Sediments Down-Under

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Sedimentology of the Middle Proterozoic McArthur Basin, northern Australia.

M. J. Jackson, M.D. Muir, & I.P. Sweet

FIELD EXCURSION 13A

12TH INTERNATIONAL SEDIMENTOLOGICAL CONGRESS

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SEDIMENTOLOGY OF THE MIDDLE PROTEROZOIC MCARTHUR BASIN, NORTHERN AUSTRALIA

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AIMS AND OBJECTIVES

The main aim of the excursion is to demonstrate a variety of sedimentary and diagenetic facies in the middle Proterozoic McArthur Basin sequence of Northern Australia. The excursion will concentrate on the well-exposed stromatolitic and evaporitic carbonates of the marginal-marine to continental McArthur and Nathan Groups which are about 1,700 Ma old, but we hope to contrast these with younger (1,400 Ma) marine clastics of the Roper Group. Specific facies or features that will be emphasised are:

1) Arid marginal-marine and/or continental sabkha facies.
2) Seasonally humid playa facies.
3) Small-scale ?marginal-marine shoaling stromatolite cycles.
4) Lagoonal stromatolites.
5) Subtidal to intertidal clastic facies.
6) Synsedimentary breccias.
7) Proterozoic weathering and calcretisation.
8) Storm and wave influenced clastic shelf sediments.
9) Proterozoic oil shales and petroleum source beds.

We intend to concentrate mainly on outcrop-scale interpretation of facies and environments. Although we will attempt to relate these facies to the evolution of the sedimentary sequence we cannot relate them to a clear and precise 'basin' evolution as a satisfactory one is not yet available. Several tectonic interpretations for all or part of the basin sequence have been suggested by various authors. Terms such as intracratonic graben, half-graben, strike slip basin, pull-apart basin, aulacogen, and extensional basin have all been suggested but due mainly to lack of detailed field observation none of them is really well enough documented to be convincing.

EXCURSION ITINERARY

Time	From	To	Time	Comments
DAY 1				
FRIDAY	Darwin	McArthur jumpup		
	(lunch Katherine)			
8.00			5.00	
	O/n camp CARPENTARIA H/W			
DAY 2				
SAT.				
8.00	jumpup	Archies Creek	10.00	
10.00	Traverse on foot	Archies Creek	5.30	
	o/n camp KILGOUR RIVER CROSSING			
DAY 3				
SUN.				
8.00	Archies Creek	Top Crossing	8.45	
8.45	Inspect Emmerugga Dolomite		12.15	
12.45	Top Crossing	Leila Creek	12.45	
12.45	Lunch at Amelia outcrop		1.30	
1.30	Inspect Amelia Evap. facies		3.30	
3.30	Leila Creek	First crossing	4.00	
4.00	Inspect Tatoola Sandstone			
	O/n camp LITTLE RIVER?			
DAY 4				
MON				
8.00	Little River	Balbirini Type Sec.	9.00	
9.00	Inspect Balbirini evaporites		9.30	
9.30	Evaps	Prima	9.40	
9.40	Inspect Prima bioherm		10.30	
10.30	Prima	Kussiella	11.00	
11.00	Inspect Kussiella bioherm		12.15	
12.15	Lunch ?McArthur River		1.15	
1.15	Lunch stop	Skull Yard	1.45	
1.45	Inspect Amos type section		4.00	
4.00	Skull Yard	Airtrip	4.10	
4.10	Inspect Dungaminnie stromatolites		5.10	

DAY 4 (contd)				
5.10	Airstrip o/n camp	o/n camp TBA		
DAY 5 TUES.				
8.00	Camp	McArthur H/S	8.30	
8.30	McArthur H/S	Beetle Spring	10.00	
10.00	Inspect Abner Sandstone		11.30	
11.30	Beetle Springs	Bessie Spring	12.30	
12.30	Lunch at Bessie Spring		1.30	
1.30	Bessie Spring	HYC	2.10	
	Inspect Barney Creek Section		3.30	no hammers
3.30	HYC	Discovery outcrop	3.40	no hammers
3.40	Inspect outcrop		4.10	
4.10	HYC	Ryan Bend	4.40	
4.40	Inspect Crawford Formation		5.30	
5.30	Ryan Bend o/n camp	Batten Creek TBA	5.45	
DAY 6				
WED.	Batten Creek	Yalco sect.	9.00	
9.00	Inspect Yalco Formation		11.00	
11.00	Yalco sect.	Tawallah W/H	12.00	
12.00	Cave paintings and lunch			
1.30	Tawallah W/H	(Ngukurr area)	5.30	
	o/n camp Roper River			
DAY 7	Roper River	Mount McMinn		
THURS.	Inspect Mt McMinn		2 hrs	
	Mt McMinn	Sherwin Creek	1 hr	
	o/n camp	?Urapunga Homestead		
DAY 8 FRI.				
8.00	Urapunga	Strangways Creek	9.00	
9.00	Strangways Creek		11.00	
11.00	At Mataranka	swim/lunch	1.00	
1.00	Mataranka	Darwin	6.00	

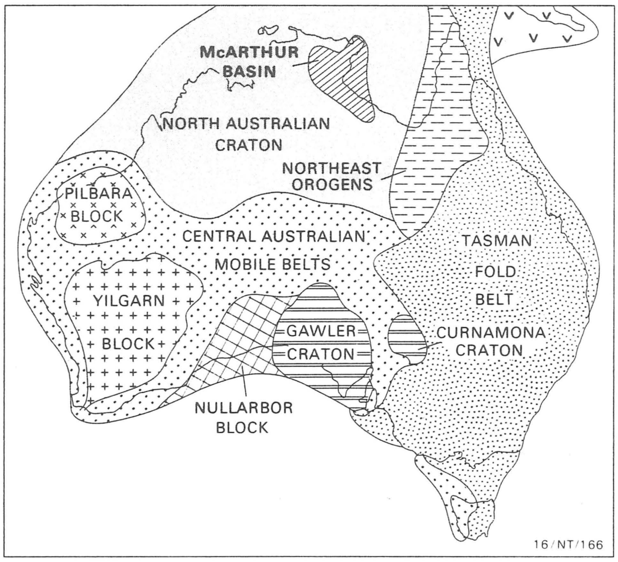


Fig. 1 Main structural subdivisions of Australia showing location of McArthur Basin (after Plumb & others, 1981).

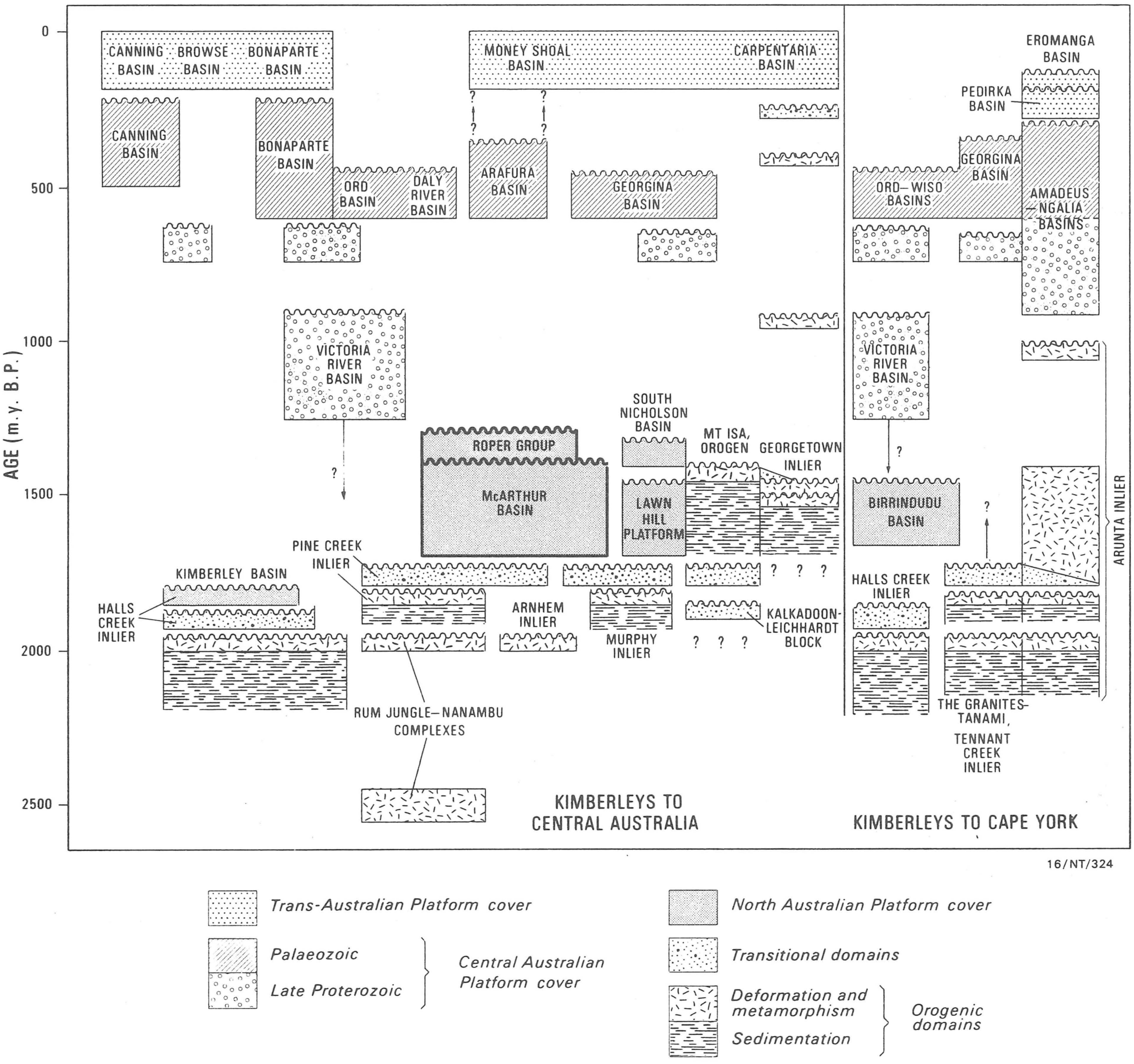


Fig. 2 Diagrammatic representation of the possible stratigraphic relationships of the various regional tectonostratigraphic sequences of northern Australia (after Plumb & others, 1981).

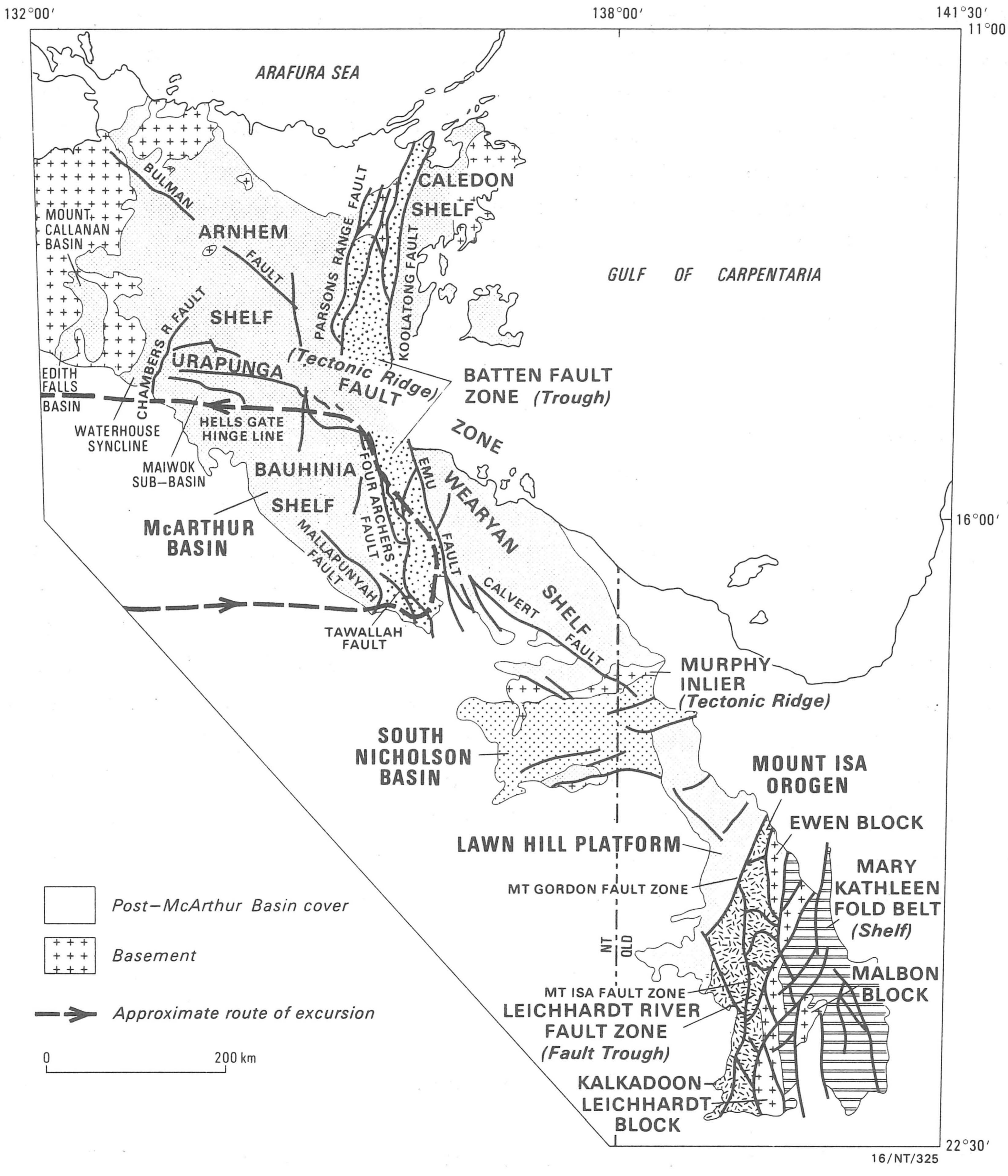


Fig. 3 Main structural subdivisions of the McArthur Basin and adjacent regions (after Plumb & others, 1981).

REGIONAL SETTING AND GEOLOGICAL OVERVIEW

Our understanding of the geological history and evolution of many parts of Australia is at the reconnaissance level. This is true to a large extent for much of the Proterozoic of North Australia. We have reasonably good 1:250,000 scale geological maps (and in small parts even better 1:100,000 maps) which show the distribution of rock units and the broad structural features of the exposed sequences. However, in most areas we only have rudimentary ideas on tectonic setting and geological evolution because of a lack of isotopic dating and detailed structural and sedimentological studies. Coherent analyses of basin type, configuration, and evolution, in the framework of modern plate tectonic models, are not available for much of the North Australian Proterozoic.

The information presented in this guide book results largely from detailed stratigraphic and sedimentological studies undertaken between 1977 and 1981 in the McArthur River region, supplemented by surface and drillcore studies in 1984/85 near the Roper River. Unfortunately, these more detailed studies cover only about half of the area defined as the McArthur Basin and as noted below this 'basin' is probably only part of a much larger depositional feature. Therefore, even after some detailed studies our knowledge is fragmentary and incomplete and our interpretations somewhat tentative. The results from the sedimentological studies in the McArthur River region have been compiled in detail in BMR Bulletin 220 (Jackson & others, in press). We had hoped that this would be available for the excursion; unfortunately, this has not been possible. As there is no other satisfactory synthesis of this information we have condensed and summarised relevant parts of it and included these in the guide book. A 1:100,000 scale geological map of the area containing most of the localities we shall visit is included with this guide book.

REGIONAL STRATIGRAPHY

The McArthur Basin contains mainly middle Proterozoic (1.7-1.0 Ga) unmetamorphosed, flat lying to gently folded sedimentary rocks that form a platform cover sequence near the eastern edge of the North Australian Craton (Fig. 1). This poorly understood craton contains small areas of Archaean basement rocks, lower to middle Proterozoic mobile belts and platform cover sequences of Proterozoic and Phanerozoic age. The McArthur Basin sequence is one of several platform cover sequences in Northern Australia and general correlations between some of these and related orogenic domains are shown in Figures 2 and 3. More recent unpublished reconaissance work especially to the south and west of the McArthur Basin area (Victoria River region and Tennant Creek area) has identified closely comparable stratigraphic sequences and identical facies indicating that some of the rocks in the area called the McArthur Basin are probably only part of much more areally extensive sequences. The term McArthur Basin is therefore mainly a term of convenience - referring to the Proterozoic rocks near the McArthur River - and it should not be construed as implying a single tectono-stratigraphic or depositional entity. Critical features such as basin margins, sediment provenance and palaeocurrent directions have not been adequately studied except in the south-central part of the 'basin'. Even the general stratigraphic and age relationships between these several areas of middle Proterozoic rocks are poorly known.

BASIN STRATIGRAPHY

The Proterozoic sequence studied by us in the south central part of the basin has been subdivided into four groups, each separated by unconformities of regional extent (Fig. 4). During the excursion we shall look at the sedimentology of the McArthur, Nathan and Roper Groups in some detail, but will only fleetingly examine one formation - the Wollogorang Formation - in the Tawallah Group.

TAWALLAH GROUP

The oldest group, the Tawallah Group, has a combined stratigraphic thickness of about 4500 m. It unconformably overlies crystalline basement in the southeast (inset on Abner Range map) about 1,800 m.y. old (see Page, 1981). Most of the Tawallah Group consists of thick formations (hundreds of metres) of resistant quartz sandstone alternating with much thinner formations (tens of metres) of deeply weathered basic volcanics and/or fine grained clastics; carbonates are rare, but do occur present in the upper one third of the group. Most of the Tawallah Group has not been studied systematically; for most formations we only have one or two detailed measured sections. As many of the good outcrops and our measured sections are outside the area we are visiting we will not see much of it. However,

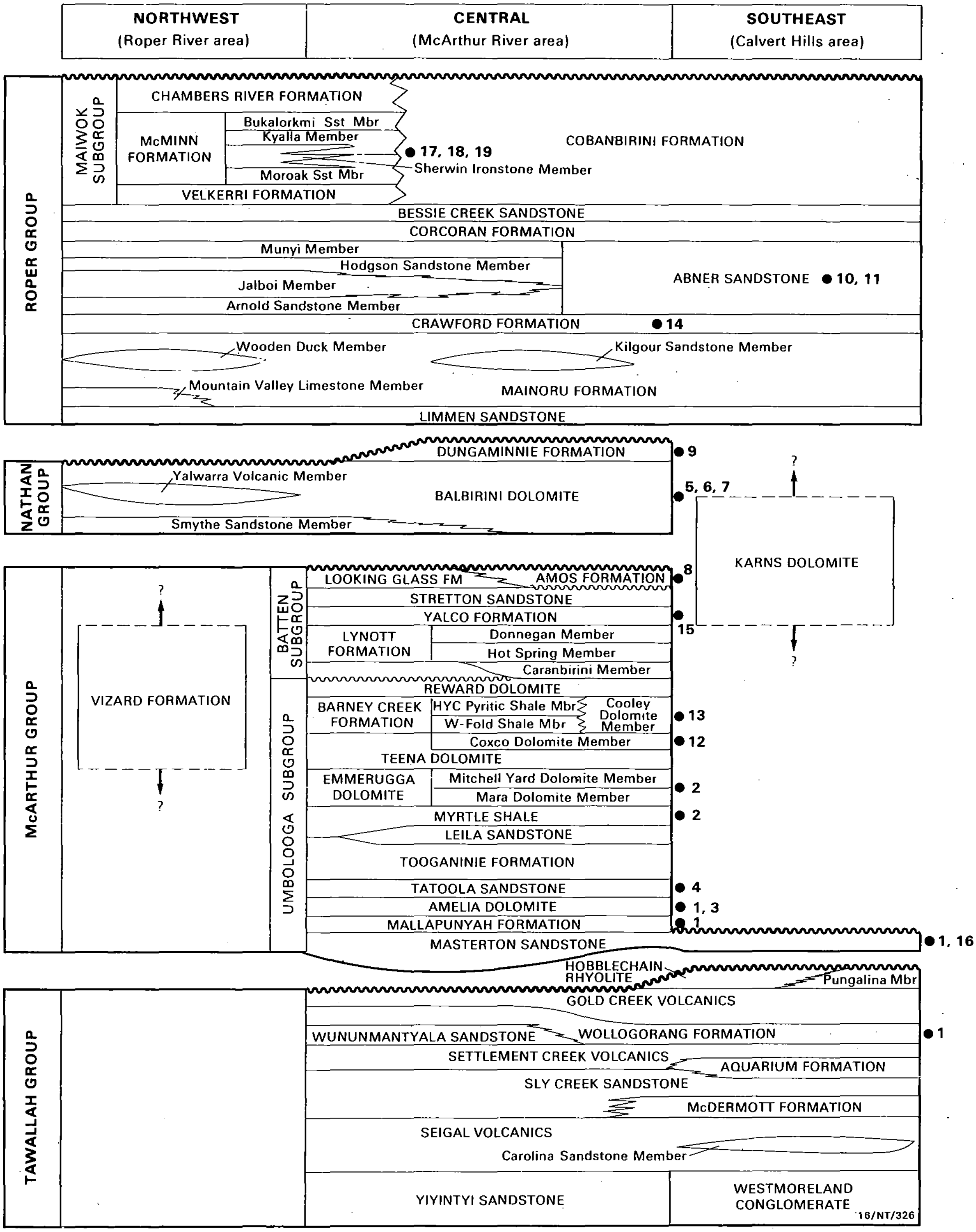


Fig. 4 Stratigraphy of the McArthur Basin in the area to be examined during the excursion, showing stop numbers.

a short description and interpretation of the group is provided here as it helps in interpretation of the succeeding groups (Fig. 5) which we will be examining in more detail.

The lower half to two-thirds of the group comprises coarse clastics and basic volcanics interpreted to have been deposited in a rifted environment. The oldest sediments in the southeast (Westmoreland Conglomerate) are arkosic and conglomeratic, and show marked lateral thickness and facies variations. Recent detailed study by the Northern Territory Geological Survey indicates that the Westmoreland Conglomerate was deposited near a rifted basin margin as a series of southwesterly prograding alluvial fans and related braided fluvial systems. The source area of the sediments was to the north and east and sporadic good indications of faulting along the basin margin are evident in the stacking of five large-scale fining-up megacycles.

The equivalent rocks to the north of the Abner Range area are represented by the Yiyintyi Sandstone (Fig. 5) - 2000 m of thick bedded medium-grained quartz sandstone which is lithic, feldspathic and pebbly near the base. This formation has not been studied and it would be imprudent to make environmental interpretations on the limited information we have.

These basal clastics are succeeded by a unit containing basic volcanics - the Seigal Volcanics - which are much thicker and are interbedded with clastics in the southeast (Fig. 5). Thin subaerial flows and interbedded clastics with shallow water and desiccation features dominate, and the presence of nearby dolerite dykes suggest mostly continental deposition related to continued rifting/extension.

The upper part of the Tawallah Group contains thick intervals of regularly bedded mature quartz arenite with features such as herringbone cross-bedding, ?tidal channels, and glauconite, indicating periods of marine deposition (parts of Sly Creek Sandstone, Aquarium Formation and Wunnunmantyala Sandstone) - implying more regular tectonic subsidence. In addition, the McDermott Formation in the southeast comprises 450 m of evaporitic and stromatolitic sandy dolostones typical of marginal marine platform sediments. However, the uppermost 1,000 m of the group also contains a widespread subaerial volcanic and redbed unit (Settlement Creek Volcanics), thick silicified intervals (?fossil silcrete), possible aeolian and fluvial sands (part of Sly Creek Sandstone, and part of Wollogorang

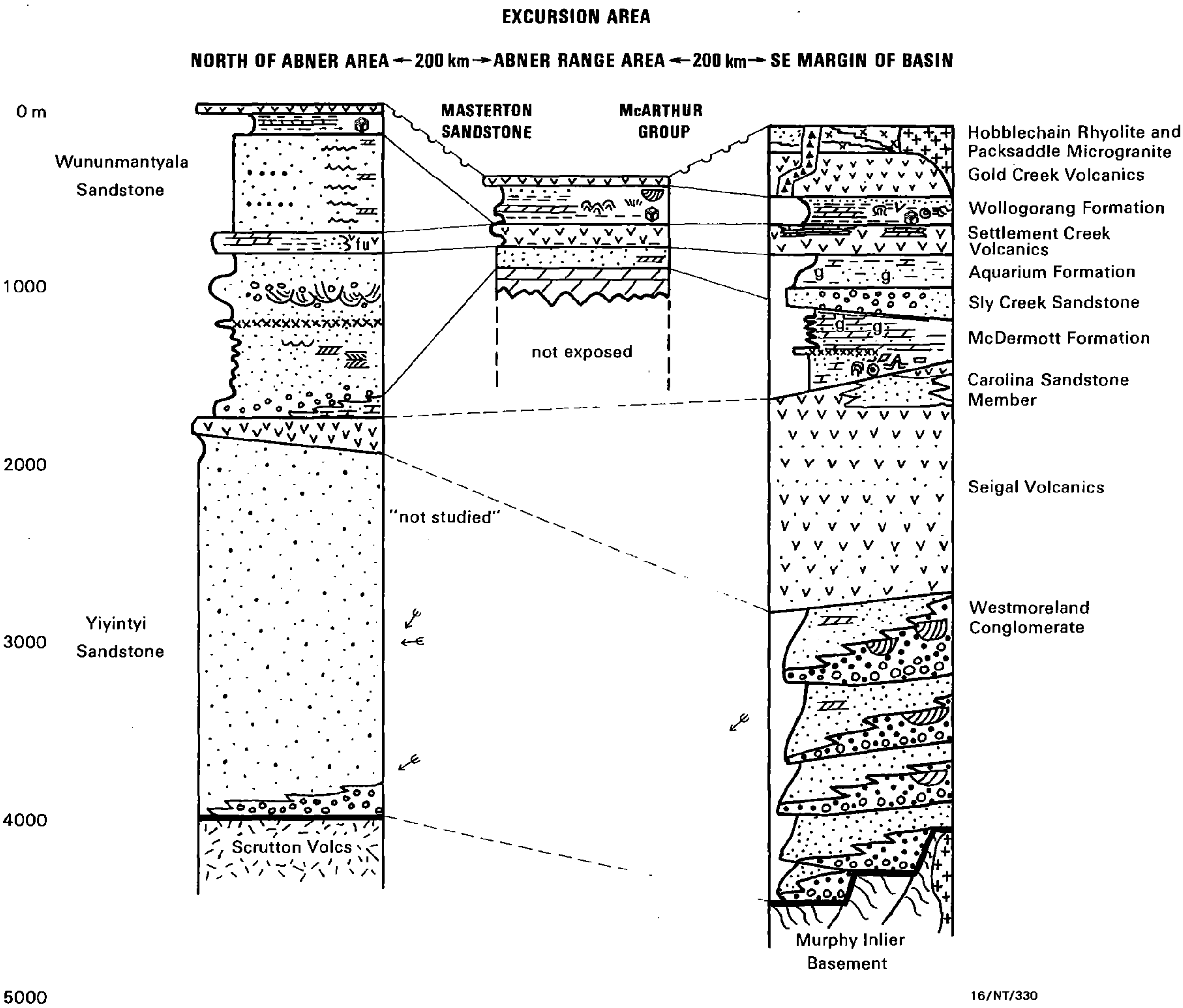


Fig. 5 Simplified stratigraphic columns through the Tawallah Group indicating the main features in sedimentological evolution. Centre column represents all that is exposed in this area.

Formation), evaporitic playa deposits (part of Wollogorang Formation), and varved lacustrine black shales (part of Wollogorang Formation) indicating periods of continental deposition and complex, rapidly varying depositional environments.

The top of the group is represented by a complex suite of intrusive and extrusive igneous rocks with felsic, intermediate and basic phases and associated volcanic sediments (Packsaddle Microgranite, Hobblechain Rhyolite, Gold Creek Volcanics, Pungalina Beds). Early igneous activity comprises mainly quiet basic to intermediate lava extrusion, latest activity is forceful intrusion, with stoping, of Cu-bearing carbonated and K-rich trachytic breccia pipes at Redbank. A minimum Rb-Sr age of 1575 $\pm$ 120 Ma has been obtained on samples from the comagmatic Packsaddle Microgranite - Hobblechain Rhyolite, but if correlations with the Fiery Creek Volcanics in the Mount Isa area are accepted, the age of extrusiion is probably around 1680 Ma.

As noted earlier only parts of the Tawallah Group have been studied in detail and some of the interpretations shown in Fig 5 should be considered tentative. However, initial terrestrial clastic deposition with basic volcanism in rifted continental crust, succeeded by more uniform subsidence with periods of marine deposition, seems to be reasonably well founded. Similarities to the rift and thermal subsidence phases during continental extension can be suggested.

During the excursion we will examine a small part of the mainly lacustrine Wollogorang Formation.

McARTHUR AND NATHAN GROUPS

The unconformably overlying McArthur and Nathan Groups (Fig. 4) consist mainly of evaporitic and stromatolitic cherty dolostones interbedded with dolomitic siltstone and shale. The two groups have a combined total thickness of about 5500 m. In most previous publications (i.e. pre-1984) the term McArthur Group was used for the whole of this sequence. However, as we identified a basin-wide unconformity within this sequence, we have split it into two groups even though the style of sedimentation of them is similar.

We will inspect most of the formations in these two groups during the excursion and details of the individual units will be contained within the description of the relevant stops. In addition, the legend to the Abner Range map also provides lithological descriptions of the formations.

The rocks are dominantly of shallow water origin and contain evidence of exposure, desiccation, weathering and erosion, e.g. cracking, breccias, diastems, karstic surfaces, and disconformities. The formations were deposited in a complex interfingering set of environments including marginal marine, lagoonal, lacustrine, and fluvial, commonly under arid conditions, but occasionally under humid climates. A few of the formations are laterally uniform over many tens of kilometres, but others show marked lateral facies changes related mainly to penecontemporaneous faulting.

The wealth and variety of evaporite pseudomorphs (sulphate, halite and possibly alkaline carbonate), and the solution collapse breccias and desiccation features suggest extensive brine and groundwater movements during and shortly after deposition. Base metal mineralisation may be related to later saline basin fluids.

The only good control we have on the depositional age of the sequence is a U-Pb date of 1690 ± 30 Ma (Page, 1981) on zircon crystals from tuffs in the Pb-Zn mineralised Barney Creek Formation (from about the middle of the sequence). This is close to the age for the host sediments to the Mount Isa Pb-Zn deposit (1670 ± 20 Ma), some 700 km to the southeast. Taken in the context of the date presented for the Fiery Creek Volcanics (ca 1680 Ma) a figure of 1660-1670 Ma for the Barney Creek Formation is preferred.

