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Preliminary Report on Total Organic Carbon (TOC) Content and Potential Source Rocks in the Cambrian Sequence of the Amadeus Basin, OP 175 & OP 178 of the Northern Territory, Australia.

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ABSTRACT

Good potential hydrocarbon source rocks appear to be undeveloped in the Cambrian sequence of the Amadeus Basin. This preliminary study of wells drilled in the basin, based primarily on total organic carbon measurements of core and cuttings, has indicated that only marginal source facies exist in the eastern part of the basin during Early Cambrian time, and the northeastern region during later Middle and Late Cambrian time.

INTRODUCTION

Since 1963, when Alice-1 discovered non-commercial 43 API^{o} oil in the Middle Cambrian Giles Creek Dolomite, and a small amount of asphaltic oil in the Late Cambrian Shannon Limestone (Pemberton et al., 1963), the Cambrian section in the eastern part of the Amadeus Basin (Figure 1) has been regarded as containing potential oil source rocks (Wells et al., 1970, page 154; Pearson & Benbow, 1976). However, no comprehensive geochemical studies to locate and qualify these putative source rocks had been undertaken until McKirdy (1977) presented an overview of the basin-wide source potential of the Late Proterozoic to Middle Ordovician sequence. McKirdy commented (p. 185):

> "Despite ample evidence that petroleum generation has occurred in the Amadeus Basin, no systematic geochemical study of the reservoir hydrocarbons themselves, nor of the sediments considered to be their source, has previously been undertaken. This is surprising, particularly in view of the increasingly important role being played by organic geochemistry in the current worldwide search for oil, both onshore and offshore ..... In the case of the Amadeus Basin, insufficient organic geochemical information is available to provide a clear regional picture of source-rock quality, volume and thermal maturity, all essential ingredients of any quantitative estimate of a basin's petroleum potential."

While an important step in the right direction, McKirdy's study was, of necessity, only an introduction to the problem of locating source rocks in the basin. McKirdy's work concentrated on core material and may not necessarily reflect the true source potential present in a particular formation.

Following McKirdy's study, no further geochemical work was undertaken in the Amadeus Basin until 1980, when Pancontinental Petroleum Limited assumed operatorship of the two major petroleum exploration permits in the basin (Operating Permits 175 and 178). At the same time, the Bureau of Mineral Resources (BMR) commenced a programme of shallow stratigraphic drilling in search of source rocks in the Late Proterozoic and Cambrian sequence of the eastern Amadeus Basin (Felton, 1981).

This report incorporates the results of analyses on behalf of Pancontinental Petroleum Limited, studies by other companies and the Australian Bureau of Mineral Resources (BMR) (McKirdy, 1977; Felton, 1981), into a comprehensive interpretation of the petroleum potential of the Cambrian sequence of the Amadeus Basin.

Methods and Materials

Kerogen is the principal precursor substance to oil and gas. The amount of kerogen can be approximated by measuring the quantity of organically derived carbon in sedimentary rocks.

Potential source rocks are distinguished by total organic carbon measurements (TOC), the amount of extractable organic matter (EOM) determined chemically or by the Rock-Eval pyrolysis method (S_1 peak), elemental analyses (hydrogen to carbon ratios, H/C) and other parameters.

Tissot & Welte (1978) showed that clastic rocks that are sources for petroleum should contain a minimum of 0.5 wt % of organic carbon, and that most good source rocks contain an average of about 2.0 wt %. Moreover, according to Momper (1978), if primary migration of petroleum from source rocks is to occur, the source rocks must contain at least 0.4 wt % organic carbon, provided the carbon is in hydrogen-rich kerogen (ie. Type II to I kerogen), but kerogens which contain relatively low amounts of hydrogen (ie. Type II-III) may require as much as 0.8 to 1.2 wt % organic carbon (1.0 to 1.5 wt % organic matter).

A further measure of source rock potential can be gained from the amount of extractable organic matter (EOM). Tissot & Welte (1978) stated that an average of 300 ppm hydrocarbons can usually be extracted from non-reservoir (ie. non source facies) rocks in basins that contain petroleum, and that a minimum of 800 ppm hydrocarbons can be extracted from source rocks in such basins. Momper (1978) reported that 825 to 850 ppm extractable hydrocarbons are needed before oil can migrate from source rocks. Hunt (1979), however, stated that adequate source rocks can have as little as 50 to 150 ppm extractable hydrocarbons.

Most petroleum generation occurs through the thermal conversion of kerogen during burial under the effects of temperature and time. Maturation of source rocks can be simulated by whole-rock pyrolysis in the laboratory, eg. the Rock-Eval Pyrolysis method.

In this study, much use has been made of the Rock-Eval pyrolysis technique (Espitalié et al., 1977) because it is a relatively rapid and inexpensive method of catagorizing potential source rocks. Rock-Eval measurements used in this study are bulk measurements made on ditch cutting samples over either 10 or 15 metre intervals down the bore hole, and yield average values. While it is realised that geochemical analyses of bulked ditch cuttings can be misleading, because they contain no information about the type of organic matter contained, the amount of possible caving, reworked material or mud additives (Jones & Edison, 1978), careful interpretation of the pyrolysis data supplemented by additional information, derived from cores and optical or reflectance microscophy of picked cuttings, should allow meaningful conclusions to be drawn.

A second limitation to the usefulness of the Rock-Eval analyses for source rock identification is that they can only be applied directly to calculations of oil-generative capacity if the kerogens being pyrolyzed are immature (Waples, 1981), because the Hydrogen Index of the source rock kerogen is decreased by migration of matured petroleum hydrocarbons. Thus, where source rocks are mature, Rock-Eval pyrolysis will give lower source potential than originally was present. The amount the values are lowered depends on the type of original organic matter: ie. type I kerogens (hydrogen rich) will be progressively more depleted in hydrogen under advancing maturation than the more humic type II or III kerogens.

Samples for geochemical analyses were selected on the following criteria:

a. Dark grey or brown coloured shale, siltstone or carbonate;
b. Association with a hydrocarbon show;
c. Availability of samples (eg. some wells are poorly represented by samples in government or industry core stores).

A listing of the sources of the samples analysed is presented in the Appendix.

50 gms of sample were taken where possible. Fresh material, both of core and cuttings, was only available from Wallaby-1, Dingo-1 and Mt. Winter-1, all the other wells being drilled between 1963 and 1966. Cuttings in these older wells were generally oven dried. As both the length of storage time and the method of drying will have adversely affected the contained organic matter in the older samples, more credence should be placed on the open air dried, and recently collected, material from Wallaby-1, Dingo-1 and Mt. Winter-1.

Samples were analysed for organic richness (Total Organic Carbon content, TOC) because organic richness is the first requirement for an oil or gas source rock. The analysis was used as a screening technique to determine which samples merited more detailed analysis, such as the Rock-Eval Pyrolysis technique (Espitalié et al., 1977).

Selected samples were also examined by Marchioni & Associates for source rock potential and maturation levels using optical fluorescence and reflectance techniques.

Stratigraphy and Depositional Environments

Wells et al. (1970) have detailed the geology of the Cambrian sequence of the Amadeus Basin. A modified stratigraphic table based on their data is presented in Figure 2. The following geological history of the Cambrian Period in the basin is modified from Wells (1976).

Isostatic uplift followed the Petermann Ranges Orogeny near the southwestern margin of the basin and provided the source of the Cambrian sediments. Gravel and feldspathic sand (Mount Currie Conglomerate and arkose at Ayers Rock) were deposited close to the uplifted area. Farther north, deltaic sands (Cleland Sandstone) were deposited; to the northeast the sands interfinger with sandstone, shale, and some marine shale and carbonate rock (Eninta Sandstone, Tempe Formation, Illara Sandstone, Deception Siltstone, and Petermann Sandstone). The predominantly clastic sediments are thinner in a north-south zone near the centre of the basin, which was probably sinking less quickly during the sedimentation. To the east, about 2000 metres of predominantly carbonate rocks and

AMADEUS BASIN

GENERALIZED STATIGRAPHIC TABLE – OP 175 & OP178

AGE	GROUP	FORMATIONS — WEST	FORMATIONS — CENTRAL	FORMATIONS — EAST	OROGENIES
TERTIARY – RECENT		Surficial deposits - Lakes, rivers and dunes.			
PERMIAN		Buck Formation	?	?	
LATE DEVONIAN	PERTNJARA	Undiffer-entiated	Brewer Conglom-erate	Undandita Member Brewer Conglomerate Ljiltera Member	ALICE SPRINGS
			Hermannsburg S'st	Hermannsburg S'st.	
			Parke Siltstone	Amulda Member Dare Siltstone Harajica Sandstone Deering Siltstone	PERTNJARA
SILURO-DEVONIAN		MEREENIE		SANDSTONE	RODINGAN
? LATE ORDOVICIAN	LARAPINTA	Gosse's Bluff S'st.			
MIDDLE ORDOVICIAN		Carmichael S'stone	Rodingan		
?—— ——? MIDDLE ORDOVICIAN		Stokes Formation	Erosion		
		Stairway Sandstone			
EARLY ORDOVICIAN		Horn Valley Siltstone			
		Pacoota Sandstone	N'dhala Member		
LATE CAMBRIAN	PERTAOORRTA	Goyder Formation			UNNAMED
MIDDLE CAMBRIAN		Cleland Sandstone: Petermann S'st, Deception Siltst., Illara Fm.	Jay Ck.	Shannon Fm	
			Hugh River Shale		
		Tempe Fm.	Giles Ck	Giles Ck Dolomite	
EARLY CAMBRIAN		Mt Currie Conglomerate	Enita Formation/ Quandong Conglomerate	Chandler Fm. Todd Rv. Dolomite Arumberra S'st. 3,4.	PETERMANN RANGE
LATE PROTEROZOIC		?	?	? Arumberra S'st. 1,2.	
VENDIAN		Maurice Formation	? Julie Fm.	Julie Formation	
		Sir Frederick Conglom./ Ellis Sandstone	Winnall Beds	Pertatataka Fm. (Cyclops Member)	
? VENDIAN – RIPHEAN		? Carnegie Formation /	Inindia	Pioneer S'st/Olympic Fm	SOUTHS RANGE
		Boord Formation	Beds	Aralka Formation	
				Areyonga Formation	AREYONGA
? LATE RIPHEAN			Bitter Springs Formations	Loves Creek Member Gillen Member	
			Heavitree Quartzite		ARUNTA
PRECAMBRIAN			Arunta Complex		

