

# A revised Triassic stratigraphy for the Lorne Basin, NSW

## ABSTRACT

Located on the mid-north coast of New South Wales, the Lorne Basin is a sub-circular basin with Triassic rocks of similar age to those of the much larger Sydney Basin. The Lorne Basin is approximately 35 km in diameter, containing mainly Triassic sedimentary rocks (in excess of 200m thick) and extensive younger intrusions.

This work presents a detailed stratigraphy of the Triassic Camden Haven Group — with redefinition of some existing formations and the description of three new units. The Cooperook Conglomerate Member (new) is part of the Camden Head Claystone and, together with the Coorabakh Conglomerate (new), forms part of the Camden Haven Group. The Coorabakh Conglomerate is laterally equivalent to the Laurieton Conglomerate. The ungrouped Milligans Road Formation (new) is the youngest Triassic sedimentary unit. All units have been deposited in a fluvial environment. Precise locations of the type sections are provided, with criteria to guide the identification of the various Triassic units. A detailed map of the Lorne Basin shows the distribution of these units and major structural elements, and together with cross-sections through the basin, allows modelling of the structural history of the basin.

**Keywords:** Lorne Basin, Triassic, Camden Haven Group, Cooperook Conglomerate Member, Camden Head Claystone, Laurieton Conglomerate, Coorabakh Conglomerate, Milligans Road Formation

## Basin setting

The Lorne Basin is an isolated sub-circular structural basin, approximately 35 km in diameter, situated in the north coast region of New South Wales between the towns of Cooperook and Wauchope (Figure 1). The basin floor is composed of Palaeozoic rocks of the New England Orogen overlain by Triassic terrestrial sedimentary rocks. These sedimentary rocks have been intruded by Late Triassic to Early Jurassic igneous rocks and later by Tertiary igneous rocks. Faulting has

disturbed the Palaeozoic and Mesozoic sedimentary sequence and the basin floor now has an overall dip of about 4° to the east. A portion of the eastern part of the basin is overlain by unconsolidated Pleistocene and Holocene sandy sediments.

This account is a description of the Triassic stratigraphy and major structural elements of the Lorne Basin. The origin and geological evolution of the Lorne Basin remains speculative at present and an interpretation is not discussed.

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**Cover photograph:** Cliffs of Laurieton Conglomerate overlying Camden Head Claystone at Grants Head (location 90). Photographer: G. W. Pratt.

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## Previous work

The 'Lorne Triassic Basin' was formally named by Voisey (1939), who described the basin as a structural unit. He named the Triassic rocks the 'Camden Haven Series' but did not subdivide the sequence. Packham (1969) discussed and formalised the stratigraphic terminology of the Camden Haven Group within the Lorne Basin. Stewart (1969) discussed the igneous rocks and presented a map of the Camden Haven District, but did not differentiate the Triassic sedimentary rocks.

Pratt and Herbert (1973) published a reappraisal of the Lorne Basin in which they presented a division of the Camden Haven Group into three formations. In stratigraphically descending order they are the Grants Head Formation; the Laurieton Conglomerate; and the Camden Head Claystone. Brief descriptions were given, together with type sections — but measured sections and exact locations were not included.

Leitch and Bocking (1980) described a portion of the northeastern part of the Lorne Basin in which they identified and named a basal formation, the Jolly Nose Conglomerate, and gave a brief description and a type section. While they could identify the three formations of Pratt and Herbert (1973), Leitch and Bocking (1980) could not reconcile the relationship between the Laurieton Conglomerate and the Camden Head Claystone, as proposed by Pratt and Herbert (1973), with their own observations.

Parisotto (1989) outlined the geology of the southwestern margin of the Lorne Basin and detailed the sedimentology of the Camden Haven Group. In the same year, van Bentum (1989) outlined the geology of the Perpendicular Point and Grants Head areas and detailed the sedimentology of the Camden Haven Group.

More recently, Higgins (2007) detailed the geology of the Diamond Head area, and Och et al. (2007) mapped the area between Bonny Hills and the Pacific Highway–Houston Mitchell Drive junction.

While the accompanying Lorne Basin map (see Map 1 in centre spread) is mostly original work by the author, the mapping of Leitch and Bocking (1980), Parisotto (1989), Higgins (2007) and Och et al. (2007) is incorporated, sometimes with minor modifications.

## Current work

This paper includes some revised and new unit descriptions for the Triassic rocks of the Lorne Basin, together with type sections, lithology (graphic representations) of measured sections and criteria to guide the identification of the Triassic units (Table 1). A map showing the distribution of the Triassic sedimentary units, the Palaeozoic basement,








152° 30'E

152° 45'E

31° 30'S

31° 45'S

**REFERENCE**

-  Basin boundary (approximate)
-  Town
-  Road
-  Railway
-  River



0 10 km

2008\_03\_0021

**Figure 1.** Lorne Basin locality map

Mesozoic and Tertiary igneous rocks and Quaternary unconsolidated sediments is presented (Map 1). It is accompanied by four cross-sections across the basin (Figure 2a, b) at locations indicated on the map — the reference for the map is below. The igneous rocks within the basin are not discussed as little detailed work has been done on them in this report. Recent work on igneous rocks includes that of Graham et al. (2006) and Higgins (2007).

Fieldwork was able to resolve the problem noted by Leitch and Bocking (1980) in that the Laurieton Conglomerate and Jolly Nose Conglomerate contact is restricted to a very small area in the immediate vicinity of Jolly Nose Hill. There the Camden Head Claystone is not developed. The work also confirmed that the Camden Head Claystone is a separate unit and not interbedded in the Laurieton Conglomerate.

The current work shows that the conglomerate forming most of the Lansdowne Escarpment (in the southwestern part of the study area) is the Cooperbrook Conglomerate Member of the Camden Head Claystone. This differs from the conclusion of Pratt and Herbert (1973), who designated it the Laurieton Conglomerate.

## Methodology

The mapping was conducted over the whole basin and was undertaken intermittently from mid-2004 to mid-2009. Vehicle access to much of the area is adequate in dry weather as a large part of the area is forest and is serviced by a network of forest roads and logging tracks. Foot access is often restricted by steep slopes and cliffs and thick to, in places, impenetrable vegetation.

Conglomerate exposures at 64 locations throughout the Lorne Basin were examined. Criteria, based on the percentages of quartz and jasper clasts of the total clast count, together with cobble frequency, bedding geometry, and the presence or absence of interbedded reddish-purple mudstone, were then developed to guide the identification of the individual Triassic conglomerate units.

The field methodology used involved scrubbing and washing the outcrop clean so that the pebble clast type could be identified by sight. A stringline was placed across the outcrop and each pebble (4 mm to 64 mm) or cobble crossed by the line was identified. At each of the 64 locations 100, and in some cases (where

**Table 1: Criteria used in the identification of Triassic units of the Lorne Basin**

Unit	jasper clasts as % of total	quartz clasts as % of total	Cobbles in 0.5 m x 0.5 m area	Reddish purple mudstone beds	Airfall tuff beds
Milligans Road Formation				absent	<b>present</b>
Grants Head Formation				<b>absent</b>	absent
Coorabakh Conglomerate	<20%	<b>&gt;25%</b>	<5	<b>absent</b>	absent
Laurieton Conglomerate	<b>&gt;20%</b>	<25%	<b>&gt;3</b>	absent	absent
Camden Head Claystone				frequent	absent
Cooperbrook Conglomerate Member	<20%	<b>&gt;25%</b>	<b>&lt;3</b>	<b>common</b>	absent
Jolly Nose Conglomerate	<5%	<5%	>5	absent	absent

**Note:** Bold indicates the significant criteria

### CROSS-SECTION REFERENCE

|| Fault showing sense of relative displacement

#### Quaternary

Qa Alluvium, unconsolidated sand and lacustrine deposits

#### Tertiary

Tv Volcanic rocks

#### Early Jurassic–Late Triassic

Trji Intrusion

Tmr Milligans Road Formation

#### Early Triassic

Camden Haven Group

Trgh Grants Head Formation

Trcc Tric Coorabakh Conglomerate  
Laurieton Conglomerate

Trch Camden Head Claystone

Trchk Cooperbrook Conglomerate Member

Ungrouped

Trjc Jolly Nose Conglomerate

#### Ordovician

Port Macquarie Block

Pzw Watonga Formation

#### Palaeozoic

Pzs Serpentinite

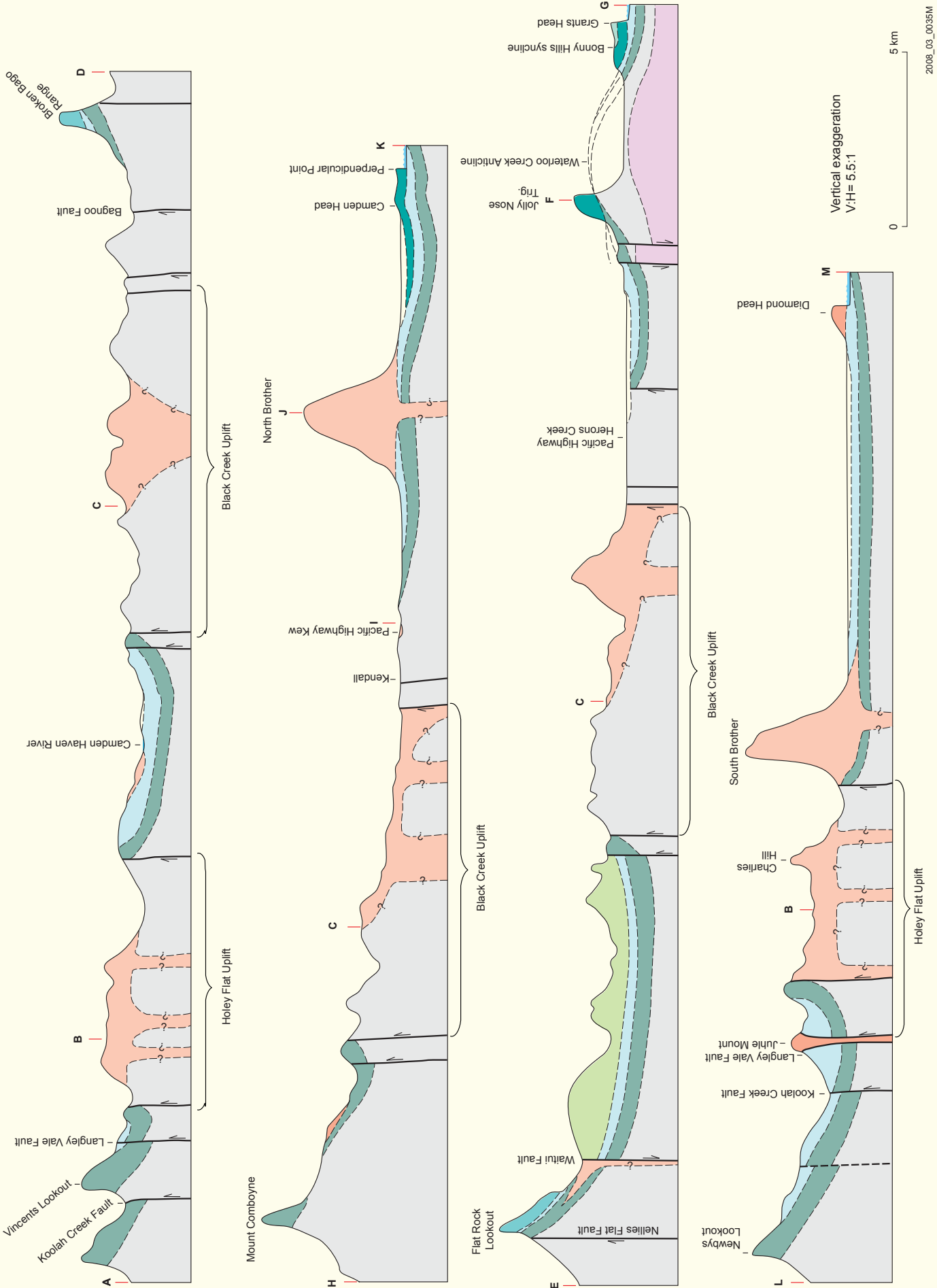
#### Carboniferous

Southern Hastings Block

Pzc Undifferentiated

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**Figure 2a.** Stratigraphic reference for cross sections



**Figure 2b.** Cross-sections across the Lorne Basin (see Map 1 for locations)

two samples were taken) 200, pebbles were counted and the percentage of each clast type calculated. Sites were selected to provide an even distribution throughout the basin and were dependent on the presence of exposures that could be cleaned. A purely random site selection, as suggested by Howard (1992), was not feasible due to unsuitable surfaces or the inaccessibility or absence of outcrop.

Grid coordinates of all locations not listed in tables 2–4 are presented in Appendix 1.

Three clast types were dominant in the study. Overall chert, jasper and quartz comprise more than 90% of the clast types. The jasper included aphanitic siliceous rocks with conchoidal to hackly fracture in shades of red, purple, mid to dark brown and variegated combinations, while black was included with chert. Quartz was vein quartz, mostly milky white but shades of yellow and very rare clear glassy

varieties were also included. Chert included opaque and semi-opaque siliceous rocks with conchoidal to hackly fracture in various colours, including black, grey, white, green, blue, buff and pale brown.

Cobble density, in the conglomerates containing cobbles, was calculated by drawing a 0.5 m by 0.5 m square on the surface and counting the number of cobbles (64 mm to 256 mm diameter) falling partly or wholly within the square. In a few rare cases a 0.5 m square was not available, so a rectangle of the same area (0.25 m<sup>2</sup>) was used. The method described provided consistent results (tables 2, 3 and 4) and was used to identify the conglomerate units.

Further criteria to guide the identification the non-conglomeratic units were also developed, including the presence or absence of beds of airfall tuffs or beds of reddish purple mudstones. The criteria to guide the identification of the Triassic units are shown in Table 1.

