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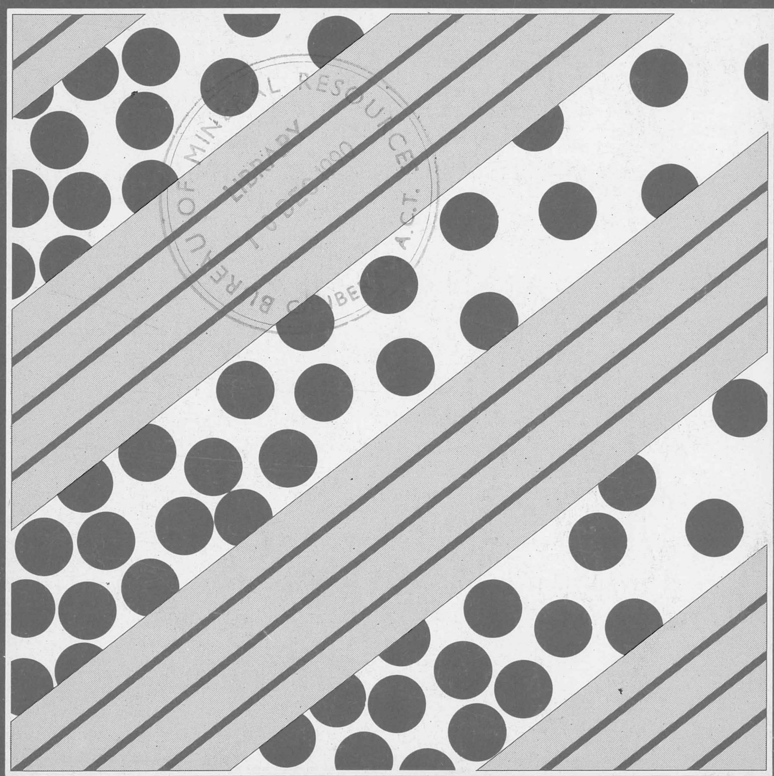
AMADEUS BASIN WORKSHOP: ABSTRACTS

EDITED BY J.M. KENNARD



BUREAU OF MINERAL RESOURCES
GEOLOGY & GEOPHYSICS

ONSHORE SEDIMENTARY &
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BUREAU OF MINERAL RESOURCES
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6 - 7 December 1990

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CONTENTS

INTRODUCTION

The Amadeus Basin is one of Australia's most important sedimentary basins, both scientifically and economically. Scientifically its significance stems from the fact that it contains some of Australia's best preserved and best exposed Proterozoic and Palaeozoic sequences which provide us with a window on the early history of the continent. Economically, it derives its importance from the fact that those same sequences host commercially exploitable oil, gas and groundwater, as well as resources of potential value in the future such as evaporites and phosphate.

After consultation with industry and the geoscientific community, it was decided to undertake a new and comprehensive multi-disciplinary study of the Amadeus Basin in order to provide the best possible basis for resource assessment and exploration in the future. This work was largely carried out under the auspices of the former Division of Continental Geology and its Chief, Peter Cook. Like all other work in the BMR, it was seen as essential to the success of the project to work closely with industry, universities and the Northern Territory Geological Survey, and this same approach is evident in this Workshop, with many of the speakers being from outside BMR.

The success of any project such as the Amadeus Basin Project is inevitably judged on the quality, and in part by the quantity, of the scientific output. Already the project has produced a large number of scientific papers, and together with the soon to be published Bulletin "Geological and geophysical studies in the Amadeus Basin, central Australia" and 1:1 000 000 scale Amadeus Basin Map Folio, it can be judged a great success. However, the ultimate test of the project's success, namely the extent to which it enables us to more successfully explore for, and more accurately assess, mineral energy and groundwater resources, is perhaps less tangible and much longer term.

This workshop is designed to highlight the principal results of the project and their relevance to the future economic potential of the Amadeus Basin.

Trevor G Powell
Chief, Onshore Sedimentary and Petroleum Geology Program

EVOLUTION OF THE AMADEUS BASIN, CENTRAL AUSTRALIA

John F Lindsay & Russell J Korsch
Onshore Sedimentary and Petroleum Geology, Bureau of Mineral Resources

A number of broad, shallow, intracratonic depressions formed on the Australian craton during the Late Proterozoic and early Palaeozoic. The development of these basins almost certainly relates to the breakup of a Proterozoic supercontinent and, in large part, basin dynamics appears to be tied to this global tectonic event (Lindsay & others, 1987). The Amadeus Basin, which is typical of these intracratonic basins, contains a complex Late Proterozoic to mid-Palaeozoic depositional succession which locally reaches 14 km in thickness (Fig. 1) (Lindsay & Korsch, 1989; Korsch & Lindsay, 1989). The application of sequence stratigraphy to this succession has provided an effective framework in which to evaluate its evolution (Lindsay 1987, 1989; Kennard & Lindsay, in press). Analysis of major depositional sequences shows that the Amadeus Basin evolved in three stages (Fig. 2). Stage 1 began at about 900 Ma with extensional thinning of the crust and the formation of half-grabens (Fig. 3). Subsidence following extension was well advanced when a second less intense crustal extension (Stage 2) occurred towards the end of the Late Proterozoic. Stage 2 subsidence was followed by a major compressional event beginning at about 450 Ma (Stage 3) in which major southward-directed thrust sheets caused progressive downward flexing of the northern margin of the basin, and sediment was shed from the thrust sheets into the downwarps forming a foreland basin. This event shortened the basin by 50-100 km and effectively concluded sedimentation.

The two stages of complex crustal extension and thermal recovery produced large-scale apparent sea-level effects upon which eustatic sea-level cycles are superimposed. Basin dynamics created depositional space and determined the location of major depocentres, whilst eustacy determined the timing of sequence boundaries and the distribution of facies associations. Since the style of sedimentation and major sequence boundaries were controlled to a large degree by basin dynamics and eustacy, depositional patterns within the Amadeus and associated basins are, to a large degree, predictable. This suggests that an understanding of major variables associated with basin dynamics and their relationship to depositional sequences may allow the development of generalized depositional models on a basinal scale. Thus it appears that sequence stratigraphy can be used as a basis for inter-regional correlation; a possibility that has considerable significance in unfossiliferous Archaean and Proterozoic basins.

References

Kennard, J.M. & Lindsay, J.F., in press. Sequence stratigraphy of the Latest Proterozoic - Cambrian Pertaoorrta Group, northern Amadeus Basin, central Australia. Bureau of Mineral Resources Australia, Bulletin 236.

Korsch, R.J. & Lindsay, J.F., 1989. Relationships between deformation and basin evolution in the intracratonic Amadeus Basin, central Australia. Tectonophysics, 158, 5-22.

Lindsay, J.F., 1987. Sequence stratigraphy and depositional controls in Late Proterozoic - Early Cambrian sediments of the Amadeus Basin, central Australia. American Association of Petroleum Geologists Bulletin, 71, 1387-1403.

Lindsay, J.F., 1989. Depositional controls on glacial facies associations in a basinal setting, Late Proterozoic, Amadeus Basin, central Australia. Palaeogeography, Palaeoclimatology, Palaeoecology, 37, 205-232.

Lindsay, J.F. & Korsch, R.J., 1989. Interplay of tectonics and sea-level changes in basin evolution: An example from the intracratonic Amadeus Basin, central Australia. Basin Research, 2, 3-25.

Lindsay, J.F., Korsch, R.J., & Wilford, J.R., 1987. Timing the breakup of a Proterozoic supercontinent: Evidence from Australian intracratonic basins. Geology, 15, 1061-1064.

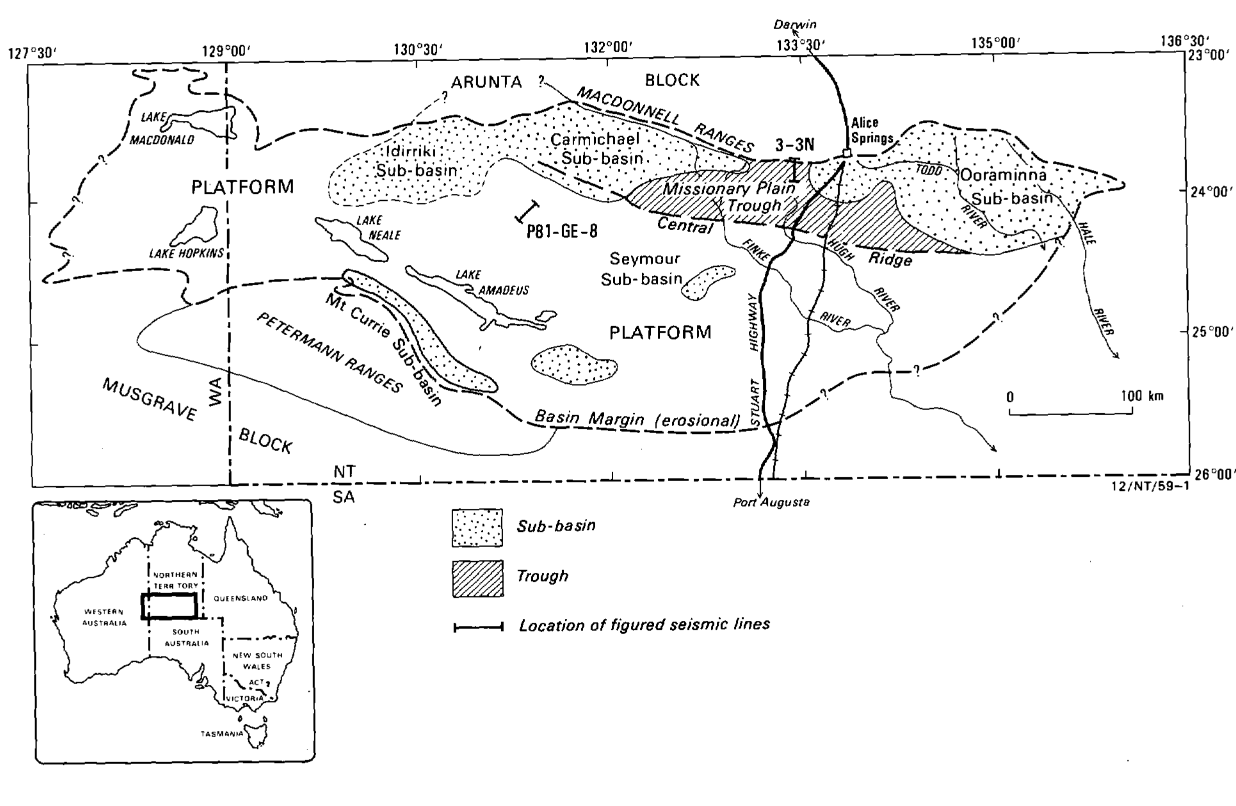


Figure 1. Map showing location of the Amadeus Basin and the main morphological features discussed in the text (sub-basins, trough, platforms, and ridges).

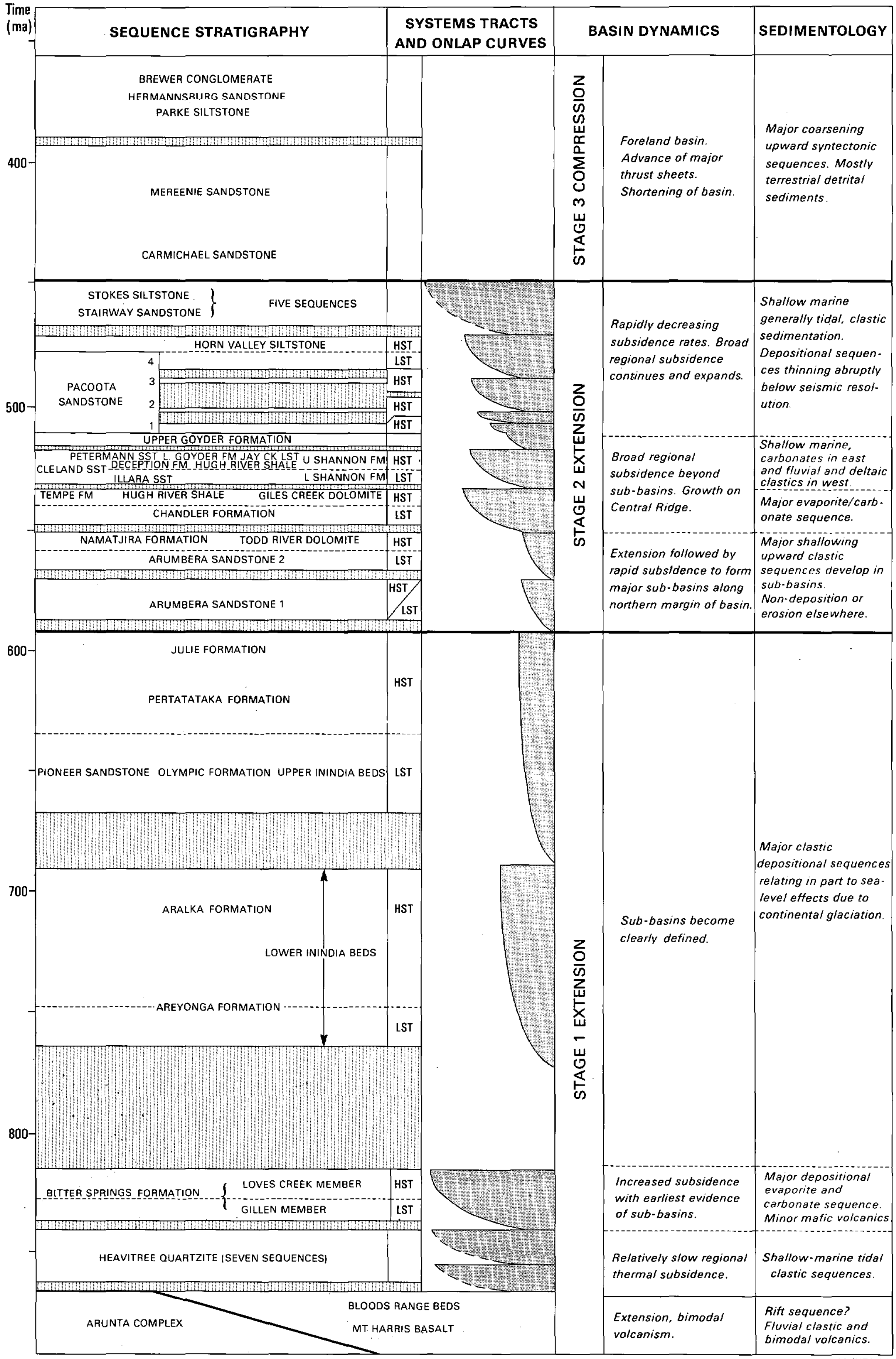


Figure 2. Simplified sequence stratigraphic chart and onlap and relative sealevel curves for the Late Proterozoic to Devonian sequences in the Amadeus Basin.

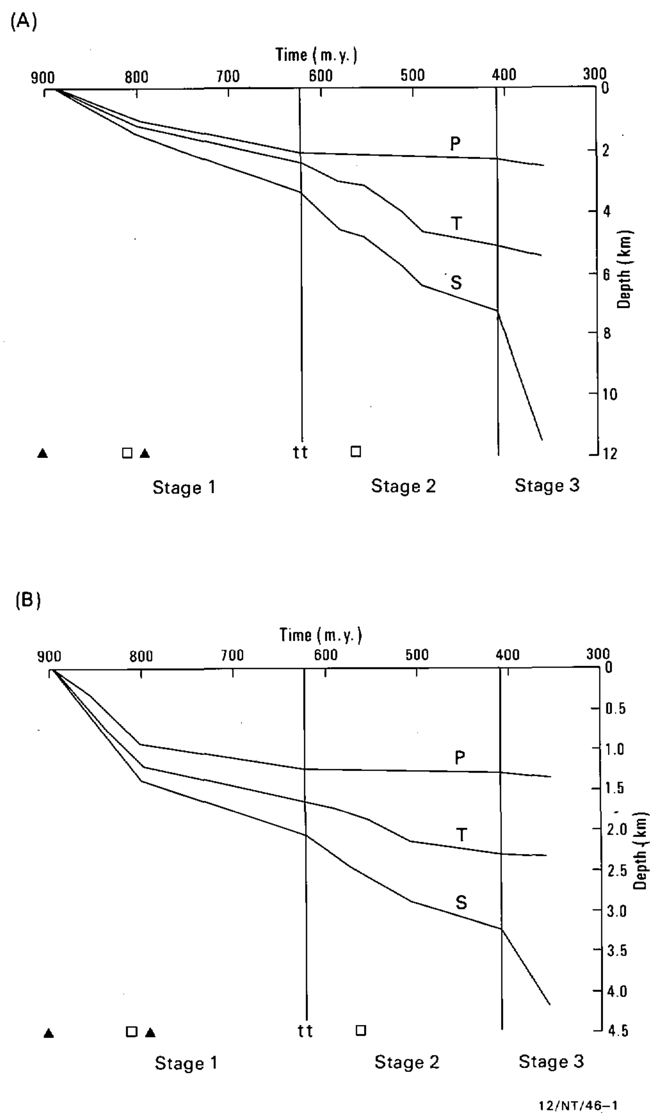


Figure 3. Subsidence curves for the three major morphological regions of the Amadeus Basin. P = platform; T = trough; S = sub-basin. **A)** Total subsidence, **B)** Subsidence with the effects of sediment loading removed.
▲ = vulcanism; ■ = evaporite units; t = turbidites.

PROTEROZOIC SEQUENCE STRATIGRAPHY OF THE AMADEUS BASIN

John F Lindsay
Onshore Sedimentary and Petroleum Geology, Bureau of Mineral Resources

Sedimentation began in the Amadeus Basin in the late Proterozoic and continued until the Late Devonian (approximately 900 to 400 Ma). The sedimentary succession preserved in the basin is complex and reflects the interaction of a number of variables such as eustacy, and global and regional tectonism. To establish a stratigraphic framework for the basin, depositional sequence concepts were used (Lindsay & Korsch, 1989; in press) leading to the recognition of at least 12 major depositional sequences.

The Late Proterozoic sedimentary rocks of the Amadeus Basin consist of a well-preserved succession of largely shallow-water sedimentary rocks which rests unconformably upon the much older Arunta and Musgrave Complexes (Fig. 1). More than twenty Proterozoic formations and members have been defined. Five sequences have been recognised in outcrop with seven more apparent in the Heavitree Quartzite (see figure 1, Lindsay & Korsch, this volume). The Proterozoic succession consists of three distinct major sedimentary packages or depositional associations: (1) the rift sequence, (2) the Heavitree/Bitter Springs Formation association and (3) the Areyonga/Pertatataka Formation association.

1. Rift Sequence: The earliest Proterozoic formations, which are very restricted in their known extent, consist of clastic sedimentary rocks and basalts along the southwestern margin of the basin, and basalts and dacites in the northwest at Kintore (Korsch & Lindsay, 1989; Lindsay & Korsch, 1989). The sedimentary rocks associated with all these units appear to be braided-stream deposits. These basal volcanics may correlate with dykes intruding the Arunta complex beneath, suggesting an age of approximately 900 Ma. However, they may correlate with the Tollu Group further to the west which suggests an age of 1064±23 Ma (Lindsay & Korsch, in press). If the latter correlation is correct, the volcanics must belong to an earlier rifting event.

2. Heavitree Quartzite/Bitter Springs Formation Association: The widespread deposition of the Heavitree Quartzite (and correlative Dean Quartzite) and the carbonates and evaporites of the Bitter Springs Formation suggest a marked change in the nature of the basin. These two units are among the most extensive units in the basin and are in large part shallow marine (often tidal) formations deposited in what is best described as a platform or ramp setting. The two units form a major depositional sequence or mega-sequence which begins as relatively shallow marine tidal deposition in the Heavitree Quartzite, deepening upward into the Gillen Member of the Bitter Springs Formation, then finally shallowing upward to a lacustrine association at the top of the Loves Creek Member. Possibly as many as seven sequences are preserved within the Heavitree Quartzite (Lindsay & Korsch, in press). The Bitter Springs Formation forms at least one deposition sequence with the evaporites of the Gillen Member forming a lowstand systems tract and the Loves Creek Member containing the transgressive and highstand systems tracts (Lindsay, 1987; Southgate, in press). The Heavitree and Bitter Springs Formations thus form a single major depositional sequence or mega-

sequence that probably relates to rapid basin subsidence.

3. Areyonga/Pertatataka Formation Association: The Bitter Springs Formation is terminated by an erosional surface upon which the fluvial and glacigene sedimentary rocks of the Areyonga Formation and its equivalents were deposited. These sedimentary rocks are in turn overlain by a series of shallow marine and fluvial formations. Two major depositional sequences are preserved in this part of the Late Proterozoic succession (Lindsay, 1989). The Areyonga Formation and the Aralka Formation form a single highstand systems tract resting on the deeply eroded Bitter Springs surface. The sea-level cycle that produced this sequence was almost certainly glacially controlled which probably explains the sharply delineated erosion surface at its base. The Pertatataka and Julie Formations at the top of this time slice form a major single, shallowing-upward, depositional sequence which begins with deep-water pelagic and turbidite units in the Pertatataka Formation and terminates abruptly with oolitic platform carbonates at the top of the Julie Formation. These units together form a highstand systems tract that can be recognized over large areas of the basin.

Exclusive of the rift sequence, the total thickness of the Proterozoic succession averages about 2,000 m although in the northeast it may be as thick as 3,000 m. Regional thickness variations imply that the sub-basins evolved rapidly and independently during the Late Proterozoic and that the general form of the Amadeus Basin was established soon after its inception in the late Proterozoic.

References

Korsch, R.J. & Lindsay, J.F., 1989. Relationships between deformation and basin evolution in the intracratonic Amadeus Basin, central Australia. Tectonophysics, 158, 5-22.

Lindsay, J.F., 1987. Late Proterozoic evaporites in the Amadeus Basin, central Australia and their role in basin tectonics. Geological Society of America, Bulletin, 99, 852-865.

Lindsay, J.F., 1989. Depositional controls on glacial facies associations in a basinal setting, Late Proterozoic, Amadeus Basin, central Australia. Palaeogeography, Palaeoclimatology, Palaeoecology, 37, 205-232.

Lindsay, J.F. & Korsch, R.J., 1989. Interplay of tectonics and sea-level changes in basin evolution: An example from the intracratonic Amadeus Basin, central Australia. Basin Research, 2, 3-25.

Lindsay, J.F. & Korsch, R.J., in press. The evolution of the Amadeus Basin, central Australia. Bureau of Mineral Resources, Australia, Bulletin 236.

Southgate, P.N., in press. A sedimentological model for the Loves Creek Member of the Bitter Springs Formation. Bureau of Mineral Resources, Australia, Bulletin 236.

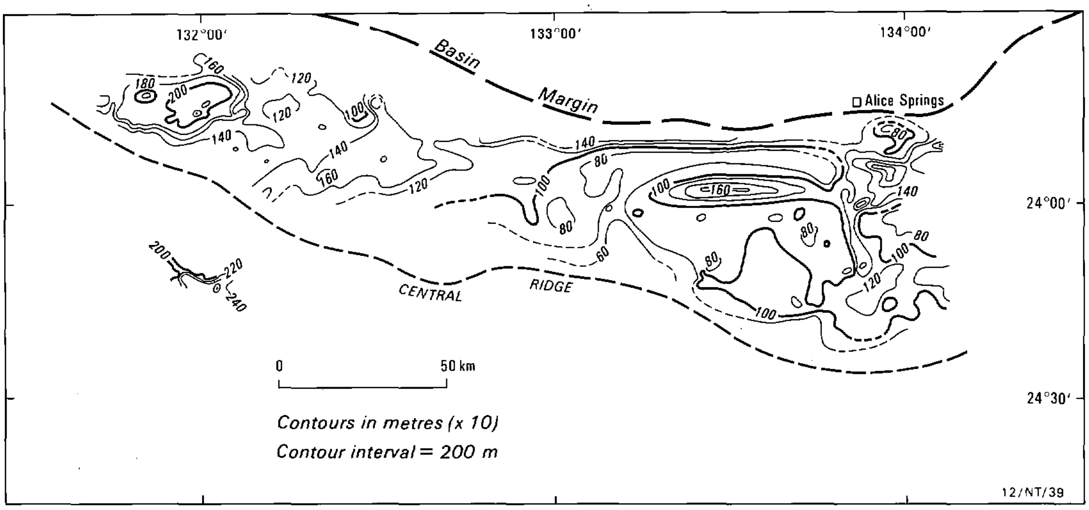


Figure 1. Isopach map of the Late Proterozoic sediments from the maximum flooding surface at the top of the evaporites of the Gillen Member of the Bitter Springs Formation to the sequence boundary at the base of the Arumbera Sandstone (after Lindsay & Korsch, 1989).

PROTEROZOIC CARBONATES AND REDBEDS OF THE LOVES CREEK MEMBER, BITTER SPRINGS FORMATION

Peter N Southgate
Onshore Sedimentary and Petroleum Geology, Bureau of Mineral Resources

Sediments of the Loves Creek Member of the Bitter Springs Formation comprise the transgressive and highstand systems tracts of a stratigraphic sequence. In the vicinity of Bluebush Dam a disconformity surface with several metres of local relief separates black recrystallized dolostones of the Gillen Member from sediments of the Loves Creek Member. Along the MacDonnell Ranges a faulted contact separates the two members. The upper boundary with rocks of the Areyonga Formation has been interpreted as both disconformable and unconformable.

Rocks of the transgressive systems tract comprise a 50 m thick interval of lithoclastic and intraclastic conglomerate and cross-bedded sandstone, passing upwards into stromatolite biostromes and bioherms and thinly bedded, glauconitic, dolo-mudstone. The calcareous conglomerates and sandstones accumulated in shallow water conditions during the initial stages of transgression. Stromatolite morphology in the bioherms and biostromes indicate accretion in progressively deeper water. The deepest water conditions are interpreted to occur in the thinly-bedded dolostone which overlies the stromatolites.

