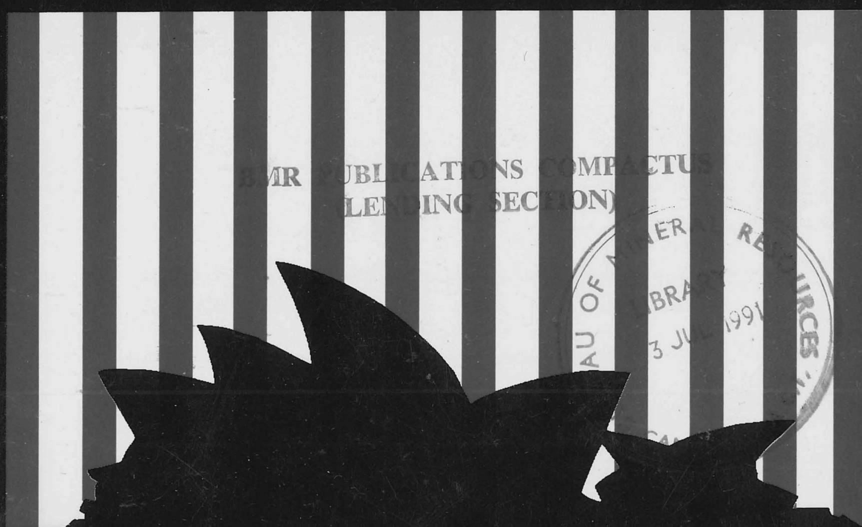
GUIDEBOOK FOR FIELD EXCURSION 2

Ordovician Siliciclastics and Carbonates of the Amadeus Basin, Northern Territory



SIXTH INTERNATIONAL SYMPOSIUM ON THE ORDOVICIAN SYSTEM

RECORD 1991 / 49

by John R. Laurie, Robert S. Nicoll & John H. Shergold

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

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ORDOVICIAN SILICICLASTICS AND CARBONATES OF THE AMADEUS BASIN, NORTHERN TERRITORY

Compiled by

John R. Laurie, Robert S. Nicoll & John H. Shergold

with contributions from D. Milton, M. Owen, J.M. Kennard, J.F. Lindsay, P.N. Southgate & G.C. Young

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Editor: John R. Laurie, Onshore Sedimentary and Petroleum Geology Branch, Bureau of Mineral Resources, Geology and Geophysics.

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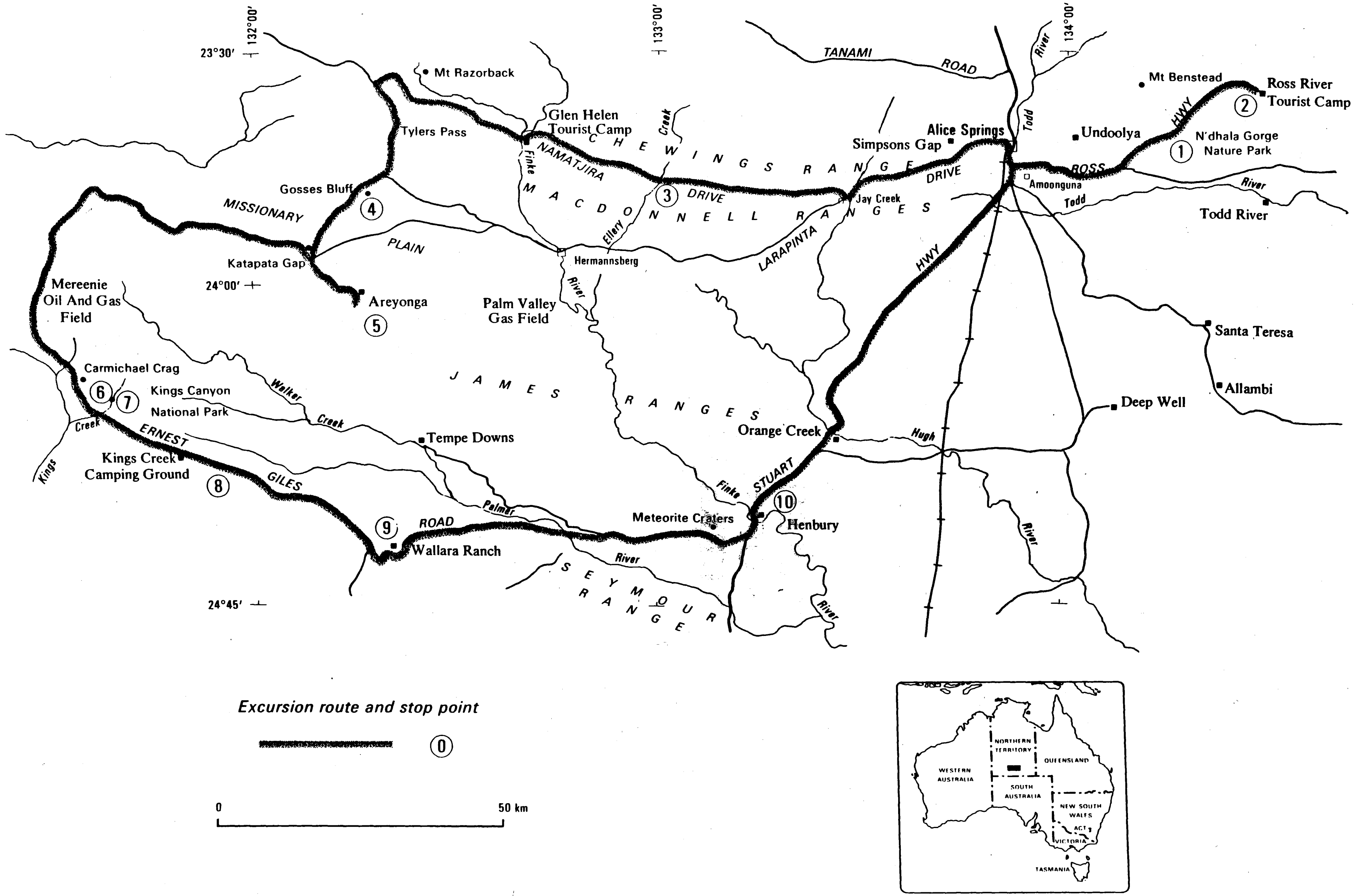


Location and Route Map

ITINERARY

JULY 8.

Party will arrive in Alice Springs individually or from the Black Mountain field trip. Accommodation at Alice Sundown Motel

JULY 9.

0900 Depart Alice Springs
1000 Arrive Williams Bore, examine Goyder to Pacoota transition
1100 Depart Williams Bore
1130 Arrive Ross River, brief examination of Cambrian section
1230 LUNCH
1330 Examine Shannon to Goyder to Pacoota transition
1500 Depart Ross River
1530 Arrive N'Dhala Gorge, examine Pacoota Sandstone and N'Dahla Member, walk in N'Dahla Gorge
1700 Depart N'Dhala Gorge
1730 Return to campsite adjacent to Ross River

JULY 10.

0830 Depart Ross River
1100 Arrive Ellery Creek, examine Proterozoic section at Ellery Creek Big Hole, arrive at Ordovician section
1200 LUNCH
1300 Examine Pacoota to base Mereenie section
1730 Return to camp at base of Pacoota section, Ellery Creek

JULY 11.

0830 Depart Ellery Creek
0930 Arrive Glen Helen, rest stop
1000 Depart Glen Helen
1100 Arrive Tyler Pass, view Gosses Bluff
1115 Depart Tyler Pass
1200 Arrive Gosses Bluff, LUNCH
1300 Depart Gosses Bluff
1500 Arrive Areyonga Gorge, examine Pacoota to base Mereenie section
1730 Return to camp adjacent to Areyonga Creek

JULY 12.

0830 Depart Areyonga Gorge
1130 Arrive Carmichael Crag, examine Stokes to Carmichael section
1200 LUNCH
1300 Depart Carmichael Crag
1330 Arrive Kings Canyon, walking tour of Kings Canyon
1730 Camp at or near Kings Canyon

JULY 13.

0830 Depart Kings Canyon campsite

0930 Arrive Roadside stop, examine Stairway Sandstone
1100 Depart Roadside stop
1230 Arrive Storm Creek, examine top Stairway Sandstone
1245 LUNCH
1330 Examine Stokes Siltstone section
1500 Depart Storm Creek
1630 Arrive Maloney Creek, examine Horn Valley Siltstone section

1730 Depart Maloney Creek
1900 Arrive Alice Springs, accommodation at Alice Sundown Motel

JULY 14.
FLY TO SYDNEY

INTRODUCTION

The Amadeus Basin is a large intracratonic basin which occupies most of the southern quarter of the Northern Territory (fig.1). It is about 800 kilometres long in an east-west direction, covers an area of about 170,000 square kilometres and contains a maximum preserved sediment thickness of about 14,000m of predominantly Proterozoic to Devono-Carboniferous strata (fig.2). The sediments are almost entirely shallow marine or terrestrial deposits. The basin is a proven petroleum province and contains two producing hydrocarbon fields (fig.3), with oil and gas being produced at Mereenie, and gas at Palm Valley, both from Upper Cambrian-Lower Ordovician sandstone reservoirs, while gas in commercial quantities has also been found at Dingo field in Upper Proterozoic-Lower Cambrian sandstones.

Underlying the basin is the Arunta block in the north, the Musgrave-Mann block and Olia Gneiss in the south and less metamorphosed sediments, volcanics and intrusives in the northwest and southeast.

Sedimentation commenced no more than 900 million years ago in the Late Proterozoic (Adelaidean) with the deposition of the Heavitree Quartzite and correlates. Following mild epeirogenic movements sediments (evaporites, carbonates, redbeds) and locally basalts were deposited (Bitter Springs Formation and Pinyinna Beds). These basal units are laterally extensive and predate the first phase of intracratonic subsidence.

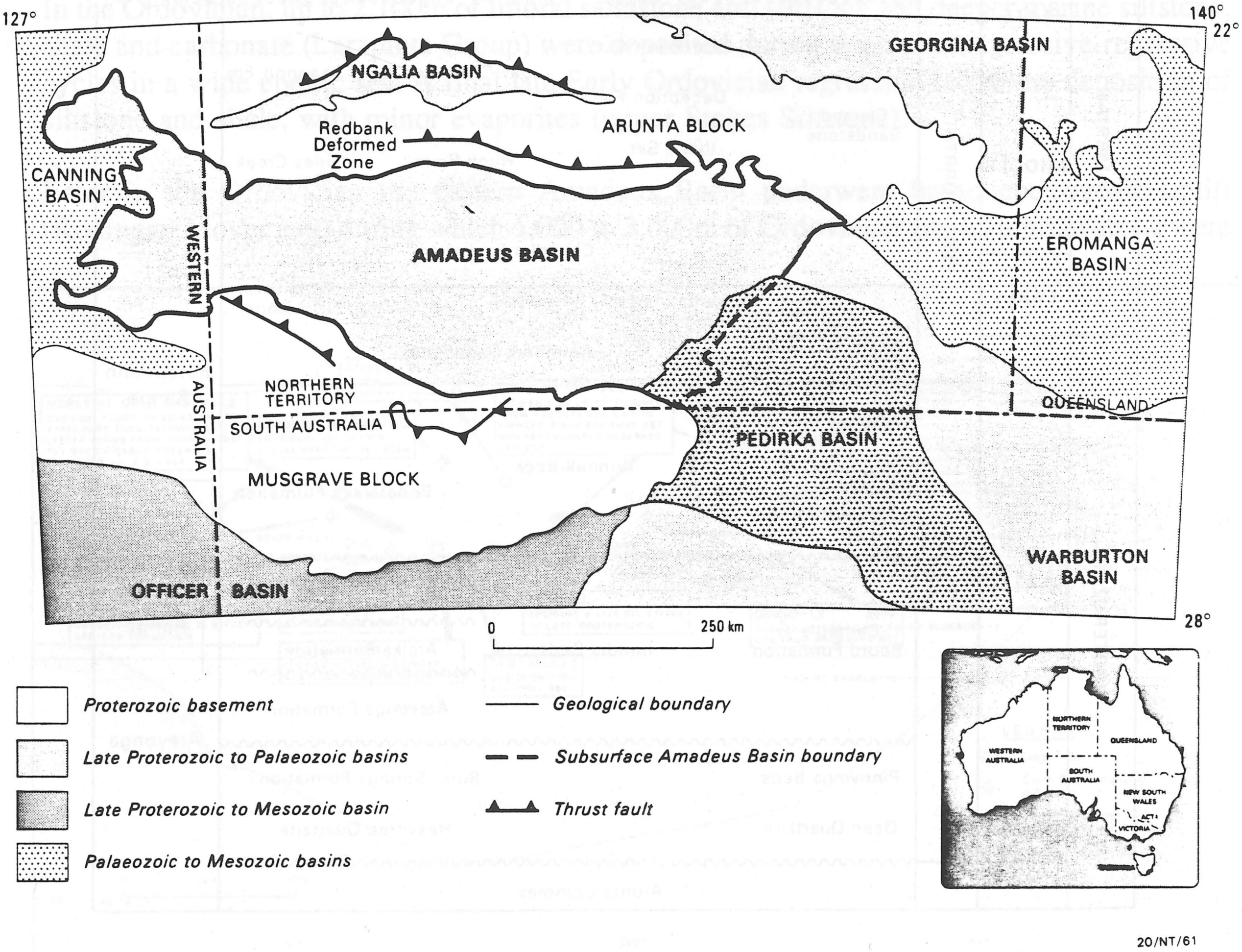


Figure 1. Location and structural setting of Amadeus Basin (from Walley & Cook, 1991)

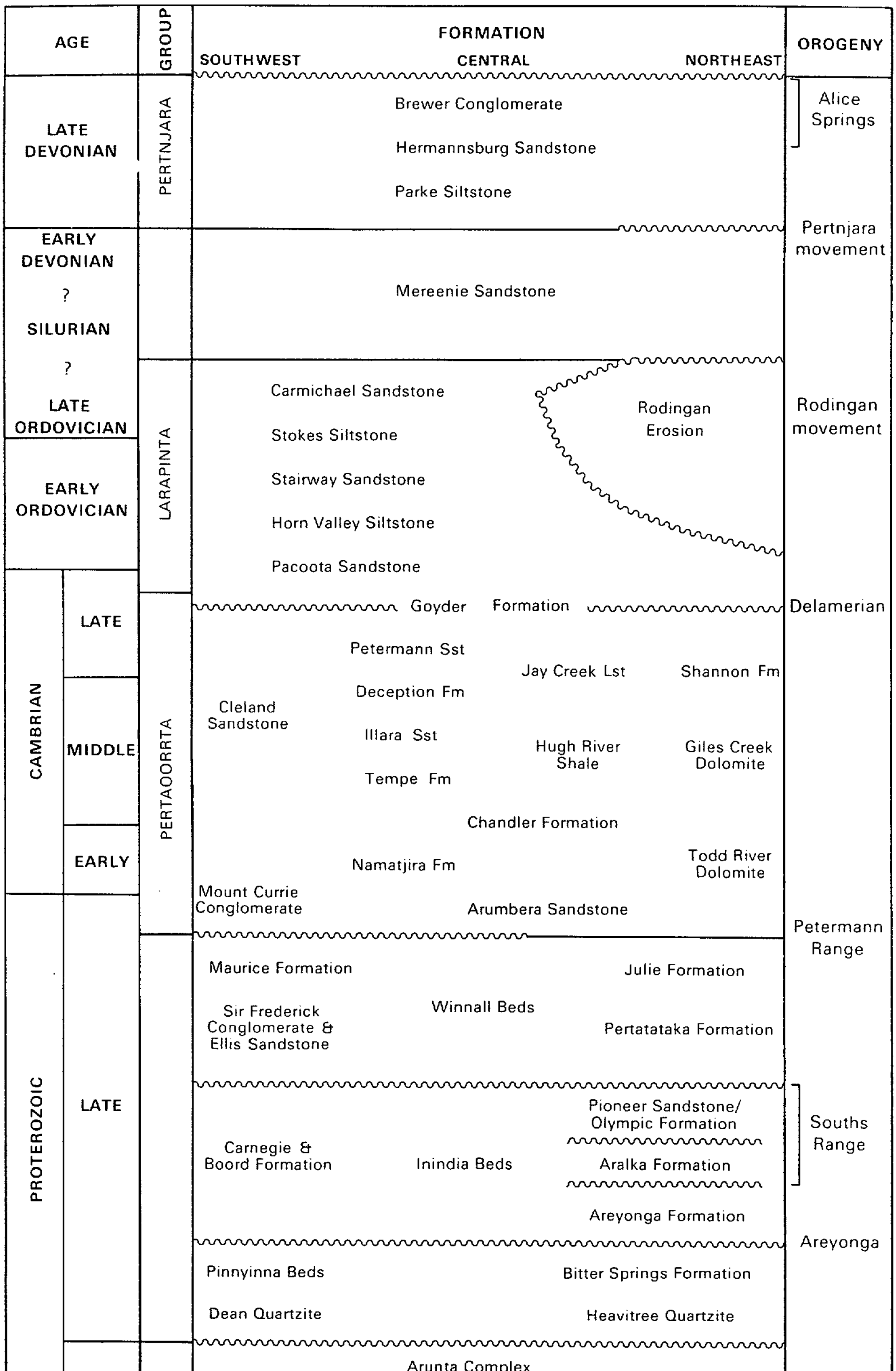


Figure 2. Simplified stratigraphy of the Amadeus Basin showing tectonic events (Kennard, Nicoll & Owen, 1986)

Subsequent Proterozoic sedimentation was localised and controlled by two periods of diastrophism and subsidence. During the first of these, the Areyonga Movement, areas to the south were uplifted and eroded and approximately 4,500m of sediment accumulated in the subsiding area to the north. These sediments include deposits of the first of two glacial episodes in the basin. Renewed uplift in the south during the Souths Range Movement resulted in the deposition of up to 2,500m of marine clastics and conglomerates in the south and about 600m of fine clastics and carbonates in the north. The record of the second Proterozoic glacial episode is restricted to the northeastern part of the basin.

Late Proterozoic deposition was terminated in the southwest by the Petermann Ranges Orogeny, with perhaps as much as 6,000m of molasse sediments being shed northward. Further north and northeast 2,000m of predominantly deltaic sediments accumulated within two sub-basins near the present northern margin of the basin. These two sub-basins persisted through the Cambrian, with the western one hosting fluvial, deltaic and shallow marine sediments and the eastern one, marine carbonates, fine clastics and evaporites (Pertaoorrta Group). The demise of the sub-basins resulted from the widespread Late Cambrian transgression (Goyder Formation) and led to a significant change in the pattern of sedimentation. Thereafter, the lithofacies become more uniform and tend to be largely basinwide in their extent.

In the Ordovician, up to 2,100m of littoral sandstone and siltstone and deeper marine siltstone, shale and carbonate (Larapinta Group) were deposited during several transgressive-regressive cycles in a wide epeiric sea. A final late Early Ordovician regression led to the deposition of siltstone and shale, with minor evaporites (upper Stokes Siltstone).

Later in the Ordovician the eastern Amadeus Basin underwent broad epeirogenic uplift (Rodingan Movement) during which 1,000 to 3,000m of Ordovician and Cambrian strata were

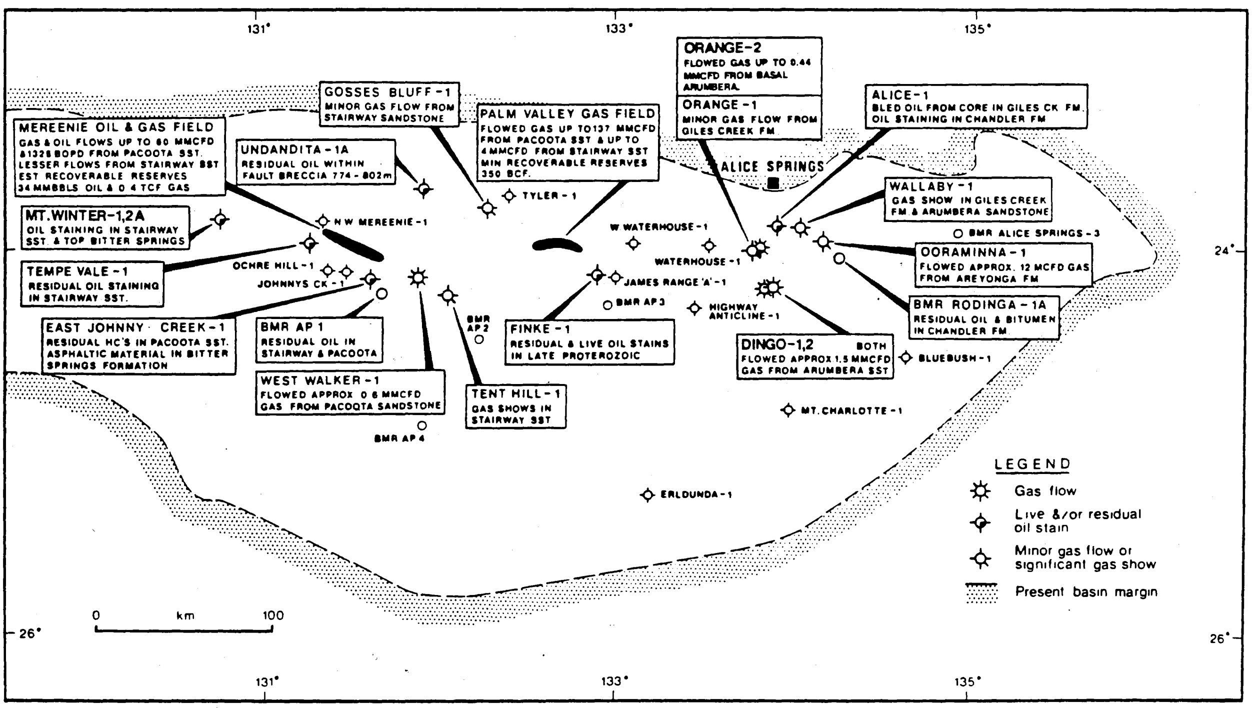


Figure 3. Hydrocarbon discoveries in the Amadeus Basin (Roe, 1991)

eroded from that part of the basin, while shallow marine deposition continued in the west (Carmichael Sandstone, lower Mereenie Sandstone). An arid desert then became established across most of the basin and up to 600m of quartz sand was deposited in an aeolian/fluvial environment (upper Mereenie Sandstone).

Mid to Late Devonian uplift of the Arunta Block along the present northern margin of the basin (Pertnjara Movement) marked the beginning of diastrophism which culminated in the Late Devonian-Early Carboniferous Alice Springs Orogeny. Up to 4,000m of non-marine molasse sediments (Pertnjara Group) accumulated in a foredeep on the southern flank of the uplift. These sediments become thinner and finer grained southward. Most of the deformation of the Amadeus Basin sequence, in the form of thrust faulting, folding and diapirism occurred during this orogeny. The Basin has remained relatively stable since this time, with extensive Mesozoic and Tertiary erosion generating the present landscape.

PROTEROZOIC FORMATIONS

HEAVITREE QUARTZITE

The Heavitree Quartzite is the oldest formation preserved in the Amadeus Basin. Isotopic data on dykes in the basement (Black & others, 1980) indicate that the formation is less that 900 Ma in age. It is the most widespread formation in the Basin and occurs at all of the present basin margins, except the southeast.

There is very little change in lithology over the mapped extent of the Heavitree Quartzite, and it is an important marker unit for delineating the structural complexities at the present basin margins. Fluvial facies predominate in this formation although parts of the formation are interpreted to have been deposited in intertidal to very shallow marine environments. (Clarke in Wells, 1976).

BITTER SPRINGS FORMATION

Rocks now referred to as the Bitter Springs Formation were initially named by Joklik (1955) as the Bitter Springs Limestone. However, Wells & others (1967) renamed the unit the Bitter Springs Formation and subdivided it into a lower Gillen and an upper Loves Creek Members.

Although rocks of this formation have a basin-wide distribution, they are generally concealed beneath the overlying Proterozoic and Phanerozoic sequence. The Bitter Springs Formation has a conformable, gradational contact with the underlying Heavitree Quartzite. The upper boundary is marked by an unconformity or a disconformity separating Bitter Springs rocks from the overlying Proterozoic sequence (Wells & others, 1970). In some areas, particularly in the northeast, the Loves Creek Member may be largely or completely eroded. Based on stromatolite and tillite correlations Walter (1972) suggested a late Proterozoic age, between 740 ± 30 Ma and 950 ± 50 Ma for the formation.

The Gillen Member is composed of an interbedded sequence of carbonates and clastics with thick evaporite deposits occurring in some areas. In outcrop the rocks are extensively folded and faulted due to solution and movement of evaporites, which renders the measurement of sections and lateral correlation of units very difficult.

Rocks of the Loves Creek Member form a regressive sequence that consists of a basal stromatolitic carbonate-sulphate evaporite unit of marine affinity, overlain by 300-350m of redbeds, calcareous redbeds, dolomitic limestone and dolostone of fluvial and lacustrine affinity.

Microfossils described by Barghoorn & Schopf (1965), Schopf & Blacic (1971) and Knoll & Golubic (1979) from the Bitter Springs Formation occur within black chert nodules in thin-bedded dolostones.

OTHER UPPER PROTEROZOIC UNITS

The Late Proterozoic sequence occurring above the Bitter Springs Formation and below the Arumbera Sandstone was divided into the Areyonga and Pertatataka Formations by Prichard & Quinlan (1962). Several members were recognised by Wells & others (1967, 1970), and recently some of these members have been upgraded to formation status (Preiss & others, 1978; Shaw & others, 1982). The following Late Proterozoic formations and members are now recognized:

TOP Arumbera Sandstone
Julie Formation
Pertatataka Formation
- Cyclops Member
- Waldo Pedlar Member
Olympic Formation/Pioneer Sandstone
Aralka Formation
- Limbla Member
- Ringwood Member
Areyonga Formation
Bitter Springs Formation
BASE Heavitree Quartzite

The Areyonga Formation occurs disconformably above the Bitter Springs Formation and consists of up to 250 m of diamictite and conglomerate of glacial origin, together with sandstone containing rare dropstones and minor shale. The uppermost unit is a dolostone which was referred to as the lower marker 'cap dolomite' by Preiss & others (1978).

Conformably overlying the Areyonga Formation is the Aralka Formation. This unit consists of up to 1000 m of predominantly shale and siltstone. In the northwest part of the basin, two members have been recognised. The lower Ringwood Member consists of dolostone and calcarenite which is in part pisolitic and stromatolitic, whereas the upper Limbla Member consists of pebbly and sandy calcarenite and festoon cross-bedded sandstone.