**Table 2: Cooperook Conglomerate Member — jasper and quartz clast percentages of total clasts**

Location ID	% jasper	% quartz	Cobbles in 0.5 m x 0.5 m area	1:25 000 map sheet	MGA coordinates (metres)	
					Easting	Northing
57	16	38	0	Lorne	474472	6500274
140	18	33	2	Lorne	473685	6499187
140	18	36	2	Lorne	473685	6499187
26	17	20#	1	Byabarra	474286	6512671
46	4	47	1	Cooperook	460421	6482407
108	11	35	2	Lorne	455532	6488610
21	20	31	1	Grants Head	478847	6512254
21	20	24#	11#	Grants Head	478847	6512254
75	18	28	0	Cooperook	464568	6479726
94	16	37	0	Byabarra	474235	6512585
115	11	36	0	Cooperook	462123	6485096
98	18	30	0	Byabarra	461770	6507397
43	14	35	0	Byabarra	471122	6509036
107	19	36	0	Lorne	457286	6487882
343	17	37	0	Lorne	455576	6488639
142	13	34	0	Grants Head	477799	6512307
147	14	37	0	Grants Head	480158	6505515
147	16	39	0	Grants Head	480158	6505515
156	13	34	0	Grants Head	479559	6504769
157	16	30	0	Grants Head	479428	6504725
154	11	36	0	Grants Head	479880	6504029
149	7	51	1	Bobin	452348	6496853
151	9	54	2	Bobin	452166	6497291
161	19	28	1	Grants Head	483900	6501674
162	17	30	1	Grants Head	483863	6501658
163	17	34	2	Grants Head	483863	6592870
160	16	33	0	Grants Head	481717	6508142
167	20	29	0	Lorne	474734	6500844

167	14	24	0	Lorne	474734	6500844
178	14	34	0	Grants Head	481677	6507643
179	18	27	1	Grants Head	481768	6507491
185	16	32	1	Grants Head	481323	6507289
186	14	32	0	Grants Head	481065	6507419
186	12	35	0	Grants Head	481065	6507419
187	16	30	0	Grants Head	480845	6507513
188	21	25	2	Grants Head	481126	6506565
36	19	30	1	Grants Head	479363	6504718
262	8	46	0	Byabarra	467800	6512769
290	15	42	1	Byabarra	467154	6512493
103	16	27	7+	Byabarra	457483	6506196
103	14	42	2	Byabarra	457483	6506196
128	15	49	2	Byabarra	457903	6505907
106	12	40	0	Cooperook	458811	6486356
106	17	39	0	Cooperook	458811	6486356
109	14	43	0	Lorne	454332	6489371
148	9	48	2	Lorne	452694	6495825
113	15	49	0	Lorne	454203	6490583
153	7	54	0	Lorne	452541	6497411
102	8	44	3	Lorne	454854	6488404
111	13	27	0	Lorne	454530	6492952
258	13	38	0	Byabarra	470915	6513759
	<b>15%</b>	<b>36%</b>	<b>1</b>			
	<b>&lt;20%</b>	<b>&gt;25%</b>	<b>&lt;3</b>			

# Basal beds +Cobble band

**Table 3: Laurieton Conglomerate — jasper and quartz clast percentages of total clasts**

Loc. ID.	% jasper	% quartz	Cobbles in 0.5 m x 0.5 m area	1:25 000 map sheet	MGA coordinates (metres)	
					Easting	Northing
118	32	24	14	Grants Head	485524	6504077
119	33	15	10	Grants Head	485533	6504027
30	34	19	10	Grants Head	485441	6503483
67	35	23	13	Laurieton	484581	6498530
120	35	19	8	Grants Head	485540	6504008
121	33	11	6	Grants Head	483255	6511178
137	31	19	11	Grants Head	480922	6506181
137	30	22	2*	Grants Head	480922	6506181
137	28	24	6	Grants Head	480922	6506181
164	26	24	4	Grants Head	484925	6503089
165	26	25	3	Grants Head	484947	6503831
326	25	22	1*	Grants Head	480734	6506189
326	22	21	1*	Grants Head	480734	6506189
342	28	21	5	Grants Head	485145	6503483
342	30	20	4	Grants Head	485145	6503483
	<b>30%</b>	<b>20%</b>	<b>6</b>			
	<b>&gt;20%</b>	<b>&lt;25%</b>	<b>&gt;3</b>			

\* Fine-grained bed

**Table 4: Coorabakh Conglomerate — jasper and quartz clast percentages of total clasts**

Loc. ID.	% jasper	% quartz	Cobbles in 0.5 m x 0.5 m area	1:25 000 map sheet	MGA coordinates (metres)	
					Easting	Northing
110	8	59	0	Lorne	453257	6494118
124	13	49	0	Lorne	453757	6495220
303	9	63	0	Lorne	453999	6495175
96	16	30	0	Byabarra	467864	6513742
96	19	26	0	Byabarra	467864	6513742
27	18	39	0	Byabarra	475300	6512995
27	18	37	0	Byabarra	475300	6512995
	<20%	>25%	0			
	101	303				
92	22	26	3	Byabarra	472025	6514805
93	24	20	0	Byabarra	472046	6514806
	16%	39%	<1%			
	<25%	>20%	<5%			

## Summary of Triassic stratigraphy of the Lorne Basin

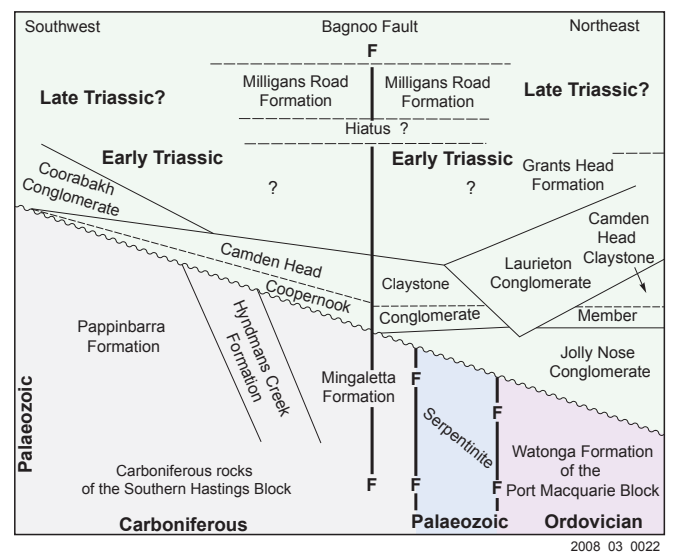
The generalised relationships between the Triassic stratigraphic units of the Lorne Basin and underlying Palaeozoic units are presented in Figure 3. In the northeastern Lorne Basin the floor to the basin is comprised of rocks of the Port Macquarie Block. These include Palaeozoic serpentinite, metadolerite and Middle Ordovician to Late Carboniferous low-grade regionally metamorphosed rocks of the Watonga Formation. The remainder and bulk of the basin floor is comprised of the sedimentary Early Carboniferous Pappinbarra and Hyndmans Creek formations and Late Carboniferous Mingaletta Formation of the southern Hastings Block. Och, Percival and Leitch (2007) and Och, Leitch and Caprarelli (2007) described the Watonga Formation while Roberts et al. (1995) described the Carboniferous formations of the southern Hastings Block.

The lowermost Triassic formation is the Jolly Nose Conglomerate (Figure 3), which is only developed in the northeastern part of the basin, north of Queens Lake and east of the North Coast Railway. It is predominantly composed of pebbles and cobbles probably derived from basin floor (basement) formations within or immediately outside of the basin perimeter.

The Jolly Nose Conglomerate is conformably overlain, as is the remainder and bulk of the basin floor, by the Coopernook Conglomerate Member of the Camden Head Claystone. That member is widely distributed throughout the basin and structurally inferred to underlie the younger Triassic rocks. It is composed predominantly of chert, quartz and jasper

pebble and granule conglomerate and sandstone, interbedded with grey and reddish purple mudstone. Clasts have been derived from beyond the basin perimeter. The member is upwards fining and grades into the remainder of the Camden Head Claystone which is composed predominantly of grey and reddish purple mudstone with minor sandstone.

The Laurieton Conglomerate overlies the Camden Head Claystone and has a limited distribution in the northeastern part of the basin, north of Watson Taylor Lake and east of the Pacific Highway. The formation is a very thickly bedded unit composed of chert, quartz and jasper cobble and pebble conglomerates, again with clasts derived from beyond the basin perimeter. In the immediate vicinity of Jolly Nose Hill the Camden Head Claystone and its Coopernook Conglomerate



**Figure 3.** Generalised relationships between Palaeozoic and Mesozoic stratigraphic units within and under the Lorne Basin



Member are not present and the Laurieton Conglomerate overlies the Jolly Nose Conglomerate.

West of the Pacific Highway the Coorabakh Conglomerate overlies (in some places) the Camden Head Claystone. It is composed of predominantly pebble and granule conglomerate, finer in grain size, richer in quartz and poorer in jasper clasts than the Laurieton Conglomerate. The Coorabakh Conglomerate is present on the Lansdowne Escarpment between the Nellies Flat Fault and Dellward Fault, and along the top of the Broken Bago Range.

The Grants Head Formation conformably overlies the Laurieton Conglomerate. The distribution is restricted to the northeastern part of the basin (north

of Queens Lake and east of the Jolly Nose Hill). The formation is an upwards-fining sequence of 60% mudstone interbedded with 40% sandstone.

Plant fossils indicate an Early Triassic age for all of these units — with the exception of the underlying Jolly Nose Conglomerate which, in the absence of palaeontological data, is indeterminate but probably also Early Triassic.

After a presumed hiatus, the Milligans Road Formation, composed of sandstone, airfall tuff and minor carbonaceous mudstone, was deposited. While no identifiable fossil plants have been recovered to confirm an age, the airfall tuffs are believed to be associated with the emplacement of Late Triassic to Early Jurassic felsic igneous rocks in the immediate vicinity.

## Triassic unit descriptions

### Jolly Nose Conglomerate (Leitch & Bocking 1980)

<i>Derivation</i>	The Jolly Nose Conglomerate was first identified and mapped by Bocking (1977), then formally named and described by Leitch and Bocking (1980). It is named after the Jolly Nose Hill, a prominent peak in the immediate area of the type section.
<i>Distribution</i>	The Jolly Nose Conglomerate has a limited extent occurring only in the northeastern part of the Lorne Basin, east of the North Coast Railway line and north of Herons Creek and Queens Lake.
<i>Geomorphic expression</i>	The Jolly Nose Conglomerate crops out poorly; most outcrops are moderately to highly weathered.
<i>Type section</i>	Leitch and Bocking (1980) nominated the type section to be on the south side of Jolly Nose Hill between GR 480537 6505540 and GR 480433 6505873 (1:25 000 map sheet 9434-1-N, Grants Head) (locations 79 and 76; all locations are listed in Appendix 1). They also indicated more accessible exposures on the former Pacific Highway (location 20) and at Cowarra quarry (location 21). There was insufficient exposure at the type section to construct a measured section.
<i>Description at type locality</i>	Leitch and Bocking (1980 p.93) comprehensively described the Jolly Nose Conglomerate. ‘Massive and rudaceous rocks dominate the Jolly Nose Conglomerate. These are mainly well rounded cobble conglomerates with an open framework and a coarse quartz sandstone matrix. The unit is characterised by the presence of mainly poorly-indurated quartz sandstone clasts, in contrast with the Laurieton Conglomerate in which most clasts are composed of chert, jasper and vein quartz. Frequently pebbly and sometimes cross-stratified quartz sandstones occur in the Jolly Nose Conglomerate.’
<i>Lithology</i>	The author examined about 30 thin sections from the former Pacific Highway location (location 20) where the clasts are least weathered. The clast lithology of the Jolly Nose Conglomerate was found to be very varied, being dominated (about 80%) by lithic and quartzofeldspathic sandstone comparable with those of the Carboniferous Pappinbarra Formation and Mingaletta Formation. Although other lithologies present include granitoids, quartzite and acid volcanic rocks, sources for all clasts can be found in basin floor rocks within the basin perimeter. The more exotic clasts may have been reworked from the Carboniferous conglomerates. This localised provenance is markedly different from the provenance of the Triassic strata higher in the sequence where chert, quartz and jasper dominate. The conglomerates are cobble-rich as shown at the type section (location 79), east of Jolly Nose Hill (location 38), Pacific Park (location 20) and at Cowarra Quarry (location 21).

<b>Thickness</b>	Leitch and Bocking (1980) estimated a thickness of 100 m for the Jolly Nose Conglomerate at the type section while the author estimates a thickness of over 140 m at a nearby section (locations 38 to 78). However the formation thins rapidly to the northwest, with a total thickness of 5 m at Cowarra Quarry (location 21) and an observed thickness of 2 m and estimated thickness of about 8 m at the former Pacific Highway (location 20).
<b>Relationships and boundary criteria</b>	The Jolly Nose Conglomerate is the lowest Triassic formation in the Lorne Basin and, where present, unconformably overlies the Palaeozoic basement rocks, as at location 20 (on the former Pacific Highway), where the formation can be seen directly overlying Palaeozoic serpentinite. In the Jolly Nose Hill area, the formation is overlain by the Laurieton Conglomerate, as at locations 76 and 78 (Photograph 1). Further south, at location 147; and west, as at locations 20 and 21, the formation is overlain by the Cooperbrook Conglomerate Member of the Camden Head Claystone.
<b>Distinguishing features</b>	The Jolly Nose Conglomerate is readily identified by its cobble clast lithology of predominantly (about 80%) lithic and quartzo-feldspathic sandstones and the rarity or absence of quartz, jasper or chert clasts. The formation crops out poorly and immediately overlies the Palaeozoic basin floor.
<b>Structural attitude</b>	The formation appears to fill a graben in the eastern floor of the basin and thins rapidly westwards beyond this depression.
<b>Correlation</b>	There are no other units in the Lorne Basin that can be correlated with the Jolly Nose Conglomerate.
<b>Age</b>	The age of the Jolly Nose Conglomerate is uncertain as no fossils have been recovered from the formation although shelly fossils were recovered from a constituent cobble. Thin section analysis of these fossils indicated that they were bivalves (rather than brachiopods) and of similar shape and size to the bivalves of the <i>Merismopteria</i> horizon in the Late Carboniferous Mingaletta Formation from which it is thought the cobble was derived.  The formation is assumed to unconformably overlie the Middle Ordovician to Late Carboniferous Watonga Formation, and is observed to overlie Palaeozoic serpentinite. The formation is overlain, in part, by the Laurieton Conglomerate which is constrained by macroflora to an Early Triassic age. The Jolly Nose Conglomerate is probably Early Triassic or perhaps Late Permian in age.



**Photograph 1.** Laurieton Conglomerate directly overlying less-resistant Jolly Nose Conglomerate at the southern side of Jolly Nose Hill (location 78). Photographer: G.W. Pratt.

## CAMDEN HAVEN GROUP

(Packham 1969)

The Early Triassic Camden Haven Group includes the Camden Head Claystone and its Cooperbrook Conglomerate Member; the Laurieton Conglomerate and its equivalent Coorabakh Conglomerate; and the Grants Head Formation.

Both Parisotto (1989) and van Bentum (1989) provided details of the sedimentology of the Camden

Haven Group. However their inclusion of the Camden Head Claystone as a component part of the Laurieton Conglomerate, contrary to the interpretation of the stratigraphy herein, does lead to confusion of the unit names but not the facies interpretation.

### Camden Head Claystone

(Pratt & Herbert 1973) — revised definition

The Camden Head Claystone is the lowermost, and most widely distributed, formation of the Early Triassic Camden Haven Group. The formation is an overall upward-fining sequence of pebble and granule conglomerate with interbedded sandstone and mudstone, including reddish purple mudstone beds unique to this formation. The basal part (approximately 30 m) of this unit is dominated by conglomerate and sandstone, now designated as a member of the formation: the Cooperbrook Conglomerate Member.

The remaining mudstone-dominated part of the formation is present in much of the basin centre, but

exposures are not common due to its generally deep weathering and recessive character.

The weathered condition of the exposures has made it impractical to delineate between the siltstones and claystones. Hence they have been grouped together as mudstones in the lithology descriptions and plots of the measured sections. The claystone name was retained as it was the original name used by Voisey who described the exposures of the top of the units at Grants Head and Camden Head where, here at least, the dominant constituent of the unit is claystone.

<b>Derivation</b>	The Camden Head Claystone is named after Camden Head where the first outcrop of Triassic rocks in the Lorne Basin was identified by Carne (1897). The formation was formally named by Pratt and Herbert (1973) who nominated, with a single grid reference, the Bago Road exposure south from Kings Creek as the type section because more of the unit was exposed there than at Camden Head. They also noted that the unit 'usually, although not always, has a thin basal conglomerate' and the 'conglomerate is identical in composition to the overlying Laurieton Conglomerate'. The latter part of this observation is now shown herein to be incorrect.
<b>Distribution</b>	The Camden Head Claystone is the most widely distributed formation throughout the Lorne Basin but, apart from the Cooperbrook Conglomerate Member, exposures are not common because it is generally deeply weathered and recessive.
<b>Geomorphic expression</b>	The presence of the Camden Head Claystone is usually suggested by undulating terrain without outcrop and the deep, usually rich red soil developed over it. There is often a noticeable change of slope and change in soil colour at the boundary of the formation and the overlying, more-resistant, Coorabakh Conglomerate. The Cooperbrook Conglomerate Member has a different geomorphic expression as described below.
<b>Type section</b>	The type section now proposed for this formation is located more precisely than the original site nominated by Pratt and Herbert (1973). The Camden Head Claystone type section is now specified as along Bago Road from GR 474286 6512671 (1:25 000 map sheet 9434-4-N, Byabarra; location 26) to GR 473623 6511952 (1:25 000 map sheet 9434-4-N, Byabarra; location 23). The lower and sand- to pebble-dominated part of the section, herein defined as the Cooperbrook Conglomerate Member, constitutes the lower part of the section from GR 474286 6512671 (1:25 000 map sheet 9434-4-N, Byabarra; location 26) to GR 474108 6512416 (1:25 000 map sheet 9434-4-N, Byabarra; location 24).
<b>Description at type section</b>	The type section for the Camden Head Claystone is exposed in road cuttings on the eastern side of the Bago Road southwards up the hill from near the Kings Creek Bridge. The Camden Head Claystone is an upward-fining sequence from pebble and granule conglomerate at the base, through sandstone to siltstone and claystone at the top. While these lithologies are interbedded in various proportions, the conglomerates are confined to the lower part of the formation.