Rocks of the overlying highstand systems tract comprise a 500 m thick interval of limestone, dolostone and red dolomitic siltstone divisable into two parasequence sets. A lower, 200 m thick interval of siliceous, stromatolite-rich dolostone and limestone occurs in a series of shallowing-upward cycles (parasequences) interpreted to be deposited in the lower parts of a highstand systems tract. Within the stromatolite-dominant unit accommodation is greatest in the lower parts of the parasequence set. Here are found cycles up to 12 m thick, composed of well developed subtidal bases, but thin and often poorly developed intertidal caps. These cycles contrast with those in the upper parts of the parasequence set where less accommodation produces thinner cycles (2-3 m thick) with comparatively thin subtidal bases, but thicker, more evaporitic, intertidal caps. The progressive thinning of parasequences, and the trend toward more evaporitive conditions as the parasequence set is ascended, provides evidence for a gradual fall in relative sea level. This resulted in the deposition of a 300 m thick interval of interbedded red dolomitic siltstone, limestone and siliceous dolostone interpreted as forming a parasequence set in the upper part of the highstand systems tract. Desiccation cracks in the red dolomitic siltstones provide evidence of subaerial exposure. Thin graded beds and laminae, with eroded bases and desiccated muddy caps, are interpreted as accumulating on broad, low relief flats in response to sediment-laden sheet floods. The interbedded carbonates crop out as strike ridges that vary between 2-30 m in thickness. Carbonate ridges greater than 5 m thick are characterised by a gradual transition from stromatolitic and two-toned limestone, to thinly bedded dolostone. Stromatolite morphology and sedimentary structures in the limestone indicates deposition in submergent environments. Desiccation cracks and halite pseudomorphs in the dolostone indicates emergent conditions during deposition of the uppermost parts of the carbonate bodies. A karst surface usually occurs on top of the dolostone unit. The lenticular geometry of the carbonate bodies, their internal facies patterns and evaporite mineral assemblage suggest deposition in lacustrine environments.

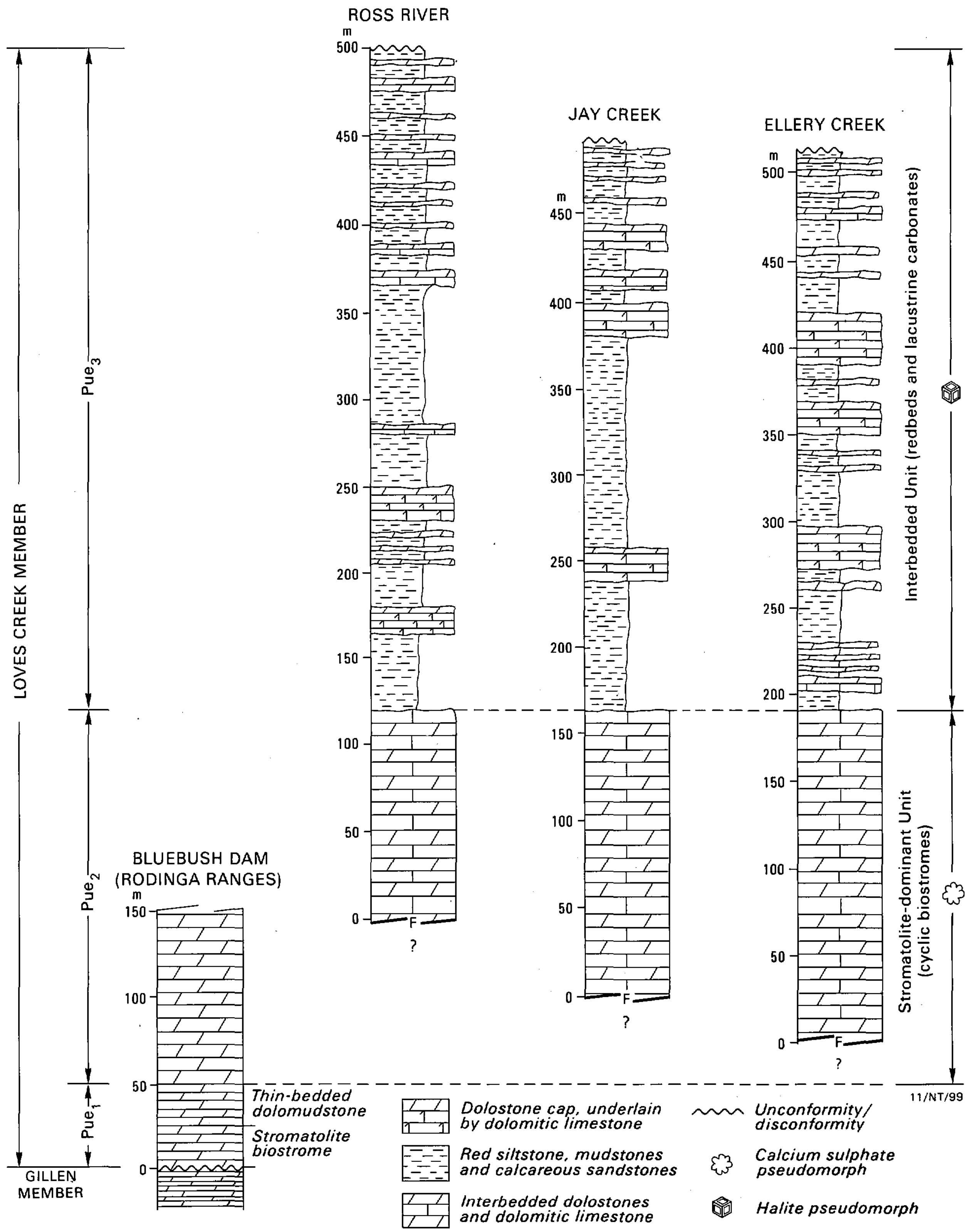


Figure 1. Stratigraphic columns for the Loves Creek Member of the Bitter Springs Formation at Ellery Creek, Jay Creek, Ross River and Rodinga area.
TST - Transgressive Systems Tract, HST - Highstand Systems Tract.

STRATIGRAPHY OF THE LATE PROTEROZOIC OLYMPIC, GAYLAD AND PIONEER FORMATIONS OF THE AMADEUS BASIN

Brad Field
DSIR Geology and Geophysics, Lower Hutt, New Zealand

This paper outlines the stratigraphic relationships of three Late Proterozoic units of the Amadeus Basin; the Olympic Formation, the Pioneer Sandstone, and a new unit, the Gaylad Sandstone. It also discusses whether the Olympic Formation can still be regarded as recording a glacial event in the Amadeus Basin (as previously proposed; e.g. Wells & others, 1967, 1970) correlated with the Marinoan glaciation (Preiss & others, 1978; Coates & Preiss, 1980; Preiss & Forbes, 1981), and also deals briefly with a sequence model of these units.

Stratigraphy

Summaries of the facies relationships and sequences for the **Olympic Formation** in the areas studied - the N'Dhala Thrust Sheet, Olympic Thrust Sheet and, in the autochthon, Dead Horse Waterhole and Mt Capitor - are shown in Figure 1. Most of the Olympic Formation consists of red and green mudstone and siltstone, with intercalated sandstone. The two most significant marker units are the conglomerate lithofacies and the dolomite lithofacies.

The conglomerate lithofacies consists generally of matrix-rich, clast-supported, rounded pebbles to cobbles of carbonate and, less commonly, quartz, quartzite, granite and gneiss. At some localities the clasts are angular, and some are faceted. Features such as channel structures, imbrication, reverse grading and matrix-supported fabrics indicate deposition from both traction currents and debris flows. In the Olympic Thrust Sheet the conglomerate also forms discrete channel-fill units surrounded by mudstone with lonestone clasts. A nearshore, mainly subaqueous environment of deposition is inferred for most of the conglomerate, and the lonestones are interpreted as dropstones transported by ice. The presence of the lonestones is the strongest evidence for a glacial event at this time.

The dolomite lithofacies generally occurs interbedded with or above the conglomerates, and is locally associated with platey rip-up clasts, oolites, weakly domal stromatolites and black cherts. An intertidal environment is inferred.

There are three main units of sandstone in the Olympic Formation, and all are of paralic, probably in part foreshore, facies. In the N'Dhala Thrust Sheet the sandstone is locally dolomite-cemented and, both here and near Dead Horse Waterhole, there are traces of glauconite.

The inferred variations in relative sea-level within the Olympic Formation suggest a pattern involving a fall at about the level of the conglomerate and a rise following the dolomite (Fig. 1).

The term **Gaylad Sandstone** has not yet been formally defined in publication. The term is here used to refer to the quartz-dominated, ridge-forming sandstones and sandy grits that occur between the mudstone, sandstone and conglomerate of the Olympic Formation, and the mudstone of the Pertatataka Formation. This description may differ from the definition proposed by Freeman & others (in press).

The Gaylad Sandstone consists of two units of ridge-forming sandstone and sandy grit (Fig. 2). Both units are highly quartzose, though the lower unit contains 5-40% feldspar, and is generally coarser grained. The base of the upper unit is marked by a quartz- and carbonate-derived pebble conglomerate up to several decimetres thick. There appears to be, at least locally, an angular discordance between the Olympic Formation and the Gaylad Sandstone which is interpreted as an angular unconformity caused by tectonism. Freeman & others (in press) interpret the apparent angular discordance as a depositional feature related to delta foresets.

The inferred changes in relative sea-level in the Gaylad Sandstone are based on very subjective modelling, but there could be as many as three falls, including the one at the base of the formation.

The **Pioneer Sandstone** was examined only at Jay Creek and Ellery Creek. It consists of two units; a thick, lower unit of medium to coarse sandstone of shoreface facies, and an upper ridge-forming unit of intertidal-tidal channel sandstone capped by stromatolitic dolomite and possibly also pebbly sandstone.

Correlations

The Pioneer Sandstone was correlated with the Olympic Formation by Preiss & others (1978), partly by correlation of the cap dolomite at Ellery Creek with the dolomite in the Olympic Thrust Sheet. This correlation would suggest that the lower part of the Pioneer Sandstone could be a time, as well as palaeoenvironmental, correlative of the paralic sands at Mt Capitor, and also implies that the Pioneer and Gaylad Sandstones are not correlatives.

Stratigraphic Sequences

Combining the inferred relative changes in sea level for the Olympic Formation and Gaylad Sandstone suggests that there are four significant sequences (1-4, Figs 1 & 2) that may prove to be useful additional lines of evidence in deciphering basin history. It is possible that none of the apparent sea-level falls is eustatic, except perhaps the one associated with the inferred glacial event. Shaw (in press) refers to deformation at the time of deposition of the Olympic and Gaylad units as the Souths Range Movement, which was responsible for the formation of the Central Ridge in the basin, and which was a precursor to the Petermann Ranges Orogeny.

References

Coates, R.P., & Preiss, W.V., 1980 - Stratigraphic and geochronological reinterpretation of Late Proterozoic glaciogenic sequences in the Kimberley Region, Western Australia. Precambrian Research, 13, 181-208.

Freeman, M., Oaks, R.Q., Deckelman, J.A., & Shaw, R.D., in press - Stratigraphy of the Gaylad Sandstone and the recognition of a new, widespread Late Proterozoic unconformity in the northern Amadeus Basin. Bureau of Mineral Resources, Australia, Bulletin 236.

Preiss, W.V., & Forbes, B.G., 1981 - Stratigraphy, correlation and sedimentary history of Adelaidean (Late Proterozoic) basins in Australia. Precambrian Research, 15, 255-304.

Preiss, W.V., Walter, M.R., Coates, R.P. & Wells, A.T., 1978 - Lithological correlations of Adelaidean glaciogenic rocks in parts of the Amadeus, Ngalia and Georgina Basins. BMR Journal of Australian Geology & Geophysics, 3, 43-53.

Shaw, R.D., in press - The tectonic development of the Amadeus Basin, central Australia. Bureau of Mineral Resources, Australia, Bulletin 236.

Wells, A.T., Ranford, L.C., Stewart, A.J., Cook, P.J., & Shaw, R.D., 1967 - Geology of the north-eastern part of the Amadeus Basin, Northern Territory. Bureau of Mineral Resources, Australia, Report 113.

Wells, A.T., Foreman, D.J., Ranford, L.C., & Cook, P.J., 1970 - Geology of the Amadeus Basin, central Australia. Bureau of Mineral Resources, Australia, Bulletin 100.

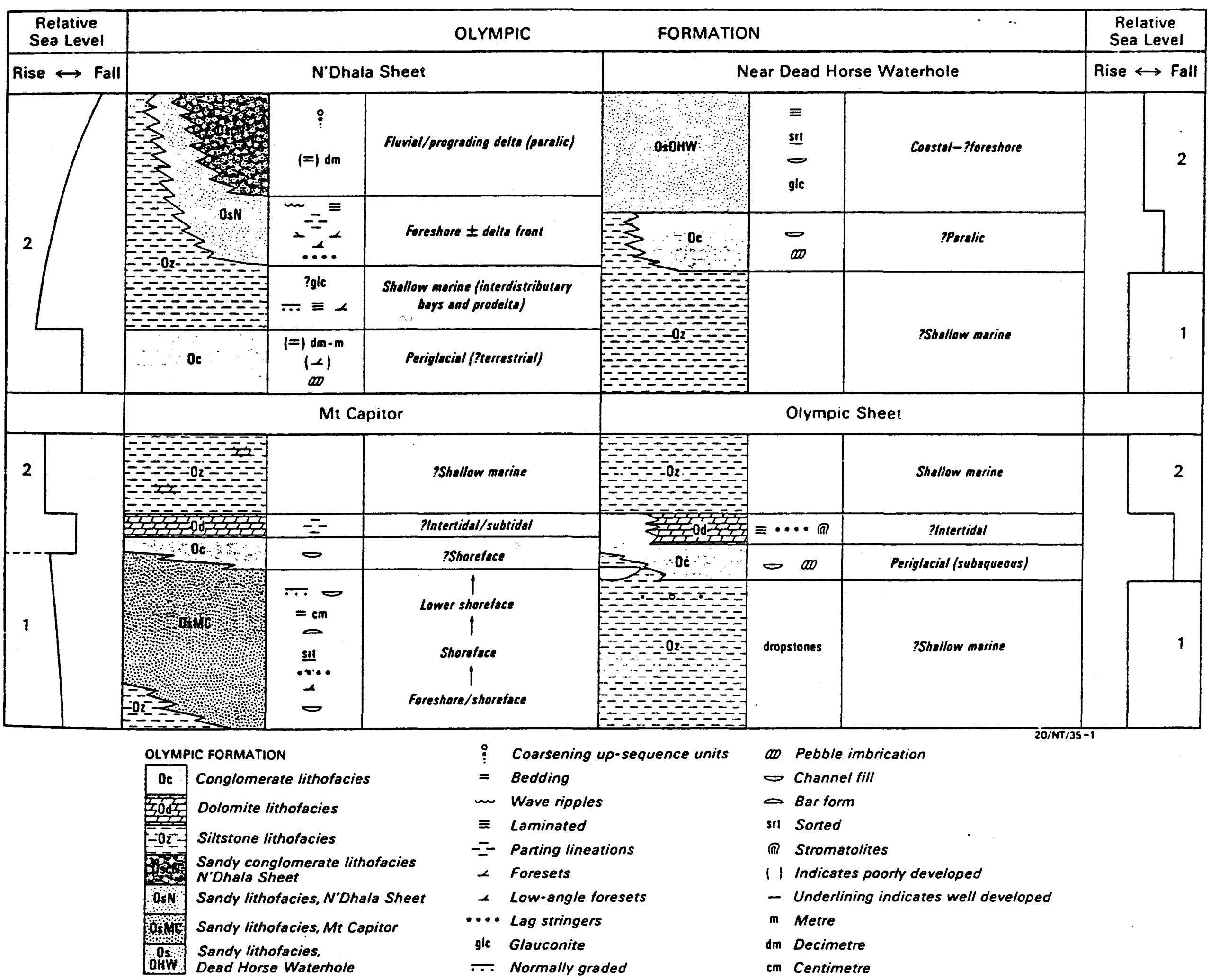


Figure 1. Lithofacies of the Olympic Formation. Deduced variations in relative sea level suggest there are two sequences (1 & 2).

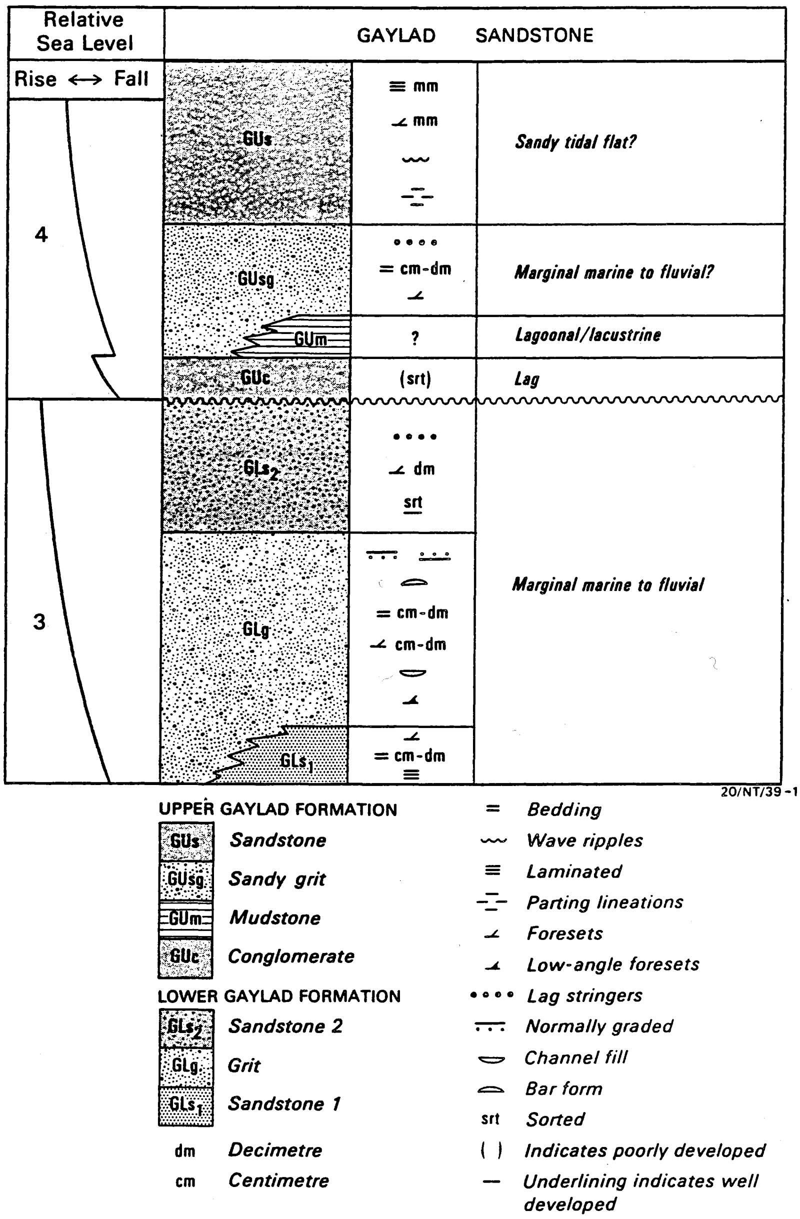


Figure 2. Lithofacies of the Gaylad Sandstone. Deduced variations in relative sea level suggest there are two sequences (labelled 3 & 4).

SEQUENCE STRATIGRAPHY OF THE LATEST PROTEROZOIC - CAMBRIAN PERTAOORRTA GROUP, NORTHERN AMADEUS BASIN

John M Kennard & John F Lindsay
Onshore Sedimentary and Petroleum Geology, Bureau of Mineral Resources

Sequence stratigraphic concepts are used to identify and analyse five major depositional sequences in the latest Proterozoic - Cambrian Pertaoorrta Group (Fig. 1). This analysis is based largely on the recognition of facies discontinuities and biostratigraphic hiatuses in field outcrops (Fig. 2) and well-logs (Fig. 3), and is integrated with seismic data. This alternative approach to sequence analysis is necessitated by the essentially layer-cake pattern of seismic reflections and scarcity of seismically-defined terminations within intracratonic strata.

Deposition of the Pertaoorrta Group was initiated by a phase of crustal extension and thermo-tectonic subsidence commencing at about 600-580 Ma. Subsidence was greatest in a series of sub-basins and a connecting trough near the present erosion-defined northern margin of the basin. A low east-west ridge (Central Ridge) separated these sub-basins from a large platform area to the south where Cambrian sediments are much thinner. Throughout much of the Cambrian, siliciclastic sediments were shed from tectonic highlands at the southern margin of the basin, and carbonate sediments were largely confined to the eastern part of the basin. Although sediment dispersal and accumulation were primarily controlled by basin dynamics, eustatic overprints are clearly recognised by changes in the pattern of successive depositional systems.

Sequence 1 (latest Proterozoic) is a coarsening basinal-deltaic-fluvial siliciclastic succession (lower Arumbera Sandstone) that extends throughout the sub-basins and connecting trough in the north. This sequence onlaps successively older units on the flanks of the Central Ridge and records a relative sea-level highstand. Basal transgressive sands at the margin of the eastern Ooraminna Sub-basin form the reservoir at the Dingo Gas Field (Fig. 3).
Sequence 2 (Early Cambrian) is restricted to the northern sub-basins. It consists of a lowstand basinal-deltaic succession (upper Arumbera Sandstone), overlain in the Ooraminna Sub-basin by tidal flat carbonates, transgressive oolitic barrier bars, and highstand archaeocyathan buildups (Todd River Dolomite) (Fig. 2).
Sequence 3 (?Early-Mid Cambrian) records a major eustatic cycle and maximum areal expansion of Cambrian marine sediments in the basin. During the lowstand, thick halite deposits, red shales and carbonates (Chandler Formation; Fig. 3) formed in a deep desiccated sub-basin; subsidence of this evaporite basin may have been controlled by salt flowage in the deeply-buried Bitter Springs Formation. Lowstand evaporites are onlapped by transgressive glauconitic sands (Dingo Member of the Giles Creek Dolomite, basal Tempe Formation), and a thin unit of skeletal wackestone and packstone with numerous phosphatic hardgrounds accumulated on the northern margin of the Ooraminna Sub-basin at this time (basal member of the Giles Creek Dolomite). Highstand deposits record the establishment of a carbonate ramp in the east (middle-upper Giles Creek Dolomite), and the widespread deposition of locally organic-rich marine muds (Tempe Formation, lower Hugh River Shale) in the west.

Sequence 4 (Mid-Late Cambrian) comprises a complex west-to-east facies mosaic. During the lowstand, fluvial sands prograded eastward into the western Idirriki and central Carmichael Sub-basins (Cleland Sandstone, Illara Sandstone), and cyclical shallow-marine shales and intertidal stromatolitic carbonates (lower Shannon Formation) accumulated on the ramp in the east. As sea-level rose, cyclical shales and subtidal thrombolitic carbonates (upper Shannon Formation, Jay Creek Limestone) spread westward across the ramp, and marine muds extended into the Carmichael Sub-basin. During the highstand, gravelly fluvial sands (Cleland Sandstone) accumulated within the Idirriki Sub-basin, and a thick fluvial-deltaic unit (Petermann Sandstone, Deception Formation) prograded eastward into the Carmichael Sub-basin. As the supply of siliciclastic sediments waned, deltaic and fluvial facies were onlapped by late highstand peritidal sands and oolitic carbonates (lower Goyder Formation).
Sequence 5 (Late Cambrian) consists of highstand, nearshore to outer shelf calcareous sands (upper Goyder Formation). Its widespread distribution indicates relatively uniform subsidence across the basin at this time, and heralds the onset of a period of protracted slow thermal subsidence that continued throughout Ordovician and Silurian time.

Analysis of these tectono-eustatic depositional sequences enables refined correlation between eastern carbonate-rich and western non-fossiliferous siliciclastic units of the Pertaoorrta Group, and helps predict the distribution of potential reservoir and source rocks.

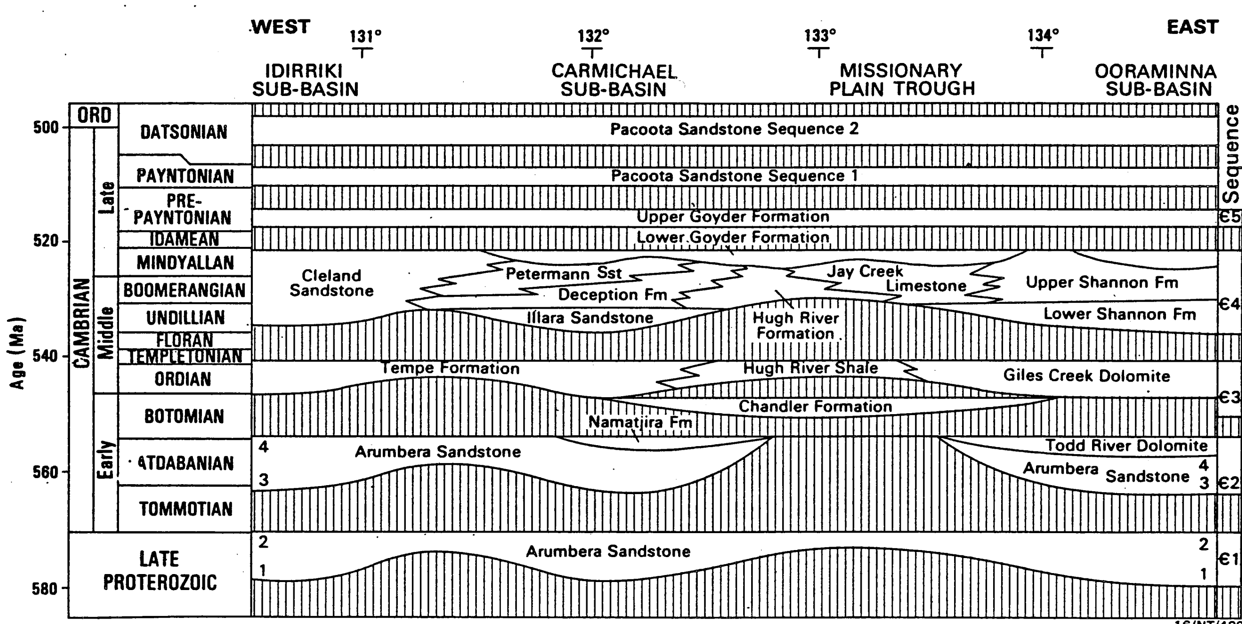


Figure 1. Interptreted time-space relationship of lithostratigraphic units and depositional sequences of the Pertaoorrta Group.