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FIGURE 2

silts were deposited in the northeastern part of the basin. The Arumbera Sandstone, the basal formation of the Pertaoorrta Group in the northeast, was overlain successively by carbonate rocks (Todd River Dolomite), evaporites (Chandler Formation), penesaline and marine stromatolitic carbonate rocks (Giles Creek Dolomite and Shannon Formation), and calcareous silt and silty sand (Goyder Formation). The Arumbera Sandstone and Goyder Formation show only minor facies changes across the central zone, indicating more uniform subsidence and widespread supply and distribution of detritus. The Jay Creek Limestone and Hugh River Shale are predominantly fine clastic units that occupy the area central to the coarser clastics in the west and the carbonate/evaporite deposits in the east.

DISTRIBUTION OF POTENTIAL CAMBRIAN SOURCE ROCKS

Cook (1982) has presented six palaeogeographic maps of the Australian continent throughout Cambrian time, and used them to model the distribution of depositional environments conducive to the preservation of potential hydrocarbon source rocks. While I am not in complete agreement with Cook's stratigraphic correlations, presented in his Figure 2, the scheme does provide a convenient frame-work in which to consider the Cambrian source rock potential of the Amadeus Basin. Consequently, the following discussion will be placed in the context of a modified form of Cook's six time interval (TI) maps, or bio-chronological intervals.

The five time interval maps produced (Figures 3 to 7) are compiled from the existing data. TOC values have been averaged by addition of the measurements from the analysed samples (not the complete interval thickness) divided by the thickness of the sampled interval. The resulting maps are unavoidably biased for the following reasons:-

1. incomplete sampling of total interval at all wells
2. subjective selection of samples to be analysed (eg. the darkest grey coloured material preferentially chosen)
3. spot samples from cores and biased towards the selection of the most obvious source facies (eg. Alice-1)
4. core material only used (eg. Alice-1) with little supplementary cuttings analysis (cost and availability of sample limitations)
5. variations between different laboratories.

Consequently, the maximum TOC value has also been added to the maps in an attempt to delineate richness trends. This value is also subject to the above mentioned vagaries.

A further major problem is the sparse data coverage, caused primarily by the vast area considered and the very low density of wells penetrating the Cambrian sequence.

Nevertheless, despite these obvious shortcomings, the time interval maps are valuable tools for localization of prospective source rock facies in the Amadeus Basin. The various maps are discussed sequentially below.

TI 1/2 Early Cambrian to Ordian (Figure 3)

This time interval includes the following formations:-

Chandler Formation
Todd River Dolomite and Todd River Equivalent
Arumbera Sandstone (including Quandong Conglomerate and Eninta Formation)

The source rock potential of these units is discussed below:-

Chandler Formation (Early Cambrian - Ordian)

The Chandler Formation thickens to the south away from the north-eastern Amadeus Basin, where it is in part represented by carbonate of the Todd River Dolomite. Outcrops of the Chandler Formation consist of limestone, dolomite and interlaminated chert; evaporites and shale are present in the subsurface. The unit dominantly comprises halite and other evaporitic minerals (anhydrite, gypsum), but contains discrete carbonate and clastic intervals. One such interval is correlatable from Wallaby-1 to Dingo-1 and has hydrocarbon shows.

Total organic carbon values in the Chandler are generally lower than 0.10%, but richer pockets are present : 0.41% was measured in Wallaby-1 in the carbonate/clastic unit mentioned above. Felton (1981) records up to 3.0% TOC in core at 108.9 metres in BMR Rodinga-1A, but apart from three samples (93.0 metres, 119.8 metres and 133.0 metres), all other samples from this well measured less than 0.20% TOC (Felton, 1981). Average TOC for the Chandler Formation at Rodinga-1A is 0.45%. The highest TOC values occur in bituminous dolomite (0.75% at 133.0 metres), dark grey shale (0.70% at 119.8 metres) or dark brown shale (3.0% at 93.0 metres).

Bituminous carbonates and clastics also occur in Dingo-1 (TOC 0.17% from 2490 - 2530 metres) and, where the unit outcrops, similar bituminous rocks consistently produce a petroliferous odour when struck with a hammer. The only measurement from the Chandler Formation from Dingo-1 was from a cuttings sample selected from the most bituminous material available on visual inspection. It is therefore impossible to give an average TOC value.

McKirdy (1977) showed that hydrocarbons isolated from core 26 in the Chandler Formation of Alice-1 were probably allochthonous (migrated) because of the relatively high saturate/aromatic ratio of the extractable organic matter (EOM). The EOM yield was also very high in this core, which had a TOC value of less than 0.01%. The few measurements available from Alice-1 are from core and may not reflect the maximum TOC present.

At Highway-1, the average TOC is 0.17% but the maximum is only 0.23%. The high oxygen index and low hydrogen index indicate that any future hydrocarbon expelled from these rocks will be gas.

The Chandler Formation must be considered to contain source rock intervals on the criterion of Tissot & Welte (1978) of greater than 0.5% TOC for clastic rocks, especially, as is generally conceded, 0.3% may be adequate for carbonate rocks (Ronov, 1958). On the criterion of Momper (1978) of the 0.4% wt % TOC requirement for primary migration, parts of the Chandler Formation must be considered as potential source rocks.

Todd River Dolomite and Todd River Equivalent (Early Cambrian)

Neither the Todd River Dolomite, which occurs in and outcrops eastwards of Wallaby-1, nor the clastic Todd River Equivalent, which extends westward and southward from Wallaby-1, contain sufficient TOC to constitute source rock facies. The dolomites are generally light coloured or pink, reflecting an oxidizing environment of deposition. The equivalent clastics are of red-bed lithology, also not conducive to the preservation of organic matter.

Arumbera Sandstone (Late Proterozoic(?) - Early Cambrian)

Only Wallaby-1 and Dingo-1 have penetrated complete thicknesses of Arumbera Sandstone. Few analyses were made in this predominantly red-bed, intertidal to fluviatile sequence, and those that were measured proved to contain very low total organic carbon values. The exception was core 10 in Orange-1, where 0.44% TOC was measured in red brown siltstone. This occurrence was regarded as a residual oil show by Core Laboratories (1981a).

McKirdy (1977) thought that siltstone in the upper part of the Arumbera Sandstone at 2292.1 metres in Alice-1 had been flushed, although he suggested that the low EOM concentration (4 ppm, 6 mg/g C) could also be a primary feature of red-beds.

Gas shows in the basal beds of the Arumbera Sandstone at Wallaby-1 and Dingo-1 may have been derived from the underlying dark grey and black shales of the Late Proterozoic Pertatataka Formation.

Eninta Formation (Early Cambrian)

Geochemical data is only available for the Eninta Formation in East Johnny's Creek-1, where 0.08 - 0.12% TOC were measured between 1478 metres and 1500 metres.

Quandong Conglomerate (?Early Cambrian)

No source rock analysis has been made on this formation, but the lithology and depositional environment of the unit preclude the development of potential source facies.

Discussion

Figure 3 illustrates the sparse spread of data points and the approximate depositional limits of the various major rock units in Time Interval 1/2. To the west of the depositional limit of the Chandler Formation evaporites, the interval is dominantly represented by sandstone and consequently the source rock potential is slight. In the northeast, where the evaporitic sediments are replaced by the Todd River Dolomite, the source rock potential is low. The best potential source facies appears to be developed in the interfingering zone between the Todd River Dolomite "reefal" facies and the Chandler Formation evaporites (eg. Wallaby-1 and Rodinga-1A), but potential sources may also be present in the dolomite/shale units within the Chandler itself. Prediction of these latter units is not yet possible on the data available, however, the interfingering zone should be discernable on seismic data and predictable from mapped surface trends.