The Olympic Formation and its lateral equivalent the Pioneer Sandstone disconformably overlie the Aralka Formation. In the northwest the Olympic Formation consists of lenticular units of sandstone, siltstone, conglomerate, shale and dolostone. Diamictite within the formation is of glacial origin, representing a younger Late Proterozoic glacial event than that recorded in the Areyonga Formation. To the west of Alice Springs, the Pioneer Sandstone consists of intertidal sandstone capped by 1 m of dolostone, the upper marker 'cap dolomite' of Preiss & others (1978). The two 'cap dolomites' can be correlated with similar units in the Ngalia and Georgina Basins to the north and northeast, and in the Adelaide Fold Belt to the south.

The Pertatataka Formation, arguably the most poorly exposed unit in the Amadeus Basin, was deposited conformably above the Olympic Formation and Pioneer Sandstone, and consists predominantly of red and green shales and siltstones, with minor thin sandstone beds. In the northeast, the lower Waldo Pedlar Member consists of thin-bedded flaggy sandstone, and the upper Cyclops Member consists of platy, rhythmically-bedded sandstone. In the northwest much of the unit was deposited by turbidity currents travelling from south to north, whereas in the northeast, ripple marks and cross-bedding in the Cyclops Member indicate a shallower water environment of deposition. These latter sediments were probably derived from the northern margin of the basin.

The Pertatataka Formation shallows up into the Julie Formation which is a widespread, relatively thin sequence of dolostone and limestone up to 150 m thick. It contains thick-bedded ooid grainstones of shallow marine origin. A dark grey foetid limestone commonly occurs near the base of this formation.

CAMBRIAN PERTAOORRTA GROUP

The Pertaoorrta Group (fig.4) comprises a mosaic of siliciclastic and carbonate facies that range in age from latest Proterozoic to latest Cambrian. This group of sediments has a maximum thickness near the present northern margin of the basin, a characteristic feature of the Lower to Middle Palaeozoic sediments in the basin. The distribution of facies and isopachs indicate that sedimentation occurred within two depocentres or sub-basins. In the eastern Ooraminna Sub-basin, fluvial-deltaic sandstones and siltstones (Arumbera Sandstone) are overlain by shallow marine carbonates, evaporites and siltstones (Todd River Dolomite, Chandler Formation, Giles Creek Dolomite and Shannon Formation). In the western Carmichael Sub-basin, however, fluvial-deltaic sandstones and siltstones (Arumbera Sandstone and equivalent Eninta Sandstone) are overlain by shallow marine sandstones and siltstones (Tempe Formation, Illara Sandstone, Deception Formation and Petermann Sandstone) which pass westward into coarse fluvial and deltaic sandstones (Cleland Sandstone). In the central

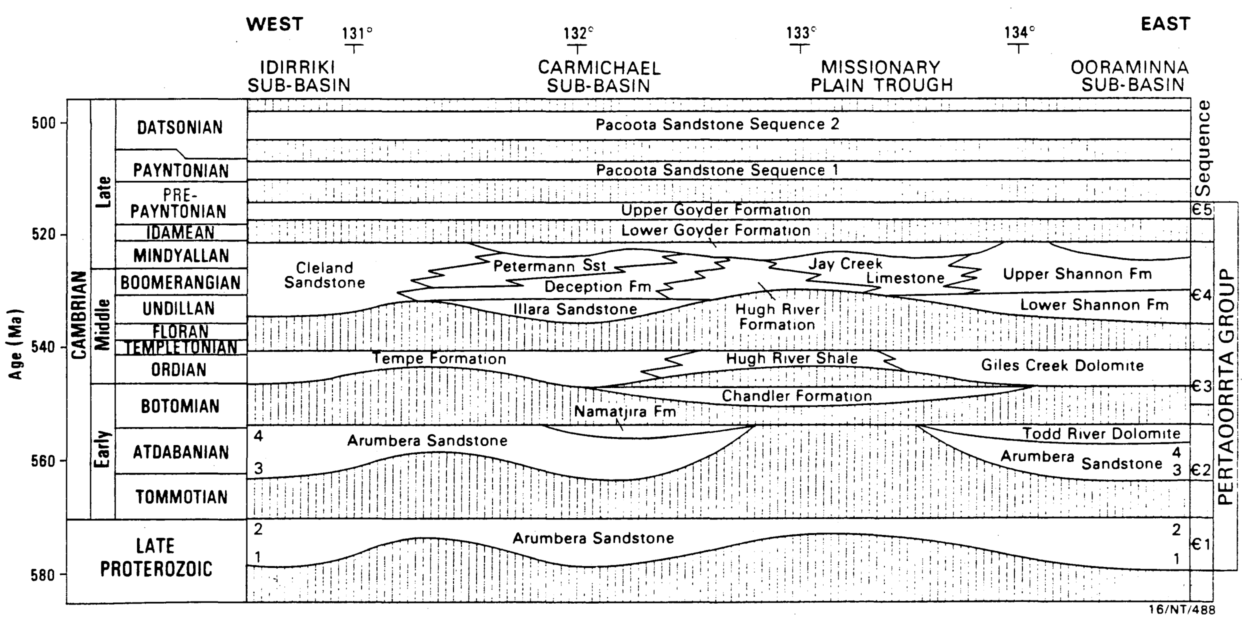


Figure 4. Interpreted relationships of lithostratigraphic units and depositional sequences of the Pertaoorrta Group (Kennard & Lindsay, 1991)

zone between the sub-basins, the basal fluvial-deltaic sandstones and siltstones (Arumbera Sandstone and equivalent Quandong Conglomerate) are considerably thinner, and they are overlain by shallow marine shales, siltstones and carbonates (Chandler Formation, Hugh River Shale and Jay Creek Limestone). Shallow marine sandstones, siltstones and carbonates at the top of the Pertaoorrta Group (Goyder Formation) were probably initially restricted to the eastern and western sub-basins, and subsequently extended across the central area, at which time separate sub-basins ceased to exist.

ARUMBERA SANDSTONE

The Arumbera Sandstone, which is a major hydrocarbon reservoir (Roe, 1991), straddles the Proterozoic-Cambrian boundary (Preiss & others, 1978, Burek & others, 1979). The formation forms a series of prominent dark red-brown strike ridges and consists of sandstone, shale and silt-stone, and locally conglomerate and carbonates. The clastic sediments are frequently a distinctive red or purple colour. In the more southern parts of the basin, coarser lensoidal units (the Quandong Conglomerate, Mount Currie Conglomerate, and the arkose at Ayers Rock) are thought to be equivalent to the Arumbera Sandstone (Ranford & others, 1965; Forman, 1966).

The formation can be readily subdivided into four lithologic units which are numbered from the base upward. Units 1 and 3 are shaly, recessive units, whereas units 2 and 4 are sandstones that form prominent strike ridges. The four units form two large-scale shallowing upward cycles that begin abruptly above the shallow water carbonates of the Julie Formation.

Abundant and diverse ichnofaunas have been obtained from the Arumbera Sandstone. (Walter, Elphinstone & Heys, 1989). At present some 30 different ichnospecies have been identified. They include a preponderance of simple horizontal burrows (*Planolites, Palaeophycus*), some vertical burrows (*Skolithos, Diplocraterion*), simple sediment filled horizontal burrows (*Didymaulichnus*), complex horizontal burrows (*Plagiogmus*), strings of fecal pellets (*Neonereites*), complex burrow systems (*Phycodes*) and anthropod swimming-grazing traces (*Monomorphichnus*).

Results from ichnofossils studies in the Arumbera Sandstone and correlative trace fossil-bearing sequences elsewhere, confirm that the upper Arumbera Sandstone (Units 3 and 4) is earliest Cambrian, and the lower part (Units 1 and 2) is latest Proterozoic.

NAMATJIRA FORMATION

The Namatjira Formation is a shallow water, high energy, mixed carbonate and clastic unit which crops out in the eastern portion of the Gardiner Range Anticline over a distance of approximately 10 km. It is not recognised elsewhere in the basin.

The Namatjira Formation lies stratigraphically between the Arumbera Sandstone and the Chandler Formation. The lower contact with the Arumbera Sandstone is gradational, whilst the upper boundary is disconformable. The formation thickens rapidly from 50 m in the west to 100 m in the east. The lower contact interfingers with the Arumbera Sandstone.

TODD RIVER DOLOMITE

The Todd River Dolomite, defined by Wells & others (1967), is a sequence of thick-bedded, archaeocyathan-rich dolostone, overlying thin-bedded sandstone, siltstone, mudstone and dolostone. It is the only formation in the basin that contains skeletal organic buildups.

The Todd River Dolomite crops out in low scarps, discontinuous ridges and rounded hills in the northeastern portion of the basin. It has a maximum thickness of 129 m at Ross River Gorge, the type section, and thins gradually to the east and south.

The Todd River Dolomite gradationally overlies, and in part probably interfingers with, the Arumbera Sandstone. It is disconformably overlain by the Chandler Formation and, the Giles Creek Dolomite. The disconformity is generally marked by a thin conglomerate comprising pink dolostone clasts, detrital dolomite grains, terrigenous sand and silt, and locally by an irregular karst solution surface.

The archaeocyathan fauna of the Todd River Dolomite has been described by Kruse & West (1980), and the phosphatic organisms by Laurie & Shergold (1984) and Laurie (1986); these faunas indicate a late Early Cambrian (Atdabanian to early Lenian) age for the Todd River Dolomite.

CHANDLER FORMATION

The Chandler Limestone was first described by Ranford & others (1965). It has since been referred to as the Chandler Formation (Schroder & Gorter, 1984; Jackson & others, 1984) because of the recognition of lithological units other than limestone within the formation. It is composed of halite, foetid carbonate mudstone, shale, and siltstone and is widely distributed in the eastern and central parts of the basin over an area of 80,000 sq. km.

The thickness and lithology of the Chandler Formation varies across the basin. In the southeast it consists of over 450 m of halite, and carbonates and clastics are absent. In the eastern central area it consists of 230 m of halite, 30 m of siltstone and 10 m of carbonate. In the western central area it consists of 30 m of siltstone and 10 m of carbonate, and halite is absent.

The widespread distribution and tectonic disturbance of the Chandler Formation has resulted in many and varied stratigraphic contacts. It is disconformably overlain by the Tempe Formation in the western central part of the basin, and disconformably overlies the Arumbera Sandstone and the Areyonga and Bitter Springs Formations. Further east, extensive salt flowage and dissolution within the Chandler Formation has produced tectonic contacts with numerous older and younger, including Ordovician, units. In the eastern central part of the basin it is overlain by the Jay Creek Limestone, and overlies the Arumbera Sandstone, Quandong Conglomerate and Bitter Springs Formation. In the east it is overlain by the Giles Creek Dolomite and disconformably overlies the Todd River Dolomite, Arumbera Sandstone and the Pertatataka, Areyonga and, perhaps, Bitter Springs Formations.

Fossils have not been found in the Chandler Formation. The overlying Tempe Formation in the Gardiner Range has an Ordian age based on fossiliferous carbonates at the top of the sequence.

TEMPE FORMATION

The Tempe Formation was first recognised by Wells & others (1965) and later described by Ranford & others (1965). The Tempe Formation is a shallow water shelf sequence dominated by shale and siltstone with thin beds of carbonate towards the top of the formation, and sandstone layers near the base. It has rapid lateral variations in lithology and sedimentology, with local areas of emergence and shallow water deposition surrounded by sediments deposited below wave base.

The Tempe Formation is confined to the northwestern parts of the central Amadeus Basin and has an average thickness of approximately 150 m. It disconformably overlies the Chandler Formation or the Arumbera Sandstone. Conformably overlying the Tempe Formation is the Illara Sandstone.

Shergold (1986) assigned a lower Middle Cambrian age based on a fauna of brachiopods, trilobites, hyoliths, ostracodes and gastropods and an acritarch assemblage. This fauna occurs within the carbonates near the top of the sequence, and thus equates the upper Tempe Formation to the lower part of the Giles Creek Dolomite in the eastern part of the basin.

GILES CREEK DOLOMITE

The Giles Creek Dolomite, defined by Wells & others (1967), is a sequence of light brown and grey limestone and dolostone, and variegated shale, siltstone, mudstone and minor sandstone. Terrigenous-rich carbonates and mudstones comprise over half of the volume of the formation at most locations, but at the type section in Ross River Gorge, dolostone and limestone are predominant.

The Giles Creek Dolomite is restricted to the eastern parts of the basin and has a maximum thickness of 383 m. It disconformably overlies the Chandler Formation and, in the east, the Todd River Dolomite. It is conformably and gradationally overlain by the Shannon Formation. To the west, the Giles Creek Dolomite interfingers with the basal part of the Jay Creek Limestone.

Hyoliths, brachiopods, gastropods, trilobites, echinoderms and chancelloriid spicules occur near the base of the Giles Creek Dolomite in the Ross River and Fergusson Synclines, and indicate an early Middle Cambrian (Ordian and Templetonian) age (Shergold, 1986).

SHANNON FORMATION

The Shannon Formation, defined by Wells & others (1967), comprises interbedded red and green shale and siltstone, grey limestone, and grey or yellow dolostone. A thick recessive interval of shale occurs at the base of the formation, except in the north.

The Shannon Formation crops out in a series of low prominently benched, strike ridges and valleys throughout the northeastern portion of the basin. It has a maximum thickness of 715 m. Thinning of the Shannon Formation to the south and east is a result of erosional truncation following uplift during the Rodingan Movement.

The Shannon Formation conformably and gradationally overlies the Giles Creek Dolomite and is conformably overlain by and interfingers with the lower Goyder Formation.

The Shannon Formation is sparsely fossiliferous. Macrofossils in the upper carbonate-rich portion of the formation indicate an early Late Cambrian (late Mindyallan) age (Gilbert-Tomlinson, in Wells & others, 1970). The lower shaly portion of the Shannon Formation is thus probably Middle Cambrian in age.

JAY CREEK LIMESTONE

The Jay Creek Limestone, defined by Prichard & Quinlan (1962), consists of limestone, siltstone, shale and minor calcareous sandstone. It is restricted to the eastern central portion of the basin between the Finke River to the west and the approximate longitude of Alice Springs. It forms a series of low, poorly exposed, limestone ridges separated by concealed intervals of fine siliciclastics. Its stratigraphic relationships with other units of the Pertaoorrta Group are poorly known. It rests with probable unconformity on the Chandler Formation and is conformably overlain by, and interfingers with the Lower Goyder Formation. East of the longitude of Alice Springs, it appears to gradationally interfinger with the Giles Creek Dolomite and Shannon Formation, and west of the Finke River it probably interfingers with the Hugh River Shale, Tempe Formation, Illara Sandstone and Deception Formation. It is about 50 m thick at the type section at Jay Creek, and progressively thickens southward to about 150 m in the Waterhouse Range and over 250 m southeast of Henbury Station.

The limestones are commonly cross-laminated and sandy, and locally contain *Girvanella* and fragments of inarticulate brachiopods, molluscs and trilobites. This fauna indicates an early Late Cambrian (Mindyallan) age, whereas trilobites near the base of the eastern-most mapped limit of the formation indicate an early Middle Cambrian (Ordian) age (Shergold, 1986). These eastern outcrops, however, are probably part of the Giles Creek Dolomite (Deckelman and Oaks, in Kennard & others, 1986).

HUGH RIVER SHALE

The Hugh River Shale, also defined by Prichard & Quinlan (1962), consists of red-brown and grey-brown siltstone and shale, and minor thin beds of dolostone, limestone, sandstone and chert. The unit is very poorly exposed and is restricted to the western MacDonnell Range at the northern margin of the basin. It has an estimated thickness of about 500 m.

The relationship of the Hugh River Shale to other units of the Pertaoorrta Group is unclear. It overlies the Arumbera Sandstone with apparent conformity, and probably gradationally interfingers to the south with the Jay Creek Limestone, Tempe Formation, Illara Sandstone and Deception Formation. East of the Finke River it is overlain by the Jay Creek Limestone, and further to the west by the Lower Goyder Formation. Both of these contacts are probably conformable and gradational. Fossils have not been found in the formation, but its stratigraphic position suggests a Lower or Middle Cambrian age.

ILLARA SANDSTONE, DECEPTION FORMATION AND PETERMANN SANDSTONE

These three units form a package of sediments with a restricted occurrence in the central part of the basin. All three units are imperfectly known, having not been studied since defined by Wells & others (1965, 1970). Both the Illara and Petermann Sandstones form prominent strike ridges with the Deception Formation rarely seen in the intervening strike valley. Their type sections are all in the central part of the Gardiner Range, west of Katapata Gap.

The Illara Sandstone reaches a maximum thickness of about 200 m in the Gardiner Range and consists predominantly of red-brown fine to medium grained, moderately sorted, cross-bedded, feldspathic micaceous quartz sandstone with minor interbeds of micaceous siltstone and shale.

The contact with the underlying Tempe Formation is gradational over several metres, and is marked by a gradual increase in the abundance and thickness of sandstone beds.

The Deception Formation has a maximum thickness of about 175 m in the Gardiner Range and dominantly consists of very poorly outcropping red-brown micaceous siltstone. Beds of fine to medium grained micaceous quarts sandstone, dolostone and limestone form a minor (generally less than 10%) proportion of the unit, and are commonly the only visible outcrops.

The Petermann Sandstone has a maximum thickness of about 250 m in the Gardiner Range and consists of red-brown, fine to medium-grained micaceous sandstone. The sandstone is generally thinly bedded, invariably cross-bedded, and ripple marks are common. Mud-flakes, slumped cross-beds and laminae enriched in heavy minerals are locally common.

All boundaries between the units are gradational and the Petermann Sandstone is probably in part laterally equivalent to the Deception Formation, and both of these units are gradationally overlain by the Goyder Formation.

The three units are thought from their sedimentary structures to have been deposited in a marine environment, and appear to represent a major shallowing-deepening-shallowing cycle.

Age diagnostic fossils have not been found in any of the units, and their suggested Middle Cambrian age is based on the age of the underlying Tempe and overlying Goyder Formations.

GOYDER FORMATION

Our understanding of the Goyder Formation is obscured by poor exposure, limited palaeontological control and confusion in the field interpretation of just which rock sequences should be assigned to the unit. Until detailed sedimentological and palaeontological studies of the unit are undertaken, our understanding of the formation will remain poor.

The Goyder Formation as mapped by Wells & others (1970) was divided into two. The 'lower Goyder Formation' consists of biostromal carbonates of Late Cambrian (Mindyallan) age overlain by dolomitic sandstone also of Mindyallan age (fig.7) (Shergold, 1986). The 'upper Goyder Formation' consisted of kaolinitic, cross-stratified sandstones containing a *Skolithos* ichnocoenosis and has no age diagnostic fossils (fig.7) (Shergold, 1986). Separation of the upper and lower Goyder Formation was based, in part, on the recognition of a 2-5 m thick zone in which an iron or manganese oxide coating occurs on the sandstone or carbonate beds, a zone that was thought to mark an unconformity in the eastern part of the basin (Kennard & others, 1986). This is now thought to be an hydrogeological feature related to porosity of the host sediment and otherwise unrelated to stratigraphy.

Lithologically, the carbonates of the lower Goyder Formation appear to be closely related to the upper parts of the Shannon Formation and Jay Creek Limestone. This part of the unit contains the *Glyptagnostus stolidotus* Assemblage--Zone, of late Mindyallan age. Initially reported from the Lower Goyder Formation in Ross River Gorge (west bank) (Öpik, 1967, volume 2, p. 16; Gilbert-Tomlinson, in Pojeta & others, 1977, p. 34), it is known now to be considerably more extensive, occurring from the Fergusson Range in the east, to as far west as the Gardiner Range Anticline, south of Areyonga. This confirms Gilbert-Tomlinson's (in Wells & others, 1967) previously undocumented correlation of the upper part of the Shannon

Formation, the upper Jay Creek Limestone, and the lower Goyder Formation. Also reported from this assemblage (Shergold, 1989; Shergold and others, 1991) are trilobites belonging to the genera *Liostracina, Henadoparia, Lophoholcus, Nomadinis, Metopotropis, Bergeronites (Palaeodotes)* and other damesellaceans, leiostegiaceans (pagodiids) and agnostoids, particularly of the *Ammagnostus* type.

The sandstones of the upper Goyder Formation are closely related lithologically to the overlying Pacoota Sandstone. Although no recognisable Idamean trilobites have yet been found in the Amadeus Basin, a younger assemblage than that of the *G. stolidotus* Zone has been identified at eight localities in the east from carbonates of the Shannon Formation, and in dolomitic and kaolinitic sands of the upper Goyder Formation which overlie basal Goyder carbonates in the Fergusson Syncline, the Waterhouse Range Anticline, and the Gardiner Range Anticline near Areyonga. This assemblage is informally referred to as the 'parabolinoidid assemblage' because it seems to lie in a stratigraphically similar position to faunal sequence VII (Parabolinoididae) as recognised by Öpik (1969) in the Bonaparte Basin. This assemblage is characterised by trilobites with truncato-conical glabella, small, anteriorly sited palpebral lobes, and transverse ocular ridges, not unlike cranidia assigned to *Apheloides* by Shergold & Cooper (1985) which occur in northern Victoria Land, Antarctica. In Antarctica, and in the Bonaparte Basin, such assemblages immediately post-date those of the Idamean Stage. They are, however, totally unlike anything recorded from contemporary strata in the Georgina Basin (Shergold, 1982), and their exact biostratigraphic position needs to be resolved.

ORDOVICIAN LARAPINTA GROUP

The Larapinta Group is composed of five formations (fig.5) of predominantly siliciclastic sediment deposited in a shallow intracratonic sea. Prichard & Quinlan (1962) defined the Larapinta Group and its constituent formations, revising terms introduced earlier by Tate (1896), Madigan (1932) and Chewings (1935). Subsequent minor amendments have been made by Wells & others (1965, 1970), and the latter contains a comprehensive summary of the geology of the Larapinta Group as understood at the completion of the regional mapping program conducted by the Bureau of Mineral Resources in the 1960's. Studies currently in progress are expected to further revise and refine our understanding of the depositional, sedimentological and palaeontological relationships of these units.

The present basin probably encompasses only about half of the former extent of Ordovician sediments in the region. Trends in formation thickness indicate that most of the units thicken toward the present northern margin of the basin along the MacDonnell Ranges and, if the basin was symmetrical, these units would have extended 100 to 150 km to the north. The shoreline configuration and connections to adjoining basins are not yet clearly defined, but by the initiation of Pacoota deposition there was probably a connection to the east across the Tasman Shelf and later, by Pacoota Sequence 3 time, there was also a connection to the Canning Basin to the west (Webby, 1978).

The Larapinta Group is economically important. The Pacoota Sandstone is the reservoir for hydrocarbons in the Mereenie and Palm Valley Fields and at West Walker #1 well. The overlying organic-rich shales of the Horn Valley Siltstone are both the source and seal for the reservoirs. Phosphate is present in the Stairway Sandstone but has not yet been found in sufficient abundance to be of economic importance.

A preliminary interpretation of the relative water depth and aerial extent of the sediments of the Larapinta Group are shown in Fig. 5. The basin reached its maximum extent during deposition of the upper Stairway Sandstone and lower Stokes Siltstone, at which time relatively shallow marine conditions prevailed throughout the basin.

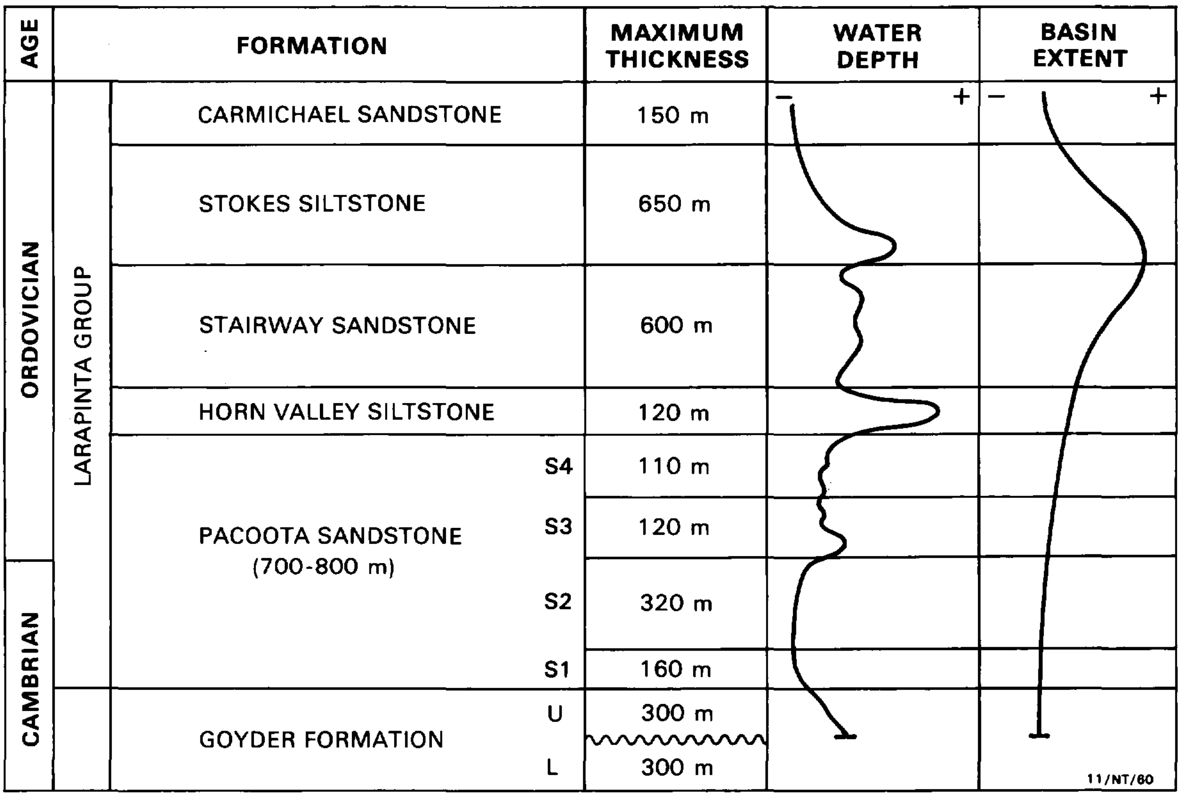


Figure 5. Formations of the Larapinta Group and interpretation of their relative depth of deposition and areal extent.

PACOOTA SANDSTONE

The Pacoota Sandstone (fig.6) is the thickest (700-800 m) but most depositionally restricted formation of the Larapinta Group. Primarily from subsurface data, the unit has been subdivided into four informal sequences, S1 (lowest) to S4, which reflect vertical lithofacies variations in a clastic dominated shallow marine environment. These roughly correspond to the informal members (P4 up to P1) used by the oil industry in the basin.

