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Fluvial architecture of Triassic-Jurassic sediments of the Bundamba Group in the northern part of the Clarence-Moreton Basin, Queensland

An Excursion Guide for the 5th International Conference on Fluvial Sedimentology

Modern and Ancient Rivers - their importance to mankind

by

A T Wells and P E O'Brien

RECORD 1993/45

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AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

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A.T. WELLS[1] and P.E. O'BRIEN[1]

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Modern and Ancient Rivers - Their Importance to Mankind

The University of Queensland
BRISBANE AUSTRALIA 5 - 9 July 1993

[1]AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

DEPARTMENT OF PRIMARY INDUSTRIES AND ENERGY

Minister for Resources: Hon. Michael Lee
Secretary: Greg Taylor

AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

Executive Director: Roye Rutland

ISSN: 1039-0073

ISBN: 0 642 19354 1

FLUVIAL ARCHITECTURE OF TRIASSIC-JURASSIC SEDIMENTS OF THE BUNDAMBA GROUP IN THE NORTHERN PART OF THE CLARENCE-MORETON BASIN

INTRODUCTION

This excursion guide provides an introduction to the fluvial sedimentology of the Triassic- Jurassic Bundamba Group in the northern part of the Clarence-Moreton Basin which is situated in the southeastern part of Queensland (Fig.1).
The excursion guide is written so that the major exposures of fluvial rocks between Ipswich and Toowoomba can be examined. Descriptions of fourteen stops are included in the guide and if all the outcrops are inspected the total road distance covered is about 350 km, with Brisbane as the starting and finishing point. Figure 2 shows the excursion route and position of the stops. The itinerary given at the end of this guide includes an appropriate number of stops based on a one day excursion.

The area is readily accessible with most of the sediments exposed in road cuttings along the Warrego Highway; others occur in cuttings on the Clifden-Gatton Road and the Murphys Creek Road, small access roads branching off the Warrego Highway . All these roads provide sealed, all weather access. Great care should be taken when examining cuttings on the Warrego Highway as it carries a large volume of traffic.The Main Roads Department generally request that appropriate signs be erected during road cutting examination on main highways. There are several small towns along the Warrego Highway that provide accommodation and where provisions may be purchased. The city of Toowoomba is a convenient stepping off point to visit geological features in the northern Clarence-Moreton Basin.

The data used in compiling this excursion guide is largely derived from the Australian Geological Survey (AGSO) Bulletin 241, (Wells & O'Brien, in press), and in particular an included paper on the sedimentology of the Bundamba Group (O'Brien & Wells, in press).

The reader is referred to Wells, O'Brien, Willis & Cranfield (1990), Cranfield, Hutton and Green (1989), and Cranfield, Schwarzbock and Day (1976), for descriptions of the regional geology of the northern part of the Clarence-Moreton Basin.

GEOLOGICAL SETTING.

The Clarence-Moreton Basin is a broad intracratonic basin covering about 40 000 km^2 and extending from the Kumbarilla Ridge in the west, to the east coast of Australia and probably beyond (Fig.1). The sediments to be examined on this excursion range in age from Late Triassic (Rhaetian) to Late Jurassic (Tithonian) and occur mostly in the Laidley Sub-basin (Fig.1) and some in the northern part of the Logan Sub-basin.The stratigraphic succession in the basin is shown in Figure 3, and a generalised section in the Laidley Sub-basin along the Clifden-Gatton Road in Figure 4.

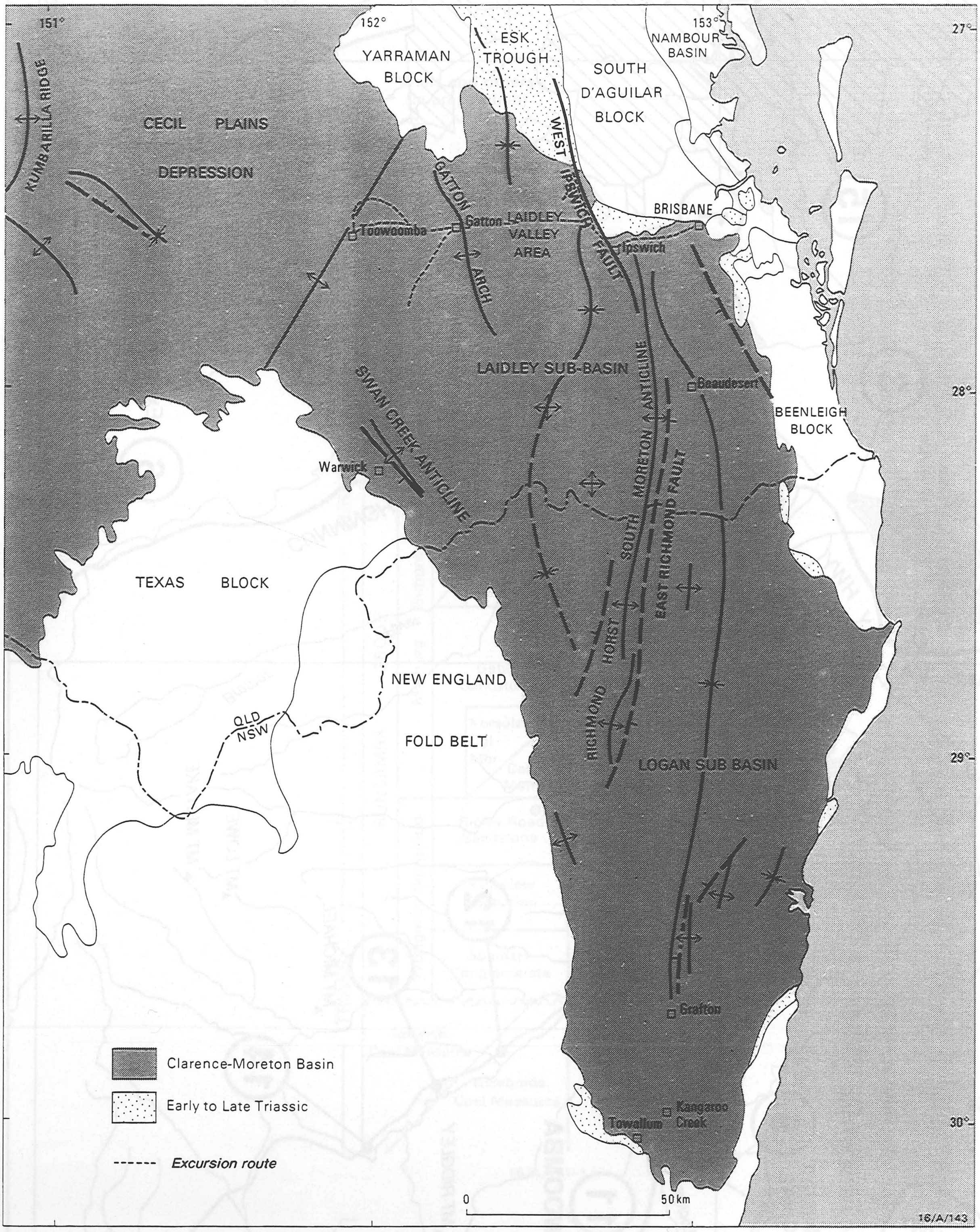

Figure 1 - Locality Map of the Clarence-Moreton Basin.

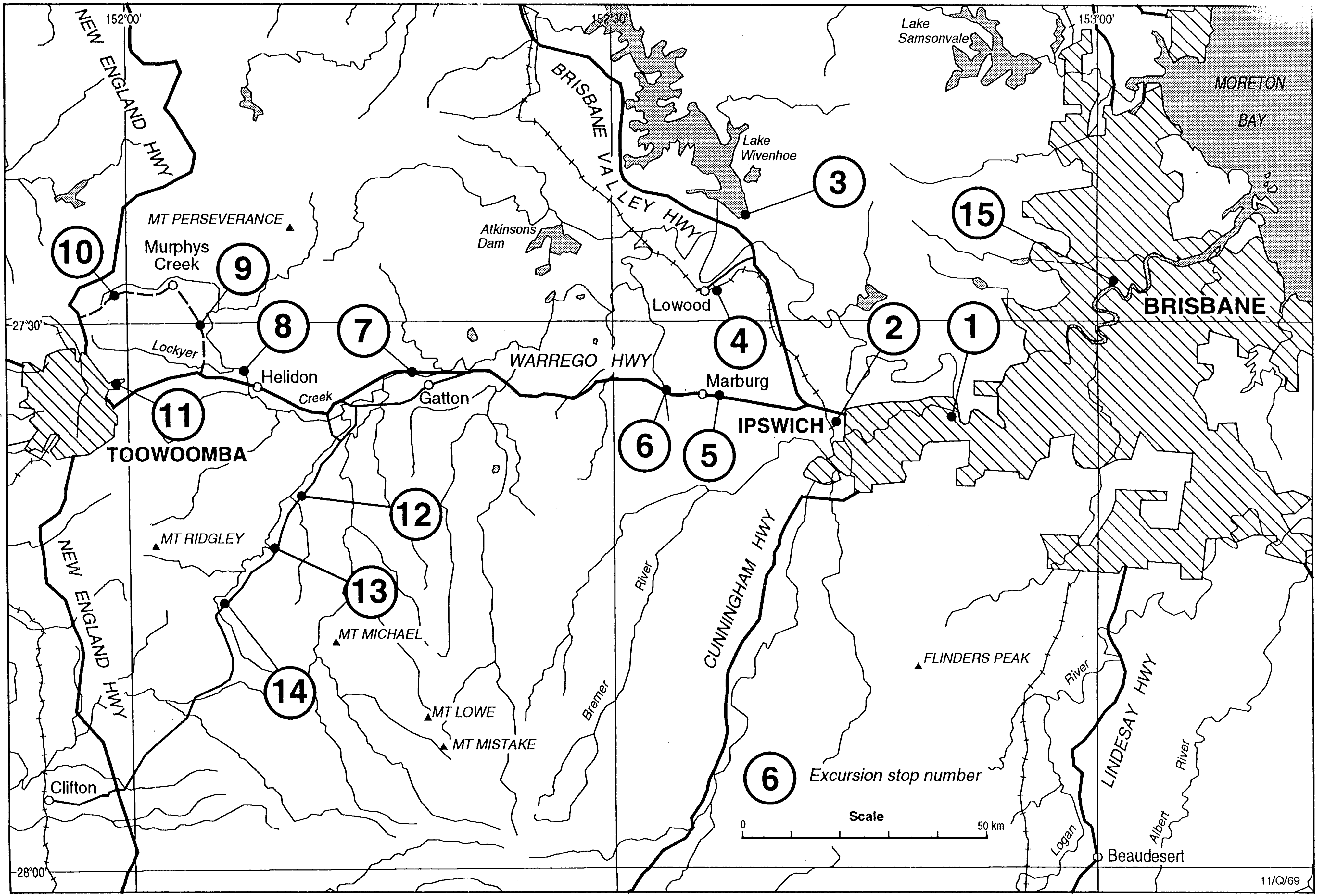

Figure 2 - Route map and stops for the excursion.

