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Hydrocarbon Potential of the Beetaloo Basin Northern Territory, Australia

Prepared for

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EXECUTIVE SUMMARY

The Beetaloo Basin (Figure 1), located approximately 500 kilometers southeast of Darwin, Northern Territory, Australia, is a broad intracratonic basin with Mesoproterozoic and younger sediments. It is, in part, superimposed on the McArthur Basin, an older sediment-filled rift basin to the east and north. This intracratonic sag basin has generally had only subtle structural modification since Mesoproterozoic sediments were deposited. This section is overlain by Cambrian volcanics and by Cambrian and Cretaceous sediments. Early compression and strike-slip movement have created a large axial arch and basin-margin highs.

The Basin has more than 3000 meters of sedimentary fill with thick, world-class source rocks. The richest interval, the Middle Velkerri Shale, has 140 meters of black shale with typical Total Organic Carbon (TOC) contents from 4 to 7%. Values as high as 12% have been measured. The Kyalla Shale, above the Velkerri, has 250 meters of black shale with TOC contents typically from 2 to 3%. In addition to the thick, very organic rich intervals, both formations consist of hundreds of additional meters of shale with about 1% TOC. The organic matter is generally oil-prone but deep burial in the center of the Basin may have resulted in the generation of significant amounts of gas. Basin modeling shows that these source rocks have produced very large amounts of hydrocarbons.

Three thick sandstone reservoirs have been documented by the limited amount of drilling in the Basin. These sandstones are interbedded with the rich source rocks and have had shows in several of the stratigraphic tests that have been drilled in the Basin. The Bessie Creek Sandstone underlies the Velkerri Shale and is only penetrated in one well on the margin of the Basin. Wells north of the Basin and on the Walton High have encountered shows in this sandstone. The Moroak Sandstone is sandwiched between the Velkerri and Kyalla Shales and has had shows of oil in the Basin. The Jamison Sandstone, overlying the Kyalla Shale, occurs above a regional unconformity that has truncated older units. Free oil was tested on a DST from this sandstone. Fractured shales and tight gas sands also provide possible targets in the Basin.

Extensive exploration by Pacific Oil and Gas from 1984 through 1993 resulted in the drilling of eleven wells in the Beetaloo Basin proper. The company approached exploration for oil and natural gas in the Basin much like a mineral exploration program. Many of the wells were stratigraphic tests drilled and cored without the benefit of seismic or defined structural closure. Pacific also acquired 2425 km of 2D seismic data covering much of the Basin east of the Daly Waters Arch.

Reprocessing of 177 km of this generally poor quality data was carried out as part of the present study and significant improvement was achieved. New structural maps were generated and they reveal that few of the wells drilled to- date were located on adequately defined closures. This is as would be expected of stratigraphic tests. Large, untested structures have now been mapped based on reinterpretation of seismic and gravity. An especially interesting area, the Arnold Arch, has been identified on seismic. The Ronald #1 well was drilled near the north end of this axial high and encountered excellent reservoir quality in the Moroak Sandstone, based on a DST with a calculated flow of 3000 barrels of water/day.

The Beetaloo Basin includes huge prospective structures and excellent source rocks. An analogous basin in Canada and the United States is the Williston Basin, an intracratonic sag basin with similar size and structural style as the Beetaloo Basin. The Williston Basin also contains an axial arch very much like the Arnold Arch with Lower Paleozoic source rock and reservoirs. Fields located on this arch (the Nesson Anticline) have produced over 520 MMBOE. Several other basins produce significant oil and natural gas from rocks of Proterozoic age, including those in Eastern Siberia and Oman. Based on modeling and analog basins, the reserve potential of the Beetaloo Basin is hundreds of millions of barrels of oil and trillions of cubic feet of gas.

Sweetpea Corporation Pty Ltd. has acquired four Exploration Permits including EP 76, EP 98, EP 99, and EP 117 within the Beetaloo Basin, as shown on Figure 1. These permits cover most of the deep basin, the axial Arnold Arch, and the basin margin highs. Initial exploration has been conducted in 2004 with a review of the available data, new basin modeling, and an evaluation of the available seismic, including reprocessing to determine the possibility of improving the data quality. This work has provided a revised interpretation of the hydrocarbon potential of Basin. It has also laid the foundation for plans for the 2005 exploration program.

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I. INTRODUCTION

Sweetpea Corporation Pty Ltd has acquired four exploration permits, EP 76, EP 98, EP 99, and EP 117 for a total of 7 million acres in the Beetaloo Basin in the Northern Territory, Australia (refer to Figure 1 in Executive Summary.) Eleven exploration wells or stratigraphic tests were drilled and more than 2600 km of seismic data were acquired by Pacific Oil and Gas from 1984 through 1993. Shows of hydrocarbons, excellent source rocks, large structures and the presence of good reservoirs makes this area highly prospective for major oil and natural gas reserves.