As already noted, formations show rapid lateral facies variations related to penecontemporaneous fauting. During deposition of much of the upper part of the McArthur Group (e.g. Barney Creek Formation, Lynott Formation and Stretton Sandstone) a north-trending half graben - The Batten Trough (Fig. 3) - had significant control on sedimentary facies and thicknesses. The eastern edge of this half graben is defined by the Emu Fault Zone - a prominent north north-east trending zone of structural weakness. The major concordant Pb-Zn-Ag mineralisation at HYC and associated Mississippi-Valley-type discordant mineralisation is spatially and genetically related to the fault zone. Equivalent aged sediments on the shelves to the west (Bauhina Shelf) and east (Wearyan Shelf, see Fig. 3) are much thinner, if present at all.

The Masterton Sandstone also contains evidence of penecontemporaneous tectonics and rift-related sedimentation, but the position and orientation of the related basin margin and the character of the rift is not clear.

The detailed studies we have completed have been restricted to the basin south of about 16°00'S.

North of our area (Arnhem Land) rocks equivalent to the Tawallah and McArthur Groups are known (from the original 1:250,000 mapping). These also occur in a north-trending graben (Fig. 3). A thin sequence of probable upper Tawallah Group and McArthur Group rocks is present in the Urapunga Tectonic Ridge - a basement high between the McArthur and Arnhem Land areas. Sedimentological studies of the sequences in these northern areas would undoubtedly provide some of the appropriate constraints needed to more clearly define the sedimentological and tectonic evolution of this mid-Proterozoic sequence.

Figure 6 (back page fold-out) is a simplified stratigraphic column illustrating the most significant sedimentological features of the McArthur and Nathan Groups, with comments relating to their environments of deposition and tectonic setting. At first sight it looks daunting, but we hope that by the end of the excursion it will prove to be a useful summary of what is a complex stratigraphic evolution. Perhaps, with your help, we can improve on some aspects of the interpretations shown.

ROPER GROUP

The uppermost Proterozoic sequence in the McArthur Basin is the Roper Group (Fig. 4). In this area it is up to about 2000 m thick, but further to the southwest it approaches three times this thickness. It unconformably overlies the Nathan and McArthur Group and consists of alternating formations of resistant clean quartz arenites (from tens to >200 m thick) andrecessive, poorly outcropping siltstone and shale (commonly 100 to 300 m thick). Sedimentologically, it is markedly different from the underlying carbonate-rich groups, as it is characterised by much more regular and uniform facies deposited in a more stable marine setting. It also appears to be significantly younger than the McArthur-Nathan Groups. A minimum age of 1280 Ma was indicated by K-Ar dating of dolerite sills that intrude the upper part of the group. The oldest Rb-Sr age measured for glauconites from this group is 1,360 Ma (McDougall and

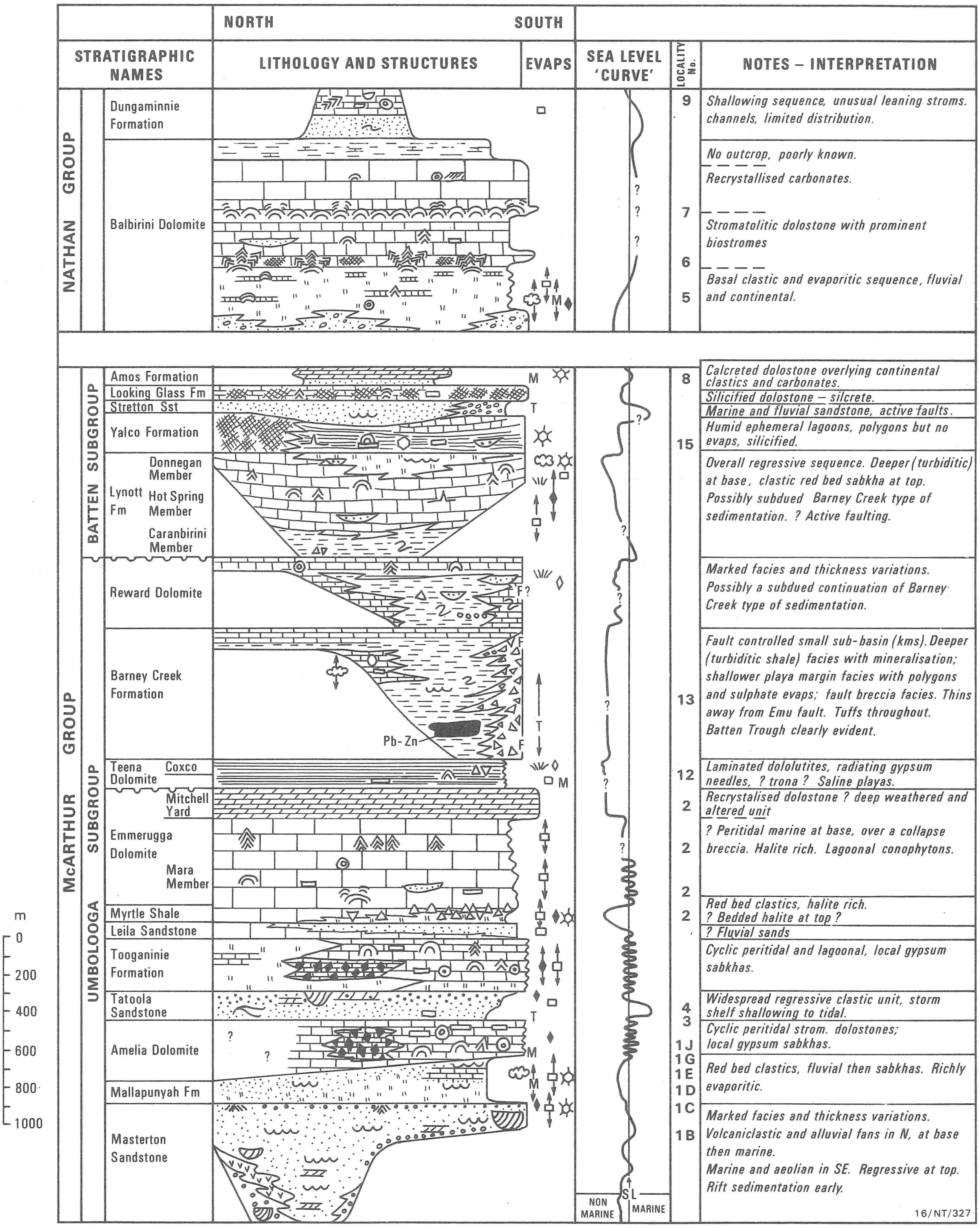


Fig. 6 Simplified stratigraphic column through the McArthur and Nathan Groups indicating the main features in their sedimentological evolution. Symbols as shown on Fig. 13 except for evaporites where square represents halite, M is K-rich mudstone, black diamond is gypsum.

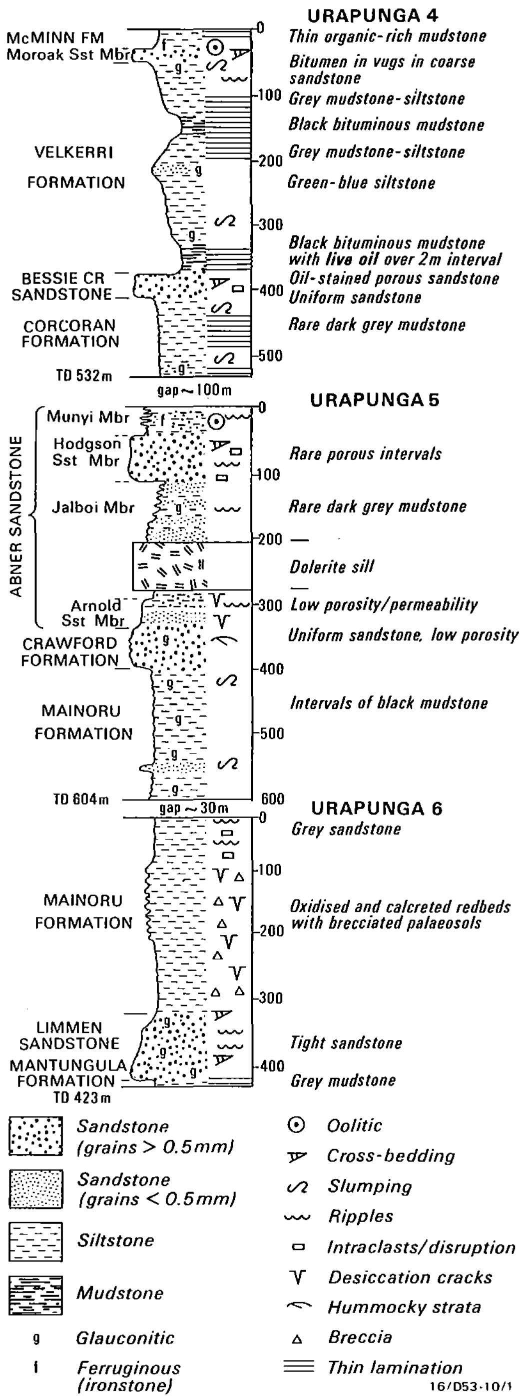


Fig. 7 Stratigraphy and main features of the Roper Group in the Roper River area based mainly on the results from the BMR 1985 stratigraphic drilling.

others, 1965), but recent dating of illite from the McMinn Formation near the top of the group by Kralik (1982) indicates a depositional age of about 1439 $\pm$ 31 Ma.

In addition to being younger and having a markedly different style of sedimentation, the depocentre of the Roper Group lies 200 km to the west of the Batten Trough, in the area formerly occupied by the Bauhinia Shelf.

Figure 7 is a simplified and generalised section through most of the Roper Group based mainly on the results of our recent drilling near Roper River. Some of these facies will be seen in outcrop during the excursion. In addition, small sections of core from the 1985 drilling program will be available for inspection during the excursion.

STRUCTURE

The present structure of the McArthur Basin is dominated by the Batten Fault Zone, a north-trending zone 50 km wide of more intense faulting through the middle of the area (Fig. 8). As noted earlier, stratigraphic reconstructions have suggested that this fault zone marks the site of a former syndepositional half-graben, the Batten Trough, in which a maximum of perhaps 12 km of sediments may have accumulated; this compares with only about 4 km on the Bauhinia and Wearyan Shelves either side of the trough. The west-trending Urapunga Fault Zone (Tectonic Ridge) marks an even thinner section above a basement rise, separating the southern part of the basin from its equivalents in Arnhem Land.

Maximum subsidence during McArthur Group time was near the eastern edge of the Batten Trough, which is defined by the complex, but poorly exposed Emu Fault Zone. The western margin of the Batten Trough cannot be so easily defined. The Mallapunyah, Hot Spring, Tawallah, and Abner Faults appear to have been intermittently active during deposition and to have controlled the thickness of some of the units. Graben development in the form of the Batten Trough was not evident during Tawallah Group times in the southern area that we have studied; but as noted earlier, convincing rift-related sedimentation further to the southeast (near D, Fig. 8) is present (Westmoreland Conglomerate, Seigal Volcanics).

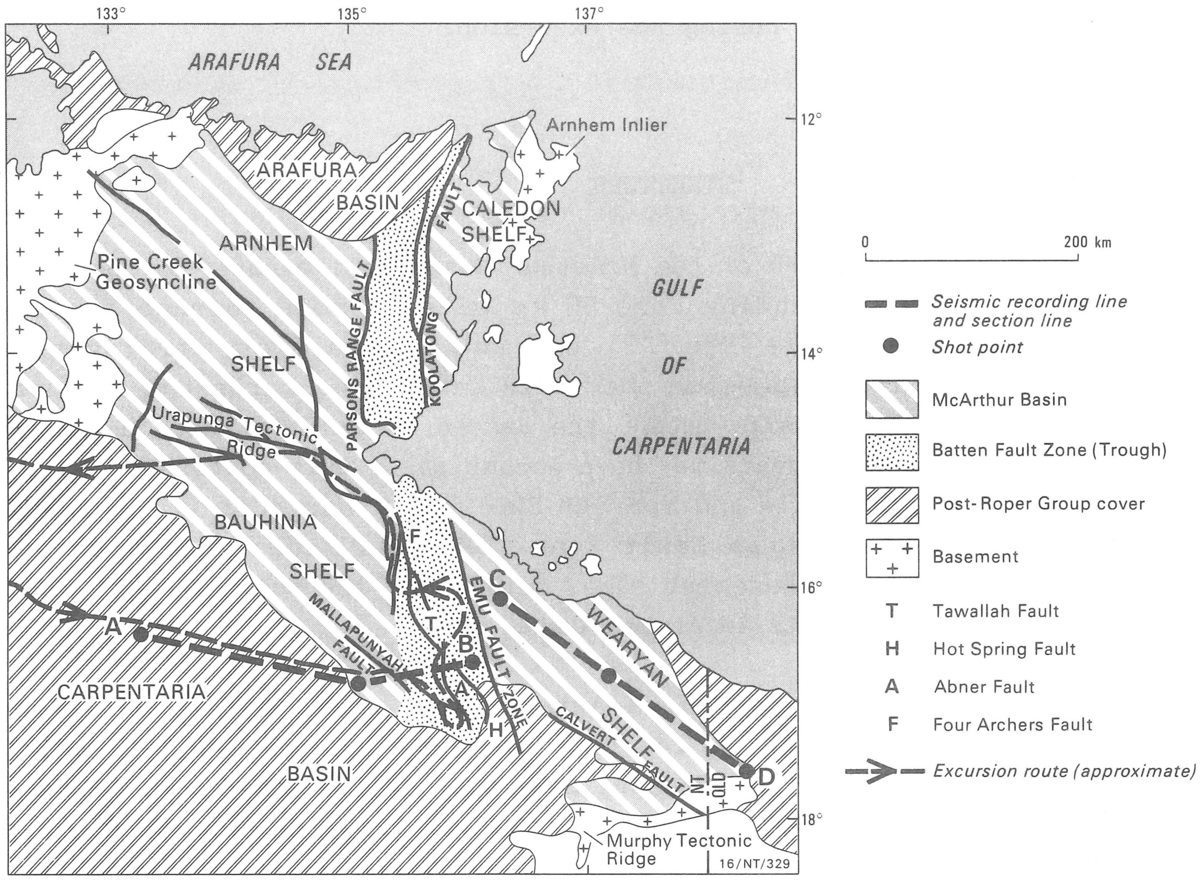


Fig. 8 Summary of main structural subdivisions of McArthur basin (after Collins, 1983), excursion route shown.

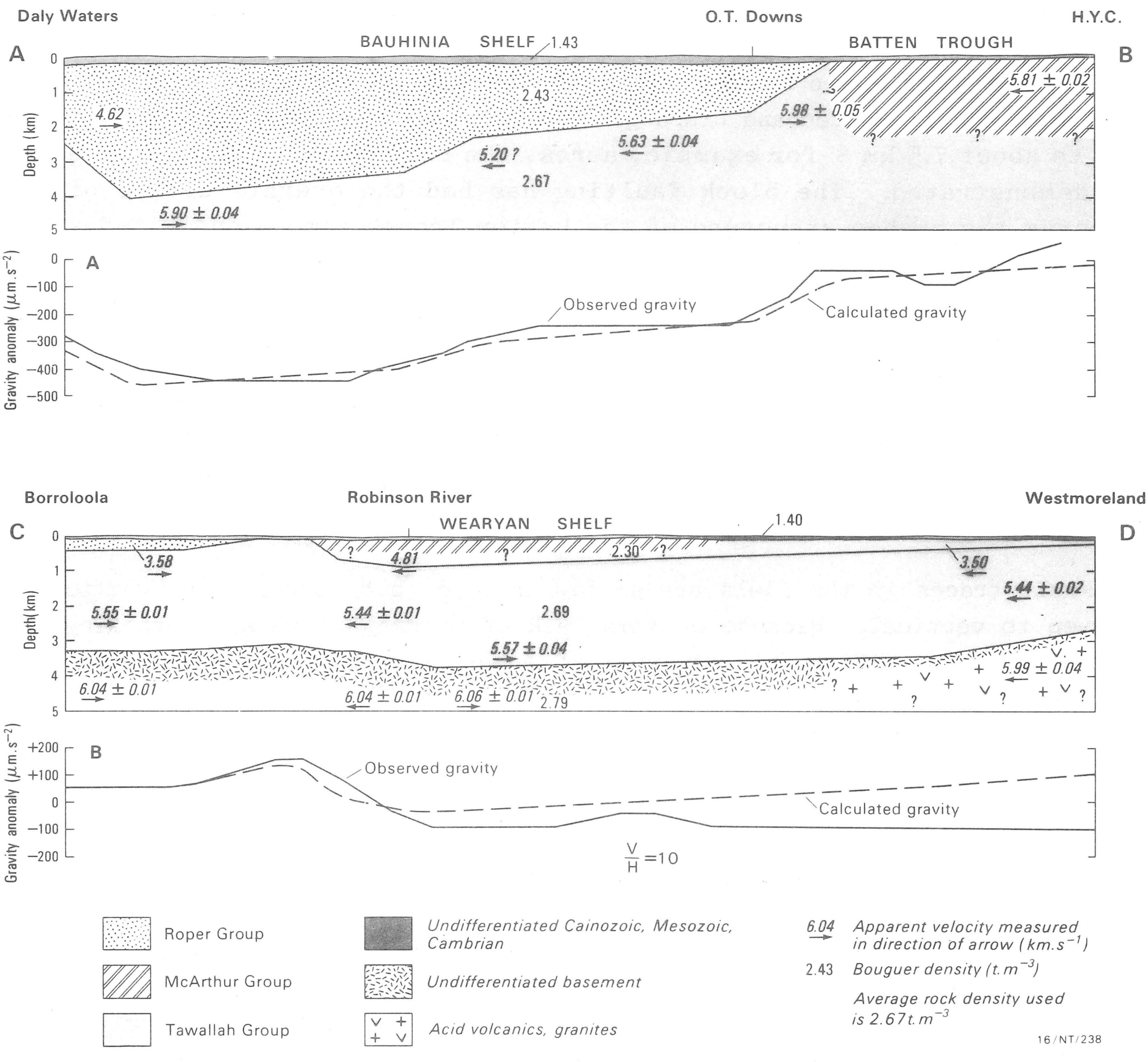


Fig. 9 West to east section across the southern part of the basin showing the main structural subdivisions (after Collins, 1983); line of section shown on Fig. 8.

Magneto-telluric, gravity and seismic studies along a transect across the southern part of the McArthur Basin in the late 1970's have provided the broad stratigraphic-structural subdivisions shown in Fig. 9. Unfortunately, relationships between the main subdivisions in the area of the Emu Fault Zone (B and C on Fig. 9) and the deeper basin structure within the Batten Trough (west of B, Fig. 9) were not clearly established.

The McArthur Basin has been deformed mainly in response to block-faulting along the Batten and Urapunga Fault Zones. Vertical displacements of up to about 7.5 km - for example, across the Four Archers Fault - have been demonstrated. The block faulting has had the overall effect of reversing the graben structure of the Batten Trough into a present-day horst, in which the oldest rocks are now locally exposed in the middle of the Batten Fault Zone.

Many folds and broad warps can be directly related to faults. The main faults of the area (e.g. those in Fig. 8) are part of a set of large-scale lineaments across northern Australia. Considerable strike-slip displacement in the basement before the initiation of the McArthur Basin can be demonstrated for some of them.

Fault traces in the field are seldom exposed, but most are thought to be steep to vertical. Because of this lack of outcrop of rocks containing structural data and in the absence of a well-constrained structural interpretation we shall not dwell of aspects of structural evolution of the basin during the excursion.

MINERAL DEPOSITS

The McArthur Basin is extensively mineralised with a wide range of metallic elements and a variety of ore deposit types. Even so, there are no working mines in the area at present. A concise detailed review of the mineralisation in this and adjacent areas was published by Williams (1980) and aspects of the depositional environments of the host rocks to the mineralisation has been provided by Muir (1983).

STOP 1 ARCHIES CREEK (GR 9510)

AIM

Walk a 2 km section through a gently dipping sequence of units across the Tawallah-McArthur Group contact. Inspect: quiet water ?lacustrine dolomitic shales of the Wollogorang Formation; regressive (shallowing) quartz sandstones of the Masterton Formation; continental redbed and continental/marginal marine sabkha environments in the Mallapunyah Formation and shallow marine stromatolitic dolostones in the Amelia Dolomite. The section is more-or-less continuous and, if we had enough time, we could inspect it metre-by-metre to trace the details of the facies changes; however, as time does not permit this, we have split it up into several individual spot localities (A to J) to indicate the main features of this part of the stratigraphic section (Fig. 10).

STOP 1A BACKGROUND

The Wollogorang Formation is a basin-wide 150 m-thick formation of mainly silty dololutite that is sandwiched between the subaerially extruded Settlement Creek and Gold Creek Volcanics near the top of the Tawallah Group (Fig. 5). Jackson (1983, 1985) has studied the unit in detail, especially in the Calvert Hills area (160 km east of here), where saline playa facies, shoreline stromatolite facies, and braided fluvial sandstone facies predominate. A deeper water low-energy black dolomitic shale facies with distinctive ovoid nodules is present in all areas near the base of the formation. Varves have been identified following detailed studies of drillcore samples from this black shale facies near Eastern Creek (130 km north-west of here) and a distal lacustrine environment is favoured (Jackson, 1985, see handout).

STOP 1A DESCRIPTION

A 3 m-thick section through the black shale facies is exposed in the northern bank of Archies Creek at this locality. Clearly visible are the ovoid nodules in laminated dolomitic shales. The nodules consist of hard crystalline dolomite (try breaking one) and are commonly organic rich (petroliferous odour). They also are commonly mineralised and often contain cores or rims of coarse crystals of various base metal sulphides (e.g., galena, sphalerite). Measurements of the thickness of bedding laminations in the nodules and comparison with bedding lamination in the surrounding sediments indicate compaction ratios up to about 8:1 for the

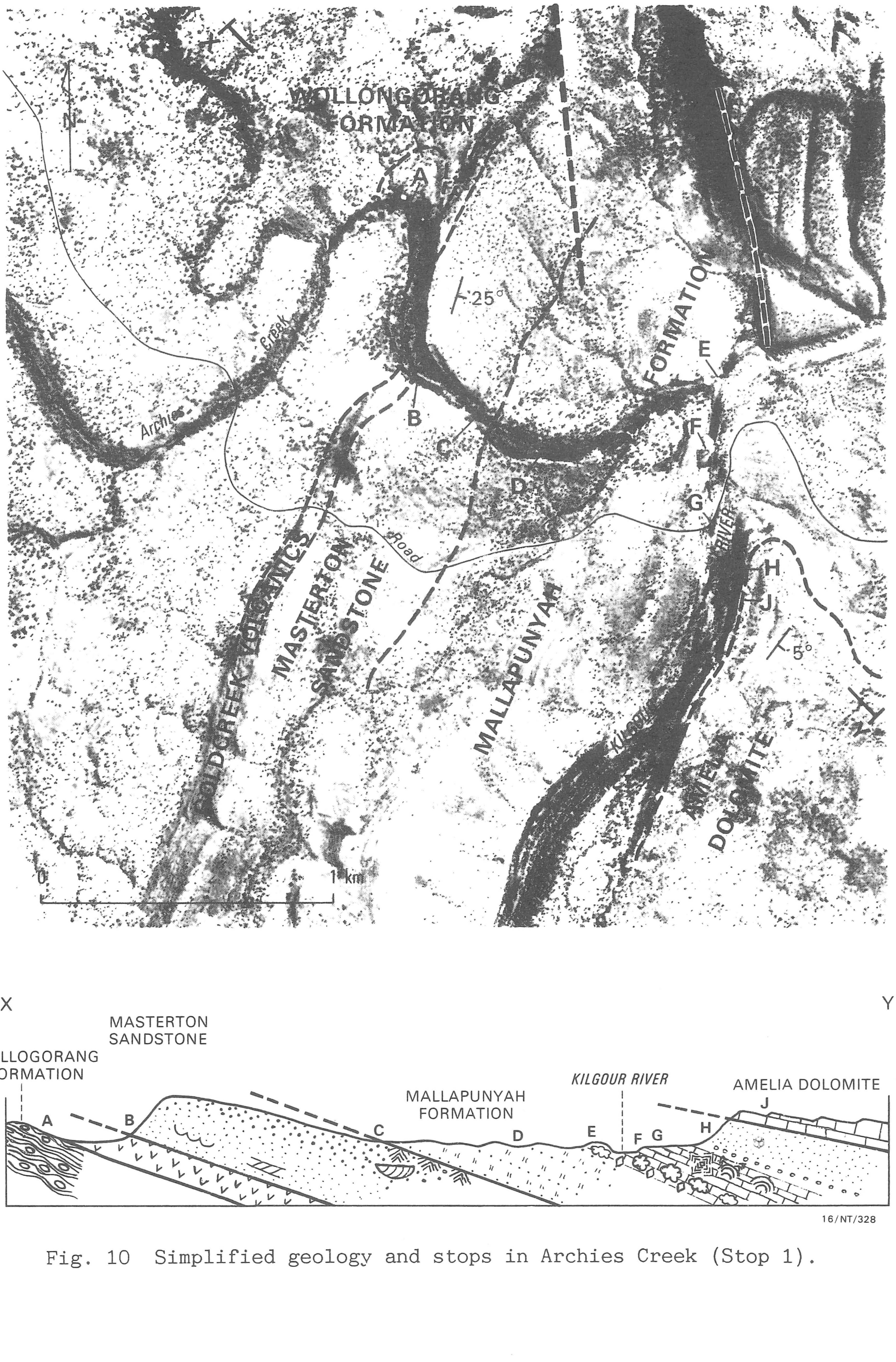


Fig. 10 Simplified geology and stops in Archies Creek (Stop 1).

dolomitic shales in this facies at Eastern Creek.

Although this latter feature cannot be established at Archies Creek, a sulphidic euxinic quiet water environment of deposition can be inferred from the lithology and lack of current structures.

The rubbly slopes above, and cliffs to the east of these ovoid beds comprise 'massive' to thick bedded dark brown to black weathering (pale blue when fresh) dololutites which lack obvious sedimentary structures, except in the 15 m immediately above the ovoid beds which contain nodular to irregularly-shaped chert interbeds (mm to cm thick) many of which appear to be distorted by sediment dewatering to form elongate flat-flake breccias. Other than this, little can be deduced from the rather uniform fine grained dolomitic sediments exposed here.

Originally, we thought that this part of the Wollogorang Formation was a likely contender for a deeper marine environment; however, the stratigraphic setting and associated fluvial and playa facies documented in most areas of good outcrop, indicate that this is highly unlikely. In fact, the recently identified varves suggest that this massive fine grained silty dololutite part of the formation is more likely to be a deeper lacustrine facies characterised by quiet sulphidic environments with seasonal deposition, largely from suspension.

In an attempt to further define sedimentary environments a stable isotope study of various rock types was carried out. Unfortunately, these results are not as clear cut as was hoped for. This information will be presented at the Congress, but in essence the S, O, and C values are more easily interpretable within a dominantly terrestrial environment rather than a marine setting, so they do lead support to the sedimentological interpretations.

ARCHIES CREEK BETWEEN STOPS 1A and 1B

The steep rubble-strewn cliffs to the east of Archies Creek between 1A and 1B contain poor outcrops of the overlying Gold Creek Volcanics - a complex suite of intrusive and extrusive K-rich intermediate igneous rocks including lavas, tuffs, agglomerates and volcaniclastic sediments. Boulders of this may be seen in the bed of the creek.

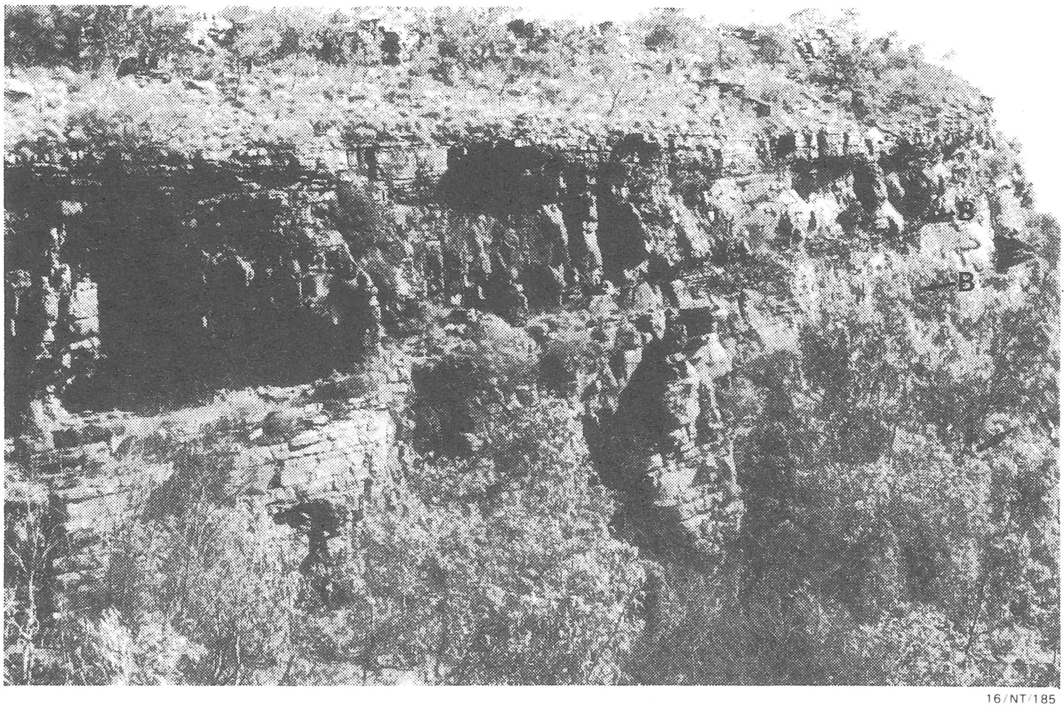


Fig. 11 Cliff face of Masterton Sandstone south bank of Archies Creek showing sandstones that occur between Stops 1B and 1C.