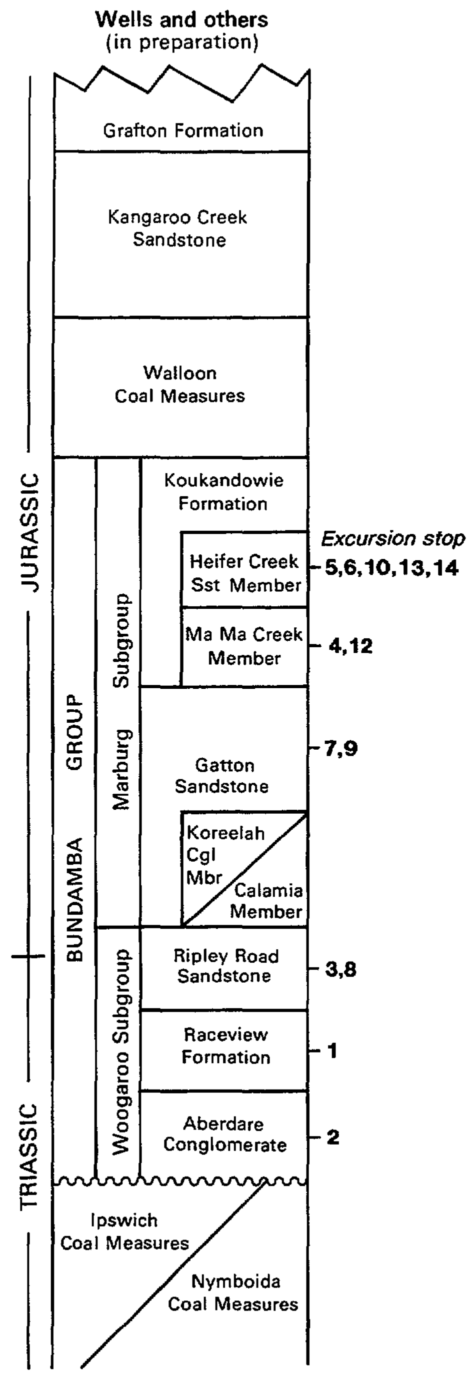

Figure 3 - Generalised stratigraphy of the Clarence-Moreton Basin.

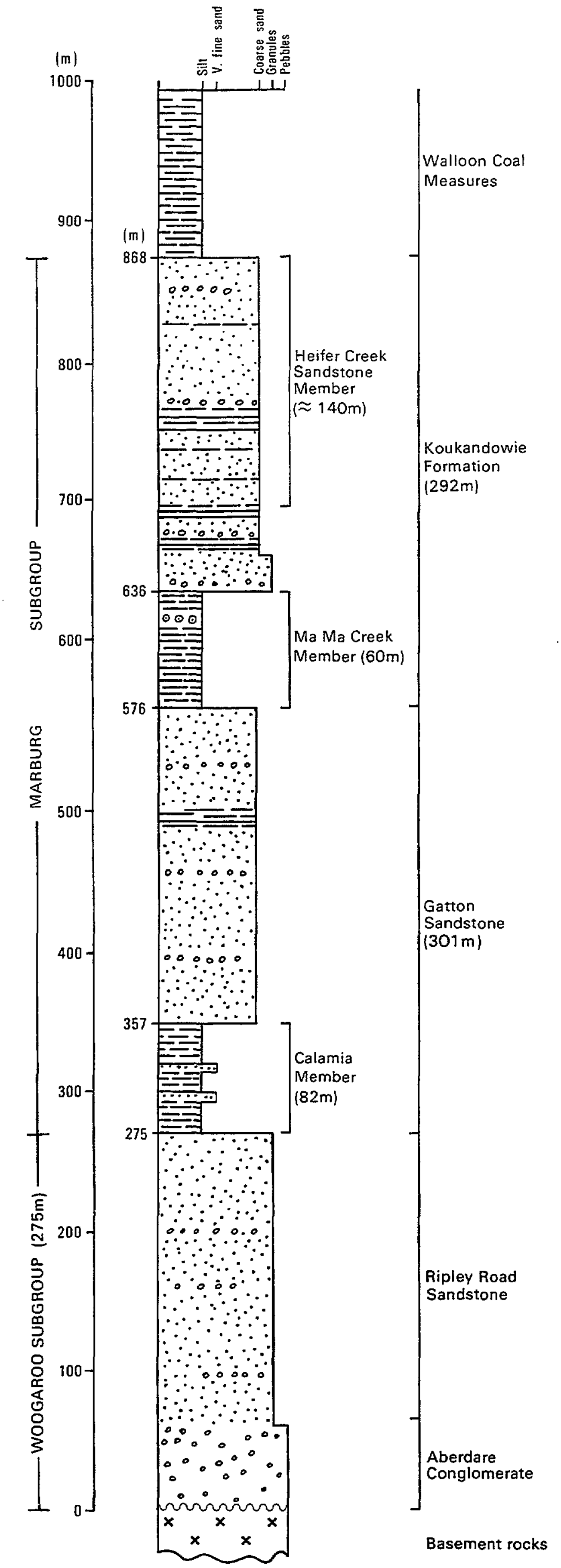

Figure 4 - Section through the Woogaroo and Marburg Subgroups of the Bundamba Group, along the Clifden - Gatton road.

The sediments of the Clarence-Moreton Basin were deposited during thermal relaxation of the crust over a series of Triassic transtensional basins. The basin fill reaches a maximum thickness of about 3.5Km in the Logan Sub-basin and is entirely fluvial so that in discussing basin analysis in it we are predominantly concerned with changes in fluvial architecture in time and space and the causes of these changes. Table 1 shows the major stratigraphic units of the Bundamba Group and an interpretation of their architecture and causes, and Figure 18 shows sedimentation models for the Bundamba Group.

The non-marine sediments of the Bundamba Group in the Clarence-Moreton Basin are divided into units reflecting their detrital composition and sedimentation style. The major units are:

1. The Raceview Formation and Aberdare and Layton's Range Conglomerates which represent deposition in highland valleys and basin margin braidplains that pass out into low-gradient suspended load streams in the sub-basin axes.

2. The Ripley Road Sandstone which is a sheet of quartzose sandstone deposited by braided streams.

3. The Gatton Sandstone replaced the Ripley Road Sandstone with a change to labile detritus and some rearrangement of palaeocurrents although braided streams persisted.

4. The Ma Ma Creek Member of the Koukandowie Formation represents a change from sandy braided streams to deposition in a flood plain with extensive lakes and swamps and sinuous and vertically aggrading streams.

5. These muddy environments were replaced by braided streams carrying quartzose sand that deposited the Heifer Creek Sandstone Member of the Koukandowie Formation.

6. In the eastern half of the basin, the Heifer Creek braided streams were replaced by sinuous channels with more extensive floodplains and carrying labile detritus.

Some changes in both composition and depositional style can be related to tectonic uplift of the hinterland and basin subsidence variations. The replacement of the Ripley Road Sandstone by the Gatton Sandstone and the change in the eastern part of the basin from the Ma Ma Creek Member to the upper Koukandowie Formation fall into this category. A rise in eustatic base level probably caused the Gatton Sandstone - Ma Ma Creek Member transition whereas the Raceview Formation - Ripley Road and Ma Ma Creek - Heifer Creek changes probably reflect cyclic adjustments of the fluvial systems to accommodate the tectonic and base level changes.

NOTES ON PURPOSE OF EXCURSION, NOMENCLATURE AND TERMINOLOGY

The sediments of the Bundamba Group form most of the Clarence-Moreton Basin fill and the principal objective of this excursion is to view all the units of this succession in the northern part of the Clarence-Moreton Basin, and asses their sedimentary attributes in terms of environments of deposition and relationship to thè tectonic history of the basin. Their stratigraphic nomenclature is discussed in Wells & others (1990), and Wells & O'Brien (in press). This excursion guide discusses the units' internal facies relationships, sediment body geometries, depositional environments and their significance for understanding basin development.

The Bundamba Group represents continuous non-marine deposition from the Late Triassic to the Middle Jurassic (Burger, in Wells & O'Brien, in press.) over an area of 40,000 km^2. Studies of fluvial facies usually concentrate on small areas of good outcrop (e.g. Lawrence & Williams, 1987) and have rarely addressed the question of what controls facies architecture in broad intracratonic basins formed by thermal relaxation (Peterson, 1984). Also, though the role of tectonism in shaping fluvial depositional styles is increasingly under scrutiny (Miall, 1981; Alexander & Leeder, 1987), the effects of climate and eustatic sea level change are more poorly understood. In the study of the Clarence-Moreton Basin, all available data was integrated to interpret the facies architecture of each unit in the Bundamba Group and so interpret the controls on deposition.

The stratigraphy of the Clarence-Moreton Basin was updated by Wells & others (1990) and data from large outcrops were documented using profiles of overlapping photographs with annotated overlays. Where possible, sediment body geometries are described using the geometric terminology of Friend & others (1979).

The facies code used is a modified version of that developed by Miall (1977, 1978) and Rust (1978). In describing some units, it was found that facies grouped together in recognisable, repeated combinations. For example, the Layton's Range Conglomerate can be adequately described in terms of its constituent facies whereas the Raceview Formation contains several distinctive types of sandstone bodies made up of several facies. Each recognisable combination of facies is described as an element, similar to the architectural elements of Miall (1985) and units where this type of subdivision is appropriate are described in terms of their constituent elements.

Miall's method of analysis subdivides fluvial deposits into local suites consisting of one or more of a set of eight basic three-dimensional architectural elements. Elements are defined by grain size, bedform, composition, internal sequence, and most critically by external geometry. All fluvial successions are composed of varying proportions of the eight proposed elements and element hierarchy is based mainly on scale, from channels down to overbank fines.

An hierarchy of bedding contacts was proposed by Allen (1983) with the idea that sandstone bodies are divisible internally into 'packets' of genetically related strata by an hierarchically ordered set of bedding contacts.The classification of bedforms into microforms, mesoforms, and macroforms is the terminology proposed by Jackson (1975).

INSPECTION POINTS

Stop 1 - Raceview Formation (Woogaroo Subgroup)

The Raceview Formation occurs in a road cutting at Redbank on the Warrego Highway about 25km west of Brisbane. The Raceview Formation here is composed of siltstone, mudstone, quartzo-feldspathic sandstone and rare coaly beds.

One element of the formation consists of lenses of sandstone up to 1.5 m thick and up to 30 m wide (Figs.5&6). The lenses rest on erosion surfaces cut in finer-grained sediments and are composed of large scale planar cross-bedded, ripple cross-laminated and flat laminated medium to fine sandstone.