Scope of Work

This Report results from an exploration study designed to better understand the petroleum geology and hydrocarbon potential of the Exploration Permits currently held by Sweetpea Corporation in the Beetaloo Basin, Northern Territory, Australia. The Report and other deliverables are based on a thorough integration of available surface and subsurface data including satellite imagery, geologic maps, geochemical data, aeromagnetic and gravity data, seismic, well data, and any other public and private data available. The goals of this study were to:

1. evaluate the oil and natural gas potential of the Beetaloo Basin based on available data,
2. identify specific areas of interest by defining structural leads,
3. determine the value of reprocessing existing seismic data, and
4. recommend a work plan for 2005 to include
   a. reprocessing existing seismic data, and
   b. acquiring new seismic data to define leads for further investigation.

Previous Work

Published and Unpublished Material

Australian literature and internal reports on the Beetaloo Basin have discussed at length the generalities of the stratigraphy, structure, source rocks, thermal history and exploration history. Only one internal (unpublished) report, the RobSearch 1997 "Technical Review of EP 18 & EP(A) 70, for Mataranka Oil NL", attempts to evaluate the total hydrocarbon potential of the basin and present exploration opportunities. In the RobSearch report, six "leads" are presented. Five of those are structures defined by existing seismic, without the benefit of modern reprocessing, and one lead is a "subcrop trap" along the northern edge of the Beetaloo Basin.

A significant contribution of the RobSearch report is the discussion defining the Beetaloo Basin as a separate tectonic feature from the greater McArthur Basin, which defends dropping the often used term "Beetaloo Sub-Basin." The Beetaloo Basin is a crustal down-warp that is satellite to the rift origin of the greater McArthur Basin. Also pointed out is the fact that each basin had a different depo-center.

In the RobSearch report, volumetric estimates are presented for the various leads. These total almost 1 billion BO with the two "richest" structural leads totaling 514 MMBO and the "Northern Sub-crop" with estimated reserves of 330 MMBO. Other "leads" approach 100 MMBO.

The RobSearch report also identifies the "Arnold Arch" along the eastern edge of the Beetaloo Basin as a likely catchment area for substantial Precambrian-generated and migrated hydrocarbons. It is likely that the Arnold Arch does have an early, pre-hydrocarbon generation, structural history and should contain the three primary potential reservoir units; the Bessie Creek, Moroak and Jamison Sandstones. This report also points out common live oil shows in sandstones and free oil recoveries during DST's of the Jamison Sandstone in the Jamison #1 well and a sandstone in the lower Hayfield Mudstone in the Balmain #1. These and other shows in non-source sediments document hydrocarbon migration into the primary potential reservoirs. Also, large volumes, billions of barrels, have been generated and migrated, and are likely preserved in large un-breached traps.

Two published articles relevant to the Beetaloo Basin evaluation appear in the 1994 APEA Journal:

1) Taylor et al., 1994, "Petroleum Source Rock in the Roper Group of the McArthur Basin: Source Characterization and Maturity Determinations Using Physical and Chemical Methods," pp. 279-296, concludes that the Velkerri became mature on the “Walton High”, which is located on the northern margin of the Basin, after major uplift of the Velkerri and older rocks, and before deposition of the Moroak and Jamison Sandstones. This conclusion is based on the finding of wide variation of maturity levels in the three wells on the Walton High, the McManus #1, the Walton #2 and the Altree #2. However, this work points out that the Velkerri reached peak maturity, in this area at least, following deposition of the Moroak and Jamison Sandstones. If this is also true of the Velkerri in deeper parts of the basin, this timing is very significant and positive for Beetaloo Basin prospectivity.

2) Lanigan et al., 1994, “Petroleum Exploration in the Proterozoic Beetaloo Sub-Basin, Northern Territory”, pp. 674-690 in APEA Journal, is a good synopsis of the exploration history of the Beetaloo Basin, and will in part be discussed elsewhere. Age of the dolerite (diabase) sills which intrude the Velkerri and older sediments is noted at 1220 to 1280 Ma. None of the wells drilled in the Beetaloo Basin encountered dolerite intrusives in sediments younger than Velkerri. This article states that the intrusive event may be time equivalent to the tectonic deformation of the Velkerri and older. The article also places the age of the Roper Group (Velkerri?) to be greater than 1430 Ma.

An article in the 1988 APEA Journal (Jackson et al., 1988, pp. 283-302) discusses the McArthur Basin generally, and focuses on the then known petroleum geology of the McArthur and Nathan Groups as well as the Roper Group. This article pre-dates drilling in the Beetaloo Basin. It is however, a good summary of general regional stratigraphy.

An excellent summary of the Velkerri Formation is presented in the AAPG Bulletin, (Warren et al., 1998, pp. 442-463). Elements of this article are used in evaluation of the Beetaloo Basin regionally and incorporated in interpretations made in this report. Source rock implications of this article are discussed and utilized elsewhere.

Flavelle authored a 1996 unpublished article entitled “Oil Development Project Southern McArthur Basin Northern Territory” with focus on the post-Velkerri, Kyalla organic-rich shale intervals. He also provides an excellent summary of the Pacific Oil and Gas Jamison #1 and Elliot #1 wells. Flavelle describes the fractured shale production of the Bakken Shale of the Williston Basin, United States. He then draws the comparison between the Bakken and the Kyalla noting that the Kyalla is both thicker and shallower than the Bakken. He further provides an economic analysis of development of fractured Kyalla based on the comparison to the Bakken Shale.