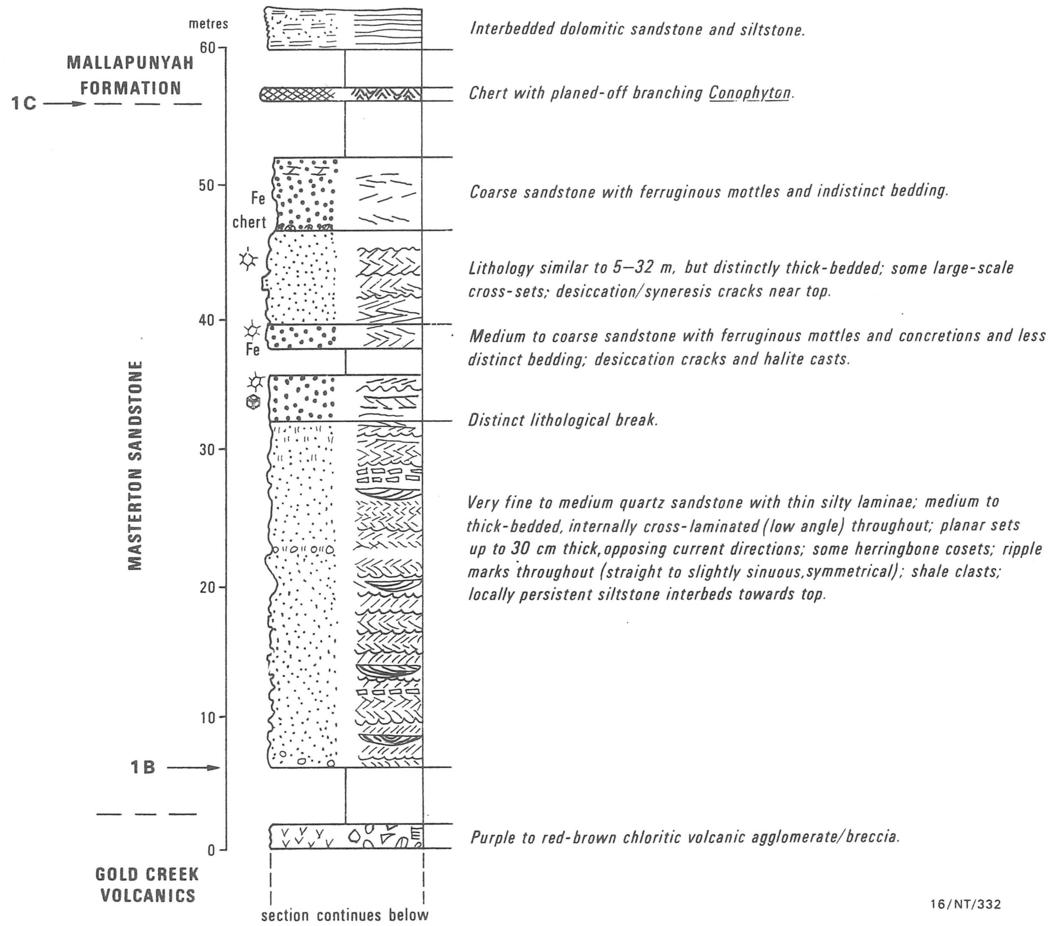


Fig. 12 Type section of Masterton Sandstone in Archies Creek.

STOPS 1B TO 1C BACKGROUND

The Masterton Sandstone (Fig. 6) is the basal unit of the McArthur Group. At most localities it disconformably or unconformably overlies the Gold Creek Volcanics and at all localities it grades up into the continental red bed facies of the Mallapunyah Formation. It is extremely variable in thickness and facies, and includes volcaniclastics facies in the northwest, rift-related alluvial fan and braided stream facies in the north, fluvial and mega-dune aeolian facies in the southeast, and uniform thick intervals of marine shelf facies at several other localities. A detailed description and analysis of the formation here is beyond the scope of this guidebook. The rocks at Stop 1B are typical of those in the finer grained shallow water (?marine) sections present in many areas and this section is, in fact, the type section for the formation. As a general statement they are also fairly representative of the quartz sandstones ('quartzites') typical of much of the Proterozoic of Australia.

STOPS 1B TO 1C DESCRIPTION

The cliff face on the south side of Archies Creek at this locality (Fig. 11) includes most of the type section and a schematic log showing its main features is shown in Figure 12. A legend for symbols used on measured sections is given in Fig. 13 (last but one page of field guide). We suggest you walk through this section, examining the outcrops at creek level at the foot of this cliff.

The main features you should see in walking through are:

1) Regular, even and mostly parallel stratification;
2) Parallel internal lamination with low angle planar and trough cross-stratification (possibly herringbone in places);
3) Dominance of fine to medium grained sandstone (lithic wacke to quartz arenite in composition), but also the presence of rare red-brown silty/shale interbeds often on rippled surfaces in the lower half;
4) Intervals of ferruginous coarser grained thicker bedded sandstone in the upper half of the section with iron and silica mottles;
5) Symmetrical and asymmetrical ripples on exhumed bedding planes. Three dominant orientations are evident (020°, 100° and 150°). Planed-off ripples, boxwork ripples and desiccation cracks in ripple troughs are present especially in the upper half of the section;

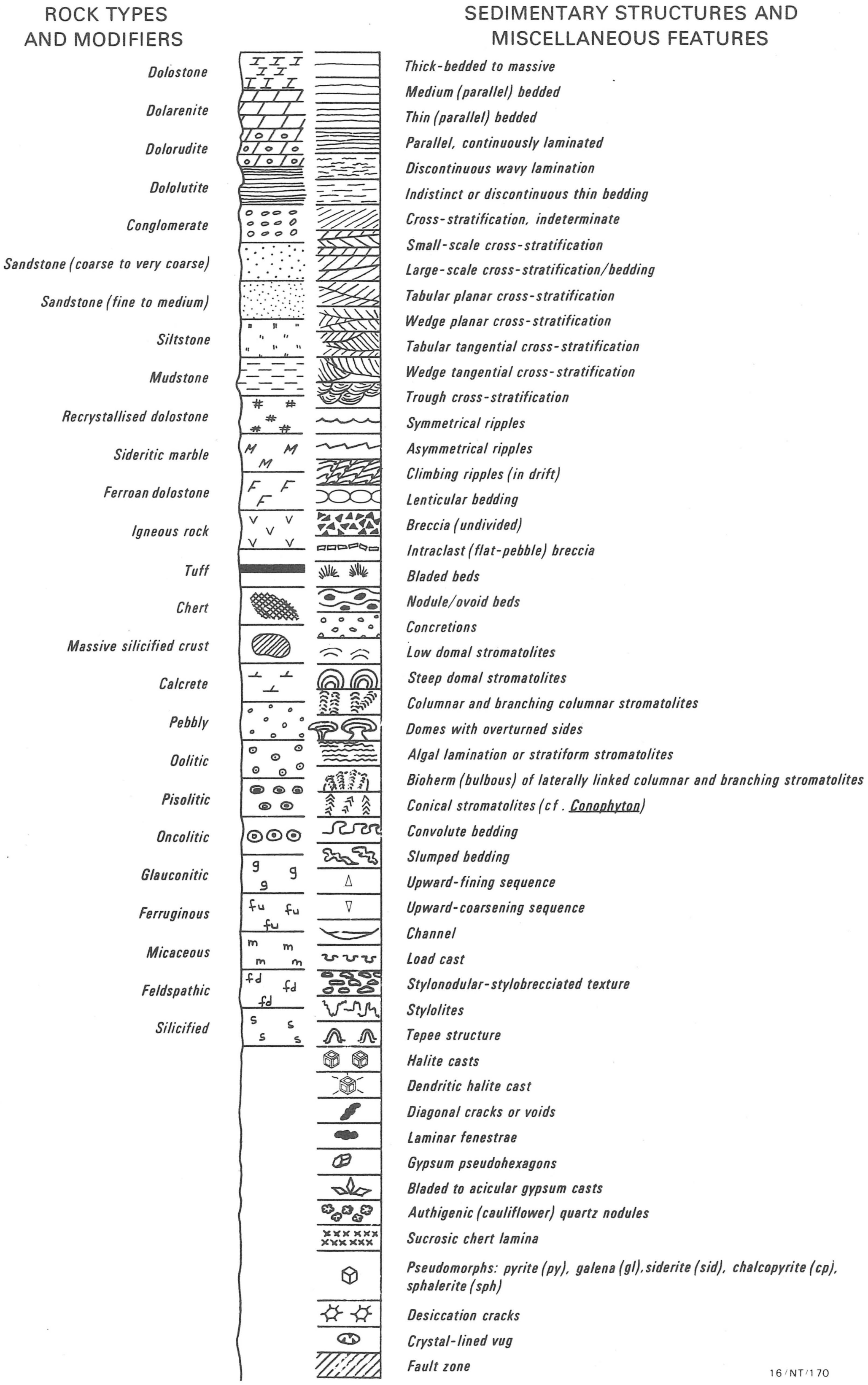


Fig. 13 Key to symbols used on sections and logs.

6) Numerous shale clast impressions;
7) Large curved parting planes - ?channels or l.b.s. of trough sets;
8) Planed-off (eroded) chertified stromatolites (Fig. 14) at the top of section (locality 1C), where the outcrop deteriorates.

The upward coarsening of grainsize, the increase in bed thickness, and decrease in maturity is interpreted as indicating a gradual shallowing of the environment. This section (and others nearby) lack features such as fining-up genetic units that would indicate fluvial environments. There is evidence of deposition of sand ripples and waves from traction currents running in various directions, and erosion of finer grained slack water deposits through most of the section. Deposition in a tidally-influenced shallow marine environment seems most likely. The planed-off stromatolites at the top are interpreted as eroded remnants (?wave cut platform) of stromatolites deposited in a supratidal lagoon.

Hypersaline waters are indicated by the presence of rare halite casts and moulds. Much more convincing evidence of extensive saline fluids during depositon is evident in an almost identical measured section through the formation at Kiana, only 8 km east of here, where halite casts and moulds (including hoppers, and skeletal and pagoda forms) were found on many bedding surfaces, some with accompanying streaming lineations.

Later groundwater movement through the coarser grained parts of the formation is suggested by the presence of the ferruginous and siliceous mottles and quartz and hematite crystal-lined vugs and cavities.

STOP 1D-1H BACKGROUND

The eroded stromatolites at locality 1C are taken as a convenient boundary to mark the contact between the coarser clastics of the Masterton Sandstone and the finer dolomitic siltstones of the overlying Mallapunyah Formation. Although the type of stromatolite varies from place to place - conical, domal, columnar - there invariably seems to be a thin (1-3 m) chertified stromatolitic (lagoonal) interval at this stratigraphic level throughout the basin. The succeeding Mallapunyah Formation is a widespread distinctive redbed siltstone and sandstone unit containing a number of evaporitic facies. Although it seldom crops out well -- the Archies Creek section (the type section) is one of the best known -- the red colour and evaporites, especially the large cauliflower cherts and halite hoppers are very distinctive.

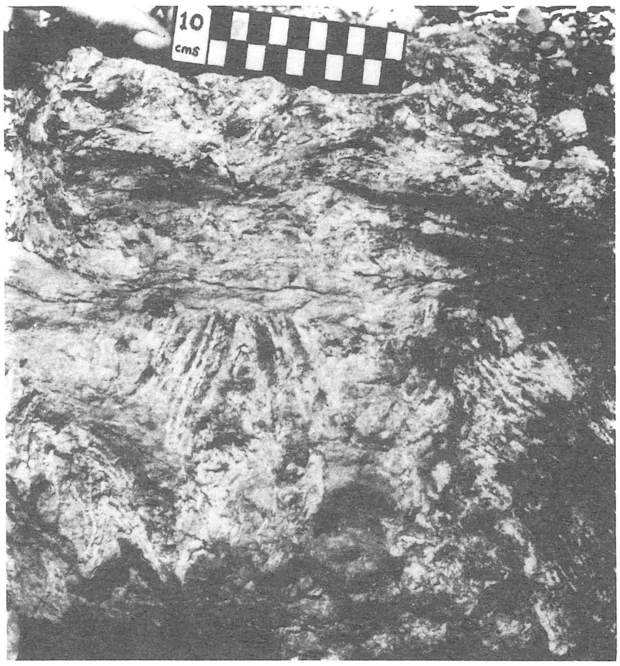


Fig. 14 Eroded chertified branching conical stromatolites (?wave cut platform) in ferruginous siltstones at the contact between the Masterton Sandstone and the Mallapunyah Formation in Archies Creek, at locality 1C.

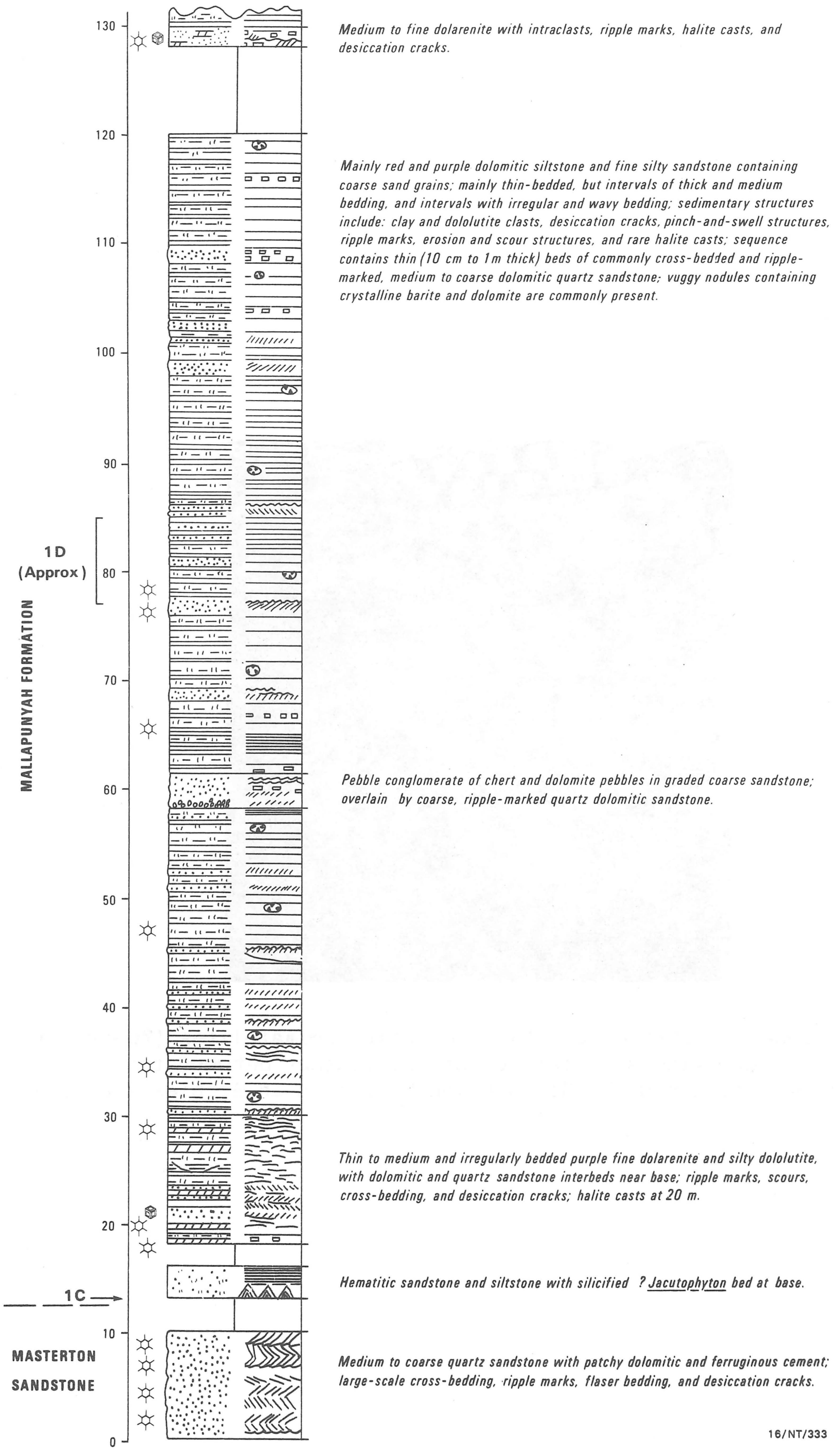


Fig. 15 Lower part of the type section of the Mallapunyah Formation in Archies Creek.

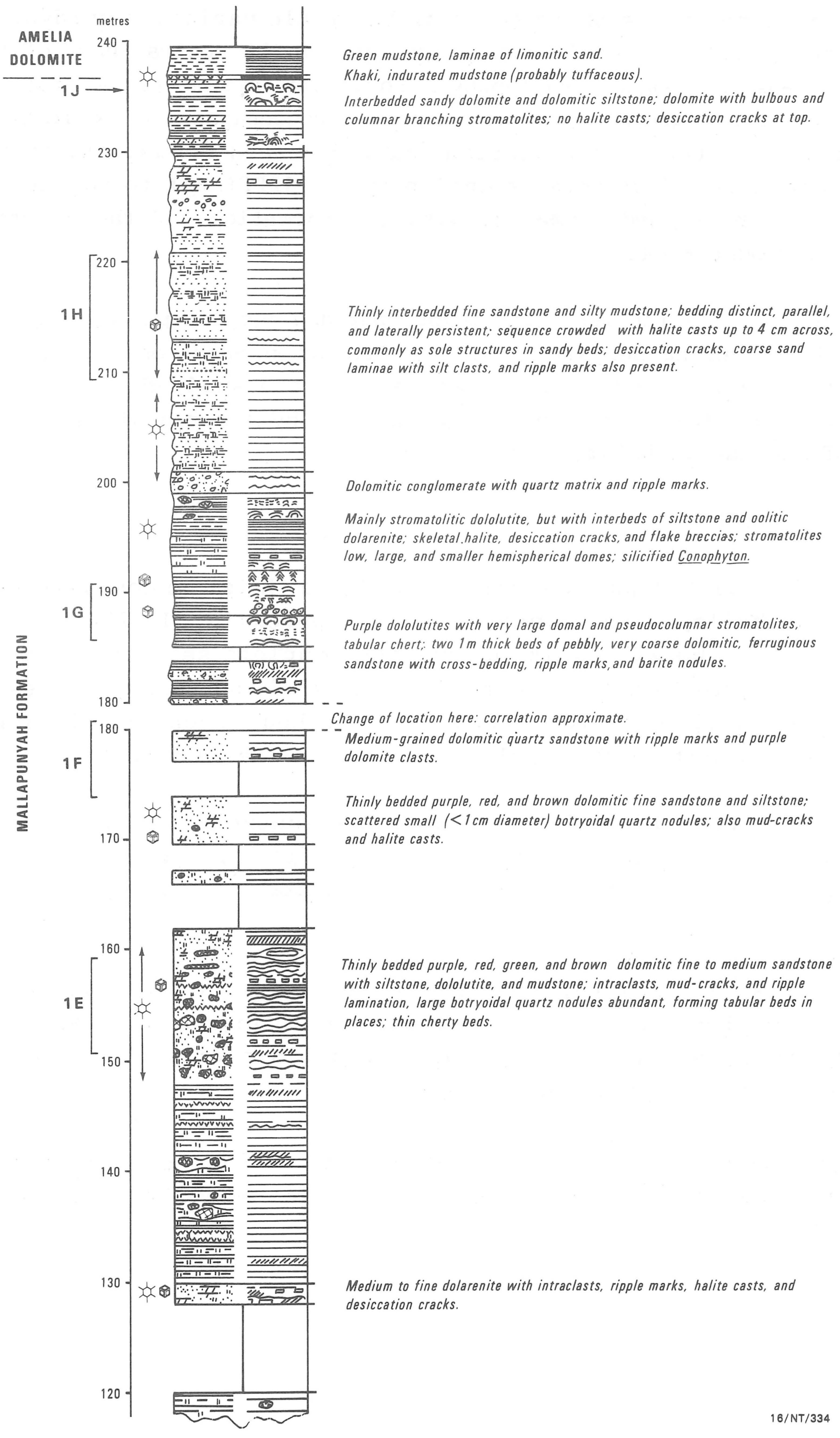


Fig. 16 Upper part of the type section of the Mallapunyah Formation in Archies Creek and Kilgour River.

On the regional scale there seems to be little variation evident in the formation, except that it is coarser grained in the central part of the area (Batten Range). Typical Mallapunyah Formation facies was evident in the appropriate stratigraphic position during a reconnaissance examination of the thinner McArthur Group section (called Vizard Formation) in the Urapunga Fault Zone. With this exception, it is difficult to relate the subdivisions of the Vizard Formation with the formations of the McArthur Group near the Abner Range.

Following on from the irregular topography and complex palaeogeography that was evident during deposition of the Masterton Sandstone it appears that the area stabilised and that a widespread and subdued terrestrial landscape evolved. This was then slowly drowned by a marine incursion at the start of the Amelia Dolomite deposition.

STOPS 1D TO 1H DESCRIPTION

The shallow east-dipping section from 1C to 1H is the complete type section of the Mallapunyah Formation; it is approximately 240 m thick (Figs. 15 and 16). We will walk through the complete section along the route shown on Figure 10 noting the main features of the various facies as we go, but we will stop for about half an hour each for detailed inspections of anhydrite sabkha cycles at 1E and halite cast beds at 1H.

The section from 1C to 1E runs along the southern bank of Archies Creek to its confluence with the Kilgour River. Outcrops are continuous in the 2-3 m high bank of the creek. In this section (0 to 148 m) you will see:

1. Main rock type is red-purple dolomitic siltstone which is either laminated or indistinctly bedded. We interpret this as being mainly of aeolian or overbank flood plain origin. 'Floating' frosted quartz grains are present in places.

2. Thin interbeds of fine to coarse grained quartz or dolomitic sandstone which are commonly ripple cross-laminated, and may be crevasse splay deposits.

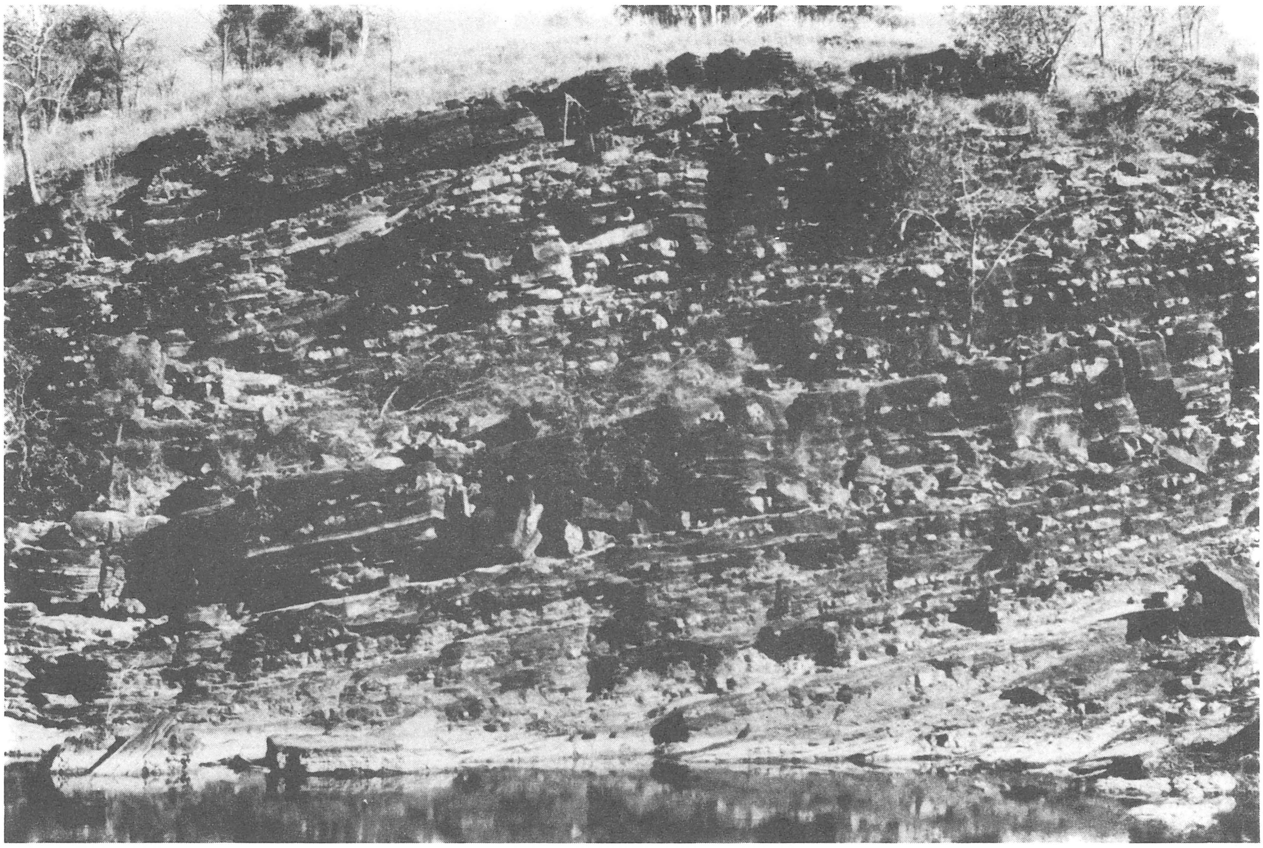
3. A 3-4 m fining-up unit of sandstone at 60 m with a basal conglomerate lag, cross-stratification, and ripple lamination, that resembles the facies model for a meandering fluvial sandstone unit.

4. Irregularly mottled pseudohexagonally-jointed intervals. These resemble leached profiles of columnar jointed fossil soils that we have seen in Phanerozoic fluvial sequences on the coast of NSW.

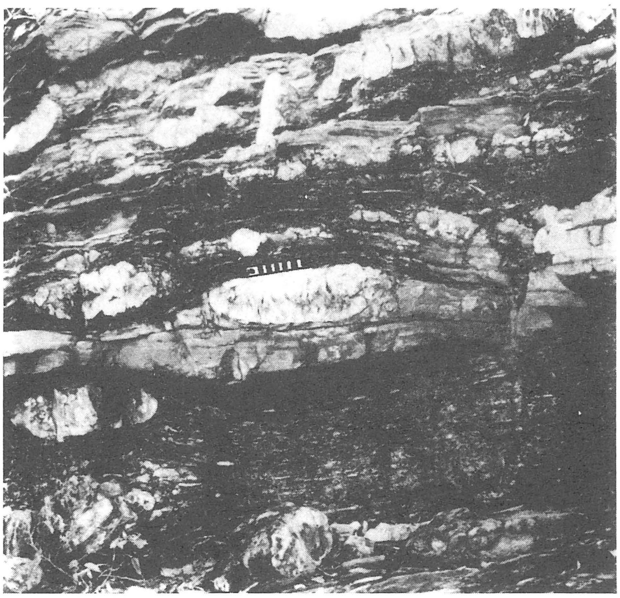
5. Desiccation cracks, early diagenetic carbonate-barite nodules, and rare halite casts, interpreted to indicate arid environments with saline groundwaters.

The interval 0 to 148 m is interpreted as a low gradient, fine grained, alluvial environment. A good recent analogy may be the anastomosing fluvial system of the present Coopers Creek in central Australia. The depositional model for such an arid-zone fluvial system comprises a mud-dominated succession with minor channel sands, desiccation cracks, minor carbonaceous horizons and duricrusts, and evaporites (Rust, 1981).

The river-side cliffs at locality 1E-1F contain spectacular large botryoidal quartz nodules (cauliflower cherts) in a thin bedded sequence of dolomitic sandstone, siltstone, dololutite and K-rich mudstone (Fig. 17A and B). The cauliflower chert nodules are remarkably similar to the anhydrite nodule beds in the Abu-Dhabi sabkhas, except that they are larger. They are obviously diagenetic, and in places they coalesce to form irregular pod-like and tabular beds. Individual "cauliflowers" have a fine cherty outer rind with an interlocking meshwork of lutecite crystals; their centres are commonly hollow and are lined with euhedral crystals of quartz, dolomite, fluorite and various sulphide minerals. Besides the disruption to the bedding caused by the diagenetic growth of these former nodules, the original stratification of the unit is also markedly discontinuous and irregular with desiccation cracks, scouring, rip-up intraclasts, ripple-form sandy lenses and load casting (Fig. 18). The K-rich mudstones are generally thin (<2 cm) and flinty. They were originally thought to be tuffs, but shards or crystals are not visible in thin sections: the rocks can best be described as diffuse K-feldspar cherty mudstone. Potassium enrichment of clays occurs in many present day hypersaline environments, both lacustrine and marine, and therefore these 'tuffs' need not necessarily indicate igneous activity.



A



B

Fig. 17 A: Cliff faces about 12 m high at locality 1E, and B: close-up of large cauliflower chert nodules in Mallapunyah Formation. Note compaction of bedding around nodules, in laminated dololutite - dolarenite rocks.

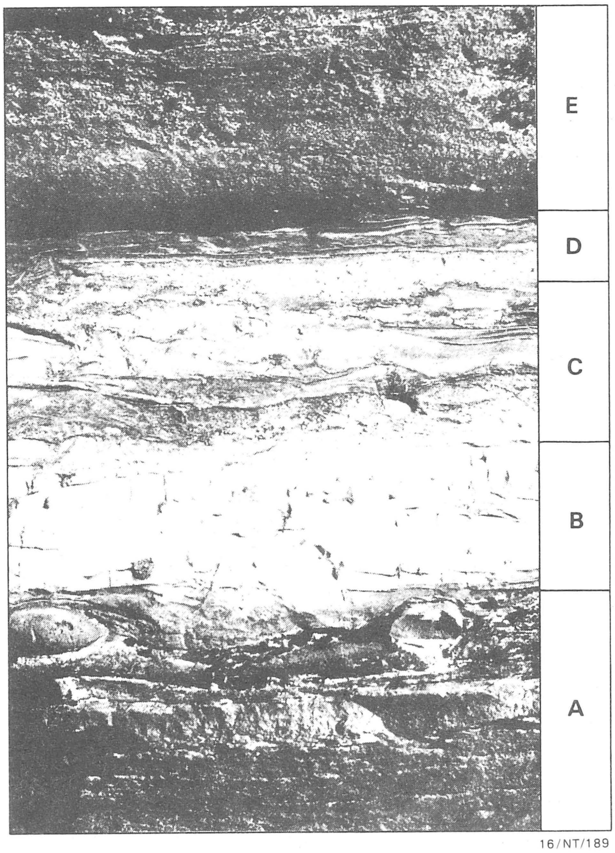


Fig. 18 Close-up of small stratigraphic interval within the cauliflower chert cliff face at locality 1E, showing range of rock types in host sediments. A - dark grey dolomitic sandstone with indistinct ripples, and ovoid diagenetic chert nodules near top; B - purple dololutite (micrite) with a load cast at base and a sharp desiccated and eroded top, also dolomite pseudomorphs; C - ripped-up dololutite clasts within sandy dolarenite; D - fining-up (graded) dolarenite bed; E - as for A. Total thickness of interval is about 30 cm. These rapidly varying units are clearly visible in cliff face.