The lenticular geometry of this element clearly indicates an origin as small channels cut in underlying sediments and filled by vertical accretion. The vertical change from planar cross bedded medium sandstone to flat laminated and ripple cross-laminated fine sandstone indicates waning stream power during deposition. These small channels are probably crevasse splay channels fed by breaches in the main channel levees (cf. Guion, 1984; Fielding, 1984, 1986). Their erosional bases indicate formation in proximal parts of the splay channel (Fielding, 1986; Smith & others, 1989).

The thinly interbedded, fine grained facies comprise elements that are typical overbank deposits. Such sandy overbank sediments are typically deposited in levees and as distal crevasse splays (Allen, 1965, Farrell, 1987) . Thin sandstone interbeds and load structures reflect rapid flood-stage sedimentation by sheet flow overtopping the levees or at the distal, unconfined end of a crevasse channel. Fine mudstones represent deposition at falling stage and the abundant plant roots and burrows, colonisation by plants and animals.

The channel elements in the Raceview Formation suggest a fairly low gradient fluvial system with suspended load channels (Schumm, 1981). Preservation of so much floodplain sediment suggests a low avulsion/subsidence ratio and narrow channel belts. (Fig. 22, Allen, 1978, Bridge & Leeder, 1979).

The main variation in element assemblages in the Raceview Formation is in the importance of sandy overbank deposits.

Figure 5 - Element comprising a sandstone lens, cut in a sandstone and siltstone element, Raceview Formation, Redbank (Stop 1). These lenses were probably cut and filled as crevasse channels.

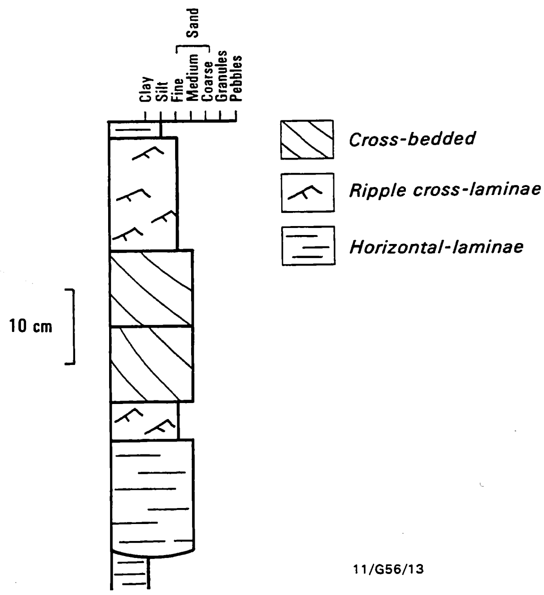

Figure 6 - Section through sandstone lens element shown in Fig. 5. The faint horizontal laminae probably indicate upper flow regime conditions following cutting of the channel. Ripple cross laminae indicate abrupt waning of stream power. The large scale cross beds indicate a return of more energetic flow which then waned. This succession of structures suggest that the channel filled by vertical accretion during two episodes of alternating high flow and low flow.

Stop 2-Aberdare Conglomerate (Woogaroo Subgroup)

The Aberdare Conglomerate occurs in a road cutting on the Warrego Highway near Muirlea about 35 km west of Brisbane. The Aberdare Conglomerate is faulted against the the Cribb Conglomerate and Hector Tuff of the Ipswich Coal Measures at the West Ipswich Fault; thin fault wedges of conglomerate, probably the Aberdare Conglomerate, occur in the Ipswich Coal Measures. The Aberdare Conglomerate, the basal unit of the Clarence-Moreton Basin succession, dips steeply westward into the Laidly Sub-basin at the fault; it is composed of polymict pebble and cobble conglomerate, sandstone and shale, and includes a pink 'shale' (?tuff) marker bed (not exposed in this outcrop). The composition of clasts in the conglomerate in the north is dominated by vein quartz and black chert with lesser amounts of metasediments, felsic volcanics and jasper pebbles. The Aberdare Conglomerate was deposited in local valley fills around the margins of the Basin. The Aberdare Conglomerate is generally thicker around the basin margins and in the Logan Sub-basin, and here is thickest in the synclines. The greater thicknesses of Ipswich Coal Measures were removed from the synclinal areas prior to the deposition of the conglomerate. Fabric analyses of the Aberdare Conglomerate generally indicate a radial drainage pattern into the Basin, but south of Ipswich the Aberdare Conglomerate and Raceview Formation occupy northwesterly trending palaeovalleys cut in synclines also trending northwesterly.

The bulk of the Aberdare Conglomerate is broadly lenticular to sheet-like and dominated by the deposits of longitudinal gravel bars. Lenticular parts are the fill of palaeovalleys cut in basement, between rising anticlines in the Ipswich area. These features are consistent with deposition by braided rivers flowing in valleys feeding stream-dominated alluvial fans and braidplains (Rust & Koster, 1984; Rust, 1984). The vertical succession from coarse valley fills to interbedded conglomerates, sandstone and fine-grained floodplain sediments indicates filling of basin-margin river valleys and development of braidplains.

Stop 3-Ripley Road Sandstone (Woogaroo Subgroup)

The largest single exposure of Ripley Road Sandstone in the northern part of the Clarence-Moreton Basin is in the spillway of Wivenhoe Dam north of Ipswich. It consists of two faces up to 25 m high and 600 m long that are oriented parallel to the northerly palaeocurrent direction (Fig. 7). Bedding dips a few degrees south.

In the lower face, the main architectural elements consist of concave-up 3rd or 4th order bounding surfaces (Miall, 1988) overlain by irregular sheets and lenses of massive coarse sandstone to granule conglomerate (SLSG). These beds, some of which contain very large mudstone clasts, rest on scour surfaces, and grade into coarse to medium grained and large scale, planar cross-bedded sandstone (PCS) (Fig.7). Thin mudstone drapes preserve some bedform upper surfaces (Fig.8). Two PCS elements are present, one consisting of compound cross-sets up to 4 m thick with descending sets up to 0.4 m thick. The other element consists of planar

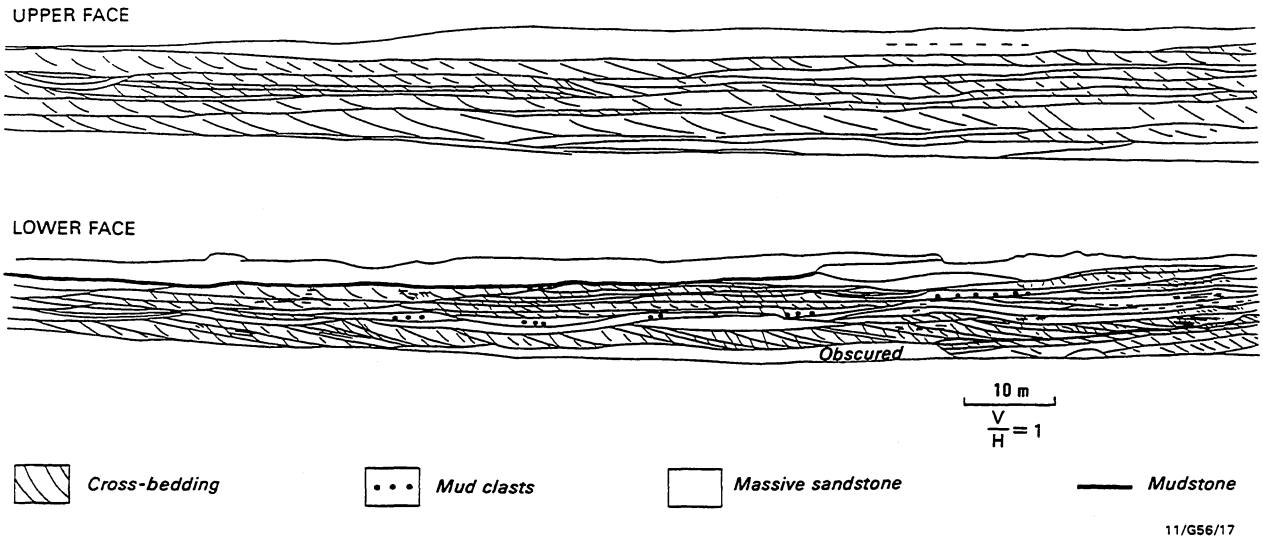

Figure 7- Sketch profile of facies distribution in the Ripley Road Sandstone in west face of the Wivenhoe Dam Spillway.

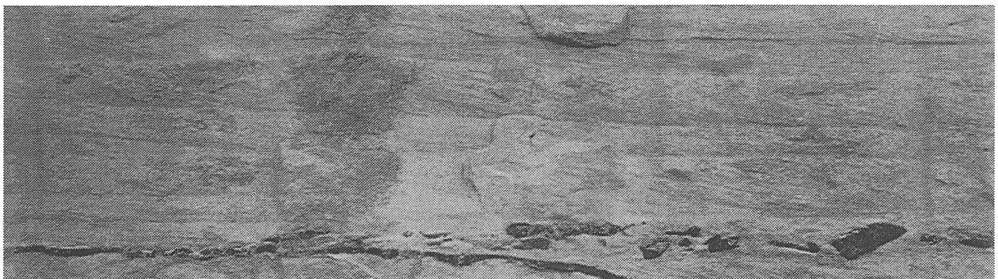

Figure 8- Large scale planar cross sets in the Ripley Road Sandstone, Wivenhoe Dam. (Stop 3). A mudstone drape preserves one small dune form.

cross sets up to 1 m thick that generally offlap one another downstream although not in so consistent a manner as in the compound cross sets. Most first order cross beds dip north. There is no consistent trend in grain size with coarse and medium sandstone cosets interbedded. The few beds and lenses of apparently horizontal laminated sandstone may be PCS sets dipping into the rock face.

The upper face contains PCS sets up to 4 m thick, and only one compound set (Fig. 7) and one thin, moderately well sorted medium grained sandstone bed with fine laminae and parting lineations that passes downstream into PCS. Second order bounding surfaces separating the cross sets are essentially parallel to bedding although some show undulations suggestive of slight erosion of underlying sets. One lenticular sandstone body with laminae parallel to its base is probably a trough cross-set oriented normal to the prevailing palaeocurrent direction (Fig. 7).

The compound cross-sets and downstream-dipping bounding surfaces in the lower face of the Wivenhoe Dam spillway cutting indicates sedimentation by downstream-accreting macroforms (Fig. 34a, Miall, 1988). In this case the macroforms did not end in major slip faces as in the Platte-type of macroform (Crowley, 1983), rather they consisted of large sand bodies with bedforms migrating over them (cf. Haszeldine, 1983a,b). The difficulty of obtaining comprehensive palaeocurrent measurements from the faces makes it impossible to tell if these bedforms were straight-crested or linguoid in plan. Facies SLSG was deposited in channel bed scours over which the macroforms advanced.