TI 3 Middle Cambrian (Templetonian) Figure 4

Formations included in TI 3 include the following:-

Giles Creek Dolomite
Tempe Formation
Cleland Sandstone (in part)
Jay Creek Limestone (in part)

Giles Creek Dolomite (Middle Cambrian)

The Giles Creek Dolomite is readily divisible on logs into four distinct units, the Upper, Middle and Lower Giles Creek Dolomite and the Dingo Member. The Lower Giles Creek Dolomite is dominantly clastic and has been correlated with the Chandler Formation by others (eg. R. Oaks, personal communication, 1981). Carbonate content in the upper two units decreases to the south, especially in the Upper Giles Creek. The Middle Giles Creek Dolomite is consistently the most calcareous. A basal, massive dolomite bed is easily correlated south from Wallaby-1 to Dingo-1, but probably thins southwards to be absent at Highway-1. The Dingo Member, a thin, sandier unit at the base of the Giles Creek Dolomite, may represent a basal, transgressive sand.

Upper Giles Creek Dolomite

In the northeastern area, in Alice-1, the upper unit reaches 0.96% TOC (ESSO, 1965) in selected samples, but averages less than 0.10%. TOC content is still lower in Orange-1, possibly reflecting a probably more oxidizing environment in the south. Oil and gas shows were encountered in the Upper Giles Creek at Alice-1 and Wallaby-1, but, significantly, there were no shows at Orange-1, Dingo-1 or Highway-1 (ie. to the southwest).

McKirdy (1977) carried out extensive analyses on cores 19, 20, 22, and 23 from the Upper Giles Creek Dolomite at Alice-1. He concluded that the extremely low proportion of saturates in the extractable (soluble) organic matter of shales from core 23 was only explicable if saturated hydrocarbons had preferentially migrated from the shales into the interbedded dolomites. The dark brown, high gravity (43° API) oil which bled from tight dolomite (core 23) over the interval 1864.2 - 1868.4 metres (Pemberton et al., 1963) is strong evidence that migration of hydrocarbons has occurred into this part of the section. Further evidence for migration is suggested by the comparatively high yield of extract from anhydritic dolomite in core 23, which had a high saturate/aromatic value.

The pristane/phytane ratios of the anhydritic dolomite (0.5) and the dolomitic shale (0.7) of core 23 (McKirdy, 1977, Table 6.11) are significantly different to that obtained from the oil that bled from the core (1.4, McKirdy, 1977, Table 6.20) to suggest that the oil is migrated. However, a problem in using pristane/ phytane ratios for correlation purposes is the uncertain effects of thermal maturation (Didyk et al., 1978).

Carbon isotopes can also be used to correlate between oil and source rocks. While for a genetically related series, kerogen-source rock-hydrocarbon-crude oil, the carbon isotope values become increasingly negative from the kerogen through to the crude oil (Silverman, 1964), the carbon isotope values of the shales in core 23 (-30.8) and the oil (-28.8) are sufficiently different (ie. 2 or more units) to suggest that a separate source rock for the oil in core 23 is likely (see Waples, 1981). Moreover, kerogen from the shale in core 23 is Type III (McKirdy, 1977), and should have produced mainly gas rather than oil, especially at the low thermal maturity (0.55% R_o, Saxby & Bruen, 1978). The evidence suggests the oil in core 23 has migrated from oil prone kerogens in mature source rocks deeper than the Upper Giles Creek Dolomite section penetrated by Alice-1.

Middle Giles Creek Dolomite

TOC values in this dominantly carbonate unit average less than 0.10% : no source potential is apparent on the criterion of Tissot & Welte (1978). However, in Highway-1, TOC values of 0.25% were measured (Core Laboratories, 1982b) in cuttings from the lower part of the unit, suggesting possible richer pockets of organic matter may be present.

Lower Giles Creek Dolomite

This dominantly red brown coloured fine clastic unit has no source rock potential. Average TOC values are consistently below 0.10%, except for cuttings from the 808 - 830 metres section at Highway-1 (0.23%). This interval also includes the basal Middle Giles Creek Dolomite : the high TOC measured may be mostly from the overlying unit (Core Laboratories, 1982b).

Dingo Member

The Dingo Member was first recognised in Dingo-1 (Gorter et al., 1982b), where it consists of a coarsening upward clastic unit with good porosity in the upper part. The unit is also recognisable on log characteristics in other wells in the eastern Amadeus Basin. Gas shows at Orange-1 may be from this unit.

The Dingo Member may represent the transgression that spread over the eastern Amadeus Basin immediately post-Chandler evaporite deposition. The unit has no source rock characteristics, but may prove to be a good reservoir in other parts of the basin.

Tempe Formation (Middle Cambrian)

Outcrops of the Tempe Formation in the Parana Hill anticline have a foetid odour (Ranford et al., 1965) which may indicate the presence of hydrocarbons, but there are no known source rock studies on surface samples from this formation.

In the subsurface, geochemical work has been carried out on the Tempe Formation in only three wells: East Johnny's Creek-1, East Mereenie-4 and Mt. Winter-1 (Core Laboratories, 1981, 1982). In East Johnny's Creek-1 and Mt. Winter-1, the shales and siltstones are generally dark grey in colour, but have consistently low (ie. less than 0.10%) TOC content. The dark colour of these fine clastics, and the foetid odour, may indicate the presence of finely divided pyrite and not organic matter. The Tempe Formation appears to have little if any source rock potential but should form a good seal over porous sands in the Eninta Formation or kaast porosity in older carbonates.

East Mereenie-4 has marginally better source rock potential in the Tempe Formation with TOCs of 0.16 - 0.20% recorded between 2469 metres and 2560 metres. If the foetid odours from the formation at Parana Hill are indicative of hydrocarbons, the source rock potential may be increasing to the north and east of the East Johnny's Creek-1 area, ie. towards the Jay Creek Limestone facies.

Jay Creek Limestone (Middle Cambrian in part)

There are no source rock analyses from rocks of undoubted Middle Cambrian Jay Creek Limestone.

Cleland Sandstone (Middle Cambrian in part)

The sandstone lithology of the formation precludes the development of source rock facies.

Discussion

Figure 4 illustrates the distribution of the various rock units included in Time Interval 3 and the spread of data points. There is no information for the central region.

The Giles Creek Dolomite has been shown to be generally non-source, although richer TOC pockets may exist. The oil shows recorded in the upper part of the unit at Alice-1 have migrated from deeper source rocks, possibly the Chandler Formation which has been shown to have potential source facies to the east of Wallaby-1.

The Tempe Formation, consistently dark grey in the subsurface and with a foetid odour in outcrop, has been considerably downgraded as a potential source rock to the west on the results to hand, but may improve in richness to the northeast of East Mereenie-4.

In general, TI 3 is devoid of hydrocarbon source rock potential.

TI 4 Middle Cambrian (Floran to Undillan) Figure 5

Formations in this interval include:-

Hugh River Shale
Deception Siltstone
Illara Sandstone
Jay Creek Limestone (in part)
Cleland Sandstone (in part)

Hugh River Shale (Middle Cambrian)

The Hugh River Shale is divisible into three units, based on the relative percentages of clastics and carbonates. The middle unit is dominantly reddish siltstone and shale while the upper and lower units contain up to forty percent carbonate.

TOC values in the Hugh River Shale are always less than 0.10%, reflecting the generally oxidizing conditions of deposition. The Hugh River is consequently regarded as non-source.

Deception Siltstone (Middle Cambrian)

The Deception Siltstone is dominantly a fine clastic unit which becomes more sandy to the west. The siltstone and shale is red brown, purple brown or grey green : these colours are generally indicative of non-source facies.

Little source rock information is available for the Deception Siltstone. Cuttings from 1966 to 2073 metres in East Mereenie-4 have a TOC content of 0.07 to 0.15%, and core 5 from the same well (1968.7 metres) has a low TOC of 0.09%. Dark grey shale from the same core are barren and contain rare, very thin graphite flakes. The dark colour of the shales is derived from the presence of very small flakes of detrital mica (A. Kantsler, letter 1980).

Cuttings from East Johnny's Creek-1 between 890 - 893 metres had a TOC of 0.13%.

The low TOC values and the general red-bed lithologies preclude the Deception Siltstone as a potential source of hydrocarbons.

Illara Sandstone

In East Johnny's Creek-1, the Illara Sandstone contains siltstone and shale beds with up to 0.10% TOC and shale in East Mereenie-4 contained up to 0.08% TOC. The unit is not considered to contain potential source rocks.

Jay Creek Limestone (Middle Cambrian in part)

There are no analyses of potential source rocks from known Floran to Undillan rocks in this formation.

Cleland Sandstone (Middle Cambrian in part)

There are no known source rocks present in this formation, which is confined to the area west and southwest of the approximate depositional limit of the fine clastic facies shown in Figure 5.

Discussion

Figure 5 illustrates the spread of analyses available for rocks in Time Interval 4. No source rock potential is apparent and no trends are indicated.

TI 5 Middle to Late Cambrian (Boomerangian to Mid Idamean) Figure 6

Formations in this interval include:-

Shannon Formation
Jay Creek Limestone (in part)
Petermann Sandstone
Cleland Sandstone (in part)

Upper Shannon Formation (Late Cambrian)

The Shannon Formation comprises siltstone, oolitic limestone and dolomite containing stromatolite colonies (Wells et al., 1970). The formation has been subdivided into the Upper and Lower Shannon Formations (Gorter et al., 1982a) in the subsurface. The Lower Shannon Formation contains a higher clastic content than the Upper Shannon and generally has thinner carbonate beds.