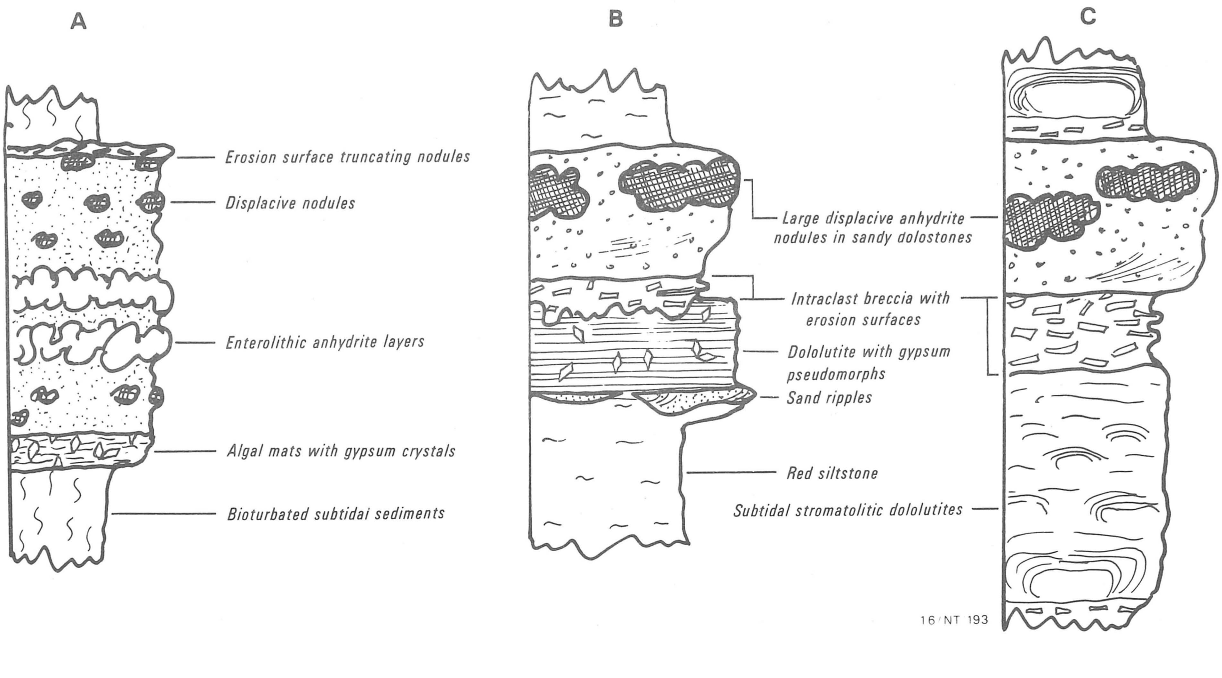


Fig. 19 Characteristic features of the modern coastal sabkha at Abu Dhabi (A), compared with two typical cycles (B and C) from the Mallapunyah Formation at locality 1E and 1F, Kilgour River Proterozoic cycles contain more extentsive anhydrite nodule beds and more evidence of erosion.

Detailed examination of the cauliflower chert interval between 1E and 1F suggests that the sediments form thin cyclic units Figures (Figs. 19 B and C). These are comparable in general with the modern day sabkha cycle at Abu Dhabi (Fig. 19A) but slightly different in detail.

Despite these minor differences we interpret this part of the Mallapunyah Formation as a stacked series of fossilised marginal marine sabkhas containing large quantities of former sulphate evaporites. The lower halves of the Proterozoic sabkha cycles show obvious differences to their modern-day counterparts, the most notable being in the character of the subtidal or lagoonal sediments and the more common erosion and variability in the sediments.

A bioherm series of stromatolites, suggestive of a gradually shallowing lagoonal environment, is present at Stop 1G (Fig. 20) about 15 m northeast of the road-river crossing. This bioherm series is closely comparable to the Balbirina prima bioherm in the Balbirini Dolomite which we will examine in detail later on in the excursion. The purple dololutite that forms the host sediments at this locality contains rare, but photogenic, skeletal hopper halite casts infilled by crystalline dolomite (Fig. 21) indicating the presence of highly evolved saline pore fluids whilst these crystals grew diagenetically in the soft and unconsolidated sediments.

The section running south from the cauliflower chert cliffs to the road crossing contains a gradually increasing content of dolomite, especially stromatolitic dololutite and oolitic dolarenite. Stromatolites include low small domes, very large steep-sided domes, pseudocolumnar forms, and conical forms. Most of these are irregularly chertified and consequently are difficult to discern in places. The increased dolomite content is interpreted as indicating an increased marine influence i.e., the sandy and silty sulphate-rich supratidal flats are gradually inundated by dolomitic lagoonal and peritidal stromatolitic environments. However, desiccation cracks, ripple form sands, intraclast breccias and tepee structures (180-200 m, Fig. 16) indicate that the environments were still very shallow and occasionally emergent.

A sharp contact, overlain by a 2-3 m thick dolomitic conglomerate at 200 m indicates a sudden regression and a probable return to continental deposition. The main cliff face at locality 1H comprises a 30 m-thick fine-grained thin-bedded clastic facies crowded with well preserved hopper

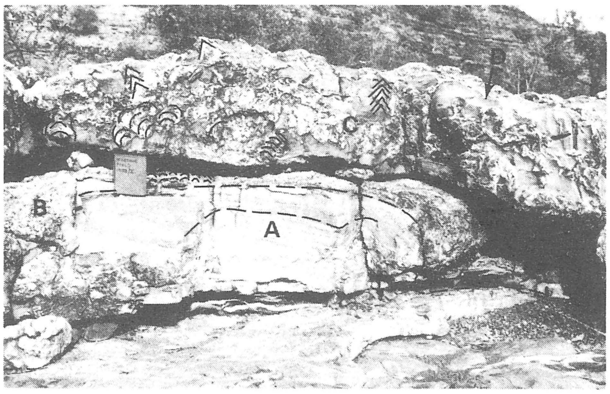


Fig. 20 Purple stromatolitic dololutite with irregular chertification near Stop 1G. The structures are hard to decipher owing to irregular chertification, but some have been highlighted by annotation: large stromatolitic dome with overhung sides (A) capped by smaller columnar stromatolites clearly visible in chert at B, overlain by biostrome containing domal to pseudocolumnar forms and irregularly branching conical forms (C); dololutite at D contains large skeletal halite casts infilled by crystalline dolomite. This is a similar bioherm series to that which we will see at locality 6 in the Balbirini Dolomite.

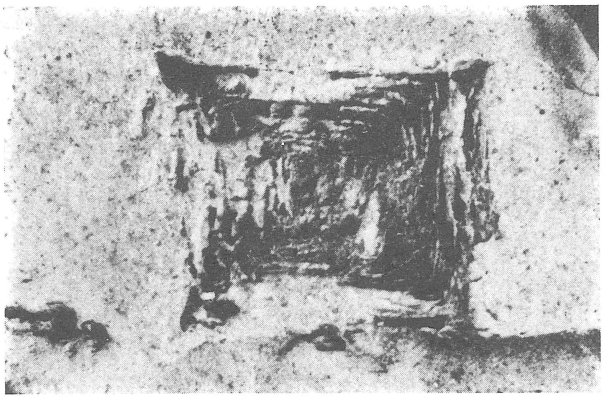


Fig. 21 Skeletal halite hopper pseudomorphs (2 cm across) in fine grained dololutite, at D in Figure 20.

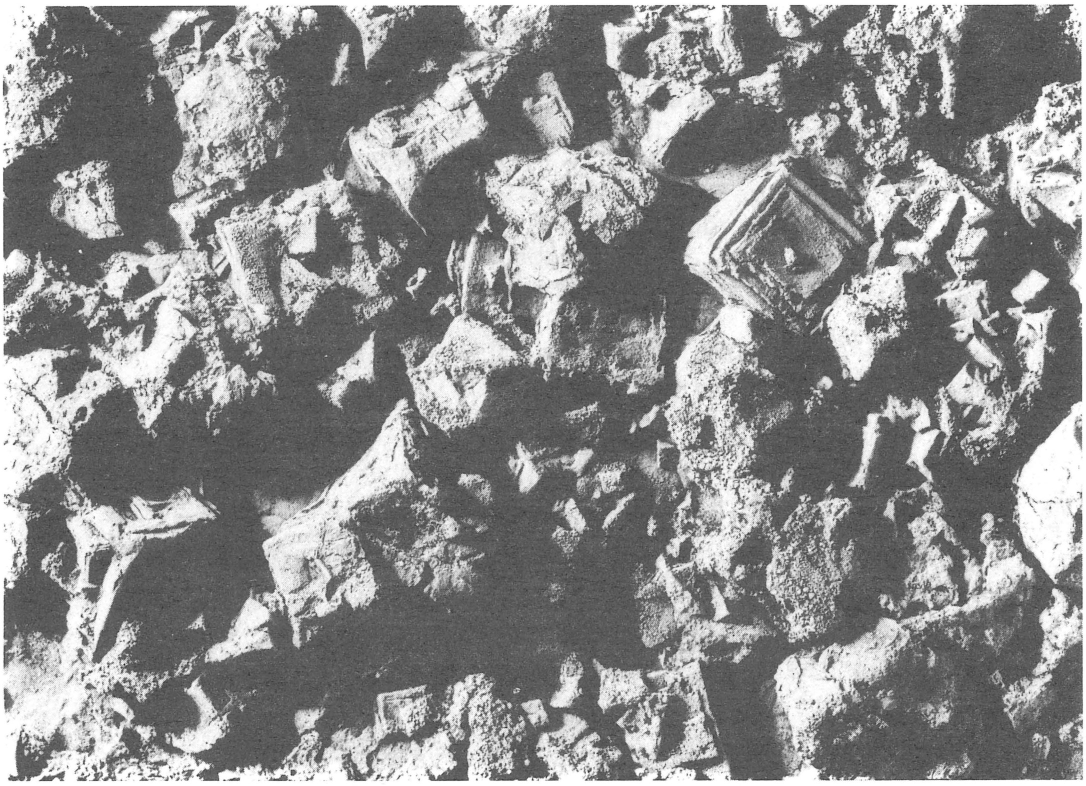


Fig. 22 Dolomitic sandstone at locality 1H in the Mallapunyah Formation consisting almost entirely of hopper halite casts and moulds. Natural scale.

halite casts and moulds (Fig. 22).

This section contains evidence of occasional emergence (desiccation) and waning traction currents (sole structures, ripple forms and clay drapes). It is broadly similar to the continental deposits in the lower half of the formation, but the sediment is mainly sand and the bedding is thicker, more laterally persistent, and more regular than that seen in Archie Creek. Handford (1981) described very similar 'haselgebirge' facies from the Permian of Texas and also compared them with coastal sabkha and salt-pan environments.

Interbeds of stromatolitic dololutite are present near the top of the cliff and indicate a gradational contact with the overlying Amelia Dolomite. Several beds of green flinty mudstone are present at the very top of the cliff. These distinctive mudstones are widespread at this stratigraphic level and provide a useful marker for the contact. These were originally interpreted as tuffs - they closely resemble the so-called 'tuff marker beds' in outcrops in the Mount Isa area - and therefore were thought to be a useful time marker. Volcanic shards could not be identified in thin sections so these also could be of evaporitic origin.

STOP 1J

If time permits we will examine the lowermost 20-30 m of the Amelia Dolomite on the top of the cliff at this locality. The formation consists of 1-2 m high steps of rugged dark grey crystalline dolomite with irregularly chertified conical stromatolites separated by 2-4 m intervals of mostly no outcrop. The type section of the Amelia Dolomite (where the rocks are much better exposed) is only 3 km north of here, but unfortunately is not easily accessible by vehicle. Figure 23 shows a log of the type section which indicates that the stromatolitic dolostones alternate with 5-14 m thick intervals of mostly fine oolitic and intraclastic dolarenite and dololutite with only thin impersistent stromatolite biostromes. Some of the thicker stromatolite units at the type section form bioherm series with large domes at the base, overlain by large columnar forms, overlain by regular conical forms and finally irregular-branching conical forms at the top. They are similar to the Jacutophyton cycles from the lower Riphean of USSR. Although the stromatolite outcrops at locality 1J almost certainly contain these bioherm series they are, unfortunately, not clearly visible.

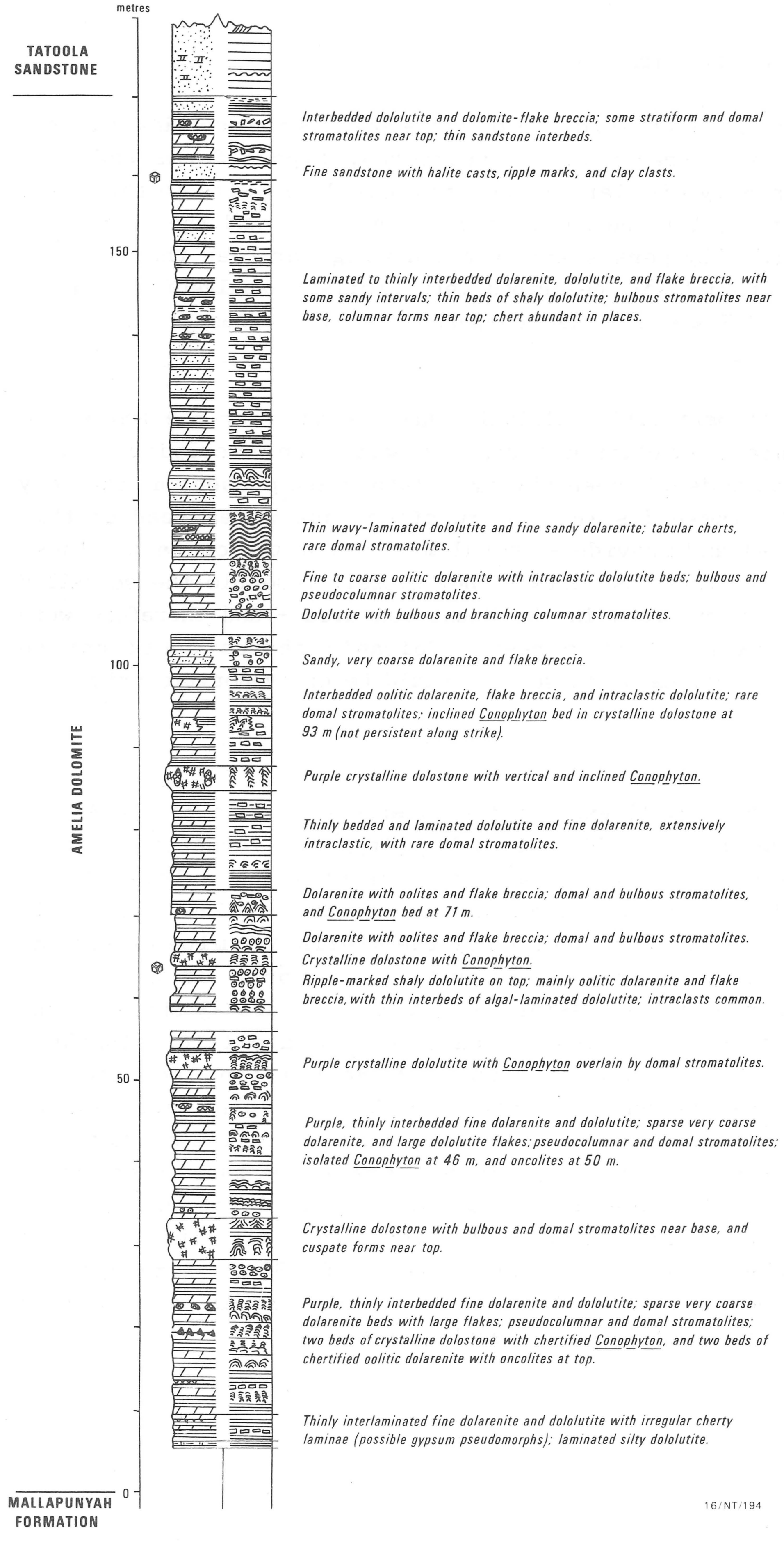


Fig. 23 Type section of the Amelia Dolomite in the Kilgour River showing interbedding of stromatolitic and non-stromatolitic units.

The alternation of these two main facies indicates deposition in an area with two contrasting environments; one is a very shallow water storm-swept agitated environment (high stress environment for stromatolites), the other is a quieter environment where complex bioherms of stromatolites were developed (?lagoonal).

NOTES

STOP 2 TOP CROSSING (GR 8042)

AIM

To walk about 500 m through a measured section of the Myrtle Shale and Emmerugga Dolomite to examine a second transgressive section with evapori ic continental redbeds overlain by evaporitic stromatolitic dolostones (cf. stop 1). A solution collapse breccia is present at the contact between the two formations and the overlying stromatolitic dolostones can be interpreted as marine or lacustrine. An unusual coarsely crystalline carbonate is present at the end of the traverse.

BACKGROUND

These two formations are situated about 1000 m stratigraphically above the Mallapunyah-Amelia sequence examined at Stop 1, but they are part of the same continuous stratigraphic sequence of the lower McArthur Group and appear to have been deposited in a similar tectonic setting (Fig. 6).

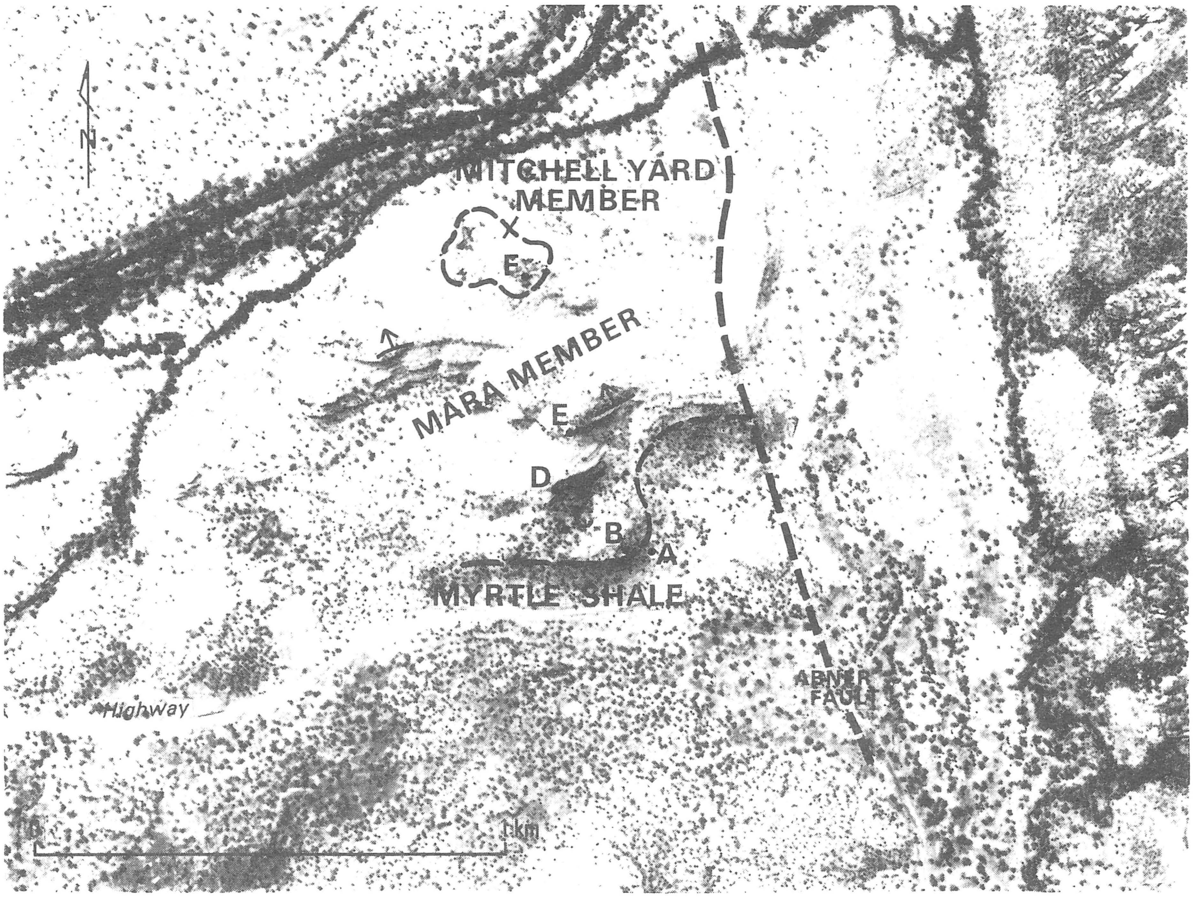
The Myrtle Shale is an evaporitic redbed unit that is up to about 60 m thick in this area, but which appears to lens out northwards. It is lithologically very similar to the lower part of the Mallapunyah Formation. It consists of thin bedded red-brown siltstone and very fine grained sandstone with rare thin interbeds of coarse grained sandstone, oolitic dolarenite and silty dololutite; halite casts (few mm - few cm across) are ubiquitous. Like the Mallapunyah Formation we interpret it as being of low gradient alluvial plain and/or lacustrine origin. The overlying Emmerugga Dolomite is a thick unit (up to about 600 m) comprising mainly resistant dark grey cherty dolostones. Original sedimentary structures are commonly obscured by varying amounts of alteration and silification which took place not only during deposition and diagenesis, but later as well: severe silicification related to Cambrian, Cretaceous and younger weathering episodes is apparent.

The lower member of the Emmerugga Dolomite (Mara Dolomite Member) has been divided into several subdivisions. Some of them are richly stromatolitic, others are characterised by variable lithologies, e.g., thick bedded dololutite, intraclastic, oolitic, and oncolitic dolarenites. The upper member of the Emmerugga Dolomite (Mitchell Yard Member) is a dark grey crystalline dololutite apparently lacking internal structures (i.e. 'massive'). It has a very distinctive jagged rillenkarren surface.

We have not done a systematic facies analysis of the Emmerugga Dolomite. The Mitchell Yard Member was deposited in a number of subtly varying subenvironments; some of these undoubtedly originated in agitated shallow water, but others formed in much quieter and possibly deeper water conditions. The origin of the Mitchell Yard Member is difficult to interpret - it is possible that it represents a facies of alteration rather than a depositional lithofacies. Some aspects of these features will examined at this stop.

STOP 2 DESCRIPTION (Fig. 24)

2A: rubble slope of Myrtle Shale: mostly float of red, green and yellow siltsone, dololutite, and very fine grained sandstone with a variety of hopper halite casts and moulds (up to a few cm across); some are deformed cubes containing white 'sugary' chert. This is a very similar facies to the hopper halite beds in the Mallapunyah Formation at Stop 1G. At the top of this rise (i.e. approaching 2B) interbedded dololutite (especially tan and yellow) becomes more common indicating a gradational



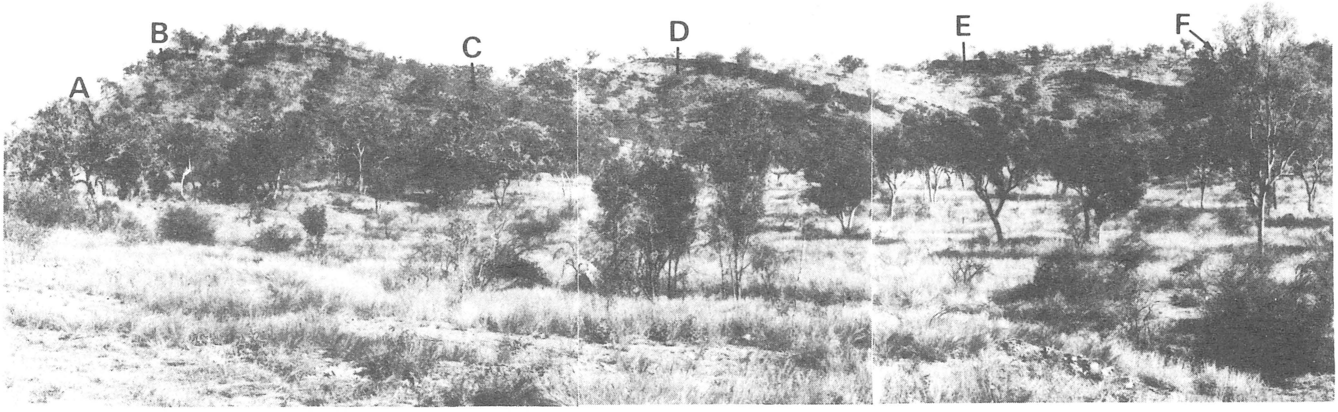


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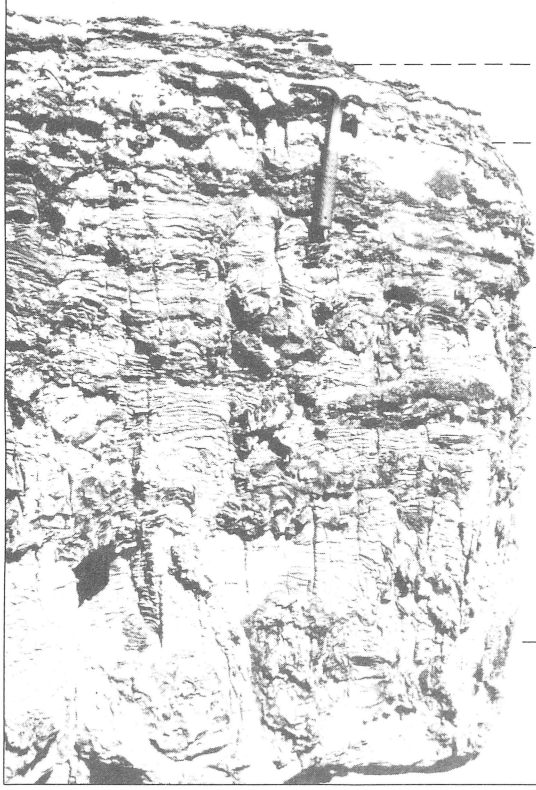
Fig. 24 Map and general view of the outcrops of the Myrtle Shale and Emmerugga Dolomite to be examined at Stop 2, Top Crossing.



OUTCROP	LITHOLOGY	INTERPRETATION	
		MARINE	CONTINENTAL
	Siltstone with mud-cracks	*Supratidal flat*	*Exposed marginal flats*
	Saccharoidal cherts		
	Flattened domes	*Intertidal (? stronger currents)*	*Lagoon (shallower part)*
	Fine dolostone with rounded to elongate domes	*Shallow subtidal*	*Lagoon (deeper part)*
	Massive fine dolostone	*? Deeper*	

16/NT/208

Fig. 25 Typical shallowing cycles in basal part of the Mara Member, Emmerugga Dolomite. These examples are actually from the Kilgour River, 40 km from Top Crossing, but similar cycles are present near locality 2.

boundary with the overlying more-resistant dolostones. Some of these dololutite interbeds contains minute rhombic holes which may be former gypsum crystals.

2B: the resistant low cliff consists of interbedded cherty stromatolitic dololutite and red siltstone with incipient brecciation developing laterally into jigsaw-type brecciation with collapse and fall-apart type of textures. Halite and gypsum casts are present. Grey saccharoidal cherty beds and lenses are thought to be mostly after halite (they consist of cubes and deformed cubes of chert). A jigsaw-type breccia is widespread at this stratigraphic level and is interpreted as a collapse-breccia probably resulting from solution of former 'beds' of halite from the top part of the Myrtle Shale.

Near locality 1, (40 km southeast of here) this basal part of the Emmerugga Dolomite comprises 8 clearly defined shallowing up cycles, each 2-4 m thick, shown schematically in Fig. 25. We believe that the section between 2B and 2C also contains these cycles, but the outcrop is not continuous enough to be sure. This locality also contains much more brecciation and more obvious evaporite pseudomorphs than the Kilgour River so it is likely that this is a more continental facies. Photogenic pagoda-type halite casts and rhombic to pseudohexagonal-shaped ?gypsum pseudomorphs are present in large stromatolite domes on the top of the scarp at 2B (Fig. 26, 27).

As will be evident from Figure 25 we are not sure whether these stromatolitic shoaling cycles are marine or continental. They closely resemble published facies models proposed for marginal marine shoaling regressive cycles (e.g. James, 1979), but they also contain a sequence of structures similar to those seen in part of the Holocene ephemeral lake systems in the Coorong region of South Australia.

Pale grey algal laminated dololutites with nodular chert and large steep-sided stromatolitic domes (Fig. 28) flanked by intraclast breccias are visible on the saddle at **2C** and in the resistant bench at **2D**. Occasionally the domes can be seen to be oriented to the northwest,but owing to the discontinuous outcrop, brecciation, and stylolitisation, it has not been possible to clearly establish whether cycles are present here. The very hard and siliceous character of the Emmerugga Dolomite here is probably related to a Cretaceous silcrete.

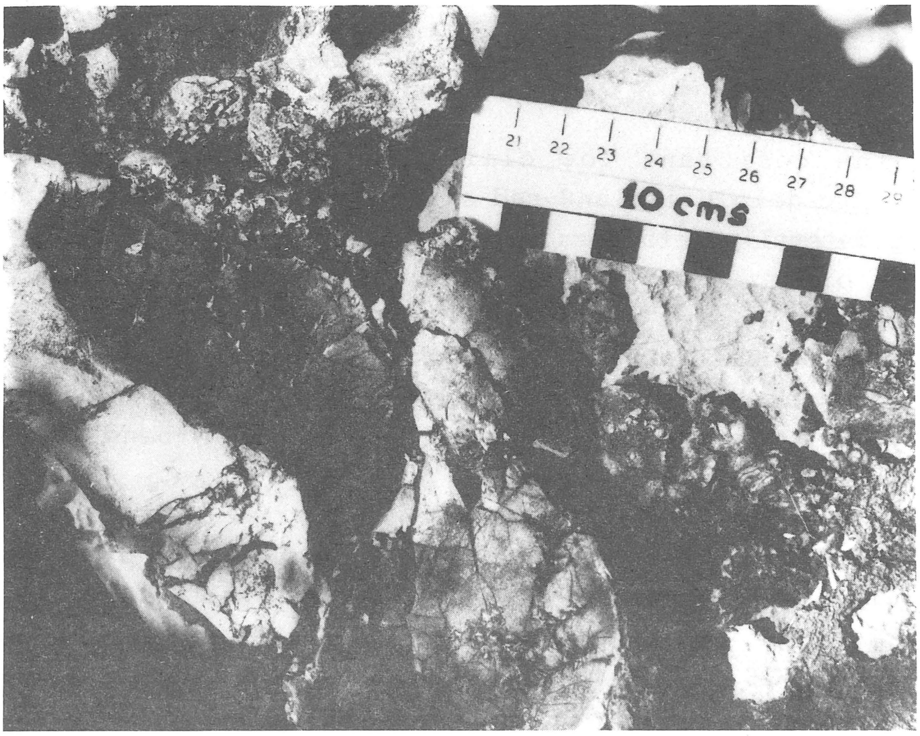


Fig. 26 Outcrop of cherty dolostones containing halite pseudomorphs at locality 2B. Pale grey rock is dololutite, darker grey rock is chert. Note cubic hoppers left centre of photo and pagoda forms at the bottom centre of photo.

