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A new lithostratigraphic framework for the Early Jurassic units in the Bundamba Group, Clarence–Moreton Basin, Queensland and New South Wales.

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Recent detailed studies of key transects throughout the Clarence–Moreton Basin have shown that a revision of nomenclature is required for units in the Late Triassic to Early Jurassic Bundamba Group. Revision of the stratigraphic nomenclature and elimination of the existing confusion in names of units in the basin was considered an essential first step in understanding basin evolution and assessing petroleum potential. We redefine the Marburg Formation as the Marburg Subgroup of the Bundamba Group and divide the Subgroup into two distinct lithostratigraphic units, the uniform sandstone of the Gatton Sandstone and the mixed sandstone and mudrocks of the younger Koukandowie Formation. The formations are upgraded existing members. The Gatton Sandstone contains locally developed members along the western basin margin. The Koreelah Conglomerate Member forms the base of the Gatton Sandstone where it overlaps basement rocks, and the Calamia Member of mixed shale, mudrocks and sandstone is a basal unit in the Gatton Sandstone in more basinward sections. The Heifer Creek Sandstone Member is a prominent quartzose sandstone unit in the Koukandowie Formation along the western margin and central parts of the basin. The older mixed mudrocks and sandstone of the Ma Ma Creek Member of the Koukandowie Formation are mainly known from the northwest. This new nomenclature preserves the integrity of existing stratigraphic names and is applicable basin-wide. One new stratigraphic name, the Koreelah Conglomerate Member, is introduced.

Introduction

Recent studies of the Clarence–Moreton Basin in Queensland and New South Wales (Fig. 1) have revealed inconsistencies in stratigraphic nomenclature, with a plethora of names mostly applied only to local areas. In addition, several units designated as members were observed to have basin-wide extent. This has severely hampered the systematic study of the basin, and indicated the need for a basin-wide consistent stratigraphic scheme, the abandonment of many published and unpublished names, and the change in status of several existing names. One new stratigraphic name is proposed to account for a locally developed conglomerate present at the base of the Early Jurassic sediments where they overlap the older sedimentary sequence and rest on Palaeozoic basement rocks. The integrity of widely used and accepted names has otherwise been preserved.

History of stratigraphic nomenclature

The principal references on the evolution and formulation of stratigraphic nomenclature of the Bundamba Group in the Clarence–Moreton Basin (Fig. 2) are Cameron (1907), Whitehouse (1955), McElroy (1963), McTaggart (1963), Staines (1964), Cranfield & Schwarzbock (1972), Day & others (1974), Cranfield, Schwarzbock & Day (1976), and Etheridge & others (1985). These papers are not discussed in detail; they are mentioned briefly in reference to the suggested upgrading of the nomenclature and the choice of existing stratigraphic names[4].

The Early Jurassic sedimentary sequence under discussion constitutes part of the 'Bundamba Beds' (now known as Bundamba Group) of Cameron (1907). He applied the term to the unproductive sandstones between the Ipswich Coal Measures and the Walloon Coal Measures in the Ipswich area. This definition is accepted here (Figs 2, 3). The upper Early Jurassic part of this sequence has been referred to as the 'Marburg Stage' (Reid, 1921), 'Marburg Sandstone' (Swindon, 1956, 1960) and 'Marburg Formation' (Whitehouse, 1955; McElroy, 1963; McTaggart, 1963). McElroy (1963) defined two members of the 'Marburg Formation', the 'Blaxland Fossil Wood Conglomerate Member' and the younger 'Koukandowie Sandstone Member' in the New South Wales part of the basin. In the northern Clarence–Moreton Basin, McTaggart (1963) subsequently divided the strata between the Esk Trough sequence and the Walloon Coal Measures (i.e. the Bundamba Group) in the Laidley Valley area into Helidon Sandstone and the overlying 'Marburg Formation' (a redefinition of 'Marburg Sandstone' of Swindon, 1956, 1960). McTaggart (1963) recognised four members within the 'Marburg Formation' — the 'Heifer Creek Sandstone Member', 'Ma Ma Creek Sandstone Member', 'Tenthill (or 'Winwill') Conglomerate Member' (Cranfield & others (1976) referred to this unit as the Winwill Conglomerate Member) and 'Gatton Sandstone Member' (Fig. 2). We restrict the name Helidon to the building stone unique to the Helidon area, and use instead Woogaroo Subgroup, or its constituent formations where appropriate, in areas where the name Helidon Sandstone has been used previously. This usage of the nomenclature conforms with that outlined by Cranfield & Schwarzbock (1972) (see below).

Staines (1964) defined three formations — Ripley Road Sandstone, Raceview Formation and Aberdare Conglomerate — below the 'Marburg Formation' in the Ipswich area (Fig. 2).

The Aberdare Conglomerate was redefined from a term originally used by Reid & Moreton (1922). These three new units were included in the Woogaroo Subgroup by Cranfield & Schwarzbock (1972), who suggested discarding the name Helidon Sandstone which they considered to include time and rock equivalents of the three lower formations of the Bundamba Group. These authors therefore recognised a subdivision of the Bundamba Group into the 'Marburg Formation' and the underlying Woogaroo Subgroup. The distinction between the subdivisions relies basically on sandstone composition. The Woogaroo Subgroup contains dominantly quartzose sandstone whereas the 'Marburg Formation' contains silty, quartz-lithic and feldspathic sandstone. The two divisions also approximate the subdivisions of McElroy (1963) in New South Wales — the 'Marburg Formation' and his 'Bundamba Group' (sic) (Fig. 2). In a review of the whole Clarence–Moreton Basin, Day & others (1974) broadly correlated the Mesozoic units in the coastal basins, mainly on the presence of an oolite marker bed, but no attempt was made to correlate the members of the 'Marburg Formation'.

The results of the Geological Survey of Queensland stratigraphic drilling in the northern Clarence–Moreton Basin

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[4] Stratigraphic names modified or abandoned in this revision are enclosed in single inverted commas throughout this paper.

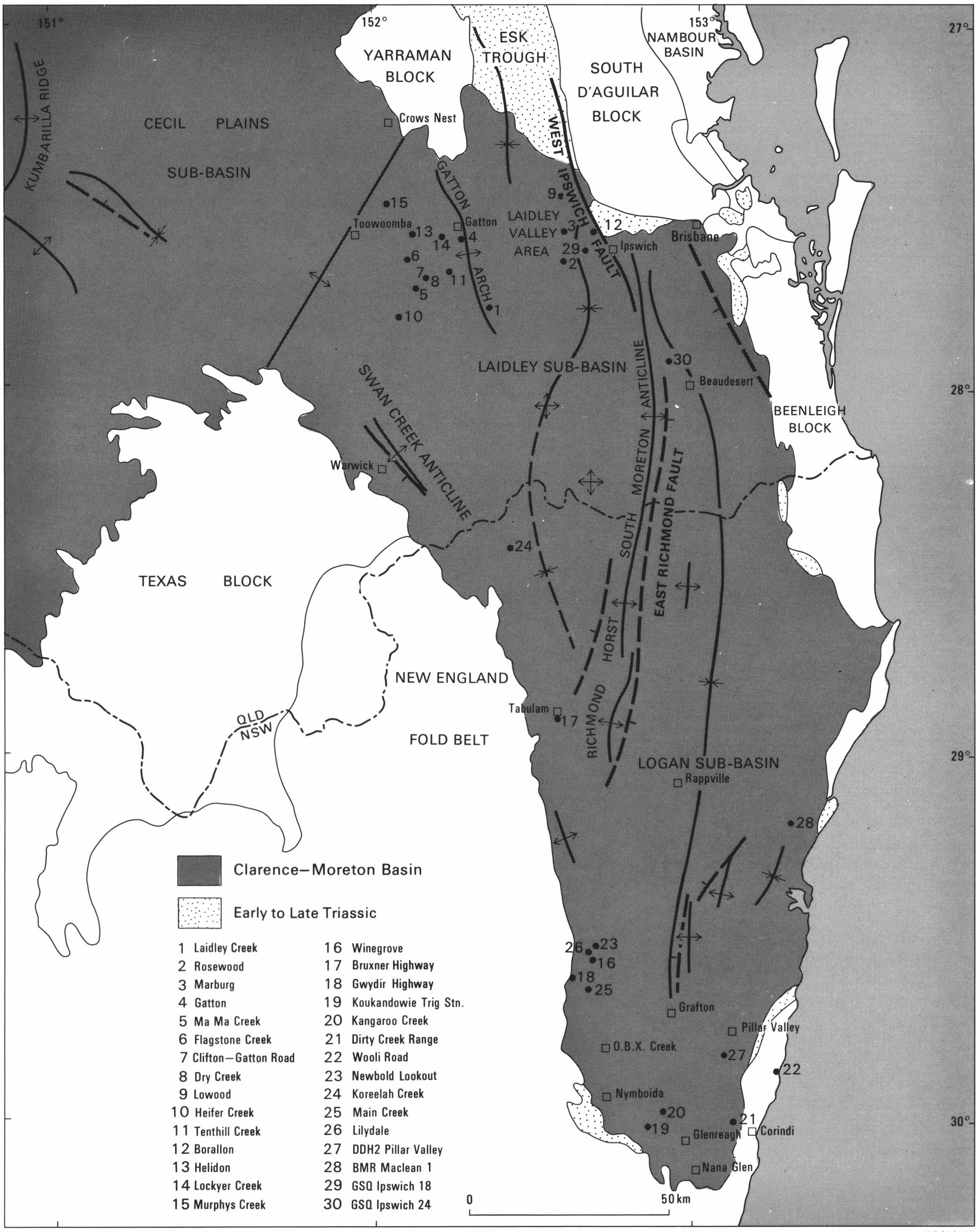

Figure 1. Locality map.

were synthesised by Gray (1975). He identified and correlated the members of the Marburg Formation, named by McTaggart (1963), across the northern part of the basin. The geology of the Ipswich and Brisbane 1:250 000 sheet areas was documented by Cranfield & others (1976), who gave a comprehensive account of the history of nomenclature for each stratigraphic unit of the Clarence–Moreton Basin.

Pillar Valley DDH 2 (Etheridge & others, 1985), a continuously cored drill hole in the southeast of the basin (Fig. 1), added considerable stratigraphic information to a poorly known part of the basin sequence. The Calamia Member, a new member at the base of the 'Marburg Formation', was identified and defined in this drill hole. The rest of the sequence was correlated with some of the members of the 'Marburg Formation' and formations of the Woogaroo Subgroup defined in the Queensland part of the basin (Figs 2, 3).

The results of BMR drilling in the Evans Head and Mallanganee areas (BMR Maclean No.1: Wells & O'Brien,

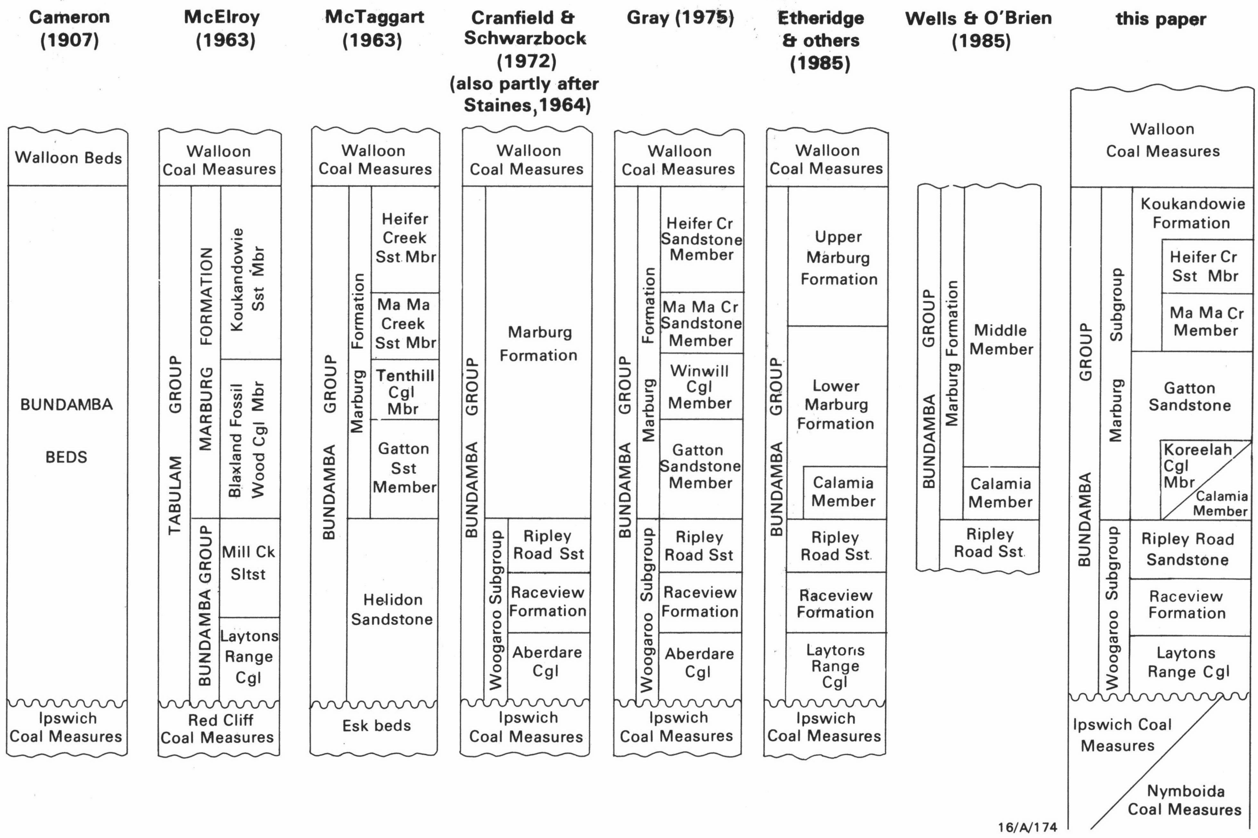

Figure 2. Evolution of stratigraphic nomenclature in the Bundamba Group and Marburg Subgroup.