Two ichnofaunas are found throughout the Pacoota Sandstone and they are usually, but not always, mutually exclusive. The *Skolithos* ichnofauna is dominated by vertical burrows and is usually confined to the thicker sandstone beds. The *Cruziana* ichnofauna is dominated by tracks and trails on bedding surfaces where resistant lithologies are interbedded with shales or friable siltstones. Many of the tracks and trails were probably made by the trilobite fauna.

Sequence 1. Sequence 1 consists of fine to medium grained, moderately sorted sandstone with

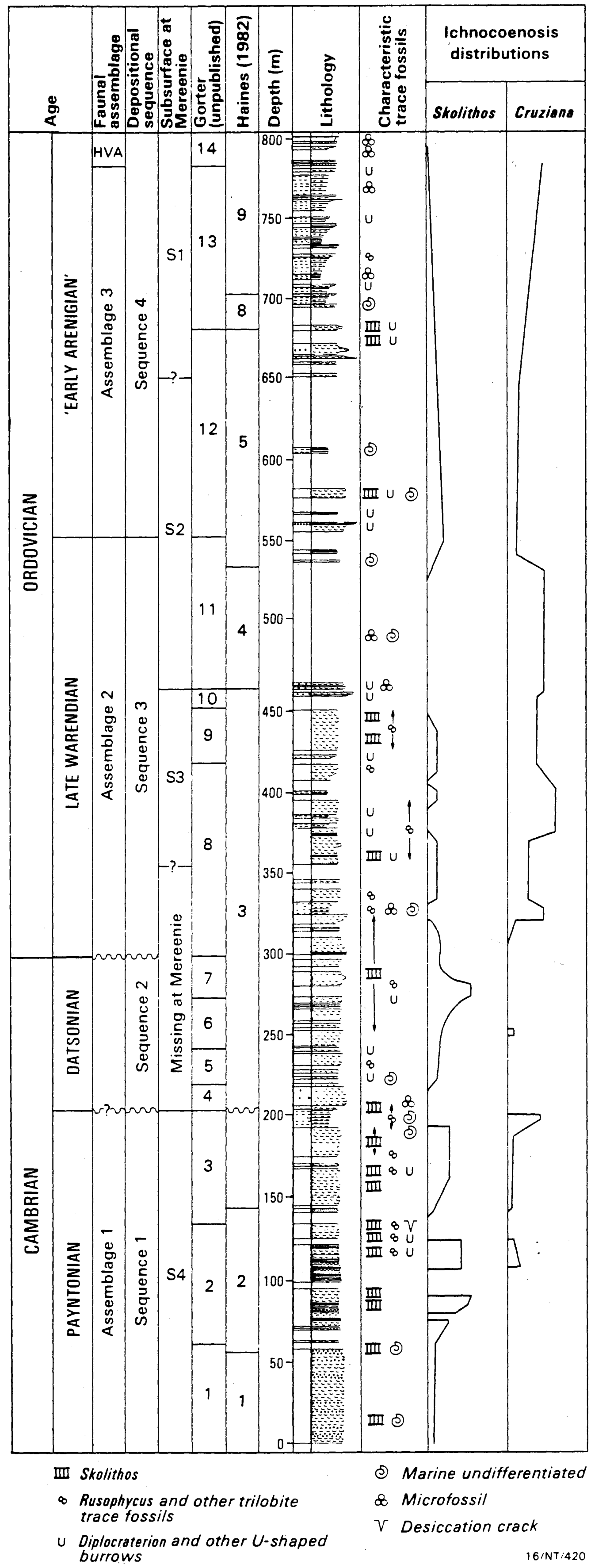


Figure 6. The type section of the Pacoota Sandstone at Ellery Creek, showing distribution of fossils, sedimentary sequences and ages (from Shergold, Gorter, Nicoll & Haines, 1991)

occasional coarse grains. It is quartzitic, kaolinitic in places, sometimes silicified and often has a calcitic or dolomitic cement. Sedimentary structures present include herringbone cross-bedding, low angle planar-tabular cross-bedding, symmetrical ripple marks, mud cracks, mud balls, scour and fill structures and trough cross-bedding. Beds of *Skolithos* pipe rock are often present but this is only a minor element of an ichnofauna dominated by simple, non-diagnostic, branching burrows. At Ellery Creek elements of the *Cruziana* ichnofacies, in particular *Rusophycus*, become more abundant in the upper part of the unit where they are associated with a *Skolithos* ichnofacies. Shelly fossils, mostly trilobites, are scarce except in the eastern area of outcrop (for example, at Ross River).

A significant time break occurs between the 'parabolinoidid assemblage' of the Upper Goyder Formation (fig.7) and that of sequence 1 (Shergold & others, 1991), i.e. the Pacoota I fauna of Gilbert-Tomlinson (in Wells & others, 1967) and Assemblage I of Shergold (1991). This trilobite assemblage is very widespread in the Amadeus Basin and elsewhere, having been recognised in 73 collections, but mostly concentrated in the Fergusson and Ross River Synclines, the Waterhouse Range Anticline, and along the Eastern MacDonnell Ranges. This assemblage is characterised by trilobites of the families Saukiidae, Tsinaniidae and Kaolishaniidae, and is essentially a similar association to that occurring in the uppermost Chatsworth Limestone and lowermost Ninmaroo Formation of the Burke River Structural Belt, eastern Georgina Basin (Shergold, 1975), and referred to the *Neoagnostus quasibilobus*/*Shergoldia nomas* and probably *Mictosaukia perplexa* Assemblage Zones, of Payntonian age (Nicoll & Shergold, 1991).

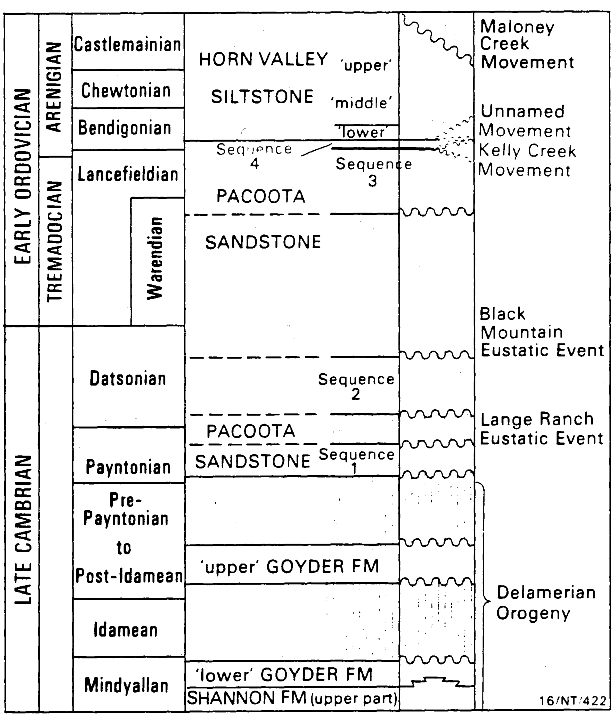


Figure 7. Distribution of sea-level events within the Pacoota Sandstone sequence.

The oldest conodont fauna found in the Amadeus Basin is found in sequence 1. It is a restricted fauna of late Cambrian coniform elements (Shergold & others, 1991) which are long ranging and have little biostratigraphic value.

Sequence 2. Sequence 2 is composed dominantly of sandstone with some conglomerate, siltstone and shale. The sandstone is arkosic to quartzitic and moderate to well sorted. Planar-tabular and trough cross-stratification are common and disturbed bedding, such as overturned cross-laminations and buckled bedding, are often present in the lower part. The distribution of sedimentary facies and ichnofacies is often cyclic. Thin-bedded sandstone, or interbedded sandstone and siltstone, grade upward into thick-bedded, planar to trough cross-stratified sandstone, the member having a sharply defined upper boundary.

This member of the Pacoota Sandstone contains neither trilobites nor other age-diagnostic fauna, and is dominated by ichnocoenoses (Haines, 1982; Shergold & others, 1991). Trace fossils of the *Skolithos* and *Cruziana* ichnofacies are sometimes abundant, with *Skolithos* most abundant in the upper part of the cycles in the lower part of the unit, whereas elements of the *Cruziana* ichnofacies become dominant within the upper part of the unit.

Sequence 3. The lower part of sequence 3 is composed of fine to coarse grained glauconitic sandstone, siltstone, shale and minor carbonate. Glauconite is abundant throughout the interval. Runzel marks (wrinkle marks) are common on the upper surfaces of fine sandstones interbedded with shales. Trace fossils belong to the *Cruziana* ichnofacies and elements of the *Skolithos* ichnofacies are rare or absent.

The upper part of sequence 3 consists of interbedded sandstone and shale, and is poorly exposed at most localities. Glauconite is also abundant in this part of the unit. The trace fossil fauna includes *Skolithos* and elements of the *Cruziana* ichnofacies, such as *Phycodes*, but other trace fossils are rare.

The shelly fauna of sequence 3 is relatively abundant, consisting mainly of bivalves, brachiopods, and locally abundant trilobites, gastropods and small nautiloids. The trilobites are referred to Assemblage 2 (Shergold, 1991; Pacoota II of Gilbert--Tomlinson, in Wells & others, 1967) which have been recognised in many collections extending across the Amadeus Basin from the Fergusson and Ross River Synclines in the east to Mount Rennie in the west. Assemblage 2 is dominated by leiostegiacean, remopleuridacean, hystricurid, pilekiine and asaphacean trilobites which form a characteristic generic association: *Apatokephalus, Asaphellus, Hystricurus, Kayseraspis, Koraipsis* and *Psilocephalina*. Similar associations occur in the *Acanthograptus-Tungtzuella* Zone of south-central China and the *Koraipsis-Hystricurus* Zone of North China and South Korea.

The conodont fauna of this member is relatively common in the northeastern and north-central parts of the basin and is dominated by species of *Drepanodus* with smooth lateral faces and *Scolopodus* aff. *S. iowensis* (Furnish, 1938). It may be correlated with the late Warendian (latest Tremadoc) conodont zone of *Chosonodina herfurthi-Acodus* in the uppermost Ninmaroo Formation of the Burke River Structural Belt, eastern Georgina Basin.

Sequence 4. Sequence 4 consists of interbedded siltstone, sandstone and shale and often has a basal pebbly horizon. Outcrops are commonly poorly exposed and covered by talus. However, a number of coarsening upward cycles can be observed in this unit. The sandstone beds usually contain vertical burrows such as *Diplocraterion*, whereas the siltstones are dominated by elements of the *Cruziana* ichnofacies, or are strongly bioturbated by non-diagnostic burrows.

This member contains trilobite Assemblage 3 (Shergold, 1991; Gilbert-Tomlinson, in Wells & others, 1967) which comprises a single undetermined species of *?Asaphellus*. The conodont fauna contains species of *Drepanodus* with well developed lateral costae, and *Bergstroemognathus extensus* Serpagli, 1974 in the upper part of the unit. These assemblages occur only in the central part of the Basin. This unit is within the early Arenig (Early Ordovician).

Depositional environment

The clastic dominated lithologies in all subdivisions of the Pacoota Sandstone are representative of shallow marine depositional conditions. Only in the western and southern parts of the basin are there sediments that might be indicative of fluvial deposition (Deckelman, 1991).

Sequences 1 and 2 of the Pacoota were probably deposited in a shallow shelf environment, and represent intertidal and subtidal sand sheets and offshore bar and bank deposits. Mud cracks and other indicators of subaerial exposure are rare in the sequence. Some of the thicker *Skolithos* beds can be traced laterally for distances of several kilometres.

Sequence 3, with its shift from sand to silt-shale dominated lithologies, distinct faunal change and abundance of glauconite, indicates an increase in water depth, at least in the central part of the basin.

The overlying Sequence 4 represent a return to a shallower conditions, as indicated by the increased abundance of *Skolithos* ichnofauna in sandstones, but the interbedded silty to shaly beds contain elements of the *Cruziana* ichnofauna, and thus indicate that deeper water conditions existed in some areas. The overlying Horn Valley Siltstone is the culmination of this trend toward greater water depth.

HORN VALLEY SILTSTONE

The Horn Valley Siltstone (fig.5) consists of thinly interbedded shale and siltstone, with bedded and nodular limestones abundant in some intervals. Exposure of the Horn Valley Siltstone is usually poor. Elphinstone & Gorter (1991) have recognised informal units in the Horn Valley (HV1-HV10), but the basal units (HV1 & HV2) are usually not exposed in outcrop sections and the mappable base of the formation is drawn at the base of a prominent dolomitic limestone unit (HV3).

The boundary between the Pacoota Sandstone and the Horn Valley Siltstone is defined at the base of the first prominent limestone bed above the siliciclastic Pacoota sequence. Except for problems relating to poor exposure, this has proven to be a relatively consistent stratigraphic horizon throughout the basin.

The basal carbonate unit of the Horn Valley Siltstone (HV3) is 1-4 m thick and consists of medium to thick, irregular bedded, dolomitic limestone. Only poorly preserved macrofossils have been observed in outcrop but nautiloids have been recovered from core. A distinctive and abundant conodont fauna has been recovered from this interval at several localities throughout the basin. It contains elements of *Bergstroemognathus hubeiensis* An, 1981 and *Oepikodus communis* (Ethington & Clark, 1964) of early Arenig age.

Above the basal carbonates there is an 18 to 40 m thick interval of shale with dispersed nodules and nodular beds of micritic limestone. Sporadic 1-3 cm thick discontinuous beds of silty bioclastic limestone are also present. In outcrop the shales have weathered to a light grey colour, but in core they are dark grey to black. Trilobites, nautiloids and brachiopods are common to abundant in this interval, and bioturbation is rare. The conodont fauna found in this middle part of the Horn Valley Siltstone is distributed throughout the basin and contains *Jumudontus gananda, Prioniodus amadeus, Erraticodon patu* and *Protoprioniodus aranda,* all previously described by Cooper (1981). The trilobite fauna in this interval contains *Lycophron howchini* (Etheridge), *'Basiliella' illarensis* (Etheridge), n. gen. aff. *Ogygitoides* n.sp. A, *Carolinites genacinaca* Ross, *Encrinurella* sp. and *Prosopiscus* sp., and is found wherever the Horn Valley Siltstone occurs.

The nodular limestone/shale sequence is followed by a 15 to 35 m thick unit of interbedded marl and shelly limestone, with occasional beds of shale and nodular limestone. In the Tempe Vale #1 well a number of cyclic sedimentation sequences have been recorded in the upper part of this interval. The lower part of each cycle is marked by a coquina with a sharp base, abundant shelly fragments, and low silt content, and is usually less than 10 cm thick. This is followed by a marl (laminated calcilutite) with a gradational base and small calcareous lenses which decrease toward the top. The upper unit of each cycle is a dark grey mudstone with faint laminations. This is followed by a sharp break and the next coquina. Trilobites, nautiloids, graptolites and brachiopods are common to abundant in this interval. Conodonts from this interval from the central-western part of the basin, include *Periodon flabellum* (Lindstrom, 1955) and *Microzarkodina* sp. indet. and is of late Arenig age. The trilobite fauna from this interval contains *Lycophron* n.sp., n. gen. aff. *Ogygitoides* n.sp. B, ?*Fitzroyaspis* n.sp aff. *irritans* Fortey & Shergold, 1974, *'Parabasilicus'* sp., *Carolinites genacinaca* Ross and *Prosopiscus* sp., and is restricted to the more westerly parts of the basin.

The uppermost part of the Horn Valley Siltstone is marked by a gradual upward transition from black shale and siltstone to interbedded carbonate and siltstone, and finally fine sandstone. This interval may be up to 10 m thick. The boundary with the overlying Stairway Sandstone is arbitrarily placed where the sand component becomes dominant.

Depositional environment

The Horn Valley Siltstone was deposited on a shallow marine shelf. The diversity of the preserved fauna indicates normal marine salinity throughout the unit. Black shales, especially in the lower part of the unit, presumably represent euxinic bottom conditions that preserved a pelagic fauna. Where the black shales are interbedded with limestones that show cyclic storm related sequences, the bottom must have been oxygenated. Above the initial carbonate unit, the lower part of the Horn Valley Siltstone is dominated by black shale. The subsequent gradual upward increase in limestone in this black shale unit is probably indicative of shoaling that ultimately led to the re-introduction of coarse clastics to form the overlying Stairway Sandstone.

STAIRWAY SANDSTONE

The Stairway Sandstone (fig.5) is the most extensive of the Larapinta Group units, cropping out sporadically throughout much of the basin. In the northern part of the basin it disconformably overlies the Horn Valley Siltstone and to the south it overlaps progressively older units, with a marked angular unconformity in many areas. The formation attains a maximum thickness of 550m in the northern half of the Basin and in most areas is divisible into three units.

The lower unit is 25-60 m thick and is composed mainly of a prominent massively bedded quartzose sandstone. It is characterised by an abundance of ripple marks and cross-beds, and ichnofossils which commonly weather to give a "ropey" texture. A notable feature of this basal unit is the local presence of thin beds of coarse ferruginous ooids. The top of the basal sandstone unit is commonly marked by a thin but remarkably persistent horizon of quartz pebbles.

The middle unit is poorly exposed in most areas, commonly forming persistent strike valleys in the northern part of the Basin. In these areas outcrop is usually rubbly with thin sandstones and occasional residual phosphatic gravels. Drilling and excavating have shown the middle unit to be up to 200 m thick and to consist of interbedded black shale, siltstone, fine sandstone and phosphorite. Thin limestone interbeds occur within the middle unit in the south-central part of the basin, and to the southwest there is a local redbed development. Body fossils and ichnofossils are relatively common.

The upper unit is best developed in the northern part of the basin where it is up to 300 m thick and forms fairly prominent strike ridges. It consists of thinly bedded, fine grained quartzose sandstone with interbeds of grey siltstone and mudstone. A few thin phosphorite beds are present. The boundary with the overlying Stokes Siltstone is commonly gradational.

The trilobite assemblages of the Stairway Sandstone have not been investigated in detail; what little is known about them is summarised by Shergold (1986, p.10). The few spot samples of the Stairway Sandstone that have been studied contain a poorly preserved, low diversity fauna which includes *Erraticodon ?balticus* Dzik and *?Aphelognathus* sp..

Depositional environment

Regional palaeogeographic data indicates that the Stairway Sandstone was deposited within a broad epicontinental seaway with an approximately east-west orientation. Palaeocurrents were dominantly from the east. The abundant fossils within the sequence point to a strong marine influence throughout, but with relatively shallow subtidal and partly intertidal conditions during deposition of the lower and upper units, and somewhat deeper conditions during deposition of the middle unit. The lower unit also shows a well defined coarsening-upwards cycle which is consistent with deposition as a regressive sand sheet. Therefore the environmental picture is broadly one of shallow (intertidal-subtidal) deposition of a seaward prograding sand sheet. This was followed by a sea-level rise and deposition of somewhat deeper water, finer grained, organic-rich phosphatic marine sediments. As sea-level gradually fell and the basin shallowed, sedimentation became coarser grained and intertidal-shallow subtidal sands were once more deposited in the basin. This regression ultimately produced hypersaline, possibly partly subaerial, sedimentation in the overlying Stokes Siltstone.

STOKES SILTSTONE

The Stokes Siltstone (fig.5) crops out over a distance of 500 km from the eastern end of the James Ranges-Mount Rodinga area in the east, to the Western Australian-Northern Territory border in the west. It occurs from the MacDonnell Ranges in the north to the Bloods Ranges in the south, a distance of over 150 km. The present eastern limit of the formation is controlled by erosion prior to the deposition of the Mereenie Sandstone (Rodingan Movement), and the northern limit by erosion associated with the Alice Springs Orogeny. The southern and possibly the western limits of the formation approximately represent the depositional extent of the unit.

The Stokes Siltstone is a recessive, valley forming unit. It has a maximum thickness of about 650 m in the north-central part of the basin, and progressively thins southward to 300 m in the Gardiner, James, and George Gill Ranges, and 20-100 m at its southernmost exposure.

The lower 50-100 m of the Stokes Siltstone consists of interbedded shale and siltstone, usually of reddish or greenish colour in outcrop, and 5-10 cm thick beds of limestone. The limestones are silty and sandy, and usually contain abundant fossil debris. The shales and siltstones are rarely exposed but the limestones, despite their thinness, are laterally continuous and individual beds may be traced over a distance of several hundred metres.

Above the highest limestone, exposures of the middle portion of the Stokes Siltstone are very rare. Where it has been observed in creek banks and gullies, this unit consists of reddish shale and lesser amounts of brown to grey-green siltstone.

The upper part of the Stokes Siltstone consists of interbedded red to green shale, grey-green siltstone and fine sandstone. In the vicinity of Carmichael Crag, the upper part of the formation is over 100 m thick and the red shale component decreases upward so that siltstone becomes dominant. Sandstone beds up to 3 m thick with festoon cross-bedding mark the base of the overlying Carmichael Sandstone. Pseudomorphs after halite are abundant on both upper and lower bedding surfaces of the dolomitic siltstones, and fossils are apparently absent. Eastward from Carmichael Crag, the siltstone beds decrease in thickness and shales or shaly siltstones are predominant.

The Stokes Siltstone appears to contain two distinct conodont faunas, neither of which has been studied sufficiently well to be able to apply names to most of the elements. However one species which has been identified is the Chinese species *Plectodina onychodonta* An & Wu, 1983. The trilobite fauna is sparse, with only two well developed horizons having been collected and both are from the lower part of the unit. Asaphids are the most common element of the fauna, but also present are *Prosopiscus* sp. and *Neseuretus (Neseuretinus)* sp. nov.. The age of the lower part of the unit is middle Llanvirn.

Depositional Environment

The Stokes Siltstone represents a range of depositional environments. Faunas of the interbedded carbonates and clastics in the lower part of the formation indicate open shallow shelf conditions. The thick sequence of shale and siltstone in the middle portion of the unit has not been sufficiently studied to interpret its depositional environment. The presence in the subsurface of both red and grey-green shales indicate that anoxic conditions were not extensively developed during the deposition of this interval.

The upper part of the formation, consisting of shale, siltstone and thin carbonates, may represent deposition in an environment of elevated salinity. Halite hoppers are abundant on the upper and lower surfaces of thin dolomitic carbonate beds. Deposition of the succeeding Carmichael Sandstone represents a return to normal marine salinity and coarse clastic sediments.

CARMICHAEL SANDSTONE

The Charmichael Sandstone (fig.5) has a wide distribution in the central and western parts of the basin, but is absent in the east where it appears not to have been deposited. It is generally poorly exposed and partially covered by scree from the overlying scarp of the Mereenie Sandstone. It has a maximum thickness of about 150 m in the southern part of the basin.

The Carmichael Sandstone has a gradational contact with the underlying Stokes Siltstone and the boundary is placed at the first significant, laterally continuous sandstone. The relationship with the overlying Mereenie Sandstone is poorly understood. In the central western part of the basin the Carmichael-Mereenie contact appears gradational but eastward the Carmichael Sandstone thins rapidly and the contact could be unconformable.

The Carmichael Sandstone consists of interbedded pale brown to red-brown sandstone, siltstone and mudstone. The sandstones are fine to medium grained, moderately sorted, and consist dominantly of quartz with not more than 5% feldspar and minor lithic grains. Kaolinite and iron oxide form the main cements. Both tabular and trough cross-bedding are common, some of which are overturned. Ripple marks are often present, and mud cracks and halite pseudomorphs occur in siltstone and mudstone. The only fossils present are rare ichnofossils, including *Cruziana.*

The age of the Carmichael Sandstone is uncertain since no age diagnostic fossils have been found, but microvertebrate remains suggest an Ordovician age, as does its apparently conformable stratigraphic position above the Stokes Siltstone.

The depositional environment of the Carmichael Sandstone is thought to have been a mixture of shallow marine, at times hypersaline, and fluvial conditions. Preliminary palaeocurrent studies suggest that fluvial facies may have been derived from the south, and that the marine facies have a bimodal distribution with a north/south orientation.

UPPER ORDOVICIAN-DEVONIAN

MEREENIE SANDSTONE

The Mereenie Sandstone (fig.8) was first described by Chewings (1894) under the name Mereenie Bluff Formation, and was later amended to its present name by Prichard & Quinlan (1962). The type section is west of Ellery Creek; sections at Stokes Pass and at Areyonga

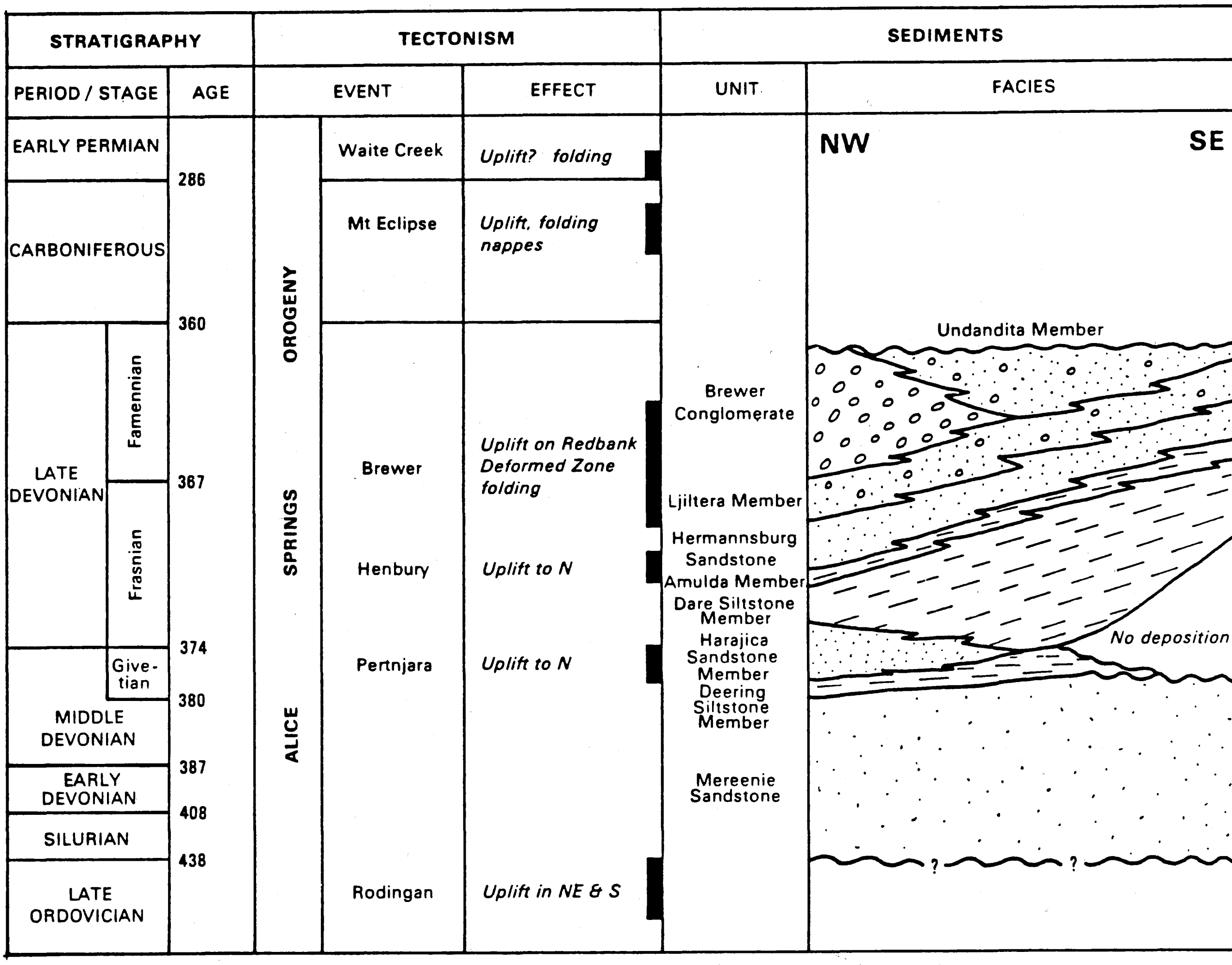


Figure 8. Schematic relationships between facies, stratigraphy, age and tectonic events of the Mereenie Sandstone and Pertnjara Group (from Jones, 1991).