An early work by the Bureau of Mineral Resources (BMR) by Powell et al. (1987), Geology and Geophysics Record 1987/48 entitled the “Petroleum Geology and Geochemistry, Middle Proterozoic McArthur Basin”, is a lengthy discussion of source rock potential of the greater McArthur Basin. It is important to note that this work preceded any seismic acquisition or drilling by Pacific Oil & Gas Pty. Ltd. in the Beetaloo Basin. This report does point out the presence of rich lacustrine pre-Velkerri source rocks, primarily in the Barney Creek Formation of the McArthur Group, in which there are organic rich intervals totaling up to 200 meters thick and up to 7% organic carbon content. Thus pre-Velkerri sediments also should have had substantial hydrocarbon charge, and may present a totally unevaluated opportunity in the Beetaloo Basin. This 1987 report discounts the deeper or older potential in the greater McArthur Basin, but since it was written prior to any seismic acquisition in the Beetaloo Basin, the geometry of deeper strata was unknown at the time the report was written.

Other articles and inter-personal communications are available including articles in the ***Oil and Gas Journal*** (Clementson, 1994) and the ***AAPG Explorer*** (Fritz, 1986). These add some insight as to the thinking by the original and later explorers of the Beetaloo Basin but little useful knowledge to further the current exploratory effort.

Exploration History

Appendices 1 and 2 contain geological and general stratigraphic descriptions of the important wells drilled within and near the Beetaloo Basin. Other important events in the evaluation of the greater McArthur Basin and the Beetaloo Basin are:

- Airborne magnetometer survey by Barkley Oil Company Pty. Ltd. in 1964.

- Aeromagnetic Survey flown in 1966.

- Kennecott Minerals, while doing mineral drilling in 1979, had a gas blow-out. This resulted in Amoco doing further work followed by the drilling of the Broadmere #1 well, east of the Beetaloo Basin in 1984.

- Drilling of the Bureau of Mineral Resources (BMR) stratigraphic core holes with the Urapunga 4 test encountering “live oil” in the Velkerri(?) shale in 1985. This well is far north of the Beetaloo Basin, near the northern margin of the McArthur Basin. In total the BMR drilled twenty shallow stratigraphic core holes from the northern margin of the McArthur Basin to the southern edge of the Beetaloo Basin.

- From 1984 to 1988 Pacific Oil & Gas Pty. Ltd. acquired 2D seismic, eventually acquiring approximately 2700 kilometers of data, and on October 5, 1988 spudded the Altree #2 well on the “Walton High” on the northern margin of the Beetaloo Basin. This was quickly followed by the Walton #2 and the McManus #1 both also located on the Walton High. Prior to that time, Pacific Oil & Gas had focused on the McArthur Basin north of the Walton High. Ten of the more significant of these wells are summarized in Appendix 1. The early exploration effort by Pacific Oil & Gas was to test anomalies in the McArthur Basin north of the Walton High. Encouraged by shows in a number of wells in that area, Pacific proceeded to test the Walton High, then began a drilling program in the Beetaloo Basin proper. The one exception was the Shea #1 in the McArthur Basin which was drilled in July of 1991, just prior to spudding the Elliott #1 in the Beetaloo Basin in August of 1991. All wells drilled by Pacific Oil & Gas in the McArthur and Beetaloo Basins were plugged and abandoned without a completion attempt.

• Additional seismic acquired from 1988 to 1992 resulted in the drilling of additional wells in an attempt to establish commercial hydrocarbon production in the Beetaloo Basin. Although several wells were intended to test geophysical anomalies, the Jamison well was drilled as a stratigraphic test prior to seismic acquisition in the area (Lanigan, 2005, pers. comm.) The excellent shows in this well generated interest and further work in the Basin center. The Burdo #1, which was the last well drilled by Pacific Oil & Gas and the last well drilled in the Beetaloo Basin by Pacific or anyone else to date, was spudded on August 26, 1993 and the rig was released on September 12, 1993 at a T.D. of 1239 meters in the Moroak Sandstone. At this time, the Bakken Shale in the Williston Basin was being successfully completed as a fractured-shale reservoir. Based on this success with a organic-rich black shale, Pacific attempted to fracture stimulate the Velkerri Shale in the Burdo well but was unsuccessful (Lanigan, 2005, pers. comm.)

• Currently Sweetpea Corporation Pty. Ltd. holds EP 76, EP 98 and EP 99 and EP 117.

Pacific Oil and Gas Historical Perspective

To supplement published accounts, additional information regarding the exploration program conducted by Pacific Oil and Gas was obtained from Kevin Lanigan, an exploration geologist formerly working in the Beetaloo Basin for Pacific Oil and Gas (2005, pers. comm.) CRA (Rio Tinto), a mining company, saw the potentially large profit margin with oil and gas and decided to form an oil and gas exploration subsidiary. Lanigan joined the exploration subsidiary, Pacific Oil and Gas, in 1989. The company had two strategies:

1. buy into conventional plays – 10% of various opportunities, but they found that approach frustrating and had no control, and
2. with people in their research group who had experience with sedimentary rocks, they looked for a niche play where no one else was working.