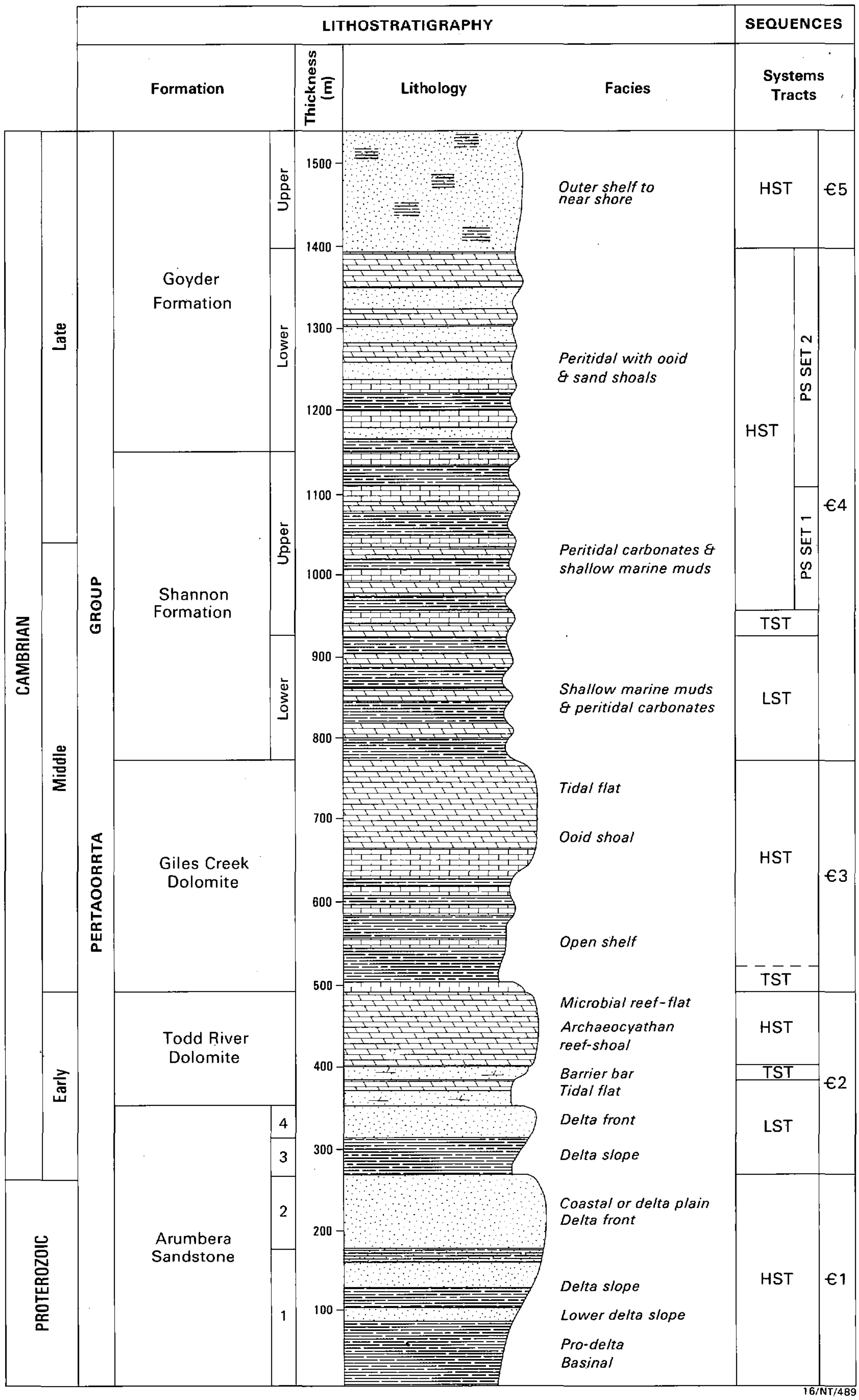


Figure 2. Lithostratigraphy and sequence stratigraphy of the Pertaoorrta Group at Ross River Gorge, NE Amadeus Basin, showing facies and systems tracts. LST - lowstand systems tract; TST - transgressive systems tract; HST - highstand systems tract.

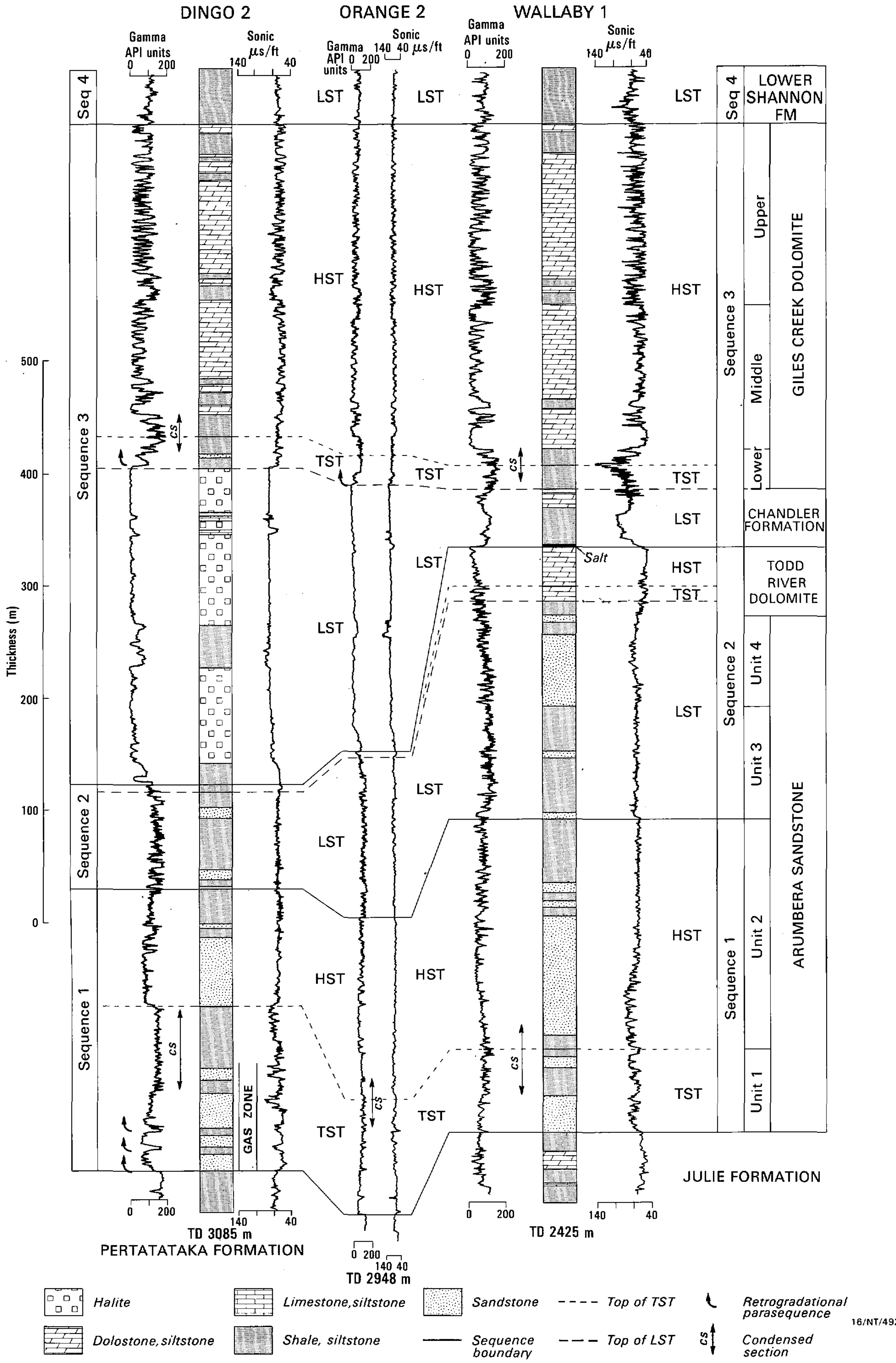


Figure 3. Well log correlation of sequences 1-3 in the eastern Amadeus Basin (western margin of the Ooraminna Sub-basin). Upward-coarsening and thinning, transgressive parasequences at the base of sequence 1 form the reservoir at the Dingo Gas Field.

DEPOSITIONAL MODEL OF EVAPORITES AND CARBONATES OF THE LOWER CAMBRIAN CHANDLER FORMATION

John Bradshaw
Onshore Sedimentary and Petroleum Geology, Bureau of Mineral Resources

The Chandler Formation is a Lower Cambrian carbonate and evaporite sequence that occurs in the eastern and central parts of the basin (Fig. 1). The carbonate is widely distributed but thin (10 m), and is an organic-rich, foetid, carbonate mudstone with abundant chert. The carbonate is dolomitised where not associated with evaporites, and only very slightly dolomitised where it is associated with evaporites. The thick (225-470 m) evaporite is almost totally composed of halite (>95%), and has bromine profiles suggesting a marine source. The chert replaced the carbonate during early stages of diagenesis, and is a direct chemical result of the mixing of solutions from the evaporitic unit, and the organic-rich carbonate. The Chandler carbonate was deposited in a subtidal restricted environment, whilst the evaporite was deposited in a shallow water, deep basin setting. The deep desiccated basin setting proposed for the Chandler Formation is analogous to the Messinian evaporites of the Mediterranean region. The carbonate and evaporite deposits represent distinct depositional phases in the evolution of the Chandler Formation (Fig.2): 1) Desiccation and evaporite precipitation; 2) Basin flooding and carbonate deposition; and 3) Karstification and evaporite precipitation.

The Chandler carbonate has been subjected to intense diagenesis and deformation as a result of flowage of the thick halite units in which it is enveloped. Minor late-stage salt dissolution has contributed to this deformation.

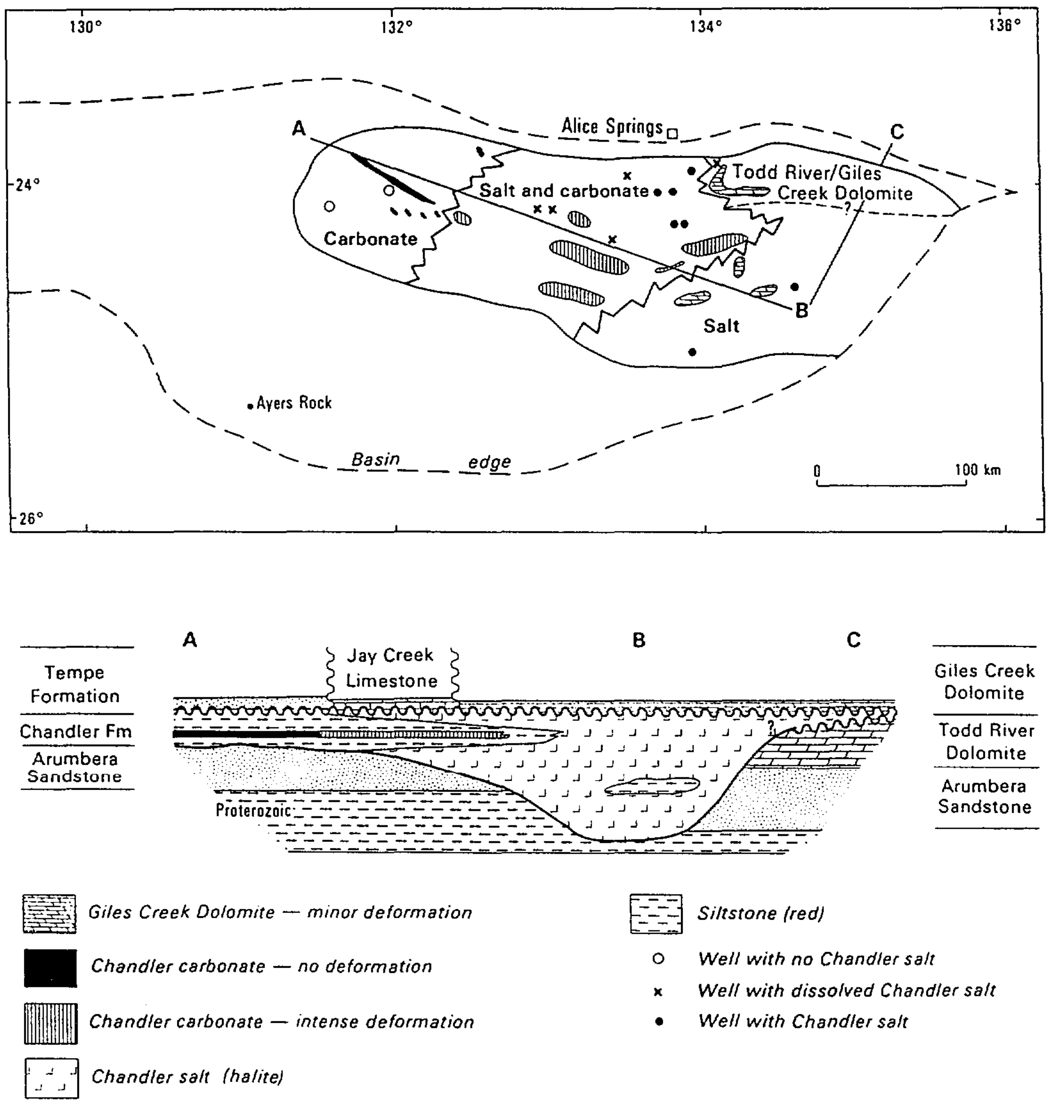


Figure 1. Distribution and diagrammatic cross-section of the Chandler Formation.

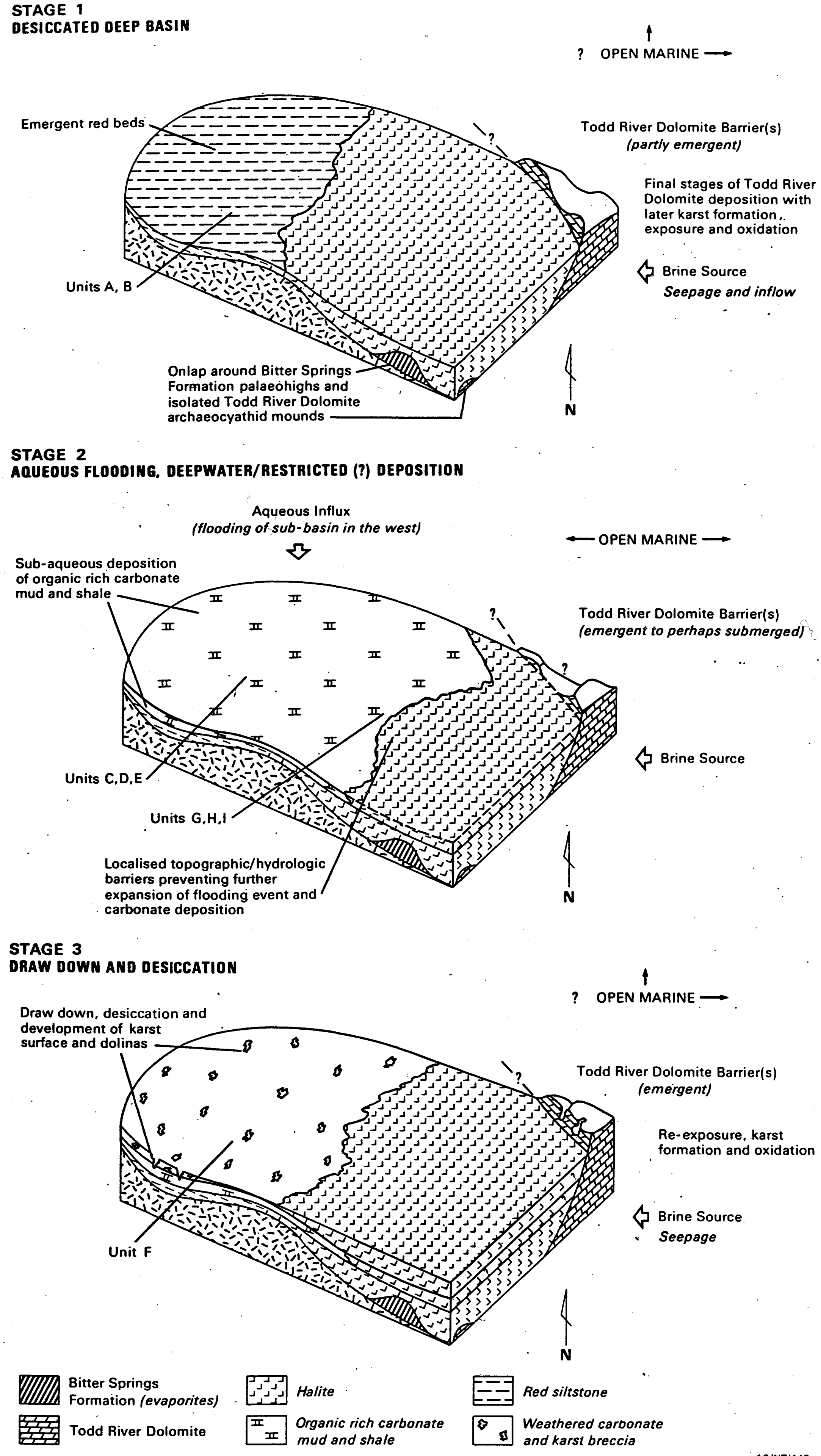


Figure 2. Diagrammatic reconstruction of the three depositional stages during the evolution of the Chandler Formation.

LATE CAMBRIAN - EARLY ORDOVICIAN BIOCHRONOLOGICAL FRAMEWORK FOR THE AMADEUS BASIN

John H Shergold, Robert S Nicoll & John R Laurie
Onshore Sedimentary and Petroleum Geology, Bureau of Mineral Resources

A Late Cambrian - Early Ordovician biochronological framework has been developed in the Amadeus Basin mainly through studies on trilobites, conodonts and ichnofosslis from the Pacoota Sandstone and Horn Valley Siltstone.

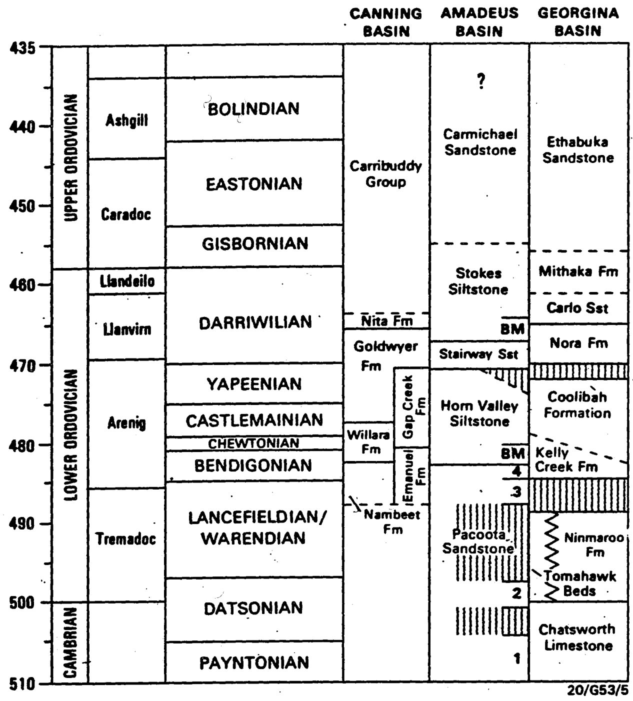
The Pacoota Sandstone is a thick deposit of siliciclastic rocks (up to 850 m) straddling the Cambrian-Ordovician boundary in the Amadeus Basin. It is economically the most important hydrocarbon reservoir of the basin, contains a potentially significant reserve of phosphorite, and may be an important aquifer; it accordingly warrants detailed study. The internal stratigraphy of the Pacoota Sandstone, not previously documented in detail on a basin-wide scale, is based here on a sequence of four informally defined sedimentary packages, separated by unconformities or disconformities. The age and stratigraphic distribution of these sedimentary sequences is measured against a preliminary and equally informal biostratigraphic scheme which involves body fossil and ichnofossil assemblages. Although a Late Cambrian - Early Ordovician age has long been known, it is now possible to date the depositional sequences, at least to stage level of resolution.

Sequence 1, characterised by channel-fill sediments in many places, has a Payntonian (latest Cambrian) to early Datsonian (earliest Ordovician) age. It overlies earlier Upper Cambrian formations (Mindyallan) with regional unconformity, and is overlain unconformably by Sequence 2. The latter is a tidally and storm-dominated sequence containing concentrations of the *Skolithos* ichnocoenosis but lacking age diagnostic body fossils. It is separated by a further major unconformity from Sequence 3, comprising predominantly phosphatic and glauconitic clastic sediments of latest Warendian (late Tremadoc) age which thus indirectly also dates Sequence 2. Sequence 4, which may be, at least in part, disconformable on Sequence 3, again contains storm and tidally-dominated sandstones rich in ichnofossils but impoverished in body fossils. The limited fauna that does occur dates this sequence at the Tremadoc-Arenig transition. The Pacoota Sandstone is in places unconformably overlain by the Horn Valley Siltstone of early Arenig age.

The Horn Valley Siltstone is economically the most important source rock of the Amadeus Basin and has been studied in detail. Conodont faunas indicate an age range from early Arenig to the latest Arenig. There are two trilobite assemblages in the Horn Valley Siltstone, the lower one being found wherever the unit is present, whilst the upper one is restricted to the more westerly parts of the basin, apparently having been subjected to erosion prior to deposition of the Stairway Sandstone.

Younger Ordovician formations have not been studied in sufficient detail to establish a highly resolved biochronology; however the lower part of the Stokes Siltstone contains conodonts and trilobites of Llanvirn aspect.

A



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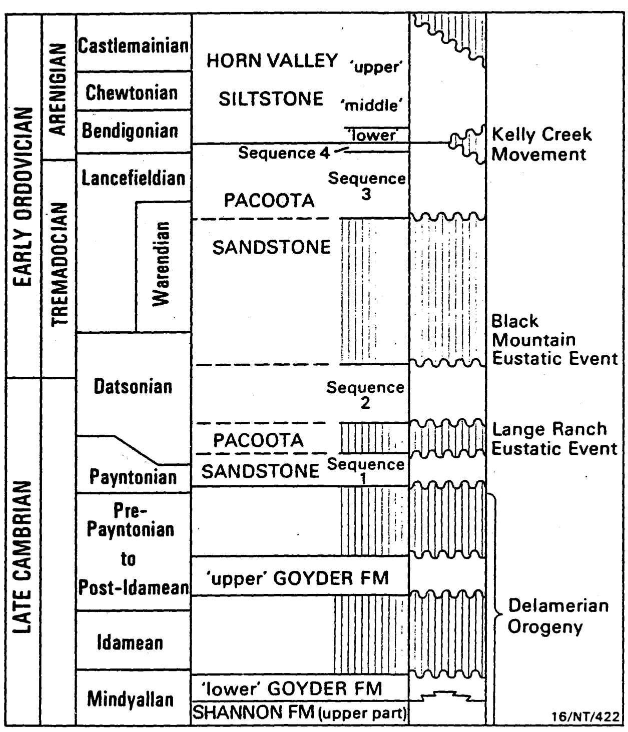


Figure 1. **A)** Late Cambrian - Ordovician stratigraphy of northern Australia.
B) Late Cambrian - Early Ordovician event stratigraphy applied to the Amadeus Basin.

SEQUENCE STRATIGRAPHY OF THE LATE CAMBRIAN AND ORDOVICIAN ROCKS OF THE AMADEUS BASIN

John D Gorter
Petroz NL, Perth

The depositional history of the Late Cambrian to Early Ordovician sedimentary succession in the Amadeus Basin is interpreted using sequence stratigraphic techniques, and rocks assigned to the Goyder Formation, Pacoota Sandstone, Horn Valley Siltstone and Stairway Sandstone (Fig.1), as well as the overlying Stokes Siltstone, Carmichael Sandstone and "Gosses Bluff" Sandstone, have been studied. As some of these sequences are known to host large deposits of oil and gas, a thorough understanding of the potential reservoir/source rock combinations in the Amadeus Basin is essential for the discovery of further oil and gas reservoirs in this vast and largely under-explored basin.

The study integrates information gathered by the oil exploration industry, government authorities and universities, and incorporates both outcrop and subsurface data. Well logs, seismic profiles, field sections, palaeontology and geochemistry all contribute to the interpretation.

Specific conclusions of note to hydrocarbon exploration include:
1. The best reservoir rocks are concentrated above the major sequence boundaries at the base of parasequence set 1 (intra-Goyder) in the eastern area, and parasequence set 8 (Pacoota P3). Parasequence set 3 reservoirs (Pacoota P4), localised on the southern and western shelf edges, are generally poor but owe their reservoir character to weathering at the pre-Tempe Vale Sequence unconformity. Parasequence set 13 reservoirs (Pacoota P1) overstep the older reservoir sequences and are concentrated in the shallower shelf areas where small-scale, shoaling clastic cycles are better developed. Parasequence set 19 reservoirs (basal Stairway) are generally very poor due to cementation of the clean sandstones, but improve to the southwest and west due to a decrease in burial-induced silicification. Sandstones developed in younger sequences are generally clean and silicified (mid and upper Stairway, Carmichael and "Gosses Bluff").
2. The source potential of the major Arenig organic-rich sediments are concentrated in the transitional zone between the lowstand sediments and the condensed section of parasequence set 16 of the Horn Valley Sequence, and in the condensed section of parasequence sets 17 and 18. Potential source beds within the Stairway Sandstone are most likely concentrated in thin condensed intervals, but may thicken to the west towards the Canning Basin.