1985; BMR Warwick 6 & 7: Wells, O'Brien, Willis & McMinn, 1990) extended most of the formations and members identified in the Pillar Valley area, and confirmed their continuity from Queensland into New South Wales.

Review of stratigraphic units

This review documents the origins and general concepts of the existing stratigraphic names as well as summarising the basin-wide characteristics of each unit, based on recent field research[5], logging of stratigraphic drill holes, interpretation of wireline logs and seismic record sections. The revised nomenclature of each unit is then presented.

'Marburg Formation' — 'Heifer Creek Sandstone Member'

The name 'Heifer Creek Sandstone Member' of the 'Marburg Formation' was applied by McTaggart (1963, p. 100) to '600–800 feet [180–240 m] of coarse, ferruginous siliceous sandstones, with minor shale and flaggy sandstone beds that can be traced between Toowoomba and Laidley Creek'.

McTaggart (1963) described the base of the 'Heifer Creek Sandstone Member' as a resistant sandstone at 800 feet [240 m] elevation that can be traced south of Helidon to Laidley Creek. This unit is a coarse-grained conglomeratic and lithic sandstone bed exposed in a very steep cutting where the Clifden–Gatton Road crosses Ma Ma Creek (Fig. 5, in the interval from 636 m to ~660 m). The composition of this sandstone is quite unlike any in the 'Ma Ma Creek Sandstone Member' below or any of the sandstones in the rest of the 'Marburg Formation' above. It is much siltier and more poorly sorted and contains more lithic clasts, mainly concentrated at the base of channel sands. This unit has also been recognised in cuttings on the railway line between Toowoomba and Murphys Creek, where it occurs in a similar stratigraphic position. McTaggart (1963) included intervals of interbedded mudrock, shale and some coal beds above this sandstone and below the predominantly quartz sandstone at the top of the sequence. He also included a two foot [~0.6 m] coal bed 100 feet [~30 m] above the base of the member in the valley of Flagstone Creek.

The new nomenclature distinguishes this intervening interval of mudrock, shale and some coal between the distinctive sandstones, one at the top of the 'Marburg Formation' and the sandstone in the Ma Ma Creek cutting on the Clifden–Gatton Road. This is necessary to rationalise the section and distinguish clear lithostratigraphic units. We consider that the sandstone shown in the interval 636–~660 m (Fig. 5) and the underlying siltstone from ~660 m to 710 m should not be included in the Heifer Creek Sandstone Member, but should be part of the undifferentiated formation.

McTaggart (1963) stated that the member is less discernible in the east where it plunges beneath the Walloon Coal Measures around Rosewood, although he considered it identifiable in the Marburg area. The member was differentiated in part on a sketch map of McTaggart (1963, text-fig. 1) and on the Ipswich 1:100 000 sheet area (Cranfield & others, 1981).

In the northwest Clarence–Moreton Basin, in the Gatton–Toowoomba area, the 'Heifer Creek Sandstone Member' occupies the interval (approximately 140 m) from the base of the Walloon Coal Measures to the top of the undivided 'Marburg Formation'.

[5] A key to all symbols used in graphic sections is shown in Fig. 4.

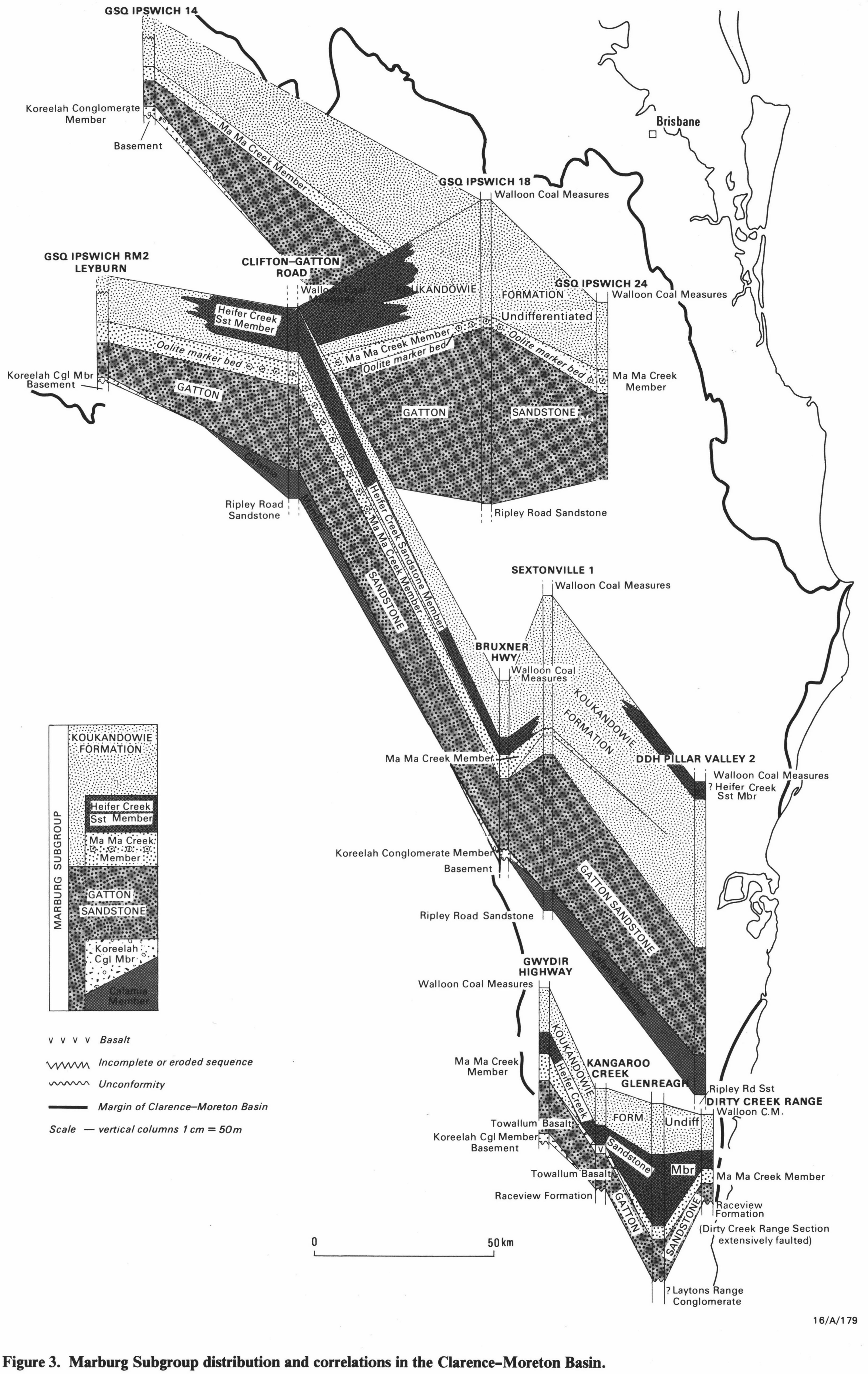

Figure 3. Marburg Subgroup distribution and correlations in the Clarence-Moreton Basin.

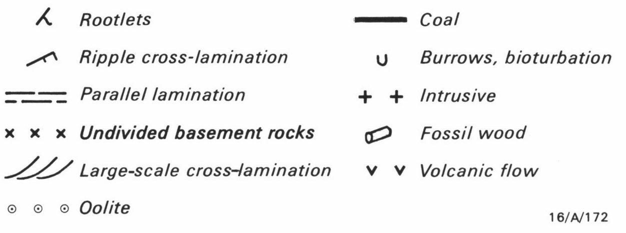

Figure 4. Explanation of symbols used on graphic logs.

The equivalent interval on the flanks of the South Moreton Anticline is much reduced in thickness and the rest of the 'Marburg Formation' below the 'Heifer Creek Sandstone Member' is undivided, indicating that the 'Ma Ma Creek Sandstone Member' is not identifiable in this region. This undivided sequence is identified on the Ipswich 1:100 000 sheet area and is most likely all 'Gatton Sandstone Member'.

The significance of the absence of the 'Ma Ma' Creek Sandstone Member' in this sequence is discussed later under this member.

Gray (1975) nominated sections in the interval 62–876 m in drill hole GSQ Ipswich 18 as new lithological reference sections for McTaggart's (1963) members.

In GSQ Ipswich 18 the reference section of the 'Heifer Creek Sandstone Member' of Gray (1975) occupies the interval from 62 m to 315 m, which includes thick (up to 15 m) intervals of shale. The member has an aggregate thickness of 60 m (or about 25%) of shale and mudstone in this drill hole. More significantly, thin beds of oolite occur at 74 m and 177 m. Oolite beds also occur lower in the sequence at 378 m and 381 m, in the 'Ma Ma Creek Sandstone Member' which occupies the interval 315 m to 417 m. Oolite has been used as a stratigraphic marker in Early Jurassic sequences in southeastern Queensland, mainly for correlation of the 'Ma Ma Creek Sandstone Member'. Day & others (1974, p. 338) stated that 'an essentially isochronous oolitic ironstone containing the acritarch-bearing horizons, has been traced from the Surat and Mulgildie Basins through the Moreton and Nambour Basins to the Maryborough Basin'.

The presence of oolite near the top of the 'Marburg Formation'[6] in GSQ Ipswich 18 indicates a brief reversal to shallow water, probably lacustrine, conditions that are normally recorded near the middle of the unit. It also casts some doubt on the stratigraphic uniqueness of the oolite horizon, and indicates that some care is required if it is to be used for correlation.

A comparison of the reference section and the outcrop on the Clifden–Gatton road shows that the 'Heifer Creek Sandstone Member' changes in lithology from east to west across the northern part of the basin. This change is interpreted as an indicator of major differences in depositional environments and distance from the provenance. In the sequence penetrated in GSQ Ipswich 24 (nominated as a reference section in this paper: see Appendix 1), the member comprises mainly overbank deposits, including bioturbated shale and mudstone and crevasse splay sandstone. By contrast the section further west at Heifer Creek contains a much higher percentage of quartzose and lithic sandstone. The sandstone occurs in fining up sequences that are terminated in places by shale; this indicates a high energy–low sinuosity stream environment of deposition.

[6] An alternative interpretation offered by one of the authors (LCC) is that the oolite could be in the base of the Walloon Coal Measures.