Pacific looked for evidence of oil and gas in mineral core holes and, spurred by Amoco's activity east of the Beetaloo Basin, focus centered on Proterozoic basins. Based on their work and government research, an initial exploration program evaluated the McArthur Basin area as the most likely basin in Australia for Proterozoic hydrocarbons. The initial work was north of the Walton High where the sediments of the Roper Group were at the surface. They drilled stratigraphic tests using slim hole coring rigs. Pacific decided that the Roper Group was too shallow in this area and, although there were good shows, the seal integrity was inadequate (Lanigan, 2005, pers. comm.) With gravity data, Pacific identified the deeper Beetaloo Basin and the focus of the project moved south.

Pacific drilled the #1 Jamison well in the deepest part of the Basin as a stratigraphic test. This was followed by several dry holes with limited shows. An internal sunset clause was established stating that, if Pacific did not make a discovery in the next several wells and specific time period, the project would be shut down. At this point in time, none of the wells had been drilled on structures; they were stratigraphic tests. Seismic in the Jamison area was shot after the well was drilled.

Lanigan (2005, pers. comm.) said that one of the major problems encountered by Pacific was the difficulty in imaging the subsurface on seismic due to limestones and basalts at the surface and Tertiary and Quaternary alluvium. Karsting in the Cambrian limestones was also a problem with seismic acquisition in some areas. Pacific drilled water bores before drilling each exploration well to provide water. At the Mason well, they produced fresh water from karstic porosity. Once they realized the presence of karsting they could identify sinkholes at the surface. He said that there are large subround features on the topographic maps that are, when examined on the surface, sinkholes.

Pacific Oil and Gas had many geoscientists with a mining background and some of the research geoscientists proposed using an electromagnetic technique reported to be successful in exploration for oil and gas in Russia. This was a type of tool familiar to mining geologists and the company hoped to find a new tool to use in exploration for oil and gas that would be more successful than seismic. There is little information available about this technique and it was apparently not successful.

Regional Geologic Setting

Beetaloo Basin Definition

Several tectonic features border the Beetaloo Basin. The northern boundary is considered to be the Walton High. To the east lies the Batten Trough and to the south is the Helen Springs High. The western margin is less well defined and probably extends beyond the Daly Waters Arch. Regional gravity data indicate a thicker sedimentary section immediately west of the Daly Waters Arch. Also to the east of the Arnold Arch, lies a less disturbed, thicker sediment package.

Relative to the McArthur Basin, the Beetaloo Basin appears to have undergone only mild tectonism. The in-hand seismic reveals that the Walton High, the Arnold Arch and the Helen Springs High all have experienced much more pre-Upper Roper Group deformation than the rest of the Beetaloo Basin. Current seismic coverage does not include the Daly Waters Arch, so the relative amount of deformation there is unknown. The Arnold Arch shows less severe deformation than either the Walton High or the Helen Springs High, making it highly prospective.

Tectonic Framework

Australia has had a long history of tectonic stability. Although Proterozoic plate positions are less well known that those of the Paleozoic and younger, the north central part of Australia has not experienced any significant compression since formation of the Beetaloo Basin. Figure I-1 shows the location of the Australian plate from Mesoproterozoic through Cambrian time.

The Beetaloo Basin is an intracratonic sag basin that formed as a satellite basin of the larger McArthur Basin (refer to Figure I-2). The McArthur Basin is a Mesoproterozoic rift basin including several troughs bounded by normal faults that have been reactivated at least twice during the Neoproterozoic as compressional and strike-slip faults. Although the Beetaloo Basin contains Neoproterozoic sediments, they are poorly defined in outcrop and seismic data. The Neoproterozoic sediments comprising the Roper Group that are fairly well defined by seismic data in the Beetaloo Basin reach 3000m thickness in the center of the basin, and were deposited at ~1400Ma. A section of Cambrian rocks deposited at ~500Ma spreads over the extent of the Beetaloo Basin, and is virtually un-deformed, except for showing erosional thinning from Ordovician to present time over the two largest structural highs: the Walton High and the Arnold Arch.

According to Plumb (1994) the oldest faults in the McArthur Basin, shown on Figure I-2, in the Walker Fault Zone, trend NNW to NNE, separating major tectonic terranes. Intense deformation and metamorphism is confined to a few narrow fault zones, with most of the section being relatively undisturbed and showing only minor diagenesis. These northerly-trending faults and sediment-filled grabens are thought to underlie the Beetaloo Basin, contributing to a north-south structural alignment of younger faults that form significant structural highs, like the Arnold Arch.

WNW trending strike-slip and compressional faults exposed in the Mitchell and Parsons Ranges northeast of the Beetaloo Basin overprint the rift faulting, still preceding Roper Group deposition, as indicated by surface mapping. At least two periods of deformation predating the Roper Group deposition probably contribute to a strong lineation of later structures that involve the Roper Group, in both northerly and westerly directions. Faults involving the Roper Group and trending NNW-SSE crop out on the eastern Bauhinia Shelf immediately northeast of the Beetaloo Basin. These probably reactivate older faults along the same direction, forming the alignments of the large structural leads, specifically the Dunmarra, 80 Meter Tower, Cooee hill, and Hemley leads (refer to the Jamison and Moroak structure maps, Enclosures 6 and 7).

