissile red/purple mudstone in this lower unit is exposed at locality GY95/6 as a very friable gravel in the road cutting of the Cookamidgera-Eugowra road, underlain by massive maroon siltstones, some layers with fine laminations, others with extensive bioturbation in the form of lighter coloured burrowings (white).

The four major cycles identified in the type section are still evident on air photos at the southern end of the Parkes Syncline, where the Bumberry Formation is truncated by faulting, but in the Bumberry Syncline the cycles are less clear. At locality GY95/2 (near the base of the formation) platey yellow sandstone outcrop as flagstones 100-200 mm thick, as also seen on upper section of the Dungeons main road cutting, east of Bindogundra Creek, exposed in an excavation on the south side of road. At locality GY95/4 the basal Bumberry according to radiometrics forms a steep track at the end of the power line clearing of white sandstone blocks and slabs with parting lineations, and rare *Leptophloeum*. This bed can be traced on air photos to The Dungeons road cut section above (east) of Bindogundra Creek, where quartzite flagstones 100-200 mm thick are well exposed on N side of road.

The lithology of the upper part of the Bumberry Formation is seen in the small bluff at locality GY95/30, with crops out at similar lithology to locality GY95/1 in the Parkes Syncline. These resistant cross-bedded sandstones are traceable on airphotos to the north as the ridge forming unit of Billygoat Ridge, including Bindogundra trig., which is the highest relief within the northern part of the Bumberry Syncline. This resistant sandstone sequence (estimated thickness from airphotos about 170 m) has its upper beds in the spillway of Lake Endeavour dam, the outcrop figured by Conolly (1965a) as Mandagery Formation. These cross-bedded sandstones, which include lag deposits containing impressions of fish fragments (including antiarchs, and rare phyllolepids) continue around the shore of the lake, and a ridge running back up to the intersection with the road to Top Valley represents the top of the sandstone sequence, although part of this was mapped by Conolly (1965a, fig. 8) as 'Pipe Formation'. At 63300346 these upper sandstones crop out on the west side of the road, with red mudstones on the eastern side and dipping to the east. These are interpreted to be basal beds of the Eurow Formation. The upper sandstones of the Bumberry are well exposed north of Lake Endeavour, the highest outcrop at 95/35 being a light grey/buff fine friable sandstone with some mudclasts, evidence of burrowing, bioturbation, etc. Generally these upper beds are more lithic than the white sandstones exposed in the spillway of Lake Endeavour dam.

Depositional environment
The fining upwards cycles presumably represent channel fills, point bars and overbank deposits formed in a large fluvial system.

Palaeontology
Lepidodendroid and fish plate remains were recorded by Conolly (1965a: 57) from the Bumberry Formation, but localities are not specified, so they could refer to any part of the Manildra-Goologong region. New fossil localities on the Parkes 1:100 000 sheet listed by Young (1997a:5) include Leptophloeum (locality GY95/4) and a diverse fish and invertebrate fauna associated with large plant stems (locality GY95/31) from within the Bumberry Formation.

Age and relationships
The diverse fish, invertebrate and plant assemblage from locality GY95/31 is assemblage 4 in the biostratigraphic scheme of Young (1999a, fig. 5), which is assigned a middle Famennian age, whilst a *Grenfellaspis* fish fauna at the top of the Bumberry Formation on the Grenfell 1:100 000 sheet indicates a late Famennian age (Young 1999b). Thus the Bumberry Formation can be considered middle-late Famennian (Late Devonian) in age, and 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 on the Grenfell 1:100 000 sheet.

EUROW FORMATION 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 (Conolly 1965a: fig. 10). Pogson & Watkins (1998) have recently proposed a 'Cookamidgera Formation' containing a lower 'Eurow Member', but this only a change of rank, and does not address the problem of the un-named upper 'undifferentiated' part of Conolly's 'Cookamidgera Sub-Group'. , which is given formation status below. Conolly's original formation name is therefore retained here, with formation rather than member status as seems appropriate for a unit of some 680 m thickness.

Derivation of name
Conolly (1965a) stated that the type area 'occupied by the fine-grained red beds of the Eurow Formation ... forms the headwaters of Eurow Creek', presumably an alternative name for the Bartleys Creek which flows to the west through Cookamidgera. The name is also used for the Eurow Mountains (formed by the basal Bumberry Formation), a major range reaching 644 m along the southeastern flank of the Parkes Syncline.

Type locality
There has been confusion about the type locality of the Eurow Formation. Conolly (1965a: 57) stated that the 'type section was measured in the Bumberry Syncline, the centre of which is occupied by the fine-grained red beds of the Eurow Formation'. However his map (fig. 8) does not show this formation occurring in the core of the Bumberry Syncline, and it seems therefore that the reference to 'Bumberry Syncline' was in error, and instead should have referred to the 'Parkes Syncline'. This is supported by Conolly's statement (1965a: 46) that the type section for the Cookamidgera Sub-group was measured in the centre of the Parkes Syncline. Since the Eurow Formation is the only named unit which was recognised by Conolly within this subgroup (Conolly 1965a, table 1), it can be presumed that this type section also applies to this formation.