Creek provide additional good reference sections.

The unit is one of the most extensive in the Amadeus Basin with an east-west extent of some 800 km and a present north-south extent, the original northern limit being unknown, of almost 200 km. It has a maximum thickness of about 1000 m in the Gardiner Range.

The Mereenie Sandstone is generally resistant to erosion and often forms spectacular bluffs and gorges. It is of particular economic importance to the region since it forms an excellent aquifer which supplies Alice Springs and many pastoral properties with fresh water.

The possible relationship of the unit with the underlying Carmichael Sandstone has been discussed earlier. The Mereenie Sandstone is generally conformably and locally gradationally overlain by units of the Pertnjara Group; in the west the Parke Siltstone, and in the east the Hermannsburg Sandstone. Locally however, this contact appears to be unconformable.

The Mereenie Sandstone generally consists of white to pale brown, exceptionally pure quartz sandstone. The sandstone is generally fine grained, rarely medium grained, well rounded and well sorted. It contains minor accessory tourmaline and zircon, and feldspar (less than 2%)

locally occurs within the top and bottom few metres of the formation.

Sedimentary structures are dominated by cross-bedding. In the lower part of the unit low-angle trough and wedge-shaped cross-sets are predominant, and trough cross-sets up to 10 m thick become common in the upper half. These larger cross-beds show features indicative of aeolian deposition. Ripple marks are also frequently present, with symmetrical ripples usually present only in the lower half. Other minor features are mud cracks and mud clasts. Vertical burrows of the *Skolithos* type occur in at least two zones in the bottom part of the unit and are up to 90 cm long.

The Mereenie Sandstone appears to have been deposited in a variety of environments, the details of which are still under investigation. Much of the lower part is thought to represent a shallow marine environment, at least in the central part of the basin, which passes up into a mixed aeolian-fluvial environment. Preliminary palaeocurrent data suggests an east-southeast trending shoreline in the lower marine part of the Mereenie Sandstone, and sediment transportation in the upper aeolian and fluvial part was dominantly towards the east and south.

Palaeontological evidence for the age of the Mereenie Sandstone is lacking, the only fossils being the trace fossils referred to above. An earlier reported occurrence of Devonian fish in the Mereenie Sandstone at Gosses Bluff (Wells & others, 1970) is now thought to have come from the overlying Pertnjara Group. The relationships with the underlying and overlying units suggest that it ranges from Late Ordovician to Early Devonian in age. However, continuous deposition over such a long interval of time is unlikely and several major depositional breaks probably occur within the sequence.

DEVONIAN PERTNJARA GROUP

The Pertnjara Group (figs 8 & 9) marks the final major sedimentation event in the Amadeus Basin. Up to 4000 m of non-marine sediments were deposited to the south of a major orogenic uplift in the Arunta Complex (Pertnjara Movement and Alice Springs Orogeny). Three formations are recognized within the Group; Parke Siltstone, Hermannsburg Sandstone and Brewer Conglomerate (Wells & others, 1970). Jones (1972, 1991) has further subdivided

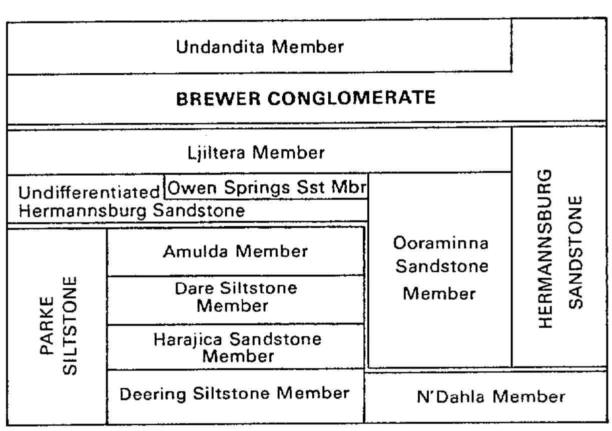


Figure 9. Stratigraphic units of the Pertnjara Group (from Jones, 1991).

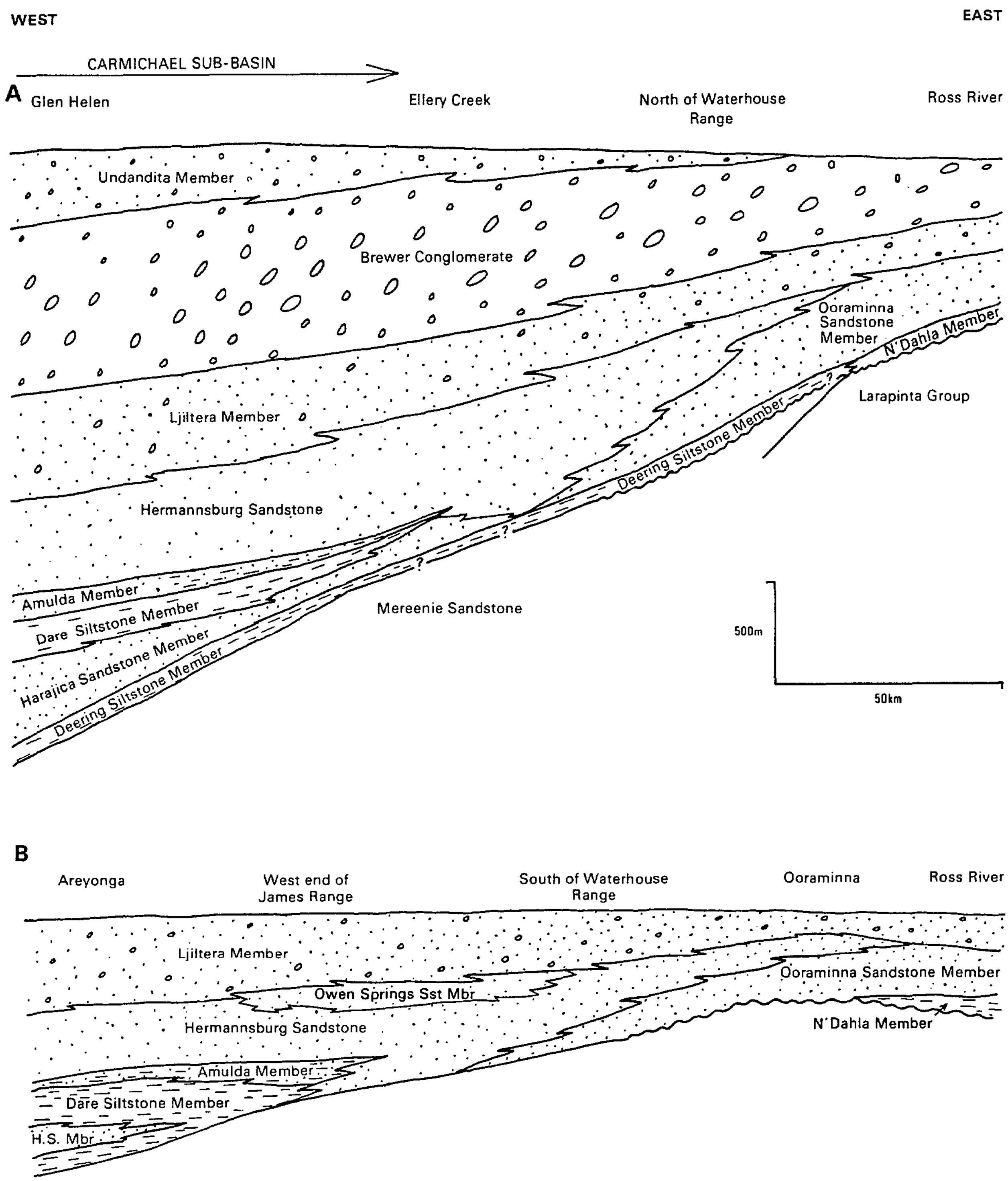


Figure 10. East-west facies relationships in the Pertnjara Group. A: Carmichael Sub-basin and Missionary Plain Trough areas. B: From Gardiner Range to Ross River (from Jones, 1991)

each formation into several members, and demonstrated complex facies relationships between the various units.

PARKE SILTSTONE

The Parke Siltstone (figs 9 & 10) is the oldest formation in the Group, and conformably overlies the Mereenie Sandstone. It has a maximum thickness of about 1000 m but is absent in most of the northeast part of the basin. The dominant lithology is poorly outcropping brown, purple and green micaceous siltstone, with thin interbeds of cross-bedded litho-feldspathic quartz sandstone, and locally thin dolomitic limestone near the base. Cross-bedded sandstone forms much of the lower half of the unit in the western MacDonnell Ranges. Ripples, desiccation cracks, halite pseudomorphs and rare gypsum pseudomorphs are present in the formation. The depositional environment of the Parke Siltstone appears to be a mixture of fluvial and lacustrine, and marks a significant change from the very mature sediments of the underlying Mereenie Sandstone, perhaps a reflection of the first (Pertnjara) movements of the Alice Springs Orogeny. Placoderm faunas and microvertebrate assemblages (Young & others, 1987; Young, 1985; 1988) from the unit indicate a Lower to Upper Devonian (Emsian-Fammenian) age (Shergold & others, 1991).

HERMANNSBURG SANDSTONE

The Hermannsburg Sandstone (figs 9 & 10) is the middle unit of the Pertnjara Group and rests conformably on the Parke Siltstone in the central and western part of the basin, and appears to be unconformable on older units in the east. It has a wide distribution throughout the basin and has a maximum thickness of about 1100 m. The formation is composed of poorly sorted red-brown to grey-grown litho-feldspathic quartz sandstone, which form repeated fining upwards fluvial cycles. The sandstones tend to become more mature in composition towards the south and east.

BREWER CONGLOMERATE

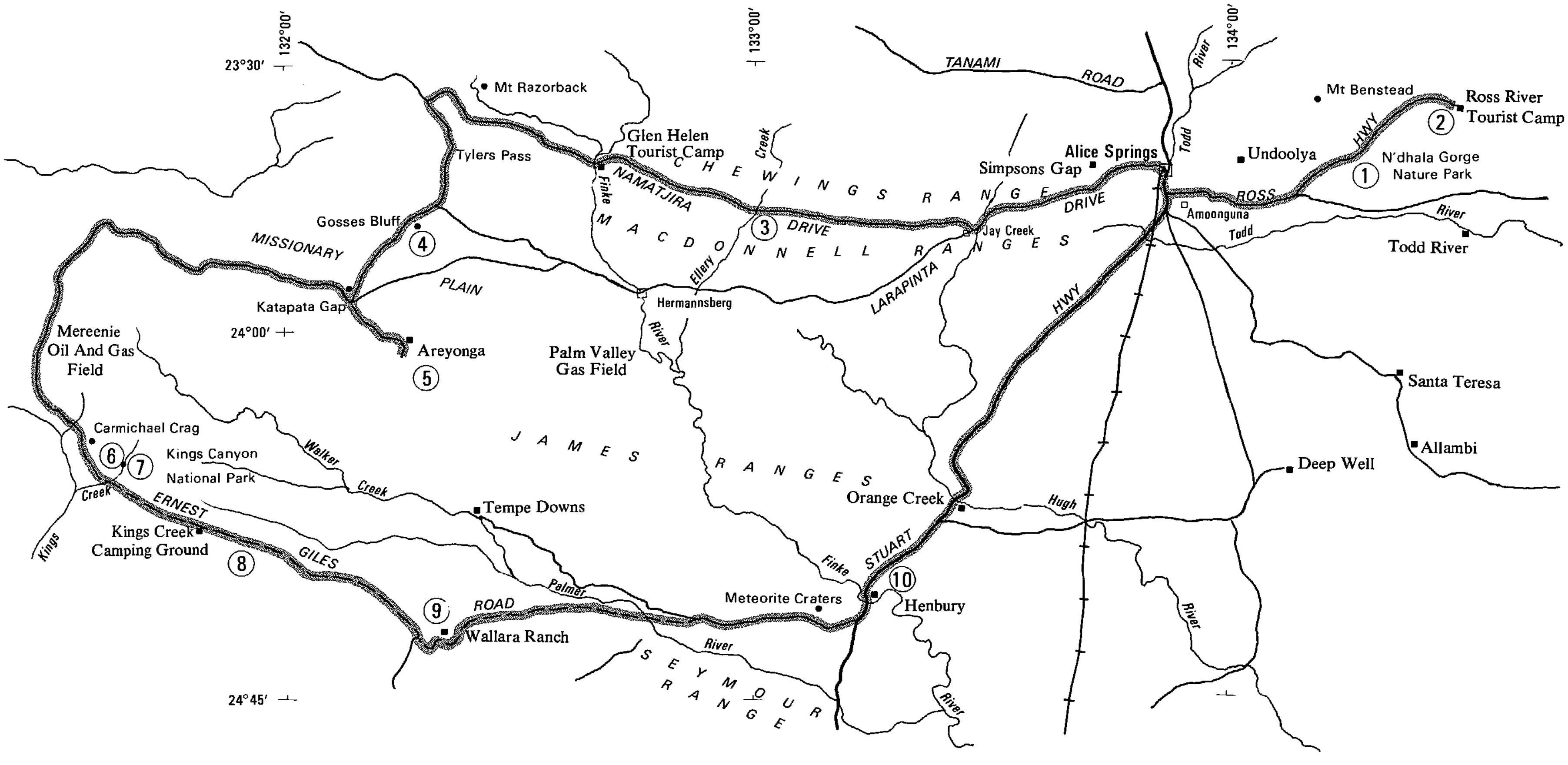
The Brewer Conglomerate (figs 9 & 10) is the youngest unit of the Pertnjara Group, and generally rest conformably on the Hermannsburg Sandstone. However, near Jay Creek and Ross River, it cuts down through older units and unconformably overlies the Cambrian Jay Creek Limestone and Goyder Formation. The Brewer Conglomerate is restricted to the northern part of the Basin and is up to 3000 m thick. It consists of polymict conglomerate, with unsorted clasts up to 1 m across, and minor pebbly sandstone and rare mudstone towards the top of the sequence. The composition of the clasts reflects the progressive stripping of the uplifted area to the north. Near the base of the formation most clasts are derived from the Cambro-Ordovician sequence, and higher in the formation the clasts are derived from progressively older units until metamorphic and igneous clasts from the Arunta Complex become a major component near the top of the formation.

The Brewer Conglomerate appears to be a synorogenic molasse deposit formed by coalescing piedmont alluvial fans on the southern flank of the rising northern margin of the Basin. Spores from a mudstone near the top of the unit south of Alice Springs indicate a latest Devonian (Famennian) age (Playford & others, 1976).

Overlying the Amadeus Basin sequence in various places are Permian sediments in the southeast and west, representing overlap by the Pedirka and Canning Basin sequences respectively; Mesozoic sediments in the southeast represent the margins of the Great Artesian

Basin; and probable Tertiary sediments in many parts of the basin. The latter are subhorizontal and rest unconformably on Precambrian, Palaeozoic and Mesozoic rocks. They include piedmont gravels, fluviatile sandstone and conglomerate, lacustrine limestone, shale and the associated silcrete (greybilly), ferricrete and calcrete.

DESCRIPTION OF EXCURSION LOCALITIES



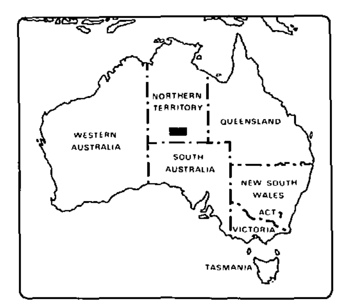


Figure 11. Location and route map.

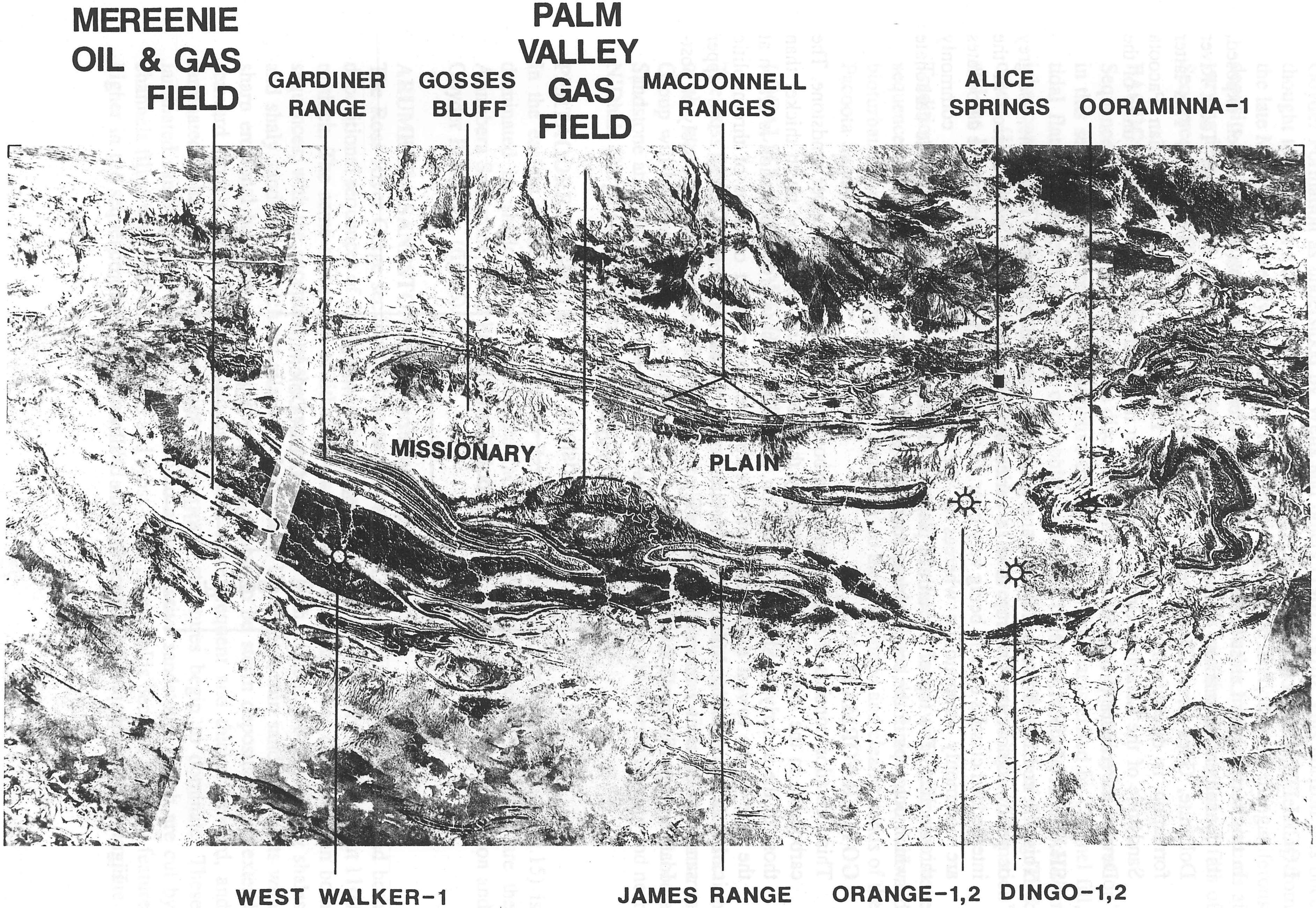


Figure 12. Landsat image of most of the Amadeus Basin showing major topographic features and hydrocarbon discoveries.

DESCRIPTION OF EXCURSION LOCALITIES

LOCALITY 1: WILLIAMS BORE SECTION

In this section, the Latest Proterozoic-Cambrian Pertaoorrta group (fig.13) is well exposed, its constituent formations in ascending order being: Arumbera Sandstone, Todd River Dolomite, Giles Creek Dolomite, Shannon Formation and Goyder Formation. This latter formation is disconformably overlain by the Late Cambrian-Early Ordovician Pacoota Sandstone of the Larapinta Group which in turn is unconformably overlain by units of the Devonian Pertnjara Group.

SHANNON FORMATION

This unit consists of interbedded red and green shale and siltstone, grey limestone, and grey or yellow dolostone. Outcrop is as a series of carbonate benches, with outcrop of the interbedded clastics usually being very poor. In the lower part of the formation the carbonates are commonly stromatolitic whereas in the upper part they become more commonly thrombolitic. The top of the unit is placed at the base of the thick thrombolitic carbonate which outcrops in the creek which crosses the section.

GOYDER FORMATION

This formation consists of a lower mixed carbonate-clastic unit and an upper sandstone. The carbonates in the lower part are commonly thrombolitic and tend to be much thicker than those of the underlying Shannon Formation, such that the base of the formation is drawn at the base of the lowest thick thrombolitic carbonate. Intermittent outcrops of thrombolitic carbonates containing Mindyallan trilobites occur to the east of the creek. The upper sandstone contains a fauna of small, poorly preserved trilobites which are probably of post-Idamean age (Shergold & others, 1991).

Pertnjara Group	Unnamed Aeolian Sandstone Unit
Larapinta Group	Pacoota Sandstone
Pertaoorrta Group	Goyder Formation
	Shannon Formation
	Giles Creek Dolomite
	Todd River Dolomite
	Arumbera Sandstone

Figure 13. Stratigraphic units present in the Williams Bore section.

A prominent black manganiferous horizon is visible within the sandstones near the top of the Goyder Formation as understood by Wells and others (1967, 1970). This horizon was once thought to represent a considerable time-break within the Goyder Formation, extending from the late Mindyallan to early Payntonian. It is now thought more likely that the manganiferous deposits are an hydrogeological feature rather than an hiatus, as this mineralisation occurs at varying levels within the Goyder formation and even extends into the lower channel-fills of Sequence 1 of the Pacoota Sandstone.

PACOOTA SANDSTONE

Sequence 1 of the Pacoota Sandstone disconformably overlies the 'upper Goyder Formation' in this section, and represents a distinctive transgressive event characterised by channel fill, tidal flat and barrier bar deposits commonly dominated by trace fossils of the *Skolithos* ichnocoenosis. The body fossils of this sequence, referred to Assemblage 1 of Shergold & others (1991) of Payntonian age, indicate an hiatus between the 'upper Goyder Formation' and the Pacoota Sandstone.

Traditionally, the base of the Pacoota Sandstone has been placed within the sandstone sequence which shows a gradational change from the poorly sorted, kaolinitic, dolomitic and bioturbated sands of the 'upper Goyder Formation' to the well sorted and cleaner sands of the Pacoota Sandstone.

LOCALITY 2: ROSS RIVER SECTION

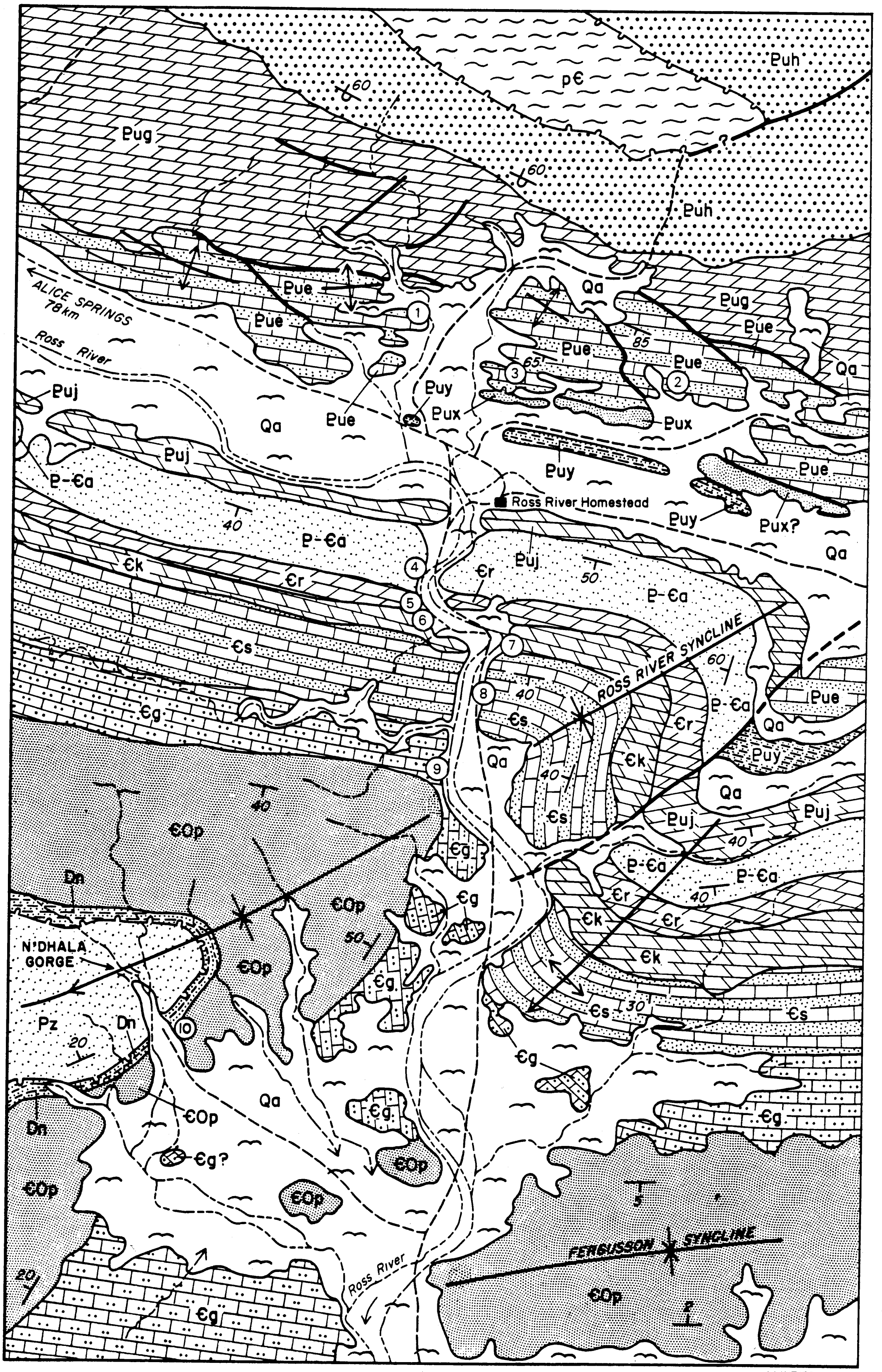
The Ross River Gorge (fig.14) and area immediately to the north provides an excellent section of the northeastern Amadeus Basin sequence. The latest Proterozoic-Cambrian Pertaoorrta Group will be examined on the northern limb of the Ross River Syncline, and the Pacoota Sandstone and units equivalent to the Devonian Pertnjara Group will be examined in and near N'Dhala Gorge along the axis of the syncline.