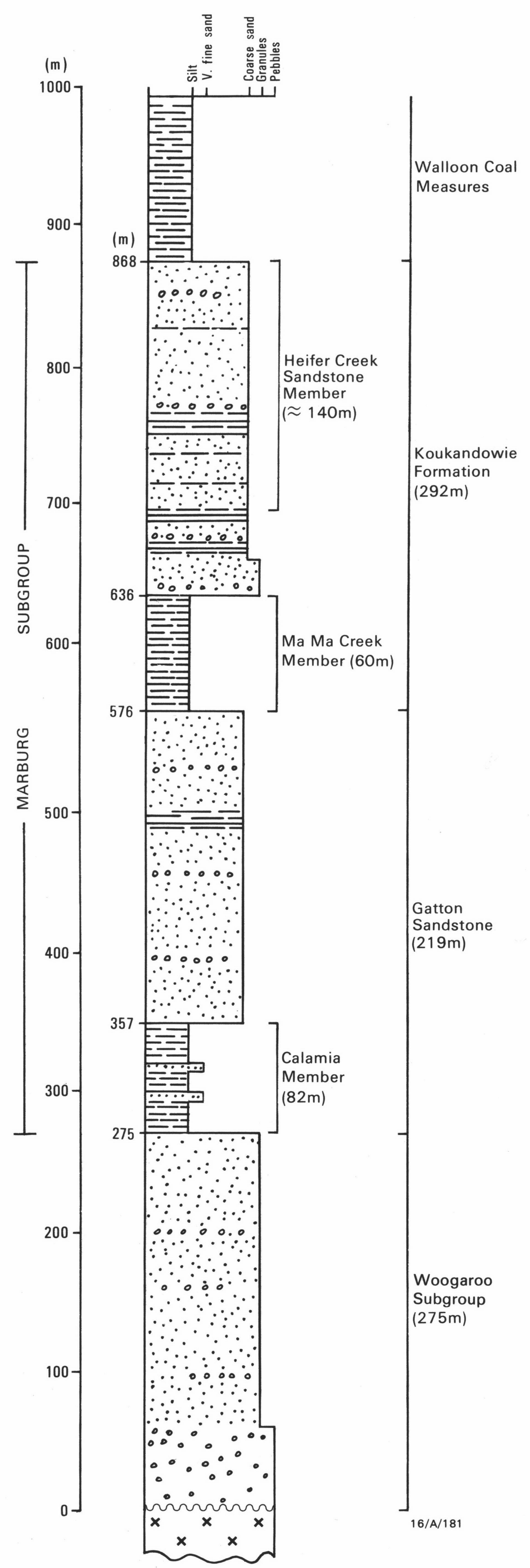

Figure 5. Graphic log, Clifden–Gatton Road.

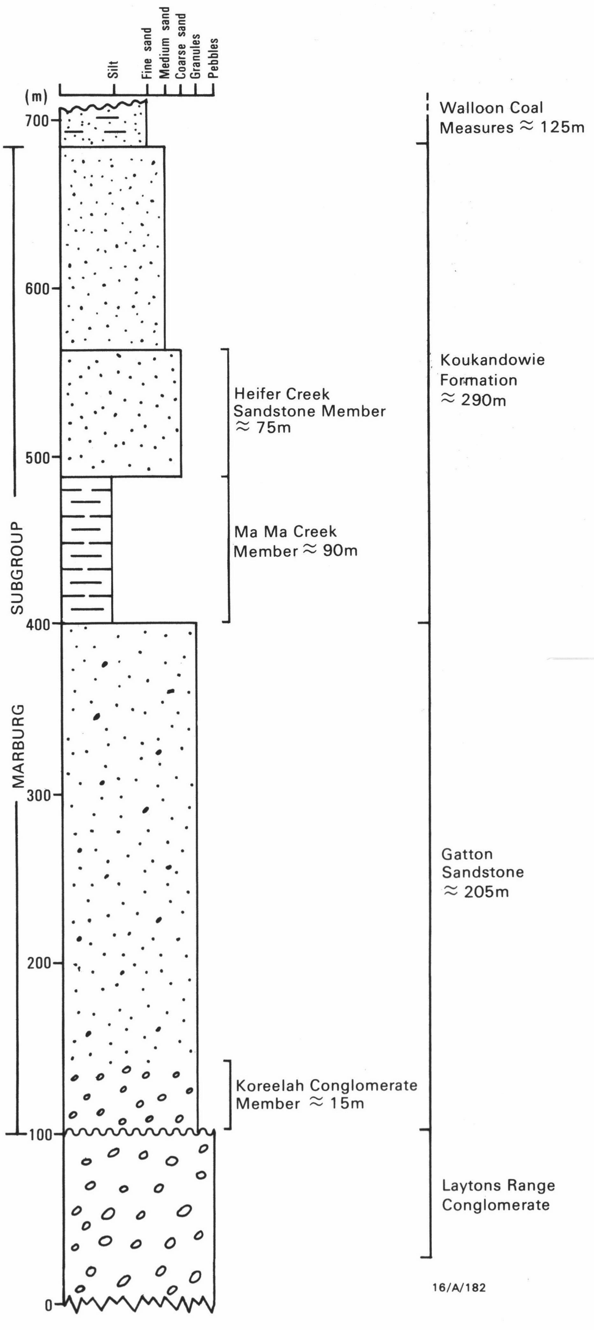

Figure 6. Graphic log, Bruxner Highway.

The sedimentary structures and fluvial architecture of the member exposed in road cuttings at Marburg indicate a contribution of high sinuosity, low energy stream deposition, as well as thicker stacked channel sand deposits. Marburg lies in an intermediate position between Heifer Creek and the reference section.

An east to west lithological transition similar to that found in the northern Clarence–Moreton Basin is apparent in the New South Wales part of the basin. A highly quartzose sandstone unit included in McElroy's (1963) 'Koukandowie Sandstone Member' is present in the west and south (Figs 5–10), and finer and siltier rocks are present in the east. The significance of the occurrence of quartzose beds in the 'Koukandowie Sandstone Member' to the new nomenclature is considered in further detail below in the section 'Koukandowie Sandstone Member', where McElroy's (1963) nomenclature is discussed. Therefore the regional facies trend in the 'Heifer Creek Sandstone Member' across the Clarence–Moreton Basin is a change in composition with an increase eastwards in the proportion of silts and muddy matrix, mudrock interbeds and lithic fragments in the sandstone.

The composition of the sandstone in the 'Heifer Creek Sandstone Member' is distinct from that in the lower part of the 'Marburg Formation'. This is used to distinguish and define the two formations (see 'Gatton Sandstone Member' section, and Appendix 1).

A new name is required for the younger of the two major units of the 'Marburg Formation' for the following reasons:

i) it is composed of distinct lithological assemblages;
ii) it incorporates areas where members are readily discernible;
iii) it incorporates areas where members are not developed and the whole unit cannot be subdivided.

It is proposed that the name Koukandowie Formation be retained for this unit. The name is derived from McElroy's (1963) 'Koukandowie Sandstone Member', the younger of the two major subdivisions of the 'Marburg Formation'.

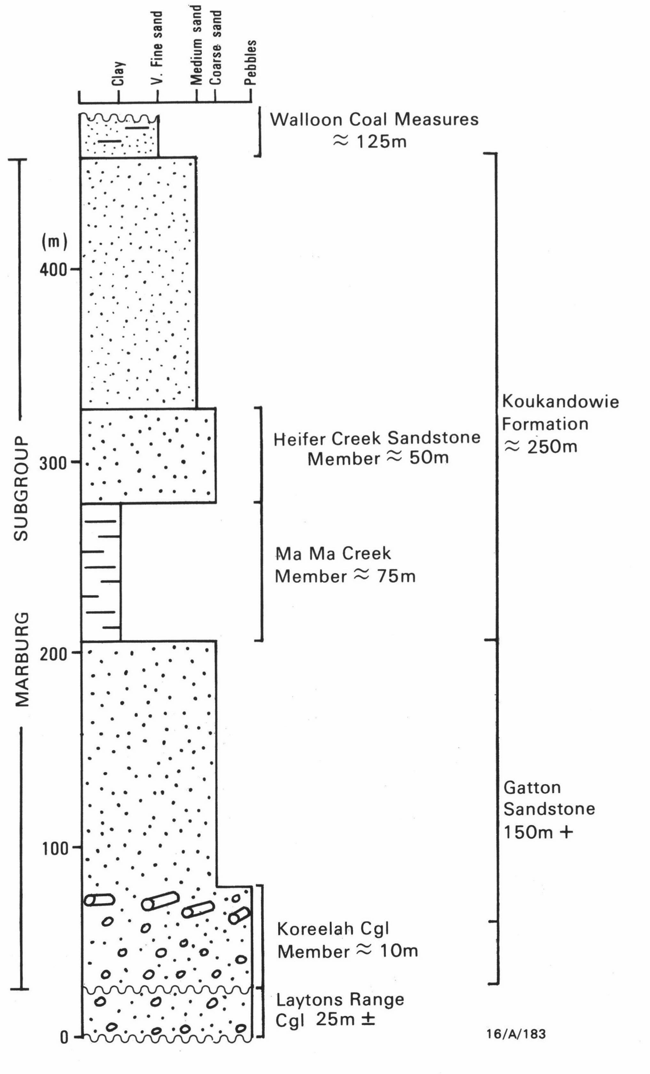

Figure 7. Graphic log, Gwydir Highway.

'Ma Ma Creek Sandstone Member'

The *'Ma Ma Creek Sandstone Member'* was defined by McTaggart (1963, p. 99) as '250 feet [76 m] of flaggy lithic sandstones, shales, and siltstones with minor fossil wood conglomerate bands. It shows good exposures around the lower reaches of Ma Ma Creek; Flagstone Creek derives its name from the strata'. McTaggart (1963) stated that the boundary with his 'Tenthill Conglomerate Member' is not sharply defined; no type section was nominated.

Gray (1975) nominated the interval 315 m to 417 m in GSQ Ipswich 18 as the lithological reference section for the member. Here the unit is predominantly shale and mudstone in the lower half, and a mixture of mostly medium and some fine to coarse grained, parallel and cross-laminated sandstone and subordinate mudstone in the upper part.

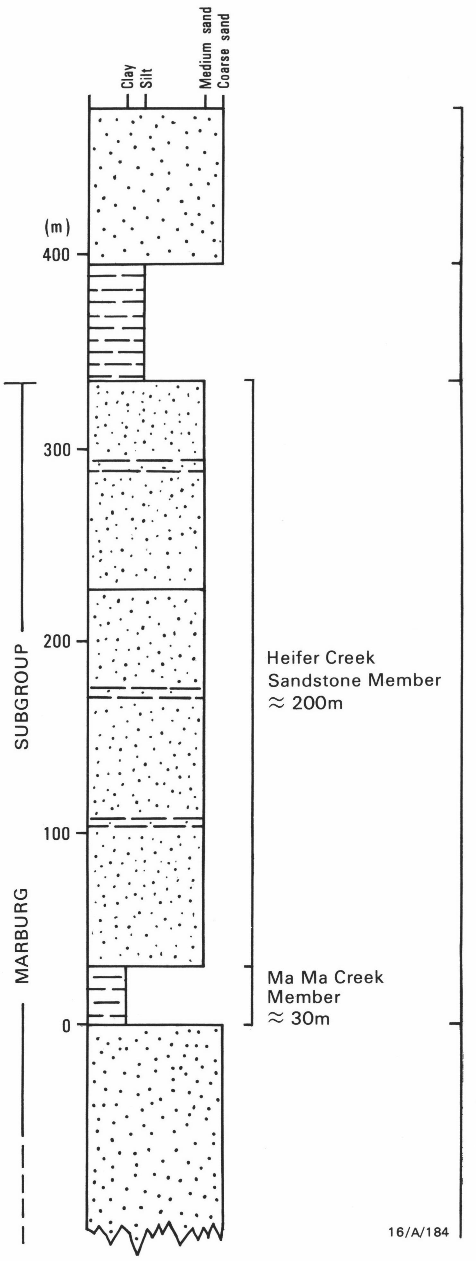

Figure 8. Graphic log, Waihou Trig, Glenreagh.

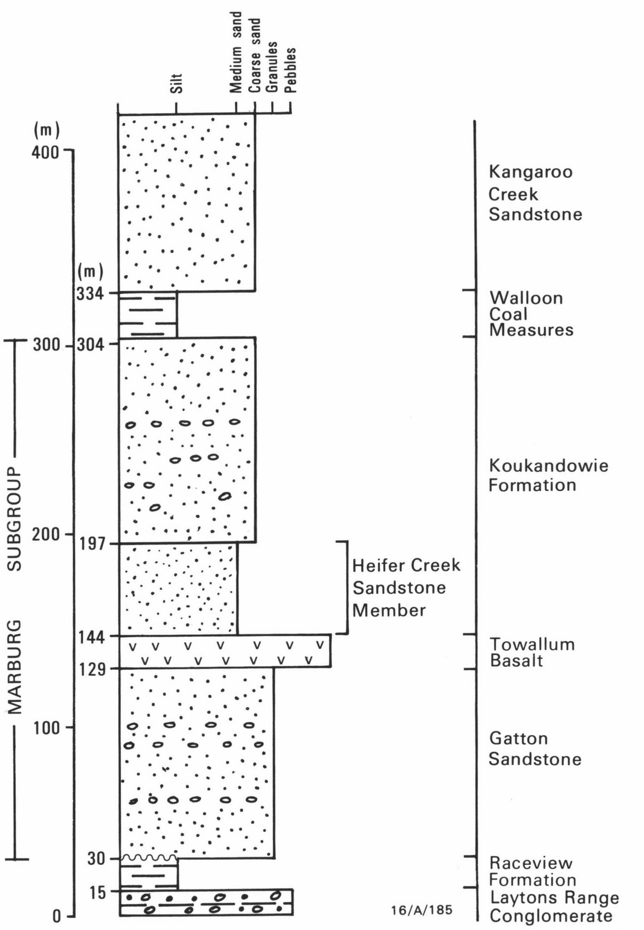

Figure 9. Graphic log, Kangaroo Creek.