Total organic carbon content values in the Upper Shannon Formation are generally less than 0.10%, but values up to 0.30% have been recorded in the upper part from selected core samples at Alice-1 (McKirdy, 1977) below an oil and gas show (Pemberton et al., 1963) in core 11. McKirdy (1977, page 223) stated:-

> "The proportion of saturates (23.3%) and total hydrocarbons (35.5%) in the extractable organic matter (EOM) of core 11 suggests that hydrocarbons have been generated in shales at this level of the sequence. Such shales are likely to have been the source of the "black asphaltic oil", which gave rise to a dull gold fluorescence, in sandstones and dolomites between 1052 and 1110 metres in the Goyder Formation (Pemberton et al., 1963)."

However, elemental analysis of kerogens isolated from shales of the Upper Shannon Formation (Type II-III, H/C = 0.99) at Alice-1 suggest a reduced potential to generate liquid hydrocarbons (McKirdy, 1977), and the indigenous origin of this asphaltic oil in the Upper Shannon Formation must remain speculative. The highest TOC values measured, outside of McKirdy's core sample, were 0.15% near the top of the Upper Shannon at Orange-1.

Lower Shannon Formation (?Middle Cambrian)

The Lower Shannon Formation has been divided into two sub units designated A and B, from top to bottom. The A unit has generally less than 0.10% TOC and therefore no source potential, according to the criterion of Tissot & Welte (1978).

Unit B also has TOC values less than 0.10%, but richer pockets are present where TOC approaches 0.24%, eg. Orange-1. McKirdy (1977) has shown that the kerogen in Unit B at Alice-1 is type II, and, as such, must be regarded as both an oil and gas source, if higher TOC (ie. 0.50%+) areas can be located.

Marchioni (written communication, 12/5/82) found only rare grains rich in alginite B and rare spores in core 11, but remarked that there was insignificant amounts of source potential present.

The highest TOC values at Alice-1 are associated with dolomitic siltstones and shales, whereas the carbonates are deficient in organic carbon. The higher organic carbon content of the shales suggests that they, and not the carbonates, would be the major oil source in the sequence, and assessment supported by the probably liptinitic (Type II) composition and high volatile matter content (60.7%) of the kerogen (McKirdy, 1977).

This variation in TOC between the fine grain clastics and the oolitic limestones and dolomites of the Shannon Formation probably reflects the original depositional conditions. The shales were deposited in deeper water, probably below wave base, where organic matter had more chance of preservation. Falling sea level or shoaling, led to higher energy carbonate deposition in a probable oxidizing environment, where organic matter was preferentially removed. The absence of an abundant or diverse biota throughout the Shannon Formation is reflected in the virtual absence of bethonic faunas and the sparsity of pelagic organisms (eg. trilobites, acritarchs) preserved as fossils. Quite probably, the adverse environmental factors which excluded the development of an abundant biomass in the Shannon Formation contributed to the low TOC presently preserved in the rocks.

Jay Creek Limestone (Middle to Late Cambrian in part)

The Jay Creek Limestone has only been analysed at Highway-1. The unit is here questionably assigned to Time Interval 5. Only one value is available, and that is from a selected core sample. Consequently, the reliability of the measurement is uncertain.

Petermann Sandstone and Cleland Sandstone in part (Middle to Late Cambrian)

Both these formations are composed of non-source facies. Siltstones and shales within the units are generally reddish or green coloured.

Discussion

West of the approximate sandstone/carbonate facies boundary (Figure 6), Time Interval 5 has little source potential. Most of the fine clastics interbedded with the sandstones are non-source facies (ie. green or reddish coloured).

In the northeast, where the Shannon Formation becomes more limy, the maximum TOC values increase, but the average TOC values are consistently very low. The higher TOC values may reflect deeper water conditions increasing in this direction.

TI 6 Late Cambrian (Mid Idamean to Payntonian) Figure 7

Formations in this interval include:-

Goyder Formation
Pacoota Sandstone (in part)

The Pacoota Sandstone is not considered further here.

Goyder Formation (Late Cambrian)

The Goyder Formation in the eastern part of the basin consists of two shoaling upward sequences, from shale and siltstone to sandstone, limestone and dolomite. The upper cycle is more dolomitized than the lower suggesting subaerial exposure (Gorter et al., 1982a). The presence of oolite and dolomite suggests oxidizing, agitated deposition, further supported by the generally light colours of the rocks. Total organic carbon (TOC) values are very low, always less than 0.10% in Orange-1 and Wallaby-1, reflecting the oxidizing environment of deposition. However, ESSO (1965) recorded 0.32% in a selected core sample from near the base of the formation at Alice-1, and Core Laboratories (1982d) have measured 0.23% TOC from 1039 - 1041 metres from the same well.

At Orange-1, TOC values reach a maximum of 0.15% but generally are lower (average 0.07%). At Dingo-1, the maximum TOC is only 0.07%. A general trend to lower maximum TOC towards the southwest is evident. This trend parallels the increasing coarse clastic content of the Goyder Formation to the south and west, and the disappearance of the shoaling sequences from the section. At Mereenie Field, the Goyder is dominantly sandstone and minor limestone with no source rock potential. Further west at Mt. Winter-1, the Goyder Formation is again predominantly sandstone with only minor red brown siltstone and shale (Gorter et al., 1982C).

However, at East Johnny's Creek-1, a selected core sample had a measured TOC of 0.32% (ESSO, 1965), equal to the maximum TOC measured in the east at Alice-1, also from a selected core sample. The validity of this one measurement is questionable.

Discussion

No source potential is expected in the Goyder Formation if the criterion of Tissot & Welte (1978) is applied, but it is clear from the trends noted above that the only area of potential source rock development is in the northeastern part of the basin near the Alice-1 well (Figure 7). However, Wallaby-1, drilled 7 km east of Alice-1 proved very low (less than 0.10%) TOC values in the Goyder Formation, suggesting that perhaps even in the northeastern area, the source rock potential of the Goyder Formation is sporadically developed.

The lower, shaly part of the shoaling sequences in the eastern area should contain the best source rocks in Time Interval 6, because of deposition below wave base. However, no completely cored sections are available to test this assumption.

CONCLUSIONS

The search for potential petroleum source facies in the Cambrian rocks of the Amadeus Basin has proved disappointing. Although the area considered is vast, the relatively few well intersections have sampled all the known prospective source rock horizons without locating any areas of potentially good source rock development.

The available geochemical data support the evidence presented by the oxidizing depositional environments of the majority of the Cambrian sequence in the Amadeus Basin, and lead to the conclusion that Cambrian source facies are likely to be extremely localised and generally poorly developed.

This study has shown that:-

1. The best source potential in the Early Cambrian (TI 1/2) appears to be restricted to the northeast in the interfingering zone between the Chandler Formation evaporites and the Todd River Dolomite "reefal" facies.

2. The Templetonian sequence (TI3), including the Giles Creek Dolomite and the Tempe Formation, is devoid of source rocks.

3. Rocks deposited in the generally oxidizing environment of Floran to Undillan time (TI4) have no source rock potential.

4. Boomerangian to Mid Idamean (TI5) rocks are non-source, except in the extreme northeastern part of the permit area where the Lower Shannon Formation is developed. Total organic carbon values are still very low even in this region.

5. Late Cambrian rocks (TI6) are generally non-source except in the northeastern part of the basin, but even there source facies distribution is sporadic.

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ADDENDUM

HEAD SPACE GAS ANALYSIS

Head space gas analysis from canned cutting samples have been used successfully as indicators of organic maturity and source rock richness (Baily et al., 1974; Jackson, 1982).

Canned cutting samples were collected from mud drilled portions of Wallaby-1 and Dingo-1 and sent to the Bureau of Mineral Resources for head space gas analysis.

The parameter of total gas ($C_1 - C_4$) and percentage wet gas ($C_2 - C_4 / C_1 - C_4$) are plotted with depth on Figure 1 for Dingo-1. The total gas content suggests that the Lower Shannon Formation has fair to good source rocks between 1646 - 1829 metres, the Hugh River Shale is non-source, as is the greater part of the Giles Creek Dolomite, although fair source rocks occur in the Middle Giles Creek. The Lower Giles Creek Dolomite and Chandler Formations plot as good source rocks. Fair to non-source potential is indicated for the Arumbera Sandstone, but this may be prejudiced by the reservoir rock properties of this red-bed sequence.

A similar plot for fifty five samples collected from Wallaby-1 is presented in Figure 2. It is obvious from this plot that there were no potential source rocks intersected by Wallaby-1 in the Cambrian section, although some fair potential is indicated at 1158 metres in the Lower Shannon Formation. A small peak is associated with fluorescence noted in the Chandler Formation at about 1829 metres.