PERTAOORRTA GROUP

In the eastern portion of the Amadeus Basin, the Cambrian Pertoorrta Group (fig.15) is dominated by shallow marine carbonate facies. The formations to be inspected are the Arumbera Sandstone, Todd River Dolomite, Giles Creek Dolomite, Shannon Formation and Goyder Formation (fig.16).

ARUMBERA SANDSTONE (fig.14, stop 4)

The Ross River Gorge section is close to the centre of the Ooraminna Sub-basin and both depositional sequences of the Arumbera Sandstone are preserved. The formation is about 1100 m thick. The same succession of lithologies and sedimentary structures occurs within both sequences, with the exception of the upper few metres. Both sequences begin in silty shales and shaly sandstones which are relatively featureless. Up section, thin sandstone units with sharp erosional bases can be seen. These units appear to be storm deposits which extend seaward from a delta front. Sandstones become more frequent and thicker upward, and laminated delta front sandstones with water escape structures begin to dominate. These laminated sandstones in turn pass upward into more massive sandstones which are cut by channels filled with mud-chip breccias and cross-beds. Slump folds become a regular feature higher in the sequence within delta front and channel deposits. Some slump units are quite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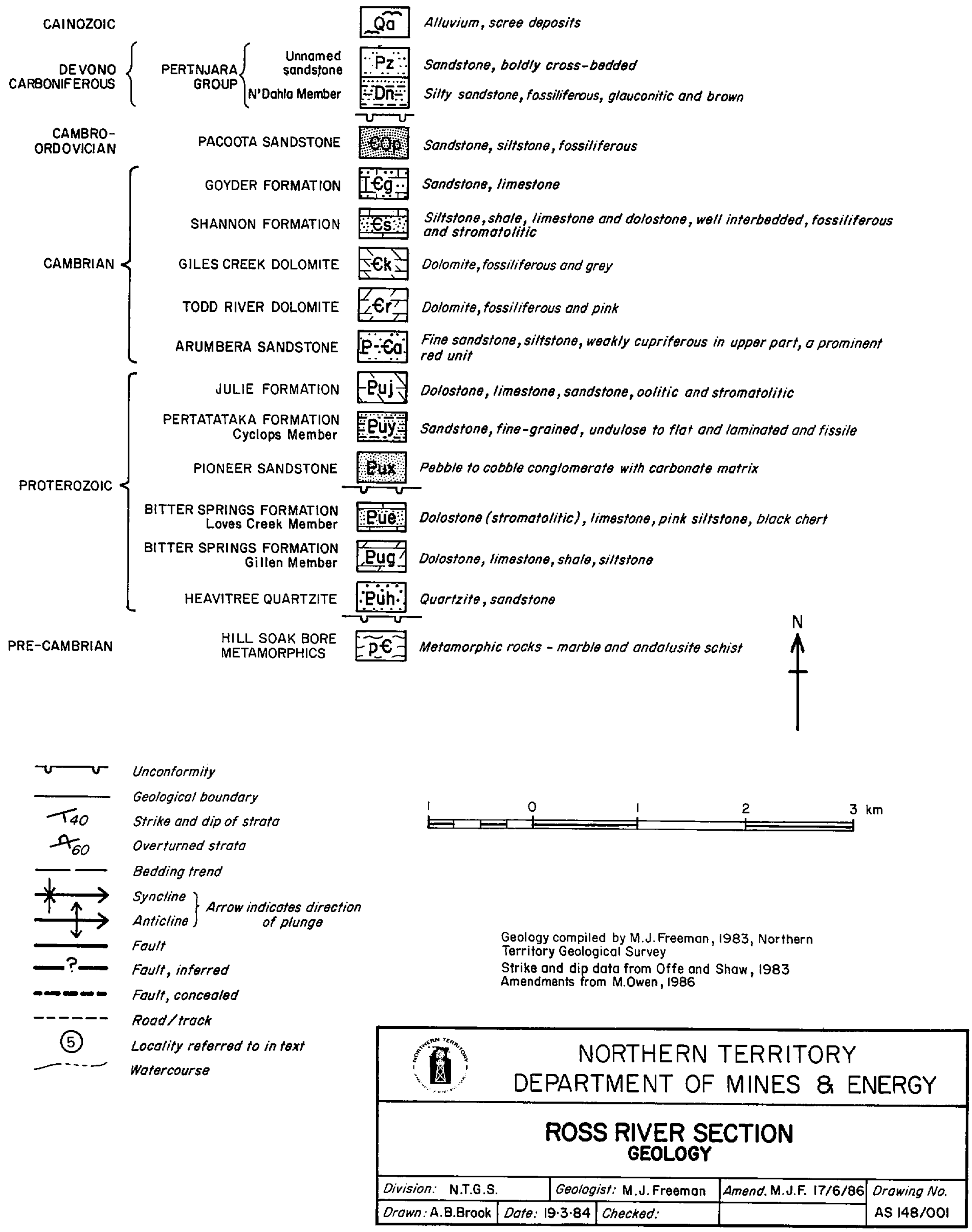


Figure 14. Geological Map of Ross River section.

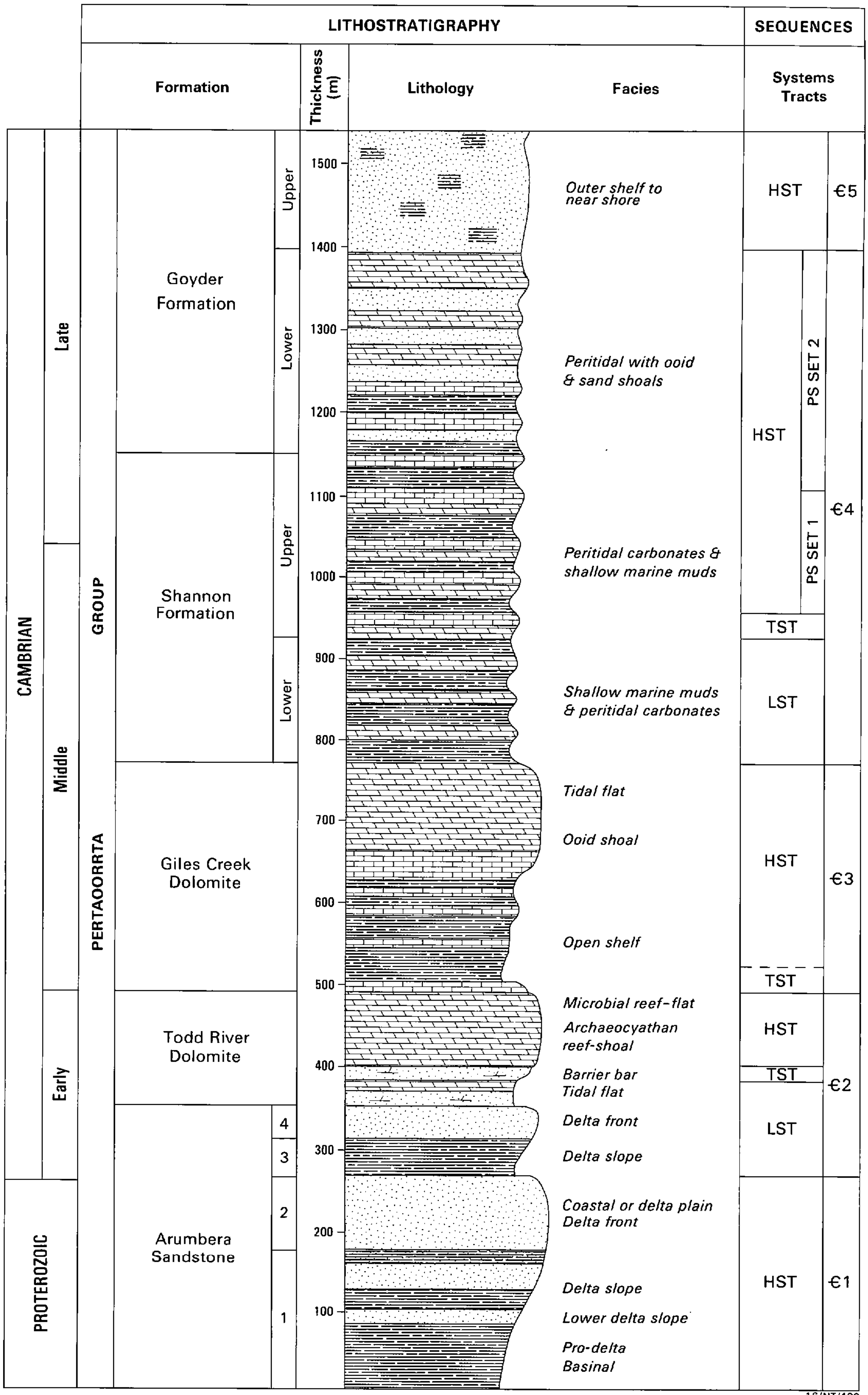


Figure 15. Lithostratigraphy and sequence stratigraphy of the Pertaoorrta Group in the Ross River section, showing facies and component systems tracts (from Kennard & Lindsay, 1991).

extensive and are up to one metre thick.

Sequence 1 is perhaps not as well exposed as Sequence 2. Careful search of the scree has found little evidence of ichnofossils in the basal sequence whereas ichnofossils are quite abundant in Sequence 2, especially immediately below the sand-rich units near the top.

The upper parts of the two sequences differ somewhat at this locality. Sequence 1 is dominated in its upper part by thick massive sandstones probably deposited in a stream mouth bar setting. In contrast, Sequence 2 passes upward into laminated shales, siltstones and carbonates which were probably deposited in a tidal flat setting. Occasional halite casts suggest hypersaline conditions in the final phase of deposition. These tidal deposits, while temporally part of the Arumbera sequence, are mapped lithologically as part of the Todd River Dolomite. Intraclastic conglomerates associated with the surface of transgression at the top of the Sequence 2 are discussed in the following section on the Todd River Dolomite.

TODD RIVER DOLOMITE (fig.14, stop 5)
The section to be examined contains four of the six lithofacies recognised within the Todd River Dolomite.

Lithofacies 1: Restricted siliciclastic-carbonate tidal flat.
This facies forms the recessive, largely scree covered, slope between the Arumbera Sandstone ridge to the north and the dolostone scarp to the south. The basal contact with the Arumbera Sandstone is picked at the first dolostone bed, which in this instance comprises a series of domed stromatolite bioherms 60-120 cm wide and 30-40 cm thick. This contact also approximates the uppermost occurrence of continuous medium and thick-bedded sandstone, and coincides with the prominent air-photo boundary between the Arumbera Sandstone and Todd River Dolomite.

This facies was deposited on a very shallow subtidal and intertidal mixed siliciclastic-carbonate flat. It forms the top of the shallowing upward Arumbera Sequence 2.

Lithofacies 3: Quartz and quartz-peloid-ooid barrier bar.
A thin bed of sandy, ooid and glauconite-rich, intraclast conglomerate occurs at the base of this facies, probably in erosional contact with the underlying tidal flat facies. The overlying sandstones and dolostones comprise 6 subfacies which appear to define three shallowing upward cycles, the lower two of which are incomplete. Offshore subtidal deposits (subfacies A, B and C) are overlain by lower shoreface subtidal deposits (subfacies D), upper shoreface and foreshore deposits (subfacies E), and tidal channels (subfacies F). The cycles probably represent a series of migrating barrier bars that transgressed across the surface of the underlying tidal flat sequence.

Lithofacies 4: (?)Stromatolitic-archaeocyathan bioherm and grainstone shoal.
This facies forms the main dolostone scarp and extends up to the base of the second prominent silicified horizon near the crest of the ridge. The basal contact with the underlying barrier bar facies is a sharp erosion surface which locally exhibits overhanging scalloped karstic features. Within the dolostone scarp the bioherms are poorly differentiated from the enclosing weakly stratified grainstone, but elsewhere within more weathered bouldery outcrops, the bioherms selectively weather out in positive relief from the interbiohermal

grainstones and packstones. The bioherms are not restricted to specific time horizons within this facies, but appear to be randomly dispersed within the enclosing sediments. They make up approximately 30% of the volume of this facies.

The bioherms have a ragged, bumpy and pitted surface of several centimetres micro-relief, and irregular bulbous protrusions and embayments several decimetres in size locally occur at their crest. They contain abundant partially silicified archaeocyaths (approx. 20-50% by volume) which are rarely in-situ.

Two horizons of large bioherms are well exposed in the cliff face at the southern edge of the water pool, at about the middle of this facies. These bioherms are truncated by scalloped karst erosion surfaces.

The archaeocyathan bioherms evidently grew in a high energy, intermittently emergent, shallow marine environment in which wave and current abrasion and bioerosion removed vast quantities of non-lithified aggregates (peloids), lithified fragments (intraclasts) and archaeocyathan debris from the bioherms to form thick sheets of interbiohermal carbonate sand and gravel. The bioherms were periodically overwhelmed and buried by these sediments, and new bioherms were subsequently re-established. Microbial communities probably effected the initial stabilization of these sediments and faciliated the growth of the archaeocyaths in a turbulent, wave-washed environment.

Lithofacies 6: Cyanobacterial mud flat.
Undulose and pustular-laminated, fenestral microbial boundstones (stratiform stromatolites) and massive dolo-mudstones of this facies can be readily examined adjacent to the creek bed at the eastern end of the dolostone scarp-ridge, immediately overlying a small channel of archaeocyathan-intraclast conglomerate. Near the crest of the ridge, these stromatolitic beds encrust the archaeocyathan bioherms of the underlying facies and form wavy to pseudocolumnar-laminated, partially linked, domal bioherms and biostromes which have 20-30 cm synoptic relief.

The Todd River Dolomite is paraconformably overlain by a 10 m thick sequence of light to dark grey, slightly foetid dolostone, calcareous dolostone and nodular black chert. This sequence contains minor amounts of phosphatic and calcareous skeletal debris, and is tentatively assigned to the Chandler Formation. It crops out on the south side of the small gully at the foot of the dipslope of the dolostone ridge, and is overlain by recessive green shales of the Giles Creek Dolomite. The contact with the Todd River Dolomite is picked at the base of a partially silicified interval of thinly interbedded, light grey, fine crystalline dolostone and silty and sandy, cross-laminated, dolo-grainstone. Detrital dolomite grains have been recognised within samples from this interval by cathodoluminescent microscopy.

GILES CREEK DOLOMITE (fig.14, stops 6,7)
The section to be examined has been subdivided into six units by Keith (1974), in descending order:

Unit 6: 100 m of interbedded light grey dolostone; thin to medium beds of laminated dolo-mudstone and fine mud-clast gainstone, domed stromatolites up to 1 m thick, thin to medium beds of fenestral dolomudstone, thick beds of bioturbated dolo-mudstone, and thin beds of mud-clast grainstone which overlie scoured surfaces.

Unit 5: 13 m of medium to thickly bedded fenestral dolo-mudstone, mud-clast grainstone and ooid grainstone.

Unit 4: 18 m of thinly interbedded dolo-mudstone, mud-clast grainstone and minor ooid and oncolitic grainstone.

Unit 3: 13 m of thin-bedded bituminous (i.e. foetid) silty dolo-mudstone.

Unit 2: 20 m of thick-bedded and thin nodular-bedded dark foetid silty skeletal lime-wackestone, skeletal calcareous siltstone and minor lime-mudstone and green shale.

Unit 1: 107 m of thin nodular-bedded dark foetid silty skeletal limewackstone, lime-mudstone and green shale.

SHANNON FORMATION (fig.14, stop 8)
Several shale-carbonate cycles typical of the upper part of the Shannon Formation can be examined at this locality. Whereas the basal portion of the formation comprises thick shale-thin dolostone cycles, dolostone is abundant in the upper part of the formation and limestone is locally common. Several carbonate lithologies are present; linked hemispheroidal stromatolites, foetid lime-mudstone, two-tone lime and dolomitic mudstone, laminated silty dolostone and dolomitic cryptalgalaminate. A relatively quiet, subtidal to locally intertidal, marine environment is interpreted for this sequence. Although thrombolites are abundant elsewhere in the upper part of the Shannon Formation, they have not been observed at this locality.

GOYDER FORMATION & PACOOTA SANDSTONE (fig.14, stops 9,10)
The lower portion of the Goyder Formation comprises medium to thickly interbedded dolostone, limestone, sandstone and minor siltstone. The dominant carbonate lithologies are medium to coarse grained ooid grainstone, mottled lime-mudstone, intraclast conglomerate, cryptalgalaminate and less commonly, domal stromatolites. Trough and planar-tabular cross-bedding, festoon cross-lamination and scour structures are widespread within the grainstones and sandstones. A shallow, relatively high energy, marine environment is indicated for this part of the formation.

The upper portion of the formation comprises white, thin to medium bedded, friable, fine grained sandstone and minor mudrock. The sandstones form thin to medium trough and (?)hummocky cross-sets, and were probably deposited on an open marine shelf. These sandstones have been extensively folded and faulted at the axis of the Ross River Syncline. A prominent black manganiferous horizon is visible within these sandstones in the ridge slope on the southern limb of the syncline. This horizon was once thought to mark a considerable time-break within the Goyder Formation, but has now been found at several levels and probably represents a hydrogeological phenomenon. The white sandstones above this horizon are conformably overlain by three prominent sandstone ledges of the Pacoota Sandstone, a feature which local aboriginals refer to as the 'dancing lubras'.

POST-ORDOVICIAN SEQUENCE AT N'DHALA GORGE (fig.14, stop 10; fig.16, loc.1; fig.17)
During the initial mapping of the Amadeus Basin by BMR in the 1960's, a thin lithic quartzo-feldspathic sandstone near the axis of the Ross River Syncline was named the N'Dhala Member of the Pacoota Sandstone. This sandstone was considered to be of Early Ordovician age and to be overlain by the Mereenie Sandstone. Recently, however, Devonian fish plates,

as well as reworked Early Ordovician and Cambrian fossils, have been found in the N'Dhala Member and these Devonian fossils necessitated a reassessment of the stratigraphic succession in the N'Dhala Gorge area (Young & others, 1987).

The N'Dhala Member is now considered to correlate with the Middle to Late Devonian Parke Siltstone of the Pertnjara Group, and to rest with slight angular unconformity on the Pacoota Sandstone. Since the Mereenie Sandstone is known to underlie the Pertnjara Group elsewhere in the basin, the sandstone above the N'Dhala Member in the Ross River Syncline cannot be the Mereenie Sandstone. This sandstone is about 300 m thick and is now considered to be laterally equivalent to sandstones in the lower or middle portion of the Pertnjara Group. A distinctive feature of this un-named sandstone is the presence of very large aeolian cross-beds, up to 15 m thick, in the upper portion of the unit.

Pre-historic rock carvings occur throughout the N'Dhala Gorge Nature Park. They appear to pre-date present Aboriginal cultures since traditional aboriginal owners of the area have no knowledge of the origin or meaning of the carvings. Please note that the use of hammers is **not** permitted within this park.

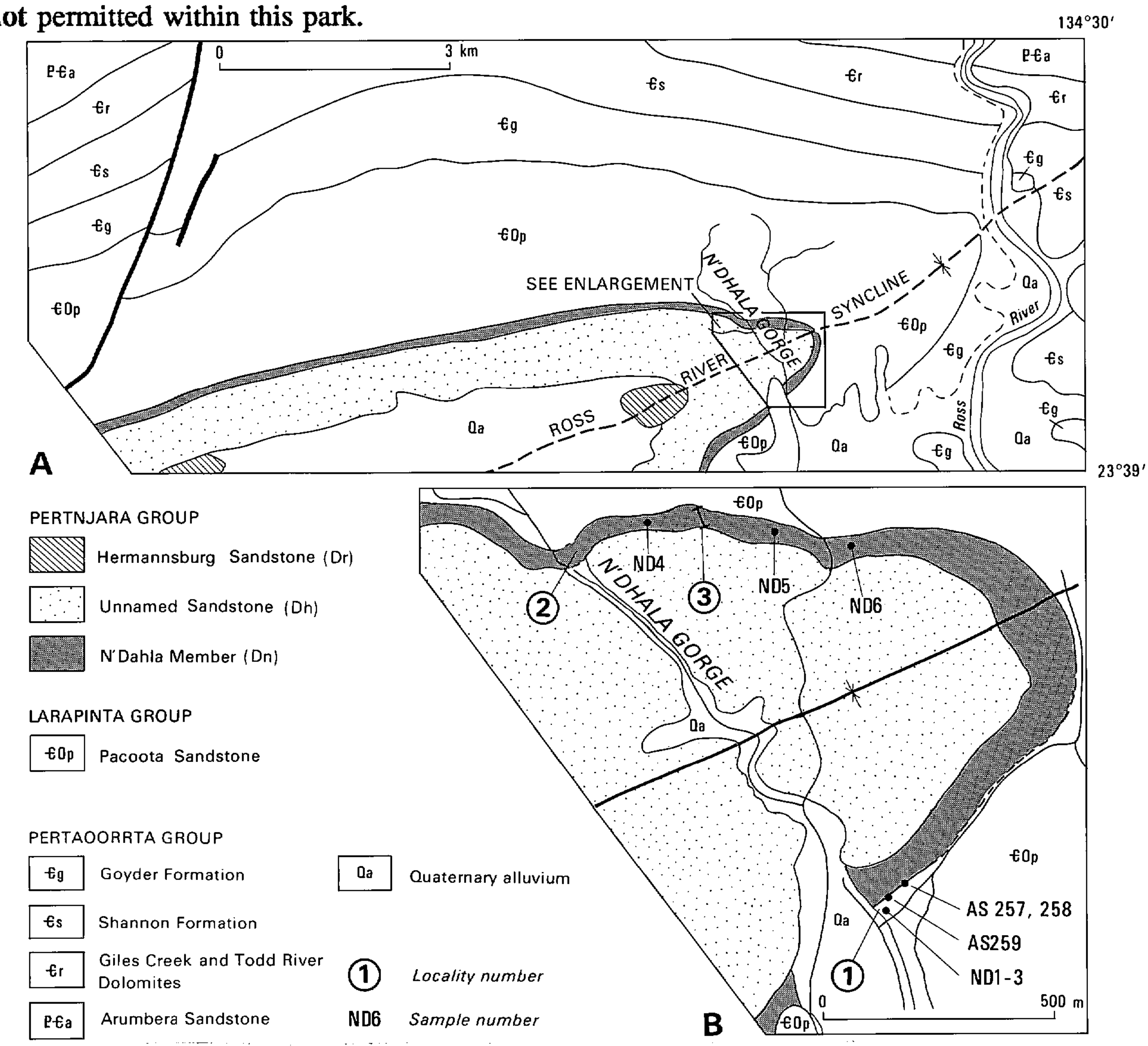


Figure 16. A - Geology of the N'Dhala Gorge area; B - Detail of N'Dhala Gorge, showing field localities (from Young & others, 1987).