The most characteristic rock type in exposures of the member is the finer grained, probably lacustrine, shale such as that exposed at Dry Creek on the Clifden–Gatton road and at Lowood. The characteristic marker oolite bed has been found only at two localities in outcrop, one a few kilometres north of Beaudesert, and the second on the Clifden–Gatton road section at 9342-153.357 on the Helidon 1:100 000 sheet area.

The 'Ma Ma Creek Sandstone Member' is not present in either BMR Maclean No.1 or the DM Pillar Valley DDH No.2 core holes but has been identified in BMR Warwick 7 (Wells & others, 1990).

In the rest of the New South Wales part of the Clarence–Moreton Basin the 'Ma Ma Creek Sandstone Member' is difficult to identify and probably does not exist in most sections. An added complication is that shaly intervals occur in the sequence above and below the prominent quartzose sandstone within McElroy's (1963) 'Koukandowie Sandstone Member'. The member occupies a stratigraphic position in the upper part of the 'Marburg Formation' and may be diachronous from north to south. Shale intervals occur in the sequences above the 'Gatton Sandstone Member' on the western flanks of the basin and the 'Ma Ma Creek Sandstone Member' has been identified on stratigraphic, lithological and palynological evidence in a stratigraphic drill hole on the basin's western flank (Wells & others, 1990). The only additional recorded occurrence of the member in the southern part of the basin includes an interval about 60 m thick in Sextonville 1 well.

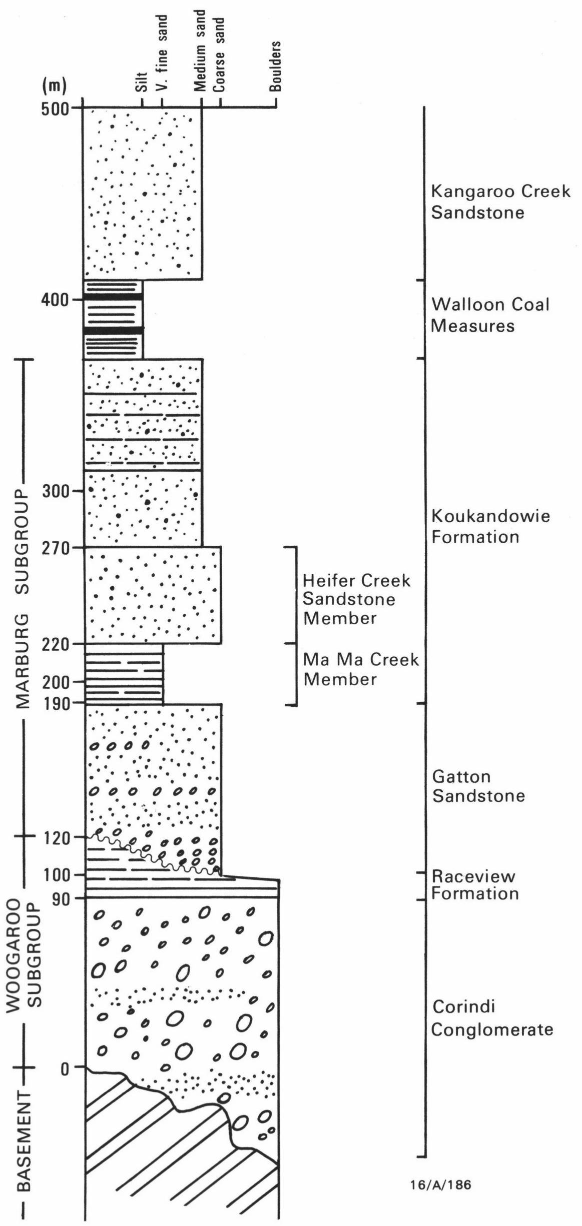

Figure 10. Graphic log, Pacific Highway.

The 'Ma Ma Creek Sandstone Member' is retained in the new nomenclature, except that the term sandstone is deleted from the name. The member has been shown to contain roughly equal proportions of sandstone and shale.

The type section (Fig. 11; Appendix 1) is composed of 54% shale and siltstone, and the rest is mostly fine-grained sandstone and rare thin coal interbeds.

'Tenthill Conglomerate Member'

The 'Tenthill Conglomerate Member' (subsequently termed the 'Winwill Conglomerate Member') of the Marburg Formation was defined by McTaggart (1963, p. 99) as '100–150 feet [30–46 m] of white flaggy sandstone with fossil-wood conglomerates that typically crop out along the lower reaches of Tenthill and Ma Ma Creeks'. It was described as having limited area, extending as far west as Crows Nest and as far east as Borallon. 'The Member is more resistant to erosion than its immediate neighbours and forms low cliffs and abrupt changes of slope' (McTaggart, 1963, p. 99).

Recent investigations in the Laidley Valley have indicated that conglomerate occurs at many levels in the 'Marburg Formation'. They have not substantiated the presence of a mappable unit of conglomerate at a unique level. Conglomerate occurs mainly as channel lag deposits, and its presence is dependent on the formation of thick channel sands. Because the 'Marburg Formation' has a fluvial architecture made up of multistorey channel sands, conglomerate can be expected to occur at several stratigraphic levels.

All the sections documented in the 'Marburg Formation' indicate that conglomerate units are not reliable stratigraphic markers, as it cannot be demonstrated that they have formed at a unique stratigraphic level. The names applied to these conglomerates are therefore abandoned.

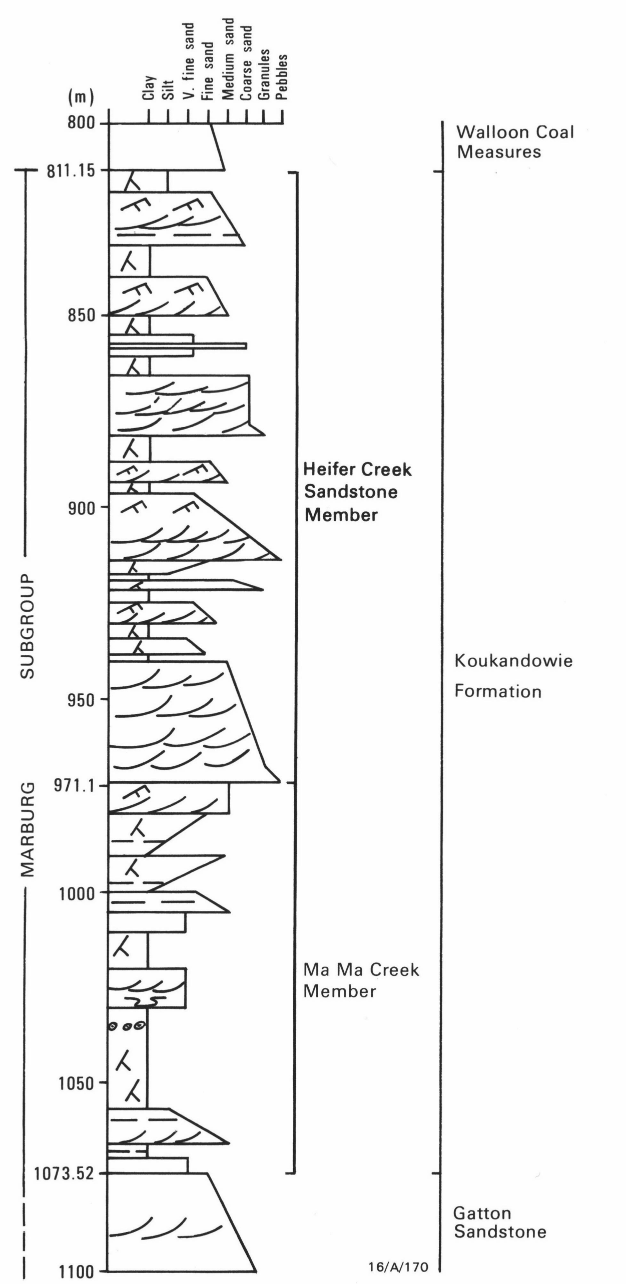

Figure 11. Generalised graphic log of the Koukandowie Formation in GSQ Ipswich 24.

'Gatton Sandstone Member'

The lowermost member defined in the Marburg Formation by McTaggart (1963) is the *'Gatton Sandstone Member'.*

> The Gatton Sandstone Member comprises 100–200 feet [30–61 m] of caliche lithic sandstone that conformably overlies the Helidon Sandstone. It shows good exposure in the bed of Lockyer Creek between Helidon and Gatton. The sandstone is quite massive and devoid of cross-bedding. Lithologically it is composed of grains of quartz and some lithic fragments set in an argillaceous matrix rich in carbonates of sodium, calcium, and magnesium. The member is an aquifer with artesian head around Helidon Spa and the above information was obtained from water bore analyses (McTaggart, 1963, p. 99).

The friable easily eroded sandstone of the Gatton Sandstone Member forms the bed of Lockyer Creek along most of its course. The member is well exposed in cuttings at the lower end of the Murphys Creek road and on the Warrego Highway near Gatton.

The 'Gatton Sandstone Member' has been identified throughout the southern part of the Clarence–Moreton Basin by its lithology, well log character and superposition. It occurs in outcrop around the margins of the basin, in stratigraphic drill holes at Evans Head, BMR Maclean No.1 and DM Pillar Valley DDH No.2, and has been identified in most of the deep petroleum exploration wells.

The composition of the 'Gatton Sandstone Member' is distinct from the 'Heifer Creek Sandstone Member'. The 'Gatton Sandstone Member' contains a high proportion of clay and silt matrix, and lithic grains. In places it is extremely poorly sorted. It commonly occurs in well defined channel sand bodies. The sedimentary structures indicate predominantly high energy, low sinuosity channel deposits, with preservation of predominantly multistorey channel sand bodies and minor overbank and splay deposits. Both planar and trough cross-bedding indicating cross-channel bars and dunes are well preserved. The composition of the 'Gatton Sandstone Member' varies only marginally throughout the basin except along the western edge, where it overlaps older units and rests unconformably on Palaeozoic basement rocks. Towards this region the unit becomes progressively more coarse-grained and grades laterally into and overlies the Koreelah Conglomerate Member.

These significant differences in composition of the two major sandstone bodies allow an easily recognisable basin-wide twofold subdivision of the 'Marburg Formation', and it is therefore proposed that the 'Gatton Sandstone Member' be elevated to formation status.

A twofold division of the 'Marburg Formation' was recognised by McElroy (1963) in the southern part of the Clarence–Moreton Basin. The name 'Koukandowie Sandstone Member' was applied to the upper part and the name 'Blaxland Fossil Wood Conglomerate Member' to the lower part. The 'Blaxland Fossil Wood Conglomerate Member' therefore approximates the 'Gatton Sandstone Member' of McTaggart (1963) and the 'Koukandowie Sandstone Member' approximates the remainder of the 'Marburg Formation' above the 'Gatton Sandstone Member'.

'Koukandowie Sandstone Member'

McElroy (1963) described a dominantly sandstone sequence of the upper part of the 'Marburg Formation' in the southern Clarence–Moreton Basin which conformably overlies the 'Blaxland Fossil Wood Conglomerate Member' in the Nymboida–Kangaroo Creek area. The name *'Koukandowie Sandstone Member'* was given to this upper unit.

This member is well exposed 2 miles (3 km) west of Koukandowie T.S. on the east side of Kangaroo Creek, and crops out on the Grafton–Nymboida road 3.5 miles [5.6 km] northeast of Nymboida Power Station (McElroy, 1963). The maximum observed thickness is stated by McElroy as 400 feet [120 m] 2.5 miles [4 km] northeast of Nymboida Colliery, although no complete section was measured and no type section was nominated. It is conformably overlain by the Towallum Basalt where this unit is developed, and elsewhere by the Walloon Coal Measures (McElroy, 1963). Recent field research in the Kangaroo Creek–Nymboida area has shown that the Towallum Basalt consistently occurs at the boundary between McElroy's (1963) 'Koukandowie Sandstone Member' and the 'Gatton Sandstone Member' (Fig. 9). This revision has meant better concordance between the isotopic dating of the Towallum Basalt and the palynological age obtained for the sediments (see Appendix 1).