Thickness
A thickness of at least 680 m was estimated by Conolly (1965a) in the type section from air photographs using average dip and width of surface exposure.

Distribution and outcrop
This formation typically is a recessive unit of poor outcrop which forms valleys stratigraphically above ridges of the Bumberry Formation, as in its type section in the core of Parkes Syncline, and in the eastern part of the core of the Bumberry Syncline. In general the only exposure observed is red mudstone in the soil cover, and along graded roads, but this is often transported from elsewhere as fill or roadmetal.

Description
Massive redbeds comprising dark grey/maroon siltstones and red mudstone/shale may be seen in gravel quarries, but are often not exposed except in areas of rapid erosion, such as in the core of the Eugowra Syncline at locality GY95/108-109, and to the south at locality GY95/111-113. More typical small exposures are seen at locality GY95/110 and 140. Worm burrows are abundant at some horizons.

The upper part of the formation is in the southern Parkes Syncline east of locality GY95/95, where flaggy bioturbated maroon siltstones underlie the massive quartz sandstones at the top of the ridge forming the Wingara Formation. Within the Bumberry Syncline the basal beds of the Eurow Formation overlying upper sandstones of the Bumberry Formation are exposed as red mudstone outcrop on the east side side of the road at 63300346, an outcrop originally mapped by Conolly (1965a, fig. 8) as 'Pipe Formation'. The southern extension of this outcrop is generally covered by soil and sandstone float to the south and along State Route 90 (Parkes-Orange road), but at locality GY95/59 a bedded outcrop of red mudstone was observed dipping gently to the east, as does another bedded outcrop to the north at locality GY95/31. These orientations indicate that the Bumberry Syncline fold axis is much further east than previously mapped.

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

Palaeontology
Lepidodendroid plants (presumably *Leptophloeum*) were recorded in shales of the Eurow Formation south of Goimbla trig. in the Eugowra Syncline by Conolly (1965a: 57).

Age and relationships
The Eurow Formation may correlate broadly with the upper part of the Weddin Formation in the outcrops south of the Lachlan River on the Grenfell 1:100 000 sheet (Young 1999b). The lycopod *Leptophloeum australe* indicates a Devonian rather than Carboniferous age (e.g. Young 1995), and nort of the Lachlan River on the Grenfell

1:100 000 sheet is associated with a fish fauna in the Eurow Formation which is assigned a provisional latest Famennian age by Young (1999a, fig. 5).

WINGARA FORMATION (Dhw) nov.

Previous nomenclature
'thin sandstone member within the Eurow Formation' Conolly (1965a)
'undifferentiated upper Cookamidgera Sub-Group' Conolly (1965a)
Cookamidgera Formation (in part); Pogson & Watkins (1998)

As noted above, Conolly (1965a) named only the Eurow Formation within his 'Cookamidgera Sub-Group', but his definition and identification of the upper part of this formation is unclear. The type section through the Parkes Syncline Railway section was recorded as a thickness in excess of 330 m of undifferentiated sediments above the eff (Conolly 1965a, fig. 10). Conolly (1965a: 57) stated that 'white sandstones form a thin sandstone member within the Eurow Formation in the Parkes Syncline', which he equated with a 'similar sandstone and siltstone sequence' in the Nyrang Creek area, in the latter case said to overlie the Eurow Formation, the same relationship as indicated in his type section (Conolly 1965a, fig. 10). This sandstone unit and overlying uppermost strata in the Hervey Group type section through the Parkes Syncline comprises the new formation erected here.

Derivation of name
From 'Wingara' property situated in the core of the Parkes Syncline adjacent to the type locality of the formation.

Type locality
The base of the type section is specified at locality GY95/95, about 1 km NE of Wingara homestead, where massive white sandstone and quartzite forms a westerly dipping sequence in the core of the Parkes Syncline.

Thickness
A measured dip of 20o at the base of the section, reducing towards the fold axis (about 500 m to the west), indicates an estimated thickness of some 150-200 m in the type section, with the top of the formation lost to erosion. Conolly (1965a) fig. 10A shows a minimum of about 200 m thickness above the basal sandstone unit at the top of his Mandagery Railway section.

Distribution and outcrop
This formation is a mappable unit around the fold axis in the southern part of the Parkes Syncline, with discontinuous westerly dipping outcrop along strike some 6 km to the NE. There is no exposure on the western limb of the syncline, which may be faulted (field checking required). Conolly (1965a) reported another sandstone outcrop at the top of his Nyrang Creek section, and an equivalent unit has provisionally been identified above the Eurow Formation in the northern part of the

Grenfell 1:100 000 sheet (Young 1999b). Elsewhere it may have been lost due to erosion of the top of the Hervey Group sequence.

Description
The base of the formation is cearly exposed in the western bank of the small creek at locality GY95/94, as a massive white cross-bedded quartzite. At locality GY93 some large load casts were observed in a similar lithology. The upper part of the type section is more bedded, with intervals of no outcrop indicating an increase in fine-grained sediments, as also indicated in the sections of Conolly (1965a) fig. 10).

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.

Age and relationships
This formation represents the eroded top of the Hervey Group sequence on the Parkes 1:100 000 sheet, which in the absence of evidence to the contrary is assumed to have a latest Devonian age.

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