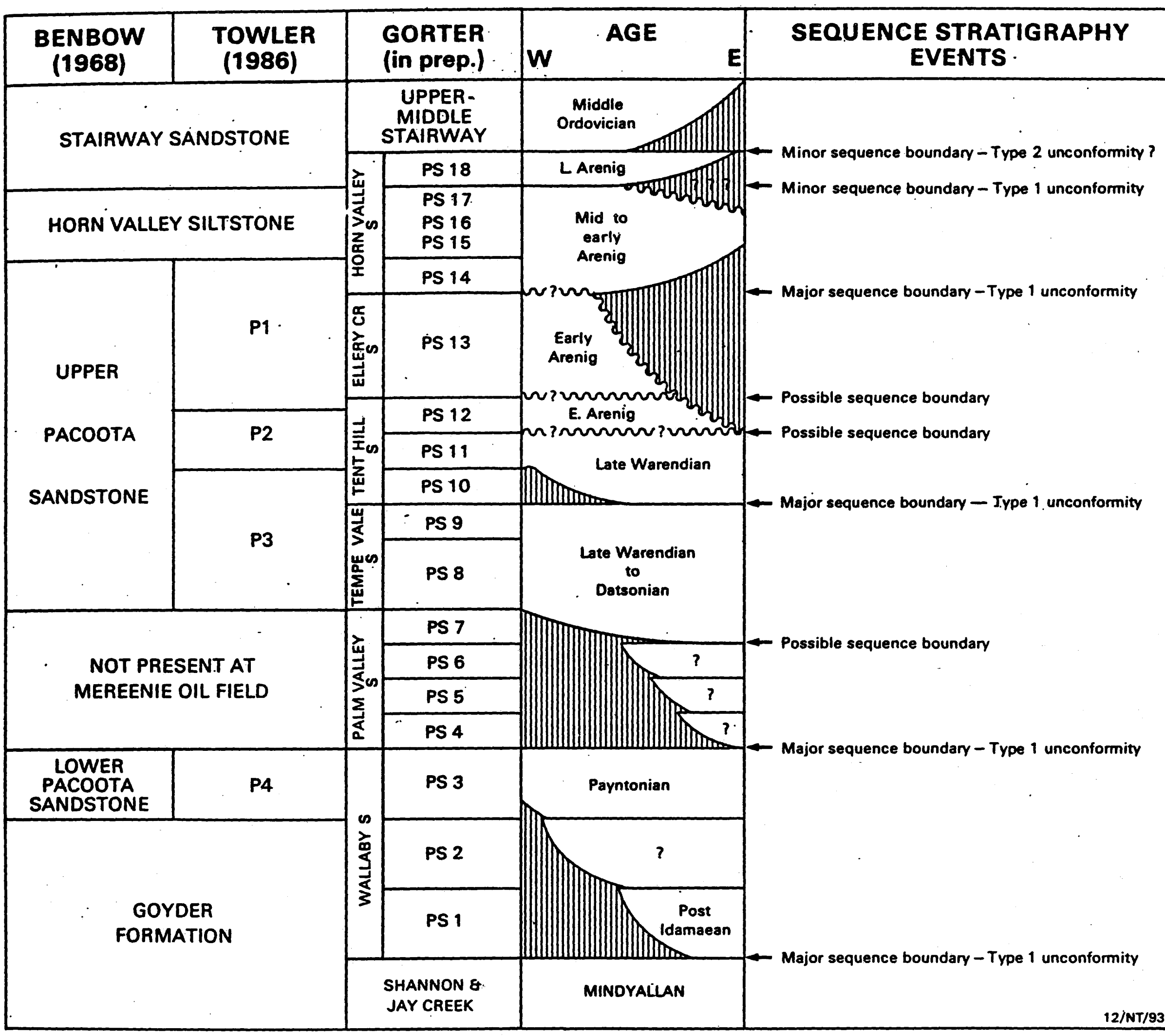


Figure 1. The Late Cambrian (Payntonian) to Early Ordovician (Arenig) sequences (S) and parasequence sets (PS) in the Amadeus Basin (after Gorter, in prep.), and previous published subdivisions of the Pacoota Sandstone.

BMR REGIONAL SEISMIC LINE AND STRUCTURE OF THE AMADEUS BASIN

Russell J Korsch[1], Russell D Shaw[2], Cedric Wright[1] & Bruce R Goleby[1]
[1] Onshore Sedimentary and Petroleum Geology, Bureau of Mineral Resources.
[2] Division of Minerals and Land Use, Bureau of Mineral Resources.

In the Late Proterozoic, the Amadeus Basin developed during an initial period of subsidence due to an extensional and/or thermal event which was followed by subsidence driven initially by thermal relaxation of the lithosphere (Stage 1). A second, less intense, episode of subsidence driven by extension (stage 2) occurred towards the end of the Late Proterozoic, and the basin was shortened during the Late Devonian - Early Carboniferous and subsidence was driven by foreland-like processes (Stage 3). Throughout the history of the Amadeus Basin, sedimentation and basin evolution are intimately related with deformational events (see Lindsay & Korsch, in press; Shaw, in press).

Accommodation Zones

Superimposed on the morphology of sub-basins, troughs, platform and ridge are a series of discordant structures, striking predominantly north-northwest, that divide the northern part of the basin into compartments, not unlike compartments formed by the interaction of extensional and transfer faults in extensional regimes, or thrusts and lateral ramps in compressional regimes.

Industry seismic data suggest that the compartments are separated by zones of discordance, here referred to as the Namatjira, Finke, Highway and Dingo zones (Fig. 1). They appear to be zones of accommodation. Sediment distribution patterns, particularly in the Early Palaeozoic, were controlled to some extent by these north-northwest trending zones. Significant structures such as the Palm Valley Anticline, Waterhouse Anticline and Gardiner Fault are confined to single compartments, with their lateral extent apparently controlled by the accommodation zones.

Basin Evolution

Stage 1. Immediately below the Heavitree Quartzite, in the southwest and northwest corners of the basin, extension-related basin sediments and volcanics may relate to the extensional or thermal event which initiated the basin. In the metamorphic Arunta Block, on the northern margin of the basin, dolerite dykes of the Stuart Dyke Swarm may also relate to this event. Following this initial stage, subsidence was episodic, complex and centred in the southern part of the basin.

Stage 2. Extension during Stage 2 is evident only in the northern part of the basin; at the same time or shortly after, a major compressional event, the Petermann Ranges Orogeny, was occurring along the southern margin. This orogeny caused detachment of the sediments above the salt horizon in the Bitter Springs Formation, northward transportation, and tight folding of the sediment pile in the south. The basin succession below the decollement plus the basement were involved in basement-cored nappes with a northward transportation direction.

Stage 3. Stage 3 was a series of compressional events, possibly beginning at about 450 Ma, in which major southward-directed thrust sheets in the Arunta Block to the north caused progressive downward flexing of the northern margin of the basin, and sediment was shed from the thrust sheets into the downwarps to form a foreland-like basin. Horizontal shortening was in the order of 50-100 km and effectively concluded sedimentation; because of this deformation the present basin margins are structural rather than depositional.

Within the basin, the structures that developed during this stage dominate the structural pattern of the basin, and can be divided into several structural styles including:
1) Thin-skinned nappes and thrust sheets in the northeastern part of the basin (see Stewart & others, in press); 2) Northward-related thrust-related structures above a major decollement in the central part of the basin (see below); and 3) A complex fold pattern reminiscent of interference patterns in the west.

The BMR deep seismic profiling experiments across the Arunta Block and Amadeus Basin were designed to test the various models that have been proposed for the tectonic evolution of the intracratonic basins and surrounding basement in central Australia. The regional seismic reflection line provides data on the geometry of some of the structures that developed in the central part of the basin during the Alice Springs Orogeny.

In the northern part of the basin, the seismic profile across the Missionary Plain shows a sub-horizontal to north-dipping, para-autochthonous sedimentary succession between about 8.5 km and 12.0 km thick. This succession shows upturning only at the northern and southern extremities, and represents an unusual, relatively undeformed region between converging thrust systems. In the intervening region, the crust appears to have been tilted downwards and northwards in response to the thick-skinned upthrusting to the north.

In the central and southern parts of the basin, the deep seismic results indicate north-directed, thin-skinned overthrusting on shallow detachments which sole in a salt horizon near the base of the sequence. On the Gardiner Thrust, the vertical uplift of the southern hanging wall is about 6 km. Seismic reflection profiling in the region immediately south of the Gardiner Thrust indicates repetition of the sedimentary sequence (Fig. 2). At the southern end of the profile, in the Kernot Range, an imbricate thrust system fans ahead of a ramp-flat thrust pair (Fig. 3).

Overall, the structure in the shallow sedimentary section in the central to southern parts of the Amadeus Basin indicates that north-directed thrusting during the Devonian-Carboniferous Alice Springs Orogeny was thin-skinned, in marked contrast to the thick-skinned south-directed thrusting in the Arunta Block that occurred during the same orogeny.

References

Lindsay, J.F. & Korsch, R.J., in press. The evolution of the Amadeus Basin, central Australia. Bureau of Mineral Resources, Australia, Bulletin 236.

Shaw, R.D., in press. The tectonic development of the Amadeus Basin. Bureau of Mineral Resources, Australia, Bulletin 236.

Stewart, A.J., Oaks, R.Q., Jr., Deckelman, J.A., & Shaw, R.D., in press. 'Mesothrust' versus 'megathrust' interpretations of the structure of the northeastern Amadeus Basin, central Australia. Bureau of Mineral Resources, Australia, Bulletin 236.

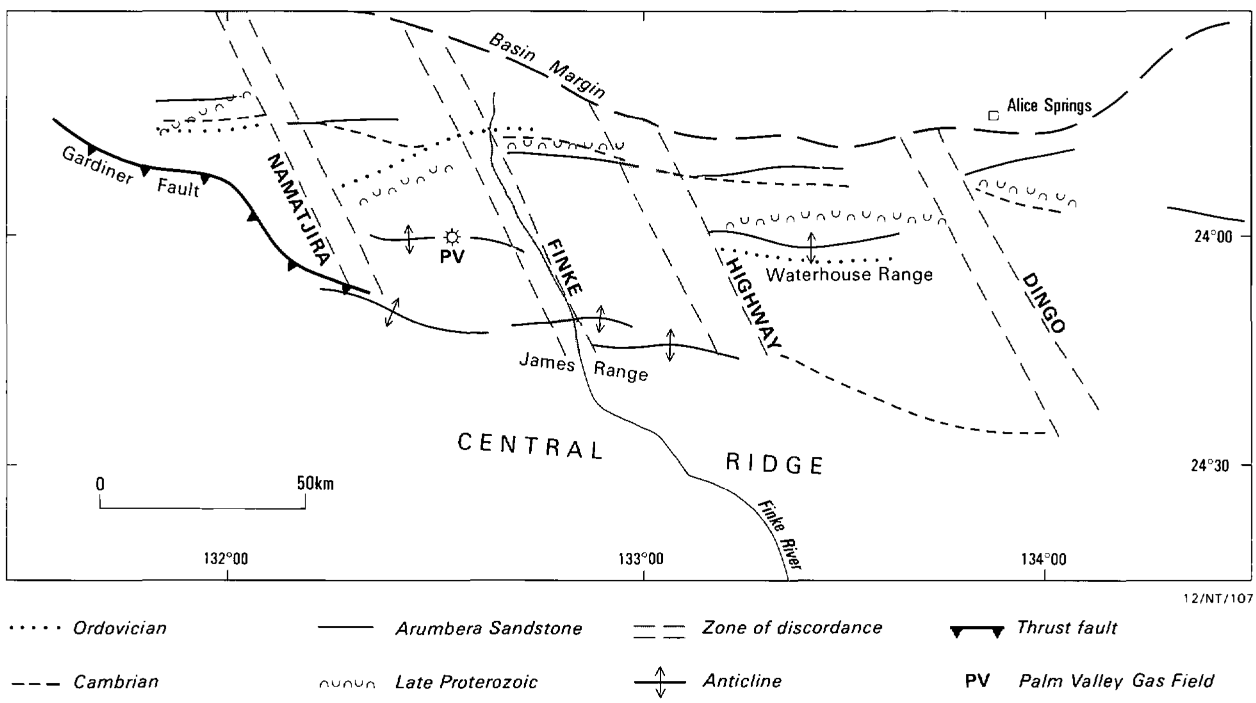


Figure 1. Positions of inferred zones of accommodation in the north-central part of the Amadeus Basin. Locations of the axes of maximum deposition for the Late Proterozoic, Arumbera Sandstone, Cambrian (including Arumbera Sandstone) and Ordovician packets of sediment used to define the zones of accommodation are also shown.

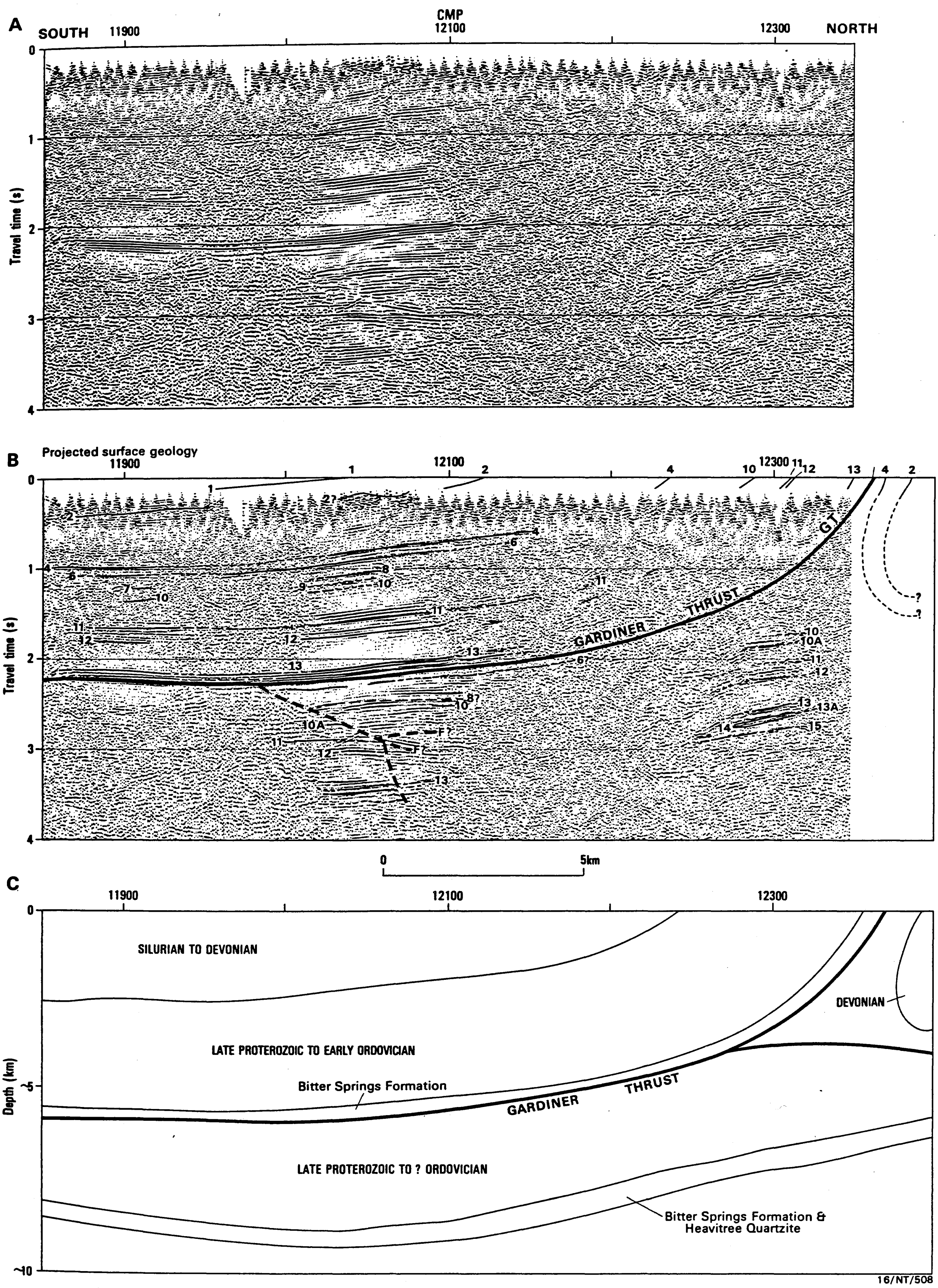


Figure 2. Section of the northern part of the BMR deep seismic reflection line from north of the Gardiner Thrust to the flat of the thrust. **A)** Unmigrated section. **B)** Interpreted section. Lines above seismic section are based on the downward projection of the surface geology. **C)** Simplified geological interpretation.

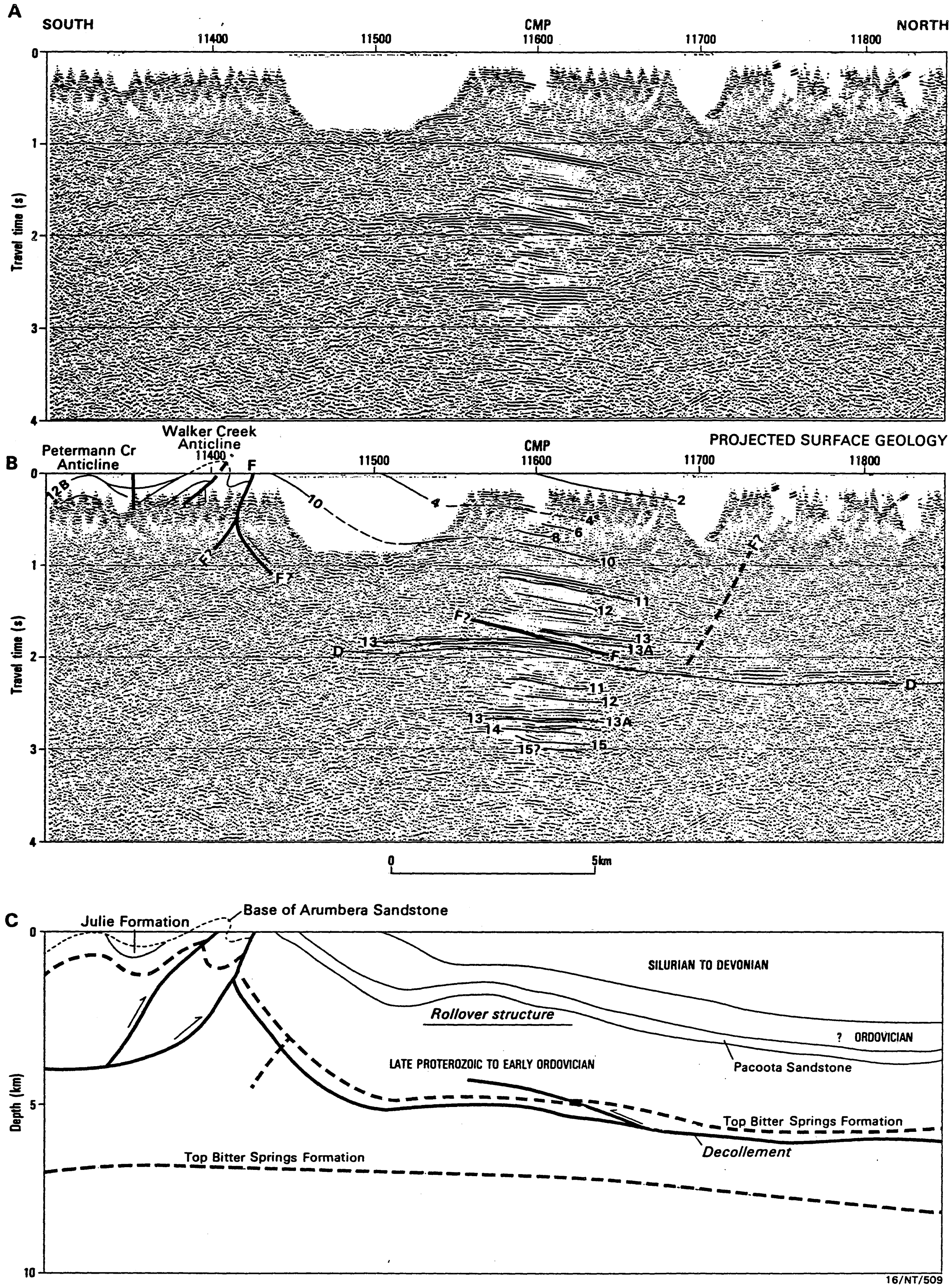


Figure 3. Section of the deep seismic reflection line from north of Tempe Downs towards the north, to the flat of the thrust running south from the Gardiner Range. **A)** Unmigrated section, **B)** Interpreted section. Lines above seismic section are based on the downward projection of the surface geology. Note that the decollement (flat) is linked to the Gardiner Thrust Zone shown in Fig. 2. **C)** Simplified interpretation.

STRUCTURAL, THERMAL AND TEMPORAL CONSTRAINTS ON PLAUSIBLE BASIN-FORMING MECHANISMS FOR THE AMADEUS BASIN

Russell D Shaw
Division of Minerals and Land Use, Bureau of Mineral Resources

The Amadeus Basin is a complex, long-lived composite basin, built up of a series of sag-like 'successor' basins localized over an apparent region of crustal weakness created during the development of the Proterozoic mobile belts. Details of basin and crustal structure can be determined from studies of cross-sections such as that provided by the BMR regional deep reflection seismic line (Goleby & others, 1989; Korsch & others, 1990; Shaw & others, in press a). The basin shape at any time can also be reconstructed from isopachs derived from particular depositional intervals, or, ideally, from seismic stratigraphy (Kennard & Lindsay, in press). The Amadeus Basin shows repeated episodes of erosion followed by renewed subsidence and a change in basin shape (Shaw & others, in press b).

Geothermal gradients can be estimated from present heat flow data, conodont and vitrinite maturation data, apatite fission track and $^{40}Ar/^{39}Ar$ isotopic studies, as well as PTt reconstructions of metamorphic events. Present indications are that the thermal gradient did not depart significantly from 25 ± 5 °C/km for most of the history of the basin (Jackson & others 1984; Gorter, 1984; Tingate, in press).

Difficulties in determining absolute timing restrict the usefulness of detailed analysis of subsidence curves as a guide to basin-forming mechanisms. Some idea of tectonic influences can be gleaned by identifying events that are synchronous on the scale of the Australian continent or within geological provinces (Lindsay & others, 1987; Shaw & others, in press a). The synchroneity of events can be assessed using biostratigraphy, lithological correlation and seismic stratigraphy.

Except for the initial period of subsidence, thermal events, on their own, do not appear to have been a major basin-forming mechanism in the Amadeus Basin. The correlations found between events in the Amadeus Basin, those in the neighbouring interconnected basins, and tectonic events at the continental or plate margins, point to regional horizontal stress fields being a major contributor to primary basin-forming mechanisms (Shaw & others, in press b). It has been demonstrated that compressional stresses are a potential explanation of such coeval subsidence (Lambeck 1983), and the same outcome is likely for extensional stresses as well as the situation where there is a drop in regional stresses levels. Basin width may be related to the effective elastic thickness of the lithosphere. Details of basin asymmetry and internal basin features such as arches and hinges may be related to specific basin-forming mechanisms. Changes in basin shape signal either a change in tectonic mechanism or in the magnitude of the tectonic driving forces. Marginal, hinterland basement uplift is more markedly linked to subsidence in the adjoining Amadeus Basin during compressional tectonism than during extensional tectonism. Determination of the basement uplift history at the margin of the Amadeus Basin also allows constraints to be placed on basin-forming mechanisms.

Basin development in the final stages during the Devonian to Carboniferous is well documented and appears to have been controlled by the episodic build-up of compressive stresses. A flexural downwarp developed into a deepening asymmetrical trough as a consequence of the initiation of southwards thrusting on the Redbank Thrust Zone. Thrust activity then transferred southwards onto a thrust wedge dominated by the Ormiston Thrust Zone. A deepening trough was filled in a series of spatially evolving pulses of conglomeratic alluvial-fan deposition. Progressive narrowing of the trough as well as symmetrical upturning of the trough margins appears to be caused by the convergence of the Ormiston and Gardiner Thrust Systems. Eventually, the Gardiner Thrust System overrode the trough. This contractile basin is narrower than that predicted by classical foreland basin models based on gravitational loading and a modified model incorporating more direct application of horizontal compression has been proposed (Shaw & others, in press b; Shaw, in press).

There is little direct evidence in the basin for extension during the Cambrian. The localized sub-basins of rapid subsidence with internal compartmentalization (Ooraminna and Carmichael Sub-basins; see Lindsay, 1987), although suggestive of extension, might have other causes such as complex regional shear or synclinal depressions formed by shortening above a detachment zone. There is a lack of documented evidence for normal faulting in the basin, with the possible exception of negative inversion of the Gardiner Thrust (J. Bradshaw, pers. comm.). Although the basin has been variously interpreted as an aulacogen or strongly oblique rift associated with that margin (Rutland, 1976; Veevers & others, 1984), there is a lack of evidence for the required faulting in the areas of thickest sediment.