The presence of downstream accreting macroforms and the absence of evidence for lateral accretion and the apparently low palaeocurrent variance indicates deposition by low sinuosity streams. Bristow (1987) concluded that macroforms are typically one half to just below total bankfull depth in low sinuosity streams. This allows an estimate of minimum bankfull depth of 4 m for the stream that deposited the Ripley Road Sandstone in the lower face, although full macroform heights have not been preserved because of scouring prior to the next depositional episode. Thin mudstone drapes on bedforms indicate sudden waning of the flow.

The element architecture in the upper face does not show the same evidence for downstream accretion of macroforms seen in the lower face and is therefore more like Model 9 of Miall (1985) which is a low sinuosity river with linguoid bars. The Ripley Road Sandstone river probably featured transverse bars because there seems to have been little divergence from the general palaeocurrent direction by the bar slip faces, although direct measurement of these directions was not possible .

Most smaller outcrops of Ripley Road Sandstone appear to display similar architecture to either the upper or lower bench at Wivenhoe. Although downstream accreting macroforms are hard to prove in small outcrops, compound cross sets are fairly common and one outcrop of Ripley Road Sandstone displays planar cross beds of coarse to medium sandstone 1 to 2 m thick separated by down-current dipping second order surfaces .

The Ripley Road Sandstone was deposited by low-sinuosity streams flowing from the south and east of the Logan Sub-basin and from the west to southwest in the Cecil Plains and Laidley Sub-basins. These two drainage systems joined in the northern Laidley Sub-basin and flowed out of the Clarence-Moreton Basin towards the northeast. The streams flowing from the west carried more mature detritus than those flowing from the south and east in the Logan sub-basin.

The streams were low sinuosity and sand dominated similar to sandy braided streams from humid settings such as the South Saskatchewan (Cant, 1978) or the Platte River (Crowley, 1983).

Stop 4- Ma Ma Creek Member (Koukandowie Formation, Marburg Subgroup)

One of the few exposures of the Ma Ma Creek Member of the Koukandowie Formation is exposed in a railway cutting at Lowood.

The most common facies element in the Ma Ma Creek Member consists of siltstone, claystone and fine-sandstone (SCS) interbedded on a scale of a few centimetres. The proportions of sandstone and siltstone vary with sandier units displaying ripple cross-laminae. Some intervals include coaly claystone beds and abundant rootlet beds whereas others lack rootlets, have well-laminated claystones and scattered burrows.

Ferruginous oolite beds are present in many Ma Ma Creek sections and have been reported from this cutting but have proved notoriously difficult to locate. Their mineralogy and characteristics are discussed by Cranfield & others (in Wells & O'Brien, in press). Oolite beds are up to 0.1 m thick and commonly overlie thin sandy beds which have erosional contacts with underlying facies. Most oolite beds are interbedded with SCS sediments or are the basal bed in a coarsening-up cycle . The one exception to this is an oolite bed in GSQ Ipswich 11 which is set in fine grained sandstone with thin mudstone laminae.

Tabular beds in the order of 1 m thick are interbedded with the SCS. These beds consist of horizontally laminated fine grained sandstone, massive, rooted fine grained sandstone or planar cross-laminated sandstone with thin ripple cross laminated units above and below the large cross set (Fig.9).

Intervals containing oolite beds are not the only lacustrine deposits in the Ma Ma Creek Member. It is probable that the SCS intervals lacking rootlet beds are at least partly lacustrine. SCS intervals with rootlet beds and coaly horizons probably represent fluvial flood basin deposits. Intervals which have a high proportion of siltstone and fine sandstone may have been deposited as distal crevasse splays or fluvial channel levees (Smith & others, 1989).

The thin sheet-like sandstone beds of Element 4 were probably deposited as distal crevasse splays, some of which developed with prograding slip faces (Fig. 69, O'Brien & Wells, 1986).

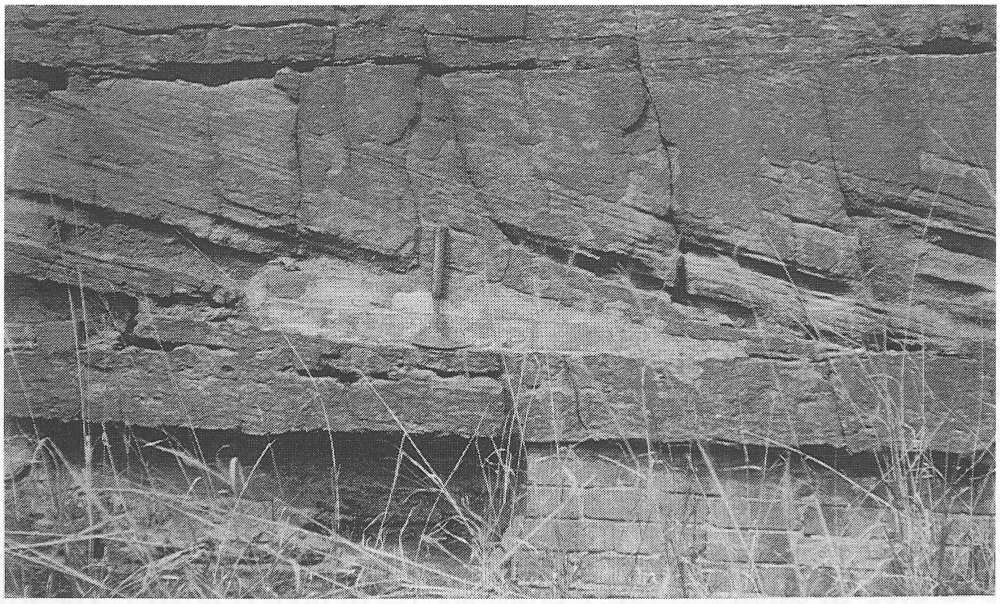

Figure 9- Ma Ma Creek Member exposed in a railway cutting near Lowood. The sandstone bed is tabular with thin ripple cross laminated units above and below the large cross set.

This assemblage of architectural elements suggests that the Ma Ma Creek Member developed as a plain with extensive lakes and anastomosing streams which fed crevasse splays and lacustrine deltas . After transgressions of adjacent floodplains, larger lakes contained areas starved of suspended sediment in which iron-rich clay oolites developed as in modern Lake Chad (Dupont, 1970). The presence of brackish water acritarchs suggests that the lakes were of elevated salinity, either because of high evaporation or because of invasion by marine water. Thin coal beds, abundant rootlets and the lack of red palaeosols suggest a humid climate making marine influence more likely.

The general depositional environment was a low gradient streams crossing alluvial plains with extensive fresh to brackish lakes or lagoons.

Stop 5-Heifer Creek Sandstone Member (Marburg Subgroup, Koukandowie Formation).

The Heifer Creek Sandstone Member is well exposed in a road cutting on the Warrego Highway about 1 km east of Marburg Township, approximately 47 km west of Brisbane. The sedimentary structures can be examined on either side of the cutting.

The cutting shows a small sandstone body about 1.5 m thick set in fine sandstone and mudstone overlying a trough cross-bedded sandstone in the lower part of the exposed section.

Here the sediment body displays lateral accretion bedding ; this unit consists of inclined beds of sandstone up to 0.6 m thick separated by siltstone and mudstone beds up to 0.05 m thick forming a cross-set 1.5 m high (Fig.10). The lowest inclined sandstone bed rests on an erosion surface cut in mudstone and a sandstone sheet (Fig.10). The inclined beds dip up to 15 degrees towards the southeast and are asymptotic to their lower bounding surface. As one follows the outcrop in the direction of foreset dip, the sandstone beds become thinner and are eventually represented by sandstone beds and lenses only a few centimetres thick separated by up to 0.5 m of mudstone. These thin sandstone beds are still inclined.

The inclined sandstone beds are parallel laminated, ripple cross-laminated or massive with abundant mud clasts (Fig. 11). There are a few trough cross sets up to 0.15 m thick in some beds. These cross-sets and the ripple cross-laminae dip towards the south-southeast indicating that the bedforms were moving obliquely down the inclined depositional surface or they dip parallel to the strike of the inclined beds. Some of the inclined beds display a succession of structures with parallel laminae overlain by ripple cross laminae which show an increasing angle of climb and are then overlain by silty, very fine sandstone or mudstone beds.

This element which shows sandstone bodies with lateral accretion bedding,

Figure 10 - Small element (1.5 m thick) of sandstone set in fine sandstone and mudstone overlying an element comprising a trough cross bedded sandstone body. Warrego Highway cutting at Marburg (Stop 5).

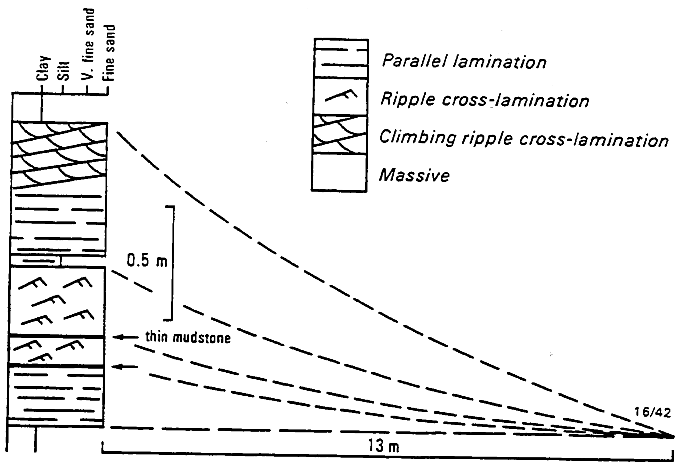

Figure 11 - Vertical section through the sandstone element at Marburg (Fig. 10). Dashed lines indicate the way bedding planes meet the base of the sandstone body asymptotically.

displays features consistent with deposition by sinuous streams (Jackson, 1978; Smith, 1987). The outcrop example differs from many channel sandstone bodies with lateral accretion sets in that it is mostly fine sandstone with few mudstone interbeds. The fine grain size suggests that it was deposited by a distal, low energy channel (Jackson 1981; Stewart, 1983). Abundant mud clasts on cross bed foresets are probably the reworked remains of low water mud drapes, normally preserved as mudstone interbeds (Smith, 1987). This combination of characteristics indicates that the stream falls at the low energy end of the spectrum of mixed load streams. Lower energy, suspended load streams have more mudstone and siltstone interbeds deposited on their point bars (Taylor & Woodyer, 1978; Stewart, 1983).

The small, muddy element exposed at Marburg is more typical of low energy, suspended load streams (Taylor & Woodyer, 1978; Stewart, 1983). Its small size indicates that it is a small floodplain channel and the interbedding of sandstone and mudstone defining its lateral accretion sets indicates intermittent flow. The reduction in the thickness of sandstone beds along the outcrop indicates progressive reduction in the amount of sand available for the channel to transport.