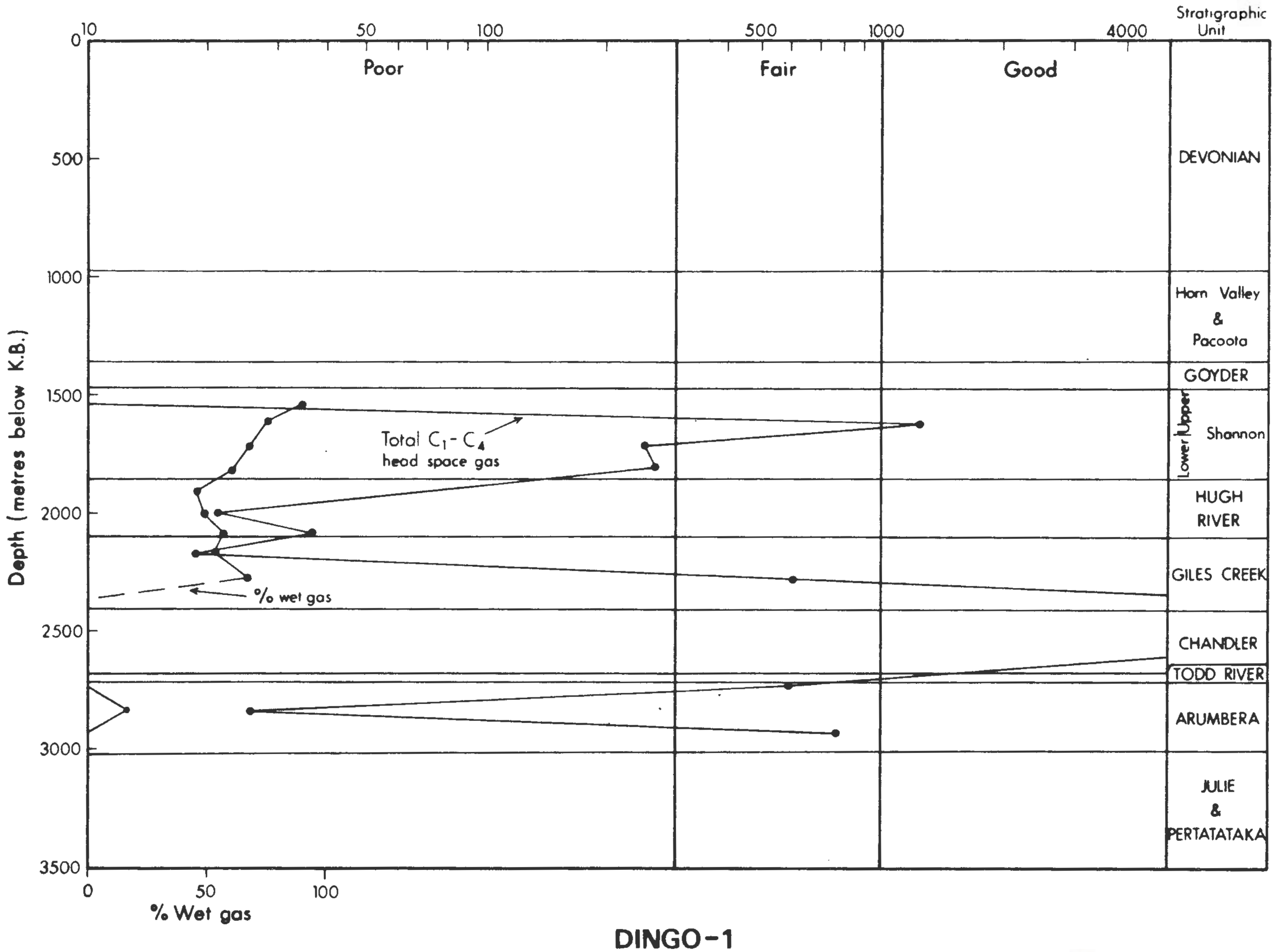

Figure 1. Plot of head space gas analytical data for canned cutting samples from Dingo-1

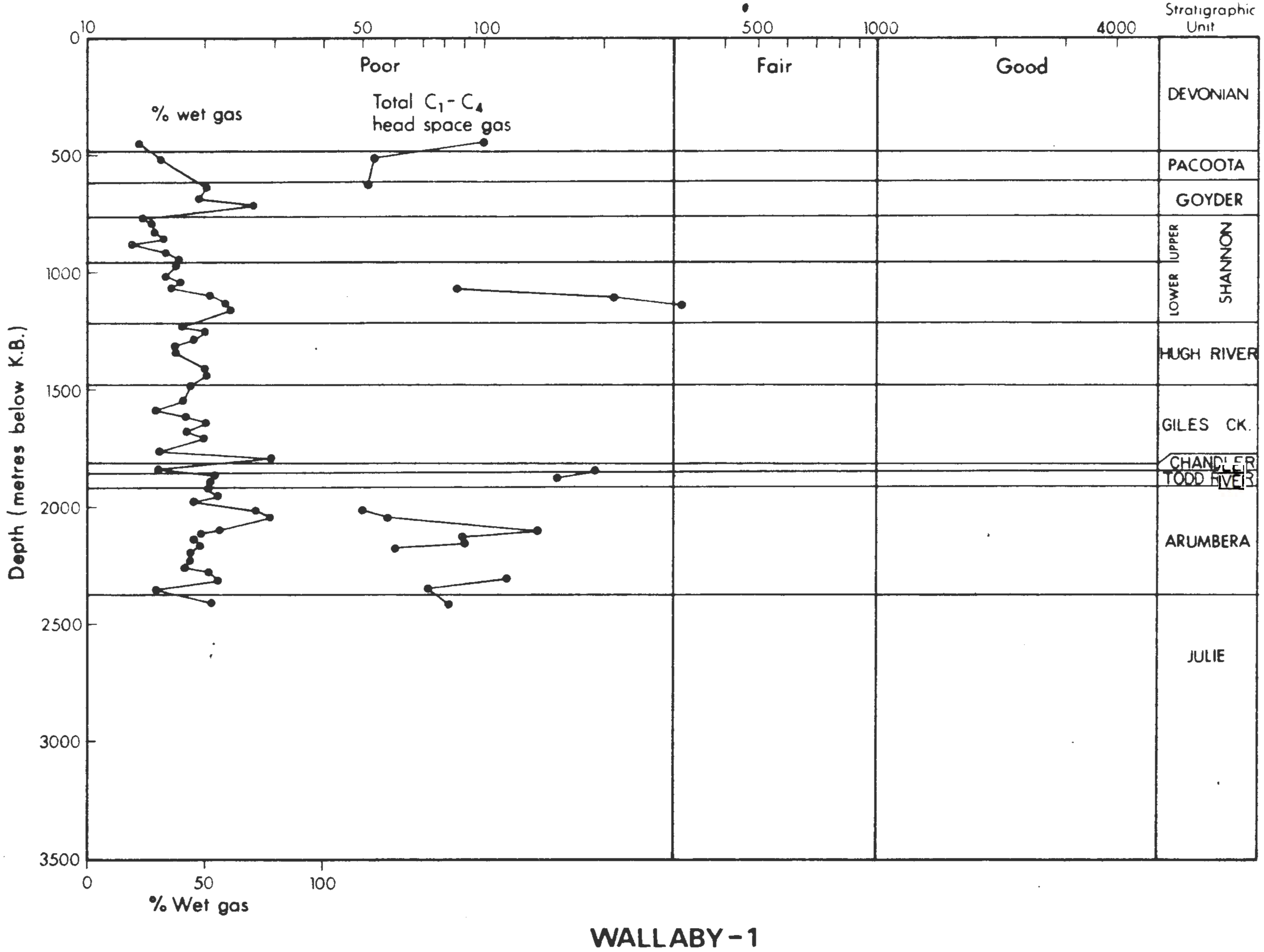

Figure 2. Plot of head space gas analytical data for canned cutting samples from Wallaby-1

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APPENDIX

ALICE.1

FORMATION	TIME	DEPTH	TYPE	SOURCE	TOC	OMT	REFERENCE
UPPER GOYDER	TI6	3127	CORE 9	BMR	0.09		MCKIRDY
LOWER GOYDER	TI6	3410-3415	CUTTINGS	MAGELLAN	0.23		CORE LAB 1982
GOYDER	TI6	3400-3450	CUTTINGS	MAGELLAN	0.11		CORE LAB 1982
GOYDER	TI6	3413	CORE 10	BMR	0.32		ESSO
SHANNON	TI5	3450-3500	CUTTINGS	MAGELLAN	0.09		CORE LAB 1982
SHANNON	TI5	3460	CUTTINGS	BMR	0.10		SHELL
SHANNON	TI5	3573-3596	CORE 11	MAGELLAN	0.24		CORE LAB 1982
SHANNON	TI5	3573	CORE 11	BMR	0.30	11-111	MCKIRDY
SHANNON	TI5	3885	CORE 12	BMR	0.07		MCKIRDY
LO SHANNON	TI5	4525	CORE 15	BMR	0.24	11	MCKIRDY
HIGH RIVER	TI4	4843	CORE 16	BMR	0.02		MCKIRDY
HIGH RIVER	TI4	4950	CUTTINGS	BMR	0.10		SHELL
UPPER GILES	TU3	5727	CORE 19	BMR	0.10		MCKIRDY
GILES CK	TI3	6064	CORE 20	BMR	0.07		MCKIRDY
GILES CK	TI3	6118	CORE 22	BMR	0.02		MCKIRDY
GILES CK	TI3	6127	CORE 23	BMR	0.01		MCKIRDY
GILES CK	TI3	6130	CORE 23	BMR	0.96		ESSO
GILES CK	TI3	6131	CORE 23	BMR	0.32	111	MCKIRDY
GILES CK	TI3	6132	CORE 23	MAGELLAN	0.10		CORE LAB 1982
MIDDLE GILES	TI3	6500	CUTTINGS	BMR	0.20		SHELL
CHANDLER	TI1/2	6760	CORE 25	BMR	0.02		MCKIRDY
CHANDLER	TI1/2	6882	CORE 26	BMR	(0.01		MCKIRDY
ARUMBERA	TI1/2	7400	CUTTINGS	BMR	0.10		SHELL
ARUMBERA	TI1/2	7513	CORE 28	BMR	0.13		ESSO