The widespread inundation and exponentially decaying subsidence in the early Middle Cambrian (Ordian and/or Templetonian) are strongly suggestive of subsidence driven by thermal decay (Lindsay & Korsch, 1989; Shaw & others, in press b). Basalts (e.g. Helen Springs Basalt) in the neighbouring Georgina Basin succession are consistent with local extension having started there as late as early Middle Cambrian (Ordian-Early Templetonian; Southgate & Shergold, in press) as conglomerates underlying this basalt correlate with the earliest Ordian sediments (Blake 1984). Localized normal faulting has been identified in the Georgina Basin in the Late Templetonian-Undillan succession of the Burke River Structural Belt and Undilla area (Southgate & Shergold, in press). This raises the question of whether the extension was spatially restricted to these localities or whether these features represent local manifestations of two extensional episodes which also extended to the Amadeus Basin. The paucity of normal faulting in the Amadeus Basin might be explained if such extension was partitioned into the lower crust and upper mantle and separated in the Amadeus Basin region from unextended upper crust by shallow-dipping detachment zones, as suggested by Shaw & others (in press b).

The mixture of mechanical controls on the other stages of Amadeus Basin subsidence are less clear, possibly because these were periods when regional stresses were neither strongly compressional nor extensional. It is interesting to note that a major increase in subsidence in the earliest Ordovician (Warendian Pacoota sequence 3) correlates with the onset of subsidence in the Canning Basin, possibly as a result of extension (Shergold & others, in press; Shaw & others, in press b; cf. Drummond & others, 1991).

The nature of tectonism initiating the Amadeus Basin is still enigmatic, partly because of insufficient data and also because later decollement and salt movements have obscured the geological record. It is by no means clear that initial subsidence is related to bimodal volcanism centred in the Petermann Ranges to the southwest of the basin (Shaw, in press). The complex early stage of subsidence, centred in the southwest of the basin, spanned from the time of basin initiation to the latest Proterozoic, and, as such represents too long a period ($\geq$ 350 Ma) for all this subsidence to be related to one rifting event.

References

Blake, D.H., 1984 - Stratigraphic correlation in the Tennant Creek region, central Australia: Warramunga Group, Thompson Creek beds, Hatches Creek Group, and Rising Sun Conglomerate. BMR Journal of Australian Geology and Geophysics, 9, 41-47.

Drummond, B.J., Sexton, M.J., Barton, T.J., & Shaw, R.D., 1991 - The nature of faulting along the Fitzroy Trough, Canning Basin, and implications for the tectonic development of the trough. Australian Society of Exploration Geophysicist's & Geological Society of Australia Conference, Sydney, Feb. 1991, 'Exploration Geophysics', Abstract.

Goleby, B.R., Shaw, R.D., Wright, C., Kennett, B.L.N., & Lambeck, K., 1989 - Geophysical evidence for 'thick-skinned' crustal deformation in central Australia. Nature, 337, 325-330.

Gorter, J.D., 1984 - Source potential of the Horn Valley Siltstone, Amadeus Basin. APEA Journal, 24, 66-90.

Jackson K.S., McKirdy D.M. & Deckelman J.A., 1984 - Hydrocarbon generation in the Amadeus Basin, central Australia. APEA Journal, 24 (1), 42-65.

Kennard, J.M. & Lindsay, J.F., in press - Sequence stratigraphy of the latest Proterozoic - Cambrian Pertaoorrta Group, northern Amadeus Basin. Bureau of Mineral Resources, Australia, Bulletin, 236.

Korsch, R.J. & Lindsay, J.F., 1989 - Relationships between deformation and basin evolution in the intracratonic Amadeus Basin, central Australia. Tectonophysics, 158, 5-22.

Lambeck, K., 1983 - Structure and evolution of the intracratonic basins of central Australia. Geophysical Journal of the Royal Astronomical Society, 74, 843-866.

Lindsay, J.F., 1987 - Sequence stratigraphy and depositional controls in Late Proterozoic - Early Cambrian sediments of the Amadeus Basin, central Australia. American Association of Petroleum Geologists, Bulletin, 71, 1387-1403.

Lindsay, J.F., & Korsch, R.J., 1989 - Interplay of tectonics and sea-level changes in basin evolution: An example from the intracratonic Amadeus Basin, central Australia. Basin Research, 2, 3-25.

Lindsay, J.F., & Korsch, R.J., in press - The evolution the Amadeus Basin, central Australia. Bureau of Mineral Resources, Australia, Bulletin 236.

Lindsay, J.F., Korsch, R.J., & Wilford, J., 1987 - Timing the breakup of a Proterozoic supercontinent: Evidence from Australian intracratonic basins. Geology, 15, 1061-1064.

Rutland, R.W.R., 1976 - Orogenic evolution of Australia. Earth Science Reviews, 12, 161-196.

Shaw, R.D., in press - The tectonic development of the Amadeus Basin. Bureau of Mineral Resources, Australia, Bulletin, 236.

Shaw, R.D., Korsch, R.J., Wright, C., & Goleby, B.R., in press a - Seismic interpretations and thrust tectonics of the Amadeus Basin, central Australia, along the BMR regional seismic line. Bureau of Mineral Resources, Australia, Bulletin, 236.

Shaw, R.D., Etheridge, M.E., & Lambeck, K., in press b - Development of the Late Proterozoic to Mid-Palaeozoic, intracratonic Amadeus Basin in central Australia: a key to understanding tectonic forces in plate interiors. Tectonics.

Shergold, J.H., Gorter, J.D., Nicoll, R.S., & Haines, P.W., in press - Stratigraphy of the Pacoota Sandstone (Cambrian-Ordovician), Amadeus Basin, N.T. Bureau of Mineral Resources, Australia, Bulletin, 237.

Southgate., P.N., & Shergold, J.H., in press - Application of sequence stratigraphic concepts to Middle Cambrian phosphogenesis, Georgina Basin, Australia. BMR Journal of Australian Geology and Geophysics, 11.

Tingate, P.R., in press - Apatite fission track analysis of the Pacoota and Stairway Sandstones, Amadeus Basin, central Australia. Bureau of Mineral Resources, Australia, Bulletin, 236.

Veevers, J.J., (editor) & others, 1984 - Phanerozoic Earth History of Australia. Oxford Geological Science Series, 2, Clarendon Press, Oxford.

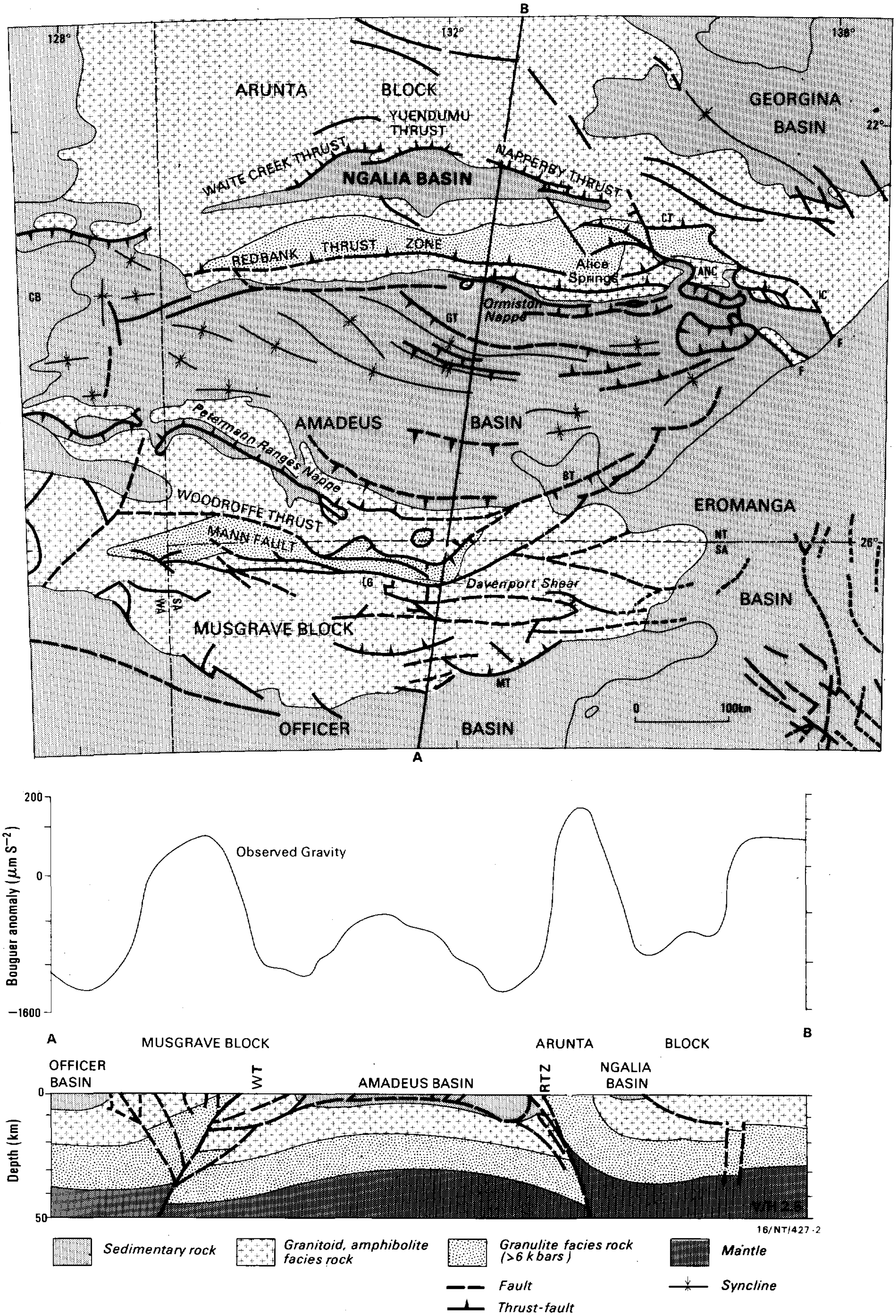


Figure 1. Major tectonic features of the Amadeus Basin and schematic cross-section (N to S) across the basin (see Shaw & others, in press a, b). The Cambrian Ooraminna (OSB) and Carmichael (CSB) Sub-basins are shown in dashed outline. Other tectonic features are: CB = Canning Basin; BT = Black Hills Thrust; GT = Gardiner Thrust; KT = Kernot Thrust Zone; MF = Mann Fault; OTZ = Ormiston Thrust Zone; RTZ = Redbank Thrust Zone; WT = Woodroofe Thrust.

'MESOTHRUST' VERSUS 'MEGATHRUST' INTERPRETATIONS OF THE STRUCTURE OF THE NORTHEASTERN AMADEUS BASIN

Alistair J Stewart
Division of Minerals and Land Use, Bureau of Mineral Resources

In the northeast of the Amadeus Basin, decollement sliding on two major evaporite horizons in the sequence formed large allochthonous thrust sheets. Two interpretations of the structure have been proposed.

The 'mesothrust' interpretation of R.Q. Oaks and J.A. Deckelman (Fig. 1A) interprets the structure in terms of two, large, continuous thrust sheets. One glided southward on a lower evaporite layer to the north of an east-trending paleotectonic high, the Central Ridge. The other glided northward on an upper evaporite layer farther south. The sheets segmented into separate but adjacent parts, mostly along backthrusts, as a result of their collision over the Central Ridge. The sheets collectively moved about 30 to 40 km to their present positions, and are unbounded to the west, which implies that the Amadeus Basin sequence to the west is also allochthonous.

The 'megathrust' interpretation of A.J. Stewart and R.D. Shaw (Fig. 1B) regards the segment forming the central and southwestern part of Oaks & Deckelman's southward-gliding sheet as parautochthon, and the remaining sheets as remnants of a single large nappe (a 'meganappe') that moved 60 or 70 km southward over a still-buried part of the parautochthon. Backthrusting, folding, and erosion segmented the meganappe into several klippen-like sheets. Westward, the meganappe ramped up-section to the surface, which implies that the western part of the Amadeus Basin is (par)autochthonous.

Restored sections in the megathrust interpretation show the major detachment fault ramping up-section in the east where a lens, 50 km long north-south and up to 2 km thick, of dominantly terrigenous clastics is enclosed in shale and thins southward. The clastics of the lens have affinities to rocks of the Georgina Basin 120 km to the north. In the west, the major ramping was north of the lens. In the mesothrust interpretation, major ramping was consistently north or south of the lens.

The megathrust interpretation predicts areas of concealed Proterozoic-Cambrian sandstone prospective for hydrocarbons beneath the exposed allochthonous strata north of the Central Ridge in the eastern part of the area. The mesothrust interpretation predicts somewhat smaller areas of Ordovician to Devonian sandstones, with better reservoir properties, in the eastern part of the area (near the northern thrust ramp) and in the southwest.

Tectonism in the basin was coeval with orogeny in the Tasman Fold Belt of eastern Australia. The thrust nappes formed when late-stage, north-south compression in the Tasman Fold Belt (attributed to a velocity change in the southward-drifting Australian plate) propagated through the plate and reactivated an east-west Proterozoic suture, and caused basement and cover thrust-faulting, uplift, and southward sliding of thrust sheets.

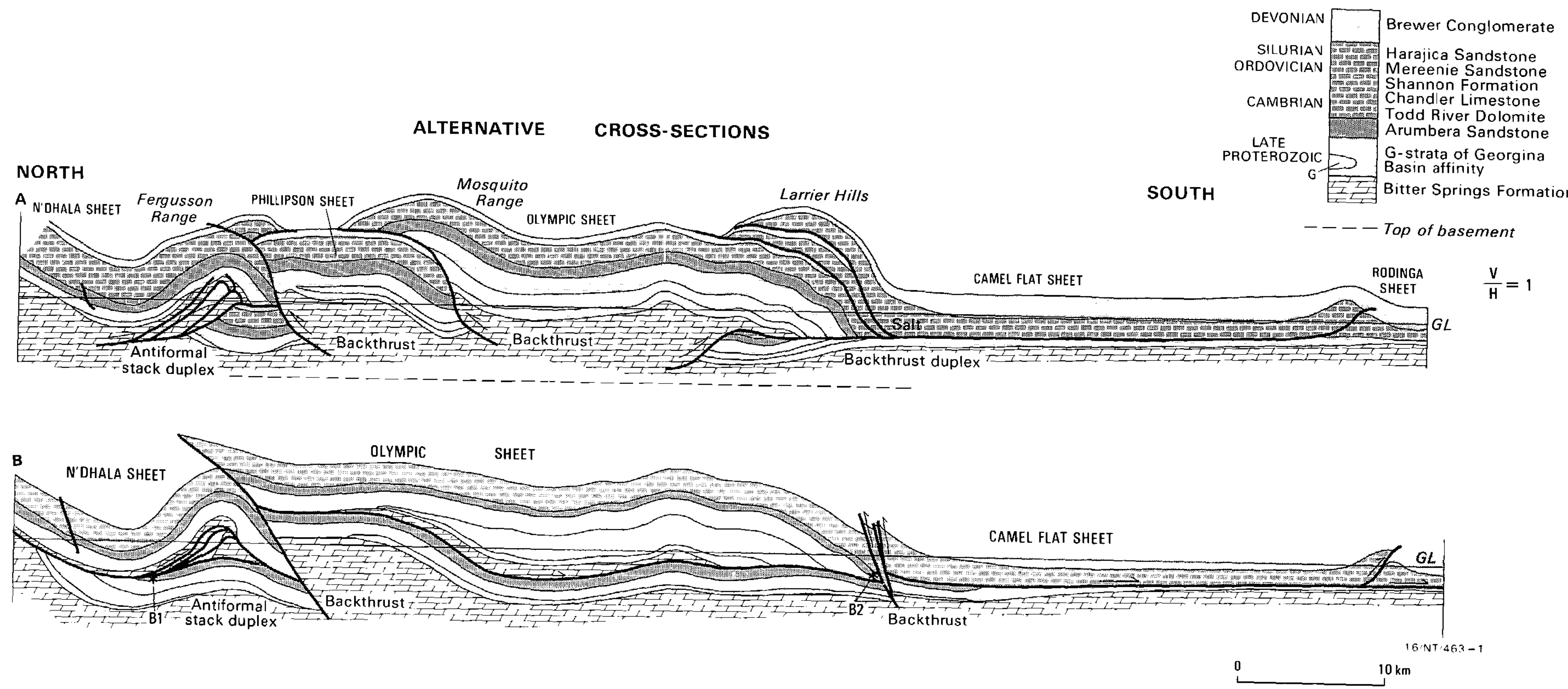


Figure 1. Structural cross-sections of the northeastern Amadeus Basin based on **A)** "Mesothrust" and **B)** "Megathrust" interpretations.

PALAEOZOIC TECTONICS: THE ALICE SPRINGS OROGENY

P R (Dick) Evans[1] & John Bradshaw[2]
[1] School of Mines, University of New South Wales
[2] Onshore Sedimentary and Petroleum Geology, Bureau of Mineral Resources

The Amadeus Basin is divided into a number of structural provinces (Fig. 1) that developed during the Palaeozoic Alice Springs Orogeny, the course of which has been extended and is described in terms of: 1) Early Palaeozoic, pre-orogenic, crustal extension and basin development; 2) Late Ordovician - Carboniferous NE-SW compressional orogenesis; and 3) Late Carboniferous - (?)Early Permian NW-SE compression (see Fig. 2).

The Southern Province is composed largely of Proterozoic formations that had been deformed during the Petermann Ranges Orogeny. The Central Anticlinal Province is a shear zone of four en-echelon trends. The Parana Hills and Mereenie trends have a left lateral orientation to each other and formed during the first phase of the orogenesis; the Gardiner Range and James Range trends are right lateral and formed during the second stage. Structures in the Northern Province were created by decollement within the evaporite-bearing Bitter Springs Formation and, to a lesser extent, in the Cambrian Chandler Formation, and by collapse of the basin fill under the burden of the Brewer Conglomerate in a style similar to the formation of diapirs along the northern front of the Pyrenees. The MacDonnell Homocline is a mountain front tip line that resembles the Triangle Zone of the Canadian Rocky Mountains. The Allambi Thrust Zone separates the Northern Province from the Camel Flat Platform that bears diapiric salt walls derived from the Chandler Formation.

The model provides a new basis for analysis of palaeo-fracture patterns, porosity development and maturation profiles within the Amadeus and Ngalia Basins. The extended duration of the Alice Springs Orogeny and changing vector of principal stresses should be further correlated with events in neighbouring basins, and thus determine the underlying controls on this distinctive phase of Palaeozoic tectonism.

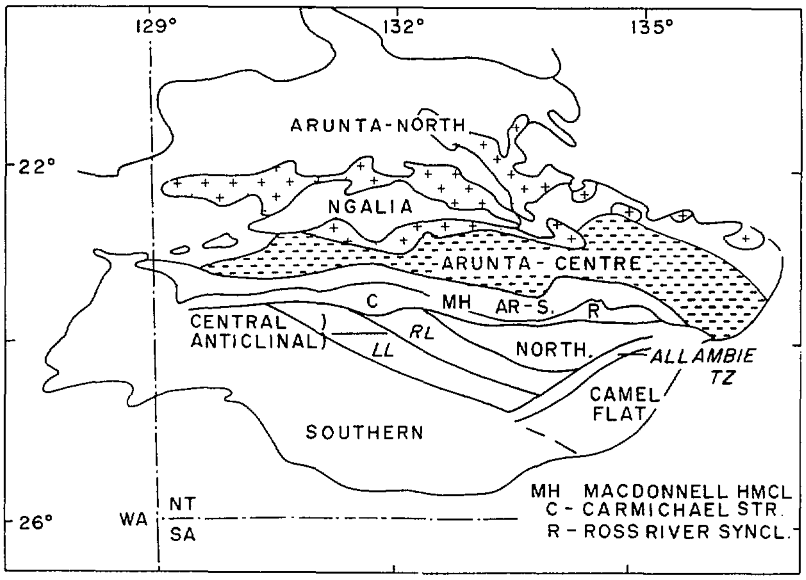


Figure 1. Structural provinces of the Amadeus Basin and Arunta Block.

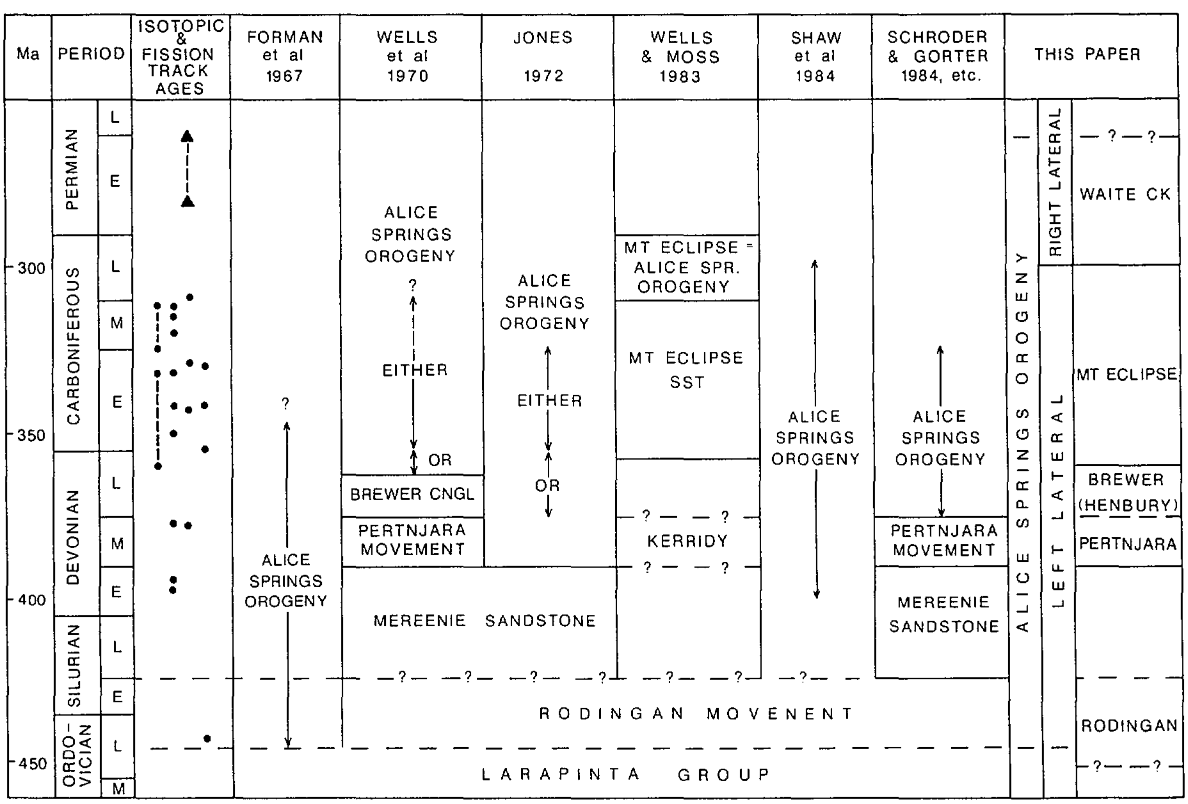


Figure 2. Concepts of the Alice Springs Orogeny.
• = isotopic ages (Shaw & others, 1984) ▲ = fission track age (Tingate & others, 1986)

PETROLEUM SOURCE ROCKS OF THE AMADEUS BASIN

Roger E Summons & Trevor G Powell
Onshore Sedimenary and Petroleum Geology, Bureau of Mineral Resources

526 Samples of Amadeus Basin sediment from exploration and stratigraphic boreholes were examined for information about source rock richness (Fig. 1) and quality. The picture that emerges from this survey is entirely consistent with data gathered in an earlier study of 87 samples (Jackson & others, 1984). Low amounts of organic carbon were present in the Cambrian Chandler Formation and in the Proterozoic Pertatataka and Bitter Springs Formations (Figs. 2-4). In these units, the abundance of kerogen was generally very low and restricted to narrow intervals, mostly within shale beds and where TOC rarely exceeded 1%. Low amounts of bitumens were widely distributed throughout the carbonates of the Proterozoic and these generally showed different compositions to bitumens extracted from the shales. Rock-Eval pyrolysis and biomarker distributions suggest that the organic matter in the Cambrian and Proterozoic sediments, where it does exist, is mature with respect to petroleum generation.

World-wide, there are only two major oil and two major gas provinces with likely source rocks of Proterozoic or Cambrian age. The oil provinces of Oman and the Siberian Platform are almost certainly sourced from Vendian-aged sediments, and both have the same anomalous biomarker and very light carbon isotope signatures suggesting that the organic matter accumulations resulted from a global, age-related biological/geological phenomenon. In terms of organic carbon content and quality, the presently known Cambrian and Proterozoic age sediments of the Amadeus Basin compare unfavourably with the sediments which sourced the old Oman and Siberian Platform oils. However, there is general agreement that the Proterozoic and Cambrian sediments could be sources for the gas accumulations in the Amadeus Basin. It should also be noted that, although this study is based on a large number of samples, the number of exploration wells involved is only about 25. Hence, the sampling density is low on a geographic basis.

Significant intervals of mature and moderate to rich source rock are confined to one unit, the Ordovician Horn Valley Siltstone (Fig. 5). Distinctive hydrocarbon distributions of bitumens extracted from the Horn Valley Siltstone confirm that the organic matter partially originated from the remains of *Gloeocapsomorpha prisca* and that the oils of the Mereenie and Palm Valley Fields have a component from this source organism. High temperature thresholds are probably necessary for hydrocarbon generation from the Type-1 and Type-2 Ordovician kerogens of the Horn Valley Siltstone. Even though there are commercial accumulations of Ordovician oil in the Amadeus Basin, the Horn Valley Siltstone is organically lean compared to some analogous, *G. prisca* containing source rocks of the Baltic Basin and North America.

References

Jackson, K.S., McKirdy, D.M., & Deckelman, J.A., 1984. Hydrocarbon generation in the Amadeus Basin, central Australia. APEA Journal, 24, 42-65.