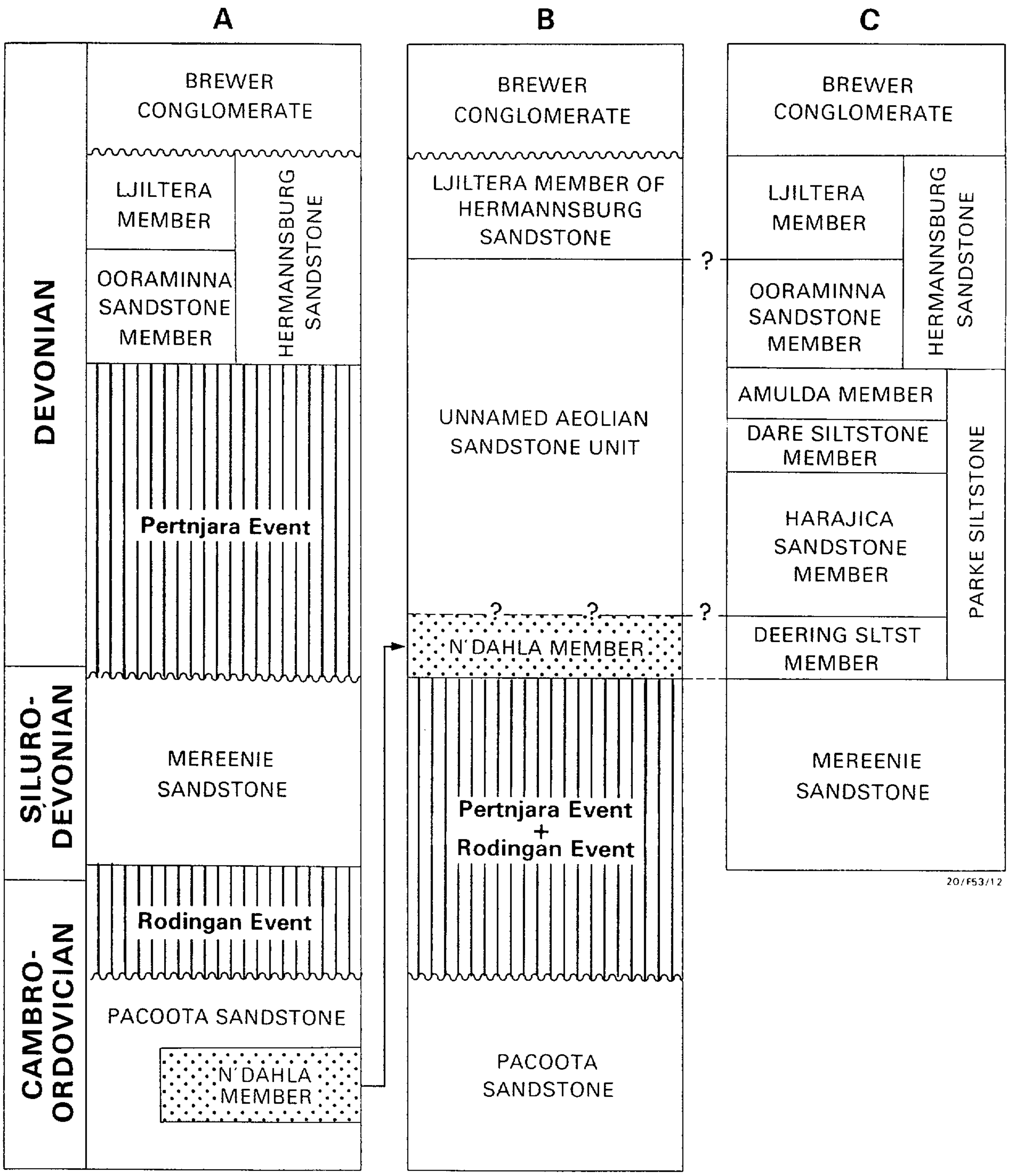
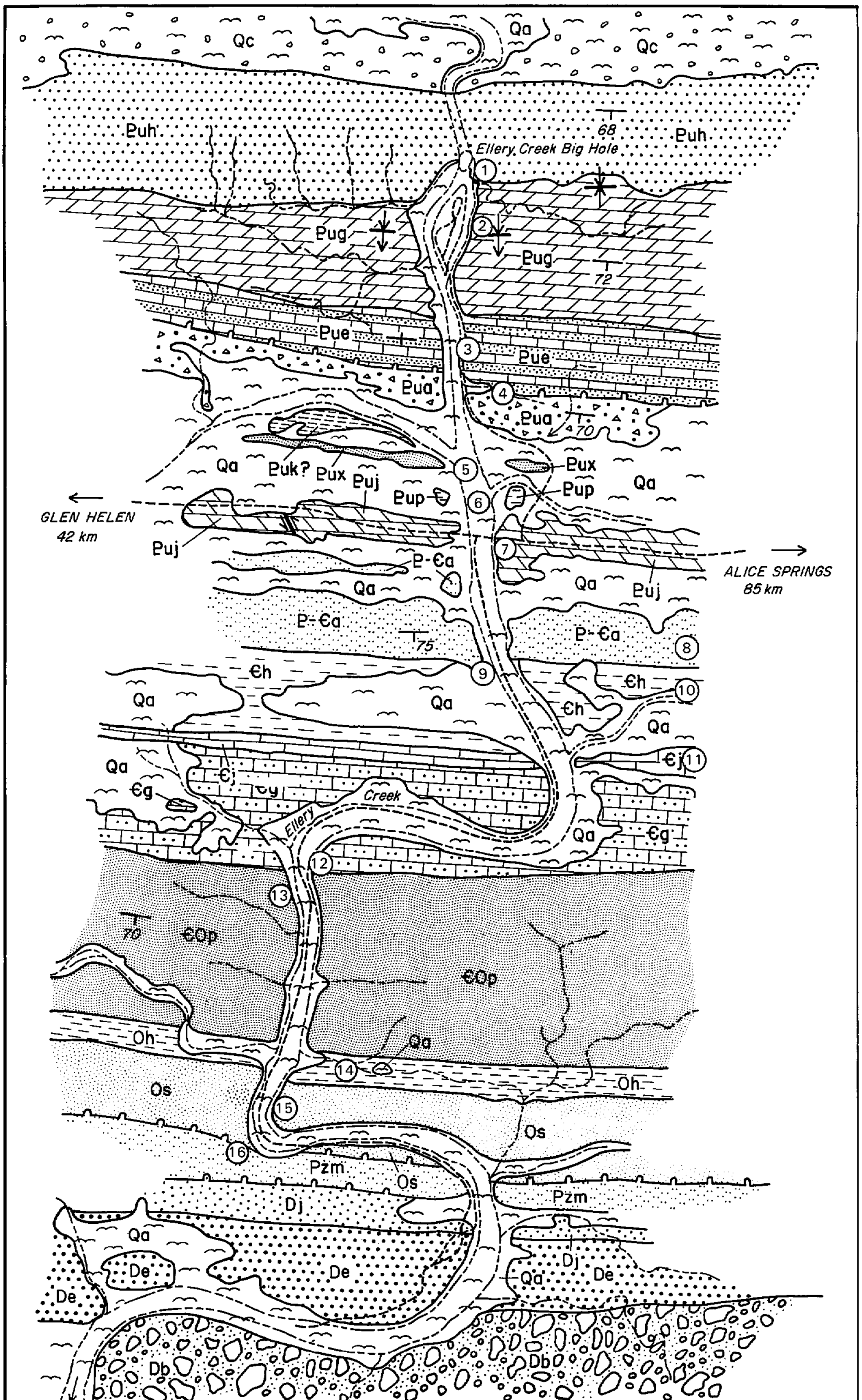


Figure 17. A - Original stratigraphic interpretation of the N'Dahla Member of the Pacoota Sandstone and overlying formations in the Ross River sequence (after Wells & others, 1970); B - Revised stratigraphy of Young & others (1987); C - Suggested correlation with members of the Pertnjara Group (Young & others, 1987).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Era/Period	Group	Formation	Symbol	Lithology
CAINOZOIC			Qa	*Alluvium, scree deposits*
CAINOZOIC			Qc	*Colluvium*
DEVONIAN	Pertnjara Group	BREWER CONGLOMERATE	Db	*Boulder conglomerate, sandstone lenses*
DEVONIAN	Pertnjara Group	HERMANNSBURG SANDSTONE, Ljiltera Member	De	*Pebbly sandstone, siltstone, conglomerate lenses*
DEVONIAN	Pertnjara Group	PARKE SILTSTONE, Harajica Sandstone Member	Dj	*Sandstone, locally pebbly*
SILURO? DEVONIAN		MEREENIE SANDSTONE	Pzm	*Sandstone; boldly cross-bedded*
ORDOVICIAN	Larapinta Group	STAIRWAY SANDSTONE	Os	*Sandstone, siltstone; fossiliferous, phosphatic*
ORDOVICIAN	Larapinta Group	HORN VALLEY SILTSTONE	Oh	*Siltstone, limestone; prolific fauna, trilobites, brachiopods, pelecypods, nautiloids, gastropods etc*
	Larapinta Group	PACOOTA SANDSTONE	€Op	*Sandstone, siltstone, fossiliferous with* Scolithus, Cruziana, *cross-bedded*
CAMBRIAN	Pertaoorta Group	GOYDER FORMATION	€g	*Sandstone, limestone*
CAMBRIAN	Pertaoorta Group	JAY CREEK LIMESTONE	€j	*Fossiliferous dolomitic limestone*
CAMBRIAN	Pertaoorta Group	HUGH RIVER SHALE	€h	*Shale, siltstone (Chandler limestone at base)*
CAMBRIAN	Pertaoorta Group	ARUMBERA SANDSTONE	P-€a	*Fine sandstone, siltstone; weakly cupriferous in upper part, prominent red unit*
ADELAIDEAN		JULIE FORMATION	Puj	*Dolostone, limestone, sandstone; oolitic and stromatolitic*
ADELAIDEAN		PERTATATAKA FORMATION	Pup	*Shale, siltstone*
ADELAIDEAN		PIONEER SANDSTONE	Pux	*Sandstone, dolostone, "Upper Cap Marker Dolostone"*
ADELAIDEAN		ARALKA FORMATION	Puk	*Shale, limestone*
ADELAIDEAN		AREYONGA FORMATION	Pua	*Diamictite, conglomerate, calcareous sandstone, tillitic siltstone*
ADELAIDEAN		BITTER SPRINGS FORMATION, Loves Creek Member	Pue	*Dolostone (stromatolitic), limestone, pink siltstone*
ADELAIDEAN		BITTER SPRINGS FORMATION, Gillen Member	Pug	*Dolostone, limestone, shale, siltstone*
ADELAIDEAN		HEAVITREE QUARTZITE	Puh	*Quartzite, sandstone*

Unconformity
Geological boundary
72 *Strike and dip of strata*
Vertical strata
Syncline
Monocline
Fault showing horizontal displacement
Road/track (some 4WD only)
9 *Locality referred to in text*
Watercourse

N

500 0 500 1000 1500 m

Geology compiled by M.J. Freeman, 1982 Northern Territory Geological Survey

NORTHERN TERRITORY
DEPARTMENT OF MINES & ENERGY

ELLERY CREEK SECTION
GEOLOGY

Division: N.T.G.S.	*Geologist:* M.J. Freeman		*Drawing No.*
Drawn: A.B. Brook	*Date:* 13·3·84	*Checked:* MJF	AS 137/001

11/NT/74 (2 of 2)

Figure 18. Geological Map of the Ellery Creek Section.

LOCALITY 3: ELLERY CREEK SECTION

Ellery Creek, which has incised the upturned northern margin of the Amadeus Basin sequence, provides one of the most complete Upper Proterozoic and Palaeozoic sections in the eastern central portion of the basin. The map of the Ellery Creek Section (fig.18) and parts of the following Proterozoic locality descriptions, are modified after an unpublished Northern Territory Geological Survey field guide compiled by M.J. Freeman.

HEAVITREE QUARTZITE (fig.18, stop 1)
The ridge on the north side of Ellery Creek Big Hole (water depth 27 m, measured in 1972) is of Heavitree Quartzite which is the basal formation of the Amadeus Basin. Here, sedimentary structures are difficult to see in the orthoquartzite, but rare cross-bedding indicates that the southernmost beds young to the south. An isoclinal recumbent fold is well displayed in the western wall of the gorge. This fold developed during the Devonian-Carboniferous Alice Springs Orogeny, at which time the Amadeus Basin sequence was uplifted along the northern margin of the basin.

BITTER SPRINGS FORMATION (fig.18, stops 2,3)
Dolostones, limestones and siltstones of the Gillen Member of the Bitter Springs Formation are well exposed in the creek bank immediately east of the car park. West of the car park, disharmonic folds are visible and are a typical response of this member to compression during the Alice Springs Orogeny. Their disharmonic nature may partly result from salt movement.

Only the upper portion of the Loves Creek Member crops out along the access track to Ellery Creek Big Hole. Faulting has resulted in the loss of the lower portion of this member which, 1km to the east, consists of 200m of stromatolite biostromes. Along the access track, the upper portion of the Loves Creek Member consists of dolostone, limestone, red calcareous siltstone and minor chert, and is generally similar to the sequence that crops out to the north of Ross River. Stromatolites, desiccated mudstones, chert nodules and concretions, halite pseudomorphs and bipyramidal quartz crystals are common in this area. The red siltstones are characterised by abundant light cream coloured reduction spots.

AREYONGA FORMATION (fig.18, stop 4)
The Areyonga Formation unconformably overlies the Bitter Springs Formation and consists of diamictite, conglomerate, sandstone and dolostone. Near the base, the diamictite consists of dispersed pebbles and boulders (up to 1.5 m diameter) in a pale grey muddy matrix. The clasts are derived from older units of the Amadeus Basin and from the Arunta Block. Clasts of the same composition occur in the overlying cobble to boulder conglomerate. Faceted and striated boulders, indicative of the glacial original of these rocks, were previously common at this site. In the upper part of the formation, diamictite and conglomerate gives way to immature sandstone which contains dispersed boulders (dropstones) of quartzite.

PIONEER SANDSTONE (fig.18, stop 5)
This unit consists mainly of sandstone deposited in an inter-tidal environment. Planar, trough and herringbone cross-bedding are present in outcrops in the creek bed. The top of the unit consists of approximately 1 m of dolostone (the upper marker cap dolomite of Preiss & others, 1978) which contains the small stromatolite *Elleria minuta*, a form unique to this locality (Walter & others, 1979).

PERTATATAKA FORMATION (fig.18, stop 6)
Poor exposure of this formation in the creek bed consist of red to grey-green mudstone and minor very thin beds (0.5-3 cm) of siltstone to very find grained sandstone. These thin sandstone beds are interpreted as distal marine turbidites. Turbidites of slightly more proximal character occur in the Pertatataka Formation at Areyonga Gorge further southwest. The Pertatataka turbidites were deposited when the water depth of the basin was at its maximum.

JULIE FORMATION (fig.18, stop 7)
The Pertatataka Formation shallows up into oolitic dolostones and limestones of the Julie Formation, lithologies indicative of a shallow marine environment.

PERTAOORRTA GROUP
In this area the Pertaoorrta Group comprises, from the base upwards, the Arumbera Sandstone, Chandler Formation, Hugh River Shale, Jay Creek Limestone and Goyder Formation (fig.19). With the exception of the basal marine-deltaic sandstone (Arumbera Sandstone), this sequence is dominated by fine grained, siliciclastic marine sediments, and marine carbonates are relatively minor. This area lies approximately mid-way between the eastern Ooraminna and the western Carmichael Sub-basins, features which exerted a major control on the type and distribution of facies throughout most of Cambrian time.

ARUMBERA SANDSTONE (fig.18, stop 8; fig.19)
Only Sequence 1 of the Arumbera Sandstone is exposed at Ellery Creek. This locality occurs at the northern edge of the Missionary Plains Trough, an area where the formation is thin due to erosion and non-deposition during Sequence 2 time.

From the ridge top the Arumbera Sandstone can be seen to consist of one major shallowing upward cycle beginning at the Julie Formation ridge just south of the highway, and extending to the top of the main Arumbera ridge. The recessive unit above the Julie carbonate consists of pelagic shale with thin sandstone units that are interpreted as distal turbidites. This part of the sequence is poorly exposed at this locality.

The upper part of the Arumbera sequence consists of a number of smaller sandstone ridges that gradually become more prominent upward. Each small ridge occurs at the top of a small shallowing upward cycle. Some of these small cycles persist over many kilometres but most are discontinuous along strike.

CHANDLER FORMATION (fig.18, stop 9)
Discontinuous outcrops of grey carbonate and minor chert occur immediately above the Arumbera Sandstone on the west bank of Ellery Creek. These outcrops represent the Chandler Formation which is only about 10 m thick in this area.

HUGH RIVER SHALE (fig.18, stop 10)
The broad valley between the Arumbera Sandstone ridge and a small, spinifex-covered, ridge of the Jay Creek Limestone is underlain by shales and siltstones of the Hugh River Shale. This unit overlies the Chandler Limestone or Arumbera Sandstone with probable unconformity. Several thin beds of dolostone and limestone crop out within the unit. A bed of stromatolitic dolostone is well exposed in the bank of the small creek at the foot of the Arumbera scree slope. This stromatolite consists of a series of low, parallel ridges (2-3 cm

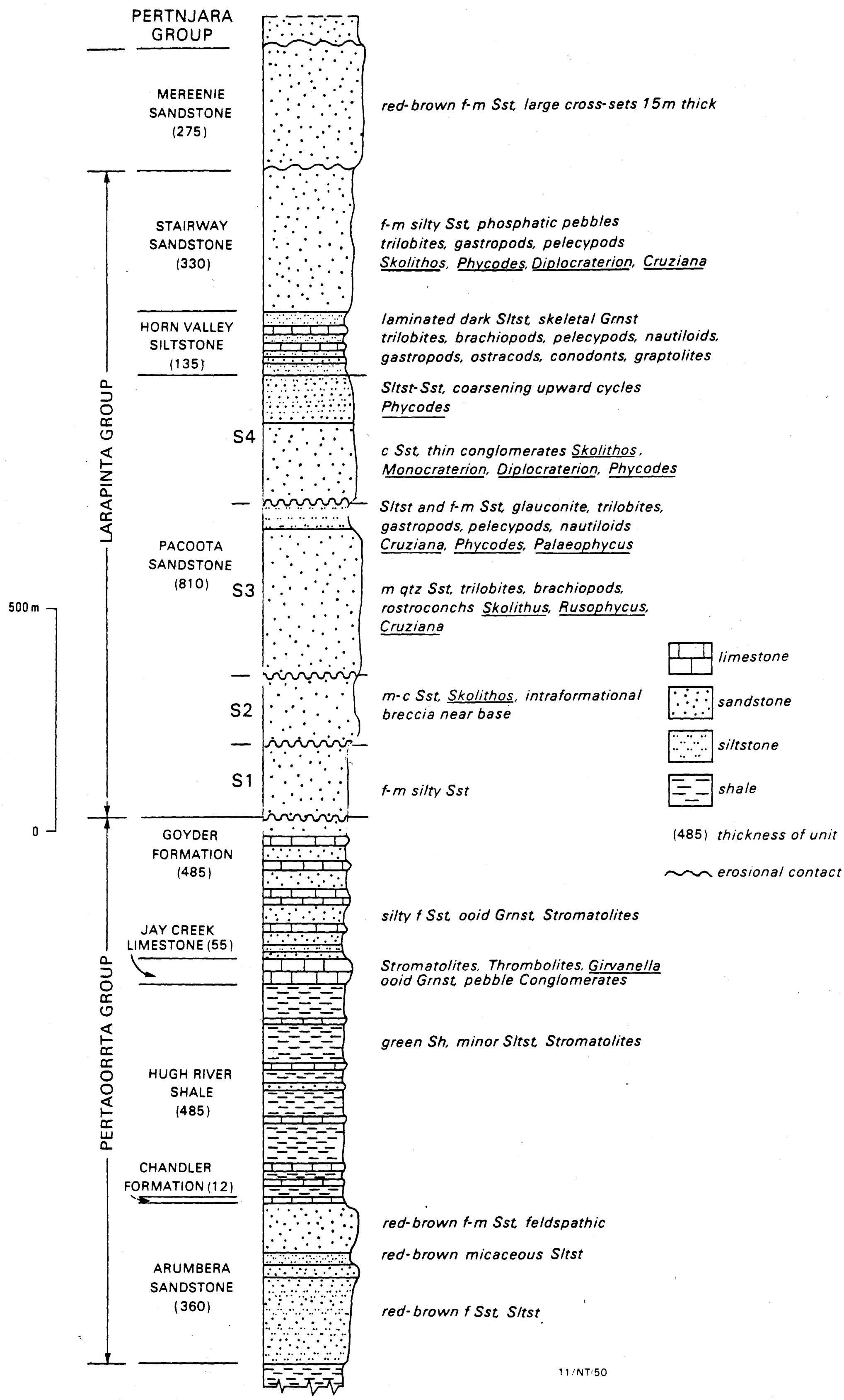

Figure 19. Cambrian to Devonian stratigraphy in Ellery Creek Section.

high and spaced 6-10 cm apart), representing a symmetrical ripple-like morphology, at the crest of a gently domed biostromal bed.

JAY CREEK LIMESTONE (fig.18, stop 11)
This low ridge consists of thrombolitic and stromatolitic boundstone, peloid and ooid grainstone, lime-mudstone and interbedded recessive siltstone and shale. The sequence is very similar to the Shannon Formation in the eastern part of the basin, and highlights the uncertain stratigraphic and lithologic differentiation of the Jay Creek Limestone from the Shannon Formation.

GOYDER FORMATION (fig.18, stop 12)
The interbedded limestones and siliciclastics of the lower part of the Goyder Formation are exposed on the northwest bank of Ellery Creek. The upper part of the Goyder Formation is exposed on the east bank, immediately below the scarp formed by Sequence 1 of the Pacoota Sandstone. This upper portion of the Goyder Formation consists of interbedded siltstone and sandstone, both of which may contain calcareous cement, as well as red and green shales. At this locality, shelly fossils and ichnofossils are rare in the upper part of the formation.

PACOOTA SANDSTONE (fig.18, stop 13; fig.20)
The Pacoota Sandstone is well exposed on both sides of the Gorge where Ellery Creek traverses the MacDonnell Range. Sequences S1 to S4 are present (fig.20), and Gorter (1991) has used this section to relate the characteristics of the outcrop to the subsurface.

The base of the Pacoota Sandstone Sequence 1 is formed by a channel fill sand body that cuts 55 m down into the underlying Goyder Formation. Sediments in the channel are intepreted as marine. The channel is overlain by interbedded sandstones, siltstones and shales that contain an abundant *Skolithus* ichnofauna. Trilobites and a sparse conodont fauna near the top date the unit as Payntonian (Late Cambrian).

The overlying Sequence 2 is about 100 m thick and consists of interbedded sandstones and siltstones. This interval has produced no body fossils, but in its lower part contains an abundant *Skolithos* ichnofauna while near the top of the sequence *Cruziana* predominates. The contact with the underlying Sequence 1 is regionally unconformable. Sequence 2 is interpreted as being deposited in a shallow water, nearshore environment. The age of this interval is uncertain, but it is thought to be of Datsonian age (latest Cambrian). In a sample of the Hermannsberg Sandstone (Devonian) collected just south of Ellery Creek, a reworked Ordovician conodont fauna contained elements of *Hirsutodontus simplex*, the only recovery of this species in the basin. It is probable that the provenance of this material is from the north of the Ellery Creek locality, and that it represents deeper water depositional conditions that may be correlative with Sequence 2.

Sequence 3 represents a return to deeper water deposition with trilobites, conodonts bivalves and rostrochonchs recovered from the unit. The unit is about 250m thick and consists of interbedded sandstones, siltstones and shales. The macrofauna of the units is similar throughout the unit, but two conodont faunas can be distinguished. It is possible that the lower subsequence lies below the Black Mountain Eustatic Event (Nicoll & others, 1991) while the upper lies above it. The conodont fauna of the upper interval is correlated with the *Chosonodina herfurthi - Cordylodus angulatus* Zone of the Georgina Basin (Shergold &

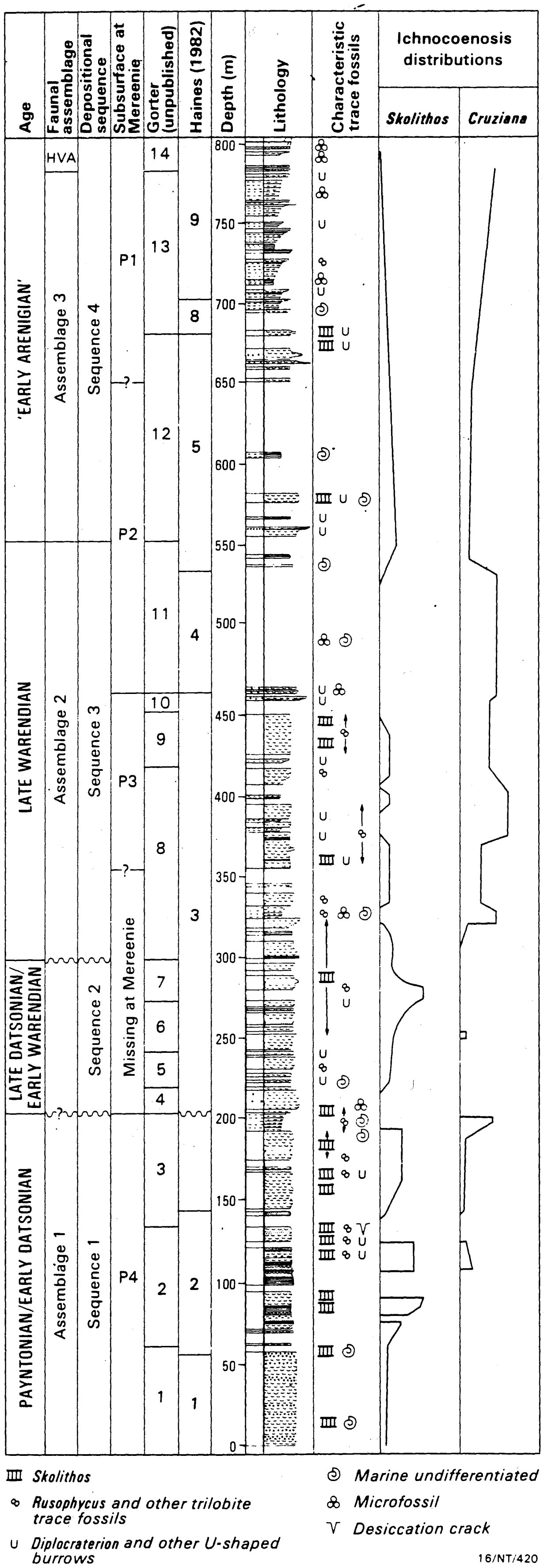

Figure 20. The type section of the Pacoota Sandstone at Ellery Creek, showing distribution of fossils, sedimentary sequences and ages (from Shergold and others, 1991).

Nicoll, 1991), but no representatives of either *Cordylodus* or *Chosonodina* have been recovered.

Sequence 4 consists of sandstone, with quartz pebbles near the base, overlain by upward coarsening cycles that grade from laminated shales to bioturbated sands. Progressively upward in the unit the shales become dominant, probably reflecting a deepening of the depositional environment. Microfossils are common and macrofossils rare in Sequence 4. Shergold (1991) identifies a single trilobite species (his Assemblage 3) from this interval and a conodont fauna has been recovered that includes *Bergstromognathus extensus*.

HORN VALLEY SILTSTONE (fig.18, stop 14)
The Horn Valley Siltstone is poorly exposed at Ellery Creek. This may be due in part to a small fault which cuts through the middle part of the unit. Below the lower carbonate beds (HV3) there is a transitional shale and siltstone sequence similar to that seen at Maloney Creek. The lower carbonate unit is also similar to that seen at Maloney Creek, and contains the same *Oepikodus communis* conodont fauna (Cooper, 1981). Above this unit the exposure of the Horn Valley Siltstone is very poor and secondary travertine obscures some of the section.

STAIRWAY SANDSTONE (fig.18, stop 15)
The Stairway Sandstone is well exposed on the east bank of Ellery Creek. It contains an ichnofauna very similar to that found in the Pacoota Sandstone and, at least in part, represents very similar depositional environments. The well preserved shelly fauna that is present in many other exposures of this formation, appears to be missing at this locality.

MEREENIE SANDSTONE (fig.18, stop 16)
An unconformable contact between the Stairway Sandstone and the overlying Mereenie Sandstone is well exposed on the steep ridge slope which deflects Ellery Creek to the east. Light coloured, well bedded, silicified sandstones below the contact contrast strongly with the overlying dark red, rather massive, sandstones of the Mereenie Sandstone. Although these two formations appear conformably at outcrop scale, regional data indicates that in passing eastward along the MacDonnell Ranges, pre-Mereenie erosion has removed progressively more (10 m/km) of the Ordovician section. At Ellery Creek at least 400 m of section (?Carmichael Sandstone, Stokes Siltstone and uppermost Stairway Sandstone) was eroded prior to deposition of the Mereenie Sandstone. This period of uplift and erosion, the Rodingan Movement, appears to have occurred in Late Ordovician time.