Fig. 27 Outcrop of dark brown rhombic and hexagonal pseudomorphs after gypsum in pale grey dololutite at locality 2B.

Fig. 28 Large domal stromatolites and nodular chert diagnostic of Emmerugga Dolomite between locality 2C and 2D

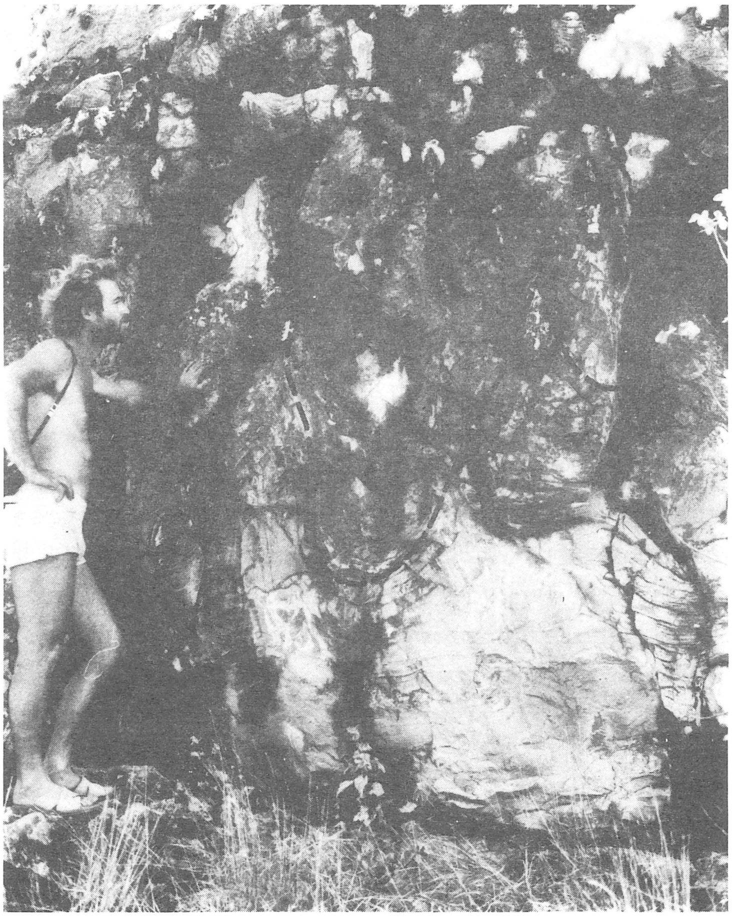


Fig. 29 Lower part of Conophyton bioherm series at locality 2D. Synoptic relief indicated by annotation. Note irregular patches of chert, in places these indicate axial zones of stromatolites.

Discontinuous outcrop and rubble of cherty stromatolitic dololutite between **2D** and **2E** is accompanied by rubble of orange dolomitic siltstone with halite casts indicating continued highly saline conditions.

2E: a 5 m-high strike ridge of dark grey crystalline dolostone with large Conophyton stromatolites at the base grading up into low relief interconnected conical forms at the top. Discontinuous pods of white and grey chert enhance the stromatolitic lamination, especially in axial parts. Fig. 29 shows the lower half of this impressive bioherm series. There is a gradual reduction in synoptic height (height along an individual algal lamination) upwards through the biostrome: this is usually interpreted as indicating a gradual shallowing of the environment. In this case we have been unable to find independent evidence to support this.

If time permits we will continue about 200 m further northwest to **2F** to inspect the karstically-weathered dark grey crystalline dolostone of the Mitchell Yard Member before returning to the bus. As noted earlier the member appears massive and structureless, and it is very difficult to discern even the bedding. Drusy veins, vague brecciation and small pseudomorphs (after ?evaporites) can be found by careful scrutiny. Based on similarities between this unit and the upper part of the Amos Formation (Stop 5) we feel that the texture of the Mitchell Yard is largely due to recrystallisation during deep weathering.

NOTES

STOP 3 LEILA CREEK (GR 7066)

The aim of this stop is to examine the evaporitic Amelia Dolomite sequence at Leila Creek. We will walk up a gentle scarp which consists of small benches of well exposed stromatolitic carbonates and poorly exposed more fissile dololutite and argillite. The main features present are shown in Fig. 30. Many of the McArthur Basin carbonates weather grey to cream, but the Amelia Dolomite here weathers to dark reddish brown. We will see traces of stromatolitic bedding in the dark carbonates, picked out in white chert and also beds of intraclast pebble conglomerate. The dark carbonates on closer examination can be seen to be a felted mass of discoidal siderite crystals pseudomorphing gypsum (Fig. 31). There are several beds of this

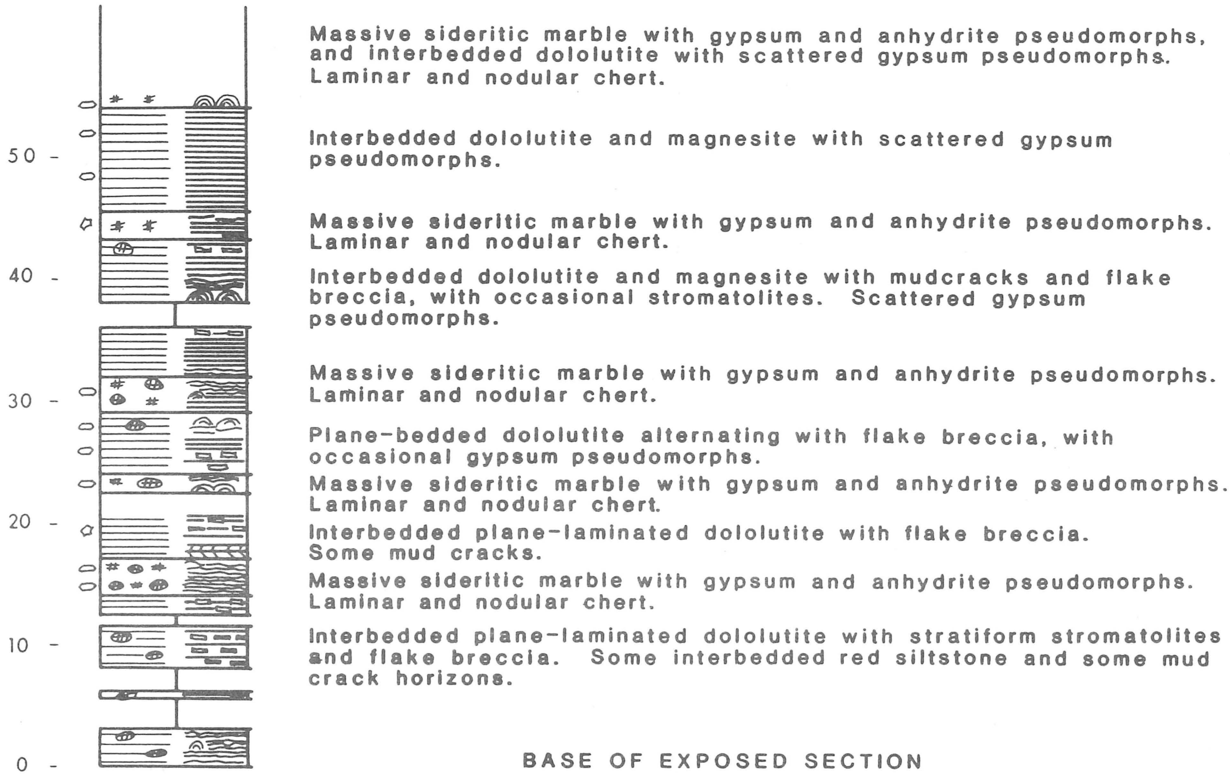


Fig. 30 Measured section of Amelia Dolomite at locality 3.

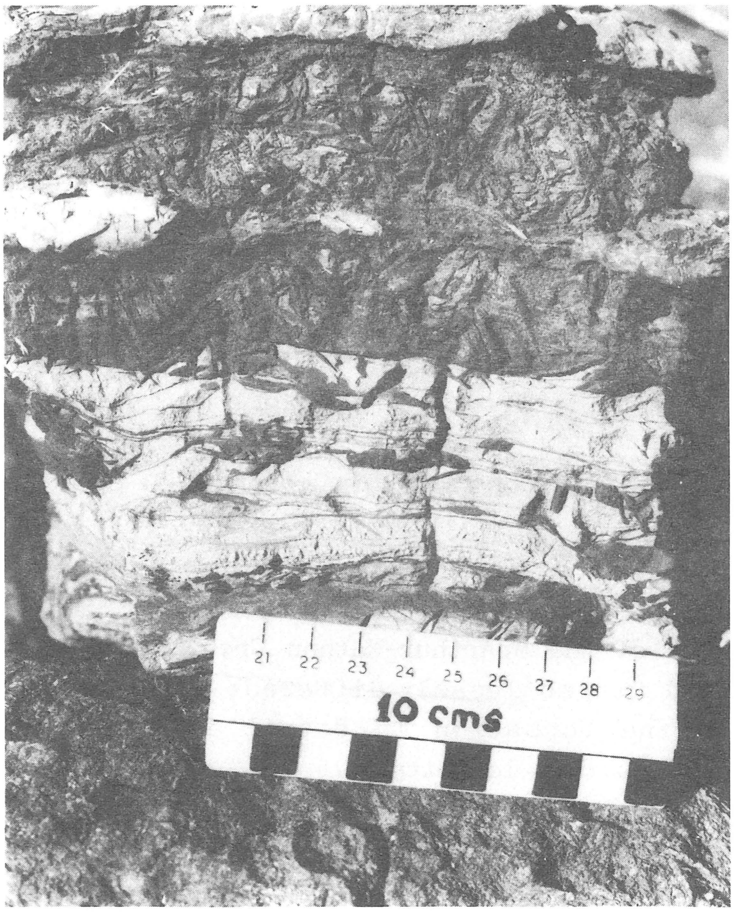


Fig. 31 Gypsum-crystal pseudomorphs of dark brown ferroan dolomite in light coloured dololutite and massive replacement of beds by ferroan dolomite (to form gypsiferous marble), Amelia Dolomite at Leila Creek, locality 3.

in the section. About one third of the way up the section gypsum pseudomorphs are preserved in light coloured dolomite, the contrast offering excellent opportunities for photography. At about this same level, there is a metre-thick section of white magnesite which is somewhat deformed. The magnesite bed is capped by a conglomerate of dololutite clasts. Desiccated silty beds and possible tepee structures are also visible at this level and indicate periods of exposure and groundwater injection in addition to extensive diagenetic evaporite deposition.

Some of the black cherts from this section contain abundant, well-preserved microfossils. Silicification is patchy in this section and although there is a well-developed silcrete at the top of the scarp, the dip slope is unsilicified and there are well preserved stromatolites and oncolites in the gypsum crystal pseudomorph beds. This sequence is interpreted as having been formed in a very arid sabkha environment similar to that of the present Persian Gulf. Although the section here is basically similar to that present at Stop 1, the stromatolites do not form distinctive bioherm series. Stop 1 lacks evaporites and is presumably a more normal open marine environment.

One puzzling feature at this locality is the areally restricted nature of these sulphate evaporites. From the top of this low rise the same stratigraphic section can be seen about 500 m away to the southeast but here there are no evaporites at all!

NOTES

STOP 4 FIRST CROSSING (GR 725684)

AIM

Inspect a short section of the Tatoola Sandstone, as it forms a marked contrast to the bulk of the McArthur-Nathan Group carbonates and seems to have been deposited in a noticeably different environment. Although we have not studied the formation in detail it contains a number of interesting features at this locality.

BACKGROUND

The Tatoola Sandstone is a widespread, thin (max. 100 m) clastic unit that separates the dominantly carbonate Amelia Dolomite and Tooganinnie Formation (Fig. 6). The formation is laterally uniform over the area we have studied. It consists of a lower finer grained thin bedded flaggy, quartz sandstone subdivision and an upper coarser grained thicker bedded dolomitic sandstone subdivision i.e. it represents a widespread (regressive) shallowing event.

STOP 4 DESCRIPTION

The two contrasting facies are visible even in this very small area of outcrop. At the base of the outcrop, the finer grained flaggy facies contains interbedded siltstone and shale. Some of the fine sandstone beds are very hard and flinty and are probably tuffaceous. The bedding is mostly continuous but pinch-and swell is common. An impressive loaded channel with internal slumping forms the main part of the outcrop (Fig. 32). Sandstone beds up to 30 cm thick adjacent to this channel contain plane lamination and hummocky or swaley cross-stratification, capping thin intraclast conglomerate bases. The tops of these sandstone beds are commonly rippled and sometimes draped with siltstone; the bases of the sandstone beds are commonly scoured, as well as loaded into the underlying beds. At the top of the small cliff (where the outcrop starts to deteriorate) coarser grained dolomitic sandstones containing weathered-out swallow-tail gypsum crystal pseudomorphs are present. These sandstones contain larger ripple forms and decimetre-scale trough cross-stratification. At other localities stromatolites, oncolites, and intraclasts attest to a marked shallowing of the environment for the upper part of the formation as it gradually interfingers with the overlying peritidal Tooganinnie Formation.

The presence of features such as climbing ripples, load casts, pinch-and-swell, slumping and hummocky stratification in the lower part of the unit suggest deposition from fast moving, heavily laden, partly storm-generated currents within subaqueous environments deeper than those evident in the upper part of the formation and in the associated carbonate formations we have examined.

Fig. 32 Main part of outcrops of Tatoola Sandstone at locality 4 showing lateral relationships between thin-bedded sands and slump channel-sand.

Fig. 34 Outcrop of dololutite and nodular chert crowded with resistant small cherty pseudomorphs after gypsum (millet seed gypsum) in lower part of Balbirini Dolomite at locality 5.

NOTES

BACKGROUND TO STOPS 5, 6, AND 7

The Balbirini Dolomite is a thick clastic and evaporitic unit that contains a variety of evaporites and stromatolites, similar to those present in many formations in the McArthur Group. It seems to have been deposited within environments similar to those of the lower part of the McArthur Group. Although it is considerably younger the evolution of the Balbirini Dolomite is comparable to the stratigraphic and facies evolution seen in the cycle Mallapunyah Formation through to Emmerugga Dolomite (see Fig. 6). As there is a widespread unconformity at the base of the Balbirini Dolomite, a significant break in sedimentation with tectonism is indicated after deposition of the Batten Subgroup, but before sedimentation of the Nathan Group occurred. The amount of time involved is not known.

A simplified log of the formation at the type section (Fig. 33) shows its main features and the relative stratigraphic positions of the three short stops.

The facies and evaporites near the base of the Balbirini Dolomite are comparable with those seen in the Mallapunyah Formation - Amelia Dolomite sequence (Stop 1) and include both pseudomorphs after gypsum and anhydrite. We will not examine these, but stop 5 has been included as it contains unusual 'millet seed' gypsum pseudomorphs. Stops 6 and 7 are of well exposed distinctive stromatolitic biostromes. The stromatolites at Stop 6 are not unlike those in the Mallapunyah-Amelia section, but those at Stop 7

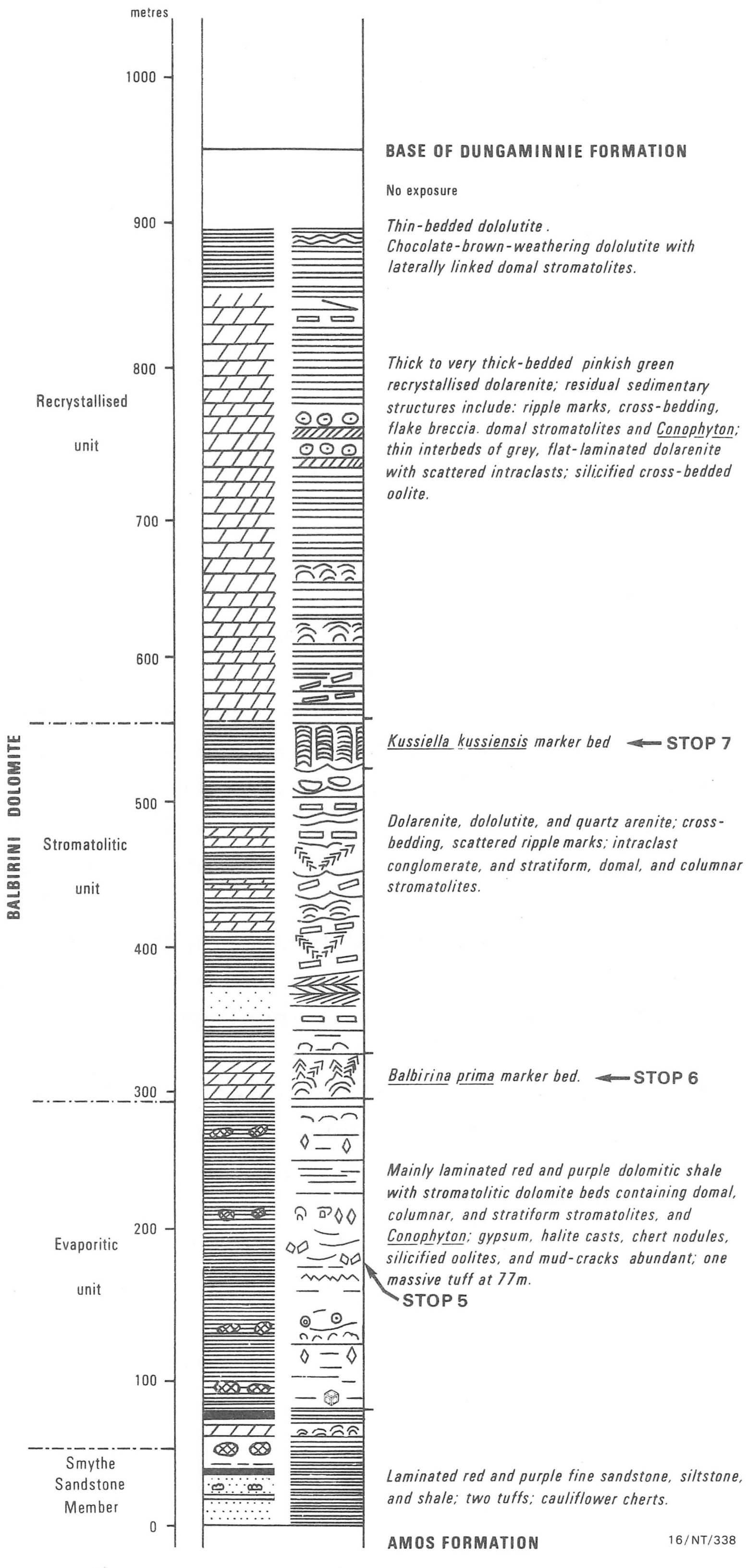


Fig. 33 Simplified and generalised reduced log of type section through the Balbirini Dolomite with Stops 5, 6 and 7 shown.

are unlike any seen elsewhere in the basin.

STOP 5 EVAPORITES IN THE BALBIRINI DOLOMITE TYPE SECTION (GR 784473)

DESCRIPTION

The aim of this stop is to examine part of the lower evaporitic subdivision of the Balbirini Dolomite. The outcrops to be examined contain alternations of carbonates with redbeds. The red siltstones and fine sandstones contain scattered halite casts and range in colour from green to brown, red, and purple. Two prominent pink "tuffites" mark the base of the evaporitic section. The more resistant carbonates include stromatolitic and oolitic dololutites and intraclastic dolarenites. One of the dololutite beds contains unusual silicified discoidal casts after gypsum (Fig. 34) with silicified seams of fibrous quartz which replace fibrous gypsum.

The gypsum crystals are interpreted as having formed by displacive growth within carbonate sediments. They are identical to recent gypsum crystals that we have been shown in Marion Lake in South Australia. The fibrous seams represent mobilization of gypsum-rich groundwater during early diagenesis.

STOP 6 BALBIRINA PRIMA BIOHERM SERIES IN THE TYPE SECTION (GR 790475)

The aim of this stop is to examine a striking bioherm series in the Balbirini Dolomite. The exposure is a short drive away and up-section from the evaporite locality. The bioherm series (Fig. 35) forms a distinctive marker horizon which can be traced laterally for 180 km. We will see a basal stratiform stromatolitic sequence about 60 cm thick, followed by 30 x 30 cm domal stromatolites with occasional small Conophyton between domes. The next unit in the bioherm series consists of 40 cm of bushy branching cherty columnar stromatolites (synoptic height 1 cm, column width 2 cm and column height 25 cm).

The most striking feature of the bioherm series is the 60-80 cm of branching Conophyton-like stromatolites (synoptic height 15-20 cm and 10-15 cm) overlying the columnar stromatolites.

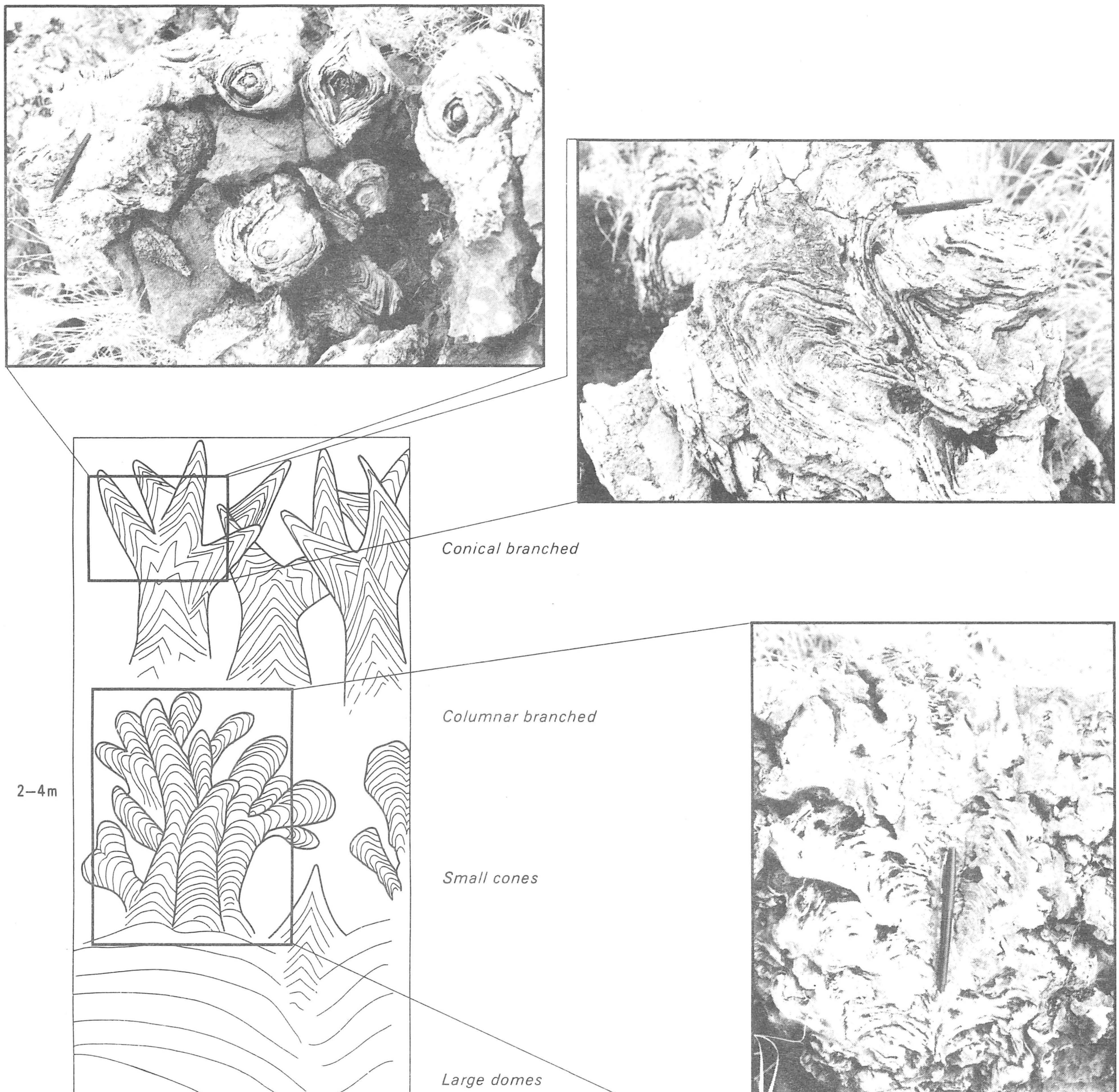


Fig. 35 Part of the Balbirina prima stromatolite biostrome at Stop 6.

Above this, we will see stratiform stromatolites which contain a well-preserved microfossil assemblage.

The bioherm series is variably silicified. The bluish-black cherts of the uppermost stratiform stromatolites are likely to contain well-preserved microfossils. The whitish chalcedonic chert, which partially or totally replaces many of the columnar and conical stromatolites, has destroyed many of the early carbonate fabrics as well as the organic matter. We interpret the depositional environment as being mainly subaqueous with the stromatolites forming in shallow pools. The microfossil assemblage indicates emergent conditions like the supratidal flats of the present day Persian Gulf. The overall environment is as likely to be lacustrine as marine.

STOP 7 KUSSIELLA KUSSIENSIS BIOHERM SERIES IN THE TYPE SECTION

After a further short drive, we will walk up a small hill to examine the *Kussiella kussiensis* bioherm series. The outcrop consists of yellowish weathering calcian dolomite, which, in contrast with the *Balbirina prima* bioherm series, is not silicified. The *Kussiella kussiensis* bioherm series is illustrated in Figure 36. Although the basal unit of the 15 m thick bioherm series consists of stratiform stromatolites, the most obvious structures are the large (50 cm) domes, and the parallel branching columnar forms of variable column height and width. We will see edgewise conglomerates between the columns, the intraclasts being composed of spalled-off laminae.

This bioherm series which is about 15 m thick, is a very persistent marker biostrome and has been mapped over a distance of at least 500 km. It is associated with Pb-Zn mineralisation in a number of places. Although it resembles the type of bioherms than form reefal barriers in other places (e.g., mid Proterozoic of NW Canada) evidence for the presence of such a feature in the associated facies is not present.

We interpret the depositional environment as being subaqueous. No erosional or desiccation features were observed within or immediately above the biostrome at this locality, but the water must have been shallow enough for storm activity to break up some of the laminae to form the intercolumnar conglomerates.

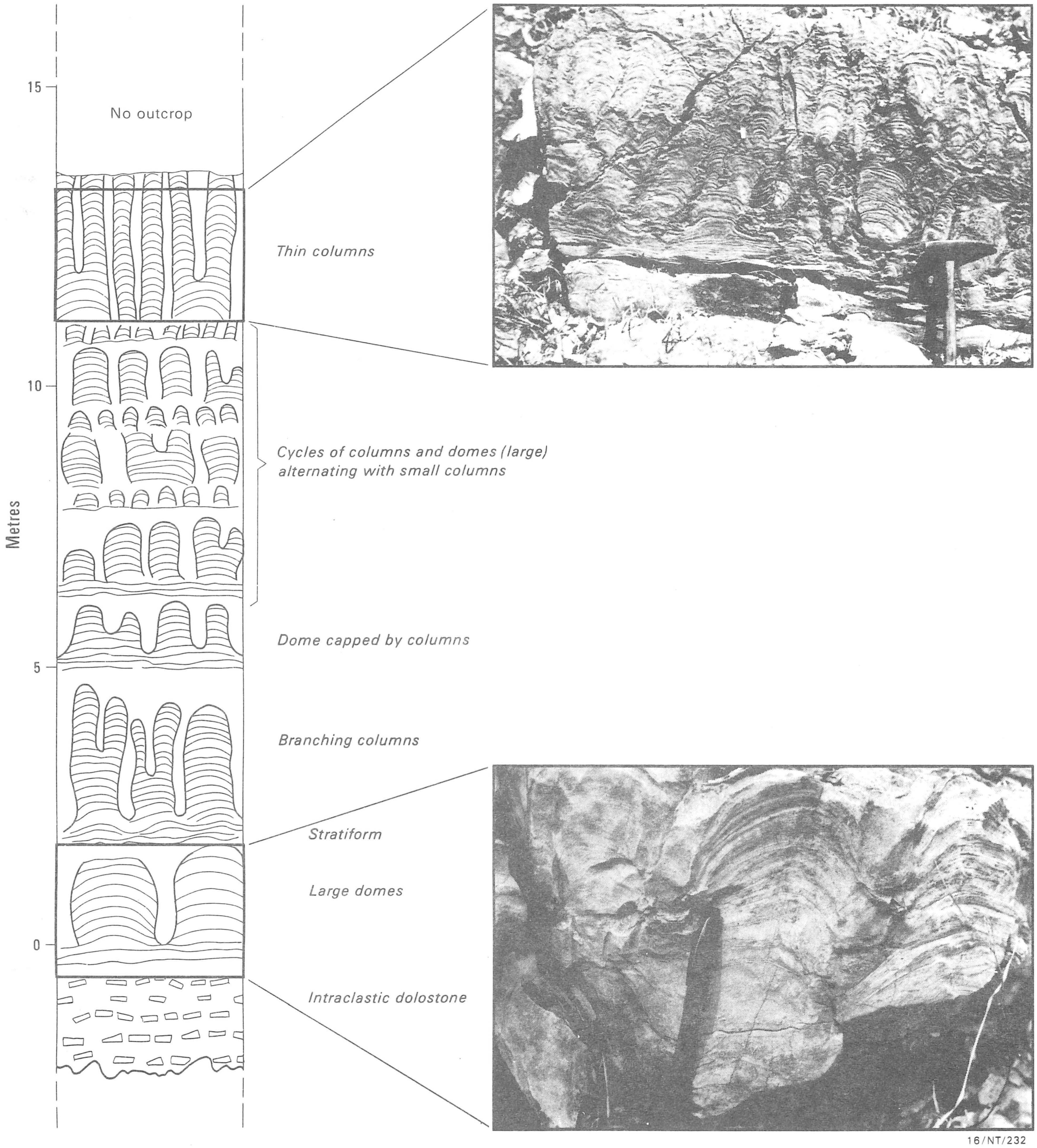


Fig. 36 Part of the Kussiella kussiensis stromatolite biostrome at Stop 7.