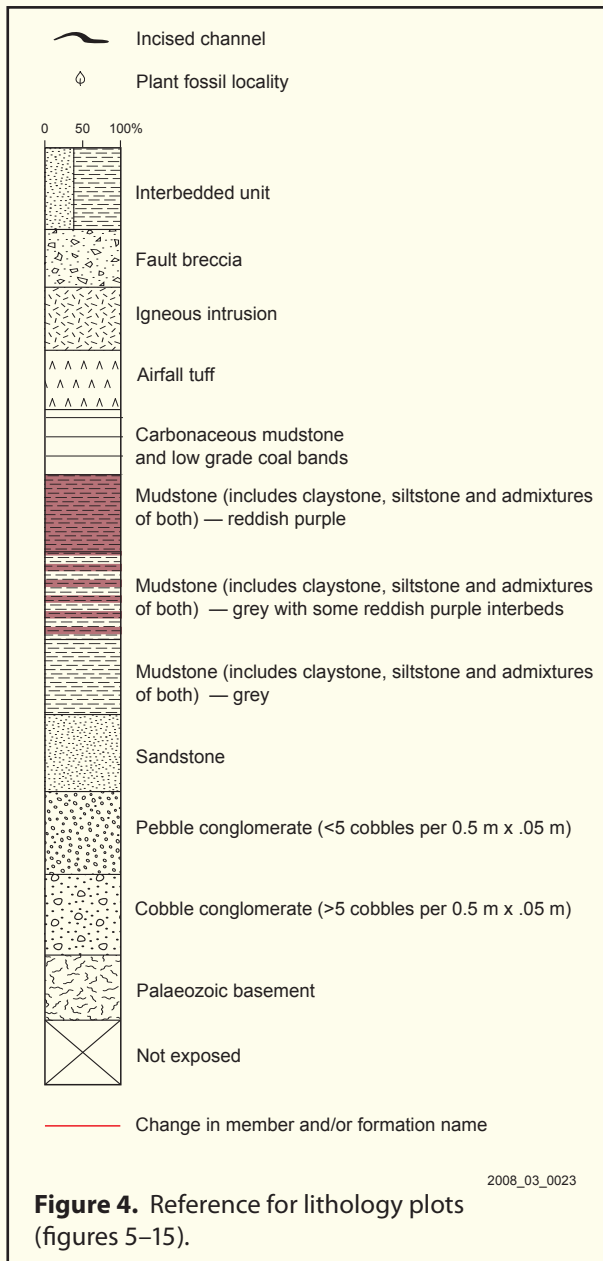
**... Description at type section** To provide more precise locations for the top and base of the section, the exposure was reassessed and measured. Bed lithology analysis of the 82 m thick Bago Road section has indicated an overall lithological composition of: conglomerate 16%; sandstone 21%; mudstone 63%.  
 The sequence fines upward, with rudaceous sedimentary rocks dominating the basal 32 m, where the components are: conglomerate 41%; sandstone 17%; mudstone 42%.  
 This basal 32 m unit contains a variety of interbedded lithologies from pebble (occasional cobble bands in some locations) conglomerate through sandstone to mudstone — although the unit is dominated by conglomerate and sandstone. This basal unit has both a lithology and topographic expression distinctly different to the upper part of the formation and so, as a mappable unit, is separated as a new member. It is herein defined as the Cooperbrook Conglomerate Member of the Camden Head Claystone.  
 The base of the Camden Head Claystone, being the base of its Cooperbrook Conglomerate Member, is defined as the bed which rests on the Jolly Nose Conglomerate, as at location 21 or the Palaeozoic rocks of the basin floor as at location 202. The top of the unit is the top of the reddish purple mudstone on which the Laurieton Conglomerate rests.  
 A graphical reference for the lithology of measured sections are presented in Figure 4. The graphical representation for the lithology of the type section of the Camden Head Claystone (location 26 to location 23), is presented in Figure 5.

**Lithology** The Camden Head Claystone is dominated by grey and reddish purple mudstone. The formation is readily identified by that reddish purple mudstone, which is absent from the other Triassic units. Some of the reddish purple mudstone weathers to grey while the grey mudstone may weather to, or be stained, reddish purple. The reddish purple mudstone is very well-developed in the upper part of the sequence and well-exposed in the coastal cliffs of Camden Head and Grants Head. Carbonaceous mudstones are not common but are exposed on the Pacific Highway 5 km north of Herons Creek (location 51). Thin ‘coaly’ beds, no longer exposed, were recorded by Morrison (1922), south of Johns River Railway station (location 116).  
 Below the mudstone-dominated top of the unit, as exposed at Camden Head and Grants Head, there is a horizon with more frequent thin- and medium-bedded sandstone beds. That horizon forms gently rounded hills throughout the outcrop area and can be seen in the cutting on the Pacific Highway 2 km south of Moorland, between Two Mile Creek and the North Coast Railway bridge (location 203). Mudstone dominates the unit between that horizon and the Cooperbrook Conglomerate Member.  
 Lithology plots of measured sections of the Cooperbrook Conglomerate Member at other exposures — Cowarra Quarry (location 22); Rock Creek, Langley Vale (location 72 to location 74); Hannam Vale (location 87 to 88); and Sapling Creek (location 20 to location 139) are presented in figures 6, 7, 8 and 9 respectively. Lithology plots of measured sections at the top of the sequence exposed at Camden Head (after Voisey, 1939) and at Grants Head (after Holmes & Ash 1979) are presented in figures 10 and 11, respectively.

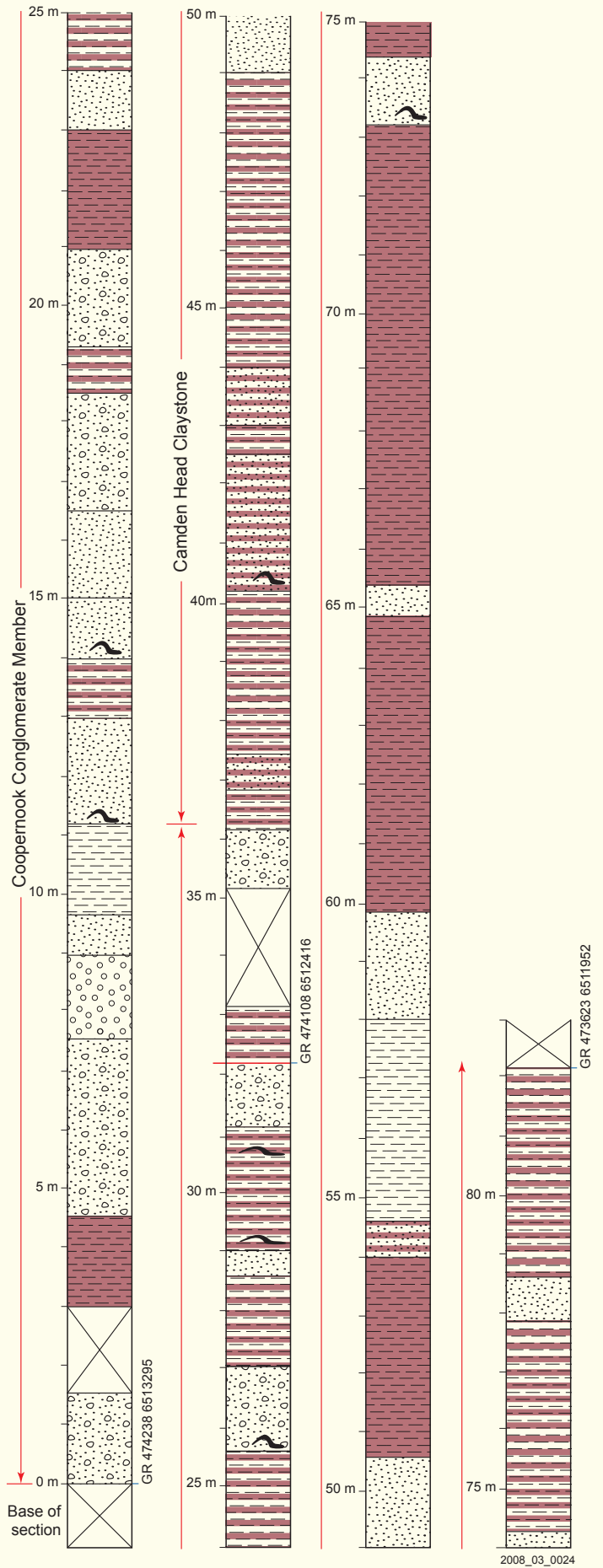
**Thickness** While a complete section has not been located, 82 m and 74 m sections have been measured at the Bago Road type section and the Rock Creek sections respectively.

**Depositional environment** The sedimentary sequence derived from sheet sands and channel sands incised into muddy overbank deposits together with the laminated reddish and grey terrestrial plant-bearing silts and clays, indicates a fluvial depositional environment for the Camden Head Claystone. From the identified megaflora, Holmes and Ash (1979 p. 68) concluded that ‘The localities from which the bulk of our flora was collected all represent a single environment, that of back-swamps bordering streams and filled by overbank flooding.’

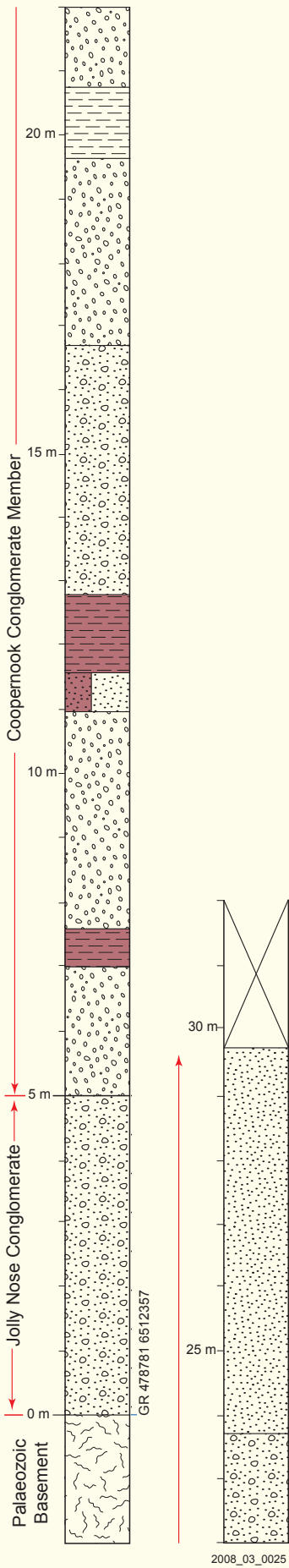
<b><i>Relationships and boundary criteria</i></b>	<p>Rocks of the Camden Head Claystone and, in particular, its basal Cooperbrook Conglomerate Member, unconformably overlie the Palaeozoic rocks of the basin floor. East of the North Coast Railway the formation overlies the Jolly Nose Conglomerate (where present) — except for a small area in the immediate vicinity of Jolly Nose Hill where the Camden Head Claystone is not present. The Camden Head Claystone is in turn overlain, generally with an erosional contact, by the Laurieton Conglomerate east of the Pacific Highway and by its lateral equivalent, the Coorabakh Conglomerate west of the Pacific Highway.</p> <p>The basal boundary of the Camden Head Claystone is chert–quartz–jasper pebble conglomerate or the reddish purple mudstone overlying the Jolly Nose Conglomerate or the Palaeozoic sedimentary rocks of the basin floor. The top of the formation is the reddish purple mudstone overlain by the cobble and pebble chert–jasper–quartz conglomerate of the Laurieton Conglomerate or more quartz-rich pebble conglomerate of the Coorabakh Conglomerate.</p>
<b><i>Distinguishing features</i></b>	<p>The Camden Head Claystone is characterised by the presence of reddish purple mudstone. Reddish purple mudstone is also sparsely interbedded with the sandstone and conglomerate of its Cooperbrook Conglomerate Member. However, mudstone is far more strongly developed in the upper part of the formation. This upper part is predominantly (about 80%) mudstone (grey or, commonly and distinctively, reddish purple). The formation is usually highly weathered and outcrops are not common. However, its presence is indicated by the red–brown clayey soil which develops over it. Clays of similar colour are also developed from weathering of some of the late Triassic to Jurassic igneous rocks. Sheet sandstone is also present, having been deposited adjacent to channels incised into the underlying mudstone.</p>
<b><i>Structural attitude</i></b>	<p>Generally the Camden Head Claystone dips slightly towards the centre of the basin. (Map 1 and Figure 2).</p>
<b><i>Correlation</i></b>	<p>There are no units in the Lorne Basin with which the Camden Head Claystone correlates.</p>
<b><i>Age</i></b>	<p>Megaflora fossils were collected by Carne (1897), Voisey (1939) and Pratt (1970), and were identified by W.S.Dun, A.B.Walkom and J.W. Pickett, respectively. Retallack (1977) and Holmes and Ash (1979) also collected and identified material from the Camden Head and Grants Head exposures. The megaflora is found in the grey mudstone while the reddish purple mudstone is deplete of plant fossils.</p> <p>Four of the five locations in the Holmes and Ash (1979) study work are at the top of the Camden Head Claystone — on the southern side of Camden Head (location 66) and in a thin bed of grey siltstone exposed at the base of sea cliffs on the northern side of Perpendicular Point. The third and fourth locations were in the Camden Head Claystone at Grants Head, 8 m and 13 m (see Holmes &amp; Ash 1979, figure 2, p. 48) below the Laurieton Conglomerate (figures 10 and 11). The fifth location was 63 m above the base of the Grants Head Formation at Bartletts Beach (location 104).</p> <p>Palynological samples from the Camden Head and Grants Head exposures were studied by Helby who reported ‘A probable upper Early Triassic age was suggested for these assemblages on the basis of comparison with Sydney Basin assemblages’ (1973 p. 146).</p>



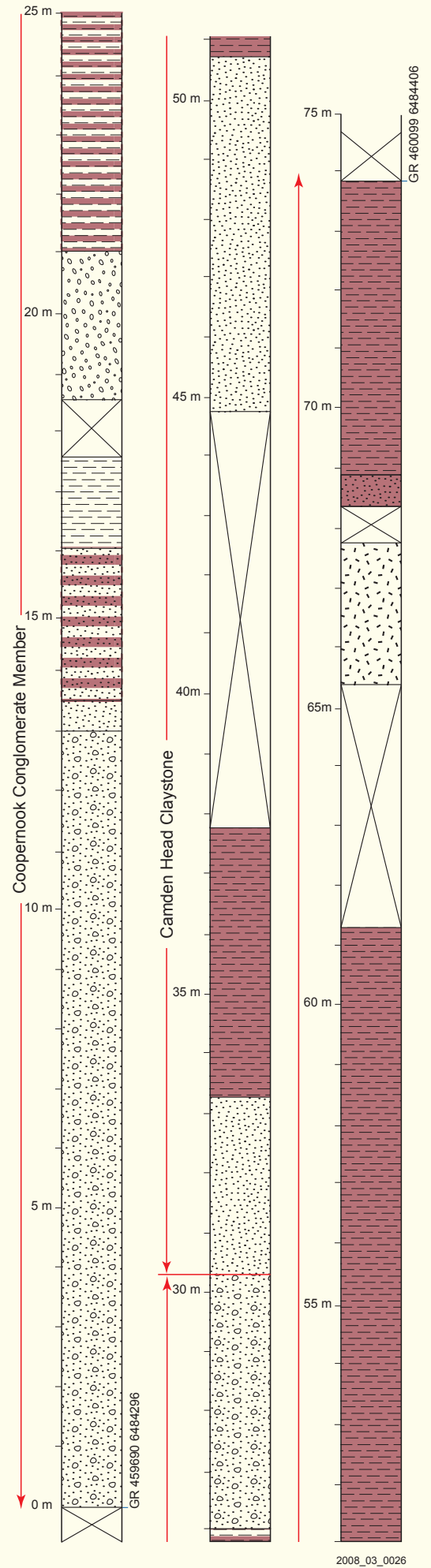
**Figure 4.** Reference for lithology plots (figures 5–15).