Stop 6-Heifer Creek Sandstone Member (Marburg Subgroup, Koukandowie Formation).

The Heifer Creek Sandstone Member is exposed in a road cutting about 4 km west of Marburg Township on the Warrego Highway, and approximately 55 km from Brisbane. A sandstone body is set in siltstone and mudstone and lateral accretion sets dip from left to right and cross-bedding dips out of the cutting.

An important element of the formation consists of sandstone bodies with well developed lateral accretion surfaces (Fig. 12). The best exposed example, in a large highway cutting west of Marburg, is 4 m thick and consists of inclined fine sandstone beds displaying laminae parallel to the lateral accretion bedding and trough cross-bedding with palaeoflows parallel to the strike of the lateral accretion surfaces (Fig. 12). Mud chips are common on foreset laminae. Individual inclined sandstone beds are up to 1 m thick but wedge out along the erosion surface that forms the base of the sandstone body (Fig. 12). The sandstone body is capped by a continuous, ripple cross-laminated fine sandstone bed 0.4 m thick.

The small, muddy element exposed at Marburg is more typical of low energy, suspended load streams (Taylor & Woodyer, 1978; Stewart, 1983). Its small size indicates that it is a small floodplain channel and the interbedding of sandstone and mudstone defining its lateral accretion sets indicates intermittent flow. The reduction in the thickness of sandstone beds along the outcrop indicates progressive reduction in the amount of sand available for the channel to transport.

Further interpretation of sedimentary structures in these types of sandstone bodies is given under Stop-5.

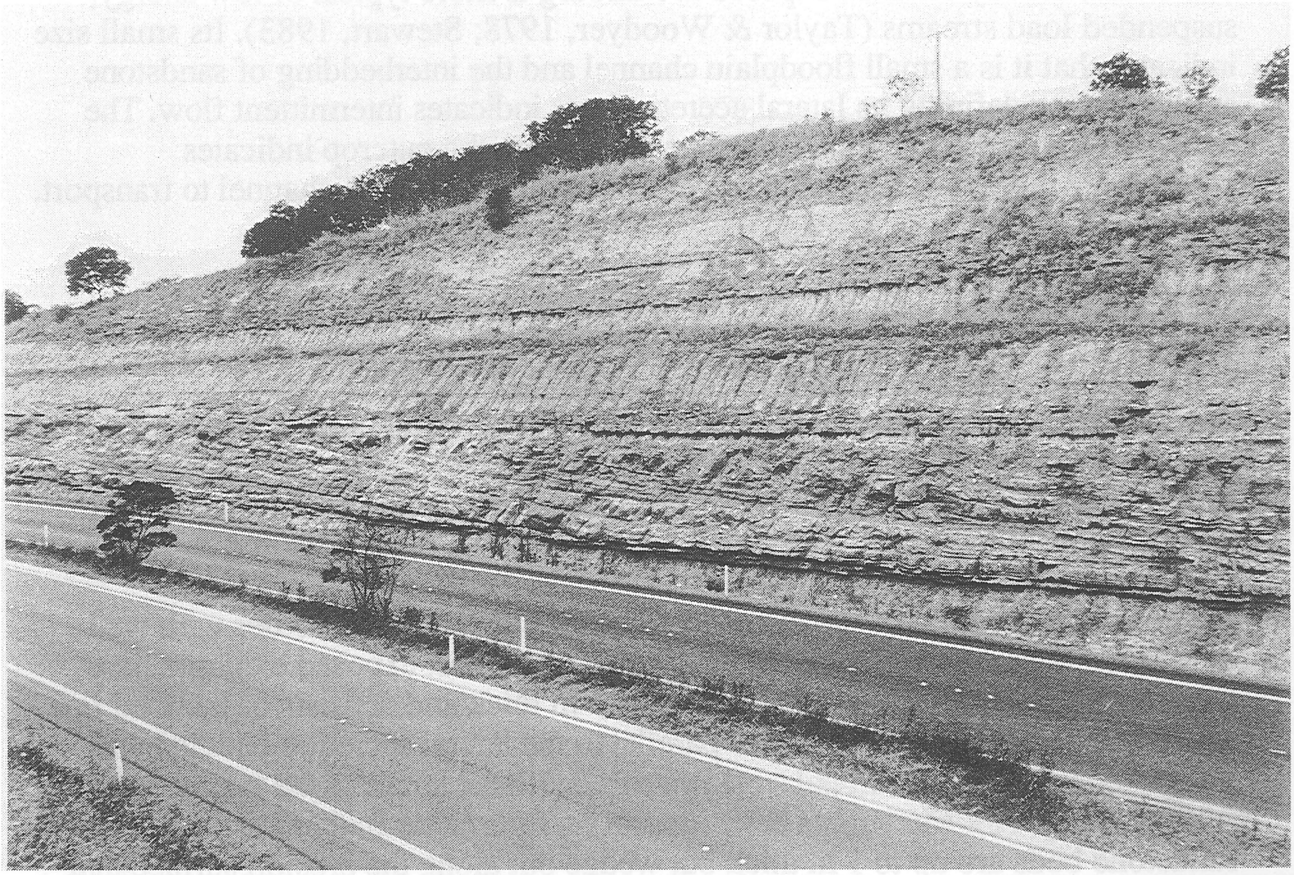

Figure 12 - An element composed of a sandstone body set in mudstone in a cutting on the Warrego Highway 3 km west of Marburg. Lateral accretion sets dip from left to right and cross bedding dips out of the cutting.

Stop 7 Gatton Sandstone (Marburg Subgroup)

The lithic labile sandstone of the Gatton Sandstone is exposed near Gatton Township. New roadcuts in the Gatton Bypass of the Warrego Highway show excellent sections with a variety of sedimentary structures exhibited.(Notes to be supplied)

Stop 8-Ripley Road Sandstone (Woogaroo Subgroup)

The Ripley Road Sandstone is exposed at the Helidon building stone quarries , about 93 km from Brisbane.

The sandstone formation at the Helidon quarries is identified as the Ripley Road Sandstone, whereas the dimension stone (chiefly facing and building) quarried at Helidon is locally known as the 'Helidon Sandstone'.The sandstone extracted here is medium to fine grained, uniform in grain size, well sorted, and is used extensively as a construction stone in southeast Queensland. The sandstone contains abundant carbonised plant remains and displays enigmatic sedimentary structures that can be the subject of a stimulating on site discussion.

The Ripley Road Sandstone is more mature than most of the Raceview Formation and is comparable to typical sandstone suites derived from craton interiors and by re-cycling of orogenic belt sediments (Dickinson & Suczek, 1979; Dickinson & others, 1983; Dickinson 1985).

The Ripley Road Sandstone was deposited by low-sinuosity streams flowing from the south and east of the Logan Sub-basin and from the west to southwest in the Cecil Plains and Laidley Sub-basins. These two drainage systems joined in the northern Laidley Sub-basin and flowed out of the Clarence-Moreton Basin towards the northeast. The streams flowing from the west carried more mature detritus than those flowing from the south and east in the Logan Sub-basin. The streams were low sinuosity and sand dominated similar to sandy braided streams from humid settings such as the South Saskatchewan (Cant, 1978) or the Platte River (Crowley, 1983). Sands were deposited in active channel belts with most of the floodplain covered with thin overbank muds. Channel deposition was primarily in downstream-accreting macroforms in deeper streams or by vertical accretion of transverse or linguoid bars. Channel-bed scour fills and bar top deposits are a relatively minor part of the active channel belt deposits. Mudstone drapes within sandstone macroforms indicate occasional rapid drops in current velocities. The lack of evidence for gradual flow decreases also suggests that gradual channel abandonment did not take place. The rate of channel migration was high relative to basin subsidence so very little floodplain mudstone was preserved.

Stop 9-Gatton Sandstone (Marburg Subgroup)

The Gatton Sandstone is exposed on the east side of the Murphys Creek Road, about 4 km north of the Warrego Highway intersection, and 105 km from Brisbane.

An element common in outcrops in the northern part of the Laidley and Logan Sub-basins consists of sandstone bodies that fine-up in some instances and have vertical zonation of sedimentary structures. Resting on a scour surface at the base is massive and trough cross-bedded coarse sandstone about 1 m thick with pebble conglomerate lenses and ferruginized logs up to 0.3 m in diameter (Figs. 13 &14). This lower facies is overlain by planar cross-bedded coarse to medium sandstone in sets 1 to 2 m thick. These sets rest at their upstream end on an erosion surface that cuts out the underlying cross set (Fig. 13). The sets thicken downstream and descend slightly relative to bedding. Graded and rhythmic-bedded foresets are common.

The planar cross sets mostly become thinner and finer up-section although some sections show planar cross-sets increasing in thickness vertically (Fig. 13). They are overlain by fine to medium-grained sandstone in trough cross-sets about 0.2 m thick and 4 m across. In sections for which palaeocurrents were obtained, the mean trough cross set paleocurrent direction diverges from the mean planar cross set direction by about 20 degrees. The trough cross-bedded interval is overlain by thinly bedded fine sandstone that grades up into siltstone and mudstone (Figs. 13 &14).

The low palaeocurrent variance in the element described above suggests deposition in low-sinuosity, sand bed streams. Downstream descending planar cross sets indicate downstream accretion of macroforms covered with straight-crested bars or bedforms so the streams were probably braided (Miall, 1985). This element exhibits a well defined vertical succession from higher flow regime to lower flow regime structures. This probably represents preservation of channel bed sediments beneath downstream accreting macroforms that are overlain by bar top or proximal overbank deposits. Such systematic preservation of a vertical sequence is similar to the South Saskatchewan model of braided stream deposition (Fig. 32a, Cant & Walker, 1976, 1978; Miall, 1978) and consistent channel migration so that the channel bed-macroform-bar top sequences were preserved. The macroform thickness of 6 to 8 m indicates a minimum channel depth of that order (Bristow, 1987).