NOTES

STOP 8 SKULL YARD (GR 787464)

BACKGROUND

The Amos Formation immediately underlies the unconformity at the base of the Balbirini Dolomite (last 3 stops) and is the youngest formation in the McArthur Group (Fig. 6). It is preserved only in a small area along the western side of the Abner Range and presumably has been eroded away from all other areas. The low karstic outcrops of the formation at this locality form strikingly unusual scenery (Fig. 37) for the McArthur area. The heavily jointed massive brownish grey dolostone with clint-and-grike surfaces is quite different from all other carbonate units in the McArthur Basin, with the possible exception of parts of the Mitchell Yard Member of the Emmerugga Dolomite.

In this formation we again see the common stratigraphic trend of continental clastics and redbeds gradationally overlain by carbonate rocks, except that here the upper part of the formation appears to represent a deep weathering or alteration profile, 'calcrete' for short. The main aim of the stop is to examine 1) the gradational change from fluvial clastic through to ?marine carbonates, and 2) the character of the calcrete profile. If time permits, we may examine the topmost few metres of the Amos Formation and the ferruginised unconformity surface (although this requires a short drive).

Fig. 37 Karstically weathered Amos Formation near top of section at Stop 8.

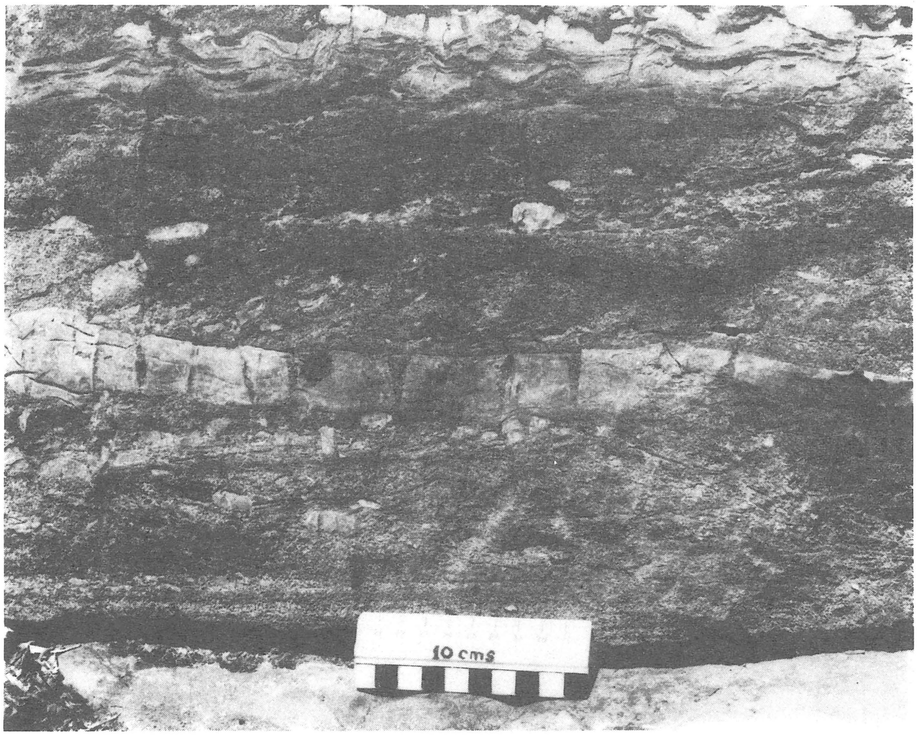


Fig. 39 Desiccated dololutite layers in coarse grained sandy dolarenite with dololutite intraclasts in Amos Formation at Stop 8, at about 50 m in type section.

DESCRIPTION

The section is about 200 m long and extends from a road-cut on the Tablelands Highway up a fairly steep scarp to a rocky knoll (Fig. 38). Strong boots are recommended. The lowest part of the section seen in the road-cut comprises reddish purple ferruginous and micaceous sandstone and siltstone. This is patchily dolomitic and also mottled and carbonate veined. Although not particularly clear, we tentatively identify thin fining-up cycles in these roadside outcrops. They appear to have sharp eroded bases, and contain cross-bedded sandstone overlain by ripple laminated sandstone-silstone. The siltstone is commonly desiccation-cracked and the vuggy, mottled and brecciated tops of these cycles are possibly pedogenic in origin.

These basal beds are succeeded by interbedded redbeds and grey dolostones; the redbeds gradually diminish between abut 30 m and 50 m (Fig, 38) i.e. in the discontinuous outcrop in the lower half of the slope east of the road-cut. Grey dolarenites and dololutites with quartz and chert granules, and beds of pink and white chert dominate between 50 and 60 m. As in other formations these cherts are potassium-rich and were originally thought to be tuffs. Shards and crystals are not evident in thin section so this cannot be proved and they may be evaporitic in origin. One of them contains unusual rhombic holes: the original mineral forming these is not known, but one suggestion is that it may have been shortite (Na, Ca, carbonate). Desiccation cracks and intraclasts in the enclosing dololutites are common; the dolarenites are cross-bedded and commonly graded, and contain ripped-up clasts of the dololutites (Fig. 39). Erosion of both chert (e.g., Fig. 40) and dolostones beds indicates several episodes of prolonged exposure.

Above about 60 m (Fig. 38), at the base of continuous rugged outcrop, structures and textures gradually become diffuse, and massive recrystallised carbonates with stylolites predominate. Pisoids are apparent at about 68 m (0.5-3 cm in diameter), and increase in abundance and size (up to 20 cm) upwards (Fig. 41 and 42). Muir (1983) interprets these as pedogenic pisoids formed in a calcrete profile. Apart from the pisoids, the most striking feature of the upper part of the unit (70-87 m) is the abundance of stylolites -- parallel, oblique, and perpendicular to bedding. Many of the stylolites enclose 'clasts' containing vague laminations (original bedding) and pisoids commonly adjoin stylolites.

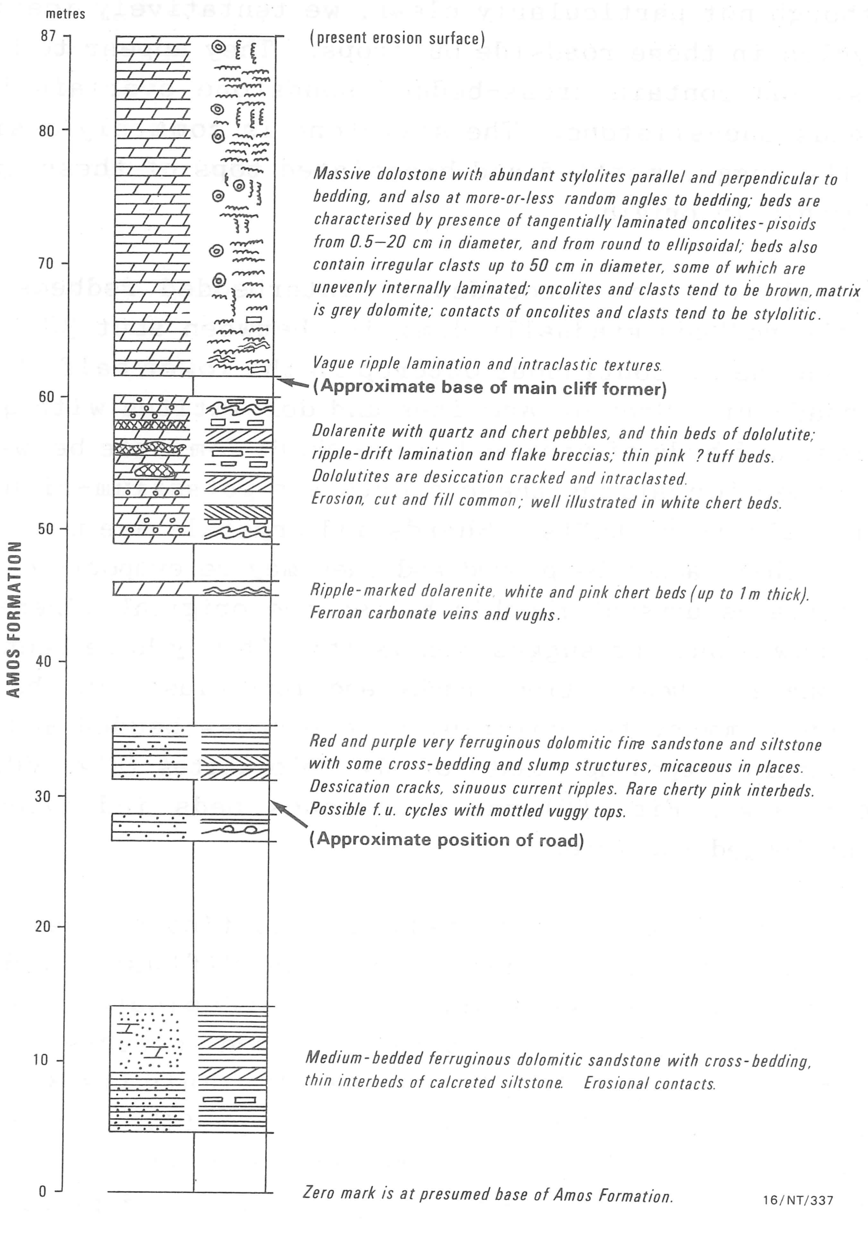


Fig. 38 Type section of Amos Formation, Stop 8.

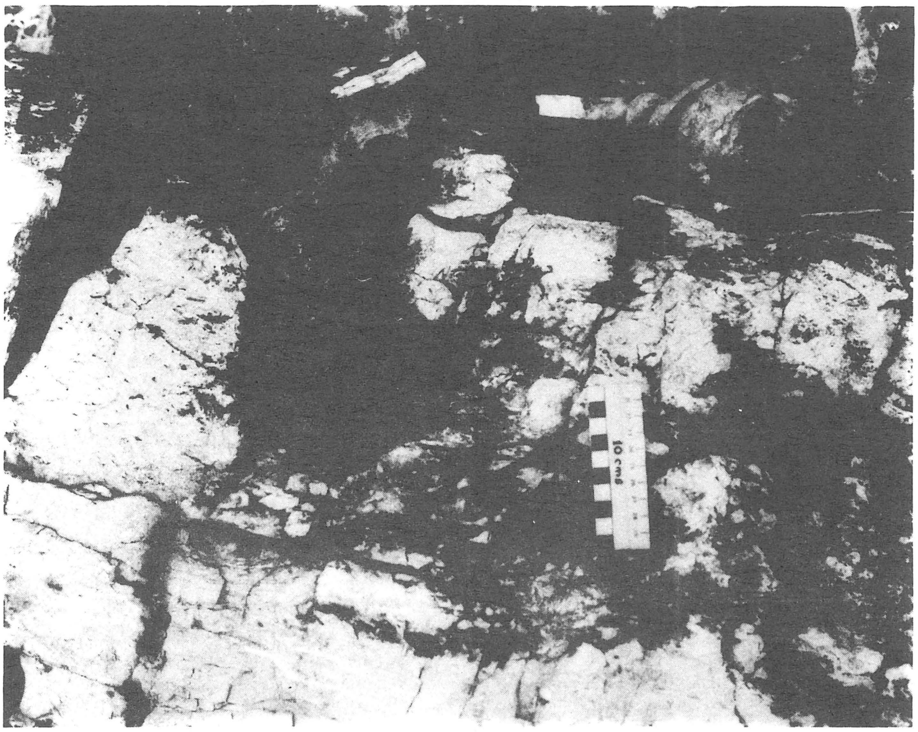


Fig. 40 Pot-hole in a white chert bed at about 58 min the Amos Formation at the type section (Stop 8), indicating chertification is mid Proterozoic in age. ?Evaporitic dolarenite fills pot-hole.

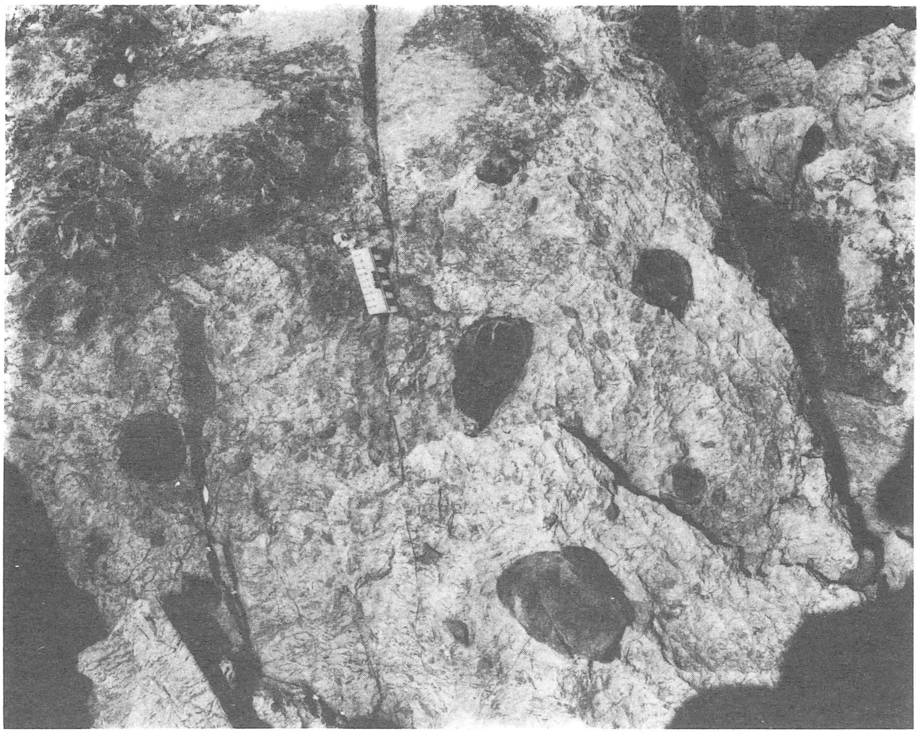


Fig. 41 Typical appearance of calcreted Amos Formation at top of hill at Stop 8. Massive stylobrecciated dolostone (pale grey) containing scattered pisoids (a few cm to 20 cm across).

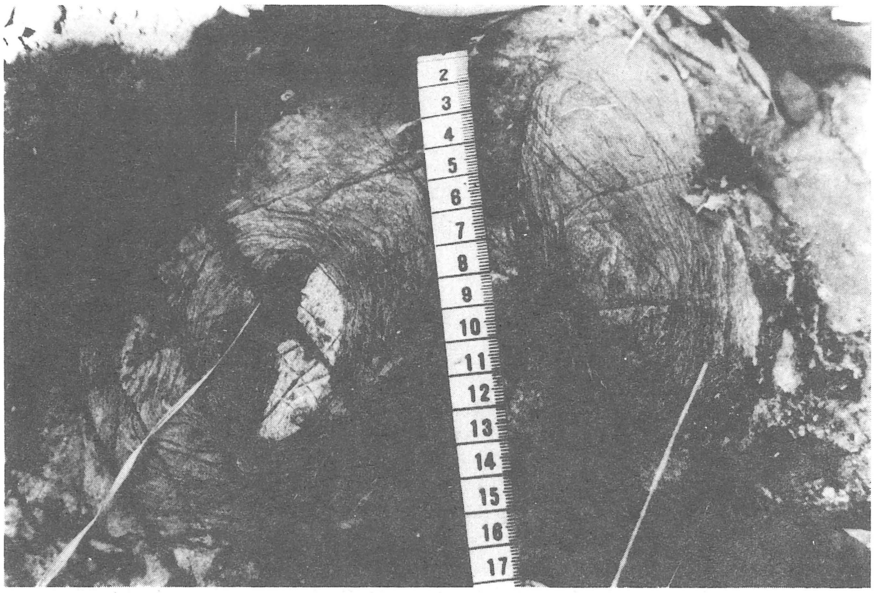


Fig. 42 Close up of two pisoids showing well laminated structure.

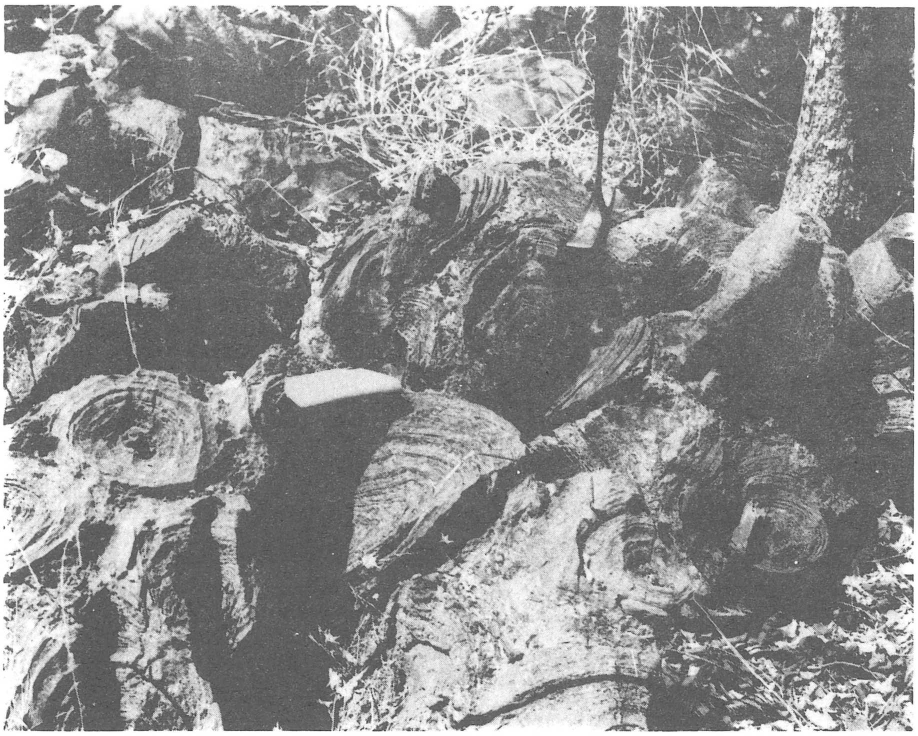


Fig. 44 Leaning conical stromatolites at Stop 9. The inclination of the individual stromatolite forms is indicated by the resistant central part of the cone on the right. The shaft of the pick is vertical, and the note book lies along the regional bedding.

The uppermost 20 m of the Amos Formation has been karstically weathered and contains numerous solution features -- such as karstic fluting, enlarged joints, caves, flowstones, and stalactites. The top surface of the formation is marked by a layer of ferricrete 2 cm thick.

In summary, the Amos Formation occurs only in a few localities, and appears to represent a series of weathering profiles developed on older carbonates and arenites. The underlying, and possibly in part equivalent, Looking Glass Formation (Fig. 6) is commonly extensively silicified both in the surface and in drill-core indicating a Proterozoic age for the silicification. The two together reinforce our interpretation of a deep weathering event at the top of the McArthur Group. This must represent one of the oldest reported occurrences of calcretes and silcretes. The mottling and veining of the redbeds in the road cut is seen as an additional example of Proterozoic soil formation and subaerial weathering similar to that occuring today on alluvial plains.

If we have time to visit the very top of the Amos Formation at its contact with the overlying Nathan Group the exposed pisoidal surface will be seen to be overlain by a thin ferricrete layer which hugs the contours of the pre-Nathan Group surface. The basal Nathan Group herè consists of fine-grained red siltstone and fine micaceous sandstone.

NOTES

STOP 9 HEARTBREAK HOTEL AIRSTRIP (GR 784545)

The aim of this stop is to examine an unusual and puzzling biostrome of leaning Conophyton-like stromatolites in the Dungaminnie Formation which is the youngest carbonate formation in the McArthur Basin (Fig. 6). The Dungaminnie Formation occurs at the northern end of the Abner Range and crops out over an area of about 6-8 sq km. In this respect, it is similar to the Amos Formation; presumably it also was originally more laterally

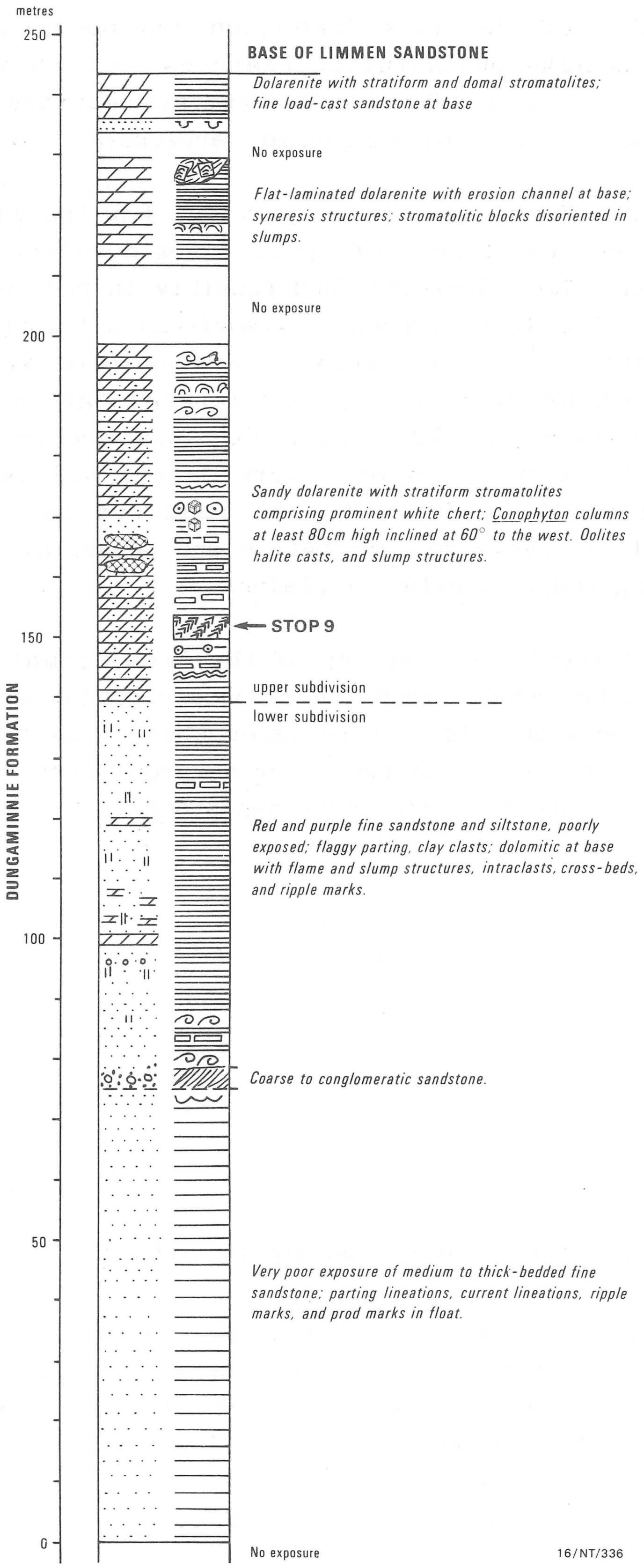


Fig. 43 Type section of Dungaminnie Formation at Stop 9.

extensive, but has been largely eroded away. The formation at the type section (Fig. 43) consists of a lower two-thirds of shallow marine quartz sandstone and dolomitic sandstone and an upper one-third of sandy dolostones with intraclasts, oolites, rare stromatolites and rare evaporites (halite). We will examine only the bench containing the stromatolite biostrome so will not dwell any further on the formation in general.

The leaning stromatolite biostrome is about 2-3 m thick and can be traced for at least 200 m along strike before the outcrop deteriorates. It has a sharp planar base, and appears to have a gradational top, although the upper contact is not well exposed. The base rests on a discontinuous breccia bed which infills hollows in an irregular eroded surface at the top of the underlying dolostone - the biostrome appears therefore to represent a distinctly transgressive facies. The underlying dolostones are mostly flat-laminated, but ripples-in-drift, intraclast breccias, desiccation cracks, and white chert blebs (evaporite pseudomorphs?) indicate that the sediments -- like most other similar formations in the basin -- were deposited under shallow-water high-energy conditions probably in an arid environment, before they were exposed and eroded.

Individual cones in the biostrome are circular, oval, or tear-shaped in plan; the plane of symmetry in the non-circular forms trends southwest, and the pointed ends of the tear-shaped stromatolites are inclined to the northeast (Fig. 44). The individual cones have a uniform size, and a maximum diameter of about 25 cm. Inter-column spaces comprise either fine-grained dololutite or intraclastic debris. Unlike most other specimens of Conophyton in the McArthur Basin -- which grew vertically -- these forms all lean uniformly in one direction. With bedding restored to horizontal, this attitude is 60° (from the vertical) towards the west and southwest.

We have been unable ascertain the reason for this steep, but uniform, attitude for the individual cones. It is possibly related to prevailing currents - we welcome any suggestions.

NOTES

STOP 10 THE ABNER SANDSTONE AT BEETLE SPRING

BACKGROUND GEOLOGY

The Abner Sandstone is one of three thick quartz arenite formations in the Roper Group, the other two being the Limmen Sandstone at the base of the group, and the Bessie Creek Sandstone at a higher stratigraphic level than the Abner (Fig. 7). Recent interest in the Abner and Bessie Creek Sandstones has centred on their potential as oil reservoirs, following the discovery of live oil in the Roper Group in 1985 (Jackson & others, 1986). Prior to this the main interest in the Abner Sandstone was because of the spectacular karst-like landforms developed at some localities (e.g., Jennings, 1983).

The Abner Sandstone ranges from less than 50 m thick in outcrops east of the Emu Fault, through 200 m in the Abner Range and in the Roper Bar area, up to 600 m or more in most southwestern outcrops. In the southeastern outcrops, including those at Stop 10, two members have been recognised, but in all other areas 4 or 5 members can be mapped; these correspond roughly to 5 facies assemblages. The major assemblage in the formation, assemblage 3, constitutes 213 m out of the 225 m of the formation at Beetle Spring (Stop 10), and is the only facies to be examined at this stop. Fine to medium grained, generally well-sorted quartz arenites dominate the formation, except in the area north of the Roper River, where interbedded shale, siltstone and sandstone, of facies assemblage 2, is the dominant lithofacies. The sandstones are mineralogically supermature, with some sands containing 99 percent plus of quartz grains.

Facies assemblage 3 of the Abner Sandstone has been interpreted as the product of deposition on a tide-dominated shelf (Sweet, 1986), and it is likely that parts of it represent intertidal flat environments.

DESCRIPTION OF STOP 10

We drive southwestwards along a fence-line towards the Abner Range, reaching the foot of it about 1 km north of Beetle Spring. In the 2 km before reaching the stop we pass over a small anticline containing McArthur Group in its core, and pass quite near the site of BMR Stratigraphic drill hole Bauhinia Downs 4, which intersected Looking Glass Formation (Fig. 6) containing globules of bitumen and other hydrocarbons in vughs (Muir and others, 1980). This was one of the factors that encouraged us to study the hydrocarbon potential of the McArthur Basin. Ground inspection begins at a point near the right side of Fig 45.

A: As we walk up the slope of the low ridge in front of the main escarpment of the Abner Range we will traverse unexposed Mainoru Formation, then a 27 m section of Crawford Formation. Hummocky cross-stratified coarse siltstone and fine sandstone, which characterise the Crawford Formation in most localities, are not exposed at Stop 10, but it is possible that they are present beneath rubble on the scarp slope. These features are present in the formation only 11 km to the northwest. The facies cropping out at stop 10 is a shallow water one, possibly representing beach or tidal flat, as it consists of trough cross-bedded sandstone with mudcracks and current ripples on some bedding surfaces. A poorly outcroping zone of siltstone and fine sandstone is present between these sandstones and the base of the Abner Sandstone.

B: The contact of the Crawford Formation and Abner Sandstone is sharp, and the possibility that there is a disconformity at this level cannot be ruled out. The basal beds are red, due to the presence of hematite cement, which postdates the main quartz cement. The hematite forms irregular bands and may represent a phase of intrastratal fluid migration much younger than that which led to the primary cementation of the sandstones. If you attempt to sample the sandstone you will find that it is extremely friable, and is now virtually lacking cement. Thin section studies suggest that this is a secondary phenomenon, probably due to solution along grain boundaries during a relatively recent weathering episode. Such a mechanism, described by Martini (1981) and favoured by Jennings (1983) to explain the formation of caves in sandstone, is believed to have operated in the Abner Sandstone, and confirms, that the landforms are true karst, not a pseudokarst. (Provided that one defines karst as the landforms due to predominantly solution processes, no confined to carbonates; see Jennings, 1983 for discussion).

C: Curved joints are present in the lower part of the Abner Sandstone near C. They consist of silicified zones which form segments of cylindrical bodies, and also sigmoidal shapes. No evidence of distortion of cross-bedding has been seen which therefore militates against an explanation involving planar joints which became curved during minor shearing movements. The origin of the joints is unknown.

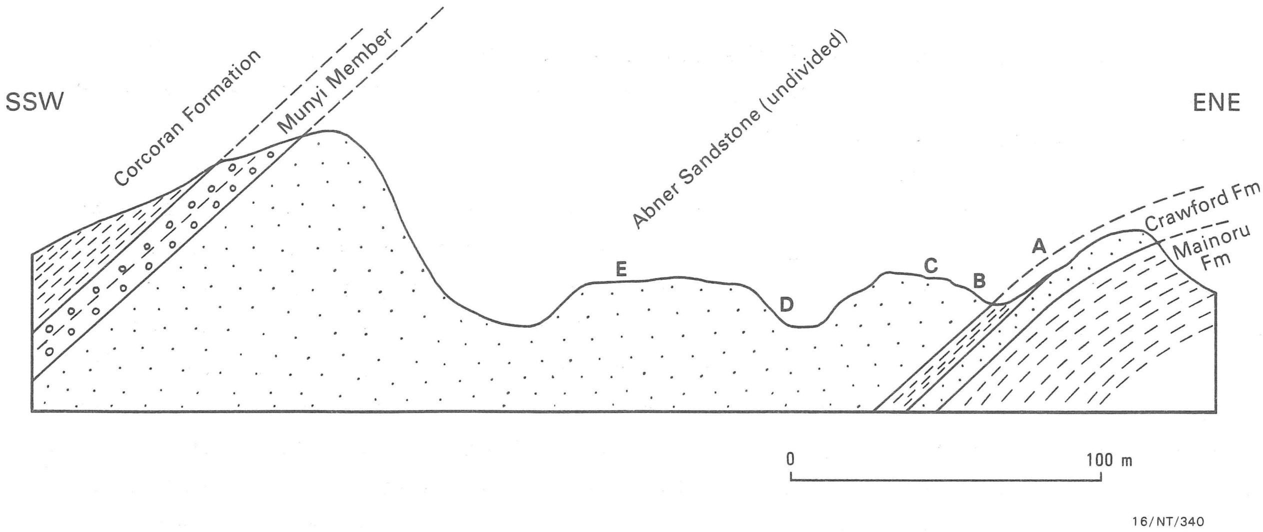


Fig. 45 Generalised cross-section of the Roper Group near Beetle Spring (Stop 10).