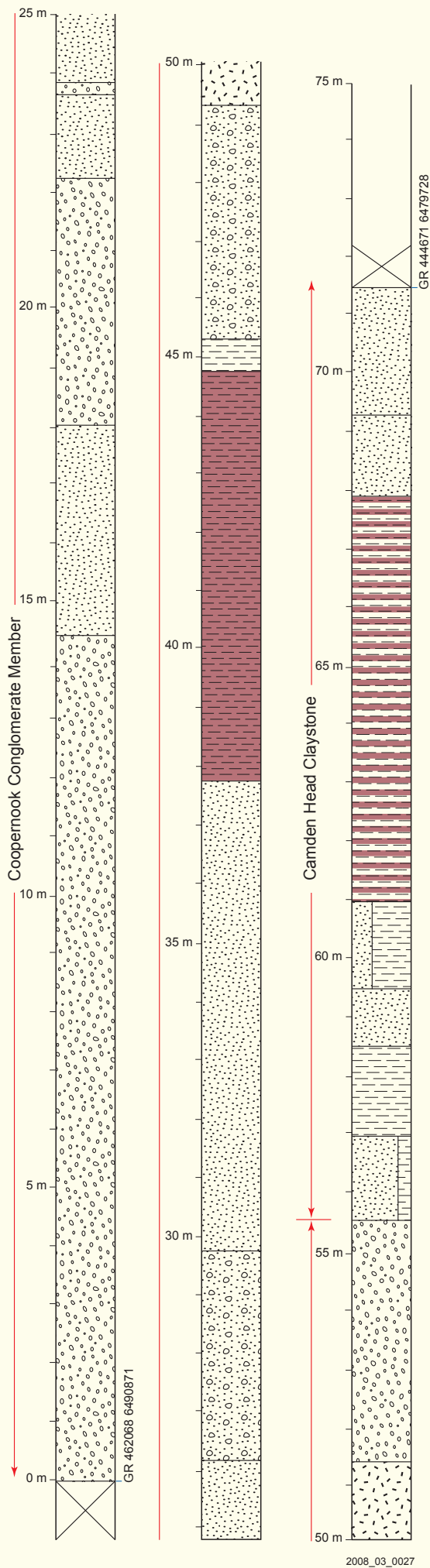
**Figure 5.** Lithology plot of the type section of the Camden Head Claystone.



**Figure 6.** Lithology plot of Cooperbrook Conglomerate Member at Cowarra Quarry.

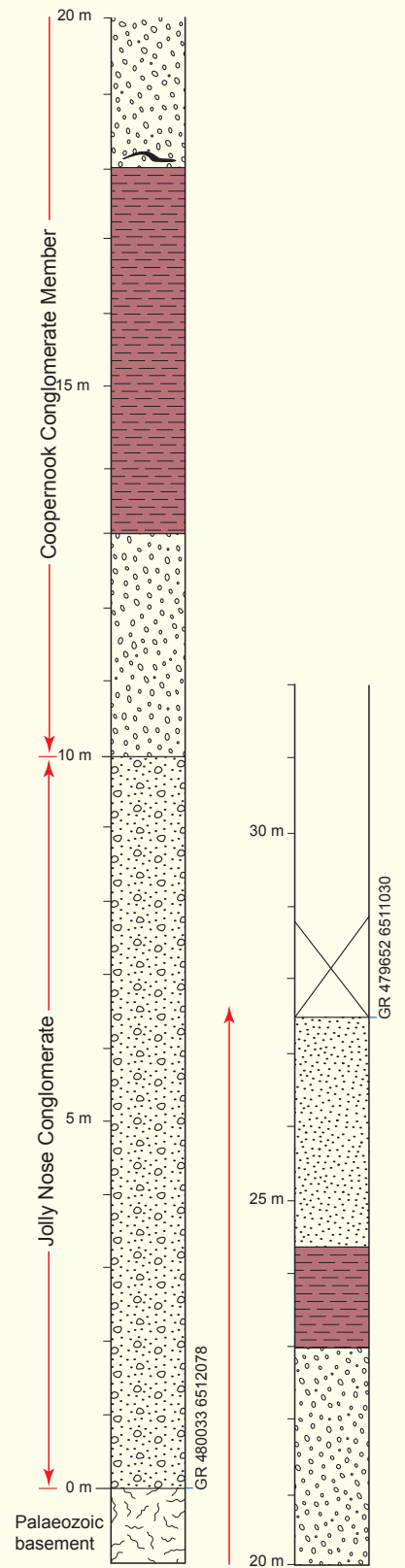


**Figure 7.** Lithology plot of Cooperbrook Conglomerate Member and Camden Head Claystone at Rock Creek, Langley Vale.



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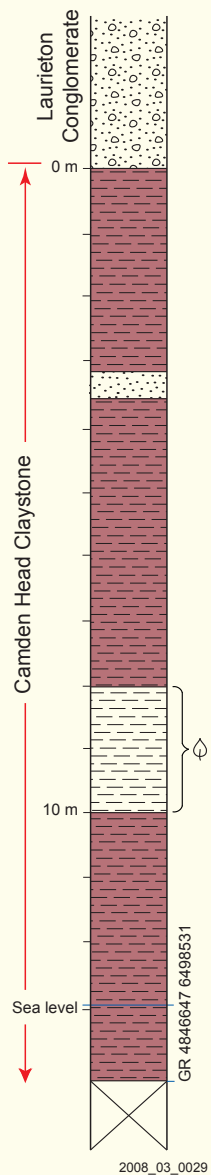
**Figure 8.** Lithology plot of Cooperbrook Conglomerate Member and Camden Head Claystone at Hannam Vale.



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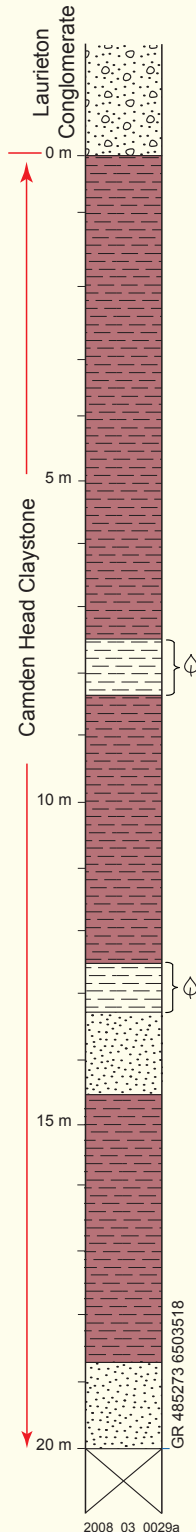
**Figure 9.** Lithology plot of Cooperbrook Conglomerate Member at Sapling Creek.



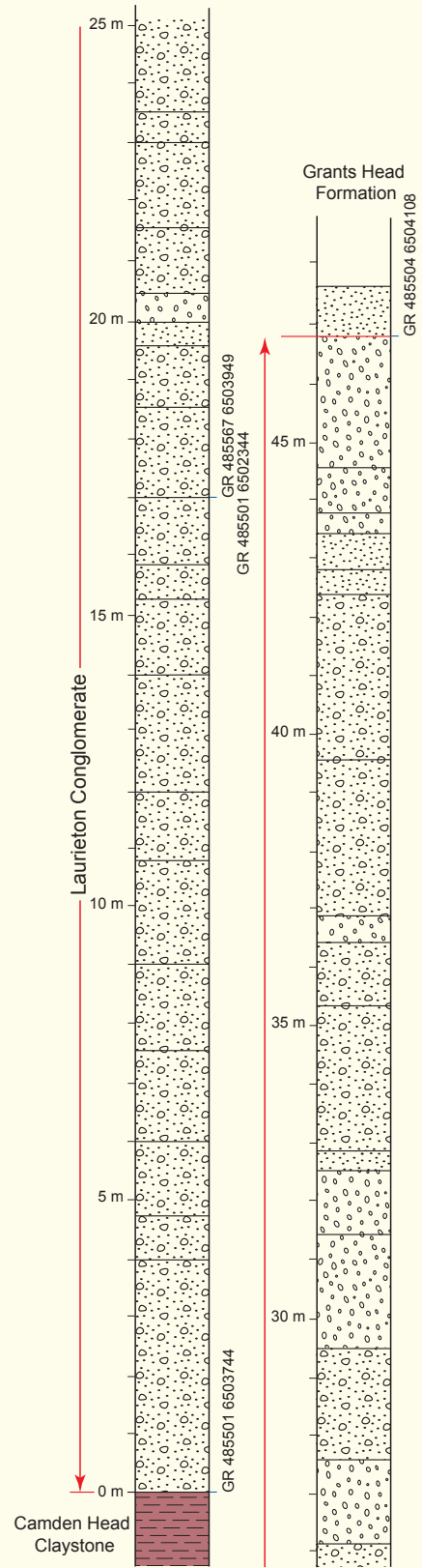


**Figure 10.** Lithology plots of top of Camden Head Claystone at Camden Head. Modified after Voisey (1939).

Note:  
Depth measured from the base of Laurieton Conglomerate

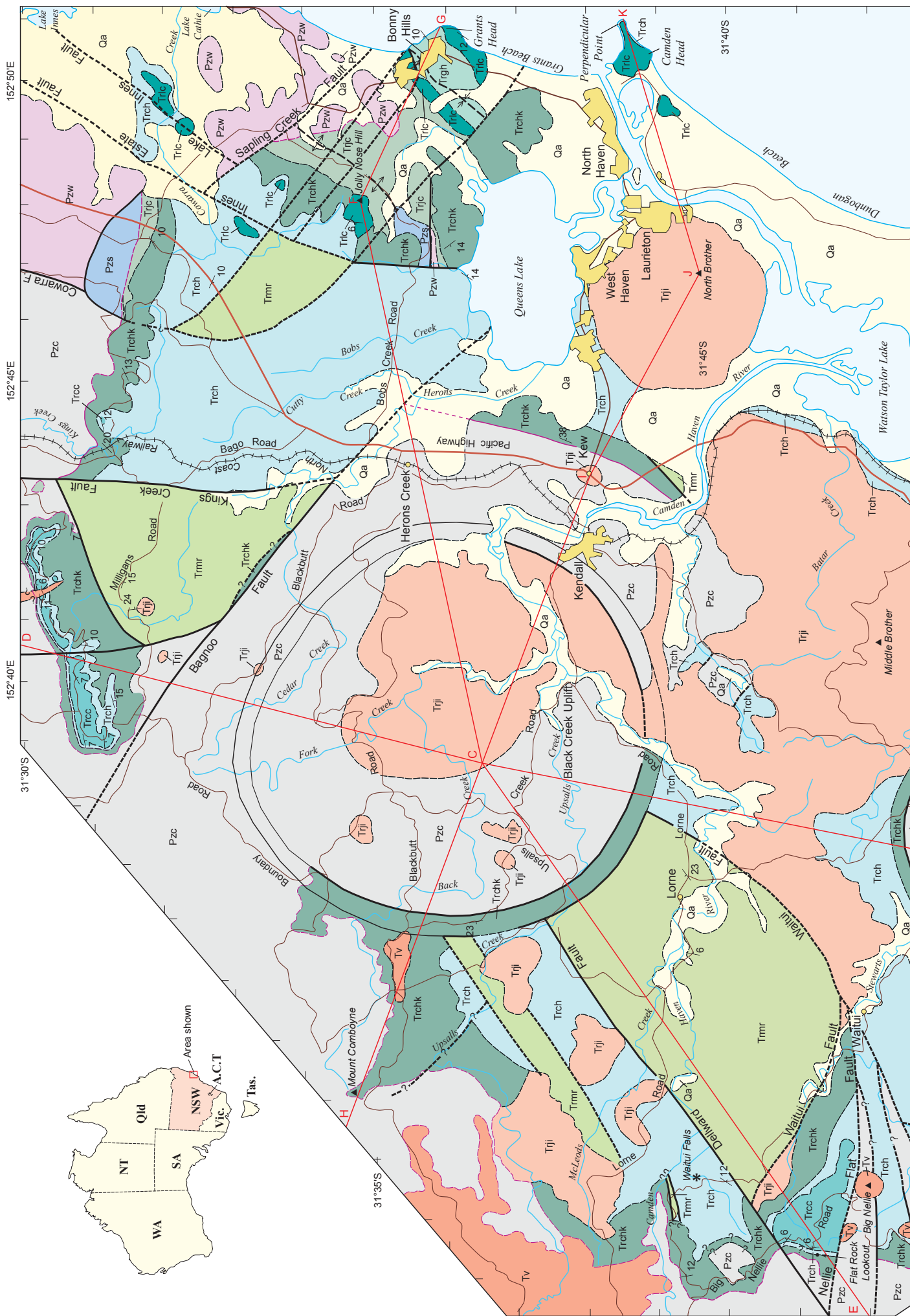


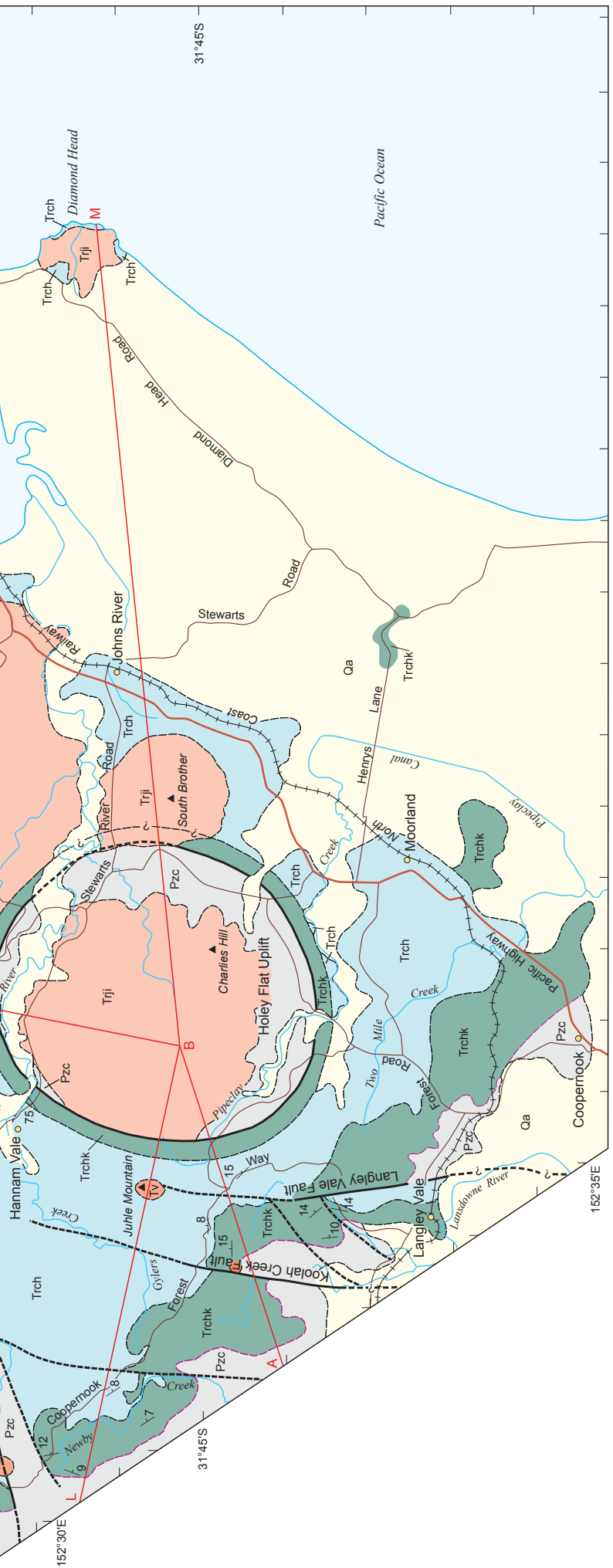
**Figure 11.** Lithology plots of top of Camden Head Claystone at Grants Head Modified after Holmes and Ash (1979).