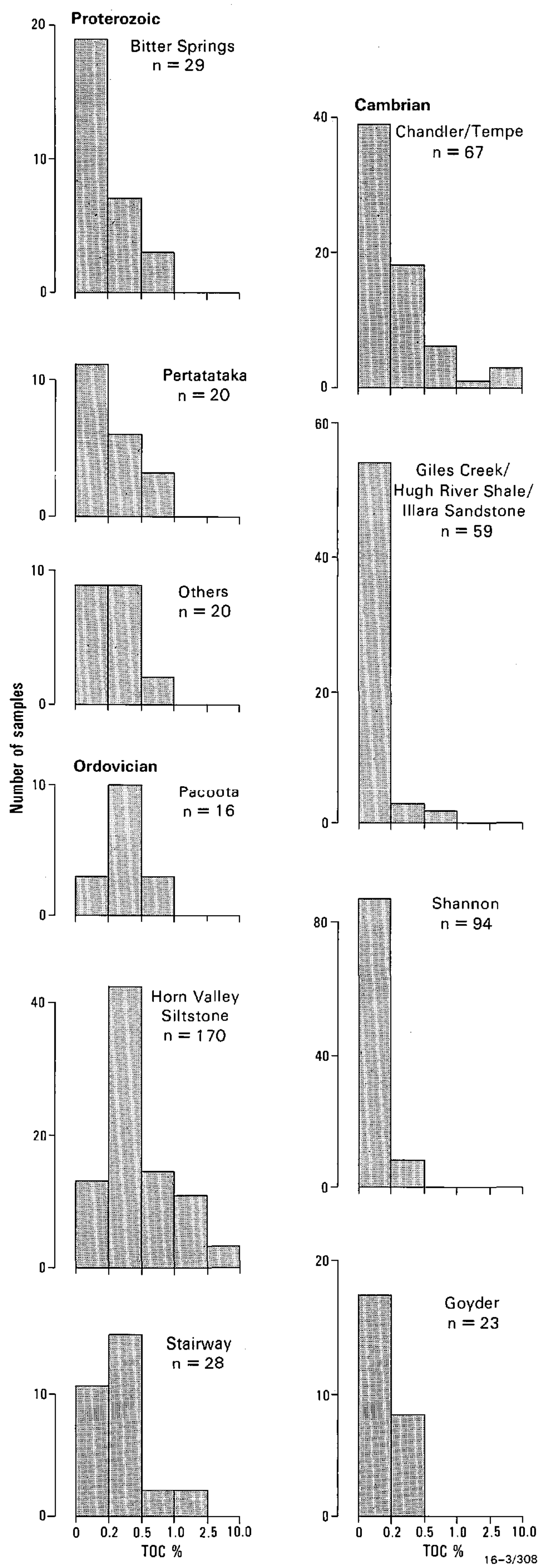


Figure 1. Distribution of organic carbon in Amadeus Basin formations.

Barney Ck. Formation ~1690 Ma
~ 900m in Glyde River #7
TOC range 0.3-5.2%
500 samp.; 200 > 1.0%, 25 > 3.0%
mature-o/mature; kerogen+bitumen

Velkerri Formation ~1400 Ma
~ 400m in Urapunga #4
TOC range 0.9-8.0%
131 samples; 70 > 1%; 50 > 3%
live oil

Bitter Springs Fm. ~850Ma
~ 692m in Mt Charlotte 1
TOC 0-1%
29 samples from 5 wells
19 < 0.2% TOC
mature, traces of kerogen
mostly bitumen/ residual oil

Nonesuch Formation ~1000Ma
~200m at White Pine
TOC generally < 0.3%
0.5-2.8% in lam. siltstone at base
mature to o/mature kerogen +bitumen
live oil

Kwagunt Formation ~850Ma
~630m Nankoweap Butte; Grand Cyn
TOC range 0.4-7.3%
89 samples analysed
1.9-7.3% in Walcott Mbr. mudstone
marg. mat. / mature kerogen+bitumen

Siberian Platform Riphean
~ 300m maximum
TOC levels 3 - 5% prevalent
o/mature for oil; wet and dry gas
MAJOR GAS PROVINCE (S)

Figure 2: Comparison of organic carbon contents of the Bitter Springs Formation samples with some other mid to late Proterozoic sediments.

Siberian Platform Vendian-Cambrian
~ 10m thick source intervals
TOC 1 - 10%
mature to o/mature kerogen+bitumen
MAJOR OIL AND GAS PROVINCE

Pertatataka Fm. ~600Ma
488m in Mt Charlotte#1
TOC 0-1%
20 samples from 5 wells
all < 1.0% TOC
mature, traces of kerogen
mostly bitumen

Oman Huqf Group Vendian-Cambrian
source thickness/ extent unknown
TOC generally <0.3%
intervals of 2.2-5.2% in
Ara, Shuram Fms (Vendian)
immature/mature; kerogen+bitumen
MAJOR OIL AND GAS PROVINCE

Dengying Fm.-Sichuan Province
~500m thickness of Sinian age
published Av. TOC 0.2-0.5%
over mature; dry gas stage
BMR TOC to 4.6% in Nantou & Doushantou Fms.
MAJOR GAS PROVINCE

Figure 3: Comparison of organic carbon contents of the Pertatataka Formation samples with some other Late Proterozoic sediments.

Chandler/Tempe Formation 67 samples TOC 0-1%	Currant Bush Limestone 35 samples TOC 0.5-13.7% organic carbon deposited cyclically
Giles Creek Formation 59 samples TOC 0-1%	Inca Formation 8 samples TOC 3-6% black shale
Shannon Formation 94 samples TOC 0-0.5%	Thorntonia Limestone 3 samples TOC 5-8.8%
Goyder Formation 23 samples TOC 0-0.5%	

Figure 4. Comparison of organic carbon contents of Cambrian age Amadeus Basin samples with some Georgina Basin sediments.

	Goldwyer Formation - Canning Basin 7 BMR samples TOC 0.5-6.3% and HI to 830 43 WMC samples TOC 0.2-6.4% and HI to 820
	Trenton Fm. - Michigan/Illinois Basins TOC to 20-25%
Horn Valley Formation 107 samples TOC 0-6.3% HI to 320 25 in the range 1-6.5%	Viola Fm. - Forest City Basin TOC to 5-8.8%
	Red R. / Yoeman Fm. - Williston Basin TOC to 35%
	Glenwood Formation - Iowa Shelf "Gutenburg Oil Rock" ~10 ft TOC to 43% HI to 920
	Kukersite Baltic Basin TOC to 60% Oil shale with a mineable 11 billion barrels of oil equivalent

Figure 5. Comparison of organic carbon contents of the Horn Valley Formation, a "diluted" kukersite with some other Ordovician sediments.

THERMAL HISTORY OF THE AMADEUS BASIN: EVIDENCE FROM APATITE FISSION TRACK ANALYSIS

Peter R Tingate
National Centre for Petroleum Geology and Geophysics, Adelaide

Introduction

The Amadeus Basin consists of late Proterozoic to Devonian sediments with most petroleum reservoired in the Cambro-Ordovician Larapinta Group which was buried under the Pertnjara Group and folded during the Devonian-Carboniferous Alice Springs Orogeny. One of the major problems in reconstructing the thermal and tectonic history of the Amadeus Basin is the limited younger stratigraphic control. Over most of the basin, a late Devonian to early Tertiary unconformity exists so any thermal history based purely on the preserved stratigraphic record is effectively unconstrained for a period of approximately 300 Ma.

The present depth distribution of oil shows and accumulations and data from various maturation indices (Fig. 1) generally indicate, or are consistent with, the Amadeus Basin having experienced higher temperatures in the past, but knowledge of the timing and style of thermal history is lacking. For this reason outcrop and borehole samples from the Amadeus Basin, concentrating on the Larapinta Group, have been analysed using Apatite Fission Track Analysis (AFTA). To further constrain the thermal history of the basin, samples were also taken from neighbouring crystalline blocks and basins.

AFTA is a technique that gives unique information about the thermal history of rocks. Fission tracks form over time in apatite due to the spontaneous decay of ^{238}U and over geological time-scales anneal or shorten over a temperature range of approximately 10 to 130°C. By etching the internal surfaces of apatite grains, the tracks become visible under a light microscope. The track density is a function of the time over which the tracks have formed and the U content of the apatite. By irradiating the apatite a measure of the ^{235}U content can be made and a radiometric age produced.

Since tracks are formed continuously over time and anneal or shorten depending on the temperatures they have been exposed to, the track length parameters contain a record of the different temperatures experienced by the rock. As well as the fission track age and length, the variation in single crystal age was also measured. These AFTA parameters, as well as their variation down boreholes or up vertical profiles in regions of high topographic relief, have been used to provide information on the thermal history of the Amadeus Basin.

Once limits on the timing and style of the thermal history for samples were made from the AFTA data and the existing stratigraphy, computer modeling of possible thermal histories was undertaken to check and refine possible thermal histories. The computer model used was based on the mathematical description of induced track annealing in monocompositional Durango apatite.

Results

Apatite fission track data from outcrop samples in the Amadeus Basin indicate that they have all experienced temperatures greater than 50°C since deposition. There is no evidence to indicate that regions within the basin exist where rocks are presently at their maximum temperatures. The fission track data from individual formations across the basin show significant variation in fission track age (200 to 650 Ma) but do not show an accompanying variation in track length parameters, indicating that the basin has experienced a complex thermal history. In general, age and length data from the basement regions have similar AFTA parameters to nearby samples within the basin, indicating that annealing has occurred on a scale greater than the basin itself.

A common characteristic of the great majority of samples is the small proportion of tracks with lengths greater than 14 μm, indicating that the samples have spent less than 100 Ma at present temperature conditions. Borehole samples from the northern part of the Amadeus Basin show evidence of rapid cooling starting between 240 and 170 Ma from temperatures ~55°C greater than present as well as cooling from temperatures ~30°C greater than present between 80 and 20 Ma. Groups of samples from various structures in the basin that were not highly annealed prior to cooling ~200 Ma give information on the thermal conditions of the Alice Springs Orogeny between 390 and 290 Ma.

Discussion

The data shows that all samples have experienced higher temperatures in the past and that constraints can be placed upon the regional thermal history at three different times; namely, between 390 and 290 Ma, between 240 and 170 Ma, and between 80 and 20 Ma. Within the Amadeus Basin, different regions appear to have reached maximum temperatures at different times. For example, at Ellery Creek on the northern margin of the basin, the Pacoota Sandstone reached maximum temperatures between 390 and 290 Ma whilst in Alice-1 (Fig. 2) and the Mereenie Field it cooled from maximum temperatures between 240 and 170 Ma. To the south-east of the basin in McDills-1, samples reached their maximum temperatures after deposition of the early Mesozoic section and started cooling between 100 and 40 Ma.

Where information can be obtained on the timing of cooling of major structures in the north of the basin, the fission track constraints are consistent with the stratigraphic constraints on the western and eastern margins of the basin; namely that folding and regional uplift had occurred after deposition of the Pertnjara Group and prior to ~290 Ma. Less annealed samples from the Arunta Block provide evidence of cooling below ~110°C in the Carboniferous but some samples may have cooled as late as the Early Permian (~270 Ma).

The estimated maximum temperatures experienced during the Alice Springs Orogeny varies with the stratigraphic age of the formations. Cambrian and Precambrian formations generally reached temperatures of 90°C or greater over most of the basin except for regions near the southern margin. The Cambro-Ordovician Larapinta Group cooled from temperatures greater than 110°C in large structures in the northern part of the basin and appears to have experienced locally lower temperatures, in places < 90°C, near the centre of the basin and temperatures greater than 90°C in the Erldunda Ranges further south. The data from the Pertnjara Group gives little information on the maximum temperatures experienced at this time but most of the outcrop samples are interpreted to have experienced temperatures less than 110°C.

In general, estimates of temperature experienced prior to cooling at ~200 Ma do not vary with the stratigraphy or structures within the basin. Apart from well samples that indicate cooling at ~200 Ma, outcrop samples from the basin and parts of the Arunta and Musgrave Blocks with fission track ages of ~200 Ma or samples with single grain ages at ~200 Ma support a regional cooling event. Most outcrop samples experienced temperatures around 70 to 90°C indicating that the samples were at approximately three kilometres depth prior to uplift and erosion starting at ~200 Ma. In parts of the basin, temperatures were locally higher or lower, suggesting greater or lesser burial.

The palaeotemperature data obtained from the broad region encompassing both basin and basement suggest that a period of epeirogenic uplift and erosion occurred across central Australia at ~200 Ma. This event coincides with Late Triassic to Early Jurassic regional uplift and erosion in the Canning Basin to the west and in sedimentary basins to the east of the Amadeus Basin. Given the widespread nature of Permo-Triassic sedimentation to the east and west of the Amadeus Basin, it is possible that the region sampled was covered by a significant thickness of Permo-Triassic cover.

The great majority of the fission track data from the basin and basement outcrop samples are not compatible with residence at temperatures < 50°C for the last 100 Ma. The data suggests that most samples were at temperatures of ~60°C prior to cooling at some time or times between 80 and 20 Ma. In the southeastern part of the basin, the fission track data indicate that samples experienced temperatures of 60°C after deposition of the Aptian sediments that occur in the region, suggesting that 1-2 km of post-Aptian cover was present over the region. Given that most of the region sampled away from the southeastern margin experienced similar temperatures at this time the possibility exists that considerable thicknesses of the Eromanga Basin sequence extended over much of central Australia. Irrespective of the geological history proposed to generate the palaeotemperature history of central Australia, kilometre scale uplift is needed at ~200 Ma and at ~80 to 40 Ma which has important implications for the palaeogeography of Australia.

Previous studies have assumed, not unreasonably given the lack of younger stratigraphic control, that maturation data from the Amadeus Basin primarily reflects the maximum temperature that the sedimentary section reached during the Alice Springs Orogeny. The fission track data shows that some parts of the basin were certainly at maximum temperatures during the Alice Springs Orogeny whilst others experienced maximum temperatures prior to cooling at ~200 Ma, including the Mereenie Oil Field. Thus the palaeotemperature data from this study show that peak generation of hydrocarbons in parts of the basin may have occurred as late as ~200 Ma.

Irrespective of the timing of oil generation in the basin, for oil to be preserved it needs to reside in reservoirs at sufficiently low temperatures so that it will not be cracked to gas. Oil accumulations and shows in the Amadeus Basin tend to be depth controlled. Figure 1 shows petroleum shows and maturation data in wells as well as the approximate position of the 110°C isotherm prior to cooling between 240 and 170 Ma derived from fission track data. In all wells the palaeoisotherm is much higher than the present 110°C isotherm due to uplift and erosion since 200 Ma. There is a strong correlation between oil shows occurring close to or above the 110°C palaeoisotherm suggesting that regionally higher temperatures prior to cooling at ~200 Ma are a major influence on the preservation of oil in the basin. Figure 1 emphasises that at least in the northern half of the basin, oil should only be sought in traps at less than ~2 km depth. Below this depth the likelihood of the preservation of oil decreases and the probability of encountering gas rises.

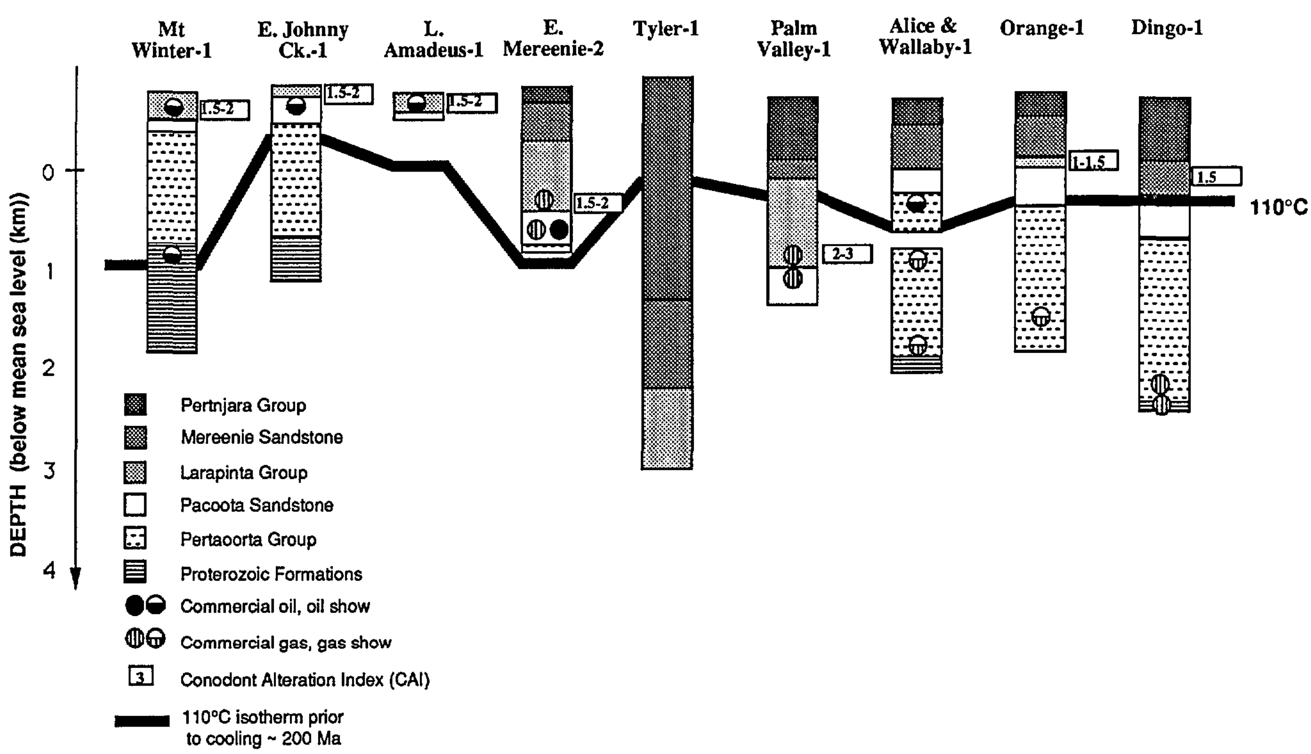
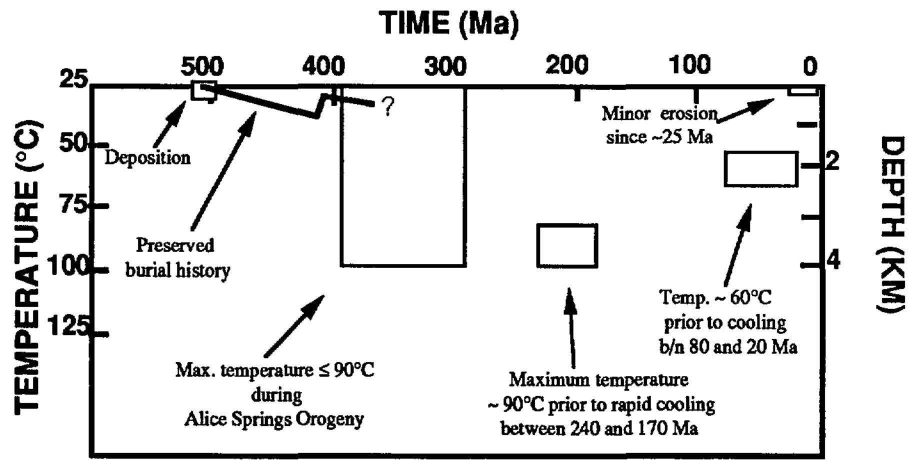
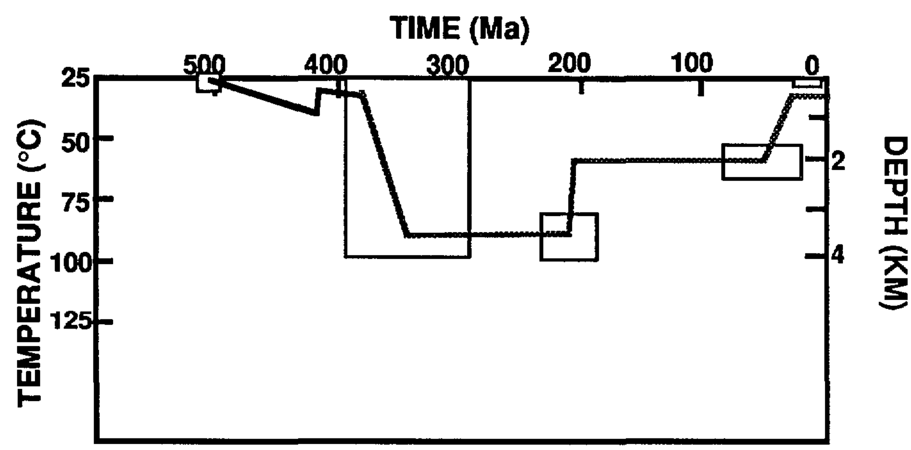


Figure 1. Hydrocarbon distribution and approximate position of 110 °C palaeo-isotherm in various Amadeus Basin boreholes.

Thermal history constraints, Pacoota Sandstone, Alice-1



Possible Thermal Histories, Pacoota Sandstone, Alice-1



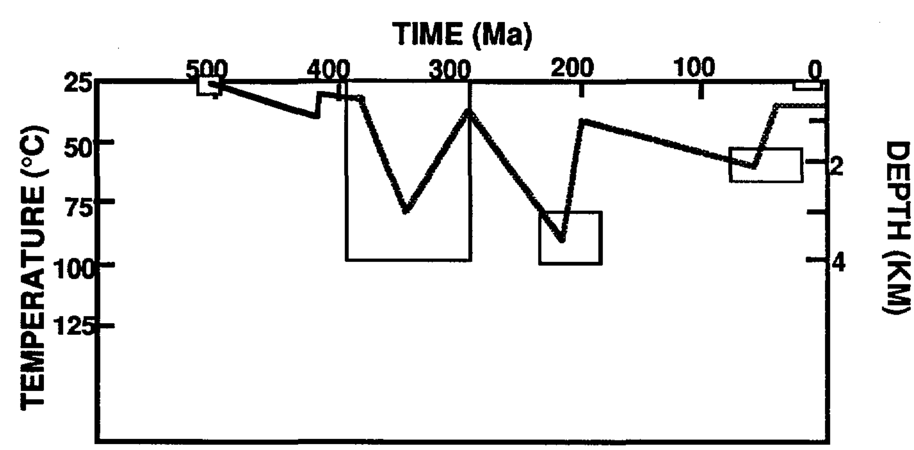


Figure 2. Thermal history constraints (top) and schematic thermal histories for the Pacoota Sandstone in Alice 1.

INTERPRETATION OF CONODONT COLOUR ALTERATION AND THERMAL MATURATION IN THE AMADEUS BASIN

Robert S Nicoll[1] & John D Gorter[2]
[1] Onshore Sedimentary and Petroleum Geology, Bureau of Mineral Resources
[2] Petroz NL, Perth

The study of conodont colour alteration to define organic maturation levels and trends in the Amadeus Basin is based on samples collected from sediments of latest Cambrian to Early Ordovician and Devonian age. Cambrian and Ordovician conodonts have been obtained from both outcrop and subsurface localities, and reworked Ordovician conodonts have been obtained from outcrop Devonian localities. The bulk of conodonts have been recovered from the Cambrian-Ordovician Pacoota Sandstone and the Ordovician Horn Valley Siltstone (Arenig) and Stokes Siltstone (Llanvirn). Some faunas have also been found in the Stairway Sandstone. A number of samples of the Carmichael Sandstone (Ordovician) and the Parke Siltstone and Hermannsburg Sandstone (Devonian) have also yielded reworked Ordovician conodonts.

The conodont colour alteration isograds in the Amadeus Basin appear to be primarily related to events of the Alice Springs orogeny, when the thick mass of molasse sediments (Pertnjara Group) resulting from erosion of the uplifted Arunta Block was deposited. Anomalies to the conodont colour isograds appear to be related to erosion associated with the Rodingan orogeny and also possibly to the effects of salt structures.

Conodont colour alteration data indicate areas on the basin margins, such as the Ordovician of the MacDonnell Ranges, and on some structural features like the Waterhouse Range Anticline, that were never deeply buried by the thick influx of Devonian sediments.

CLASTIC PETROLEUM RESERVOIRS OF THE LATE PROTEROZOIC AND EARLY PALAEOZOIC AMADEUS BASIN

John F Lindsay[1] & John D Gorter[2]
[1] Onshore Sedimentary and Petroleum Geology, Bureau of Mineral Resources
[2] Petroz NL, Perth

The Amadeus Basin is one of the continent's major onshore hydrocarbon-producing basins. Three economically important fields have been discovered in the basin, two are currently in production whilst a third is as yet undeveloped. Most of the hydrocarbons occur in structural traps developed over major salt features derived from evaporites in the Late Proterozoic Bitter Springs Formation. These structure were, in many cases, initiated in the Late Proterozoic but grew most rapidly in the late stages of basin evolution during the late Palaeozoic Alice Springs Orogeny.

Depositional models, based on basin dynamics, suggest that in extensional intracratonic basins such as the Amadeus Basin, reservoir units are likely to be deposited in two settings; 1) early in basin evolution concurrent with or immediately following extension, or 2) late in basin development during the final stages of thermal subsidence (Lindsay & Korsch, 1989). The two major clastic reservoir units in the Amadeus Basin, the Arumbera and the Pacoota Sandstones, occur in these two settings and allow a direct comparison. The Late Proterozoic/Early Cambrian Arumbera Sandstone was deposited early in basin evolution when subsidence was relatively rapid, whilst the latest Cambrian/Early Ordovician Pacoota Sandstone was deposited during the final stages of basin evolution when the subsidence rate was slow.