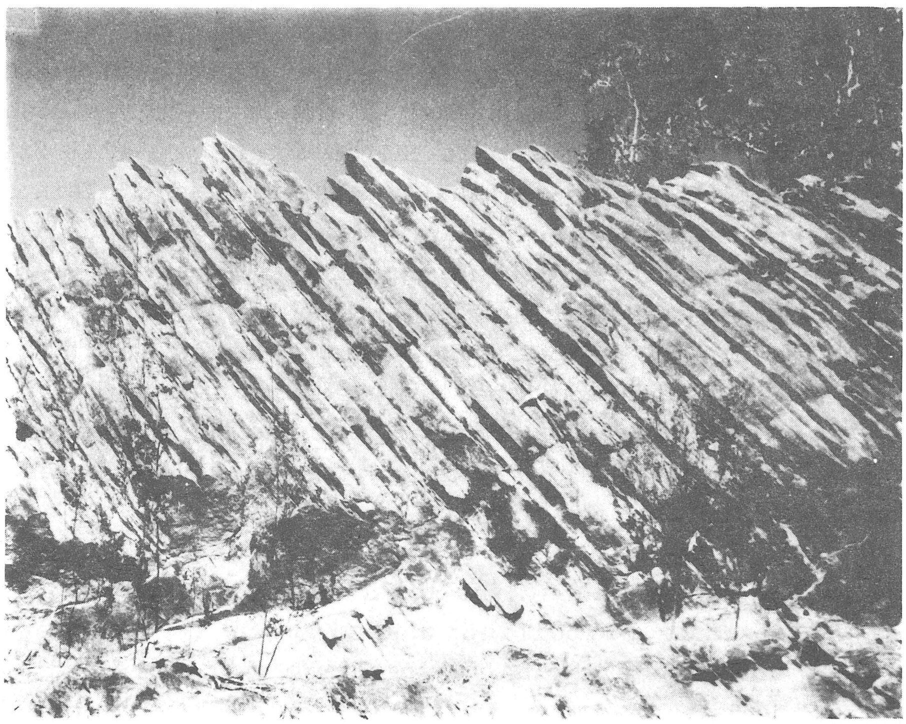


Fig. 47 Characteristic bedding in the lower part of the Abner Sandstone at Stop 10. When examined in detail trough cross-beds are often recognisable in beds which appear massive or plane-bedded. Note the hammer for scale.

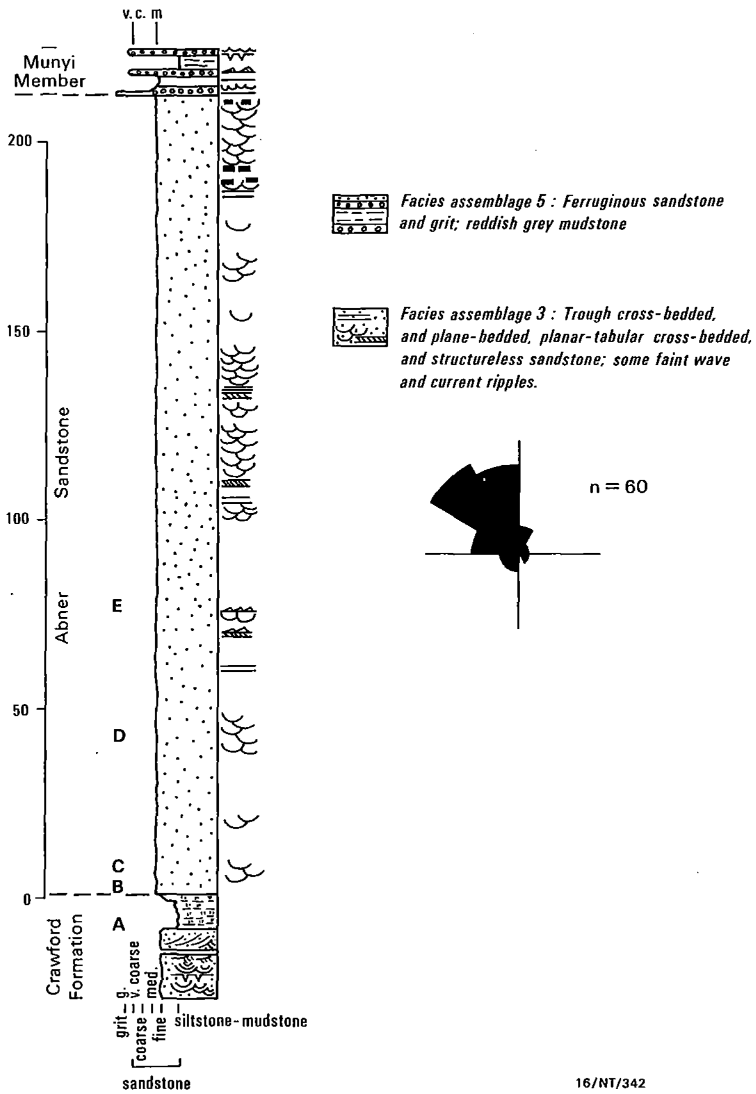


Fig. 46 Measured section of the Crawford Formation and Abner Sandstone at Stop 10.

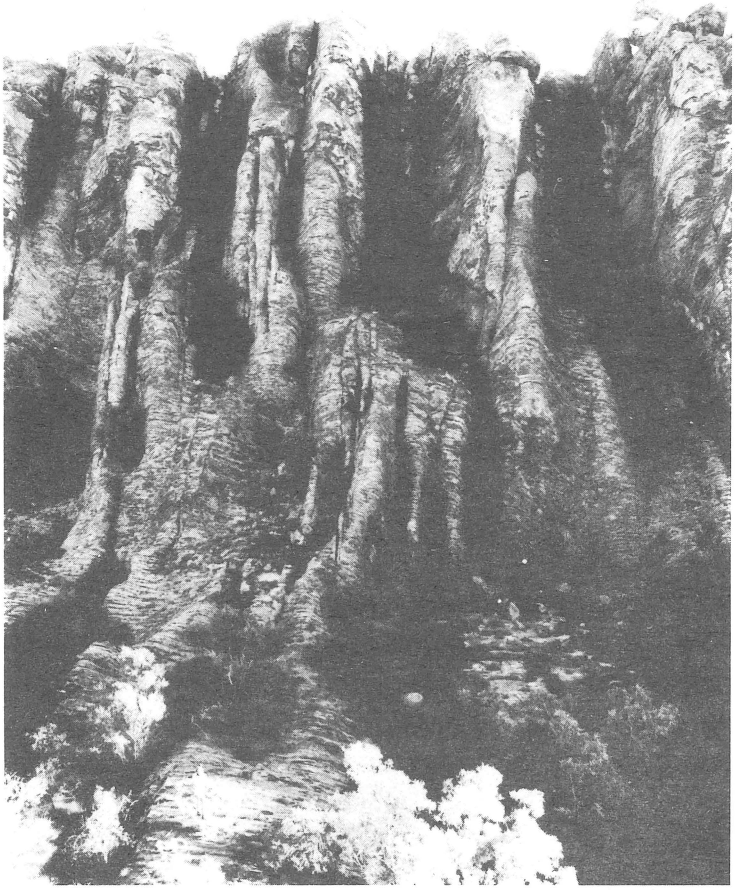


Fig. 48 Cliff of Abner Sandstone forming the eastern escarpment of the Abner Range 1 km north of Beetle Spring; accelerated wasting of sandstone along subvertical joints has led to the development of a series of chimneys and intervening buttresses. Cliffs are about 60 m high. Figure in foreground for scale.

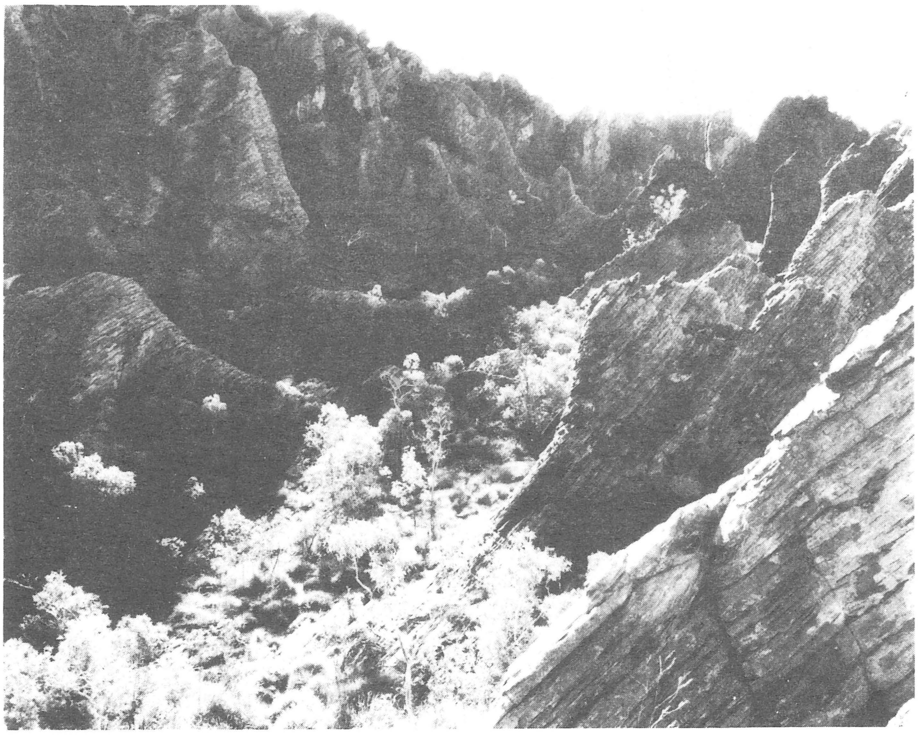


Fig. 49 Karst topography developed in Abner Sandstone 1 km north of Beetle Spring, Abner Range. View is taken looking north.

D: The main features of Facies Assemblage 3 of the Abner Sandstone (Fig. 46) are displayed at D, viz. its uniform fine to medium grain-size, trough cross-bedding, plane bedding, and planar, poorly silicified bedding plane (Fig. 47). You may fine wave ripple marks on some bedding planes if you search hard, but they are generally poorly preserved because of the lack of silicification. Palaeocurrent studies reveal a bimodal, bipolar distribution for readings of foreset bedding, with one mode dominant. Such a pattern, and the other features described, have led to the interpretation of this facies assemblage as representing a tide dominated shelf (Sweet, 1986). Sandwaves are an important bedform in such environments, and evidence for their existence might be expected to be preserved in these outcrops. No conclusive have been documented, but a crossbed set over 0.5 m thick, with very prominent normally graded foreset laminae, observed in outcrops north of the Roper River, may be a bedform of the type described by Terwindt (1970), Allen (1981) and others. Mud drapes are absent from the Abner Sandstone and this may result from deposition in a generally mud free environment.

E: Excellent views of the Abner Range escarpment can be had from Point E. The buttresses which extend out from the main cliff line are well displayed (Fig. 48), as are the karstic landforms (Fig. 49). Similar landforms develop on much of the Bessie Creek Sandstone within the Abner Range syncline (Fig. 50).

NOTES

Fig. 50 Aerial view of Bessie Creek Sandstone in the Abner Range, showing the development of pinnacle karst in a supermature quartz sandstone; pinnacles are up to 30 m high.

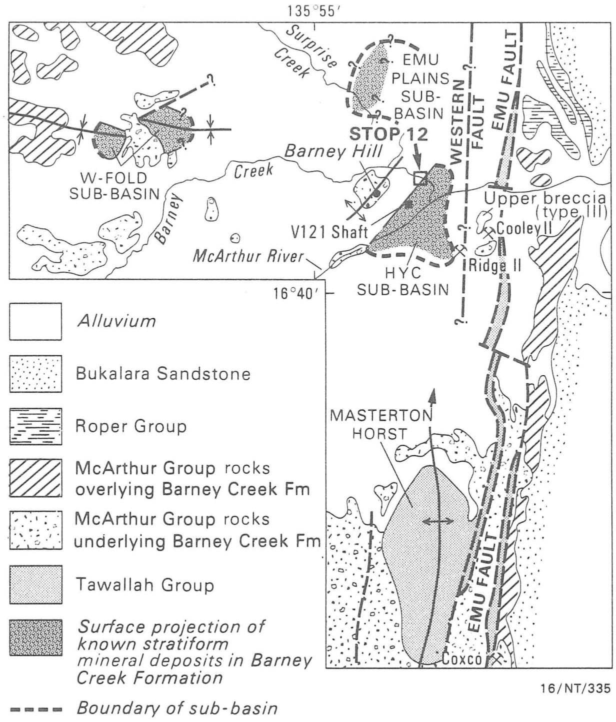


Fig. 51 General map of McArthur Mine area showing extent of individual mineralised sub-basins.

STOP 11 BESSIE SPRING (GR 9056)

This locality has been included solely for its recreationalquality. We plan to have lunch here and have allowed time for a swim. The cliffs forming the sides of the waterhole are of Abner Sandstone of a similar facies to that seen at Beetle Spring.

STOP 12 BARNEY CREEK (not on Abner Map)

BACKGROUND

The McArthur Basin is well known for its large disseminated stratiform base metal deposit at the HYC (Here's Your Chance) Mine. The mineralisation occurs in the HYC Pyritic Shale Member of the Barney Creek Formation in about the middle of the McArthur Group (Fig. 6). As indicated on Fig. 6 the deposition of the Barney Creek Formation was greatly affected by penecontemporaneous faulting along the Emu Fault Zone. Rapid facies variations (over only a few km) are evident in small sub-basins that developed close to the Emu Fault. Figure 51 shows the main mineralised sub-basins -- none of them is more than a few square km in size. Unfortunately for us, the Barney Creek Formation seldom crops out so this intriguing relationship between sedimentation and mineralisation is difficult to demonstrate. In addition, we have done very little work on the unit - most of the information is derived from extensive company studies of drillcore and underground excavations.

There are, however, some natural outcrops in Barney Creek adjacent to the mine where we can see some aspects of this part of the stratigraphic section. The upper part of the underlying Teena Dolomite and part of the ore sequence is exposed. Ore beds and interore breccias of the HYC Deposit (227 mt of 4.1%Pb, 9.2%Zn,41 ppm Ag) are exposed in the creek, and one of the mineralised interore breccias, which forms the gossan, crops out nearby. We will walk along the creek section (Fig. 52) and drive to the gossan outcrop. Because it is the only section available we ask you not to use hammers.

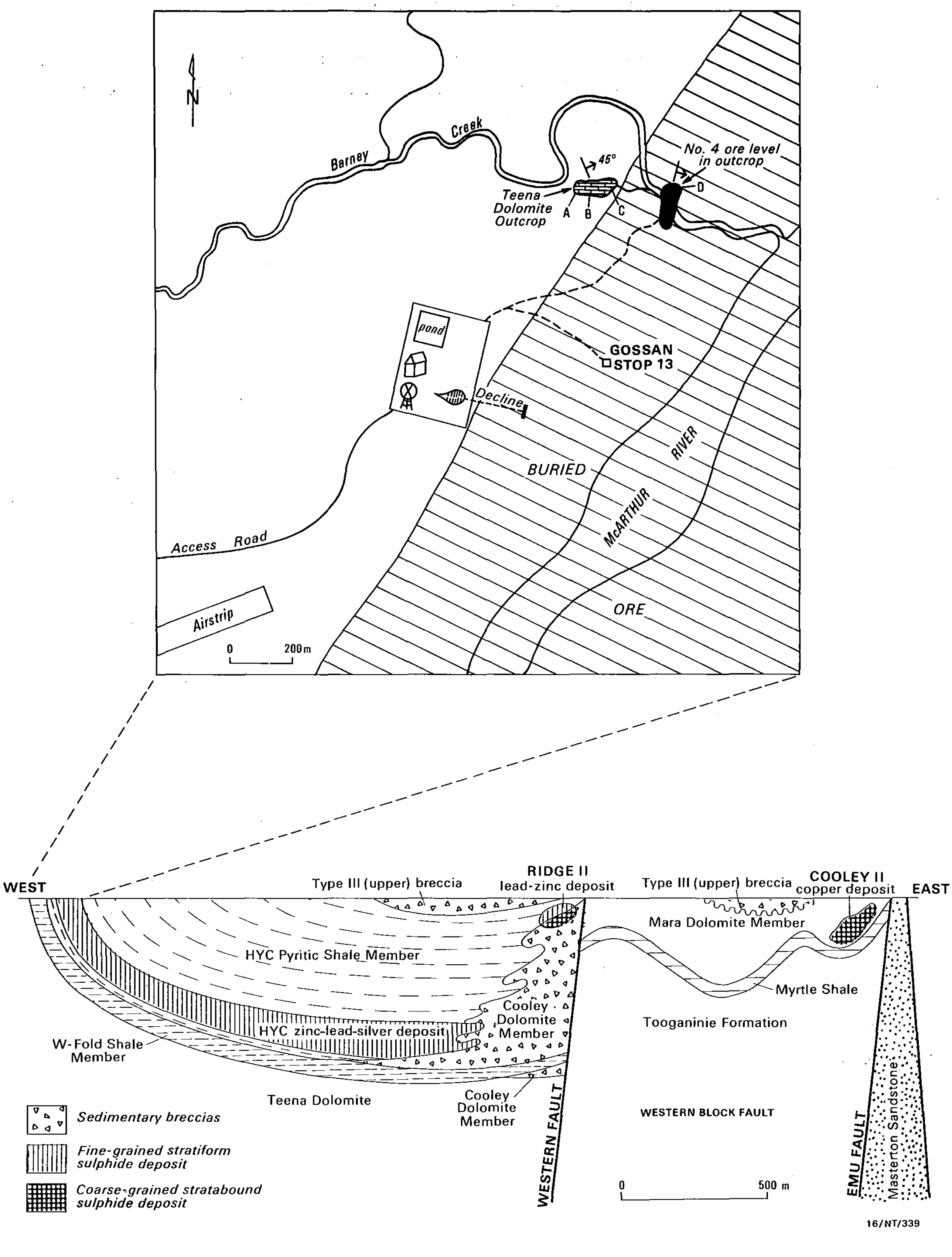


Fig. 52 Detailed map of localities 12 and 13 and cross-section showing attitude of beds in subsurface.

DESCRIPTION OF STOP

The Teena Dolomite largely consists of thick to thin bedded or laminated dololutite, with abundant chert nodules in places. The Coxco Dolomite Member (the upper part of the Teena Dolomite), which we will see in Barney Creek, comprises thick to thin-bedded dololutite with abundant casts after radiating gypsum needles which have six-sided cross-sections, and discoidal and monoclinic crystal casts also after gypsum. These are clearly visible between locality B and C.

A most distinctive rock type seen at the beginning of the section (A) is the orangey-yellow "paisleyite" (Fig. 53). The patterning is interpreted as being a liesegang-type effect resulting from weathering. The age of the weathering is somewhat equivocal, but blocks of "paisleyite" occur in the interore breccias of the Barney Creek Formation. Galena veins and crystals up to 5 mm in diameter are associated both with the "paisleysite" and the crystal casts along the creek.

The depositional environment of the Teena Dolomite is interpreted as supratidal or lacustrine and evaporitic. The "paisleyite" implies periods of at least partial emergence and vadose alteration.

Good exposures of the weathered ore beds and interore breccias can be seen in the creek bed at locality D. The breccias are chaotic, unsorted and ungraded, and contain angular blocks up to 3 m in diameter. These blocks are mainly stromatolitic carbonates from the lower parts of the McArthur Group and from the Tawallah Group: some are mineralised, and blocks of "paisleysite" also occur. Primary structures in the ore beds (which at D are just rubbly laminated shaley rocks) include graded bedding, ripple marks, cross bedding, scouring and slumping. Evaporite casts and pedogenic pisoids are also present. Unfortunately, due to weathering, none of these structures can be seen in the creek section,

The fresh mineralised rocks are extremely fine grained and consist of pyrite, galena and accessory marcasite, arsenopyrite, chalcopyrite, sphalerite, and freibergite and tetrahedrite. These are altered at the outcrop to the carbonates smithsonite, and cerussite, and to various silicates, oxides and hydroxides.

Fig. 53 Outcrop of Teena Dolomite with "paisleyite" texture.

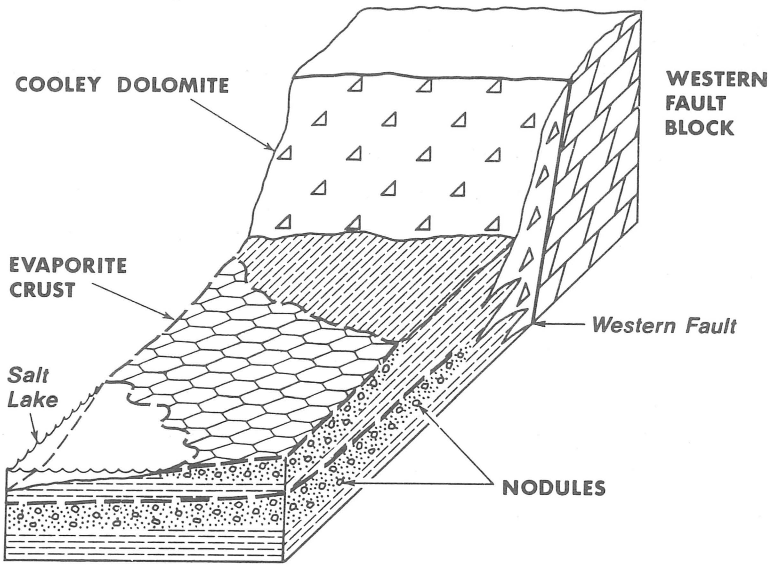


Fig. 54 Interpreted palaeogeography and facies relationships of units in McArthur Mine area during deposition of the Barney Creek Formation. Courtesy of Neil Williams & Ross Logan, C.E.C. Ltd, Brisbane.

NOTES

STOP 13 GOSSAN OF HYC DEPOSIT

The gossan consists of a silicified interore breccia containing cerussite and smithsonite and the white to pale blue fibrous zinc material, hemimorphite. We would prefer that hammers are not used here, but loose fragments may be collected, and material from the dumps can be removed.

INTERPRETATION

Early interpretations of the setting of the HYC mineralisation envisaged a deep water euxinic environment. However, because of the presence of thin carbonate crusts, tepee structures, nodular anhydrite casts, and pedogenic pisoids, Williams & Logan (1981) have recently interpreted one facies of the Barney Creek Formation as being of lagoonal or lacustrine origin with a nearby fault scarp spasmodically providing talus for the Cooley Dolomite and the chaotic interore breccias (Fig. 54).

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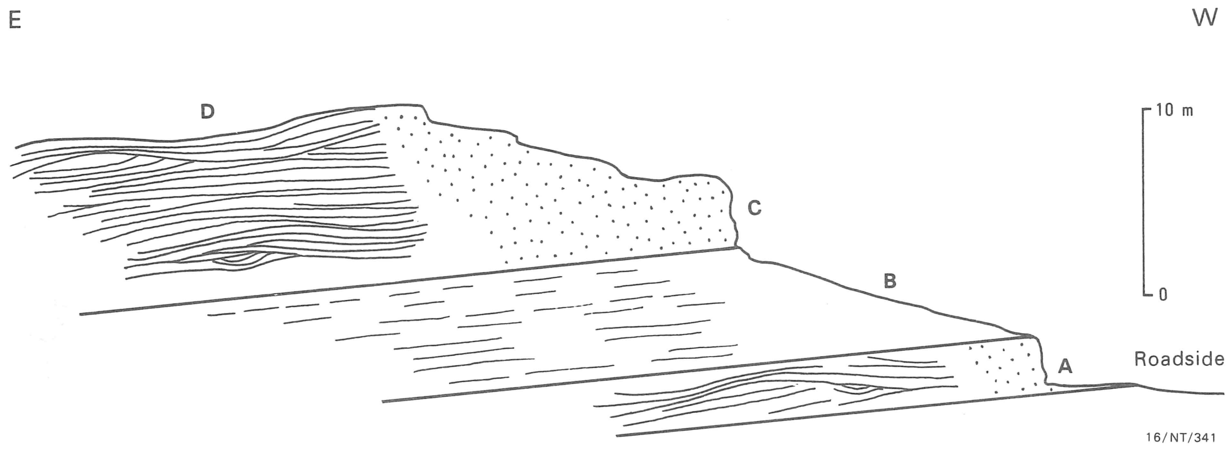

Fig. 55 Generalised cross-section of the lower Crawford Formation at Stop 14.

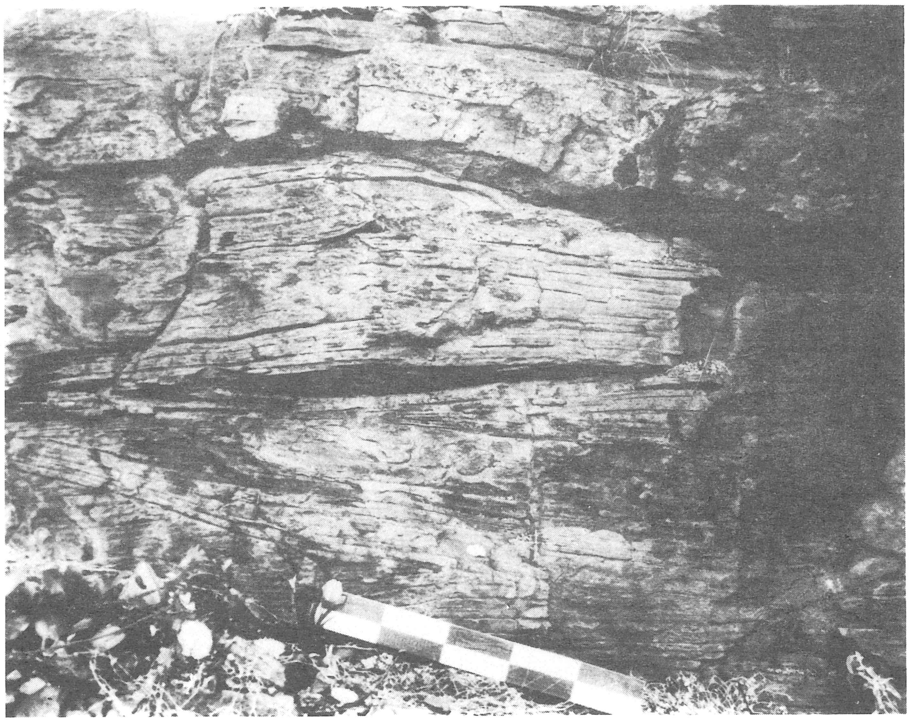

Fig. 56 Hummocky cross-stratification (HCS) in vertical section through beds. Note the gently concave and convex bedding laminae, truncations, and thinning of bundles of laminae. Scale is 0.5m long. Point C, Stop 10 (Crawford Formation).

STOP 14 CRAWFORD FORMATION NEAR RYAN BEND

BACKGROUND

The Crawford Formation is a transitional unit within the Roper Group, above the marine shales of the Mainoru Formation, and below the fine to coarse grained, shallow marine Abner Sandstone (Fig. 7). It ranges from 30 m thick in the southeast to over 250 m in the northernmost outcrops. In most areas it consists of very thick beds of micaceous, glauconitic coarse siltstone to fine sandstone in which the dominant sedimentary structure is hummocky cross stratification (HCS). Interbedded with the HCS facies are thinly interbedded to laminated units of graded fine sandstone and siltstone to mudstone. In the Abner Range and some other southwestern outcrops the HCS-sandstones are absent or poorly developed. Where present they are overlain by trough-crossbedded fine to medium glauconitic sandstone, some of which contain mudcracks. The sequence thus appears to represent a shallowing episode, with environments ranging from open shelf, through shoreface to intertidal and supratidal.

DESCRIPTION (FIG. 55)

The Crawford Formation at this locality is estimated to be 55 m thick, of which we will examine the lower 25 m.

A: The basal beds of the Crawford Formation are typical of the HCS facies in that they are composed of coarse siltstone to very fine sandstone; are richly micaceous and contain some glauconite. The HCS consists of gently undulating laminae with a hummock wavelength of of 3-4 m and height of 0.1-0.2m.

B: Several metres of mudstone and siltstone separate the HCS beds, but do not crop out.

C: The sequence from about half way up the slope, right to the top of the hill consists of HCS sandstone, and good example of the structures are visible both in outcrop and in fallen blocks (Fig. 56).

D: The most spectacular examples of HCS are observed on the surface of the dipslope, and a good impression of its true nature can be gained. The relationship of hummocks to swales, and their three-dimensional character is clearly visible: they form saucer-shaped depressions

Fig. 57   Saucer-shaped depressions in a bedding plane of Crawford Formation at Point D, Stop 10. These are the surface expression of swales, or concave-up laminae in HCS (see Fig. 56). Scale is 0.5 m long.