The name Koukandowie is retained for the upper of the two units in the 'Marburg Formation', and is elevated to formation status.

A relatively clean quartzose sandstone within McElroy's (1963) 'Koukandowie Sandstone Member' forms a prominent sandstone bench and cliff-forming interval in the upper half of the 'Marburg Formation'. This prominent quartz sandstone member has been identified in several sections in over 500 km along the western and southern margins of the basin (Figs 5–10) and is an important marker unit. It has not so far been differentiated on the eastern basin margin such as the Pillar Valley section of the Wooli Road, or in the Pillar Valley DDH No.2, although quartzose sandstone intervals have been described from the upper part of the 'Marburg Formation' in the drill hole. West of Kangaroo Creek it has been identified on the Grafton–Nymboida Road, OBX Creek and north to the Gwydir Highway, near Newbold Lookout, in a quarry south of Tabulam on the Rappville road, in the Bruxner Highway sections, in the Koreelah Creek area and in railway cuttings and small scarps on hillslopes on the northwestern outskirts of Warwick. In the Warwick area the quartz sandstone member occupies the same stratigraphic position as the quartzose sandstone in the upper part of the Clifden–Gatton road section at Heifer Creek, i.e. in the upper part of the 'Marburg Formation' just below the Walloon Coal Measures. Hence the quartz sandstone unit is undoubtedly equivalent to the Heifer Creek Sandstone Member of McTaggart (1963).

The quartz sandstone marker bed occurs at various stratigraphic levels in the Marburg Formation, as follows:

> Pacific Highway/Dirty Creek Range — above the ?Ma Ma Creek Member (Fig. 10);
> Glenreagh — in the basal part of the Koukandowie Formation overlying possible Ma Ma Creek Member (Fig. 8);
> Kangaroo Creek — above the Towallum Basalt at the base of the Koukandowie Formation (Fig. 9);
> Gwydir Highway/Newbold Lookout — in the basal half of the Koukandowie Formation (Fig. 7);
> Bruxner Highway — in the basal part of the Koukandowie Formation (Fig. 6);
> Warwick/Clifden–Gatton Road — occupies the upper part of the Marburg Subgroup and is equated with the 'Heifer Creek Sandstone Member' of McTaggart (1963) (Fig. 5).

The name Heifer Creek Sandstone Member is therefore extended to the southern parts of the basin to describe this important quartz sandstone marker bed within the Koukandowie Formation.

'Blaxland Fossil Wood Conglomerate Member'

The base of the 'Marburg Formation' in New South Wales was defined by McElroy (1963) as the stratigraphic interval containing 'a remarkable accumulation' of fossil wood in a coarse-grained conglomeratic sandstone, granule conglomerate and minor cobble and pebble conglomerate.

The name *'Blaxland Fossil Wood Conglomerate Member'* was used for the unit. McElroy (1963) used the 'Blaxland Fossil Wood Conglomerate Member' to differentiate the Marburg Formation from his 'Bundamba Group' (sic) (equivalent to the Woogaroo Subgroup in Queensland). The member is the older of the two units constituting the 'Marburg Formation' in the southern, New South Wales part of the Clarence–Moreton Basin.

The term 'Blaxland Fossil Wood Conglomerate Member' is abandoned and the name Gatton Sandstone is retained for this unit. The principal reasons for this change are detailed in Appendix 1. The term Gatton Sandstone has been more widely accepted than the term 'Blaxland Fossil Wood Conglomerate Member'. The position and identification of the latter has commonly been misinterpreted in the Early Jurassic sequence in New South Wales. Although the Gatton Sandstone commonly contains abundant fossil wood and conglomerate in discrete intervals, the beds seem to occur at different stratigraphic levels, and their position is probably controlled by the preservation of a fluvial sedimentation cycle.

The maximum thickness quoted for the 'Member' by McElroy (1963) is 150 feet [45 m], and logs of fossil wood up to 60 feet [18 m] long and up to 2 feet [0.6 m] in diameter are reported. The host rock is medium to coarse grained quartz-lithic sandstone and quartz sandstone, fine quartz sandstone to fine quartz-pebble and granule conglomerate. White quartz pebbles are common to most outcrops of the member. The wood is mostly replaced by hematite and limonite, and rarely by silica. Although no type section was nominated, an excellent continuous exposure is cited by McElroy (1963) 2.5 miles [4 km] northeast of Nana Glen, which is the maximum known thickness.

Revised stratigraphic framework

The recent research in the Clarence–Moreton Basin has highlighted major inconsistencies of the previous stratigraphic nomenclature and duplication of names for the same unit. This has been especially noticeable when attempting correlation of formations across the border from New South Wales into Queensland, and has severely hampered basin-wide studies.

The principal reasons for this unsatisfactory nomenclature have been the lack of data and the lack of a basin-wide perspective of regional facies relationships. Many of the stratigraphic schemes proposed were based on sequences established at the basin margins where local facies are developed. Workers studying local areas invented new local names which were isolated from the concept of a basin-wide stratigraphic scheme. Reconciliation of these sequences with those in central basin areas is possible only with a new stratigraphic scheme.

The new scheme presented here is based on a study of selected sections throughout the basin, re-interpretation of all deep well sections, new seismic sections, and the results from fully cored stratigraphic drill holes. This synthesis has largely overcome the major difficulties of regional facies correlation. From the discussion in the review of stratigraphic units it is apparent that several lithofacies in the Marburg sequence have a basin-wide distribution, whilst others are comparatively locally developed. A revised nomenclature is therefore necessary. The suggested scheme for the rationalisation of the previous nomenclature, to account for the distribution of these lithological associations, is outlined below and shown in Figures 3 and 12.

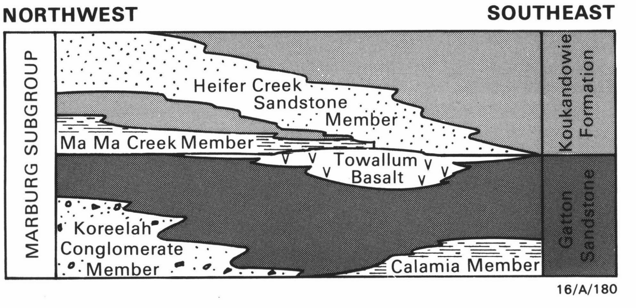

Figure 12. Rock relationship diagram.

All the criteria necessary for redefining and revising the existing and new stratigraphic units discussed are detailed in Appendix I.

Marburg Subgroup

The Marburg Subgroup is upgraded from the 'Marburg Formation'. The precise limits of the Marburg interval have not been adequately described and the boundaries nominated in various publications are unsatisfactory.

We define the limits of the Marburg Subgroup primarily on sandstone composition; the quartz–feldspar–lithic arenites of the Marburg Subgroup are overlain by the Walloon Coal Measures which contain volcanic litharenites; the lower boundary is marked by a change to clean quartz sandstone in the Ripley Road Sandstone of the Woogaroo Subgroup.

Gatton Sandstone

Field sections, well logs, and seismic reflection sections (Fig. 13) all support the basic twofold division of the Marburg Subgroup. The lower uniform quartz–feldspathic and lithic arenite comprises the Gatton Sandstone. The name Gatton Sandstone is derived from McTaggart's (1963) 'Gatton Sandstone Member' but is redefined to include the conglomerates formerly called either the Tenthill or Winwill Conglomerate Members, lithostratigraphic terms that are now discarded.

Calamia Member

The Calamia Member (Etheridge & others, 1985) of mixed sandstone, shale and mudrock is a basal unit in the Gatton Sandstone in basinward sections.

Koukandowie Formation

The upper lithologically more variable sequence is composed of quartzose and quartz–feldspathic–lithic sandstone, siltstone, mudrock and some coal of the Koukandowie Formation. The name is derived from McElroy's (1963)

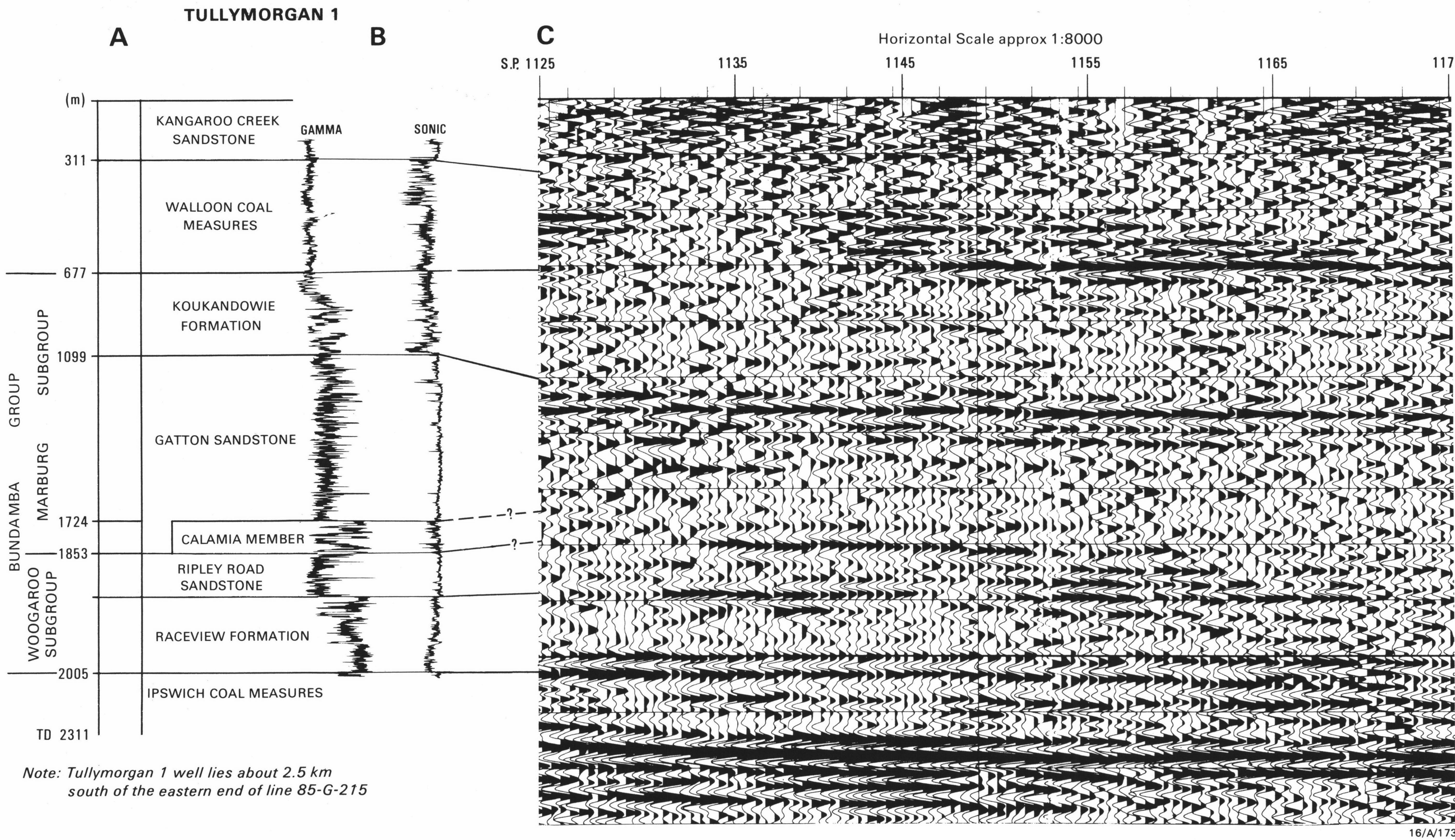

Figure 13. Seismic character of Bundamba Group.
A, Well sequence in Tullymorgan No.1 (Boisvert & Williams, 1965); B, Gamma and sonic logs of Tullymorgan No.1; C, Segment of data from Grafton seismic survey, Line 85-G-215 (Hartogen Energy Ltd).

'Koukandowie Sandstone Member' and includes all the sequence in the Marburg Subgroup above the Gatton Sandstone.

These contrasting sequences in the two formations are similarly well defined on seismic record sections (Fig. 13), and the upper boundaries of the two units are readily distinguished. However, the base of the Gatton Sandstone is mostly not easily identified on these records, because it has a similar seismic acoustic response to the underlying Ripley Road Sandstone.

The term 'Blaxland Fossil Wood Member' of McElroy (1963) is discarded in favour of Gatton Sandstone, a more widely used and accepted term for the older of the two formations in the Marburg Subgroup.