The Gatton Sandstone was deposited by low-sinuosity streams flowing south to north through the Clarence-Moreton Basin . As with the Ripley Road Sandstone, streams traversed areas of greater subsidence without deflection, indicating that they were near grade. Most of the basin was traversed by sand bed streams, mostly resembling Model 9 of Miall (1985) with fields of transverse bars separated by deeper channels and capped by shallow water deposits where emergent. Downstream accreting macroforms developed in places (the element described above) and chute channel reworked abandoned channel deposits . Away from the active channel belts, fine-grained sediments were deposited on the floodplain but were frequently reworked because of rapid avulsion and wide channel belts (Bridge & Leeder, 1979). Small scale floodplain channels deposited lenticular sands on the floodplain and built levees of stacked crevasse channels

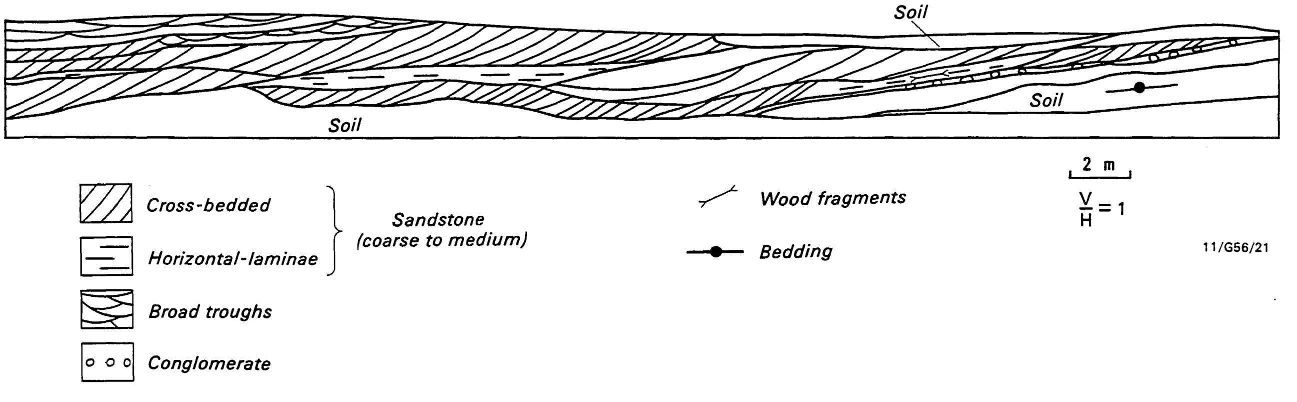

Figure 13 - Profile of an element composed of a sandstone body in the Gatton Sandstone, Murphy's Creek Road. Profile is approximately parallel to the palaeocurrent direction.

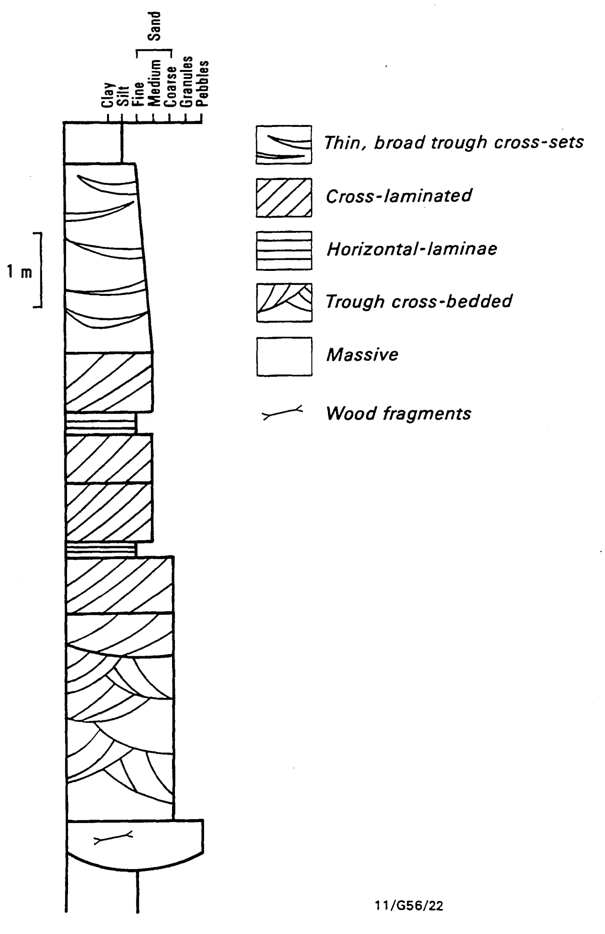

Figure 14 - Vertical section through a sandstone body (the same element as shown in Fig. 13), Gatton Sandstone, Warrego Highway, 5 km west of Helidon.

(cf. Coleman, 1969).

The main alluvial plain was fed by valleys cut in bedrock. These valley fills consisted of gravelly channel deposits (Koreelah Conglomerate Member) with fine-grained floodplain deposits flanking them. Their elevated position meant that these floodplain sediments were oxidised soon after deposition and so developed red colours. Colluvium and debris flow deposits are also preserved in these valley fills. Occasional severe floods fed coarse detritus and fallen timber down some of these valleys into the southwestern corner of the basin.

Coarse detritus fed into the basin was gradually diluted by sand, first forming pebble conglomerate deposited in deeper channels in the river tracts. Eventually, in elements far removed from the basin margins, pebbles formed thin lags on channel floors channel. The absence of the Koreelah Conglomerate Member and conglomeratic channel deposits in the facies assemblage along the eastern edge of the Logan Sub-basin, indicates that the Gatton Sandstone on the present eastern basin margin was deposited well away from the eastern depositional margin.

Stop 10-Heifer Creek Sandstone Member (Marburg Subgroup, Koukandowie Formation).

The Heifer Creek Sandstone Member is exposed in a road cutting on the northern end of Murphys Creek Road, about 3 km from the intersection with the New England Highway.

The particular section of interest shows a sandstone lens set in mudstone and sheet sandstone units. This element consists of lenses and sheet-like units of trough cross bedded medium to fine grained sandstone that do not fine up. The sandstone lenses and sheets have erosional bases, in places overlain by lenses of massive sandstone containing mud clasts. They typically have a tabular bed of horizontally laminated and ripple cross laminated fine sandstone at the top and are overlain by fine grained facies (as shown in Fig.10). They range from 2 to 5 m in thickness. In this example, on the Murphys Creek Road, in which the edge of the sandstone body is preserved, the body can be seen to be a lens cut into a sheet sandstone element (Fig. 15). Most sandstone bodies classified in this element contain one or two storeys, the lower one consisting of a thin layer of massive and cross bedded sandstone mostly eroded by the base of the main sandstone body.

The sandstone bodies of the element described above are interpreted as channel fills that lack evidence of lateral or downstream accretion. They probably formed by vertical accretion of sand moving in three dimensional dunes with some massive sand accumulating in the deepest parts of the channel and the sheets of flat laminated and ripple cross-laminated sandstone accumulating as levee or bar top sediments. The most likely depositional model is that of low sinuosity, single channel streams (Bridge & others, 1986).

The relationship between the element channel fill and the crevasse splay sheet

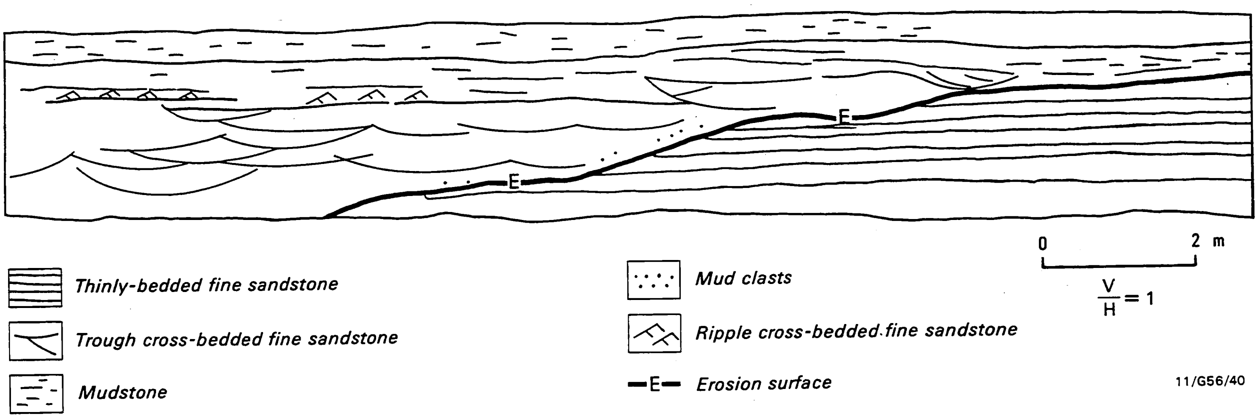

Figure 15 - Element composed of a sandstone lens set in mudstone and sheet sandstone elements, Murphy's Creek Road, Toowoomba.

sandstone depicted in Figure 15 is similar to that seen where deltaic distributary channels cut through previously deposited distributary mouth bar sediments as the distributary system grows (Caravoc & Saxena, 1979). This suggests that this particular channel was a crevasse splay channel and that other sandstone bodies of this element may also be splay channels of various sizes.

Stop 11- Toowoomba-Picnic Point Lookout.

Toowoomba is about 125 km from Brisbane and the Picnic Point Lookout provides a spectacular view east across the Triassic-Jurassic sediments preserved in the Laidley Sub-basin of the Clarence-Moreton Basin with the Tertiary intrusives at Flinders Peaks to the south of Ipswich visible on the horizon. The densely wooded hills to the north are underlain by the Ripley Road Sandstone preserved in the Gatton Arch, a south-easterly plunging fold at the northern margin of the Clarence-Moreton Basin. Thick Quaternary alluvial sediments in the Laidley Valley cover the Gatton Sandstone and lower part of the Koukandowie Formation (chiefly the Ma Ma Creek Member). Low hills and mesas further south are composed chiefly of Heifer Creek Sandstone Member, which are in turn overlain by Tertiary basalts now preserved in steep escarpments.

The escarpment at Toowoomba (The 'Great Dividing Range'), as viewed from Picnic Point, is composed of Tertiary basaltic extrusives (mainly olivine basalt-trachyte suite) of the Main Range Volcanics. A large isolated mesa capped by volcanics occurs immediately in front of Picnic Point and the edge of the 'Great Escarpment ', here also composed of Tertiary volcanics, is visible to the south-east.

Stop 12-Ma Ma Creek Member (Marburg Subgroup, Koukandowie Formation).

The Ma Ma Creek Member is composed of easily eroded rock types, chiefly shale, siltstone and interbedded sandstone; outcrops are rare. The cutting in the Ma Ma Creek Member on the Clifden-Gatton Road, where it crosses Dry Creek, is one of these rare exposures. The cutting is about 40 km from Toowoomba.

In places the Member contains amphibian fossils, which suggests freshwater deposition whereas spinose acritarchs indicate brackish conditions.

Chamositic oolites are common in the Member in the northern part of the basin and may represent condensed intervals caused by sediment starvation after transgression by lagoons or lakes. The thin sheet-like sandstone bodies were probably deposited as distal crevasse splays, some of which developed with prograding slip faces.

Fragments of oolitic rock from the Ma Ma Creek Member can be found in the debris deposits exposed in a road cutting on the east side of the Clifden-Gatton Road , ~ 0.5 km south of the deep cutting at stop 13.

The most common facies element in the Ma Ma Creek Member consists of siltstone, claystone and fine-sandstone interbedded on a scale of a few centimetres. The proportions of sandstone and siltstone vary with sandier units displaying ripple cross-laminae. Some intervals include coaly claystone beds and abundant rootlet beds whereas others lack rootlets, have well-laminated claystones and scattered burrows.