**Figure 12.** Lithology plot of type section of the Laurieton Conglomerate at Grants Head.

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- Quaternary**  
 Qa Alluvium, unconsolidated sand and lacustrine deposits
- Tertiary**  
 Tv Volcanic rocks
- MESOZOIC**  
**Late Triassic – Early Jurassic**  
 Trji Intrusion  
 Trmr Milligans Road Formation

- Early Triassic**  
 Trgh Camden Haven Group  
 Trch Grants Head Formation  
 Trtc Coorabakh Conglomerate  
 Trch Laurieton Conglomerate  
 Trchk Camden Head Claystone  
 Trch Coopermook Conglomerate Member  
 Trjc Jolly Nose Conglomerate

- PALAEOZOIC**  
 Pzs Serpentinite  
 Port Macquarie Block  
 Pzw Undifferentiated – includes Ordovician to Carboniferous Watonga Formation and Permian Karikeree Metadolomite
- Carboniferous**  
 Southern Hastings Block  
 Pzc Undifferentiated – includes Carboniferous Pappinbarra Formation, Hyndmans Creek Formation and Mingaleitta Formation

- Geology reference**
- Geology boundary accurate
  - - - - - Geology boundary approximate
  - ? - - - - - ? Geology boundary inferred
  - Lineament position accurate
  - ? - - - - - ? Lineament concealed
  - Fault, accurate
  - - - - - Fault, approximate
  - - - - - Fault, concealed
  - ? - - - - - ? Fault, inferred
  - ? - - - - - ? Fault concealed, inferred
  - Mesozoic–Palaeozoic unconformity, accurate
  - - - - - Mesozoic–Palaeozoic unconformity, approximate
  - - - - - Mesozoic–Palaeozoic unconformity, concealed
  - Cross-sections
  - Dip and strike with direction of facing

**REFERENCE**

- Topography reference**
- Highway
  - Road
  - Railway
  - Built-up area / location
  - Lake / river
  - Coastline



## Cooperbrook Conglomerate Member new member

The Cooperbrook Conglomerate Member is an (overall) upward-fining sequence of pebble conglomerate with interbedded sandstone and grey or reddish purple mudstone beds. The unit forms most of the Lansdowne Escarpment in the southwestern part of the Lorne

Basin and underlies the Broken Bago Range in the north. In the centre of the basin the Cooperbrook Conglomerate Member surrounds all of the circular Holey Flat Uplift and the southwestern quadrant of the Black Creek Flat Uplift.

<b>Derivation</b>	The name Cooperbrook Conglomerate Member is derived from the village of Cooperbrook, near which the unit crops out extensively.
<b>Synonymy</b>	This member was previously the lower part of the (then undifferentiated) Camden Head Claystone.
<b>Distribution</b>	<p>The Cooperbrook Conglomerate Member is a widespread unit in the Triassic sequence of the Lorne Basin. It is present around the perimeter of the basin from Coralville in the southeast then westward and northwestward along the Lansdowne Escarpment, where it forms the cliff line, to the Lorne–Comboyne Road in the west of the basin and then to 5 km northeast of Mount Comboyne (Map 1).</p> <p>In the north of the basin the Cooperbrook Conglomerate Member is developed along the Broken Bago Range and east from the Bago Road to the Pacific Highway and Kew. The member crops out west of Bonny Hills both north of the Jolly Nose Hill and south towards Queens Lake.</p> <p>A further outcrop of the Cooperbrook Conglomerate Member occurs around the perimeter of a circular, 7 km diameter exposure of Carboniferous basin floor rocks between Hannam Vale and Moorland, the Holey Flat Uplift. Another exposure crops out around part of the perimeter of the Black Creek Uplift, from the Lorne Road between Lorne and Upsalls Creek to near Mount Comboyne (location 101). A further, near-vertical outcrop strata occurs adjacent to the Bagnoo Fault on Old School Road, 5 km northwest of Herons Creek at location 43 (Map 1).</p>
<b>Geomorphic expression</b>	Where conglomerate dominates, the Cooperbrook Conglomerate Member is often cliff-forming while the upper part of the member — with a finer component — forms a more rounded topography. Where the upper part has been eroded fully and the conglomerate has been deeply weathered, such as in the Cooperbrook to Coralville area, the unit forms a gently undulating topography.
<b>Type section</b>	The type section for the Cooperbrook Conglomerate Member is nominated as from Tunnel Road GR 474286 6512671(1:25 000 map sheet 9434-4-N, Byabarra; location 26) next to the Kings Creek Bridge southwards along the Bago Road to GR 474108 6512416 (1:25 000 map sheet 9434-4-N, Byabarra; location 24). The top of the member is defined as the top of the uppermost conglomerate bed in this section and is conformably overlain by the remainder of the Camden Head Claystone. The base of the formation is not exposed in this section, although the lowest exposure is thought to be only a few metres above the Palaeozoic basin floor rocks. Elsewhere, the base of the Cooperbrook Conglomerate Member, is defined as the bed which rests on the Jolly Nose Conglomerate, as at location 21 or the Palaeozoic rocks of the basin floor, as at location 202. A lithology plot of the type section is shown as part of the lithology graphic for the Camden Head Claystone in Figure 5.



**Photograph 2.** General thinning- and fining-upwards trend in Cooperbrook Conglomerate Member at Bago Road type section (location 25). Photographer: G.W. Pratt.

<b>Description at type section</b>	In its type section the Cooperbrook Conglomerate Member is an upward-fining sequence of interbedded pebble and granule lithic quartzose conglomerate and sandstone with minor, generally grey, mudstone, although some mudstone has a distinctive reddish purple colour. Bedding thickness in the conglomerates ranges from very thick to thin bedded, the thicker beds becoming less frequent upwards in the section. Conglomerate beds in the basal 10 m to 20 m may contain cobble- and jasper-rich bands up to 1 m in thickness. However, these bands are rarely repeated and are often interbedded with reddish purple mudstone. These features, together with different jasper and quartz clast percentages (of total clasts), distinguish the unit from the Laurieton Conglomerate.
<b>Remarks on other exposures</b>	Reddish purple mudstone occurs at or very close to the base of the unit in several other exposures throughout the basin. In some places, channel deposits rest on the basin floor and these often contain cobbles and an elevated proportion of jasper clasts as seen in Taylors Quarry, Kew at Locations 54 and 55 or in the west at Locations 100, 101 and 197. Towards the centre of the basin the conglomerate tends to be finer grained.
<b>Lithology</b>	<p>The type section of the Cooperbrook Conglomerate (Figure 5) consists of conglomerate 41%; sandstone 17%; and mudstone (siltstone, claystone) 42%. The general bed thinning and upward-fining trend can be seen in outcrop in Photograph 2.</p> <p>At the type section, jasper clasts constitute 16% and quartz clasts 37% of the total clasts while the average of 51 samples (each of 100 pebbles) throughout the basin was jasper 15% and quartz 36% of total clasts. In conglomerate exposures throughout the basin, there are less than 3 cobbles per 0.5 m × 0.5 m square. Table 2 presents the jasper and quartz clast percentages of total clasts measured in 46 locations. (At some locations two separate samples were taken.)</p> <p>The significant proportion of chert and jasper clasts is typical of the New England Orogen provenance which is also commonly the provenance of Triassic strata in the Gunnedah Basin and northern Sydney Basin. The input of quartz as clasts into the Gunnedah Basin and Sydney Basin is considered to be from Lachlan Orogen (to the west) but the source of quartz clasts for the Lorne Basin is uncertain. It may have been from the Lord Howe Island Rise to the east. Chert and jasper are also common in the Watonga Formation, immediately northeast of the Lorne Basin.</p>
<b>Thickness</b>	Although most measured sections do not expose both the top and base of the member, most are considered to start within a few metres of the base. The member has an estimated thickness throughout the basin of between 30 m and 50 m. The greatest thickness (estimated maximum 50 m) is developed in the west of the basin in the Mount Comboyne area.
<b>Depositional environment</b>	Interbedded sheet sands and muddy overbank deposits with incised channel sands indicate a fluvial environment for deposition of the member. A good example is seen at location 75 (Photograph 3).
<b>Relationships and boundary criteria</b>	The member conformably overlies the Jolly Nose Conglomerate in the northeastern part of the Lorne Basin, as at Cowarra Quarry (location 21). Elsewhere it unconformably overlies the Palaeozoic basement as at Taylors Quarry, Kew (locations 54 and 55). This exposure has been destroyed by recent roadworks. The Cooperbrook Conglomerate Member is conformably overlain by the remainder of the Camden Head Claystone as in the type sections for both units at location 24.



**Photograph 3.** Channel sandstones incised into reddish purple mudstone overbank deposits of the Cooperbrook Conglomerate Member at the Cooperbrook Cemetery Quarry (location 75). Photographer: G.W. Pratt.

<b>Distinguishing features</b>	The member is predominantly (about 60%) conglomerate and sandstone. Cobbles are rare, and there are few very thick (>100 cm) beds. The very thick beds usually occur as individual layers rather than stacks of several very thick beds. Thin interbedded reddish purple mudstone is common, enabling the unit to be readily distinguished from the Grants Head Formation and the otherwise very similar Coorabakh Conglomerate — in both of which reddish purple mudstones are very rare or absent. Jasper clasts are usually <20% and quartz clasts usually >25%. The base of the Cooperbrook Conglomerate Member coincides with that of the Camden Head Claystone and the top of the member is the uppermost bed of pebble conglomerate overlain by sandstone or reddish purple mudstone.
<b>Structural attitude</b>	Outcrops around the basin perimeter generally have a slight dip towards the basin centre, usually less than 10°. Within the basin the Cooperbrook Conglomerate Member has been folded to very steep dips around two circular zones in which the basement rocks have been uplifted through the Triassic cover. On the Old School Road, at location 43, the member has been tilted to a near vertical position adjacent to the Bagnoo Fault.
<b>Correlation</b>	There are no units in the Lorne Basin with which this member correlates.
<b>Age</b>	Although fossils have not been recovered from the member, an Early Triassic age is indicated by the conformable stratigraphic position of the Cooperbrook Conglomerate Member at the base of the Camden Head Claystone, the top part of which contains megafloora fossils of probable late Early Triassic age (Holmes & Ash 1979).

### Laurieton Conglomerate (Pratt & Herbert 1973) — revised definition

This is a very thick-bedded unit of cobble and pebble conglomerate forming the coastal cliffs of Grants Head, Perpendicular Point, Camden Head and the prominent ridge to the west of Bonny Hills, Jolly Nose Hill.

<b>Derivation</b>	The Laurieton Conglomerate was noted by Carne (1897) and Voisey (1939) and formally named by Pratt and Herbert (1973) after Laurieton, the nearest town to the major outcrops.
<b>Distribution</b>	The Laurieton Conglomerate is developed as isolated headlands around the northeastern perimeter of the Lorne Basin, as well as an upfolded exposure at the Jolly Nose Hill.
<b>Geomorphic expression</b>	The Laurieton Conglomerate is a resistant, cliff-forming unit well-exposed along the coast between Camden Head and Grants Head and on the eastern and southern sides of Jolly Nose Hill.



**Photograph 4.** Laurieton Conglomerate overlying Camden Head Claystone at the base of the type section at Grants Head (location 90). View to the south. Photographer: G.W. Pratt.



**Photograph 5.** Boundary between the Laurieton Conglomerate (right foreground) and the Grants Head Formation (left background) at the junction of their type sections. The staff is 2 m (location 31). View to the north east. Photographer: G.W. Pratt.

<b>Type section</b>	<p>Pratt and Herbert (1973) nominated the exposure at Grants Head as the type section for the Laurieton Conglomerate. A precise location at Grants Head, between GR 485501 6503744 (1:25 000 map sheet 9434-1-N, Grants Head, location 90, Photograph 4), and GR 485504 6504108 (1:25 000 map sheet), 9434-1-N, Grants Head, location 31) is now specified as the location of the type section. This is a complete and unbroken section with exposures of both the base and the top of the formation.</p> <p>The base of the formation is exposed at the foot of the cliff at GR 485501 6503744 (location 90). The section then offsets along the bed to GR 485567 6503949 (location 117) from where the section continues up-dip along the rock platform to the base of the overlying Grants Head Formation at GR 485504 6504108 (location 31, Photograph 5). A lithology plot of the Laurieton Conglomerate measured section is presented in Figure 12.</p>
<b>Description at type section</b>	<p>The type section for the conglomerate is exposed in cliffs and then along the rock platform on the northern side of Grants Head. Pratt and Herbert's (1973) original description has been revised to: the Laurieton Conglomerate is dominated by reddish to grey, poorly to moderately sorted pebble to cobble conglomerate usually with very thick (&gt;100 cm) beds, as exposed on the southern side of Grants Head (location 342); (Photograph 6). Pebble and minor granule conglomerate and sandstone interbeds are uncommon and beds of reddish purple mudstone are absent. The subrounded to subangular clasts are predominantly chert with lesser jasper and quartz. The fabric is clast-supported and the matrix is poorly sorted sandstone to claystone. Bedding is generally very thick with some minor thick-bedded strata.</p>
<b>Remarks on other exposures</b>	<p>While the type section description for the Laurieton Conglomerate is consistent with most other exposures, at Little Grants Head, 800 m southwest of the type section, there is a distinct decrease in clast size with pebble and granule conglomerate dominating. There is also a change in the relative proportions of quartz to jasper clasts, although jasper clasts still predominate over quartz clasts, a characteristic of the Laurieton Conglomerate.</p>
<b>Lithology</b>	<p>At the type section, jasper clasts comprise 33% and quartz clasts 20% of the total clasts and 12 cobbles per 0.5 m × 0.5m square, while the average of 15 samples (100 pebbles each) throughout the basin was jasper 30% and quartz 20% of total clasts and 6 cobbles per 0.5 m × 0.5 m square.</p> <p>Jasper clasts usually comprise &gt;25% of total clasts while quartz clasts are usually &lt;25% and there are usually more than 3 cobbles per 0.5 × 0.5 m square. Table 3 presents the jasper and quartz clast percentages of total clasts measured at 11 locations.</p> <p>The significant proportion of chert and jasper clasts is typical of the New England Orogen provenance and is also typical of the Triassic strata in the Gunnedah Basin (Digby Conglomerate) and northern Sydney Basin (Munmorah Conglomerate).</p>
<b>Thickness</b>	<p>At the type section the Laurieton Conglomerate is almost 47 m thick. There is an observed thickness of approximately 60 m at Jolly Nose Trigonometric Station but at that location the top of the unit is not exposed and hence the true thickness is greater.</p>

<b>Depositional environment</b>	<p>For the Laurieton Conglomerate the very thick bedding, crude cross stratification, clast-supported framework; poor to moderate sorting, and the subrounded to subangular clasts and their pebble to cobble size, indicate rapid deposition in a high-energy environment from a source of abundant supply. These features would suggest deposition in the main channel areas of a braided stream subject to periods of major flooding. Parisotto (1989, p.116) noted that sheetflood deposits and braided streams are most common in the mid-alluvial fan region. He concluded that 'the Laurieton Conglomerate was deposited in a mid-alluvial fan environment that was relatively flat and dominated by water-laid deposits, in particular those by sheetfloods'.</p>
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**Photograph 6.** Very thick beds of Laurieton Conglomerate at the south side of Grants Head. Only 2.3 m of the staff is visible (location 342). Photographer: G.W. Pratt.