Across much of the McArthur Basin, the oldest sediments show no significant metamorphism. Uplift of large syndepositional rift blocks now appears to be a common feature of ancient rift systems. Thus, the rocks now at the surface were never more than a few kilometers deeper than their present positions.

Within the Beetaloo Basin there are large north-south trending structural highs that appear to have been influenced by the pre-existing major crustal zones of weakness of the Walker Fault Zone. These form large petroleum-prospective lead areas, since burial history shows the structures to have been positive since deposition of the major source-rock sections, the Velkerri and the Kyalla shales.

Smaller structural highs trending in a more east-west direction exist throughout the basin. These appear to be formed by compressional strike-slip fault systems that parallel the late-stage faulting visible in outcrop elsewhere in the McArthur Basin. On a few seismic lines of unusually high resolution, (Line ME91-64, Appendix III) the faults and fractures are easily identifiable, and clearly do not penetrate the laterally-continuous Hayfield Mudstone. Thus the Hayfield claystones and siltstones should form an ultimate seal for deeper fractured reservoirs, especially the immediately underlying Jamison Sandstone.

II. BEETALOO BASIN STRATIGRAPHY

The Beetaloo Basin stratigraphy is extensively discussed in existing reports and literature. Of particular note is the June 1997 RobSearch Report. For the purposes of this report, emphasizing the exploration significance of the strata within the Beetaloo Basin, less effort will be spent on nomenclature and more on the source-reservoir-seal, geophysical, or other exploration significance of the various depositional units. The stratigraphy of the interval of interest is shown in Figure II-1. Enclosures 1 and 2 are restored stratigraphic cross sections that have reconstructed depositional history and attempted to restore approximate original thicknesses in the Beetaloo Basin. Unconformities are very important in the Basin and may ultimately provide a trapping mechanism for hydrocarbons. These cross sections emphasize the stratigraphic position and magnitude of the unconformities. Enclosure 3 is a structural log cross section from north to south across the Basin.

Sediments, Layered and Related Rocks of the Beetaloo Basin

Tertiary & Cretaceous

Mullman Beds: Some of the surface and shallow strata in the Beetaloo Basin consists of Cretaceous “Mullman Beds”. These are not well defined or of explorational significance other than that they often form the surface and are considered to be Cretaceous and/or Tertiary in age. In the Elliott #1 these sediments are described as poorly consolidated, yellow-brown weathered mudstone with occasional sandy intervals. Lost circulation is occasionally a concern in this regolithic overburden. Apparently the lower portion of the Mullman Beds is in part marine as glauconite becomes present in a black claystone. The Mullman Beds are not present as a continuous unit, and only occasionally are mentioned as part of the stratigraphic sequence. These unconsolidated surface sediments may have a negative impact on seismic data acquisition and resulting data quality.

Cambrian

Jindukin Formation: Like the Mullman Beds, the Jindukin is not present throughout the Beetaloo Basin. In the Elliott well the Jindukin Formation is over 200 meters in thickness and of variable lithology including sandstone and siltstone, with increasing dolomitic content with depth. The lower portion of the unit is dominated by dolomitic siltstone. The lower portion of the Jindukin can present lost circulation problems.

Tindall Limestone: The Tindall Limestone is commonly present in Beetaloo Basin wells. It can be up to 300 meters thick and is variable in thickness or may be absent altogether. Like the Jindukin, it can offer operational challenges with common lost circulation and even cavernous (karst?) nature. The Tindall Limestone, together with the Antrim Plateau Volcanics usually immediately beneath, offer a challenge to geophysical acquisition due to their variable thickness, erratic presence and high velocity which will contribute to complicated ray paths and signal scatter.

Antrim Plateau Volcanics: These volcanic beds (also sometimes referred to as the “Nutwood Downs Volcanics”) are extrusive in nature and for that reason are unconformable on both their upper and lower surface. They can exceed 350 meters in thickness as they do in the Ronald #1 well. No mention of lost circulation occurs in these beds so, other than being a “hard rock” unit to penetrate above the potentially economic units of the Roper Group, they are of little significance. Geophysically they offer the most significant challenge as they, together with the Tindall Limestone, can create reflective energy traps which limit frequency content and complicate ray paths during seismic recording. The extent of the Antrim Plateau Volcanics within the Beetaloo Basin based on aeromagnetics is discussed in Chapter IV. GEOPHYSICS.

Bukalara Sandstone: The Bukalara Sandstone is a basal Cambrian unit that is occasionally present at the Pre-Cambrian/Cambrian unconformity. It is present in the Jamison #1 well where it is approximately twenty-five meters thick and in the Balmain #1 where it is approximately 100 meters thick. The Bukalara has excellent reservoir quality and although neither it nor any of the younger units have had reported shows, the Bukalara would constitute a very good potential reservoir should it be found in a viable trap and have been charged by secondary migration from older stratigraphic units. Since the Bukalara is a sandstone of variable thickness and occurs only occasionally, it may represent a valley-filling fluvial sandstone.