Ma Ma Creek and Heifer Creek Sandstone Members

Two members are defined in the Koukandowie Formation — a siltstone, shale, sandstone sequence of the Ma Ma Creek Member, and the prominent bench-forming quartz sandstone unit, the Heifer Creek Sandstone Member. The name 'Ma Ma Creek Member' is redefined from McTaggart's (1963) Ma Ma Creek Sandstone Member because in most sections it is a unit of mixed lithology and in some sections mudrock predominates. The name Heifer Creek Sandstone Member is derived from McTaggart's (1963) unit of the same name. It is redefined and restricted to the prominent resistant bench and cliff forming quartzose planar cross-bedded sandstone that occurs at various stratigraphic levels in the Koukandowie Formation.

Koreelah Conglomerate Member

The Koreelah Conglomerate Member is a new name proposed for a conglomerate locally developed at the base of the Gatton Sandstone. The member is present on the basin's western margin, and possibly also in the south, where the Gatton sandstone overlaps older sediments and rests either on older basin formations or basement rocks.

In the light of this new nomenclature it is worth noting that the generalised stratigraphy in the New South Wales part of the Clarence-Moreton Basin proposed by Ties & others (1985; Figs 4–6) recognised the basic subdivisions of the Bundamba Group but assigned incorrect names to the units. Their sequence, from the base of the Bundamba Group, is Raceview Formation/Laytons Range Conglomerate, 'Pillar Valley Formation' (informal unit), Ripley Road Sandstone, and Marburg Formation. Regional correlation of well logs and seismic lines shows that the correct sequence of units should be Raceview Formation/Laytons Range Conglomerate, Ripley Road Sandstone, Gatton Sandstone, and Koukandowie Formation. No evidence has been found for a regional unconformity in the Marburg Subgroup as suggested by Ties & others (1985).

Conclusions

Recent field studies and a re-interpretation of well logs and seismic reflection sections in the Clarence-Moreton Basin have indicated that major changes in stratigraphic nomenclature are required.

A revised stratigraphic framework for the Early Jurassic sequences of the Clarence-Moreton Basin has been developed that clarifies the sedimentary history of the basin and the distribution of porous and permeable units. The new scheme, which involves mainly a change of status of units, recognises the distribution and continuity of lithologic entities and their depositional environments. It should assist systematic basin-wide study.

Acknowledgements

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Appendix 1. Definition and redefinition of stratigraphic units.

Name and rank: Marburg Subgroup, Bundamba Group

Derivation. The name is from the town of Marburg in the Ipswich 1:250 000 sheet area, Queensland.

Synonymy. The unit is redefined from Marburg Formation and upgraded to the Marburg Subgroup. The name was originally used by Reid (1921) as Marburg Stage of the Walloon Coal Measures. The term Marburg Formation was first published by Whitehouse (1955) and this name was formally defined by McTaggart in 1963 (see Cranfield, Schwarzbock & Day, 1976).

Distribution. Throughout the Clarence–Moreton Basin.

Geomorphic expression. See description of constituent formations and members. The cleaner quartzose conglomeratic sandstone intervals form prominent benches and cliffs. The lithic and silty sandstones form rounded hills and slopes, and the siltstone and mudrocks weather recessively.

Reference section. Outcrops of most units are incomplete and deeply weathered. A reference section was nominated by Gray (1975) in GSQ Ipswich 18 stratigraphic drill hole over the interval 203'5" [620 m] to 2874' [876 m].

Type section. The type section of the Marburg Subgroup is described under the two constituent formations — the Koukandowie Formation (GSQ Ipswich 24) and the Gatton Sandstone (GSQ Ipswich 18; Figs 11, 14).

GSQ Ipswich 24 and Ipswich 18 were originally logged and described by officers of the Geological Survey of Queensland (Gray, 1975; Cranfield, 1981) and subsequently relogged by A.T. Wells and P.E. O'Brien of the Bureau of Mineral Resources, Canberra.

Description at type section. The Marburg Subgroup comprises the Koukandowie Formation and the underlying Gatton Sandstone and their respective component members, and as such is described under each of the members. The Marburg Subgroup is conformably overlain by the Walloon Coal Measures in GSQ Ipswich 18 and 24, and conformably overlies the Woogaroo Subgroup in GSQ Ipswich 18. The base of the Subgroup was not reached in GSQ Ipswich 24.

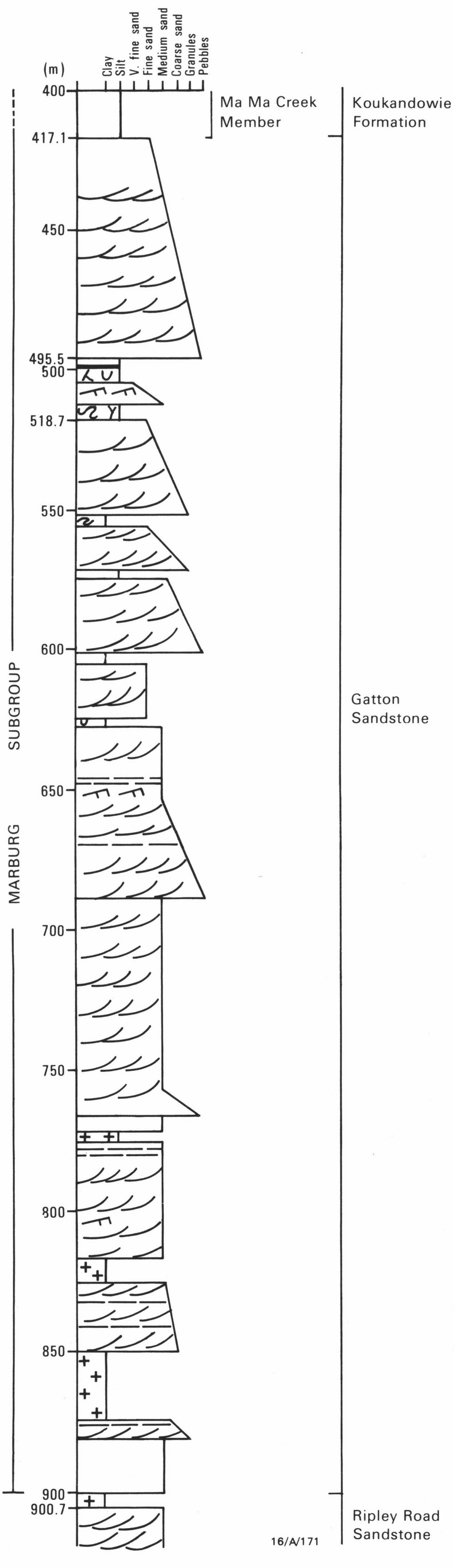

Figure 14. Generalised graphic log of the Gatton Sandstone in GSQ Ipswich 18.

The Ma Ma Creek Member of the Koukandowie Formation is differentiated in GSQ Ipswich 18 and 24, but no members of the Gatton Sandstone are apparent in either well section.

Regional aspects. The Marburg Subgroup occurs throughout the Clarence–Moreton Basin. In all outcrops where the upper contact is visible (there are very few) it is conformably overlain by the Walloon Coal Measures. The lower contact is an unconformity over wide areas, particularly on the western margin of the basin where the Subgroup overlaps Late Triassic sediments and Palaeozoic basement rocks. In the southern part of the Clarence–Moreton Basin (notably in the Coast Range, Glenreagh and Nymboida areas), an angular unconformity occurs at the contact with the underlying Woogaroo Subgroup. Elsewhere the Marburg and Woogaroo Subgroups are apparently conformable.

McElroy (1963) used the base of the lowest fossil wood horizon as the base of his Marburg 'Formation'. The top was taken as the first pebble band below the Walloon Coal Measures or alternatively at the base of the coal-bearing sequence of dark shales, claystones and friable sandstone of the Walloon Coal Measures.

These boundary criteria have proved to be unsatisfactory. Sandstone composition is proposed as the most reliable method of distinguishing the Marburg Subgroup from bounding sequences. The Marburg Subgroup contains labile quartzose-lithic and feldspathic sandstones, whereas the underlying Ripley Road Sandstone is predominantly clean quartzose sandstone that is very resistant to weathering. The sandstones in the overlying Walloon Coal Measures are volcanolithic and very friable.

Constituent units. The basic subdivisions of the Marburg Subgroup are the Koukandowie Formation and the underlying Gatton Sandstone and their respective members. The names Koukandowie and Gatton were formerly applied to members, but as it has been demonstrated that they extend over the basin as mappable units, they are redefined as formations. The Marburg 'Formation', of which they were a part, is therefore upgraded to Marburg Subgroup.

Age and evidence. Palynofloral assemblages in the Marburg Subgroup indicate an Early Jurassic age (Rhaetian to possibly basal Bajocian) (Cranfield & others, 1976; McKellar, 1981). Details of the ages of each formation and member of the subgroup are described later in this report.

References. Reid (1921), McTaggart (1963).

Name and rank: Koukandowie Formation, Marburg Subgroup

Derivation. From Koukandowie Mountain (Trig Station), (MM874.824, Grafton 1:100 000 sheet area 9438) at the southern margin of the Clarence–Moreton Basin.

Synonymy. The unit name is derived from the Koukandowie 'Sandstone Member' of the 'Marburg Formation' as published by McElroy (1963). The formation is the younger of the two units of the Marburg Subgroup defined in this paper.

Distribution. The formation has been identified throughout the Clarence–Moreton Basin, wherever the Marburg Subgroup is identified.

Reference section. No type section was given for the Koukandowie Sandstone Member by McElroy. Gray (1975) subsequently nominated the interval in GSQ Ipswich 18 from 203′5″ [62.0 m] to 1368′4″ [417.07 m] as the reference section for the interval equivalent to the Koukandowie Formation.

Type section. The interval from 811.15 m to 1073.52 m in GSQ Ipswich 24 (Fig. 11) is here nominated as the type section, as it is considered that the reference section in GSQ Ipswich 18 is atypical and the boundaries with adjacent units are not readily defined.

Description at type section. In the type section in GSQ Ipswich 24 the total Koukandowie Formation contains about 67% sandstone. The Ma Ma Creek Member contains 54% shale and siltstone whereas the overlying remainder of the undifferentiated Koukandowie Formation contains 80% sandstone.

The sandstone in the undifferentiated upper part of the Koukandowie Formation is fine to coarse grained, commonly in stacked multistorey fining-up sequences about 10 m thick in the upper part of the formation and up to 40 m thick in the lower part. The sandstone is mostly cross-laminated and rippled. Thin pebble conglomerates occur at the base of channel sands. Interbedded mudstone intervals are 10–12 m thick with fine-grained sandstone laminae, cross-laminae and rootlets. In places the mudstone exhibits brecciated soil textures.

Fossils. The formation contains plant fossils, fossil wood and palynomorphs.

Depositional environments. The upper part of the Koukandowie Formation in GSQ Ipswich 24 was laid down as predominantly channel deposits, with floodplain siltstone interspersed with probable fining-up crevasse splay sandstones. The lower part of the formation — the Ma Ma Creek Member — is mainly claystone and shale with chamositic oolite, deposited in lacustrine conditions.

Relationships and boundary criteria. The boundaries of the formation with other units are conformable.

The upper boundary of the Koukandowie Formation corresponds to the change of sandstone composition described under the Marburg Subgroup.

The lower boundary of the formation is defined as the change from predominantly mudrocks of the Ma Ma Creek Member to the multistory medium to very coarse grained, quartz-lithic to lithic sandstone bodies of the Gatton Sandstone.

Where the Ma Ma Creek Member is not recognisable, the boundary is the change from the variable sandstone/siltstone/shale sequence of the Koukandowie Formation to the uniform quartz–feldspathic–lithic sandstone and subordinate conglomerate of the Gatton Sandstone.

In the southern part of the Clarence–Moreton Basin the Koukandowie Formation disconformably overlies the Towallum Basalt which in turn overlies the Gatton Sandstone.

Distinguishing features. The sandstone composition, lithological assemblages and associations, and stratigraphic position are the main methods for distinguishing the formation. The characteristics and sequences in the constituent members, where they are identifiable, can also be used to distinguish the formation.

Most of the attributes of the formation are shown on the graphic log of GSQ Ipswich 24 (Fig. 11).

The sandstone of the Koukandowie Formation is quartzose to quartz-lithic, with silty and clayey matrix and varying amounts of channel-base conglomerate and overbank shale. The lithological sequence penetrated in GSQ Ipswich 24 is characteristic of the formation.

Regional aspects. The Koukandowie Formation is widely distributed and identified throughout the Clarence–Moreton Basin in the Marburg Subgroup.

The Koukandowie Formation has been identified in most deep well sections; in the southern Clarence–Moreton Basin it has been continuously cored in Pillar Valley DDH No.2 stratigraphic drill hole and corresponds to the 'Upper Marburg Formation' of Etheridge & others (1985).