<b>Relationships and boundary criteria</b>	<p>The Laurieton Conglomerate overlies the Camden Head Claystone with an erosive contact. However, in the Jolly Nose Hill area, the Camden Head Claystone and Coopernook Conglomerate Member are (locally) absent and there the Laurieton Conglomerate overlies the Jolly Nose Conglomerate (Map 1 and Figure 2). Poorly developed bedding in both units and their coarse cobble grainsize rendered the nature of the contact indeterminate, but it is presumed to be paraconformable. The Laurieton Conglomerate is conformably overlain by the Grants Head Formation.</p> <p>The basal boundary of the Laurieton Conglomerate is the contact between the chert–jasper and quartz cobble and pebble conglomerate of the Laurieton Conglomerate and the reddish purple mudstone of the underlying Camden Head Claystone or, in the immediate vicinity of Jolly Nose Hill, the lithofeldspathic sandstone cobble conglomerate of the Jolly Nose Conglomerate. The top of the formation is the top of the uppermost bed of chert–jasper–quartz pebble conglomerate underlying the pebbly sandstone of the Grants Head Formation.</p>
<b>Distinguishing features</b>	<p>The distinguishing features of the Laurieton Conglomerate are the abundant cobbles, poor sorting and dominantly very thick (&gt;100 cm) beds. Jasper clasts usually constitute &gt;30% and quartz clasts usually &lt;25%. There are generally more than 5 cobbles per 0.5 m × 0.5 m square. Beds of reddish purple mudstone are absent. The formation crops out strongly; is often cliff-forming; and is characterised by the very thick beds of the dominating conglomerate so well-exposed in the coastal cliffs and at Jolly Nose Hill.</p>
<b>Structural attitude</b>	<p>The Laurieton Conglomerate has been folded into north–south-trending open folds with a final basin-ward dip from the westernmost anticline (Map 1 and Figure 2).</p>
<b>Correlation</b>	<p>Pratt and Herbert (1973) considered the Laurieton Conglomerate to include the conglomerates of the Lansdowne Escarpment, Mount Comboyne and Broken Bago Range. However, those conglomerates are shown herein to be the Coopernook Conglomerate Member of the Camden Head Claystone. The conglomerates overlying the Camden Head Claystone are sufficiently different from the Laurieton Conglomerate to warrant their description as a separate new formation, the Coorabakh Conglomerate, albeit laterally equivalent to the former.</p>
<b>Age</b>	<p>Although fossils have not been recovered from the Laurieton Conglomerate, palynological samples from the Camden Head Claystone, 9 m below the Laurieton Conglomerate and from the Grants Head Formation at Bartletts Beach, 63 m above the Laurieton Conglomerate (location 104) place the formation in a transitional zone between the underlying <i>Protohaploxypinus samoilovichii</i> Assemblage and the <i>Aratrisporites tenuispinosus</i> Assemblage (Helby 1970, 1971, 1972). These floras are found in the Terrigal Formation, and underlying Clifton Subgroup, of the Sydney Basin and suggest an upper Early Triassic age for the Laurieton Conglomerate.</p>

## Coorabakh Conglomerate new formation

The Coorabakh Conglomerate is a unit of pebble conglomerate and interbedded sandstone — but lacking the reddish purple mudstone of the Coopernook Conglomerate Member. The unit is present in part of the Lansdowne Escarpment near Flat Rock Lookout

(Figure 2) and also forms the north-facing cliffs to the south of Stewarts River.

The Coorabakh Conglomerate also forms the capping of the Broken Bago Range in the north of the Lorne Basin.

<b>Derivation</b>	<p>The Coorabakh Conglomerate is named after the Coorabakh National Park where the formation is exposed in the cliffs forming part of the Lansdowne Escarpment.</p>
<b>Synonymy</b>	<p>The conglomerate was earlier mapped as part of the Laurieton Conglomerate (Pratt &amp; Herbert 1973).</p>
<b>Distribution</b>	<p>Between the Nellies Flat Fault and Dellward Fault the conglomerate is exposed along the Lansdowne Escarpment (in the southwestern part of the Lorne Basin). It extends northeastwards to terminate in a northeast-facing cliff line overlooking Stewarts River, and also forms the capping along the top of the Broken Bago Range in the north. The formation is not preserved in the central part of the basin.</p>



<b>Geomorphic expression</b>	The conglomerate is cliff-forming, with both west-facing and northeast-facing cliffs between the Nellies Flat Fault and Dellward Fault (as can be seen from location 273; Photograph 7) and north-facing cliffs along the top of the Broken Bago Range. There is often a noticeable change of slope and change in soil colour at the boundary of the formation and the underlying less-resistant Camden Head Claystone.
<b>Type locality</b>	An exposure of the Coorabakh Conglomerate measurable as a type section has not been located. However, good exposures suitable for, and designated as, a type location are present along Oskies Trail from GR 54050 6495119 (1:25 000 map sheet 9434-4-S, Lorne; location 331) to GR 453458 6494980 (1:25 000 map sheet 9434-4-S, Lorne; location 328).
<b>Description at type locality</b>	Loose boulders and outcrop are exposed along Oskies Trail from location 331 westwards to the junction with the Cooperbrook Forest Way where, about 100 m to the south, the unit is exposed at the cliff top of the Lansdowne Escarpment at location 228. The Coorabakh Conglomerate is a dominantly pebble to granule conglomerate with interbedded sandstone and minor cobble conglomerate bands. Beds of reddish purple mudstone are absent. The formation frequently changes from thick to medium bedding although thick beds form the majority. The bed contacts are often gradational. The base of the unit is defined as the bed resting on the uppermost reddish purple mudstone of the Camden Head Claystone. The top of the unit is not constrained by other exposed overlying units.
<b>Lithology</b>	At the type location, jasper clasts in the Coorabakh Conglomerate made up 11% and quartz clasts 54% of the total clasts (the average of the two samples, each 100 pebbles), while the average of nine samples (each 100 pebbles) throughout the Lorne Basin was jasper 16% and quartz 39% of total. Quartz clasts dominate (usually >25%) over jasper clasts (usually <20%). However there is a slight increase in the proportion of jasper clasts eastwards along the Broken Bago Range. Table 4 presents the jasper and quartz clast percentages of total clasts measured at seven locations. The significant proportion of chert and jasper clasts is typical of a New England Orogen provenance. A possible source of the high proportion of quartz was mentioned under the Cooperbrook Conglomerate Member of the Camden Head Claystone.
<b>Thickness</b>	No strata overlie the Coorabakh Conglomerate, so the true thickness is not known. However, an estimated minimum thickness of approximately 30 m is suggested from exposures on both the Lansdowne Escarpment and the Broken Bago Range.
<b>Depositional environment</b>	The rapid variation from poorly sorted cobble conglomerates to moderately well-sorted sandstones, the rapid and alternating bed thicknesses, and the absence of overbank deposits with incised channel deposits suggest a fluvial braid plain environment for deposition of the Coorabakh Conglomerate. The coarser beds suggest rapid deposition in the deeper major channels. Such an environment would feature rapid deposition from a range of probably short-lived and variable flows with an abundant supply of clast material.
<b>Relationships and boundary criteria</b>	This conglomerate conformably overlies the Camden Head Claystone throughout the Lorne Basin. No overlying strata have been located. The base of the formation is the top of the uppermost bed of reddish purple mudstone of the Camden Head Claystone. The top of the formation is not defined.

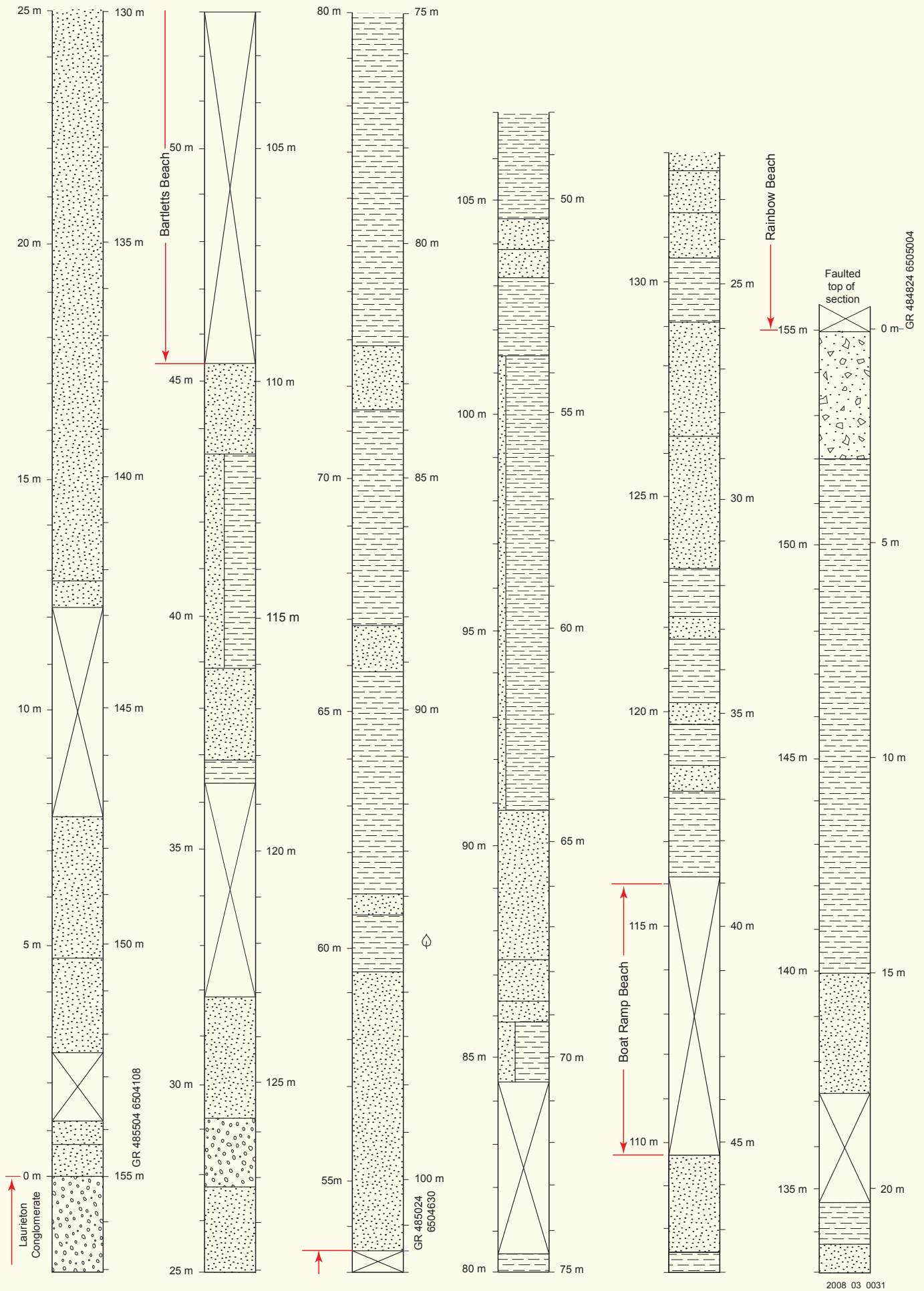


**Photograph 7.** North-east facing cliffs of Coorabakh Conglomerate south of Stewarts River (location 273).  
Photographer: G.W. Pratt.

<i>Distinguishing features</i>	The conglomerate is distinguished by its stratigraphic position, the relative proportion of quartz and jasper clasts, its bedding geometry and the absence of interbedded reddish purple mudstone. While the Coorabakh Conglomerate is very similar to the Cooperbrook Conglomerate Member of the Camden Head Claystone in terms of the relative proportion quartz and jasper clasts and its bedding geometry, it is differentiated from the Cooperbrook Conglomerate Member by its stratigraphic position and the absence of beds of reddish purple mudstone.
<i>Structural attitude</i>	The Coorabakh Conglomerate dips towards the basin centre, at angles of between 6° and 10°.
<i>Correlation</i>	The conglomerate is considered to be the lateral equivalent of the Laurieton Conglomerate.
<i>Age</i>	Fossils have not been recovered from the Coorabakh Conglomerate. However being the lateral equivalent of the Laurieton Conglomerate — which is constrained above and below by palynological evidence suggesting a late Early Triassic age (Helby 1970, 1971, 1972) — the Coorabakh Conglomerate is also considered to be of that age.

### Grants Head Formation (Pratt & Herbert 1973) — revised definition

The Grants Head Formation is the uppermost formation of the Camden Haven Group. It has only been identified east of the Pacific Highway and north of Queens Lake. It is well-exposed in the cliffs and along the rock platform from the north side of Grants Head through Bartletts Beach and Boat Ramp Beach and	intervening headlands to the southern end of Rainbow Beach in the Bonny Hills area. The overall upwards-fining unit is comprised of interbeds of sandstone and mudstone in which mudstone dominates (at approximately 60%) and sandstone is the minor component (at 40%).
<i>Derivation</i>	The Grants Head Formation was described and formally named by Pratt and Herbert (1973), after Grants Head where, on the northern side, the formation is best exposed in the coastal cliffs and adjacent rock platform.
<i>Distribution</i>	The formation is only exposed on the northeastern edge of the Lorne Basin. The author has not identified the formation west of the Jolly Nose Hill.
<i>Geomorphic expression</i>	The Grants Head Formation forms low coastal cliffs and crops out poorly in the gently undulating lowlands in a shallow syncline in the immediate vicinity of Bonny Hills.
<i>Type section</i>	The type section is exposed in cliffs and along the rock platform from the northern side of Grants Head to the southern end of Rainbow Beach at Bonny Hills. Pratt and Herbert (1973) nominated the exposure at Grants Head as the type section. A precise location at Grants Head, between GR 485504 6504108 (1:25 000 map sheet 9434-1-N, Grants Head; location 31; Photograph 5), and GR 484824 6505004 (1:25 000 map sheet 9434-1-N, Grants Head; location 33) is now specified as the location of the type section. A lithology plot of the measured section is presented in Figure 13.
<i>Description at type section</i>	The formation is an overall upward-fining sequence grading from minor pebble and granule conglomerate interbedded with lithic–quartz sandstone and siltstone near the base, passing upwards into interbedded quartz–lithic and quartz sandstone and grey mudstone. The unit contains a wide variety of bedding thicknesses and sedimentary structures. Bedding thicknesses range from thick beds of granule conglomerate and sandstone to very thinly laminated beds of mudstone. Sedimentary structures include cross stratification, parallel laminations, flaser bedding, ripple laminations, occasional palaeosols, and upward-fining sequences.
<i>Lithology</i>	Analysis of the type section (Figure 13), indicated lithological composition of: conglomerate 1%; sandstone 40%; and siltstone and claystone 59%. The formation fines upwards with rudaceous rocks dominating the basal 45 m (conglomerate 3%; sandstone 66%; and siltstone and claystone 31%). Siltstone and claystone dominate the upper 110 m, with sandstone (30%) and siltstone and claystone (70%).
<i>Thickness</i>	The Grants Head Formation at the type section is 155 m in thickness. However, the top of the section is faulted out so the true thickness may exceed that figure.