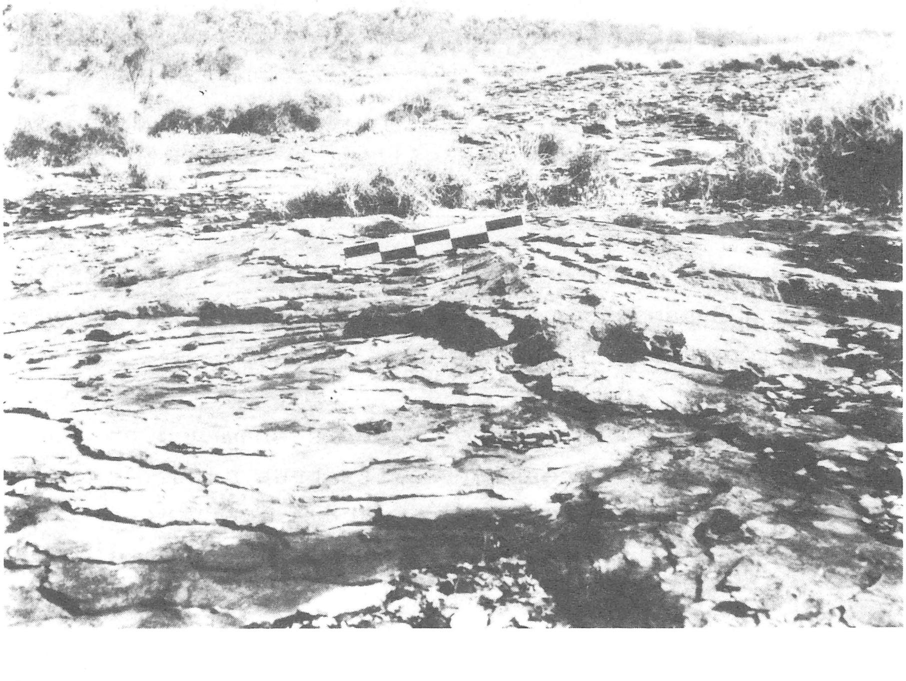

Fig. 58   Right-hand end of scale rests on convex-up laminae. These are similar in appearance to intersecting trough cross-beds, but differ from them in that most laminae continue over the high point, down into the adjacent swale. Point D, Stop 10.

(Figs. 57, 58) alternating with roughly symmetrical hummocks. Laminae commonly thin over hummocks, and low angle truncations occur in some instances.

DISCUSSION

Since HCS was named by Harms & others (1975) it has been widely recognised as a product of high wave energy (storm dominated) shoreface environments (e.g., Bourgeois, 1980; Moore & Hocking, 1983). Recently, discussion has centred on whether HCS is generated mainly by oscillatory flows, or by unidirectional flows (Allen, 1985, Allen & Pound, 1985), the conclusion being that a unidirectional component is essential. A re-evaluation of structures on modern shelves (Swift & others, 1983) has revealed what may be modern hummocky bedforms on the the Atlantic Continental Shelf of North America, at depths of 20 m or more, i.e. true 'shelf' rather than shoreface.

The HCS in the Crawford Formation, occuring in a sequence between laminated shales and tidal sandstones (Sweet, 1986), is interpreted as a shoreface sandstone deposited on a storm dominated shelf. It is likely that a minor disconformity separates the storm laid sandstones from the tidal deposits above.

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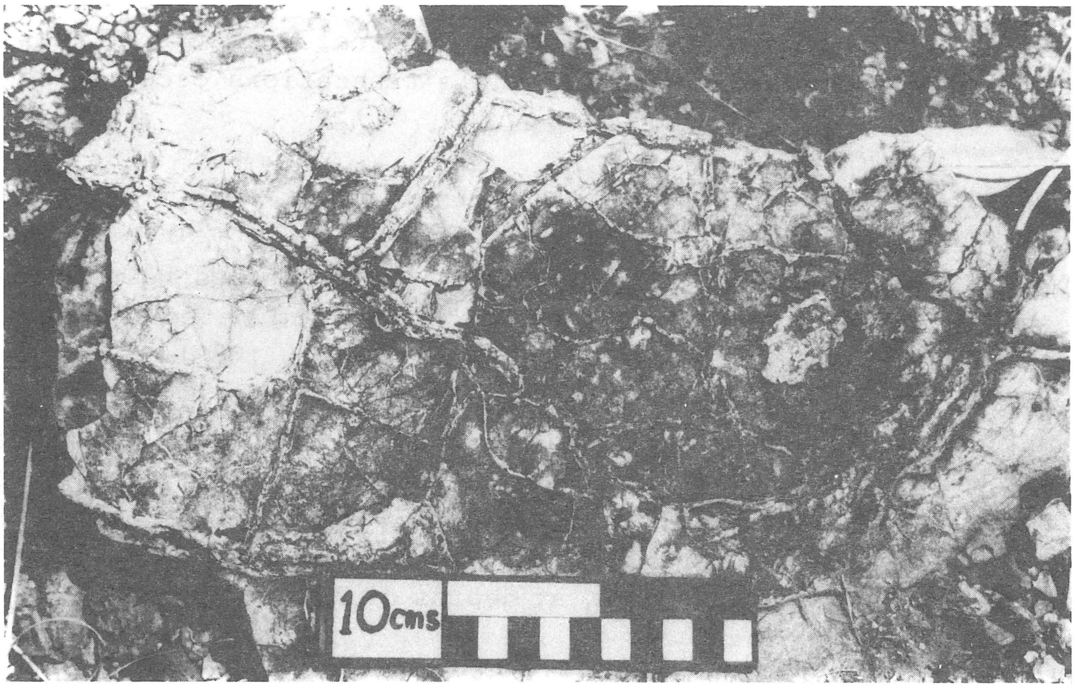

Fig. 59 Bedding plane slab of dololutite with chertified desiccation cracks at locality 15. Large cracks show multiple phases of cracking and infilling.

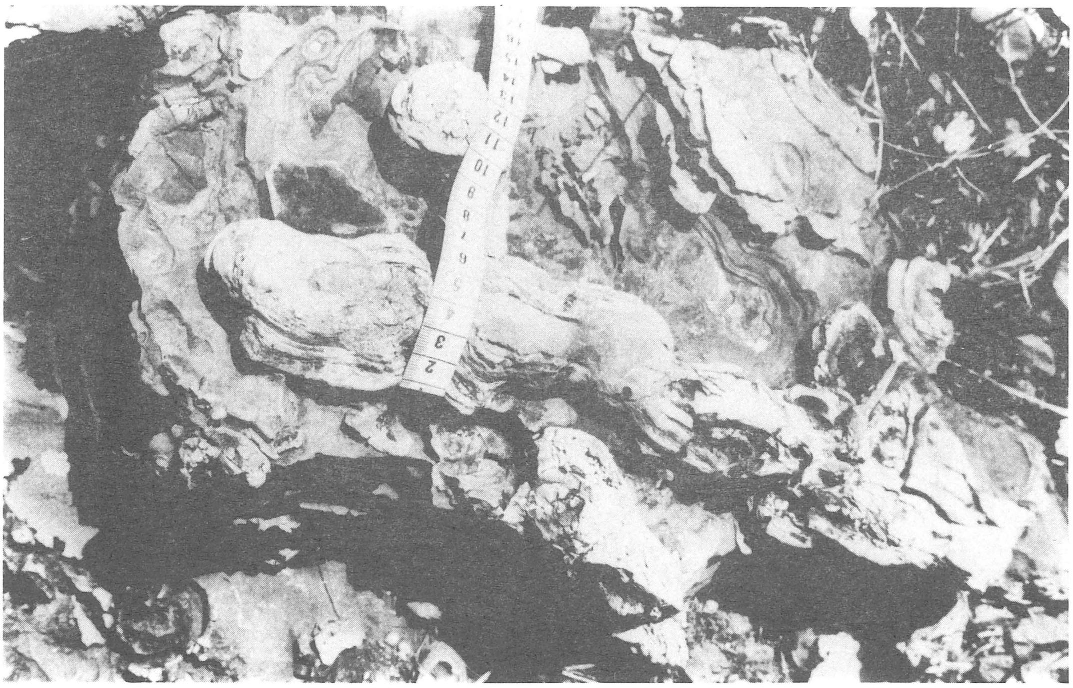

Fig. 60 Plan view of part of a tepee at locality 15. Chertified small domal stromatolites have developed along the tepee cracks. In modern day examples this is due to nutrient-rich upwelling groundwaters.

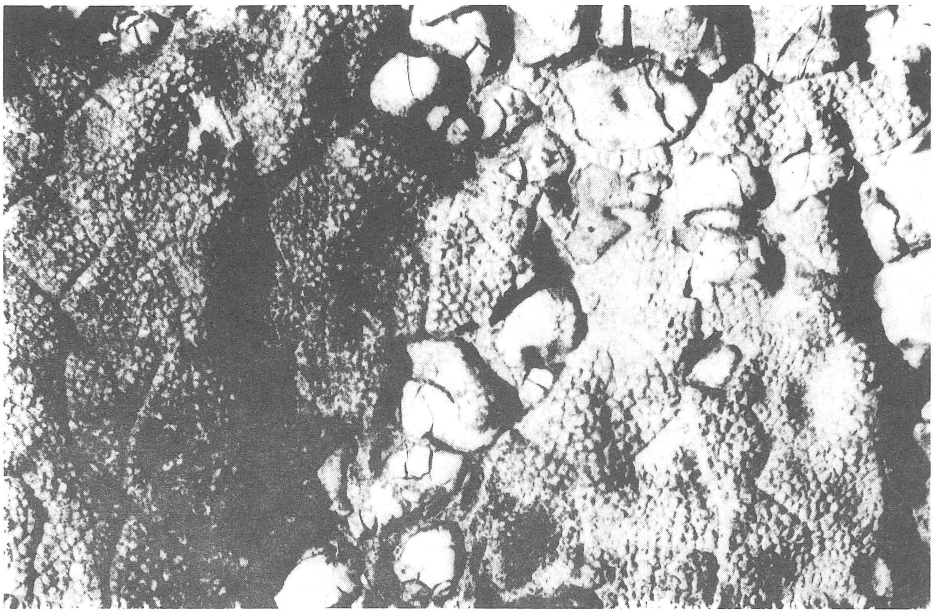

Fig. 61 'Brain' texture in mudcracked phosphatic dololutite of the Yalco Formation at locality 15. Width of field of view 9 cm.

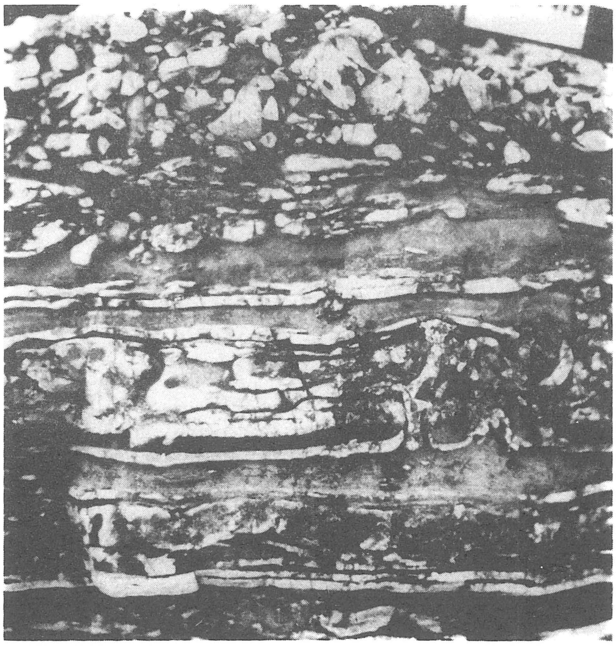

Fig. 62 Intraclast breccia (wind deflation) near the top of the Yalco Formation at locality 15.

STOP 15 BATTEN CREEK (not on Abner Map)

The aim of this roadside stop is to examine the cherty carbonate sequence of the Yalco Formation, which is near the top of the McArthur Group (Fig. 6), as it contains a variety of structures which have been used to draw a close comparison with some of the facies in the modern Coorong Lagoon of South Australia. We will take an easy walk up the scarp. On this section, we would prefer it if you did not use hammers except as scales for photos. We will see numerous examples of desiccation structures in carbonates. These consist of various types of desiccation cracks (Fig. 59), vertically stratified tepee structures at the margins of polygonal plates, small domal stromatolites growing along tepee boundaries (Fig. 60), "brain texture" (Fig. 61) (indicative of phosphorite), and wind deflation breccias (Fig. 62). The carbonates are interbedded with thin dark grey low angle cross-bedded litharenites. A typical section and its interpretation is shown in Figure 63.

Many of the structures are partially silicified, making the details more obvious, but in most exposures of the Yalco Formation pervasive silicification has destroyed all the primary structures. Muir & others (1980) have compared the sedimentary structures seens in this section with those being formed in ephemeral lakes at the south end of the Coorong Lagoon (South Australia), and we interpret the depositional environment of the Yalco Formation as having been lacustrine and evaporitic with a seasonally humid climate.

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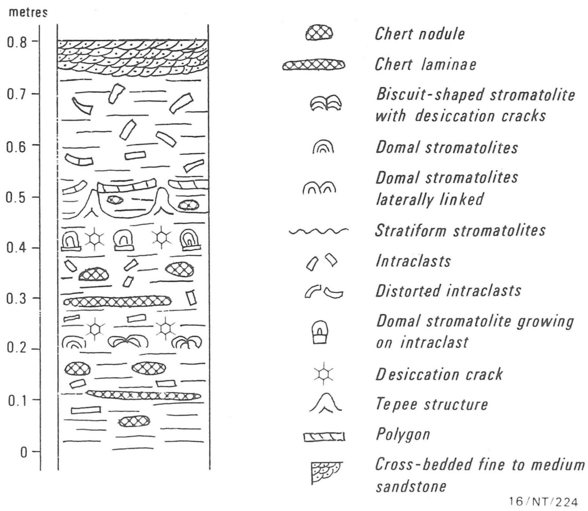

Fig. 63 Small cycle present in Yalco Formation at locality 15. This is interpreted as illustrating the gradual sealing, and then flooding of a smaller Proterozoic lake. The initial sealing is indicated by the tepees at 0.5 m which cap a gradually shallowing subaqueous sequence.

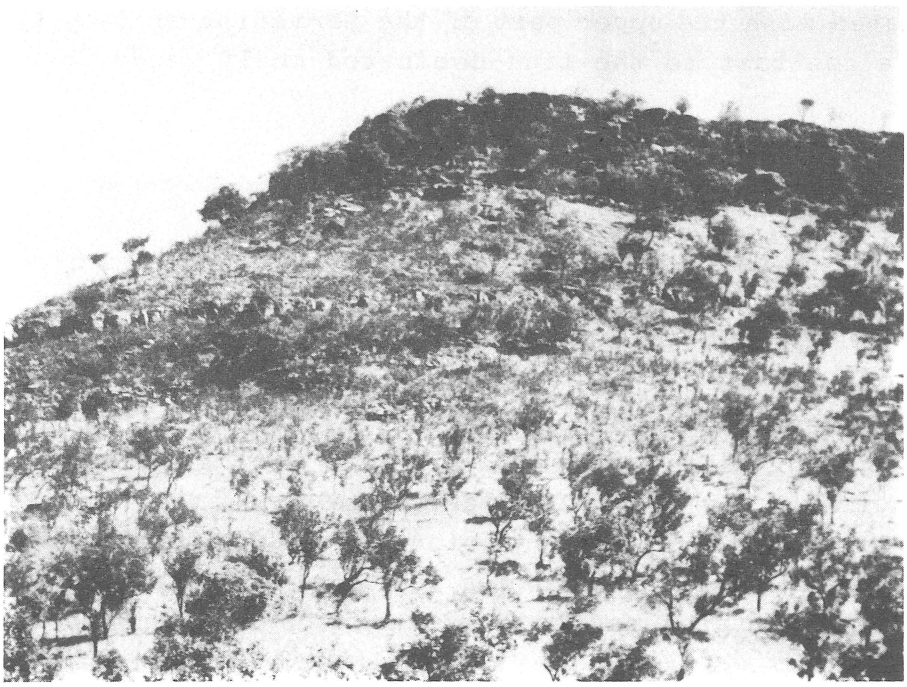

Fig. 64 Northeastern side of Mount McMinn showing discontinuous outcrop of Velkerri and McMinn Formation.

STOP 16 TAWALLAH WATER HOLE (not on Abner Map)

This is solely a scenic stop for lunch (or o/n) depending on progress. The caves here contain a wealth of Aboriginal art including native animals and fish. The cave is developed in the Masteron Sandstone.

STOP 17 MOUNT McMINN (not on Abner Map)

AIM

The aim of this stop is to examine a discontinuous section (but one of the better ones known!) through the lower part of the McMinn Formation, which is near the top of the Roper Group (Fig. 7). The underlying formation - the Velkerri Formation - contains rich hydrocarbon source beds and live oil, in what are tentatively interpreted as deeper marine shelf environments (Jackson & others, in press). The lower part of the McMinn Formation, in contrast, contains some of the shallowest facies seen in the Roper Group. It also contains laterally extensive deposits of oolitic and pisolitic ironstones which, prior to the discovery of the Hammersley BIF's, were attractive economic deposits of iron. This surface section is complemented by the core material described at the next stop, and it will be contrasted with the upper part of the formation at Stop 19. It also provides a contrast to the tide-dominated shelf sands seen at Beetle Spring.

DESCRIPTION

The section that we will walk up is shown in Figures 64 and 65. The lower slope (where we park) consists of the Velkerri Formation which does not outcrop. The first outcrops are a series of sandstone benches (middle part of Fig. 64, 50-80m in Fig. 65) forming the base of the McMinn Formation. These rocks are characterised by marked grainsize variations, (coarse sand to siltstone); evidence for strong currents (parallel lamination, trough cross-bedding, large ripples, common intraclasting) and evidence for fairly rapid deposition of clastic material (sandstone injection structures). Discontinuous ferruginous sandstones and siltstones on megaripped surfaces and beds of sandy oolitic ironstone and also present.

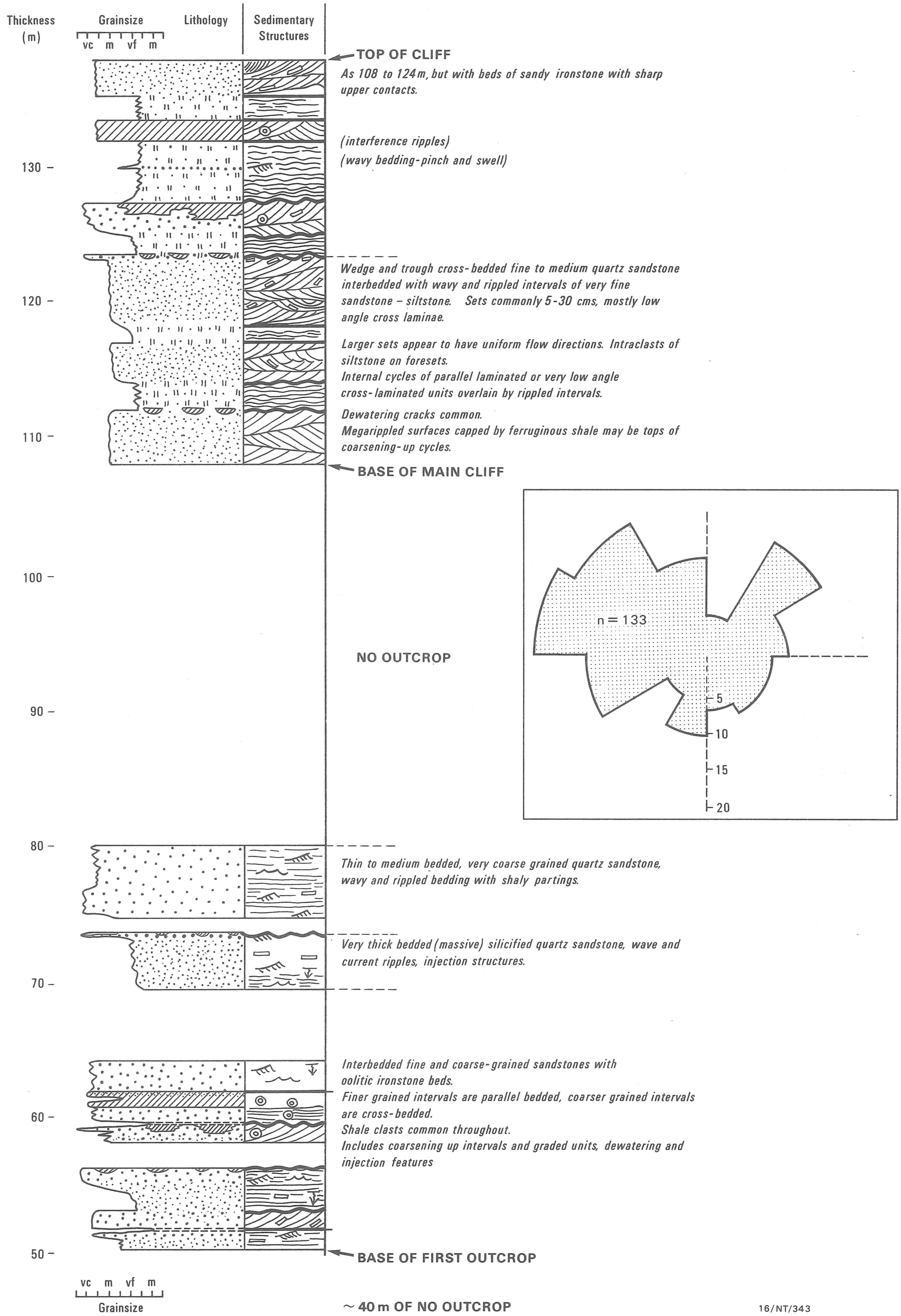

Fig. 65 Section through lower part of McMinn Formation at Mount McMinn (hillslope shown in Fig. 64). Interval 70-80 m corresponds to low continuous bench about half way up slope in Fig. 64. Rose diagram is cross-bedding and ripple measurements from this and two adjacent sections.

The upper half (124-140 m) of the continuous outcrop at the top of the hill consists of very similar rocks, but the lower half (108-124 m) is noteably finer grained and less variable. It appears to consist of subtle coarsening up cycles about 5 m thick (see Fig. 65). The lower parts of these cycles are wavy, thin-bedded siltstone and sandstone, the upper parts are trough and wedge cross-bedded fine to medium grained sandstone.

INTERPETATION

Environmental interpretations are hindered by the discontinous nature of the outcrop, but within the regional stratigraphic setting a very shallow shoreline environment is preferred. Because of the coarse grainsize and common trough cross-bedding a fluvial environment was originally thought to be a possibility. However, palaeocurrent analyses at this and two adjacent localities have indicted a wide range of palaeocurrent directions (Fig. 65) which seems to be difficult to reconcile with a fluvial environment. A bimodal pattern is evident with a dominant direction towards the northwest (?onshore) and a secondary trend towards the northeast (?longshore). The cross-bedded oolitic ironstones presumably represent a shoal or bank setting within this coastal environment. At outcrops about 5 km to the southwest potholed hardgrounds in the oolitic ironstones indicate that the iron formations must have been deposited in very shallow shoals which were prone to periods of emergence and erosion. The finer grained coarsening-up cycles between 98 and 125 m presumably represents lightly deeper, more offshore environments.

NOTES

STOP 18 SHERWIN CREEK

We do not have a specific locality to visit at Sherwin Creek. The aim of this stop is to examine some core material from our 1985 drilling program - especially from units within the Roper Group that outcrop poorly. We hope to find a suitable shady spot to describe and discuss some of the initial results of this largely subsurface study. We have not completed this project so the interpretations are preliminary. We welcome your comments on the interpretations we have made.

There is only a small amount of core material, but it will be available for examination during the rest of the excursion.

As mentioned earlier, the Velkerri Formation in this area contains live oil and a thick section of prime hydrocarbon source beds (see handout).

NOTES

Core	Formation & depth (m)	Comments URAPUNGA No. 4
1	McMinn (30)	Oolitic ironstone and interbedded black mudstone (cf stop 17)
2	McMinn (32)	Laminated sandstone-mudstone with injection and possible desiccation features (cf base of section at Mount McMinn)
3	McMinn (37)	ditto, is any of this desiccation?
4	McMinn (41)	)Coarse grained, vuggy, quartz sandstone equivalent to)basal beds at Mount McMinn). Some bitumen, but rocks)tight
5	McMinn (22)	
6	Velkerri (47)	Crinkley laminated siltstone-mudstone with slumps (?slope facies)
7	Velkerri (103)	Parallel laminated blue mudstone (quiet deeper marine)
8	Velkerri (255)	Massive blue mudstone organic-poor ?deep marine
9	Velkerri (87)	Organic-rich dark grey mudstone
10	Velkerri(138)	Organic-rich (ca 2% TOC) black mudstone with horizontal calcite vein and cone-in-cone structure (potential source bed, some veins have hydrocarbons associated, pressure release on unloading)
11	Velkerri(346)	Brown mudstone-siltstone from within interval containing live oil
12	Bessie Creek (373)	White cross-bedded quartz sandstone - typical sub-surface facies - poor reservoir prospect (cf. outcrop at Beetle Spring)

13	Corcoran(436)	Crinkley laminated pyritic siltstone-mudstone (mostly below wave base, marine shelf)
		URAPUNGA 5
14	Abner (93)	Red brown medium to coarse sandstone typical of Hodgson Member, again fairly tight
15	Abner (122)	Graded, rippled shallow water sandstone-mudstone units in Jalboi Member
16	Abner (169)	ditto with desiccation cracks; these two units appear to be similar facies to the McMinn Formation and also contain iron formations.
17	Abner (160)	Quartz sandstone with dish structures (Jalboi Member)
18	Crawford (363)	Glauconitic sandstone-siltstone. Glauconite like this is preent in almost all formations in the Roper Group and we use it to infer dominantly marine environments.
19	Mainoru (14)	Rippled glauconitic sandstone-mudstone. (from Urapunga No. 6)
20	Mainoru (486)	Poor quality source bed of grey laminates.

STOP 19 STRANGWAYS CREEK (Roper Highway)

AIM

These are optional stops we will make if time permits. They are road cuttings through the upper part of the McMinn Formation in which siltier parts of the formation are well exposed. The steeply-dipping section visible at the first of the two road cuttings is shown in Fig. 66. As the rocks are more gently dipping at the second road cutting only part of the section is exposed (equivalent to the beds between 10-30 m in Fig. 66), but the very low angle swaley cross-bedding of the prominent sandstone unit is more clearly visible.

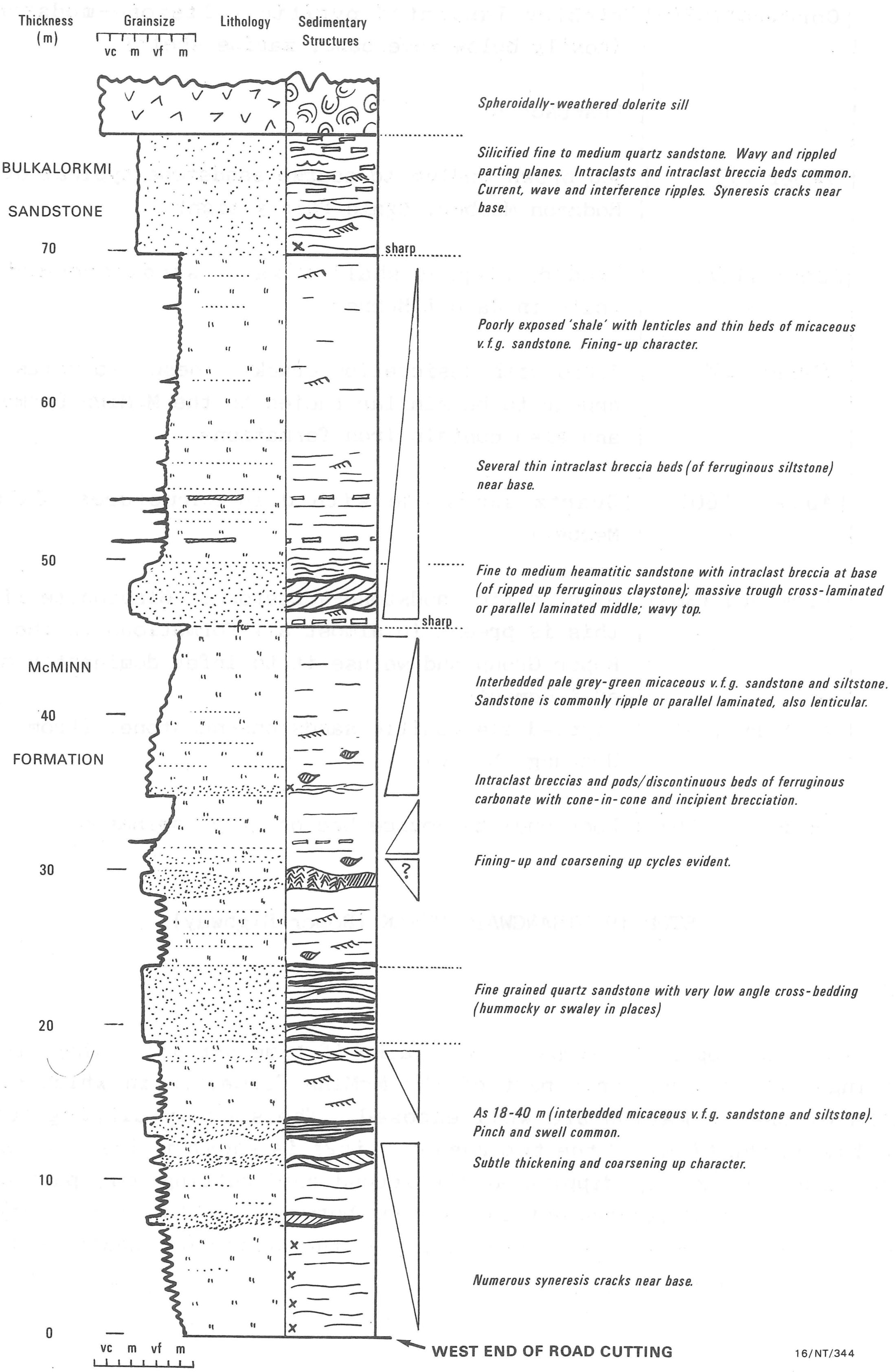

Fig. 66 Section through upper part of McMinn Formation near Strangways Creek, about 80 km west of Mount McMinn.

DESCRIPTION

Except for in the drilling, this is one of the few reasonably continuous sections of shaley Roper Group where sedimentological features and stratigraphic trends can be seen. Two transgressive fining-up-cycles are evident in the upper half of the road cut (35 to 47 m and 47 to 70 m). Trends/cycles are not so clear in the lower half of the cutting, but two possible coarsening-up cycles may be present between 0-20 m, but these are not particularly clear.

INTERPRETATION

The more regular bedding, finer grainsize and general absence of current structures in the upper parts of the fining-up cycles indicates deposition in quiet, low-energy shelf environments below wave base, i.e., a distinct contrast with the shallower, higher energy environments from near the base of the formation at Mount McMinn. The lower parts of these fining-up-cycles contain intraclast breccias which are interpreted as storm rip-ups of ferruginous beds probably originating from shoreline environments (such as seen at Mount McMinn). The presence of hummocky-swaley bedding in the 5 m-thick sandstone bed at 20 m and the sedimentary features in the sandstone bed at 48 m (Fig. 66) support this interpretation.

STOP 20 MATARANKA

If time permits we stop here for a swim in the thermal pool.

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