Precambrian – Roper Group

McMinn Formation

Hayfield Mudstone The Hayfield Mudstone member of the McMinn Formation was deposited as a regional thick organic poor shale and siltstone. The Hayfield Mudstone may also be known as the Chambers River Formation, but in this report it will be known by its more commonly used name. It is the uppermost and youngest of the preserved Precambrian sediments in the Beetaloo Basin. It is unconformably overlain by either the Bukalara Sandstone, the Antrim Plateau Volcanics or the Tindall Limestone and appears to be conformable with the underlying Jamison Sandstone. The Hayfield Mudstone appears to be totally absent north of the Walton High and is also not present in the Elliott well near the southern margin of the Beetaloo Basin. A 280 meter section of Hayfield Mudstone is present on the Walton High in the McManus #1 well. Due to the Hayfield Mudstone's fairly uniform and considerable thickness (approximately 400 meters) in the central portion of the Beetaloo Basin, and correlatible internal markers (log character), it is reasonable to assume that it once occupied a much more regional extent.

Where not erosionally absent, approximately sixty meters above the conformable contact with the Jamison Sandstone, a sandy zone containing common hydrocarbon shows occurs. This zone was drill stem tested in the Jamison #1, the Mason #1 and the

Shortland #1 wells. Recoveries were poor, primarily small amounts of mud, with the only hydrocarbon recovery being a flow of gas, too small to measure (TSTM) plus 13 liters of mud in the Jamison well. This sandstone is relatively thin at three to seven meters and would not constitute a major explorational target.

The primary potential economic significance of the Hayfield Mudstone is that it is a seal for the conformably underlying Jamison Sandstone in a structural setting. Lithologically the Hayfield Mudstone is variously described as claystone and siltstone, massive to fissile, well indurated, in various shades of brown, gray, green, and reddish. The Hayfield Mudstone does become increasingly sandy toward the base. Notably, glauconite is a common, but minor, constituent attesting to the marine origin of this unit. It was likely deposited as a typical basin-wide mudstone and shale with the sandier intervals representing either a slight shallowing or possibly flood periods or higher flow rates from the sediment supplying rivers.

Jamison Sandstone The Jamison Sandstone Member of the McMinn Formation was informally named due to its presence in the Jamison #1 well where shows resulted in extensive testing. It had previously (and probably stratigraphically more properly) been known as the Bukalorkmi (not to be confused with the Cambrian Bukalara) Sandstone Member of the McMinn Formation. For consistency and because of common usage in the Beetaloo Basin, Jamison Sandstone will be the name used in this report.

The Jamison sandstone has a transitional, conformable upper contact with the overlying Hayfield Mudstone, and is universally in unconformable contact with the Kyalla Shale Member of the McMinn Formation below. The Jamison Sandstone is erosionally absent on the Walton High but does occur to the north in the greater McArthur Basin in the Pacific Oil & Gas Shea #1 well where a twenty meter thickness was present at the surface. Within the Beetaloo Basin proper, the Jamison is clearly very widespread. The Jamison Sandstone is generally approximately 100 meters thick but expands to about 160 meters in the eastern portion of the Beetaloo Basin in the Burdo #1 well.

Reservoir properties of the Jamison Sandstone appear best in the upper fifty meters. Visual porosity is usually described as poor or nil with occasional fair observations mentioned. Drill stem tests in the Jamison #1 and Mason #1 occurred in the upper portion where over 1000 meters of gas cut muddy water was recovered on a DST in the Jamison #1 along with a small flow of gas. Within that DST interval from 895.3 to 901 meters the Jamison #1 had measured core porosity up to 12.4% and permeability up to 121 millidarcies. Another DST of the upper portion of the Jamison Sandstone in the Jamison #1 well recovered 448 meters of gas cut formation water, a gas flow too small to measure and 1.5 meters of free oil. Thus where the Jamison Sandstone is found in trap geometry with the Hayfield Mudstone as a seal and where hydrocarbon charge preceded diagenetic carbonate and silica cementation of pore space and throats, it constitutes a major economic target in the Beetaloo Basin.

Lithologically the Jamison Sandstone is described as light to medium gray in color, occasionally brown or green gray, very fine grained to medium grained and moderately to well sorted. The Jamison Sandstone appears to exhibit a general coarsening upward with a common cleaner ten to twenty meter zone in the upper one-third of the unit. Above this cleaner sandy zone, the Jamison becomes quickly more shaley until it becomes indistinguishable from the overlying Hayfield Mudstone. The base of the Jamison Sandstone is characterized by an abrupt unconformable change from the clearly relatively quiet water, reducing conditions present in the Kyalla to the much higher energy environment responsible for deposition of the Jamison. Previous studies cite transport direction for coarse sediments in the Beetaloo Basin as south to north. However, with the thickest Jamison sandstone in the Burdo #1 well, located in the east-central portion of the Basin, and the fact that Jamison Sandstone is found well north of the Walton High, in the McArthur Basin, it is difficult to present a strong case for any particular sediment transport direction. However, the Jamison likely represents a fluvial sandstone at its base with gradually increasing marine influence as is evidenced by the increasing amounts of shale and claystone until the typical Hayfield mudstone lithology becomes dominant.