**Figure 13.** Lithology plot of type section of the Grants Head Formation.

<b>Depositional environment</b>	A fluvial depositional environment for the Grants Head Formation is indicated by the presence of cross-stratified sheet and channel sandstone deposits, levee deposits, ripple lamination, flaser bedding, laminated grey siltstones with root casts and occasional palaeosol horizons. Megafossil floral material was collected and examined by Holmes and Ash (1979) from the Grants Head Formation and they also suggested a depositional environment of backswamps bordering streams and filled by overbank flooding for the plant-bearing strata.
<b>Relationships and boundary criteria</b>	The Grants Head Formation conformably overlies the top pebble conglomerate bed of Laurieton Conglomerate (Figure 13) at its type section. However, the top of the section is faulted so that its overlying stratigraphic relationships are unknown. Along most of the type section, the Grants Head Formation is unconformably overlain by beds up to 3 m thick of ferricrete-containing clasts of Grants Head Formation, grading in size from granule to boulders, set in a ferruginised matrix of mud to pebble conglomerate and well exposed at Boat Ramp Beach (location 32). These ferruginised beds are probably of Quaternary age.
<b>Distinguishing features</b>	The distinguishing features for the Grants Head Formation are the absence of reddish purple interbedded mudstone and the absence of cobbles in the conglomerates of the lower, coarser part of the formation. Near the top of the cliff at the northern end of Bartletts Beach at Bonny Hills (location 104) a reddish purple hue is imparted to grey mudstones by a veneer of flakey ferruginised float from ferruginised horizons above. Close examination revealed the horizon to contain plant remains. Also absent from the Grants Head Formation are the tuff beds and poor coaly horizons characteristic of the younger Milligans Road Formation.
<b>Structural attitude</b>	The Grants Head Formation has an average dip of 10° towards 320°.
<b>Correlation</b>	There are no units in the Lorne Basin which correlate to the Grants Head Formation.
<b>Age</b>	Helby (1972) examined a sample which yielded 10 species of palynomorphs from the northern end of Bartletts Beach (location 104), 63 m from the base of the formation. Bocking (1977) also collected samples from this location and identified <i>Dicroidium dubium</i> var. <i>australe</i> (Jacob & Jacob) Retallack. Holmes and Ash (1979) collected and identified more species from the same location. Both the palynology and megafossil samples suggest a late Early Triassic age for the Grants Head Formation.

## UNGROUPED

## Milligans Road Formation new formation

The Milligans Road Formation is a sequence of interbedded mudstone, carbonaceous mudstone and poor coaly bands, occasional granule to pebble conglomerate, tuffaceous sandstone and airfall tuff. While some tuffs are relatively hard and

form resistant outcrops, others, and interbedded mudstones, are deeply weathered and recessive in character. The formation occurs in fault-bounded blocks in the northern and western portion of the Lorne Basin.

<b>Derivation</b>	The Milligans Road Formation is named after Milligans Road, along which it crops out in several places, albeit poorly.
<b>Distribution</b>	The formation is exposed at the intersection of Bago Road and Milligans Road (location 95) and extends westward, with few outcrops along Milligans Road to near the junction with Rollover Road. Separate outcrops also occur on the Pacific Highway 1 km north of the Camden Haven River Bridge and about 5 km north of Herons Creek (although the latter exposure has been destroyed by recent roadworks). A downfaulted block of the formation occurs between Lorne and Stewarts River, while further small downfaulted blocks occur from Swans Crossing southwest to the Lorne–Comboyne Road, and on the ‘Camden Road 4WD’ track 5 km west of Dellward.
<b>Geomorphic expression</b>	The formation usually forms gently undulating terrain towards the centre of the Lorne Basin. However in the area between Waitui Falls and Lorne, resistant tuff beds form a prominent ridge north of Stewarts River.
<b>Type section</b>	The type section is designated to be from the base of the tuff exposed at the Bago Road–Milligans Road intersection GR 469986 6512134 (1:25 000 map sheet 9434-4-N, Byabarra; location 95) to the top of the airfall tuff beds exposed in a quarry 200 m to the southwest at GR 473259 6511362 (1:25 000 map sheet 9434-4-N, Byabarra; location 28).

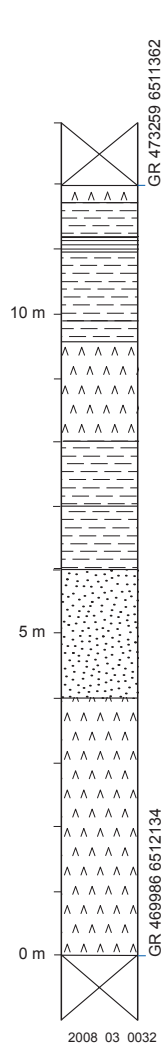
A lithology plot for the type section is presented in Figure 14. A lithology plot (Figure 15) for the measured section exposed in the Volcanic Resources Quarry (GR 470332 6512062, 1:25 000 map sheet 9434-4-N, Byabarra; location 45; Photograph 8) is presented for comparison.

<i>Description at type section</i>	The type section of the Milligans Road Formation is exposed in the roadside embankment at the intersection of the Bago Road and Milligans Road, southwestward along the gutters up a track leading to a quarry at the top of the rise. The beds are weathered and poorly exposed. However, the sequence of sedimentary and pyroclastic rocks of presumed Late Triassic age — and uniquely containing airfall tuff beds often associated with carbonaceous mudstone and thin poor ‘coal’ beds — occurs at several locations within the Lorne Basin. Thus the sequence warrants description as a new formation, the Milligans Road Formation. The tuffs are thickly bedded whereas the sandstones and mudstones are laminated to thinly bedded and the poor ‘coal’ beds are laminated or very thinly laminated.
<i>Lithology</i>	The Milligans Road Formation, as at locations 45 and 95, consists of brown quartz–feldspathic sandstone with mica flakes, siltstone and grey mudstone with minor conglomerate. Also included are carbonaceous mudstone and thin, poor ‘coal’ beds up to 500 mm in thickness, together with diagnostic off-white airfall tuff up to 10 m in thickness. At location 45 the basal 300 mm of the more than 9 m-thick tuff bed contains accretionary lapilli up to 20 mm in diameter. In the southwest of the Lorne Basin, along Isaacs Road, tuff beds, each several metres thick, are exposed in several locations, including locations 170, 172 and 173. Those at location 170 are weathered, friable and blue–grey in colour while those at locations 172 and 173 are fresh, hard and range from pale buff to orange–brown.
<i>Thickness</i>	A thickness of 12 m is recorded at the type section while a thickness of 27 m is exposed in the Volcanic Resources Quarry (location 45).
<i>Depositional environment</i>	The presence of carbonaceous mudstone with thin, ‘coal’ beds suggests back swamps in an overbank fluvial environment.
<i>Relationships and boundary criteria</i>	As the exposures of the formation appear to occur in fault-bounded blocks and neither the top nor the base of the formation is exposed boundary criteria cannot be determined. However, the inferred Late Triassic age suggests that this formation overlies the other Triassic formations after a presumed depositional hiatus. The unit is identified by its distinguishing features.
<i>Distinguishing features</i>	The Milligans Road Formation is identified by the presence of airfall tuff often associated with carbonaceous mudstone and thin, poor ‘coaly’ beds.
<i>Structural attitude</i>	The Milligans Road Formation occurs in fault-bounded blocks in the northeastern and southwestern parts of the Lorne Basin.
<i>Correlation</i>	There are no units in the Lorne Basin with which this formation can be correlated.
<i>Age</i>	While highly fragmented plant remains have been found at two locations, no identifiable material has yet been recovered from the Milligans Road Formation. These locations are on Milligans Road (GR 470918 6512474, 1:25 000 map sheet 9434-4-S) and North Branch Forest Road (GR 463189 6498582, 1:25 000 map sheet 9434-4-S, Lorne; location 243).

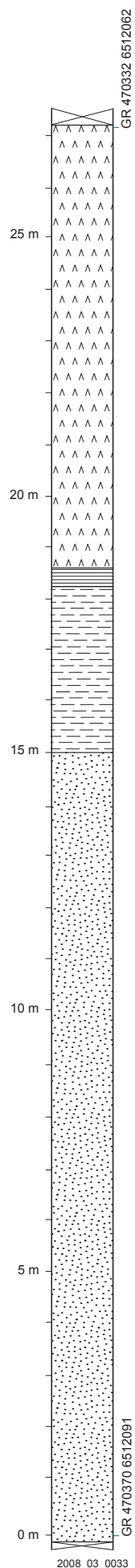


The introduction of airfall tuff into this sequence suggests that it is associated with the emplacement of Late Triassic to Early Jurassic igneous rocks both within the Lorne Basin (Graham et al. 2006) and further northwest with the Werrikimbe Volcanics.

**Photograph 8.** Airfall tuff overlying coaly (poor) and carbonaceous mudstone beds at the Volcanic Resources Quarry (location 45). Photographer: G.W. Pratt.



**Figure 14.** Lithology plot of the type section of the Milligans Road Formation.



**Figure 15.** Lithology plot of the Milligans Road Formation at the Volcanic Resources Quarry.

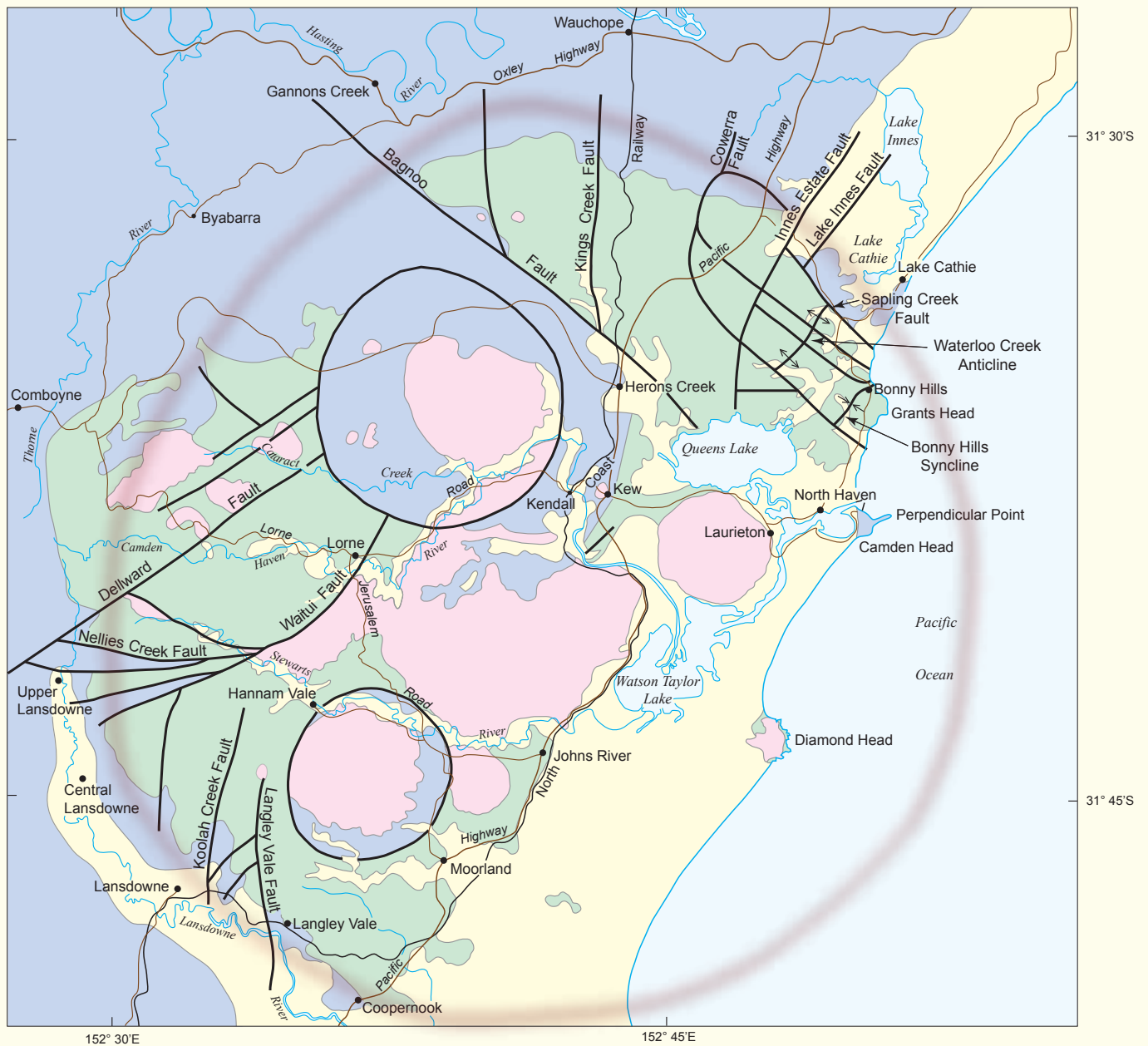
## Structure

The floor of the Lorne Basin has a pronounced easterly dip of about 4°. The floor falls from over 500 m ASL on the southern side of Mount Comboyne to an estimated 40 m BSL at the southern end of Watson Taylor Lake, a direct distance of 25 km. In places around the basin rim, the floor appears to dip inwards at a much steeper dip as is evidenced in the Mount Comboyne, Cold Nob and Boundary Road junction area, on the Bago Road north from King Creek and in the Slaters Road–Big Nellie Road junction area.

The location and pattern of major faults is shown in Figure 16. The northern part of the Lorne Basin is transected by a major NW–SE fault, the Bagnoo Fault (the extended Herons Creek Fault of Voisey 1939), which has a significant downthrow on the northern side. Transecting the Jolly Nose Ridge there are four faults sub-parallel to the Bagnoo Fault, including the Sapling Creek Fault of Leitch and Bocking (1980). This latter fault was unable to be confirmed by the author to the west of its intersection with the Innes Estate Fault. The Kings Creek Fault trends approximately north–south and transects the Triassic sedimentary rocks in the northern part of the basin. Along the Bagnoo Fault on the Old School Road (location 43), faulting has exposed the Cooperbrook Conglomerate Member, which has an almost vertical attitude here.

In the northeast of the Lorne Basin, the area between Grants Head and the western side of Jolly Nose Hill appears to be the most deformed. This area is underlain by the Port Macquarie Block and its deformation history was detailed by Leitch and Bocking (1980). They recognised an approximately north–south fault on the western side of Jolly Nose Hill, now named the Innes Estate Fault (Och, Leitch & Caprarelli 2007). This fault terminated two southeast-trending faults between and subparallel to the Sapling Creek Fault and Bagnoo Fault. A third subparallel fault is proposed herein — to the south of the two just mentioned faults. This fault was active prior to, or at the commencement of, Triassic sedimentation and formed the southwestern wall of a graben which was then filled by the Jolly Nose Conglomerate. Deposition of the Jolly Nose Conglomerate continued after the graben was filled and the sedimentation spread thinly towards the southwest. This fault also appears to form the northeastern boundary of the Palaeozoic serpentinite.

There is a large downfaulted block of Milligans Road Formation rocks between the Bagnoo Fault and the Broken Bago Range. This block is bounded, in part, by the Bagnoo Fault on the south and the Kings Creek Fault on the east. Another large downfaulted block of Milligans Road Formation rock extends southwestwards from the Lorne–Dellward area to Stewarts River and is bounded by the Dellward Fault on the northwest,



**REFERENCE**

- |  |                              |  |                              |
|--|------------------------------|--|------------------------------|
|  | Quaternary sediments         |  | Basin boundary (approximate) |
|  | Mesozoic igneous rocks       |  | Faults                       |
|  | Triassic sedimentary rocks   |  | Anticline                    |
|  | Palaeozoic sedimentary rocks |  | Syncline                     |
|  |                              |  | Town                         |
|  |                              |  | Roads                        |
|  |                              |  | Railway                      |
|  |                              |  | River                        |



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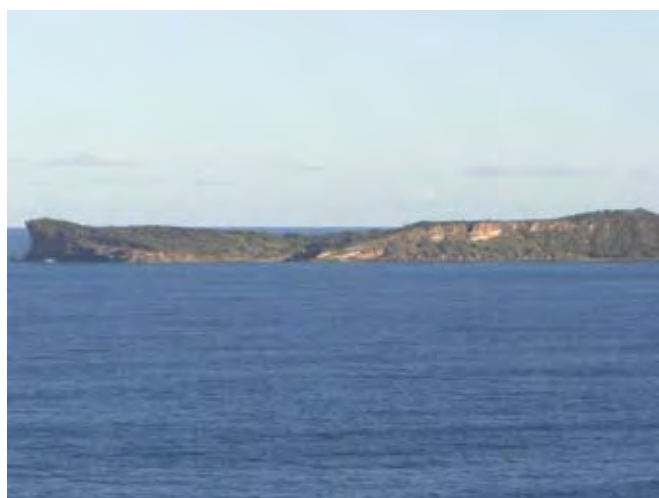
**Figure 16.** Location and pattern of faults in the Lorne Basin showing simplified geology.

the curving Waitui Fault on the south and east and the Back Creek Uplift on the north. Faults subparallel to the Dellward Fault bound blocks of Milligans Road Formation further to the northwest. Four faults splay from the Waitui Fault south of Stewarts River and appear to provide the conduits for the Big Nellie, Small Nellie and Flat Nellie volcanic plugs.