DINGO.1

FORMATION	TIME	DEPTH	TYPE	SOURCE	TOC	OMT	REFERENCE
UP GOYDER	TI6	4500-4550	CUTTINGS	PANCON	0.03		CORE LAB 1982
UP GOYDER	TI6	4550-4600	CUTTINGS	PANCON	0.05		CORE LAB 1982
UP GOYDER	TI6	4600-4650	CUTTINGS	PANCON	0.07		CORE LAB 1982
UP GOYDER	TI6	4650-4700	CUTTINGS	PANCON	0.04/0.05		CORE LAB 1982
LO GOYDER	TI6	4700-4750	CUTTINGS	PANCON	0.06		CORE LAB 1982
LO GOYDER	TI6	4750-4800	CUTTINGS	PANCON	0.06		CORE LAB 1982
LO GOYDER	TI6	4800-4850	CUTTINGS	PANCON	0.06		CORE LAB 1982
UP SHANNON	TI5	4850-4900	CUTTINGS	PANCON	0.04		CORE LAB 1982
UP SHANNON	TI5	4900-4950	CUTTINGS	PANCON	0.05		CORE LAB 1982
UP SHANNON	TI5	4950-5000	CUTTINGS	PANCON	0.05		CORE LAB 1982
UP SHANNON	TI5	5000-5050	CUTTINGS	PANCON	0.04		CORE LAB 1982
UP SHANNON	TI5	5050-5100	CUTTINGS	PANCON	0.03/0.04		CORE LAB 1982
UP SHANNON	TI5	5100-5150	CUTTINGS	PANCON	0.06		CORE LAB 1982
UP SHANNON	TI5	5150-5200	CUTTINGS	PANCON	0.07		CORE LAB 1982
UP SHANNON	TI5	5200-5250	CUTTINGS	PANCON	0.05		CORE LAB 1982
UP SHANNON	TI5	5250-5300	CUTTINGS	PANCON	0.05		CORE LAB 1982
UP SHANNON	TI5	5300-5350	CUTTINGS	PANCON	0.05		CORE LAB 1982
UP SHANNON	TI5	5350-5400	CUTTINGS	PANCON	0.04		CORE LAB 1982
UP SHANNON	TI5	5400-5450	CUTTINGS	PANCON	0.06		CORE LAB 1982
UP SHANNON	TI5	5450-5500	CUTTINGS	PANCON	0.06		CORE LAB 1982
LO SHANNON	TI5	5500-5550	CUTTINGS	PANCON	0.06		CORE LAB 1982
LO SHANNON	TI5	5550-5600	CUTTINGS	PANCON	0.05		CORE LAB 1982
LO SHANNON	TI5	5600-5650	CUTTINGS	PANCON	0.05		CORE LAB 1982
LO SHANNON	TI5	5650-5700	CUTTINGS	PANCON	0.05		CORE LAB 1982
LO SHANNON	TI5	5700-5750	CUTTINGS	PANCON	0.10		CORE LAB 1982
LO SHANNON	TI5	5750-5800	CUTTINGS	PANCON	0.05		CORE LAB 1982
LO SHANNON	TI5	5800-5850	CUTTINGS	PANCON	0.07		CORE LAB 1982
LO SHANNON	TI5	5850-5900	CUTTINGS	PANCON	0.08		CORE LAB 1982
LO SHANNON	TI5	5900-5950	CUTTINGS	PANCON	0.06		CORE LAB 1982
LO SHANNON	TI5	5950-6000	CUTTINGS	PANCON	0.06		CORE LAB 1982
LO SHANNON	TI5	6000-6050	CUTTINGS	PANCON	0.07		CORE LAB 1982
LO SHANNON	TI5	6050-6100	CUTTINGS	PANCON	0.07		CORE LAB 1982
GILES CK	TI3	6900-6950	CUTTINGS	PANCON	0.03/0.03		CORE LAB 1982
GILES CK	TI3	6950-7000	CUTTINGS	PANCON	0.03		CORE LAB 1982
GILES CK	TI3	7000-7050	CUTTINGS	PANCON	0.03		CORE LAB 1982
GILES CK	TI3	7050-7100	CUTTINGS	PANCON	0.03		CORE LAB 1982
GILES CK	TI3	7100-7150	CUTTINGS	PANCON	0.03		CORE LAB 1982
GILES CK	TI3	7150-7200	CUTTINGS	PANCON	0.03		CORE LAB 1982
GILES CK	TI3	7200-7250	CUTTINGS	PANCON	0.04		CORE LAB 1982
GILES CK	TI4	7250-7300	CUTTINGS	PANCON	0.04/0.04		CORE LAB 1982
GILES CK	TI3	7300-7350	CUTTINGS	PANCON	0.04		CORE LAB 1982
CHANDLER	TI1/2	8170-8280	CUTTINGS	PANCON	0.17	111	CORE LAB 1982
GILES CK	-	9585	JUNK SUB	PANCON	0.06		CORE LAB 1982

EAST JOHNNYS CK.1

FORMATION	TIME	DEPTH	TYPE	SOURCE	TOC	QMT	REFERENCE
GOYDER	TI6	1836	CORE 2	BMR	0.32		ESSO
PETERMANN	TI5	2000-2050	CUTTINGS	MAGELLAN	NIL		CORE LAB
DECEPTION	TI4	2920-2930	CUTTINGS	MAGELLAN	0.13		CORE LAB
ILLARA	TI3/4	3440-3450	CUTTINGS	MAGELLAN	0.10		CORE LAB
TEMPE	TI3	4100-4150	CUTTINGS	MAGELLAN	0.09		CORE LAB
TEMPE	TI3	4150-4200	CUTTINGS	MAGELLAN	0.04		CORE LAB
TEMPE	TI3	4200-4250	CUTTINGS	MAGELLAN	0.05		CORE LAB
TEMPE	TI3	4250-4300	CUTTINGS	MAGELLAN	0.05		CORE LAB
TEMPE	TI3	4300-4350	CUTTINGS	MAGELLAN	0.05		CORE LAB
TEMPE	TI3	4350-4400	CUTTINGS	MAGELLAN	0.06		CORE LAB
TEMPE	TI3	4370	CORE 5	BMR	0.18		ESSO
TEMPE	TI3	4400-4450	CUTTINGS	MAGELLAN	0.05		CORE LAB
ENINTA	TI1/2	4850-4900	CUTTINGS	MAGELLAN	0.08		CORE LAB
ENINTA	TI1/2	4900-4920	CUTTINGS	MAGELLAN	0.12		CORE LAB

EAST MEREENIE.1

FORMATION	TIME	DEPTH	TYPE	SOURCE	TOC	OMT	REFERENCE
PACOOTA	TI6	3806.3	CORE 7	BMR	0.28	11	MCKIRDY
PACOOTA	TI6	3809	CORE 7	BMR			MCKIRDY
PACOOTA	TI6	3853	CORE	BMR	0.36		MCKIRDY

EAST MEREENIE.2

FORMATION	TIME	DEPTH	TYPE	SOURCE	TOC	OMT	REFERENCE
PACOOTA	TI6	4201	CORE 4	BMR	0.79		ROBERTSON 1981
PACOOTA	TI6	4215	CORE 4	BMR	0.30		MCKIRDY
PACOOTA	TI6	4349	CORE 7	BMR	0.89		MCKIRDY
PACOOTA	TI6	4468	CORE 14	BMR	0.20		MCKIRDY

EAST MEREENIE.4

FORMATION	TIME	DEPTH	TYPE	SOURCE	TOC	OMT	REFERENCE
PACCOOTA	TI6	4195.75	CORE 1	BMR	0.46		MCKIRDY
DECEPTION	TI4	6456	CORE 5	BMR	0.18		ROBERTSON 1981
DECEPTION	TI4	6450-6500	CUTTINGS	OILMIN	0.15		CORE LAB 1982
DECEPTION	TI4	6459	CORE 5	MAGELLAN	0.09		CORE LAB 1982
DECEPTION	TI4	6530-6550	CUTTINGS	OILMIN	0.07		CORE LAB 1982
DECEPTION	TI4	6550-6590	CUTTINGS	OILMIN	0.10		CORE LAB 1982
DECEPTION	TI4	6650-6680	CUTTINGS	OILMIN	0.08		CORE LAB 1982
DECEPTION	TI4	6750-6800	CUTTINGS	OILMIN	0.12		CORE LAB 1982
ILLARA	TI3/4	7100-7150	CUTTINGS	OILMIN	0.06		CORE LAB 1982
TEMPE	TI3	7600-7650	CUTTINGS	OILMIN	0.08		CORE LAB 1982
TEMPE	TI3	7750-7780	CUTTINGS	OILMIN	0.09		CORE LAB 1982
TEMPE	TI3	7800-7850	CUTTINGS	OILMIN	0.07		CORE LAB 1982
TEMPE	TI3	7850-7900	CUTTINGS	OILMIN	0.08		CORE LAB 1982
TEMPE	TI3	8050-8100	CUTTINGS	OILMIN	0.04		CORE LAB 1982
TEMPE	TI3	8100-8200	CUTTINGS	OILMIN	0.13		CORE LAB 1982
TEMPE	TI3	8200-8250	CUTTINGS	OILMIN	0.20		CORE LAB 1982
TEMPE	TI3	8250-8300	CUTTINGS	OILMIN	0.19		CORE LAB 1982
TEMPE	TI3	8300-8350	CUTTINGS	OILMIN	0.20		CORE LAB 1982
TEMPE	TI3	8350-8400	CUTTINGS	OILMIN	0.16		CORE LAB 1982