Kyalla Shale The Kyalla Shale member of the McMinn Formation represents one of two major source-rock units in the Beetaloo Basin. The Kyalla Shale originally occupied the entire Beetaloo Basin and probably much of the Greater McArthur Basin as well. It represents a deep basin, low energy "starved basin" type of deposit with high organic content, particularly in the lower portion immediately above the Moroak Sandstone and, where preserved, beneath the unconformably overlying Jamison Sandstone. The Kyalla Shale is conformable with the Moroak Sandstone.

Rb-Sr dating of the Kyalla from illites places the age at 1429 +/- 31 Ma.

The Kyalla is a significant source rock in the Beetaloo Basin, where it is universally mature. Organic content in the Kyalla Shale is generally less than 2% but does, though rarely, exceed 6% in the lower organic rich zone. One sample at 1580 meters in the Jamison #1 well was reported to contain 8.97% TOC. The source rock properties and their significance will be discussed elsewhere.

With the exception of scattered remnants in the McArthur Basin (see Lady Penrhyn well, Appendix II), distribution of the Kyalla is restricted to the heart of the Beetaloo Basin where it reaches a thickness of approximately 730 meters in the Jamison #1 well. It thins because of increasing erosion beneath the Jamison Sandstone to the east and is found to be only 170 meters thick in the Ronald #1 well and 390 meters in the Burdo #1. In both the Ronald and Burdo wells however, the organically richer lower Kyalla is present. Its regional distribution far to the north of the Beetaloo Basin is confirmed by its presence in the Lady Penhryn #1 and #2 wells and the Shea #1 in the McArthur Basin. The Shea #1 penetrated 220 meters of Kyalla Shale were penetrated. Probably nowhere in the Beetaloo Basin is a complete section of Kyalla Shale preserved. The strong erosional contact with the overlying Jamison Sandstone precludes complete preservation.

Oil and gas shows are nearly universal within the Kyalla Shale with numerous reports of strong odor and gas and oil “bleeds”.

Lithologically the Kyalla Shale is described as siltstone and claystone, light gray to very dark gray and brown, massive to fissile and containing occasional thin sandstone units. The best live oil shows are normally from the siltier and sandier zones. The southern-most well in the Beetaloo Basin, the Elliott #1 appears to be missing approximately the upper 75 meters of the Kyalla Shale due to erosion. The Kyalla in the Elliott #1 contains several sandy zones, three of which were tested. Results indicated that all three zones were tight with only a small amount of mud recovered on all DSTs. The increase in sand content in the Elliott well does indicate a coarse clastic source relatively nearby and may, at least for the Kyalla Shale, indicate a southerly source for coarser Kyalla clastic sediments.

The Kyalla Shale is a source rock that should have generated enormous volumes of hydrocarbons in the Beetaloo Basin, with significant potential as a seal for the underlying Moroak Sandstone. The Kyalla is likely responsible for generating the hydrocarbons encountered in the Jamison Sandstone and the sands in the lower Hayfield Mudstone. It may also have charged the underlying Moroak Sandstone in part.

Moroak Sandstone The Moroak Sandstone of the McMinn Formation represents one of the more significant economic reservoir targets in the Beetaloo Basin. It occupies a position stratigraphically between the two major source units, the overlying Kyalla Shale and the underlying Velkerri Shale. The contact with the Kyalla appears conformable while the contact with the underlying Velkerri, though less certain, may be unconformable. Confusing this issue is a paucity of penetrations of the boundary between the Moroak and the underlying Velkerri. This contact is clearly unconformable in the Altree #2 well on the Walton High where only about eighty meters of Moroak remain.

The Moroak Sandstone is at least 408 meters thick in the Elliott #1 in the southern part of the Beetaloo Basin. Based on correlations, it appears that at T.D. the Elliott well was very close to the contact between the Moroak and the underlying Velkerri. The next thickest penetration of the Moroak was in the Ronald #1 where approximately 100 meters were drilled.

The Moroak has the two best fluid recoveries on DSTs reported in the Beetaloo Basin. In the Ronald #1, the upper Moroak yielded 3108 liters of salt water in a total flow period of twenty-four and one half minutes. This equates to approximately 3000 barrels of fluid per day. This rate may have been greater but the well "killed itself" presumably by approaching hydrostatic head during the flow period. In the Elliott #1 the upper Moroak was again tested and during a total of ninety-eight minutes of flow period, yielded 5200 liters of "highly saline formation water". Core porosities within the Moroak range from about 6% to 15% with a few measurements up to 19% in the McManus #1 from depths near 700 meters. In the Elliott #1, core measurements from about 1340 meters to 1400 meters ranged from near 0% to nearly 10% porosity. Porosity seems to decrease significantly with increasing burial depth.