In the southern part of the basin the Koolah Creek Fault and Langley Vale Fault, again trending north-south, transect the Triassic sedimentary units. Both faults have an eastside-up throw of about 60 m and appear to have provided conduits for Tertiary volcanic plugs — Juhle Mountain in the case of the Langley Vale Fault.

Leitch and Bocking (1980) recognised the Waterloo Creek Anticline and the Bonny Hills Syncline — both trending southwest in this area. Further south there is a shallow syncline and anticline between Perpendicular Point and Camden Head, visible from the southern side of Grants Head at location 126 (Photograph 9).

As a consequence of the differing interpretations of the stratigraphy of the Jolly Nose Hill area between this work and that of Leitch and Bocking (1980), there are some minor differences in the structural interpretation. However, this paper further supports the conclusions of Leitch and Bocking (1980) that the folding and faulting of the Camden Haven Group show that significant deformation occurred in the eastern part of the New England Orogen subsequent to the Late Permian orogenic climax and that this deformation was mainly from movement on basement faults. Furthermore this work demonstrates that significant movement also took place in other parts of the Lorne Basin after the Early Triassic deposition of the Camden Haven Group — contemporaneous with, or prior to, the Late Triassic or Early Jurassic igneous event.



**Photograph 9.** Shallow syncline and anticline between Perpendicular Point (left) and Camden Head (right) viewed from south side of Grants Head (location 126). Photographer: G.W. Pratt.

Other localised faulting and folding of the Triassic rocks in the Lorne Basin has resulted from emplacement of the many igneous bodies within the basin. For example, beside the Pacific Highway, 5 km north of the Stewarts River Bridge (location 122), beds of the Camden Haven Claystone have been tilted as the Middle Brother laccolith was emplaced beneath them (Photograph 10). This exposure was weakly thermally indurated — but has been destroyed by recent roadworks. Country rocks surrounding other major intrusions have suffered little, if any, thermal effects. A borehole at the Laurieton Quarry penetrated the floor of the North Brother laccolith and found that ‘there is a surprising lack of metamorphism evident in the carbonaceous shale and lack of chilled margin in the micro-syenite in the contact zone cored in hole LQ 1’ (Chesnut 1968, p.4).

There are two unusual faults inside the basin, the Black Creek Uplift and the Holey Flat Uplift (Map 1 and Figure 16). These are circular in outline and are 11 km and 7 km in diameter, respectively. The Palaeozoic basin floor has been uplifted — sufficient to allow the overlying cover of Triassic sedimentary rocks to be eroded away. Strata have been tilted to steep angles, almost vertical in the Holey Flat Uplift (Photograph 11). The beds have retained their usual dip towards the centre of the basin within a distance of several hundred metres outwards from the uplift rim.

The Holey Flat Uplift is defined by a very steeply dipping ridge of Cooperbrook Conglomerate Member, while a ridge of Cooperbrook Conglomerate Member defines the southwestern quadrant of the Black Creek Uplift. The Triassic cover has been removed over the remainder of the Black Creek Uplift but its location is marked by two concentric lineaments about 300 m to 400 m apart. Their specific location is usually indicated topographically by gullies or saddles in the ridges.

Both of these structures predate emplacement of the Brothers intrusions. Igneous rocks of the South



**Photograph 10.** Moderately dipping beds of the Camden Head Claystone near the Middle Brother intrusion on the Pacific Highway (location 122). This exposure was removed by recent roadworks. Photographer: G.W. Pratt.



Brother Mountain overlies the eastern rim of the Holey Flat Uplift while the Black Creek Uplift appears to have controlled the emplacement of igneous rocks southwest from Kendall. The Black Creek Uplift has been identified in this paper and the Holey Flat Uplift was identified by Pratt (1970). Both features are clearly visible on Google Earth images.

The Lorne Basin has, unusually, two circular uplifts within the basin. Circular uplifts centred within a circular basin are suggestive of the central uplift zone of a large impact crater. A possible impact origin for the Lorne Basin was first suggested, on the basis of other criteria, by Tonkin (1998). Investigations are ongoing.

## Summary

The Lorne Basin is a sub-circular basin with a basement of Carboniferous and Ordovician sedimentary and metasedimentary rocks, respectively, and infilled predominantly with Early Triassic clastic sedimentary rocks. The basal formation is the Jolly Nose Conglomerate, which is only developed in the northeastern part of the basin and is overlain by the Cooperbrook Conglomerate Member of the Camden Head Claystone (Camden Haven Group). This conglomerate member forms the basal bed over the remainder of the basin and is overlain by its 'parent' Camden Head Claystone. In the eastern part of the basin the Camden Head Claystone is overlain by the Laurieton Conglomerate but, in the immediate vicinity of Jolly Nose Hill, the Camden Head Claystone is not present and the Laurieton Conglomerate rests on the Jolly Nose Conglomerate. Around the basin rim in the southern and northern parts of the basin the Camden Head Claystone is overlain by the Coorabakh Conglomerate, a lateral equivalent of the Laurieton Conglomerate. In the Grants Head area the Laurieton



**Photograph 11.** Near-vertical beds of the Cooperbrook Conglomerate Member adjacent to the Holey Flat Uplift 1 km east of Hannam Vale (location 87). The staff is 2 m. Photographer: G.W. Pratt.

Conglomerate is conformably overlain by the Grants Head Formation.

The Triassic sediments were deposited in a fluvial environment. This included mid-alluvial fan, braid plain, channel and overbank (including backswamp) environments.

During the Triassic, structural movement caused the basement to be uplifted into the Early Triassic rocks to form the circular Black Creek Uplifts and Holey Flat Uplift. These structures influenced the emplacement of Late Triassic to Early Jurassic igneous intrusions. Associated with these intrusions was further sedimentation combined with the deposition of airfall tuffs to form the Milligans Road Formation. Further movement along basement faults produced the north-south Langley Vale, Koolah Creek, Kings Creek and Innes Estate faults, together with the northwest-southeast Bagnoo Fault and several sub-parallel faults in the Jolly Nose Hill area. The timing of this faulting is uncertain and some faults are thought to have been reactivated during the Triassic.

This work has provided more detail of the basin morphology, together with the sequence and provenance of its Early Triassic infill.

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## References

- BOCKING M.A. 1977. The geology of the Lorne Basin and underlying lithologies in the region of Grants Head. MSc Preliminary thesis. University of Sydney. (unpublished).
- CARNE J.E. 1897. Report on the geology and mineral resources of the coast between Port Macquarie and Cape Hawke. *New South Wales Department of Mines Annual Report for 1896*.
- CHESNUT W.S. 1968. Camden Haven breakwater materials investigation. Progress report on drilling and geophysical investigation of Laurieton quarry area. *Geological Survey of New South Wales, Report GS 1968/295*.
- GRAHAM I., SUTHERLAND L. & ZWINGMANN H. 2006. Mesozoic to Cenozoic magmatism, Lorne Basin, N.S.W. In: D. Denham ed. *Australian Earth Sciences Convention: convention handbook 2006*, Geological Society of Australia, Melbourne.
- HELBY R.J. 1970. Plant microfloras from the Lorne Basin. *Geological Survey of New South Wales, Palynology Report 1970/07*.
- HELBY R.J. 1971. Review of Late Permian and Triassic palynology of New South Wales. Geological Survey of New South Wales Palynology Report 1971/06. *Geological Survey of New South Wales, Report GS 1971/595*.
- HELBY R.J. 1973. Review of Late Permian and Triassic palynology of New South Wales. *Geological Society of Australia Special Publication 4*, pp. 141–155.
- HIGGINS D. 2007. The geology of the Diamond Head area, Lorne Basin, New South Wales. Geology 308 Field Project, University of New England, Armidale. (unpublished).
- HOLMES W.B.K. & ASH S.R. 1979. An early Triassic megafossil flora from the Lorne Basin, New South Wales. *Proceedings of the Linnean Society of New South Wales*, **103**, 47–70.
- HOWARD J.L. 1993. The statistics of counting clasts in rudites: a review, with examples from the upper Palaeogene of southern California, USA. *Sedimentology* **40**, 157–174.
- LEITCH E.C. & BOCKING M.A. 1980. Triassic rocks of the Grants Head district and the post-Permian deformation of the southeastern New England Fold Belt. *Journal and Proceedings of the Royal Society of New South Wales* **113**, 89–93.
- MORRISON M. 1922. Application for aid to bore for coal at Johns River. *New South Wales Department of Mines Annual Report for 1921*, 64.
- OCH D.J., LEITCH E.C. & CAPRARELLI G. 2007. Geological units of the Port Macquarie–Tacking Point tract, north-eastern Port Macquarie Block, Mid North Coast region of New South Wales. *Quarterly Notes of the Geological Survey of New South Wales* **126**.
- OCH D.J., PERCIVAL I.G. & LEITCH E.C. 2007. Ordovician conodonts from the Watonga Formation, Port Macquarie, northeast New South Wales. *Journal and Proceedings of the Royal Society of New South Wales* **128**, 209–216.
- PACKHAM G.H. 1969. The New England region. Triassic System, pp. 270–271. In: Packham G.H. ed. *The Geology of New South Wales. Journal of the Geological Society of Australia*. **16** (1), 1–654.
- PARISOTTO D.F. 1989. Appreciation of the geology in the southwest margin of the Lorne Basin. Field Project (62360), University of Technology, Sydney. (unpublished).
- Pratt G.W. 1970. Marginal notes for Camden Haven geological sheet. *Geological Survey of New South Wales, File GS 1970/725*.
- PRATT G.W. & HERBERT C. 1973. A reappraisal of the Lorne Triassic Basin. *Geological Survey of New South Wales, Records* **15**, 205–212.
- RETALLACK G.J. 1977. Reconstructing Triassic vegetation of eastern Australasia: a new approach for the biostratigraphy of Gondwanaland. *Alcheringa* **1**(3), 247–277.
- ROBERTS J., LEITCH E.C., LENNOX P.G. & OFFLER R. 1995. Devonian–Carboniferous stratigraphy of the southern Hastings Block, New England Orogen, eastern Australia. *Australian Journal of Earth Sciences* **42**, 609–634.
- STEWART J.R. 1969. The Lorne Basin and adjacent areas pp. 537–538. In: Packham G.H. ed. *The Geology of New South Wales. Journal of the Geological Society of Australia*. **16** (1), 1–654.
- TONKIN P.C. 1998. Lorne Basin, New South Wales: evidence for a possible impact origin? *Australian Journal of Earth Sciences* **45**, 669–671.
- VAN BENTUM A. 1989. The Triassic stratigraphy and sedimentology of Perpendicular Point and Grants Head, mid north coast, New South Wales. BAppSc Thesis, University of Technology, Sydney. (unpublished).
- VOISEY A.H. 1939. The Lorne Triassic Basin and associated rocks. *Proceedings of the Linnean Society of New South Wales* **64**, 225–265.

# Appendix 1

Location numbers	1:25 000 map sheet	MGA coordinates (m)	
		Easting	Northing
20	Grants Head	480033	6512078
21	Grants Head	478847	6512254
22	Byabarra	478781	6512357
23	Byabarra	473623	6511952
24	Byabarra	474108	6512416
25	Byabarra	474238	6513295
26	Byabarra	474286	6512671
28	Byabarra	473259	6511362
31	Grants Head	485504	6504108
32	Grants Head	484990	6504772
33	Grants Head	484824	6505004
36	Grants Head	479363	6504718
38	Grants Head	481258	6506022
43	Byabarra	471122	6509036
45	Byabarra	470332	6512062
51	Grants Head	478858	6510296
54	Lorne	474419	6500254
55	Lorne	474329	6500116
58	Lorne	473952	6498475
66	Laurieton	484647	6498531
72	Cooperook	459673	6484344
74	Cooperook	460099	6484406
75	Cooperook	464568	6479726
76	Grants Head	480433	6505873
78	Grants Head	480900	6506118
79	Grants Head	480537	6505540
87	Lorne	444671	6479728
88	Lorne	462068	6490871
90	Grants Head	485501	6503744
95	Byabarra	469986	6512134
100	Byabarra	461774	6507793
101	Byabarra	462893	6507088
104	Grants Head	485024	6504630
116	Lorne	471381	6488795
117	Grants Head	485567	6503949
122	Lorne	474139	6492631
126	Grants Head	485299	6503540
139	Grants Head	479652	6511030
147	Grants Head	480158	6505515
169	Lorne	455256	6497036
170	Lorne	455337	6496118
172	Lorne	457148	6495709
173	Lorne	458665	6496713
197	Byabarra	462276	6507417
202	Cooperook	461701	6481412
203	Cooperook	465936	6480998
228	Cooperook	459148	6484629
231	Lorne	455550	6488589
243	Lorne	463189	6498582
260	Byabarra	470918	6512474
273	Lorne	455600	6495487
328	Lorne	453458	6494980
331	Lorne	454050	6495119
342	Grants Head	485145	6503483
343	Byabarra	470370	6512091

# Quarterly notes

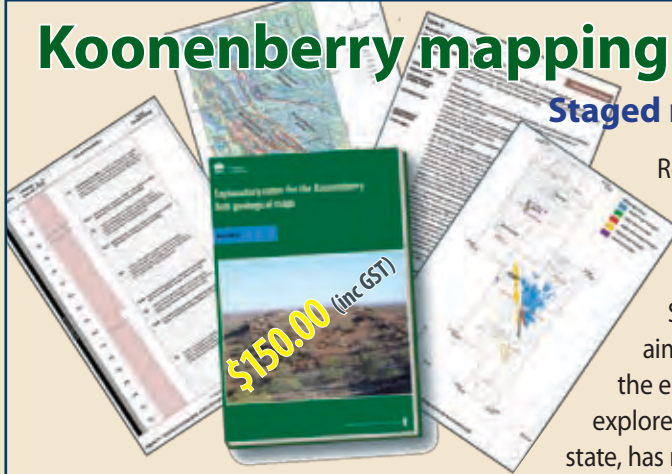
## Future papers:

'Phoenix: an early Devonian granite-related tungsten deposit from the eastern Lachlan Orogen, New South Wales' by P.M. Downes, P. Lennox, S. Wood, D. Phillips & A. Dunlop

'Review of Cambrian and Ordovician stratigraphy in NSW' by I.G. Percival, R.A. Glen & C.D. Quinn

## Koonenberry mapping project

Staged release throughout 2010



Representing many years of work, the **Koonenberry Project** is one of the largest ever undertaken by the Geological Survey of New South Wales. The aim, to further investigate and map the economic potential of this under-explored north-western corner of the state, has resulted in revised interpretations of the region's tectonic development with direct implications for the belt's metallogensis and exploration potential.

Exploration companies have expressed considerable interest in the region with licences already granted for gold and copper exploration.

Comprising over 20 maps, detailed explanatory notes (over 500 pages and a DVD), and a second DVD with all the original datasets, the staged release has started with the bulletin. Some maps are now available and the balance, plus the datasets are scheduled to be available by the end of the year.

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