HIGHWAY.1

FORMATION	TIME	DEPTH	TYPE	SOURCE	TOC	OMT	REFERENCE
JAY CK	TI5	592	CORE 1	BMR	0.15		MCKIRDY
UP GILES CK	TI3	1784	CORE 3	BMR	0.10		MCKIRDY
MIDDLE GILES	TI3	2350-2400	CUTTING	OILMIN	0.08		CORE LAB 1982
MIDDLE GILES	TI3	2438	CORE 4	BMR	0.13	111	MCKIRDY
MIDDLE GILES	TI3	2400-2450	CUTTINGS	OILMIN	0.10		CORE LAB 1982
MIDDLE GILES	TI3	2450-2500	CUTTINGS	OILMIN	0.13		CORE LAB 1982
LO GILES CK	TI3	2500-2550	CUTTINGS	OILMIN	0.25	11	CORE LAB 1982
CHANDLER	TI1/2	2550-2600	CUTTINGS	OILMIN	0.12		CORE LAB 1982
CHANDLER	TI1/2	2650-2700	CUTTINGS	OILMIN	0.23	111	CORE LAB 1982
CHANDLER	TI1/2	2700-2750	CUTTINGS	OILMIN	0.17		CORE LAB 1982

MT WINTER.1

FORMATION	TIME	DEPTH	TYPE	SOURCE	TOC	OMT	REFERENCE
TEMPE	T3	4409.8	CORE 2	PANCON	0.08		CORE LAB
TEMPE	T3	4412.4	CORE 2	PANCON	0.08		CORE LAB
TEMPE	T3	4416.8	CORE 2	PANCON	0.08		CORE LAB
TEMPE	T3	4421.8	CORE 2	PANCON	0.07		CORE LAB

ORANGE.1

FORMATION	TIME	DEPTH	TYPE	SOURCE	TOC	OMT	REFERENCE
UP GOYDER	TI6	3920-3950	CUTTINGS	MAGELLAN	0.08		CORE LAB 1981
LO GOYDER	TI6	4110-4170	CUTTINGS	MAGELLAN	0.06		CORE LAB 1981
LO GOYDER	TI6	4260-4270	CUTTINGS	MAGELLAN	0.07		CORE LAB 1981
LO GOYDER	TI6	4290-4320	CUTTINGS	MAGELLAN	0.07/0.07		CORE LAB 1981
UP SHANNON	TI5	4350-4390	CUTTINGS	MAGELLAN	0.08		CORE LAB 1981
UP SHANNON	TI5	4410-4430	CUTTINGS	MAGELLAN	0.15		CORE LAB 1981
UP SHANNON	TI5	4610-4620	CUTTINGS	MAGELLAN	0.09		CORE LAB 1981
UP SHANNON	TI5	4680-4690	CUTTINGS	MAGELLAN	0.07		CORE LAB 1981
UP SHANNON	TI5	4710-4750	CUTTINGS	MAGELLAN	0.12		CORE LAB 1981
UP SHANNON	TI5	4790-4830	CUTTINGS	MAGELLAN	0.08		CORE LAB 1981
UP SHANNON	TI5	4840-4860	CUTTINGS	MAGELLAN	0.07		CORE LAB 1981
UP SHANNON	TI5	4880-4900	CUTTINGS	MAGELLAN	0.10/0.10		CORE LAB 1981
UP SHANNON	TI5	4900-4930	CUTTINGS	MAGELLAN	0.07		CORE LAB 1981
LO SHANNON	TI5	4930-4960	CUTTINGS	MAGELLAN	0.08		CORE LAB 1981
LO SHANNON	TI5	4990-5020	CUTTINGS	MAGELLAN	0.11		CORE LAB 1981
LO SHANNON	TI5	5020-5040	CUTTINGS	MAGELLAN	0.07		CORE LAB 1981
LO SHANNON	TI5	5040-5070	CUTTINGS	MAGELLAN	0.14		CORE LAB 1981
LO SHANNON	TI5	5080-5110	CUTTINGS	MAGELLAN	0.08		CORE LAB 1981
LO SHANNON	TI5	5110-5140	CUTTINGS	MAGELLAN	0.06		CORE LAB 1981
LO SHANNON	TI5	5140-5160	CUTTINGS	MAGELLAN	0.09		CORE LAB 1981
LO SHANNON	TI5	5200-5230	CUTTINGS	MAGELLAN	0.24		CORE LAB 1981
LO SHANNON	TI5	5230-5260	CUTTINGS	MAGELLAN	0.23		CORE LAB 1981
LO SHANNON	TI5	5260-5290	CUTTINGS	MAGELLAN	0.11		CORE LAB 1981
LO SHANNON	TI5	5290-5320	CUTTINGS	MAGELLAN	0.11		CORE LAB 1981
LO SHANNON	TI5	5320-5350	CUTTINGS	MAGELLAN	0.12		CORE LAB 1981
LO SHANNON	TI5	5350-5380	CUTTINGS	MAGELLAN	0.11/0.09		CORE LAB 1981
LO SHANNON	TI5	5380-5410	CUTTINGS	MAGELLAN	0.09/0.11		CORE LAB 1981
LO SHANNON	TI5	5410-5440	CUTTINGS	MAGELLAN	0.08		CORE LAB 1981
LO SHANNON	TI5	5440-5470	CUTTINGS	MAGELLAN	0.09		CORE LAB 1981
LO SHANNON	TI5	5470-5500	CUTTINGS	MAGELLAN	0.07/0.08		CORE LAB 1981
LO SHANNON	TI5	5500-5530	CUTTINGS	MAGELLAN	0.10/0.11		CORE LAB 1981
LO SHANNON	TI5	5530-5560	CUTTINGS	MAGELLAN	0.08		CORE LAB 1981
LO SHANNON	TI5	5560-5590	CUTTINGS	MAGELLAN	0.08		CORE LAB 1981
LO SHANNON	TI5	5590-5620	CUTTINGS	MAGELLAN	0.07/0.07		CORE LAB 1981
LO SHANNON	TI5	5620-5650	CUTTINGS	MAGELLAN	0.10		CORE LAB 1981
HUGH RIVER	TI4	5650-5680	CUTTINGS	MAGELLAN	0.06/0.07		CORE LAB 1981
HUGH RIVER	TI4	5680-5710	CUTTINGS	MAGELLAN	0.06/0.06		CORE LAB 1981
HUGH RIVER	TI4	5710-5740	CUTTINGS	MAGELLAN	0.05		CORE LAB 1981
HUGH RIVER	TI4	5770-5800	CUTTINGS	MAGELLAN	0.06		CORE LAB 1981
HUGH RIVER	TI4	5800-5830	CUTTINGS	MAGELLAN	0.06		CORE LAB 1981
HUGH RIVER	TI4	5830-5860	CUTTINGS	MAGELLAN	0.05/0.06		CORE LAB 1981
HUGH RIVER	TI4	5860-5890	CUTTINGS	MAGELLAN	0.07/0.06		CORE LAB 1981
HUGH RIVER	TI4	5890-5920	CUTTINGS	MAGELLAN	0.07		CORE LAB 1981
HUGH RIVER	TI4	5920-5950	CUTTINGS	MAGELLAN	0.04/0.04		CORE LAB 1981
UP GILES DOL	TI3	6330-6360	CUTTINGS	MAGELLAN	0.04		CORE LAB 1981
UP GILES DOL	TI3	6390-6420	CUTTINGS	MAGELLAN	0.04/0.03		CORE LAB 1981
UP GILES DOL	TI3	6440-6470	CUTTINGS	MAGELLAN	0.06/0.04		CORE LAB 1981
UP GILES DOL	TI3	6670-6700	CUTTINGS	MAGELLAN	0.04		CORE LAB 1981
UP GILES DOL	TI3	6820-6870	CUTTINGS	MAGELLAN	0.07		CORE LAB 1981
UP GILES DOL	TI3	6940-6950	CUTTINGS	MAGELLAN	0.04		CORE LAB 1981
UP GILES DOL	TI3	7020-7050	CUTTINGS	MAGELLAN	0.04		CORE LAB 1981
UP GILES DOL	TI3	7079.9	CORE 8	BMR	0.12	111	ROBERTSON 1980
MIDDLE GILES	TI3	7120-7150	CUTTINGS	MAGELLAN	0.09		CORE LAB 1981
MIDDLE GILES	TI3	7250-7260	CUTTINGS	MAGELLAN	0.08		CORE LAB 1981
MIDDLE GILES	TI3	7350-7370	CUTTINGS	MAGELLAN	0.08		CORE LAB 1981
MIDDLE GILES	TI3	7370-7400	CUTTINGS	MAGELLAN	0.09		CORE LAB 1981
LO GILES CK	TI3	7440-7460	CUTTINGS	MAGELLAN	0.12		CORE LAB 1981
LO GILES CK	TI3	7460-7490	CUTTINGS	MAGELLAN	0.07		CORE LAB 1981
LO GILES CK	TI3	7490-7520	CUTTINGS	MAGELLAN	0.06		CORE LAB 1981
LO GILES CK	TI3	7520-7550	CUTTINGS	MAGELLAN	0.11		CORE LAB 1981
LO GILES CK	TI3	7550-7580	CUTTINGS	MAGELLAN	0.10		CORE LAB 1981
CHANDLER FM	TI1/2	7580-7600	CUTTINGS	MAGELLAN	0.17		CORE LAB 1981
CHANDLER FM	TI1/2	7640-7660	CUTTINGS	MAGELLAN	0.09		CORE LAB 1981
CHANDLER FM	TI1/2	7660-7690	CUTTINGS	MAGELLAN	0.28/0.28		CORE LAB 1981
CHANDLER FM	TI1/2	7690-7720	CUTTINGS	MAGELLAN	0.23		CORE LAB 1981
CHANDLER FM	TI1/2	7730-7810	CUTTINGS	MAGELLAN	0.21		CORE LAB 1981
CHANDLER FM	TI1/2	7894-7920	CUTTINGS	MAGELLAN	0.19		CORE LAB 1981
TODD RV EQ	TI1	8280-8310	CUTTINGS	MAGELLAN	0.06		CORE LAB 1981
TODD RV EQ	TI1	8310-8400	CUTTINGS	MAGELLAN	0.05		CORE LAB 1981
ARUMBERA	TI1	8715-8724	CUTTINGS	MAGELLAN	0.44		CORE LAB 1981
ARUMBERA	TI1	8810-8820	CUTTINGS	MAGELLAN	0.14		CORE LAB 1981
ARUMBERA	TI1	8840-8870	CUTTINGS	MAGELLAN	0.11		CORE LAB 1981