Constituent units. Two members, the Heifer Creek Sandstone Member and the Ma Ma Creek Member, occur within the Koukandowie Formation. In many areas the members cannot be identified, and under the revised stratigraphic scheme the sequence is referred to as undivided Koukandowie Formation.

Correlation. The Koukandowie Formation is broadly correlated with the Hutton Sandstone and upper part of the Evergreen Formation of the Surat Basin sequence.

Age and evidence. The formation contains plant fossils, fossil wood, spores, pollen grains and sporadic acritarchs.

The Koukandowie Formation contains palynofloras similar to those formed in the lower Eurombah Formation, Hutton Sandstone and the post-oolite ironstone section of the upper Evergreen Formation of the Surat Basin. The age of the palynoflora is late Toarcian to early Bajocian, interpreted principally from McKellar (1974, 1981). The Towallum Basalt, which underlies the Koukandowie Formation, is dated isotopically at 187±5 Ma (Flint & others, 1976; corrected) and agrees well with the ages assigned to the palynofloras (193–181 Ma; D. Burger, BMR, personal communication, 1989).

Reference. The name 'Koukandowie Sandstone Member' was first proposed by McElroy (1963).

Name and rank: Heifer Creek Sandstone Member, Koukandowie Formation

Derivation. The name is derived from Heifer Creek in the southern Laidley Valley area in southeast Queensland.

Synonymy. The term was first published by McTaggart (1963), but no type section was nominated and its full extent was not adequately described.

The unit as redefined corresponds to the upper predominantly quartzose sandstone of McTaggart's (1963) Heifer Creek Sandstone Member, described chiefly from the southern part of the Laidley Valley and in southeast Queensland.

Distribution. The Heifer Creek Sandstone Member is present mainly along the western and southern flanks and central parts of the Clarence–Moreton Basin.

Geomorphic expression. The Heifer Creek Sandstone Member is resistant to erosion and commonly forms low but steep cliff faces, benches, and abrupt changes in hill slopes.

Reference section. No type section was given for the Heifer Creek Sandstone Member by McTaggart (1963). Gray (1975) nominated the interval 62 m to 315 m in GSQ Ipswich 18 as the lithological reference section for the member. This section is considered to be lithologically atypical of the member, and the boundaries with adjacent units are not readily defined. It is therefore not suitable for a type section. We nominate the section from 841.15 m to 971.1 m in GSQ Ipswich 24 as a more representative reference section (Fig. 11).

Type section. The section exposed on the Clifden–Gatton road between grid references 110.265 and 116.316 on the Helidon 1:100 000 sheet area (9342) is here defined as the type section (Fig. 5).

Description at type section. The Heifer Creek Sandstone Member is predominantly quartz rich and some quartz-lithic, medium to very coarse grained sandstone in thick to very thick beds, with steep planar cross-beds. The sandstone occurs mostly in thick fining-up sequences with thin beds of granule conglomerate at the base, and grading through fine sandstone to siltstone beds at the top of the sequence.

The Heifer Creek Sandstone Member is about 125 m thick in the Clifden–Gatton road section, but is about half this thickness in the southern and western parts of the basin.

Fossils. Plant microfossils, including spores, pollen grains and sporadic acritarchs; non-diagnostic plant impressions and fossil wood.

Depositional environment. The depositional environment is low sinuosity, fluvial, stacked channel-sand deposits.

Relationships and boundary criteria. Boundaries with other units are conformable. A contact with extrusives is present in the south where the Heifer Creek Sandstone Member overlies the Towallum Basalt.

The stratigraphic position of the Heifer Creek Sandstone Member varies within the Koukandowie Formation (Fig. 4). It may underlie either undifferentiated Koukandowie Formation or the Walloon Coal Measures, and overlie the Gatton Sandstone, undifferentiated Koukandowie Formation or the Towallum Basalt. Some well intersections indicate an interdigitating relationship of the member with the Koukandowie Formation.

The upper boundary of the member is taken as the change from predominantly light coloured, medium to coarse and very coarse grained quartzose sandstone to silty, finer grained, khaki weathered quartz-lithic sandstone of the Koukandowie Formation, or in places by the contact with dark grey to black shale, carbonaceous shale, and volcaniclastic, quartz-poor, fine-grained sandstone of the Walloon Coal Measures.

The lower boundary is taken as the change from predominantly medium to very coarse grained quartzose sandstone to quartz-lithic, yellow brown and khaki weathered sandstone and shale of the Koukandowie Formation, or in places, quartz and quartz-lithic sandstone and grey shale and siltstone of the Ma Ma Creek Member of the Koukandowie Formation.

Distinguishing features. The quartzose lithology, coarse grain size, pebble beds, thick to very thick beds, prominent steep planar cross-beds and scarp-forming habit of the member are the main distinguishing features.

Regional aspects. The member extends almost continuously from Murphys Creek in the north, to the upper reaches of Heifer Creek, to Warwick, Koreelah Creek, Bruxner Highway, Gwydir Highway, OBX Creek, Georges Knob, Kangaroo Creek, Glenreagh and probably as far southeast as the Dirty Creek and Coast Ranges.

The member has not so far been distinguished in well sections from the central part of the Clarence–Moreton Basin.

The member occurs at a progressively lower stratigraphic level in the Heifer Creek Formation from north to south. In the Clifden–Gatton road section the member occurs at the top of the Marburg Subgroup; on the Bruxner Highway near Tabulam it occurs near the middle of the subgroup above the upper boundary of the Gatton Sandstone; at Blaxlands Flat it immediately overlies the Gatton Sandstone, and at Kangaroo Creek it is in contact with the Towallum Basalt which in turn overlies the Gatton Sandstone.

Correlation. The Heifer Creek Sandstone Member is lithologically similar to the Hutton Sandstone of the Surat Basin sequence.

Age. The age is late Early Jurassic on the evidence of spores and pollen grains from the member in the northern part of the basin chiefly in the Ipswich 1:250 000 sheet area. The member here ranges in age from Toarcian to Bajocian, and contains palynofloras similar to those of the post-oolitic ironstone section of the upper Evergreen Formation, Hutton Sandstone and lower Eurombah Formation of the Surat Basin (De Jersey, 1971; McKellar, 1981).

Because the Heifer Creek Sandstone Member occurs at different stratigraphic levels within the Koukandowie Formation, it may be time transgressive.

Reference. McTaggart (1963).

Name and rank: Ma Ma Creek Member, Koukandowie Formation

Derivation. The name comes from Ma Ma Creek in the Laidley Valley, southeast Queensland.

Synonymy. The name of the unit was first proposed by McTaggart (1963) and published as Ma Ma Creek 'Sandstone' Member.

Distribution. The member is recognised chiefly in the Laidley Valley area. Identification of the member elsewhere is difficult, although it is possibly present in parts of the southern Clarence–Moreton Basin. It is absent at many localities and in many well sections.

Geomorphic expression. Not characteristic; mostly weathers recessively, and generally obscured by alluvium,.

Reference section. McTaggart (1963) did not nominate a type section. Gray (1975) designated the interval 1030′3″ [314.02 m] to 1368′4″ [417.07 m] in GSQ Ipswich 18 as a reference section.

Type section. The type section for the Ma Ma Creek Member is nominated as the interval 971.1 m to 1073.52 m in GSQ Ipswich 24 (Fig. 11).

Description at type section. The graphic log of GSQ Ipswich 24 (Fig. 11) shows the lithological sequence in the member. The depositional environment is considered to be lacustrine. The member is characterised by the presence of a chamositic oolite in the siltstone.

Fossils. Plant and wood fossils and spores, pollen grains and sporadic acritarchs.

Depositional environment. The most characteristic rock type is a fine-grained, grey shale/siltstone sequence which in drill core commonly contains 2–10 cm beds of chamositic oolite. The depositional environment is considered to be lacustrine.

Relationships and boundary criteria. The base is generally taken as a sharp boundary between dark grey siltstone and shale of the Ma Ma Creek Member with quartzose, lithic and feldspathic, cross-bedded sandstone, fine to coarse and very coarse grained sandstone of the underlying Gatton Sandstone.

The upper boundary is less well defined because many sections of the Ma Ma Creek Member, such as those present in GSQ Ipswich 18 and 24, show a high proportion of sandstone in the upper part of the member. The upper boundary is therefore taken as the first appearance of coarse to very coarse grained sandstone, the base of which is commonly marked by a thin granule and pebble conglomerate. This boundary is interpreted as the base of the first stacked multistorey, fining-up channel sand.

The underlying, upper part of the Ma Ma Creek Member is commonly cross-laminated to ripple cross-laminated, uniform, fine and medium grained sandstone with interbedded mudstone intervals. This sandstone commonly forms 2–5 m cliff faces in the creeks around the Lockyer Valley.

Regional aspects. Identified outcrops of the Ma Ma Creek Member are confined to the northern part of the basin, and the finer grained shale and siltstone are poorly exposed and difficult to identify. Poor outcrops doubtfully referred to as the Ma Ma Creek Member are found as far south as sections on the western flank of the basin where they are cut by the Bruxner and Gwydir Highways.

Correlation. The Ma Ma Creek Member is broadly correlated with the upper part of the Evergreen Formation in the Surat Basin sequence.

Age. The member is late Early Jurassic and contains the upper limit of palynological assemblage D (De Jersey, 1971, 1976; McKellar, 1981) which lies in the interval 1035.29–1034.19 m of GSQ Ipswich 18. It is also associated with the succeeding interval J2 (Toarcian) in JM Urbenville 1.

The palynofloras are equivalent to those recovered from beds next to the oolitic ironstone sequence in the upper Evergreen Formation and the basal Hutton Sandstone of the Surat Basin. The age is Toarcian, according to McKellar (1974, 1981).

Reference. McTaggart (1963).

Name and rank: Gatton Sandstone, Marburg Subgroup

Derivation. The name comes from the township of Gatton in the Laidley Valley, Ipswich 1:250 000 sheet area, Queensland.

Synonymy. The unit was originally named Gatton Sandstone Member by McTaggart (1963). Although the 'Blaxland Fossil Wood Conglomerate Member' of McElroy (1963) was never adequately defined, it is evident that it is equivalent to the Gatton Sandstone. Although McElroy's (1963) unit name has equal priority, we prefer to use Gatton Sandstone because:

1. it has gained wide acceptance and is entrenched in the literature, particularly in Queensland where the Marburg Subgroup is well documented;
2. the term 'Blaxland Fossil Wood Conglomerate Member' has not been widely used or accepted, and is commonly used in a variety of ways. We prefer to avoid further confusion by redefining the formation, and retaining the name Gatton Sandstone.

Distribution. The formation is basin-wide in the Marburg Subgroup.

Geomorphic expression. Mostly rounded hillslopes of low relief. No characteristic topographic features.

Type section. McTaggart (1963) did not give a type section for the Gatton Sandstone Member. Gray (1975) nominated GSQ Ipswich 18 over the interval 1368.1′ [417.07 m] to 2955.0′ [900.7 m] as the reference section; this is here designated the type section (Fig. 14).

Description at type section. The lithological succession and thickness in the type section are shown in GSQ Ipswich 18 drill log (Fig. 14).

The principal rock types in the type section are:

sandstone	quartz-lithic to lithic, cross-bedded, medium to very coarse grained in multistorey fining-up sequences, interspersed clasts, in white silty matrix; carbonaceous laminae, pebbly at channel bases, mostly poorly sorted and bedded, subangular, in part feldspathic, occasional volcanic clasts and coal spars, clay pellets, in part finely micaceous, parallel-laminated, cross-laminated and ripple cross-laminated, common fossil wood fragments.
conglomerate	pebble and cobble, mostly at base of channel sands, clasts of jasper, quartzites, volcanic metasediments; very coarse grained quartzose/quartz-lithic/feldspathic matrix;
siltstone/shale	dark grey to black, wavy irregular bedding, possible relict soil intervals, thin interlaminae of siltstone, in part bioturbated, occasional load casts;
coal	very thin laminae in siltstone.

Fossils. Fossils include wood fragments, plant remains and spores, pollen grains, and sporadic acritarchs.

Relationships and boundary criteria. Minor diastems and hiatuses are present in the Gatton Sandstone but no major depositional breaks are recorded. Upper and lower contacts are apparently conformable, except where the formation overlaps Palaeozoic basement, in which case the lower boundary is an angular unconformity. A regional unconformity separates the Gatton Sandstone from the Raceview Formation of the Woogaroo Subgroup in the southeast at the Coast and Dirty Creek Ranges.

Distinguishing features. The stratigraphic position and lithology of the sequence are the main distinguishing features. The sandstone in the formation is predominantly very coarse grained, poorly sorted, quartz-lithic and lithic sandstone in channel sand bodies and minor overbank deposits. The formation commonly contains fossil wood.