LOCALITY 4: TYLER PASS & GOSSES BLUFF

GOSSES BLUFF ASTROBLEME
Gosses Bluff (figs 21, 22, 23) is the central uplift of a dissected impact crater (Crook & Cook, 1966; Milton & others, 1972). The Bluff itself consists of slices of bedrock, from the upper Stairway Sandstone (normally lying at a depth of about 3 km) through the Parke Siltstone, that were transported upward and inward during the perhaps minute-long crater-forming rarefaction stage following the even briefer compressional stage of an asteroid or comet impact. Although modified by later erosion, the profile of the Bluff approximates the boundary, higher in the stronger units and lower in the weaker, between the zones of coherent

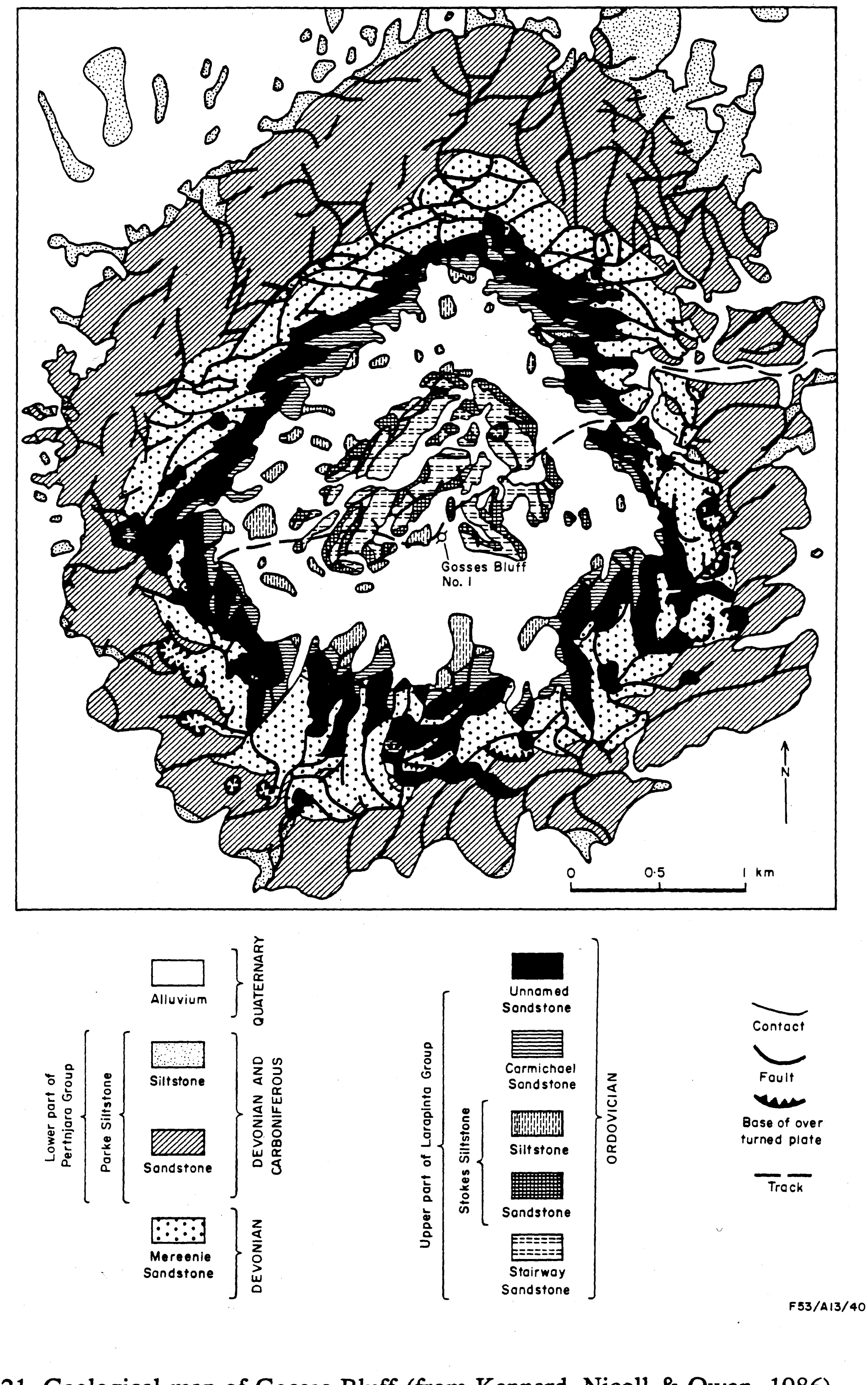

Figure 21. Geological map of Gosses Bluff (from Kennard, Nicoll & Owen, 1986)

displacement where rock moved essentially as a series of thrust slices and the zone of incoherent displacement where rock was brecciated and ejected from the crater bowl. The central uplift probably emerged as a central peak through brecciated and partially melted debris that lay in a crater with a rim-to-rim diameter of 20-25 km. The crater rim has been completely destroyed by erosion; only remnants of the shocked breccia remain on the plain around the Bluff.

At a cursory view, geologic features at the Bluff may look disappointingly ordinary. Closer study, however, shows that they are indeed distinctive and indicate the extreme violence of the Gosses Bluff event. Shatter coning and characteristic deformation features observed in mineral grains indicate that the exposed rocks underwent shock pressures of tens to a hundred or more kilobars. Shock melting of quartz, as seen at Mt. Pyroclast requires 400-500 kbar shock pressure. Hypervelocity impact is the only process that can account for the features exhibited by Gosses Bluff and other cryptoexplosion structures throughout the world.

An excellent view of Gosses Bluff can be obtained from the trigonometrical station on the hilltop at Tyler Pass. The limit of the disturbance, and the approximate site of the original crater rim, extends to within 7 km of this point. The smooth upper surface of the high Bluff, although it approximates the structural boundary mentioned above, is an erosional surface (perhaps correlatable with the summit surface of the McDonnell Ranges), indicating that the Bluff has been buried and exhumed.

Proceed to the Bluff past scattered outcrops of Brewer Conglomerate and Hermannsburg Sandstone, often heavily calcreted. The steep outer wall of the Bluff marks the contact of the Harajica Sandstone and the Dare Siltstone Members of the Parke Siltstone. The road enters the Bluff along the outlet stream, whose zigzag course is largely determined by faults. The red sandstone of the outer Bluff is Harajica Sandstone, the lighter sandstones of the inner Bluff are Mereenie Sandstone, with Carmichael Sandstone at the base.

Shatter cones are ubiquitous at the Bluff. Individual cones complete through 360° are not common, but stereographic plotting reveals that all the striations on the various partial cones seen at any one site fit a virtual cone with an apical angle of about 80°. The angle the cone axes make to the bedding increases regularly toward the centre of the Bluff. If the beds are restored to the position they had at the time of impact, the cone axes point towards a focus above the centre of the Bluff, about 2 km above the level of the Harajica Sandstone in the restored section. This fits the hypothesis that shatter cones form with their axes normal to a shock front that propagates from the point of impact early in the event, before any gross displacement of rock occurs. Individual shatter cones start at minor discontinuities in the rock, usually on bedding planes. A photogenic variety is the "feathered pipe rock" in the Mereenie Sandstone at the top of the Bluff in the southeast corner, where each *Skolithos* tube initiated a family of shatter cones.

The centre of the Bluff is a plain with scattered outcrops of Stokes Siltstone. The low ridges at the centre are of sandstone from a narrow stratigraphic interval at the base of the Stokes Siltstone and the top of the Stairway Sandstone, repeated in a series of fault slices. Conspicuous milky-white rounded quartz grains in a bimodal sandstone (rather arbitrarily assigned to the basal Stokes) owe their appearance to shock deformation, as may be seen in thin section. At the centre of the structure is the Exoil Gosses Bluff No.1 well, drilled in 1965

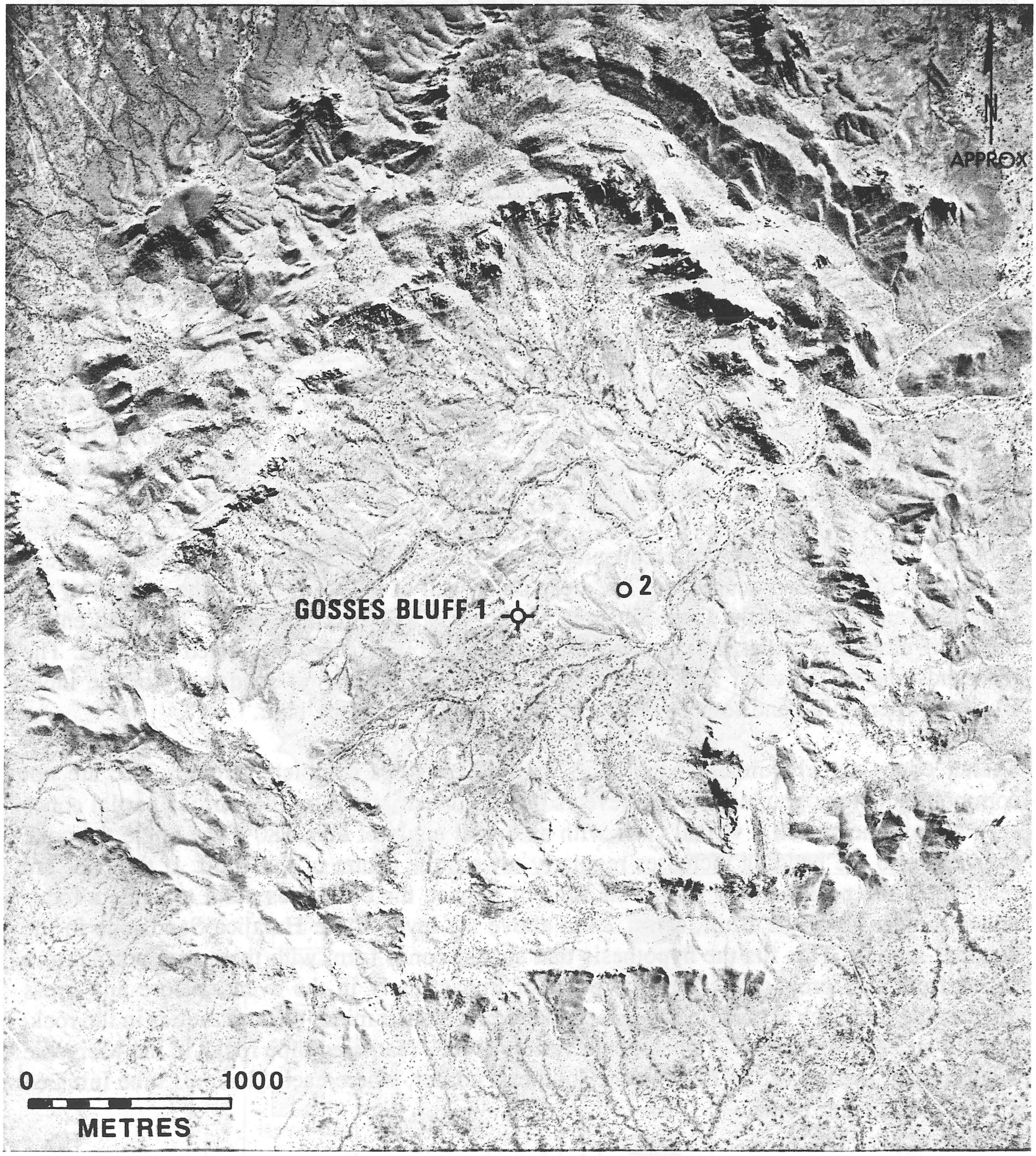

Figure 22. Aerial photograph of Gosses Bluff, showing petroleum exploration wells.

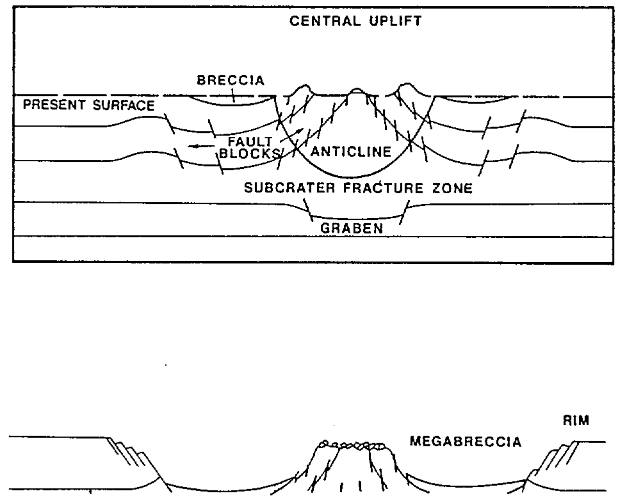

Figure 23. Diagrammatic cross section of a complex type impact crater (from Donofrio, 1981) above, with a cross section of Gosses Bluff below (from Roe, 1991)

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and abandoned at 1383 m in steeply dipping Stairway Sandstone, and to the east the Magellan Gosses Bluff No. 2 well, drilled in 1989 to 2652 m in moderately dipping, but still steeply faulted Pacoota Sandstone.

Mount Pyroclast, to the south of Gosses Bluff, is the only prominent remnant of the highly shocked breccia that once occupied the crater floor and covered the outer flanks of the crater. Toward the top of the Mount, melt breccia remains, with sandstone and shale clasts showing gross flowage and vesiculation, and petrographic evidence of recrystallization from glass. $^{40}Ar/^{39}Ar$ dating of sanidine-rich pumiceous material from here has yielded a date of 142.5 Ma, placing the event near the beginning of the Cretaceous Period.

LOCALITY 5: AREYONGA GORGE

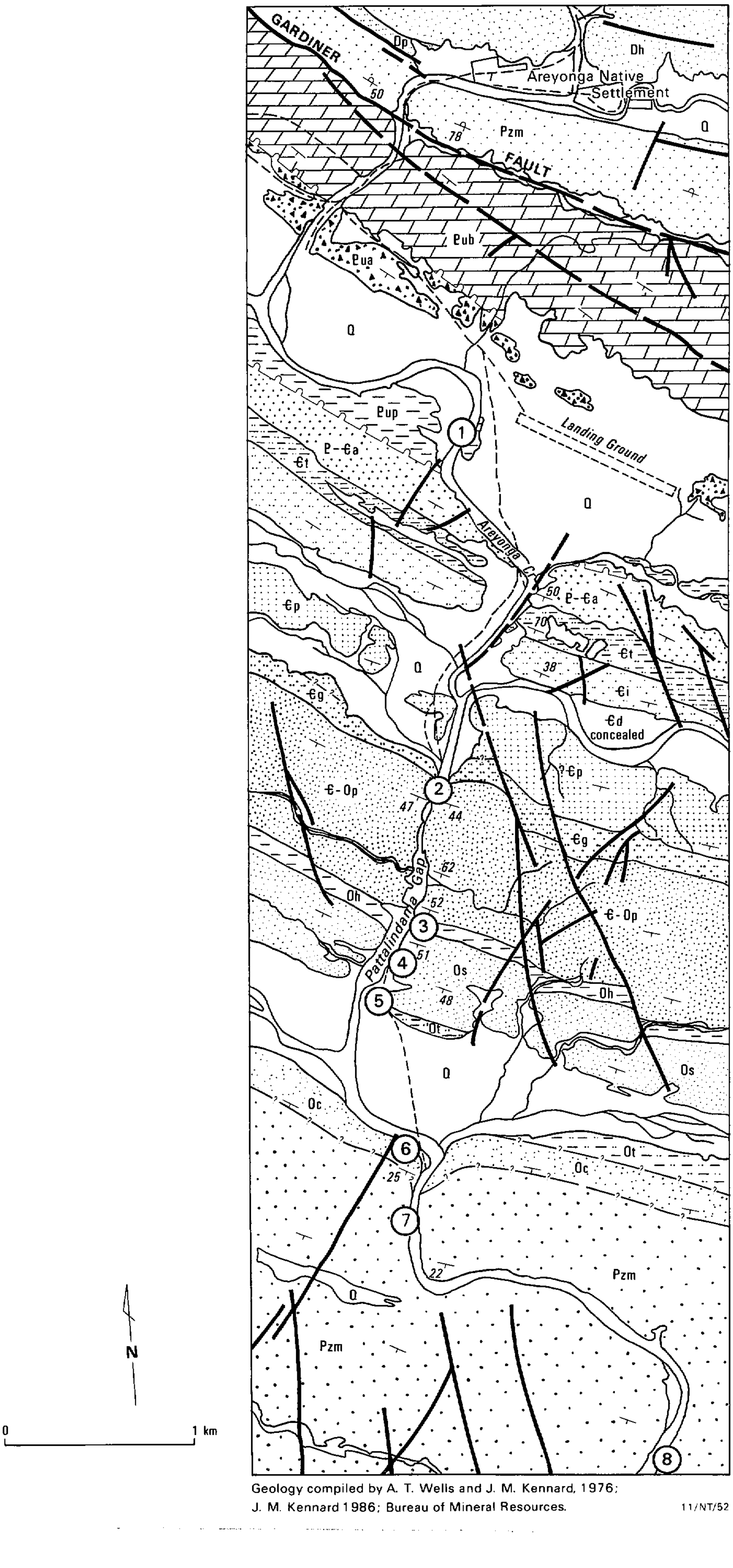
The Areyonga Creek section (figs 24, 25) provides one of the most complete Upper Proterozoic and Palaeozoic sections in the western central portion of the basin. The northern limb of the Gardiner Range Anticline is thrust faulted, and the Cambro-Ordovician section is missing. However a complete Late Proterozoic (Bitter Springs Formation) to Devonian (Hermannsburg Sandstone) section is present on the south limb of the anticline. The Larapinta Group and the base of the Mereenie Sandstone will be examined along Areyonga Creek.

LARAPINTA GROUP

A complete section of the Larapinta Group is present at Areyonga Creek, there being no evidence of pre-Mereenie erosion associated with the Rodingan Movement in this part of the basin.

GOYDER FORMATION AND PACOOTA SANDSTONE

The Goyder Formation is poorly exposed or covered on the hill slope below the scarp that



Geology compiled by A. T. Wells and J. M. Kennard, 1976; J. M. Kennard 1986; Bureau of Mineral Resources.

11/NT/52

Age	Group	Unit	Symbol	Lithology
CAINOZOIC			Q	*Alluvium, scree*
DEVONIAN	PERTNJARA GROUP	HERMANNSBURG SANDSTONE	Dh	*Sandstone*
		PARKE SILTSTONE	Dp	*Siltstone, sandstone*
SILURO (?) DEVONIAN		MEREENIE SANDSTONE	Pzm	*Sandstone*
ORDOVICIAN	LARAPINTA GROUP	CARMICHAEL SANDSTONE	Oc	*Sandstone*
		STOKES SILTSTONE	Ot	*Siltstone, minor sandstone, limestone*
		STAIRWAY SANDSTONE	Os	*Sandstone, siltstone (phosphatic)*
		HORN VALLEY SILTSTONE	Oh	*Siltstone, limestone (fossiliferous)*
		PACOOTA SANDSTONE	Є-Op	*Sandstone, conglomerate horizons, basal breccia*
CAMBRIAN	PERTAOORRTA GROUP	GOYDER FORMATION	Єg	*Sandstone, siltstone, dolostone, limestone*
		PETERMANN SANDSTONE	Єp	*Sandstone, minor siltstone*
		DECEPTION FORMATION	Єd	*Siltstone, shale (concealed)*
		ILLARA SANDSTONE	Єi	*Sandstone, siltstone*
		TEMPE FORMATION	Єt	*Siltstone, sandstone, limestone dolostone*
		ARUMBERA SANDSTONE	P-Єa	*Sandstone, conglomerate*
PROTEROZOIC		PERTATATAKA FORMATION	Pup	*Siltstone, shale, sandstone, limestone*
		AREYONGA FORMATION	Pua	*Sandstone, siltstone, diamictite*
		BITTER SPRINGS FORMATION	Pub	*Dolostone (stromatolitic), limestone, siltstone*

Unconformity

Geological boundary

40 *Strike and dip of strata*

Fault

Road/track

Watercourse

3 *Excursion stop*

11/NT/53

Figure 24. Geological Map of the Areyonga Gorge section.

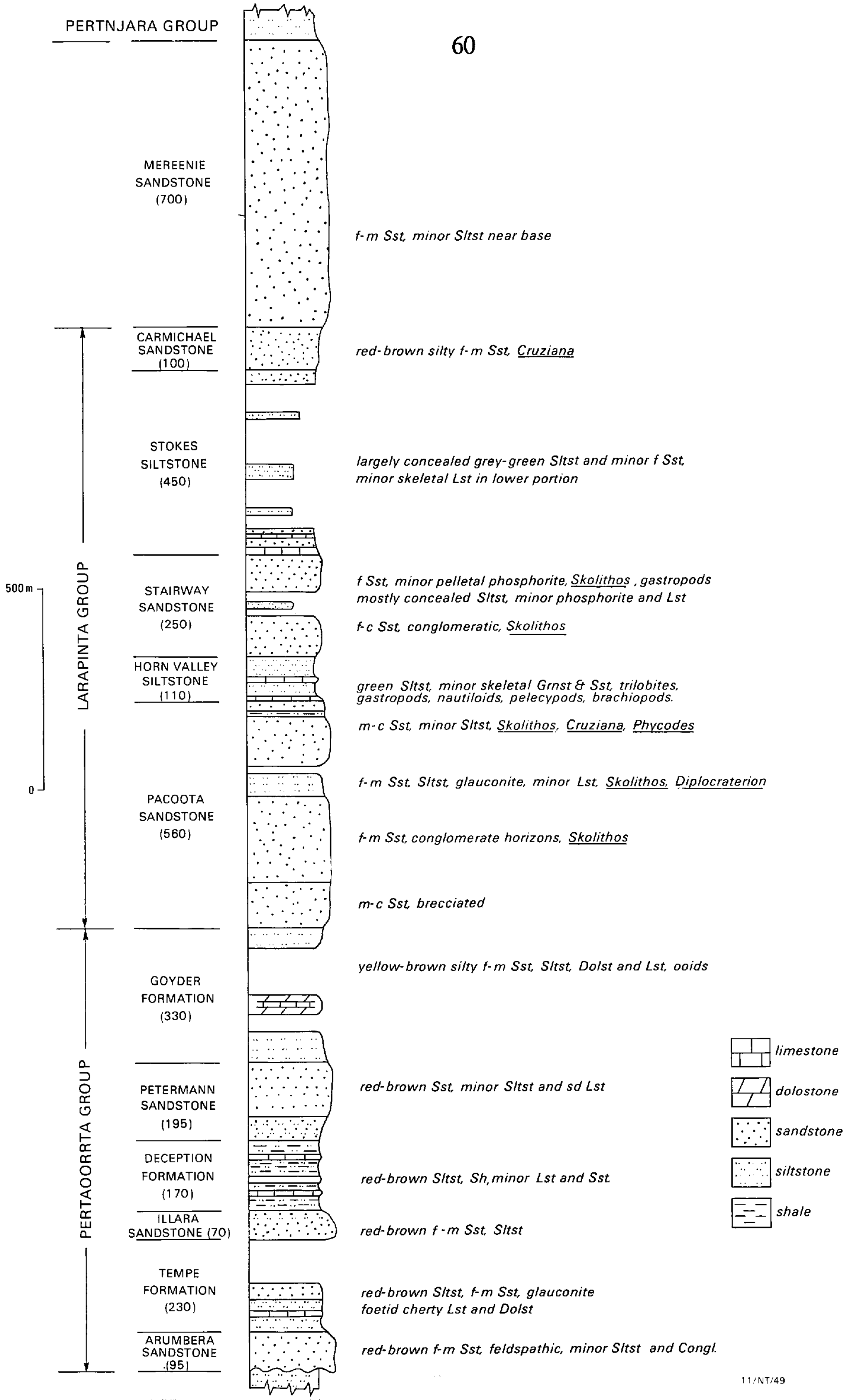


Figure 25. Cambrian to Devonian stratigraphy in Areyonga Gorge section

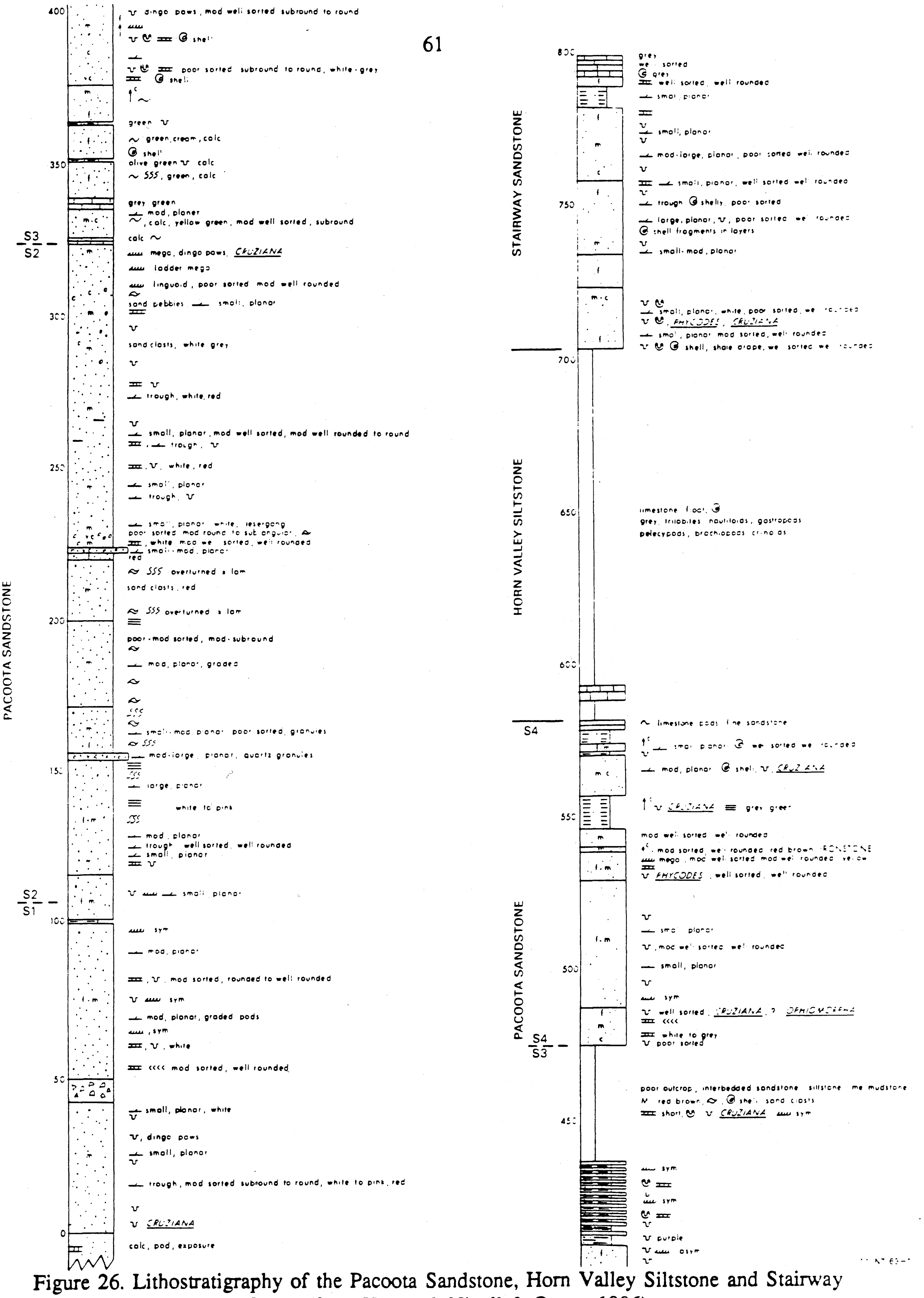


Figure 26. Lithostratigraphy of the Pacoota Sandstone, Horn Valley Siltstone and Stairway Sandstone in Areyonga Gorge (from Kennard, Nicoll & Owen, 1986)

marks the base of the Pacoota Sandstone Sequence 1. The Pacoota Sandstone is well exposed along both sides of the creek. Major lithofacies and sedimentological features are indicated on the measured section (fig.26). Compared with the Ellery Creek section, there appears to be a significant reduction in the silt and shale content of the Pacoota Sandstone at this locality. This trend is especially noticeable at the base of Sequence 3 which at Ellery Creek is represented by shale, siltstone and a thin limestone bed, but at Areyonga Creek the interval consists of fine sandstone and some siltstone. In Sequence 4 the shale or siltstone at the base of the coarsening upward cycles at Ellery Creek is replaced by siltstone and fine sandstone in most cycles at Areyonga Creek.