Sandstone beds of another element occur in tabular beds in the order of 1 m thick and are interbedded with the finer grained element described above. These beds consist of horizontally laminated fine sandstone, massive, rooted fine sandstone or planar cross-laminated sandstone with thin ripple cross laminated units above and below the large cross set.

The presence of rootlets and thin coaly beds in the Ma Ma Creek Member and the amphibian fossils suggest a fresh water environment of deposition whereas the spinose acritarchs suggest brackish conditions. The large proportion of fine-grained facies in the Ma Ma Creek Member indicates a change from the Gatton Sandstone sandy braidplain to low energy floodplains or lacustrine environments. Within this context, ferruginous oolites, which are usually found on shallow marine shelves, seems anomalous (cf, Van Houten & Purucker, 1984; Odin, 1988). However, likely mechanisms of oolite formation do not require marine conditions.

The common position of the oolite beds above an erosion surface and at the base of coarsening-up cycles suggests that they are condensed intervals caused by sediment starvation after transgression by lagoons or lakes (Loutit & others, 1988).

This assemblage of architectural elements suggests that the Ma Ma Creek Member developed as a plain with extensive lakes and anastomosing streams which fed crevasse splays and lacustrine deltas. After transgressions of adjacent floodplains, larger lakes contained areas starved of suspended sediment in which iron-rich clay oolites developed as in modern Lake Chad (Dupont, 1970). The presence of brackish water acritarchs suggests that the lakes were of elevated salinity, either because of high evaporation or because of invasion by marine water. Thin coal beds, abundant rootlets and the lack of red palaeosols suggest a humid climate making a marine influence more likely.

The general depositional environment was a low gradient streams crossing an alluvial plain with extensive fresh to brackish lakes or lagoons.

Stop 13-Heifer Creek Sandstone Member (Marburg Subgroup, Koukandowie Formation).

The Heifer Creek Sandstone Member of the Koukandowie Formation occurs in a deep cutting on the Clifden-Gatton Road, where it crosses Ma Ma Creek, about 53 km from Toowoomba. The sandstone in the element here is coarse to medium

53 km from Toowoomba. The sandstone in the element here is coarse to medium grained, cross-bedded and occurs as multistorey, sheet like bodies up to 40 m thick. Storeys are separated by horizontal erosion surfaces (fourth order surfaces) which have pebble lags and thin patches of massive sandstone along them. Four different storeys are present in large outcrops. They are:

a) The most common storey is composed of planar cross-sets between 0.3 and 1 m thick which display no evidence of downstream or lateral accretion.

b) Medium sandstone in compound cross-sets 1 to 2 m thick bounded by third order surfaces that delineate lenses 30 to 50 m across normal to the palaeocurrent direction (Fig. 16).

c) Medium-grained sandstone in trough cross-sets 1 to 2 m thick and 20 to 30 m across.

d) Interbedded planar and trough cross bedded coarse to medium sandstone. These cross-sets are 0.3 to 1 m thick and, in some examples, fine-up.

Most storeys show little or no vertical change in grain size but a few outcrops feature thin horizontally laminated or ripple cross-laminated fine to medium sandstone beds preserved just below the overlying fourth order bounding surface. Palaeocurrents are strongly unidirectional in storeys. Lateral accretion surfaces are absent and, apart from compound cross sets, few outcrops show evidence of downstream accretion, usually in the form of one cross set overlapping the previous one downstream. Palaeocurrent variance within storeys is low.

The Koukandowie depositional environment, after deposition of the Ma Ma Creek Member, consisted of braided, sandy trunk streams flowing north with extensive vegetated floodplains into which the major streams spread broad sandy levees and sinuous to straight crevasse channels fed splay complexes. Sinuous and straight tributary streams were also present. With time, the proportion of floodplain and sinuous to straight streams increased in the Logan and eastern Laidley Sub-basins, whereas further west, braided channel belts and sandy avulsion complexes were the dominant features of the floodplain.

Stop 14- Heifer Creek Sandstone Member (Marburg Subgroup, Koukandowie Formation).

The Heifer Creek Sandstone Member is exposed in a cutting on the Clifden-Gatton Road about 58 km from Toowoomba (Fig.17).

The outcrop shows sandstone bodies with lateral accretion surfaces probably deposited from sinuous streams. The lateral accretion surfaces preserved at the top of the lower sandstone body are overlain by a large lens composed of interbedded finer grained sandstone , siltstone and shale which show overlapping relationships in a northerly direction, and thus they overlap the sandstones of the

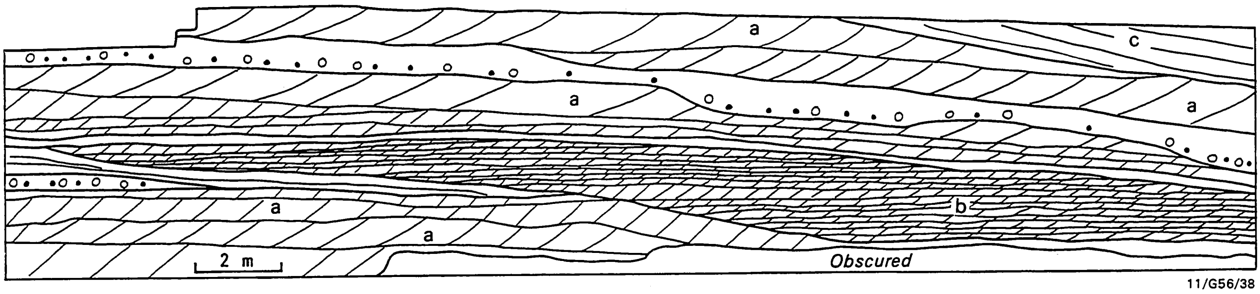

Figure 16 - Sketch profile of part of an element comprising a sandstone body in the Koukandowie Formation, taken from a large road cutting at Ma Ma Creek, Clifton-Gatton road. Letters refer to storey types:
a. Planar cross beds. b. Lenticular compound cross sets. c. Very large trough cross set. A fourth order bedding surface with a pebble lag and massive sandstone overlying it runs through the profile.

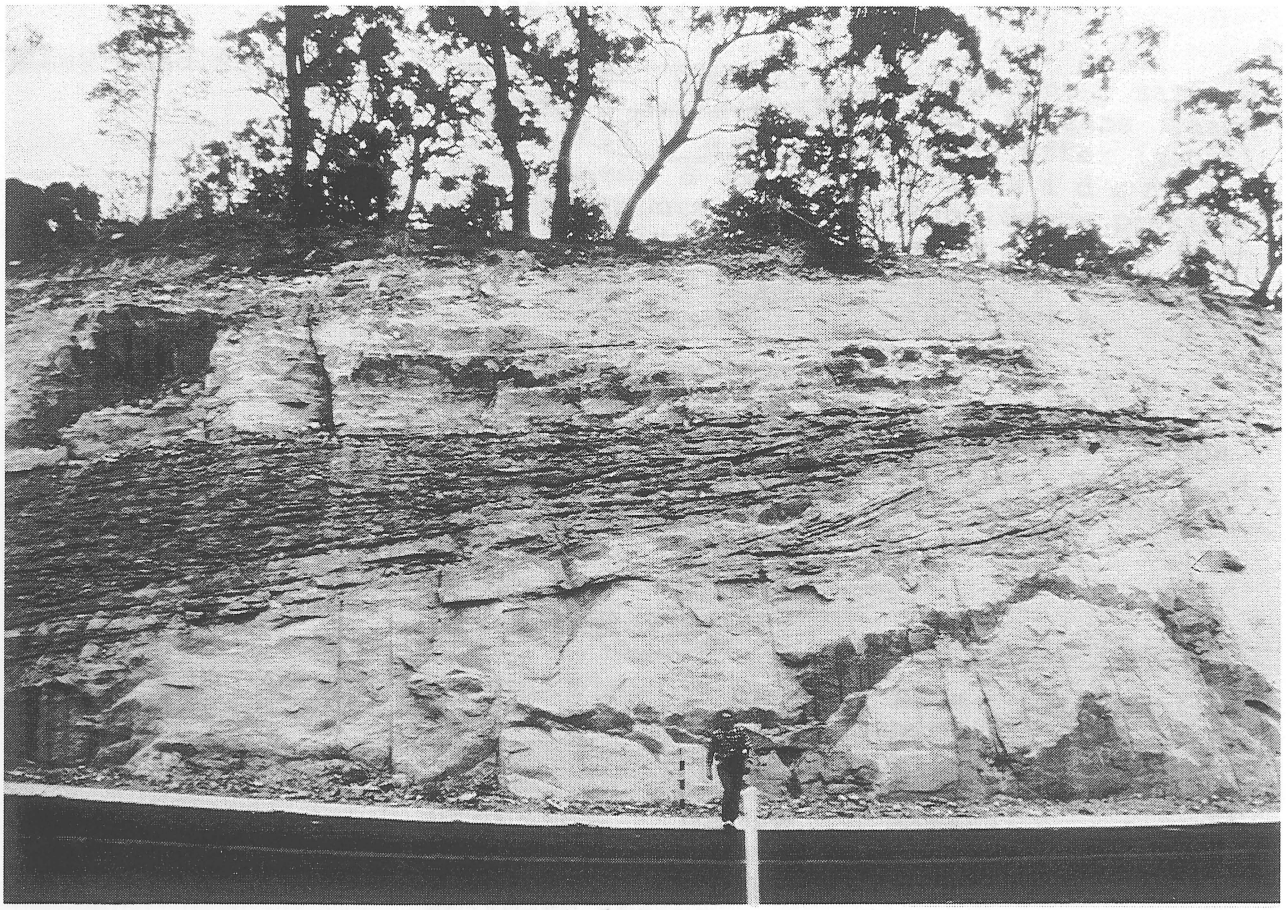

Figure 17 - Heifer Creek Sandstone Member of the Koukandowie Formation, Clifden- Gatton Road (Stop14). Probable abandoned channel fill showing onlapping relationships, and overlying lateral accretion sets and massive channel sands.