PALM VALLEY.1

FORMATION	TIME	DEPTH	TYPE	SOURCE	TOC	OMT	REFERENCE
PACOOTA	TI6	5730	CORE 16	BMR	0.47		MCKIRDY
PACOOTA	TI6	5764	CORE 16	BMR	0.21		MCKIRDY
PACOOTA	TI6	6167	CORE 18	BMR	0.36		MCKIRDY
PACOOTA	TI6	6362.6	CORE 19	BMR	0.26		MCKIRDY
PACOOTA	TI6		CORE 19	BMR	0.52		ROBERTSON 1981
PACOOTA	TI6	6472	CORE 20	BMR	0.29		MCKIRDY

PALM VALLEY.3

FORMATION	TIME	DEPTH	TYPE	SOURCE	TOC	OMT	REFERENCE
PACOOTA	TI6	6792	CORE 2	BMR	0.20	111	MCKIRDY
PACOOTA	TI6	6815	CORE 2	BMR	0.42	111	MCKIRDY
PACOOTA	TI6	6819.6	CORE 2	BMR	0.07		MCKIRDY
PACOOTA	TI6	6831	CORE 2	BMR	0.27	111	MCKIRDY

RODINGA.1A

FORMATION	TIME	DEPTH	TYPE	SOURCE	TOC	JMT	REFERENCE
CHANDLER	TI1/2	86.5	CORE	BMR	0.15		FELTON 1981
CHANDLER	TI1/2	93.0	CORE	BMR	0.40		FELTON 1981
CHANDLER	TI1/2	106.0	CORE	BMR	<0.05		FELTON 1981
CHANDLER	TI1/2	108.0	CORE	BMR	<0.05		FELTON 1981
CHANDLER	TI1/2	108.5	CORE	BMR	0.20		FELTON 1981
CHANDLER	TI1/2	108.9	CORE	BMR	3.00		FELTON 1981
CHANDLER	TI1/2	113.3	CORE	BMR	0.20		FELTON 1981
CHANDLER	TI1/2	118.1	CORE	BMR	0.10		FELTON 1981
CHANDLER	TI1/2	118.5	CORE	BMR	0.15		FELTON 1981
CHANDLER	TI1/2	119.8	CORE	BMR	0.70		FELTON 1981
CHANDLER	TI1/2	120.0	CORE	BMR	0.10		FELTON 1981
CHANDLER	TI1/2	133.0	CORE	BMR	0.75		FELTON 1981
CHANDLER	TI1/2	155.2	CORE	BMR	0.05		FELTON 1981

WALLABY.1

FORMATION	TIME	DEPTH	TYPE	SOURCE	TOC	OMT	REFERENCE
GOYDER FM	TI	2380-2390	CUTTINGS	PANCON	0.08/0.09		CORE LAB 1981
GOYDER FM	TI6	2400-2410	CUTTINGS	PANCON	0.10		CORE LAB 1981
GOYDER FM	TI6	2430-2440	CUTTINGS	PANCON	0.09		CORE LAB 1981
GOYDER FM	TI6	2440-2450	CUTTINGS	PANCON	0.09		CORE LAB 1981
UP SHANNON	TI5	2540-2550	CUTTINGS	PANCON	0.07		CORE LAB 1981
UP SHANNON	TI5	2550-2560	CUTTINGS	PANCON	0.08		CORE LAB 1981
UP SHANNON	TI5	2580-2590	CUTTINGS	PANCON	0.07		CORE LAB 1981
UP SHANNON	TI5	2820-2830	CUTTINGS	PANCON	0.07		CORE LAB 1981
UP SHANNON	TI5	3030-3040	CUTTINGS	PANCON	0.04/0.03		CORE LAB 1981
LO SHANNON	TI5	3150-3160	CUTTINGS	PANCON	0.06		CORE LAB 1981
LO SHANNON	TI5	3160-3170	CUTTINGS	PANCON	0.06		CORE LAB 1981
LO SHANNON	TI5	3230-3240	CUTTINGS	PANCON	0.07		CORE LAB 1981
LO SHANNON	TI5	3240-3250	CUTTINGS	PANCON	0.06		CORE LAB 1981
LO SHANNON	TI5	3250-3280	CUTTINGS	PANCON	0.05		CORE LAB 1981
LO SHANNON	TI5	3280-3310	CUTTINGS	PANCON	0.07		CORE LAB 1981
LO SHANNON	TI5	3310-3340	CUTTINGS	PANCON	0.06		CORE LAB 1981
LO SHANNON	TI5	3340-3370	CUTTINGS	PANCON	0.07/0.06		CORE LAB 1981
LO SHANNON	TI5	3370-3400	CUTTINGS	PANCON	0.08		CORE LAB 1981
LO SHANNON	TI5	3400-3430	CUTTINGS	PANCON	0.06		CORE LAB 1981
LO SHANNON	TI5	3430-3460	CUTTINGS	PANCON	0.04		CORE LAB 1981
LO SHANNON	TI5	3460-3490	CUTTINGS	PANCON	0.04		CORE LAB 1981
LO SHANNON	TI5	3490-3520	CUTTINGS	PANCON	0.05		CORE LAB 1981
LO SHANNON	TI5	3520-3550	CUTTINGS	PANCON	0.06		CORE LAB 1981
LO SHANNON	TI5	3550-3600	CUTTINGS	PANCON	0.07		CORE LAB 1981
LO SHANNON	TI5	3600-3650	CUTTINGS	PANCON	0.06		CORE LAB 1981
LO SHANNON	TI5	3700-3750	CUTTINGS	PANCON	0.06		CORE LAB 1981
LO SHANNON	TI5	3800-3850	CUTTINGS	PANCON	0.11/0.08		CORE LAB 1981
LO SHANNON	TI5	3850-3900	CUTTINGS	PANCON	0.10		CORE LAB 1981
LO SHANNON	TI5	3910-3920	CUTTINGS	PANCON	0.21		CORE LAB 1981
HUGH RIVER	TI4	4040-4050	CUTTINGS	PANCON	0.07		CORE LAB 1981
UP GILES CK	TI3	4980-5000	CUTTINGS	PANCON	0.04		CORE LAB 1981
UP GILES CK	TI3	5080-5090	CUTTINGS	PANCON	0.08		CORE LAB 1981
UP GILES CK	TI3	5115-5119	CORE 1	PANCON	0.04		CORE LAB 1981
UP GILES CK	TI3	5190-5200	CUTTINGS	PANCON	0.06		CORE LAB 1981
UP GILES CK	TI3	5240-5250	CUTTINGS	PANCON	0.03/0.04		CORE LAB 1981
UP GILES CK	TI3	5320-5350	CUTTINGS	PANCON	0.02		CORE LAB 1981
UP GILES CK	TI3	5350-5370	CUTTINGS	PANCON	0.15		CORE LAB 1981
LO GILES CK	TI3	5840-5850	CUTTINGS	PANCON	0.07		CORE LAB 1981
CHANDLER FM	TI1/2	5920-5930	CUTTINGS	PANCON	0.40/0.41		CORE LAB 1981
ARUMBERA	TI1	6610-6640	CUTTINGS	PANCON	0.01		CORE LAB 1981