HORN VALLEY SILTSTONE

The transition interval from the Pacoota Sandstone into the Horn Valley Siltstone is not exposed, but on the east bank and adjacent small stream gully the basal dolomitic limestone (HV3 of Elphinstone & Gorter, 1991) of the Horn Valley is exposed. The rest of the Horn Valley sequence is very poorly exposed.

STAIRWAY SANDSTONE

The lower 80 m of the Stairway Sandstone is well exposed on both the east and west bank of the creek bed. It consists of medium to fine grained sandstone, generally similar to the upper part of the Pacoota Sandstone, with an abundant ichnofauna. Some beds contain shelly fossils, usually preserved as moulds, with abundant brachiopods, nautiloids and occasional trilobites. Above this is a poorly exposed interval of about 160 m with several limestone beds concentrated near the base, middle and upper parts. Thin beds of pelletal phosphorite occur at the top of this interval. The rest of this interval is very poorly exposed. The upper part of the Stairway Sandstone consists of about 40 m of fine to coarse grained sandstone with a well developed ichnofauna in the lower part.

STOKES SILTSTONE

The lower 30 m of the Stokes Siltstone is relatively well exposed to the east of the creek and consists of a series of limestone beds separated by covered intervals that in other sections comprise red and grey shale. Several of the beds have large 'tepee'-like structures in their upper part. The majority of the Stokes Siltstone, above the basal carbonate beds is concealed. Elsewhere it is formed of red or green siltstone and shale with minor fine sandstone and dolostone, within which halite pseudomorphs are common.

CARMICHAEL AND MEREENIE SANDSTONES

The well exposed section through the Carmichael and Mereenie Sandstones in Areyonga Gorge shows the typical development of the two units in the central part of the basin, close to the depocentre of both units. The sequence can be divided into two broad facies, within each of which several sub-facies have been recognised.

The contact of the Carmichael Sandstone with the underlying Stokes Siltstone is not exposed at this locality but evidence from elsewhere in the central part of the basin indicates it is conformable and gradational.

The lower part of the sequence, from 0-380m, is thought to have been deposited in a shallow marine environment. The basal 101m of the section (the Carmichael Sandstone) appears to represent a deltaic sequence with thick to very thick, cross-bedded sandstone interbedded with thinly bedded sandstone and siltstone. The proportion of thick-bedded sandstone increases upwards. The sandstone has a fine to medium grain size, is well sorted and is composed of quartz with minor feldspar. Palaeocurrents are polymodal, with a northwest-southwest bimodal component slightly dominant.

The interval from 101-275m (in the lower Mereenie Sandstone) appears to be predominantly an upper shoreface environment with medium to thick bedded, planar and cross-bedded quartz sandstone. Both symmetrical and asymmetrical ripples are common, and some are bevelled. Palaeocurrents are bimodal north-south in the lower part, becoming dominantly unimodal southwards higher in the interval.

Above 275m an interval with numerous bioturbated horizons extends up to 380m. In this interval, the fine quartz sandstone contains minor clay matrix, is medium to very thick bedded, and cross-bedding is common. Ripples are less common than in the underlying interval. Palaeocurrent directions are mainly towards the south. *Skolithos* dominates the ichnofauna and some bioturbated beds extend at least 2 km along strike. The depositional environment is uncertain, though may be intertidal.

Above 380m the Mereenie Sandstone becomes exclusively terrestrial, with both aeolian and fluvial facies present. From 380-753m, aeolian environments dominate the sequence. Large trough cross-beds (up to 6m thick and in co-sets up the 35m thick) are interbedded with interdune deposits up to 10m thick. The aeolian dunes are composed of well sorted and rounded fine grained quartz sand, while the interdune material is well rounded and often has a bimodal size distribution (very fine and medium to coarse) and some clay matrix. Both wet and dry interdune environments are recognised. The dominant wind direction is towards the northeast with a small southward mode also present. Thin fluvial horizons are also present.

From 753m to the conformable contact with the Parke Siltstone at 801m, a fluvial environment dominates the sequence, though an interval of aeolian dunes between 768-778m indicates that desert conditions were still present in the region. Indeed, elsewhere, particularly around Tempe Downs, about 50 km south of Areyonga Gorge, aeolian facies continue to the contact with the Parke Siltstone.

LOCALITY 6: CARMICHAEL CRAG

The stratigraphic section exposed at Carmichael Crag (fig.27) extends from the upper part of the Stokes Siltstone, through the Carmichael Sandstone and into the base of the Mereenie Sandstone. The Stokes Siltstone is poorly exposed, but consists of red and green siltstone and shale with thin (10-25mm) beds of dolomite or dolomitic siltstone. The surfaces of the dolomitic siltstone are frequently covered with small to large halite pseudomorphs that have probably developed postdepositionally in the soft sediment. No ichnofossils, body fossils or microfossils have been recovered from the upper part of the Stokes Siltstone. The lack of any fossils and the presence of halite in the upper part of the Stokes Siltstone is indicative of deposition in a hypersaline environment.

The contact between the Stokes Siltstone and the overlying Carmichael Sandstone is gradational and is placed at the base of the first prominent sandstone bed. This change from fine to mixed coarse and fine clastic sedimentation is interpreted as representing the

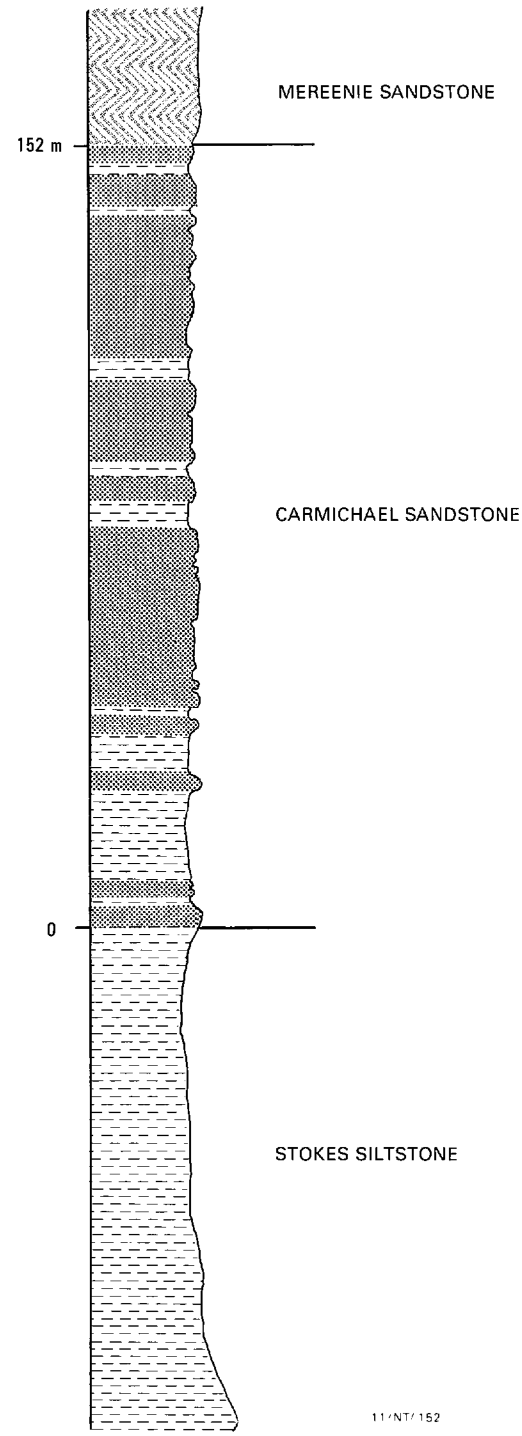


Figure 27. Lithostratigraphy of the Carmichael Crag section.

introduction of coarse sediments from the basin margins associated with the Rodingan Movement.

The Carmichael Sandstone at Carmichael Crag consists of interbedded sandstone, siltstone and shale. Ichnofossils in some beds indicate a return to more normal marine salinity, but large bodyfossils have not been recovered from the unit. Reworked Ordovician conodonts have been recovered from some localities. The unit is interpreted as having been dominately marine in origin, but in parts of the basin it may have been the product of a fluvial environment.

The Mereenie is exposed at the top of the cliff, but this unit will be examined later at Kings Canyon.

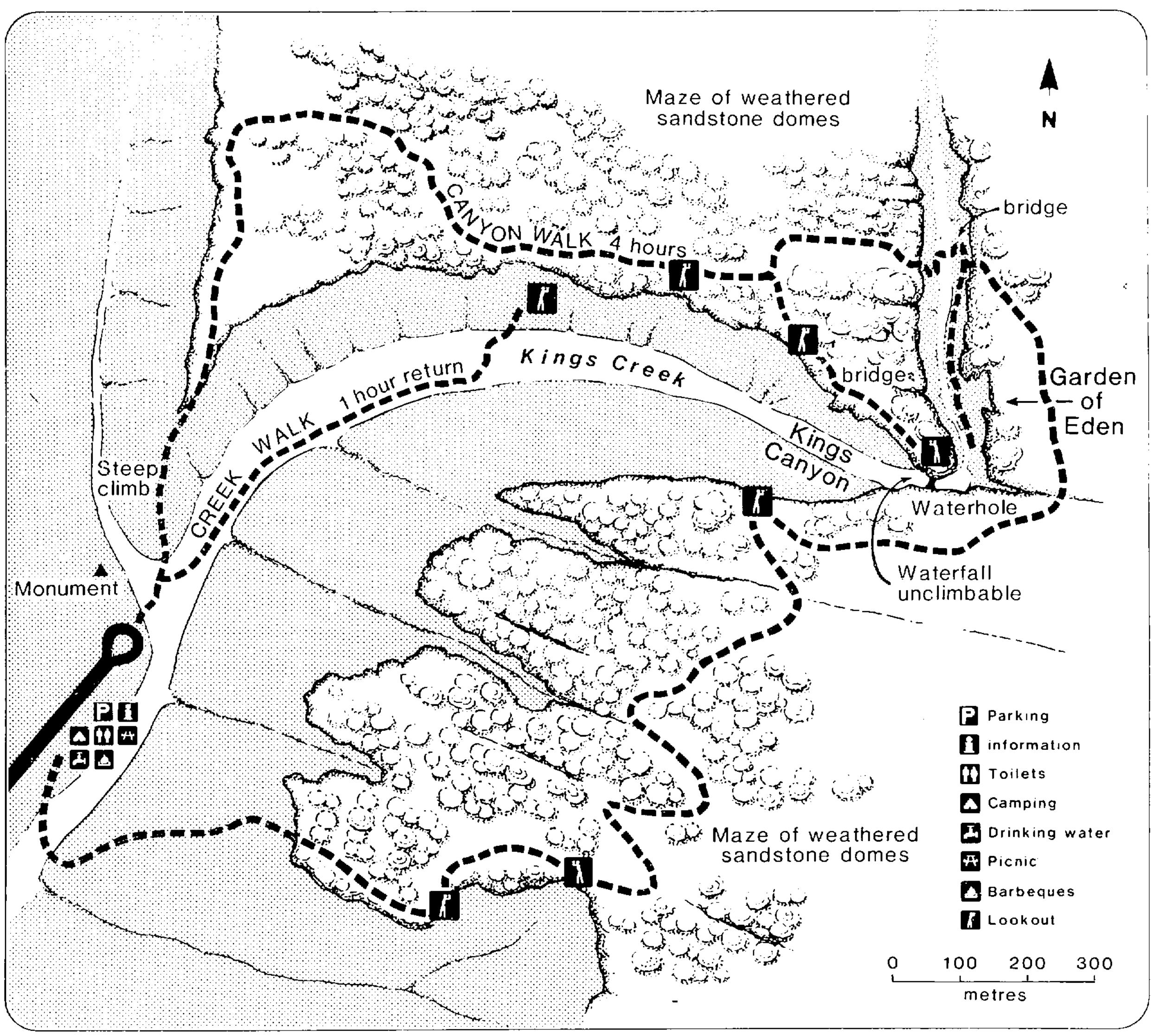


Figure 28. Map of Kings Canyon.

LOCALITY 7: KINGS CANYON

Kings Canyon (fig.28) is a spectacular gorge cut into the Mereenie Sandstone escarpment of the George Gill Range by Kings Creek. Here the Mereenie Sandstone consists of white to pale redbrown, friable, well rounded and sorted, ripple-marked, fine- to medium-grained quartz sandstone which is thinly to massively bedded and characteristically cross-bedded with sets up to 3m thick and tens of metres long. The red to brown colour is a superficial staining which distinguishes the Mereenie Sandstone from the underlying darker Carmichael Sandstone in cliff sections. The sandstone is well jointed and forms prominent joint patterns. The dome-shaped forms above the Canyon result from preferential erosion along joint planes.

The south wall of the Canyon is a slightly curved, iron-stained joint face coated in places by a silica veneer and occasionally marked by runnels. An elliptical structure about 20m across, composed of a series of concentric ridges and troughs of low relief can be seen on the upper part of this wall. These markings are thought to have been caused by sudden stress relief during propagation of joints in the Mereenie Sandstone (Bagas, 1988).

LOCALITY 8: STAIRWAY SANDSTONE ROADSIDE STOP

STAIRWAY SANDSTONE

This exposure of the Stairway Sandstone is typical of many in the basin where the dip of the unit is relatively low. In situ exposure is rare, and float is the rule. Trend lines indicate the strike of the beds. However, closer examination of the section reveals an abundant, and relatively diverse macrofauna consisting of nautiloids, bivalves, rostroconchs and occasional trilobites, all of which are preserved as moulds. Little detailed work has been attempted on this fauna.

LOCALITY 9: STORM CREEK

Here the upper part of the Stairway Sandstone and the lower part of the Stokes Siltstone (fig.29) will be examined. The upper part of the Stairway Sandstone consists of thin to medium bedded sands and silts. Some intervals are fossiliferous, with large nautiloids forming the most visible part of the fauna. In the uppermost part of the unit at Storm Creek, some of the sands contain halite pseudomorphs. Contact with the overlying Stokes Siltstone appears to be gradational, and the boundary is placed at the top of the last prominent sandstone bed.

The Stokes Siltstone consists of interbedded gray to reddish shales and limestones. Both lithologies are fossiliferous; trilobites, bivalves, nautiloids and brachiopods are common. Bryozoans are especially abundant in the uppermost limestone beds. Burrows are common in some of the beds and conodonts are common to abundant in the limestones. Deposition of the limestones and shales appears to have been cyclic. The upper part of the Stokes is very poorly exposed, however across the valley to the north, red siltstones and shales are found near the top of the unit. This formation is overlain by the Carmichael Sandstone which forms the cliffs to the north.

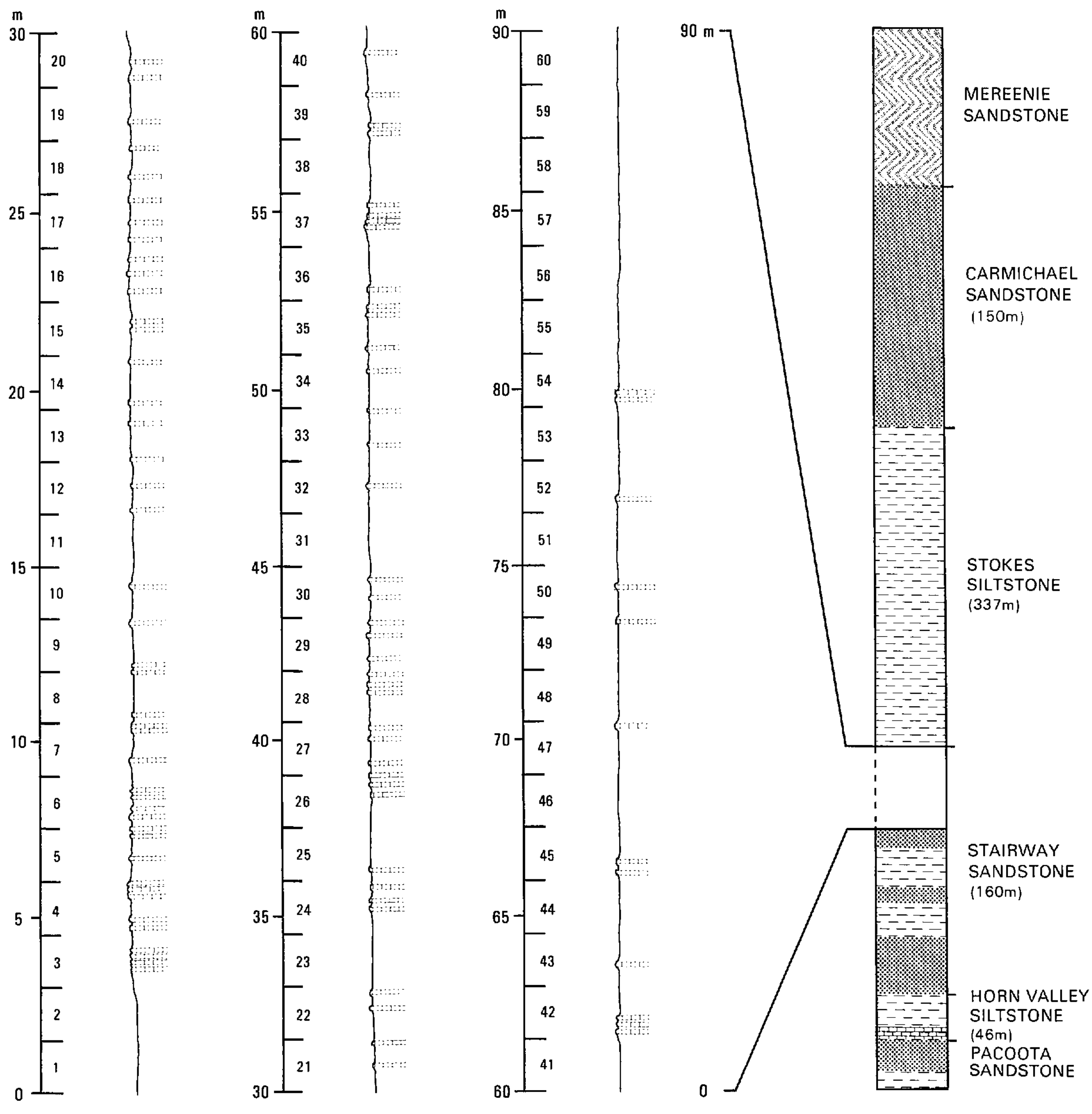


Figure 29. Lithostratigraphy of Stokes Siltstone in Storm Creek section.

LOCALITY 10: MALONEY CREEK

HORN VALLEY SILTSTONE

Exposures of the Horn Valley Siltstone (fig.30) occur in a drainage ditch on the east side of the highway, about 200m north of the bridge over Maloney Creek, 120 km south of Alice Springs. The Pacoota Sandstone is also exposed in the drainage ditch below the Horn Valley Siltstone, and exposure of the Pacoota Sandstone continues to the south along Maloney Creek. Above the Horn Valley Siltstone, sandstones of the lower part of the Stairway Sandstone crop out along a small creek bed and on the adjacent hill slope. Additional exposure of the middle part of the Horn Valley Siltstone can be observed in an excavation located 50m to the east of the ditch. The section examined by Cooper (1981) is located just west of Maloney Creek and does not expose any of the shale and silt intervals seen in this section which is the result

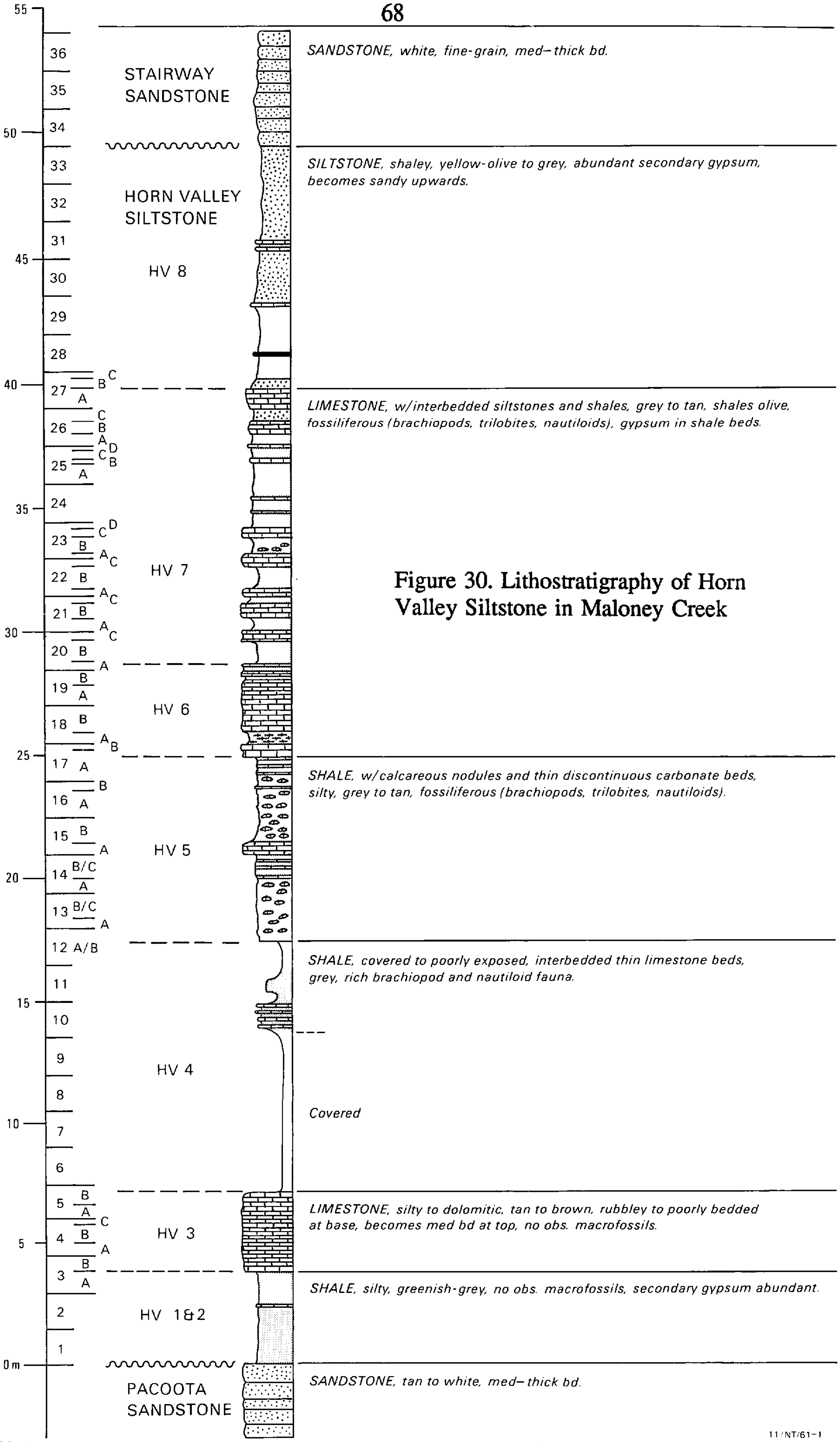


Figure 30. Lithostratigraphy of Horn Valley Siltstone in Maloney Creek

of post-1971 highway construction.

The Pacoota Sandstone at this locality is truncated by pre-Horn Valley erosion. The unit exposed below the Horn Valley is thought to be Sequence 2 of the Pacoota Sandstone, but could be as low as Sequence 1. No age diagnostic fossils have been documented in the unit at this locality. The exposure of the lower part of the Pacoota Sandstone located 200m east of the highway bridge has been interpreted as fluvial sands, possibly part of a non-marine channel fill interval.

The drainage ditch provides the best exposure of the lower part of the Horn Valley Siltstone in the eastern part of the basin. Except for about 8m near the base of the section, the exposure is continuous. The shales and siltstones have been deeply weathered, and lack the characteristic black colouration evident in subsurface samples.

Subdivisions HV1 to HV8 of the Horn Valley Siltstone (Elphinstone & Gorter, 1991) are recognised in this section (Fig. 32). The lowest interval (HV1-HV3) is the basal dolomitic member and underlying shale. The unit is about 7.5m thick in this section as compared with about 10m at the Ellery Creek section. The dolomitic limestone contains a distinctive conodont fauna that contains *Oepikodus communis*. Macrofossils are uncommon and poorly preserved.

The HV4-HV5 interval is 17.5m thick and consists of interbedded siltstone and shale, and contains micritic limestone nodules and nodular limestone beds. Fossils are abundant in this interval, especially within the shales. In some localities well preserved trilobites are abundant on the surfaces of the nodules.

The HV6-HV7 interval is 15m thick and comprises interbedded limestone, siltstone and shale. These lithologies frequently occur in cycles consisting of a storm deposited basal fossil coquina, that grades upward through a calcareous siltstone to shale.

The uppermost unit, HV8 is 9.5m thick and consists of siltstone and fine sandstone. This unit is paraconformably overlain by the Stairway Sandstone, the upper part of the Horn Valley Siltstone having been eroded prior to Stairway deposition. Gorter (1991) shows this as a progressive eastward erosion of the upper part of the Horn Valley Siltstone.

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