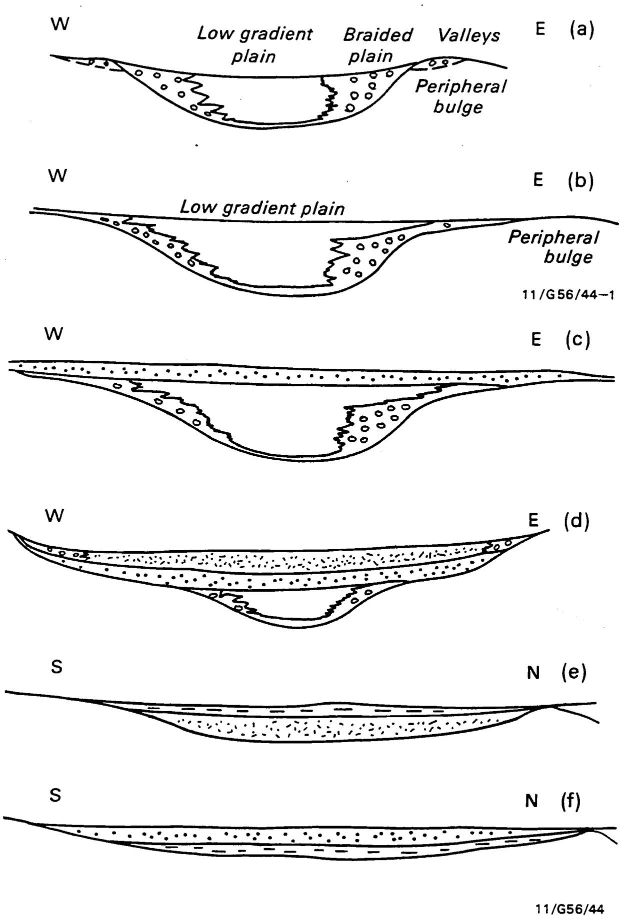

Figure 18 - Sedimentation models for the Bundamba Group, Clarence-Moreton Basin.

TABLE 1 Sedimentation changes in the Bundamba Group, Clarence-Moreton Basin.

FORMATION	CHARACTERISTICS	CONTROLLING PROCESSES
Aberdare & Layton's Range Congs. Raceview Fm.	Alluvial fan & valley fill conglomerates passing basinwards into mixed load fluvial sediments. Lithic sandstones. Radial palaeocurrents.	Initial rapid subsidence. Flat basin floor and steep edges.
Ripley Road SS.	Sheet-like, bedload stream deposits. Quartzose sandstones. S to N palaeocurrents in E, W to E in the W.	Landscape matured and streams reach grade after initial subsidence. Subsidence possibly slow so high Avulsion/Subsidence.
Gatton SS.	Sheet-like, bedload stream deposits. Diachronous change to lithic sandstones. Palaeocurrents all S to N. Some basement blocks emerge briefly.	Tectonic rejuvenation of basement areas, tilting of the W part of the basin.
Ma Ma Creek Mbr. Koukandowie Fm.	Lacustrine and suspended-load fluvial sediments. Chamositic oolite, brackish water acritarchs. Change mappable through adjacent basins.	Base level rise, probably sea level rise or tectonic damming of the distal end of drainage system.
Heifer Creek Mbr., Koukandowie Fm.	Sheet-like, bedload stream deposits. Quartzose sandstones. S to N palaeocurrents.	Re-establishment of graded system after base level rise. Mature landscape providing quartzose detritus.
Koukandowie Fm above Heifer Creek Member (East only).	Mixed-load & bed load stream deposits. Lithic sandstones. S to N palaeocurrents.	Tectonic rejuvenation and slightly increased subsidence in the east (Logan Sub basin).

abandonment took place either at a late stage of waning flow regime, or more likely as a result of channel avulsion. Overbank and floodplain sediments then gradually filled the abandoned channel.

CONCLUSIONS

Major stratigraphic subdivisions of the Bundamba Group reflect sedimentation changes induced by tectonism and eustacy (Table 1). The Bundamba Group displays several recurring "cycles" or motifs. One such motif is analogous to coarsening-up tectonic cyclothems (Blair & Bilodeau, 1988, Heward, 1978) consisting of muddy, low gradient streams at the start of the "cycle" passing up into sandy, braided streams as the system approaches a graded condition (Fig 91a, O'Brien and Wells, in press). This motif is displayed by the Raceview Formation to Ripley Road Sandstone, Calamia Member to Gatton Sandstone and Ma Ma Creek Member to Heifer Creek Member transitions.

The other motif displayed by the Bundamba Group consists of fining-up transitions (Fig. 91b, O'Brien and Wells, in press). In the case of the Ripley Road Sandstone to Calamia Member and the Heifer Creek to overlying Koukandowie Formation transitions, an increase in the abundance of labile detritus and some reorganisation of palaeocurrents suggests increased tectonic subsidence and uplift of the basin hinterland as the cause of the sedimentation change. The Gatton Sandstone - Ma Ma Creek transition was caused by eustatic sea level rise.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the reviews of Ian Sweet and Peter Southgate whose comments assisted considerably in improving this excursion guide. Figures for the guide were produced by the Cartographic Services Unit of the Australian Geological Survey Organisation.

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FIGURES

Figure 1 - Locality Map of the Clarence-Moreton Basin.

Figure 2 - Route map and stops for the excursion.

Figure 3 - Generalised stratigraphy of the Clarence-Moreton Basin.

Figure 4 - Section through the Woogaroo and Marburg Subgroups of the Bundamba Group, along the Clifden - Gatton road.

Figure 5 - Element comprising a sandstone lens, cut in a sandstone and siltstone element, Raceview Formation, Redbank (Stop 1). These lenses were probably cut and filled as crevasse channels.

Figure 6 - Section through sandstone lens element shown in Fig. 5. The faint horizontal laminae probably indicate upper flow regime conditions following cutting of the channel. Ripple cross laminae indicate abrupt waning of stream power. The large scale cross beds indicate a return of more energetic flow which then waned. This succession of structures suggest that the channel filled by vertical accretion during two episodes of alternating high flow and low flow.

Figure 7- Sketch profile of facies distribution in the Ripley Road Sandstone in west face of the Wivenhoe Dam Spillway (Stop 3).

Figure 8- Large scale planar cross sets in the Ripley Road Sandstone, Wivenhoe Dam. A mudstone drape preserves one small dune form.

Figure 9- Ma Ma Creek Member exposed in a railway cutting near Lowood (Stop 4). The sandstone bed is tabular with thin ripple cross laminated units above and below the large cross set.

Figure 10 - Small element (1.5 m thick) of sandstone set in fine sandstone and mudstone overlying an element comprising a trough cross bedded sandstone body. Warrego Highway cutting at Marburg (Stop 5).

Figure 11 - Vertical section through the sandstone element at Marburg (Fig. 10). Dashed lines indicate the way bedding planes meet the base of the sandstone body asymptotically.

Figure 12 - An element composed of a sandstone body set in mudstone in a cutting on the Warrego Highway 3 km west of Marburg (Stop 6). Lateral accretion sets dip from left to right and cross bedding dips out of the cutting.

Figure 13 - Profile of an element composed of a sandstone body in the Gatton Sandstone, Murphy's Creek Road (Stop 9). Profile is approximately parallel to the palaeocurrent direction.

Figure 14 - Vertical section through a sandstone body (the same element as shown in Fig. 13), Gatton Sandstone, Warrego Highway, 5 km west of Helidon.

Figure 15 - Element composed of a sandstone lens set in mudstone and sheet sandstone elements, Murphy's Creek Road, Toowoomba (Stop 10).

Figure 16 - Sketch profile of part of an element comprising a sandstone body in the Koukandowie Formation, taken from a large road cutting at Ma Ma Creek, Clifton-Gatton road (Stop 13). Letters refer to storey types:
a. Planar cross beds. b. Lenticular compound cross sets. c. Very large trough cross set. A fourth order bedding surface with a pebble lag and massive sandstone overlying it runs through the profile.

Figure 17 - Heifer Creek Sandstone Member of the Koukandowie Formation, Clifden- Gatton Road (Stop14). Probable abandoned channel fill showing

onlapping relationships, and overlying lateral accretion sets and massive channel sands.

Figure 18 - Sedimentation models for the Bundamba Group, Clarence-Moreton Basin.

a. During early thermal relaxation subsidence, the basin was relatively narrow with steep sides. Conglomerates (Aberdare and Layton's Range Conglomerates) were deposited in valleys and braidplains and low gradient streams deposited a mud dominated fluvial sequence in the basin axis (Raceview Formation).

b. As subsidence progressed, the peripheral bulge moved away from the basin so the braidplains retreated up-valley and low gradient systems replaced them (Raceview Formation).

c. Reduced subsidence and erosional maturation of the hinterland meant that the streams built up to a near-graded condition. Relatively high stream slopes favoured braided streams and high avulsion to subsidence ratio favoured preservation of a sheet of quartzose sandstone (Ripley Road Sandstone).

d. Rejuvenation of the hinterland produced an influx of labile detritus (Gatton Sandstone). Initial relatively higher subsidence caused preservation of fine-grained fluvial sediments (Calamia Member) before braided stream deposition continued.

e. For the first time, eustatic sea level rise caused the backwater effect to extend upstream of the basin lip, changing the sandy braidplain to a fluviolagoonal plain with widespread lakes and anastomosing channels (Ma Ma Creek Member of the Koukandowie Formation).

f. Rapid aggradation returned the system to a near graded state with sandy braided and some meandering streams (Koukandowie Formation). Erosional maturation of the hinterland produced a trend toward quartzose sandstone (Heifer Creek Member).

TABLES

Table 1 - Sedimentation changes in the Bundamba Group, Clarence-Moreton Basin.

ITINERARY BASED ON A ONE DAY EXCURSION

FLUVIAL ARCHITECTURE OF TRIASSIC -JURASSIC SEDIMENTS OF THE BUNDAMBA GROUP IN THE NORTHERN PART OF THE CLARENCE-MORETON BASIN

Summary of stops, estimated distances & travel times, locations & parking areas.

Stop No.	Distance km ~ from Brisbane	Travel Time (mins.):	(Cum.)-On Rocks	Location	Parking
1	27	27	(27) -20	Redbank	South side of road, in cutting, just past raised pedestrian crossing (bridge)
2	37(27+10)	12	(37)-20	Muirlea	Western end , south side of cutting.
5	49(37+12)	12	(49)-20	Marburg	Western end , north side of cutting
6	54(49+5)	5	(54)-20	Two Tree Hill	Western end, south side of cutting, access road near top of hill.
8	95(54+42)	42	(95)-20	Helidon	At Helidon Quarry, from access road on north side of the Warrego Highway
11	113(95+18)	18	(113)-60	Toowoomba	Picnic Point parking area.
12	148(113+35)	35	(148)-20	Dry Creek	Southern end of cutting , small cleared area on eastern side of road near Dry Creek Bridge.
13	156(148+8)	8	(156)-20	Ma Ma Creek	Southern end of cutting, small cleared areas on either side of road. Small parking area on west side of road, at northern end of cutting.
14	161(156+5)	5	(161)-20	Heifer Creek	Cleared verge area opposite cutting east side of road.
15	270(161+109)	109	(270)-00	Brisbane	

Total Distance=~270 km

Total Travelling Time= ~4.5 hours

Total time examining outcrops + lunch= ~3.5 hours

Total time= ~8 hours