Depositional environment. Predominantly low sinuosity fluvial deposits in high energy environments.

Regional aspects. The lithology of the formation varies little throughout the basin, except where it overlaps the Palaeozoic basement rocks in the west. Here the formation is much coarser grained, contains beds of conglomerate and grades downwards into thick conglomerate. The conglomerate is formally defined in this paper as the Koreelah Conglomerate Member of the Gatton Sandstone.

The upper boundary of the Gatton Sandstone is marked by the change from uniform quartz-lithic and lithic sandstone to a variable sequence of quartzose and quartz-lithic sandstone, siltstone, shale and some coal of the overlying Koukandowie Formation.

The lower boundary is delineated mostly by a change in sandstone composition to clean quartz sandstone of the Ripley Road Sandstone. In places the base of locally developed members forms the lower boundary of the Gatton Sandstone. The Koreelah Conglomerate Member of the Gatton Sandstone unconformably overlies basement rocks, and in more basinward areas the interbedded siltstone, shale, and fine and medium grained sandstone of the Calamia Member form the base of the Formation.

Constituent units. The Calamia Member is a thin unit at the base of the Gatton Sandstone and the Koreelah Conglomerate Member forms the base of the Gatton Sandstone where the formation overlaps basement rocks.

A prominent thin unit near the base of the Gatton Sandstone is characterised by the abundance of large fossil wood fragments (commonly ferruginised) in a coarse-grained, conglomeratic sandstone matrix.

The beds occur in outcrop along the western and southern flanks of the basin and are best exposed in road cuttings on the Gwydir Highway, Bruxner Highway and Copmanhurst–Jackadgery road (grid reference MN 697.317, Grafton 1:100 000 sheet area). The thickness of this unit is an estimated 5–10 m. It contains blocks and logs of fossil wood up to 20 m long and nearly 1 m in diameter.

Further study of these beds may show that they constitute an important marker bed near the base of the Gatton Sandstone and deserve formal status. Definition and naming of this unit should wait until it can be shown that it is a continuous member in the formation.

Correlation. The Gatton Sandstone is correlated with the lower part of the Evergreen Formation of the Surat Basin.

Age and evidence. The formation is basal Early Jurassic and includes elements of palynostratigraphic assemblages C and D (De Jersey, 1976; McKellar, 1981) and unit J1 of Evans (1966).

Palynofloras of assemblage D from the upper part of the formation indicate a Toarcian age (McKellar, 1974; Helby & others, 1987) equivalent to assemblages from the immediate pre-oolitic ironstone sequence of the Ma Ma Creek Member (McKellar, 1981).

Reference. McTaggart (1963).

Definition of new stratigraphic unit

Name and rank: Koreelah Conglomerate Member, Gatton Sandstone

Derivation. The name comes from the small settlement of old Koreelah in northeastern New South Wales (grid reference MP 435.585, Warwick 1:100 000 sheet area).

Synonymy. The Koreelah Conglomerate Member has not been recognised previously either as a facies equivalent of part of the Gatton Sandstone or as a discrete mappable unit. On existing geological maps, many of the outcrops previously mapped as Laytons Range Conglomerate and Marburg 'Formation' have been shown to be a conglomerate developed as a western marginal facies of the Gatton Sandstone (principally the basal Gatton Sandstone).

Distribution. The member is preserved chiefly in narrow discontinuous strips along the western and parts of the southern margin of the Clarence–Moreton Basin. The strips are oriented parallel to the basin margins. The conglomerate was probably deposited in alluvial fans and stream channels emanating from them. The discontinuous outcrops suggest that they may represent parts of preserved fans and deposits along palaeo-stream axes.

Geomorphic expression. Mostly poorly exposed in low mounds or in road cuttings.

Type section. The type section lies about 10 km southwest of Warwick along the New England Highway, at grid reference LP 978.702 on the Allora 1:100 000 sheet area.

There are no continuous complete sections of the Koreeelah Conglomerate Member. The best outcrops are those along road cuttings on the New England and Bruxner Highways. The base of the member in the type section is present in outliers and at the basin margin east and southeast of the Leslie Hall Dam, such as outcrops at LP 963.784 and outcrops on the Cunningham Highway 15–17 km west of Warwick.

The top of the member grades into the Gatton Sandstone between the exposures on the New England Highway and a quarry in the Gatton Sandstone at MP 002.708.

Description of type area. The member consists of conglomerate, sandstone, siltstone and shale. Pebble to cobble conglomerate is the dominant lithology in most outcrops but the relative proportion of rock types varies considerably from one outcrop to another.

The predominantly clast-supported conglomerate is polymict with subrounded and a few angular and rounded clasts mostly 3–5 cm (and a maximum of 16 cm) across. The conglomerate is predominantly mudstone metasediments, with subordinate black chert, felsic volcanics, fine-grained sandstone, slatey metasediments and reef quartz in a matrix of coarse-grained sandstone containing fresh angular feldspar grains.

The conglomerate is both matrix and clast supported and has poorly defined bedding, including trough cross-beds. In a few places the clasts show a slight imbrication.

Fine and coarse grained lithic and feldspathic sandstone occurs as interbeds of variable thickness.

Red and grey siltstone is interbedded in some of the conglomerate exposures. In places the mudstone encloses lenses of conglomerate and coarse-grained sandstone up to 3 m thick.

Thickness. Only incomplete sections are present in outcrop. The maximum known exposed thickness is ~20–30 m on the Bruxner Highway (grid reference 470.030, Drake 1:100 000 sheet area)

About 5 m of conglomerate penetrated by GSQ Ipswich RM2 at Leyburn probably equates with the Koreelah Conglomerate Member.

Fossils. The member has no internal evidence for depositional age. Superimposition and lateral relationships indicate that the member is approximately the same age as the Early Jurassic Gatton Sandstone of the Marburg Subgroup.

Diastems and hiatuses. There is evidence for minor hiatuses and diastems.

Depositional environment. The member was probably deposited as a series of alluvial fans and braided stream deposits along the western and southern margins of the Clarence–Moreton Basin.

Relationships and boundary criteria. The member unconformably overlies Palaeozoic and Early Triassic basement rocks, and is inferred to overlie Late Triassic sediments of the Bundamba Group.

The member occurs at the local base of the Marburg Subgroup. It is interpreted to grade laterally into the Gatton Sandstone, and doubtfully into the Heifer Creek Sandstone of the Marburg Subgroup. Precise boundaries are not readily defined, because of lateral and vertical facies transitions. Lateral and vertical boundaries may be defined by the last significant beds of pebble conglomerate in the unit. Contacts are rarely observed and are typically gradational.

Distinguishing features. The combination of pebble–cobble conglomerate and coarse-grained arenitic assemblages in the member distinguishes it from the bulk of the basin sequence. The Late Triassic basal conglomerates of the basin (Laytons Range, Corindi and Aberdare Conglomerates) are superficially similar to the Koreelah Conglomerate Member, but there is usually a higher proportion of sandstone interbedded in the Koreelah Conglomerate Member, and it is distinguished in many places by the abundance of fossil wood. The sandstone interbeds are lithologically similar to those of the Gatton Sandstone.

It is not always easy to distinguish the basal Late Triassic conglomerates from those in the Early Jurassic, and in some instances a demonstration of lateral transition to the Marburg Subgroup is the surest way of distinguishing the two.

Structural attitude. The Koreelah Conglomerate Member generally dips at low angles into the basin.

Regional aspects. The Koreelah Conglomerate Member is distributed along the western and southern margins of the basin on the Cunningham and New England Highways, west and south of Warwick, on the Bruxner Highway west of Tabulam, Gwydir Highway west of Main Creek and probably also on the Pacific Highway at the Dirty Creek Range.

The proportion of conglomerate, sandstone, and fine-grained rocks varies from locality to locality. In places shales and fine sandstones are present in the sequence. Ferruginised and siliceous fossil wood, logs and fragments are common.

The formation typically occurs as a pebble–cobble conglomerate, with abundant coarse sandstone interbeds and a similar sandy matrix. The lithology of the clasts in the conglomerate is controlled largely by the composition of the underlying basement.

The known maximum exposed thickness is ~20–30 m in the area west of Tabulam on the Bruxner Highway. The true thickness is probably much greater, but exposure is discontinuous.

Correlation. There are no units that can be correlated both lithologically and temporally with the Koreelah Conglomerate Member.

The Koreelah Conglomerate Member is laterally continuous with the Gatton Sandstone of the Marburg Subgroup.

Its relationship to the Calamia Member, a basal member of the Gatton Sandstone further east, is not known.

Discussion. The evidence for the existence of the younger conglomerate and the reasons for proposing a new member name may be summarised as follows:

1. The conglomerate occurs in the exposed base of the Marburg Subgroup along the western and southern margins of the basin. In this area the subgroup overlaps the older formations in the basin and unconformably overlies Palaeozoic and Early Triassic basement rocks.
2. The Marburg Subgroup shows evidence of general coarsening towards the basin margin, and the proportion and thickness of conglomerate interbeds increase towards the margin.
3. The clast composition is noticeably different in some local areas from that found in the Laytons Range, Aberdare, and Corindi Conglomerates. Fossil wood commonly constitutes a large percentage of these clasts.
4. The sandstone interbeds in the conglomerate are similar in composition to those found in the Marburg Subgroup.
5. The basal conglomerate member is apparently continuous with the Marburg Subgroup. No unconformity is apparent between the Marburg Subgroup and the conglomerate member which would be expected if an overlapping relationship existed.
6. The suggested identification of the conglomerate present locally at the base of the Marburg Subgroup in contact with the Raceview Formation in the southeast provides additional evidence for the age and stratigraphic position of the member.

Data on other units

Name and rank: Calamia Member, Gatton Sandstone

Derivation. From Calamia Parish in the Pillar Valley area, southeast of Grafton, New South Wales.

Synonymy. First published by Etheridge & others (1985).

Distribution. The member was first identified in the DM Pillar Valley DDH No.2 drill hole and was thereafter extended to neighbouring well sections.

Geomorphic expression. The member weathers recessively and outcrop is fragmentary. A few poor exposures are present in the Coast Range, the best being in a quarry on the Grafton–Wooli Road, grid reference NN 171.047 on the Bare Point 1:100 000 sheet area. Shale of the Calamia Member crops out here beneath bluffs of the Gatton Sandstone.

Type section. The type section nominated by Etheridge & others (1985) is the interval 92 m thick [926–1018 m] in the DM Pillar Valley DDH No.2, based principally on the gamma ray log response. An alternative interpretation of the boundaries based solely on the lithological log is a sequence 108 m thick in the interval 881–989 m.

Description. The detailed sequence in the member is given in the Department of Mines descriptive log of Pillar Valley DDH No.2, and on a graphic log re-compiled by two of the authors (ATW & PO'B) from this description.

The member is composed of siltstone and mudrocks, and fine to medium grained sandstone. It is 137 m thick in Pillar Valley DDH No.2. No palynomorphs were recovered from one sample collected from the member. There is no record of diastems or hiatuses.

Depositional environment. Predominantly overbank and minor channel depositional facies of a fluvial environment.

Relationships. The member is apparently conformable with bounding units. It separates the Gatton Sandstone of the Marburg Subgroup from the Ripley Road Sandstone.

Boundary criteria. The member is lithologically similar to the Gatton Sandstone but contains a higher proportion of siltstone and claystone units. The channel sandstones are finer grained, quartzose and have a siliceous matrix.

Distinguishing features. The lithology of the member and its gamma ray log response distinguish it from neighbouring units.

Regional aspects. The member is widespread in the subsurface but does not outcrop well and has been observed only in fragmentary exposures in the Coast Range. A correlatable unit with a similar stratigraphic position, gamma ray response and lithology has been identified in Tullymorgan No.1 and Sextonville No.1 wells, and as far north as the Laidley Sub-basin (Ipswich 19-22R and Beef City Water Bore).

The interval in Ipswich 19-22R falls within Assemblage D.

Correlation. Etheridge & others (1985) consider that it may represent a distal facies of the lower Evergreen Formation from the Surat Basin.

Age. The member contains no internal evidence of age. The Marburg Subgroup is Early Jurassic. The basal parts of the subgroup, probably including strata equivalent to the Calamia Member, contain the upper limit of the basal Early Jurassic *Polycingulatisporites crenulatus* zone. The Ripley Road Sandstone beneath is Upper Triassic in NS 272 Ipswich, and in GSQ Ipswich 1 the uppermost part of the sandstone is in the lower part of Assemblage C, and thus is probably latest Triassic.

Reference. Etheridge & others (1985).