The Arumbera Sandstone was deposited in response to two eustatic sea-level cycles as part of two major, coarsening-upward, depositional sequences in a shallow marine environment (Lindsay, 1987; Lindsay & Gorter, in press). Sediments were supplied from the southwest by braided streams and were deposited in a coastal-plain setting in association with small-scale deltas. The Pacoota Sandstone was also deposited in a shallow marine environment although the sediments were deposited predominantly in a tidally influenced, shelf setting. A total of 11 depositional parasequence sets, most of which appear to be transgressive and often coarsening-upward in nature, have been identified in the formation (Gorter, in preparation).

Despite the differences in the timing of their deposition and their depositional setting, the gross reservoir quality of the two major units is very similar and controlled by facies and diagenesis. In general, the main post-depositional controls on reservoir quality relate to the distribution of clays in the pore system, resulting from the breakdown of feldspar and labile rock fragments, and the dissolution of feldspar grains. Where sands were well sorted at the tops of the major coarsening-upward sequences, feldspar was removed allowing massive quartz cementation of the clean sands. However, at the tops of the smaller coarsening-upward parasequences, where sorting is poorer, primary porosity is poor due to clays but secondary porosity developed in the remaining detrital feldspars. Thus, whilst larger-scale factors relating to basin dynamics were important in determining the regional facies setting (e.g. water depth and depositional space) for the deposition of these two reservoir units, it was the smaller-scale facies associations and resultant diagenesis that ultimately determined reservoir quality. While both reservoir units are in part heavily cemented and have a reduced reservoir quality due to clay minerals, they both have secondary porosity generated by the dissolution of feldspar.

References

Benbow, D.D., 1968 - Case history: Mereenie Field. APEA Journal, 8, 114-119.

Gorter, J.D., in preparation - Late Precambrian to Early Ordovician sedimentation in the Amadeus Basin, central Australia. Ph.D. Thesis, University of New South Wales, Sydney, Australia.

Lindsay, J.F., 1987 - Sequence stratigraphy and depositional controls in Late Proterozoic-Early Cambrian sediments of the Amadeus Basin, central Australia. American Association of Petroleum Geologists, Bulletin, 71, 1387-1403.

Lindsay, J.F., & Gorter J.D., in press - Clastic petroleum reservoirs of the Late Proterozoic and Early Paleozoic Amadeus Basin, central Australia. In Rhodes, E.G. & Moslow, T. (Eds.), *Marine Clastic Reservoirs*. Springer-Verlag.

Lindsay, J.F., & Korsch, R.J., 1989 - Interplay of tectonics and sea-level changes in basin evolution: an example from the intracratonic Amadeus Basin, central Australia. Basin Research, 2, 3-25.

Towler, B.F., 1986 - Reservoir simulation in the Mereenie Field. APEA Journal, 26, 428-446.

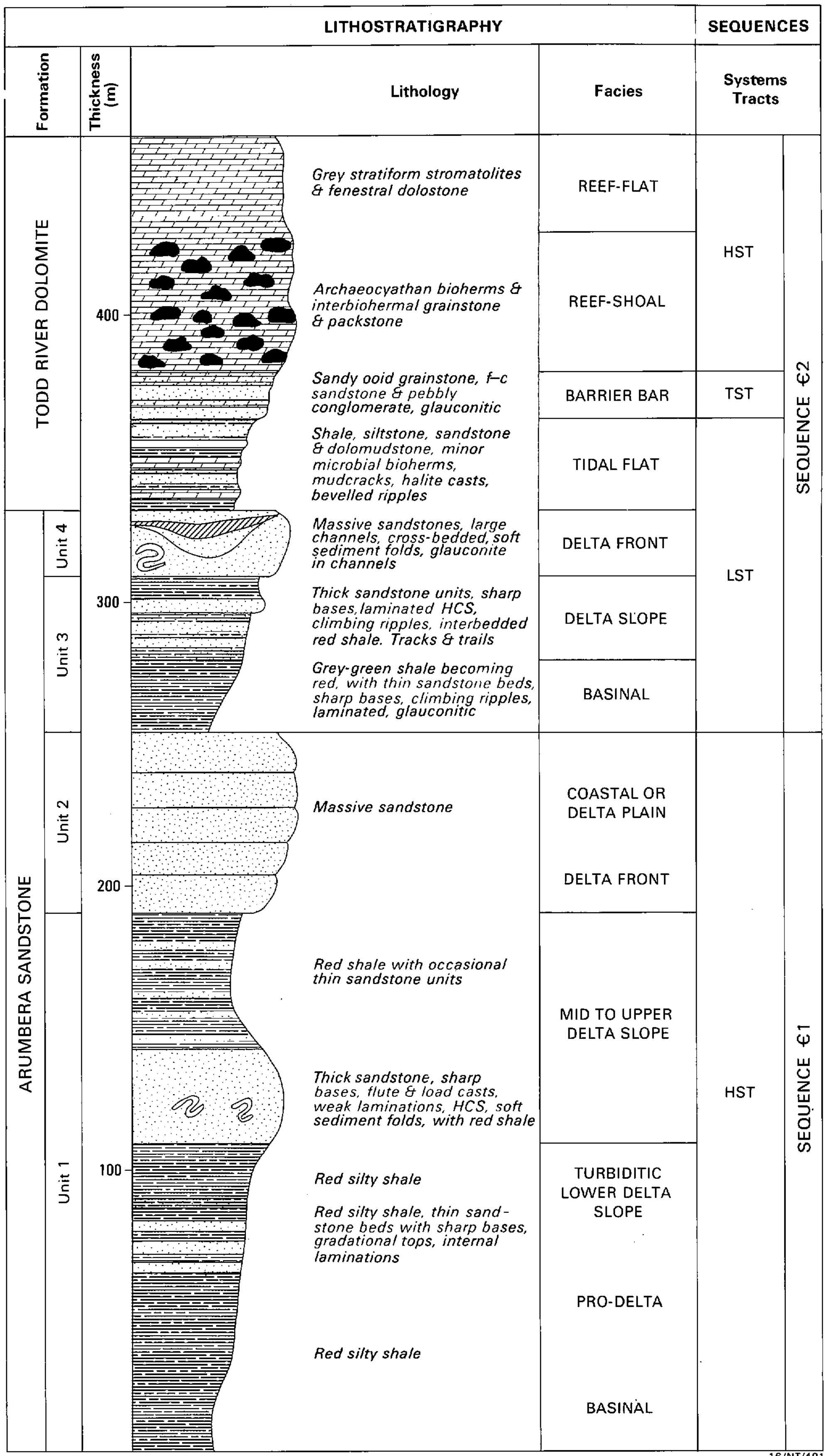


Figure 1. Detailed section through the Arumbera Sandstone in the Ooraminna Sub-basin (134° 29'E, 23° 36'S) showing the two depositional sequences and the interpreted facies associations. At this locality the clastic sediments of sequence 2 are relatively thin compared with its development closer to the center of the sub-basin.
HST = Highstand systems tract, TST = Transgressive systems tract, LST = Lowstand systems tract.

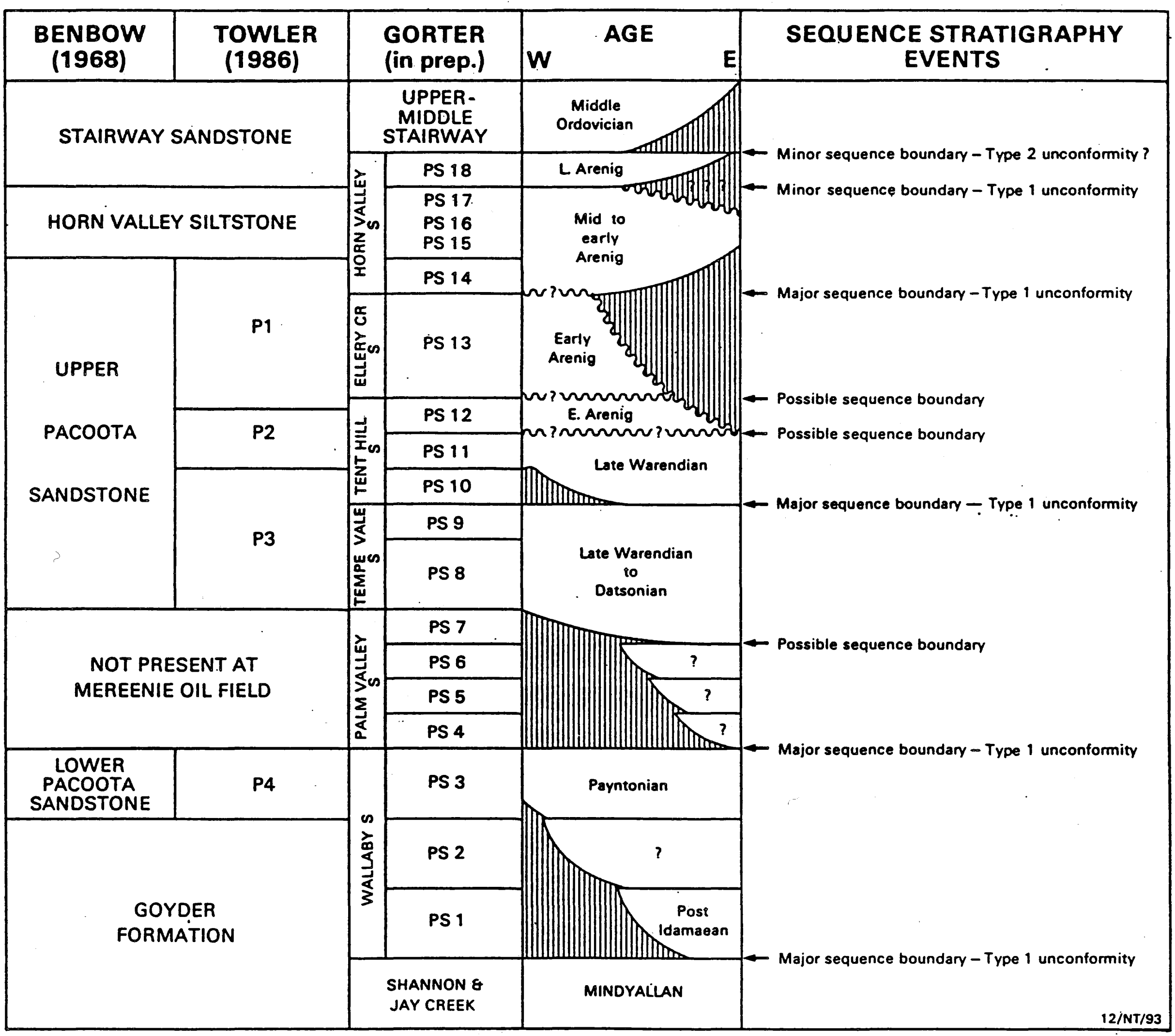


Figure 2. Comparison of stratigraphic subdivisions of the Pacoota Sandstone based on published Mereenie Field usage (Benbow, 1968; Towler, 1986) and that developed by Gorter (in prep.).

A FLUVIAL FACIES IN THE PACOOTA SANDSTONE: ITS RESERVOIR POTENTIAL AND IMPLICATIONS FOR PETROLEUM EXPLORATION

James A Deckelman
Magellan Petroleum Australia Limited, Brisbane

In June of 1982, Magellan Petroleum Australia Limited commissioned a field study of the Pacoota Sandstone in order to determine its reservoir potential in the unexplored north-central and northwestern parts of the Amadeus Basin. Early in the course of this study, a fluvial facies was recognised in the lower part of the formation. Previously, the Pacoota Sandstone was considered to be entirely marine in origin. Subsequent integration of core and log data showed that this fluvial facies forms the lower part of the P3 unit and correlates directly with the primary producing interval at the Mereenie oil and gas field.

In order to differentiate dominantly fluvial sediments in the lower part of the P3 from estuarine and shoreface sediments in the upper part of the P3, the P3 interval is here divided into a dominantly fluvial lower unit, the P3B, and an estuarine and shoreface upper unit, the P3A (Figs 1 & 2). The P3B unit is the focus of this paper.

Environment of Deposition

The P3B is interpreted as a deposit that accumulated in a dominantly fluvial environment on the basis of: locally erosional lower bounding surface of the unit; absence of body fossils and ichnofossils; lobate lateral geometry of the unit; wedge-shaped vertical geometry of the unit; abundant early syngenetic haematite; subarkosic, pebbly, and conglomeratic nature of sandstone in the unit; presence of pebble and cobble conglomerate; abundant trough cross-stratification with cross-sets up to 1.35 m thick; overturned cross-laminae; relatively abundant asymmetrical ripple marks; contorted stratification; beds in excess of 1 m in thickness; unimodal palaeocurrent distribution. Thin, discontinuous beds of grey siltstone and bioturbated sandstone, locally present in the P3B unit, record short periods of estuarine influence.

Detailed bedform analysis and vertical and lateral lithofacies relationships indicate that the P3B formed by the lateral migration and downslope progradation of a system of distal, small to moderate sized, mixed load and bedload, sandy braided streams. The P3B braided stream system was characterised by unconfined, essentially unidirectional flow. The geometry of the unit (Fig. 3), a northwestward increase in the size of framework grains and allochthonous pebbles, an eastward increase in sorting and roundness of sand grains, pebbles and cobbles, and easterly palaeocurrent orientations suggest that the P3B was derived from a source that lay to the west-northwest.

Because of the absence of land plants in Ordovician time, the P3B braided stream system has no direct modern analog. Bedforms in the P3B, however, resemble those in the South Saskatchewan River, a well-documented braided stream in western Canada.

Reservoir Potential

Sonic logs, neutron/density logs, and the results of drill-stem testing at the Mereenie Field indicate that porosity and permeability are greatest in the P3 and P1 units. A comparison of outcrop and core data with wireline-logs shows that high porosity zones in the P3 are restricted to an interval in the lower part of the unit that correlates directly with the P3B (Fig. 4). Drill-stem tests show that the P3B unit is the primary producing interval in the Pacoota Sandstone at the Mereenie Field (Fig. 5). In a recent study of the Mereenie Field, original proved in-place reserves in the P3B unit were estimated to be approximately 124 BCF of gas-cap gas, 73 BCF of solution gas, and 32 million barrels of oil (O'Sullivan, 1990). Proved in-place oil reserves in the P3B unit comprise approximately 86% of total proved oil reserves at the Mereenie Field.

Implications for Petroleum Exploration

Primary porosity and original permeability in the P3B are controlled by depositional texture and the abundance of clay matrix. In the P3B, sand grain size increases northwestward, grain roundness increases eastward, and the degree of sorting decreases northwestward. The northwestward increase in grain size and the eastward increase in roundness suggest that original sandstone permeability may have been greatest in the west and northwest parts of the study area. The northwestward decrease in sorting may have limited the increase in permeability somewhat.

Clay matrix is present in outcrop of the P3B throughout the study area. Because most of this matrix is an epigenetic weathering product of feldspar, lateral and vertical variation in the amount of orthomatrix and protomatrix cannot be determined accurately. It is likely, however, that a significant amount of matrix in fine and very fine grained sandstone is protomatrix. Protomatrix would have reduced the original porosity and permeability of the sediments, but would have preserved any remaining porosity and permeability by inhibiting the formation of quartz overgrowths.

Anagenetic silicification is the most significant diagenetic event affecting the present lateral distribution of porosity and permeability in the P3B unit. Petrophysical, petrographic, and sonic velocity data show that anagenetic silicification is most extensive in the northeastern part of the study area. To the south, where anagenetic silicification is considerably less, porosity and permeability are considerably greater. It is likely that the southward decrease in silicification is related primarily to decreased pressure solution associated with the south-southwestward decrease in thickness of the Devonian Pertnjara Group. Because the presence of clay matrix inhibits the formation of quartz overgrowths, trends in silicification also are related to the distribution of clay matrix.

The present lateral distribution of porosity and permeability in the P3B unit is controlled to a lesser extent by the distribution of feldspar. Petrographic analyses indicate that secondary porosity in the Pacoota Sandstone formed by anagenetic dissolution of feldspar. Anagenetic dissolution of feldspar is the cause of the relatively high porosity and permeability of the P3B unit at Mereenie Field. It would seem likely that feldspar would be most abundant in the west and northwest parts of the study area because: 1) sediments were derived from a source that lay to the west-northwest, and 2) in a fluvial system, considerable downstream loss of labile minerals takes place as a result of mechanical abrasion during transport and chemical weathering during storage. In the P3B unit, however, the abundance of feldspar is inversely related to grain size which decreases southeastward away from the source area. Because sand grain size decreases southeastward, feldspar is likely to be most abundant near the southeastern depositional limit of the unit (Fig. 3). Where feldspar is most abundant, the potential for development of secondary porosity is greatest.

Primary and secondary porosity trends, when combined, suggest that the reservoir potential of the P3B unit is likely to be greatest in the south.

References

O'Sullivan, T., 1990 - A review of the in-place hydrocarbons, Mereenie Field: Unpublished report for AGL Petroleum, 92p.

Type section P3B Unit

SECTION NAME: South Deering Creek (section H)
LATITUDE: 23°42′56″ south
LONGITUDE: 131°41′49″ east
GEOGRAPHIC LOCATION: 8.6 km northeast of Camels Hump; 1.6 km south of Station 490 on Seismic Line P81-U2
1950 AIR PHOTO REFERENCE: Mt Liebig Run 12, number 5090

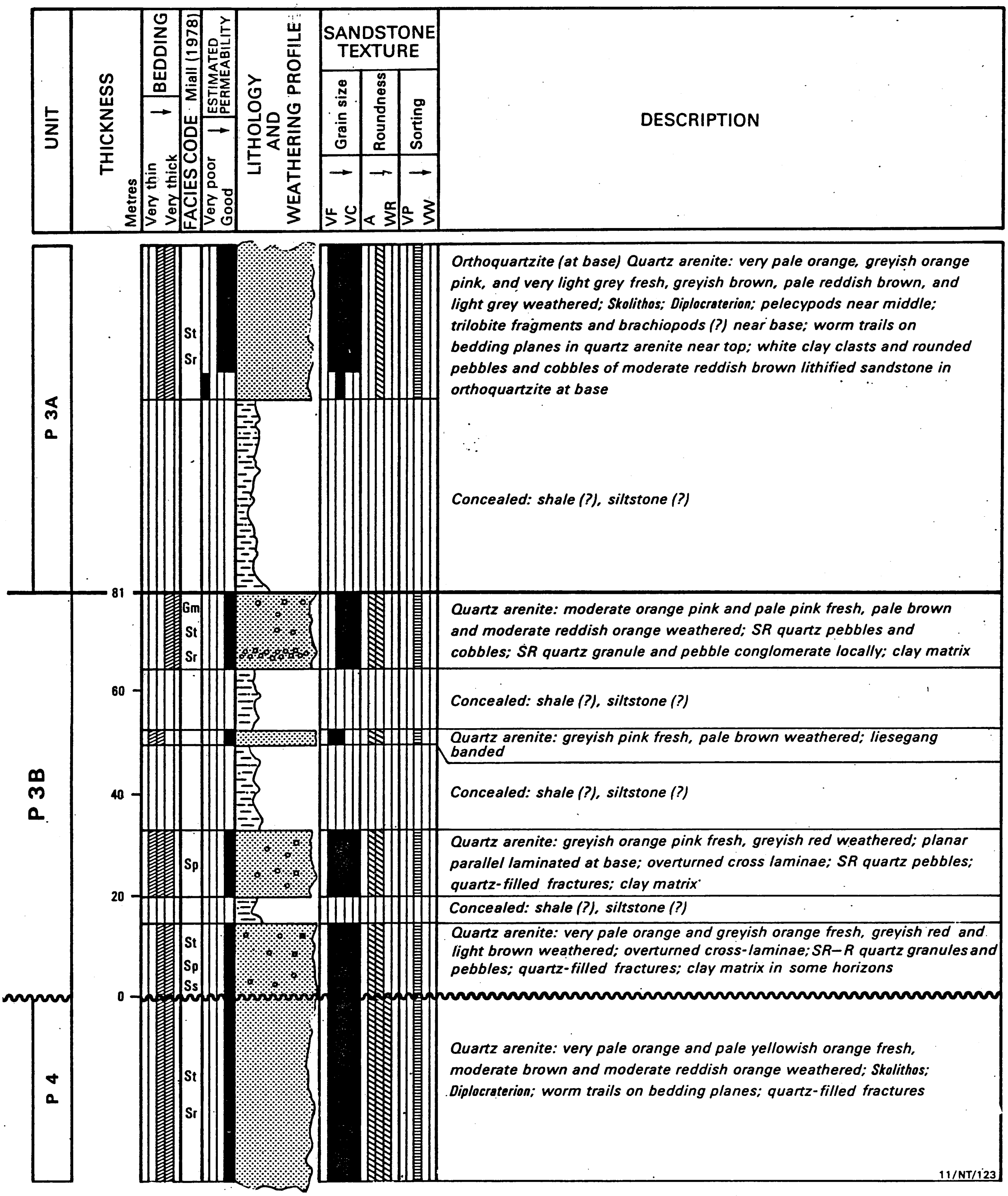


Figure 1. Type section of the P3B unit, Pacoota Sandstone.

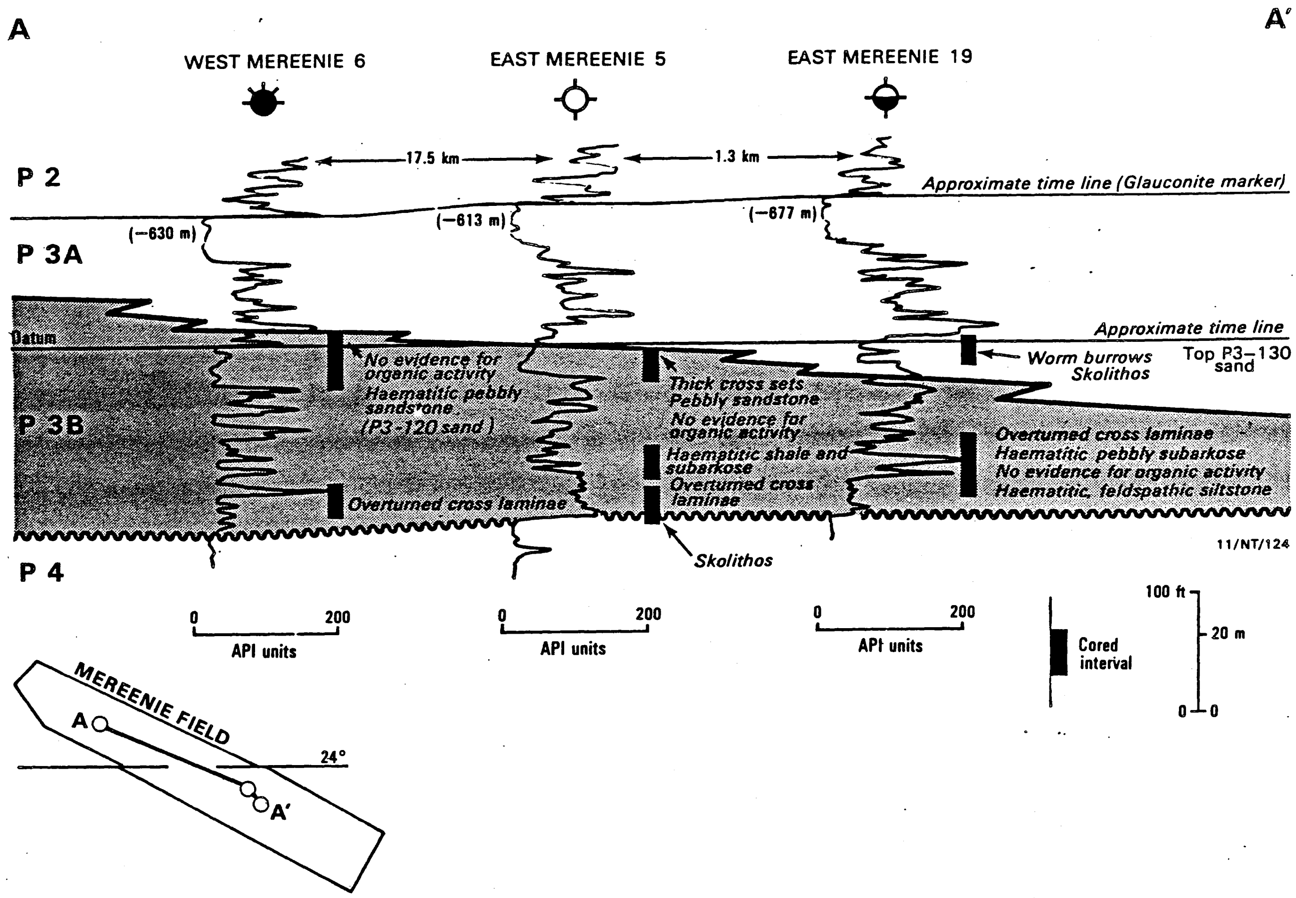


Figure 2. Gamma-ray log correlation diagram showing division of the P3 interval into a lower fluvial unit, the P3B, and upper estuarine and shoreface unit, the P3A.

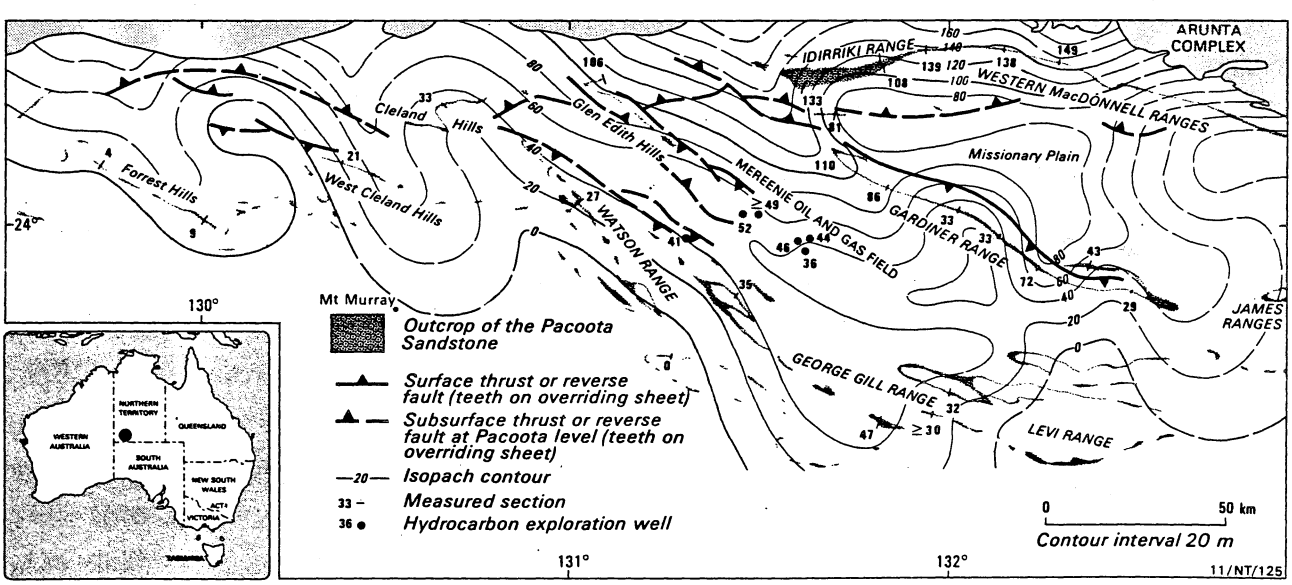


Figure 3. Isopach map of the P3B unit.

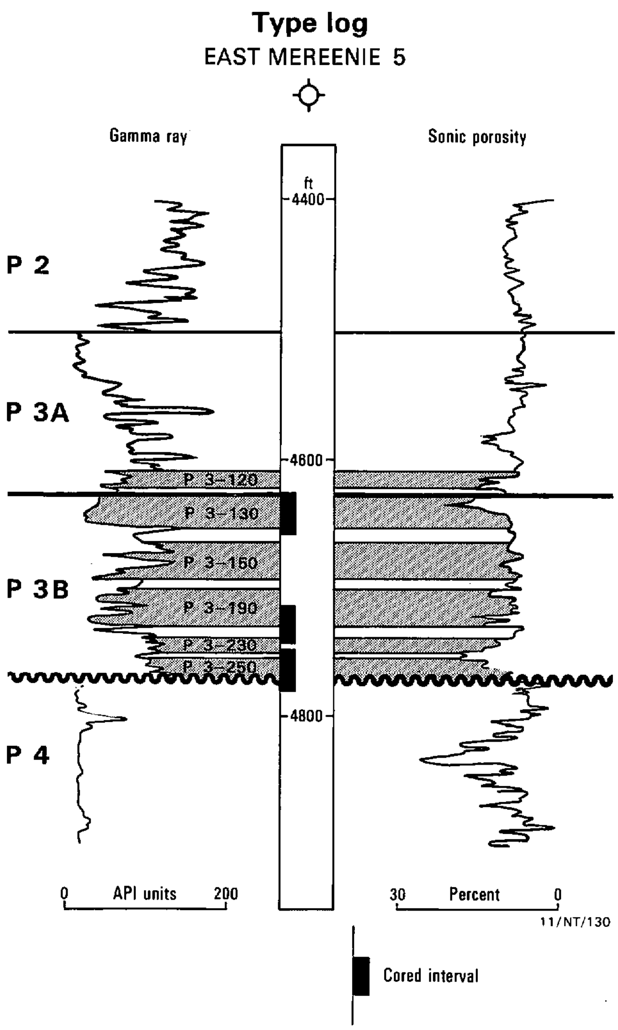


Figure 4. Type log of the P3B unit showing its internal subdivision and relatively high porosity.

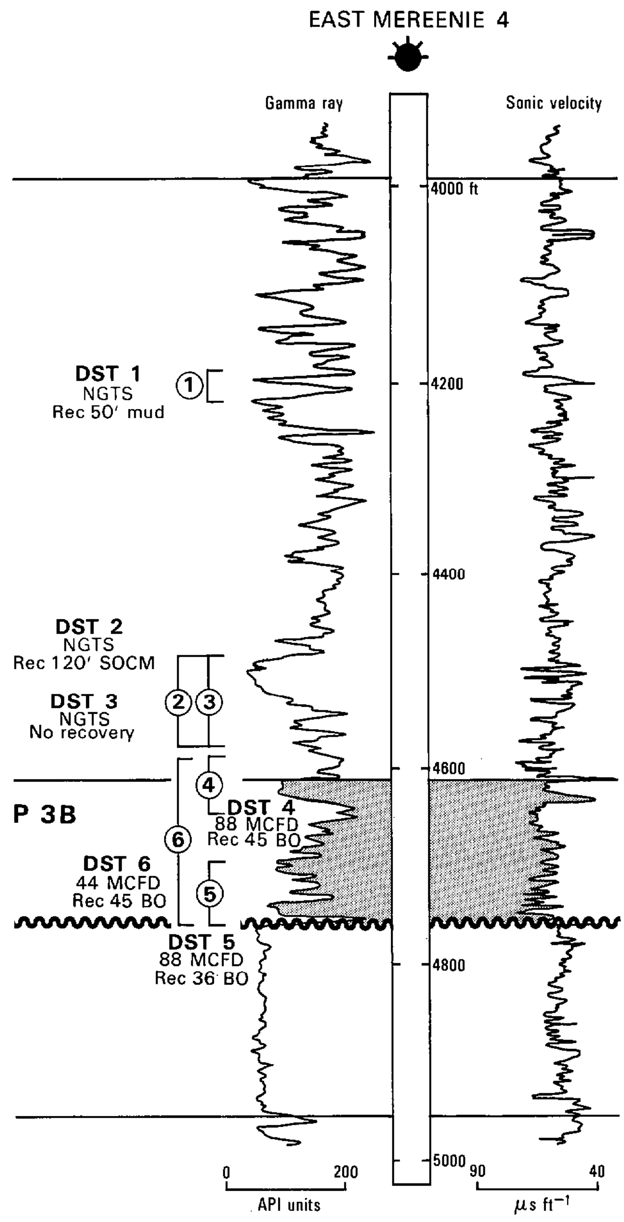


Figure 5. Gamma-ray and sonic log response of the Pacoota Sandstone at East Mereenie 4 well showing the direct correlation of the P3B unit with the primary producing interval at the Mereenie Field.

REMOTE SENSING OF NATURAL GAS SEEPAGE, PALM VALLEY GAS FIELD

Colin J Simpson[2], John R Wilford[2], L F (Taro) Macias[2] & Russell J Korsch[1]
[1] Division of Minerals and Land Use, Bureau of Mineral Resources
[2] Onshore Sedimentary and Petroleum Geology, Bureau of Mineral Resources

The leakage of hydrocarbons from sub-surface traps is thought to be responsible for a number of chemical and botanical changes at the land surface and some of these have been detected by remote sensing (Abrams & others, 1985; Lang & others, 1985).

In 1985 the NASA remote sensing research aircraft and its advanced instruments was flown over 54 Australian sites (Huntington & Simpson, 1985) including a BMR test site on the Palm Valley Gas Field in the Amadeus Basin, Northern Territory. The Palm Valley site was flown to test for signs of hydrocarbon gas seepage and one factor considered during site selection was the dominance of a single rock unit (Hermannsburg Sandstone) in surface exposure. At the time of the Palm Valley data acquisition, no information was available to BMR of any surface sites in petroleum fields in Australia where hydrocarbons were known to have leaked or were currently leaking.

Of the three advanced sensing systems flown over Palm Valley, the 8-band NS001 Thematic Mapper Simulator (TMS), which records bandpasses identical to the 7-band Landsat Thematic Mapper (TM), was of most immediate interest to BMR.

Digital image processing of the TMS data showed a zone of colour (referred to as the colour anomaly) on the surface above the main gas pool at Palm Valley (Fig. 1). The colour anomaly which is approximately 6 km long and up to 1.5 km wide is not obvious on conventional colour aerial photography or Landsat MSS imagery. It has an irregular shape, although the SE side tends to be aligned in part on an ENE orientation which is sub-parallel to a significant fracture system to the SSW of the anomaly. These observations suggested that the colour anomaly was possibly controlled by structure and locally by the stratigraphy. The zone transgressed bedding, and on its southern edge appeared to be confined beneath the base of the uppermost sandstone unit. Detailed examination of the remotely sensed imagery, supported by geomophological examination of colour aerial photography, showed that the colour zone coincided with locally incised drainage, which had eroded through the harder sandstone that forms the uppermost topographic unit of the anticline into a softer sandstone beneath.

Drainage incision on the southern flank of the anticline is topographically and stratigraphically deeper than on the northern flank. The fact that no similar colours showed in areas of equivalent rock exposure on the southern flank of the anticline indicated that the colour zone was anomalous and suggested that its colours did not relate to regional stratigraphy or any associated phenomena such as vegetation.

Field investigations

Field investigations were carried out to try and establish whether the colour anomaly could be an expression of rock alteration related to seeping hydrocarbon gas. Several significant differences between the anomalous zone and similar terrain outside the zone were noted (Table 1). Spinifex grasses are the dominant vegetation species over the anticline; however, within the colour anomaly the spinifex is very sparse or absent, and a low shrub with bluish leaves (*Indigofera leucotricha*) dominates.

INSIDE COLOUR ANOMALY	OUTSIDE COLOUR ANOMALY
Sandstone colour	
Brown	Reddish-orange.
Colour pervasive throughout rock.	Colour restricted to surface weathering. Unweathered interior tends to be white.
Vegetation	
Spinifex very sparse, minor grass. Mostly 'blue' bush (*Indigofera leucotricha*)	Spinifex dominant. No *Indigofera leucotricha*
Secondary carbonate	
Calcrete coats fractures and weathers to a soil and float component.	No calcrete.
Soil pH	
pH 7 - 8	pH 5 - 6

Table 1. Differences observed in the field between the colour anomaly and surrounding terrain of the Palm Valley Anticline.

When all the differences indicated in Table 1 were considered together, the possibility of the colour anomaly resulting from chemical alteration associated with hydrocarbon gases could not be ruled out and a second phase of limited, but specific, investigations was initiated. These involved inorganic geochemistry, carbon and oxygen isotope analysis, a detailed airborne magnetics and gamma spectrometrics survey, and a soil gas survey. With the exception of the latter all other investigations were inconclusive and are not discussed here but are reported in full in Simpson & others (in press).

Soil gas survey results

A soil gas survey, in which the hydrocarbon gas content of selected soil samples is measured, was considered the most likely method of establishing whether any relationship existed between the colour anomaly and the subsurface gas pool. For logistical reasons, the soil gas survey was restricted to the northern flank of the anticline. Sampling was carried out along a traverse A-D across the northern limb of the anticline (Fig. 1) including a section B-C along the colour anomaly.

Each soil gas sample was analysed for five free-alkanes; methane, ethane, propane, iso-butane and n-butane. These alkanes (C1 to C4) are easily volatilised and readily migrate from the underlying reservoirs, to the surface, along fractures and joints and/or through diffusion and groundwater solutions. Threshold values (the concentration of a gas species above which samples are considered anomalous) for each gas type sampled in the Palm Valley survey were as follows: methane 22.1 ppm, ethane 1.13 ppm, propane 0.27 ppm, butane 0.15 ppm, and total gases (C2 + C3 + C4) 1.34 ppm (methane was excluded from the total gas calculation because it can be generated biogenically in the soil). Results from part of a soil gas survey by Magellen Petroleum Australia Ltd were also considered from a survey line located on Hermannsburg Sandstone approximately 6 km east of the colour anomaly and are shown in the X-Y profile plots of Figure 2.

The soil gas profiles for C2+C3+C4 on sample line A-B-C-D (Fig. 2) show that there is a concentration of above-threshold values for each of the gas species sampled on traverse lines B-C which is within the broadest, western sector of the colour anomaly. With soil gas analyses, high values are more significant than low values, and the saw-tooth nature of the profiles resulting from interspersed low values over the western end of the colour anomaly on B-C may reflect atmospheric dilution of those gas samples because of the shallow soils.

Discussion

The overall increase in free-alkane gas concentrations coincident with the colour anomaly detectable in TMS (and in TM) remotely sensed data suggests that the colour anomaly is the surface expression of alteration caused by long-term seepage of hydrocarbon gases. The Landsat TM satellite system therefore has the potential to be a useful and cost-effective tool in hydrocarbon exploration and field development.

It should be noted that the Palm Valley hydrocarbon-related, remotely sensed colour anomaly, the first of its type reported in Australia, is primarily influenced by carbonate-rich soil geochemistry and vegetation. These are variable environmental parameters which, in the case of Palm Valley, are determined by variations both within the local geology and the indigenous arid zone vegetation. The use of Landsat TM in exploration for hydrocarbon gas seepage sites in other environments, both locally (e.g. carbonate-rich lithologies) and regionally, will require additional research. Field verification of the cause of any colour anomaly in remotely sensed data can be difficult. In the case of possible hydrocarbon seepage sites, our results suggest that a controlled soil gas survey is the most reliable approach. Such case documentation may provide stimulation for similar industry applications research in other basin environments.

Grateful acknowledgement is extended to Magellan Petroleum Australia Limited for permission to use data from part of their soil gas survey over Palm Valley Anticline.

References

Abrams, M.J., Conel, J.E., & Lang, R.H., 1985 - The Joint NASA/Geosat Test Case Project Final Report. American Association of Petroleum Geologists, Tulsa, Oklahoma.

Huntington, J., & Simpson, C.J., 1985 - Major new Australian/US remote sensing initiative. The Australian Geologist, 57, 34-5.

Lang, H.R., Alderman, W.H., & Sabins, F.F., Jr., 1985 - Patrick Draw, Wyoming, petroleum test case report. In Abrams, M.J., Conel, J.E., & Lang, R.H. (Eds) The Joint NASA/Geosat Test Case Project Final Report. American Association of Petroleum Geologists, Pt 2, Vol. 2, 11.1-11.112.

Simpson, C.J., Wilford, J.R., Macias, L.F. & Korsch, R.J., 1989 - Satellite detection of natural gas seepage: Palm Valley Gas Field, Amadeus Basin, central Australia. APEA Journal, 29, 196-211.

Simpson, C.J., Wilford, J.R., Macias, L.F. & Korsch, R.J., in press - Remote sensing of natural hydrocarbon seepage at the Palm Valley Gas Field, Amadeus Basin, central Australia. Bureau of Mineral Resources Australia, Bulletin 236.

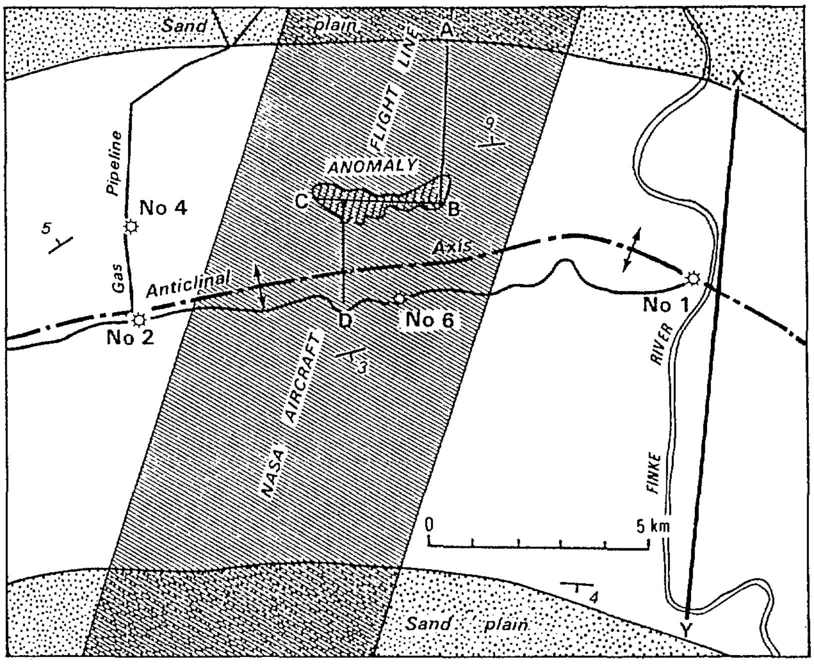


Figure 1. Generalised plan of the Palm Valley Gas Field showing the area imaged by the NASA aircraft research flight, and locations of the remotely sensed colour anomaly and soil gas survey lines (A-B-C-D; X-Y).

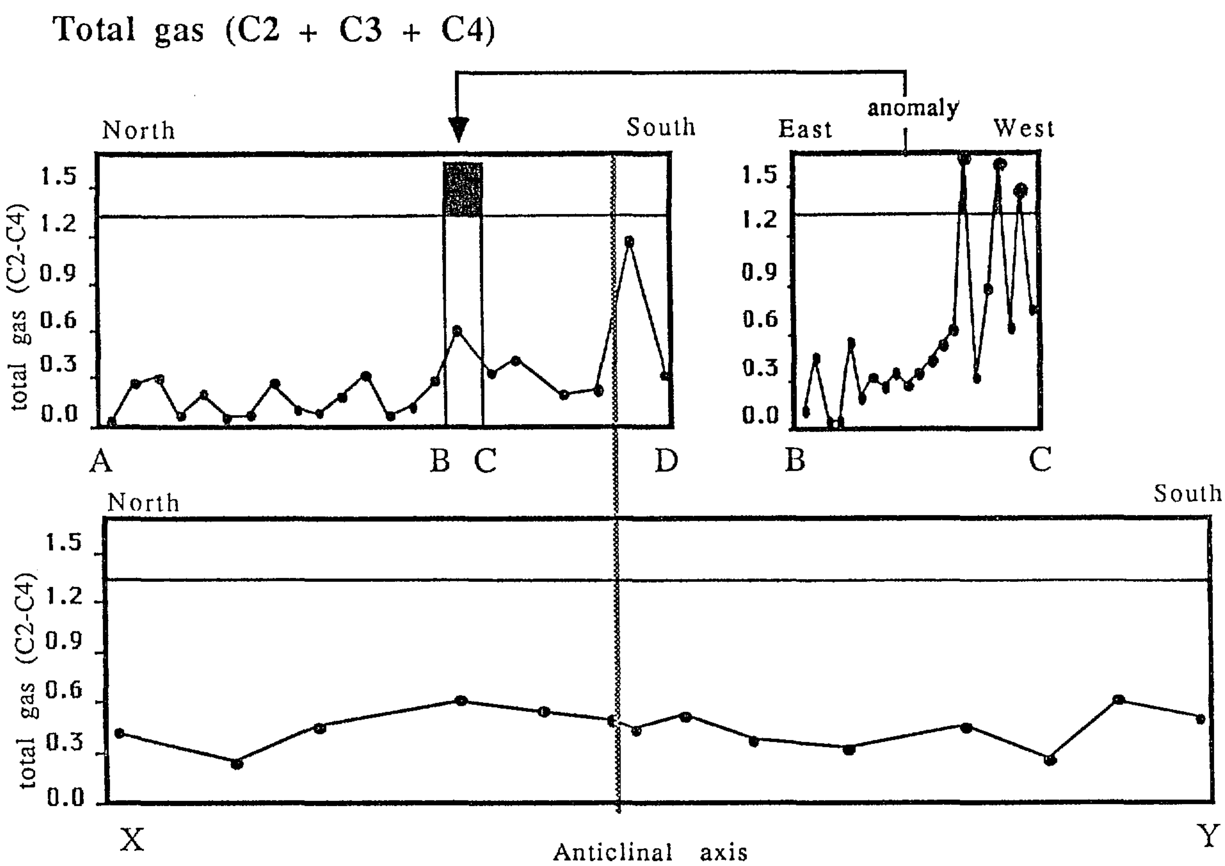


Figure 2. Total soil gas (C2+C3+C4) values (ppm), detected on N-S sample line A-B, C-D, X-Y (see Fig. 2 for line locations in relation to the colour anomaly). Box B-C shows the ground width of the colour anomaly. The height of box B-C equals the maximum soil gas value detected, the point value within the box shows the average of all samples taken within the anomaly. Line B-C (E-W) shows all sample values within the anomaly. Blacked-in values are above the calculated threshold of 1.34ppm. Line X-Y at the same scale gives an indication of soil gas background values for the Hermannsburg Sandstone over the complete anticline.

CURRENT EXPLORATION ACTIVITIES IN THE AMADEUS BASIN: MAGELLAN PETROLEUM AUSTRALIA LTD

Laurence E Roe
Magellan Petroleum Australia Ltd, Brisbane

Magellan Petroleum commenced exploring for oil and gas within the Amadeus Basin in 1960. 29 exploration wells have been drilled in the ensuing 30 years, resulting in the discovery of the Palm Valley Gas Field, the Mereenie Oil and Gas Field and the Dingo Gas Field. Magellan presently operates the Palm Valley Gas Field (OL.3) and the exploration lease OP.175, in which the Dingo field is located. The Mereenie Field (OL.4, OL.5) is operated by AGL (as Moonie Oil).

Palm Valley has been on production since 1983, when the gas pipeline to Alice Springs was completed. In 1986, a pipeline from the Amadeus Basin to Darwin was commissioned - more than doubling production from the field. Recent engineering studies, based on reservoir simulation, have determined the proved in-place reserves to be 845 BCF (970 PJ). At present, the field produces gas at a rate of 22.3 MMCFD, equivalent to an annual rate of 8.13 BCF (9.33 PJ).

Combined uncontracted gas reserves at Palm Valley and Mereenie presently exceed 700 BCF (803 PJ). As a consequence, discussions are being held with three potential customers: Nabalco Pty Ltd for its alumina smelter at Gove; Mt Isa Mines for its mining complex in western Queensland, and; the South Australian government for domestic supply to Adelaide. Further development plans at Palm Valley are contingent on the outcome of these discussions.

OP.175 covers the Eastern part of the Amadeus Basin and contains the Dingo Gas Field where an appraisal well is currently being drilled. In-place proven reserves at Dingo are estimated to be 112 BCF (128 PJ).

The Amadeus Joint Venture is presently reassessing remaining prospects and leads within the lease.

PRELIMINARY DATA FROM WALLARA 1 WELL, EP 20: SIRGO EXPLORATION COMPANY INC.

G Weste
Sirgo Exploration Company Inc.\ Indigo Oil Pty. Ltd., Adelaide

EP 20 was granted to Indigo Oil Pty Ltd in January, 1988. The permit covers the southern flank of the "Central Ridge" and the northern portion of the "southern platform" of the Amadeus Basin, and lies immediately south of OP 175 and north of EP 26. Satellite imagery interpretation, followed up by airborne and soil gas micro-seepage surveys, were carried out to June 1990 when Sirgo Exploration Company Inc. farmed into the permit. Sirgo are earning a majority interest in EP 20 by meeting the permit seismic and drilling commitments. To date Sirgo has drilled one well (Wallara 1) and has acquired 76 km of seismic data. The permit commitments for 1991 are the acquisition and processing of 100 km of seismic data.

Wallara 1 was drilled in July-August 1990 as a combined stratigraphic well and test of a broad soil gas micro-seepage anomaly. The well location (1.6 km north of Wallara Ranch, 180 km southwest of Alice Springs) is of interest because it lies midway between the "northern" Amadeus Basin wells (e.g. Tent Hill 1, 52 km to the northwest, and Finke 1, 80 km to the northeast) and the "southern" Amadeus Basin wells (e.g. Erldunda 1, 214 km to the southwest). Stratigraphic data from this intermediate area will assist correlation of the northern and southern stratigraphic units of the basin.

Wallara 1 was drilled as a "slim-hole" and was fully cored from 334 m to total depth 2001 m. The well was spudded in Cambrian sediments and terminated in the ?top of the Gillen Member of the Bitter Springs Formation. No significant oil or gas shows were detected. An anticlinal structure evident on the closest seismic line, Sydney Oil line WR-05, appeared to trend west for 4 km to the Wallara soil gas anomaly. Recently acquired seismic data indicates that the anticline is terminated east of Wallara 1 and that the well was sited off structure. This resulted in the secondary objective (below the Gillen salt) being deeper than the drill's capacity.

Detailed stratigraphic correlation of Wallara 1 is not yet complete. Initial interpretation indicates that the base of the Cambrian may be at 714 m. Scattered poor outcrops in the vicinity of the well site are mapped on the 1:250 000 Henbury geological sheet as

Goyder Formation. The Cambrian interval consists of oxidised siltstone and minor poorly sorted sandstone. An 89 m thick red-brown sandstone with abundant silt and clay matrix and a thin basal pebbly sandstone may be equivalent to the Arumbera Sandstone. The Cambrian section is underlain by a 558 m thick grey siltstone unit deposited by turbidity flows well below wave base. This unit could be assigned to the Pertatataka Formation or to its southern equivalent, the Winnall Beds. An underlying 152 m thick diamictite is probable Areyonga Formation or equivalent Inindia Beds. A 86 m thick dolostone-shale-sandstone unit unconformably underlies the diamictite and is probable Finke Beds. Alternatively, this unit could be included within the Inindia Beds. 282 m of interbedded oxidised siltstone and dolostone correlate well with the upper "lacustrine" portion of the Loves Creek Member of the Bitter Springs Formation and also with the Johnny Creek Beds as described in other exploration wells. This unit has distinct erosional unconformities at its top and base, and warrants formation status. 204 m of stromatolitic dolostone represents the "marine" portion of the Loves Creek Member of the Bitter Springs Formation. The basal 5 m in Wallara 1 consists of dolostone disrupted by anhydrite which comprises 60% of this interval. This may represent the top of the Gillen Member of the Bitter Springs Formation.

Although no significant hydrocarbon shows were detected in Wallara 1, visible porosity of up to 12% was observed in Cambrian sandstones, and vuggy porosity occurs in dolostones of the Bitter Springs Formation. Source rock analyses have yet to be carried out.