Lithologically, the Moroak Sandstone consists of predominantly fine to coarse quartz sand. It occasionally has some anhydrite cement and commonly has authigenic silica cement. In the Elliott #1 well, where the most complete section of the Moroak was penetrated, the upper eighty-five meters appears to be relatively massive. The Moroak was cored in the Elliott well, and a detailed description is included as Appendix V. The color is generally varying shades of gray to reddish, yellowish or brownish. Some anhydrite veining is noted. The unit is described as very tight, and "chert-like". Grain size is mostly fine but some grains up to coarse are noted. Of possible depositional significance, there are noted small shale clasts occasionally delineating the bedding planes. Overall the Moroak exhibits a cleaning-upward and coarsening-upward trend until the relatively rapid transition into the overlying Kyalla. The lower portion of the

Moroak is darker gray. In the core description it is noted that the gradation into the upper Velkerri may occur between 1583 and 1685 meters of depth. Soft sediment deformation features are present and increase with depth. This may indicate rapid deposition and de-watering of the unconsolidated sediments associated with rapid loading. Common fractures and stylolites are noted in the core. Usually these fractures are healed with anhydrite but occasionally are open. Natural fracturing could enhance reservoir quality and contribute significantly to permeability.

The Moroak is clearly a regional sand and potential reservoir in the Beetaloo Basin. It is present on the Walton High and in several wells to the north in the McArthur Basin. In the Lady Penrhyn #1, the Moroak contained common shows and as in the Elliott #1, had soft sediment deformation features. In the Alexander #1 in the McArthur Basin, the Moroak was composed of coarse to medium sand and had pore filling bitumen throughout. This is a clear example of ample hydrocarbon charge to the Moroak, indicating further the prospectiveness of this potential reservoir.

Velkerri Formation Like the Kyalla Shale Member of the McMinn Formation, the Velkerri Formation represents a significant source rock for the Beetaloo Basin. In the Beetaloo Basin the Velkerri, with an age of about 1.43 Ga (Warren et al., 1998) is penetrated only on the Walton High, with the exception of the possible penetration of the top of the formation in the Elliott #1 well. It represents a “starved basin” type deposit with three highly organic rich intervals generally near the middle of the unit. In the organic rich portion of the Velkerri, TOC levels commonly exceed 4% and occasionally reach 8%. The three organic-rich units are twenty-five to thirty meters thick each. Although the Velkerri was not penetrated south of the Walton High, the presence of a thick section on the Walton High and common penetration in the McArthur Basin north of the high, suggest it is almost certainly present in the subsurface of the Beetaloo Basin where it has generated enormous volumes of hydrocarbons

Like the Kyalla member of the McMinn Formation, the Velkerri Formation seemingly always contains hydrocarbon shows including strong odor, and live oil and gas “bleeds”. On the Walton High, the Velkerri attains a thickness of approximately 1150 meters (based on internal correlations and “restored thickness” (Enclosure 2) between the Altree #2 and McManus #1 wells.

The contact with the overlying Moraok Sandstone is probably unconformable in the McManus #1 well, and certainly unconformable in the Altree #2 well, both on the Walton High. If, as is suspected, the contact is gradational in the Elliott #1 well in the southern portion of the Beetaloo Basin, it may well be conformable there. Either way, the Velkerri would act as a significant source for charge to the overlying Moroak Sandstone. The base of the Velkerri is of uncertain conformability with the underlying Bessie Creek Sandstone. Certainly there was a dramatic environmental change from the coarse clastics of the Bessie Creek to the shales and siltstones of the Velkerri, but whether there is a significant time gap is unknown. The Velkerri would have been a significant source of hydrocarbon charge to the underlying Bessie Creek Sandstone and also would likely provide a competent seal.

Overall the Velkerri is a coarsening upward sequence with greenish, organic poor, shales present in the lower and upper portion of the formation and the organic richest portions near the middle. The shoaling upward into the Moroak Sandstone likely represents basin-wide deltaic progradation and an increase in depositional environmental energy.

Age estimates for the Velkerri center around 1430 Ma.

Lithologically the Velkerri, where less organically rich, is a siltstone with minor claystone inter-beds. Occasionally thin sandy zones occur, none of which reach economically significant thickness. Color is gray to dark gray. Some current bedding and possible soft sediment deformation features are noted. In the organic rich zones, the lithology becomes thinly laminated shale of “brownish-black” color. The coarsening upward sequence with greenish shales present below and above the organic rich zones, followed by the shallowing into the overlying Moroak Sandstone represents a gradual transition to a higher energy environment, likely the result of some basin filling event such as regional deltaic progradation.

Bessie Creek Formation The Bessie Creek Sandstone is the third of the significant reservoirs of the Beetaloo Basin. Although not penetrated within the Beetaloo Basin outline south of the Walton High, the thick (400 meters plus) Bessie Creek in the Altree #2 well and common penetrations of the Bessie Creek in McArthur Basin wells, point to the regional nature of the Bessie Creek and almost certain presence in the Beetaloo Basin.

In the Altree #2 well on the Walton High the Bessie Creek Sandstone is described as generally fine to very fine grained, with occasional mention of medium grain size, and light to medium and occasionally dark gray in color. Visible porosity is rare but some is noted near the top of the formation. In the McArthur Basin north of the Walton High, the Bessie Creek occasionally exhibits fair to good porosity. Also, very significantly, in the McArthur Basin, the Bessie Creek Sandstone is noted as containing pore-filling bitumen. This indicates that the Bessie Creek retained good porosity prior to and during generation and migration of hydrocarbons, and that the Bessie Creek received good charge from the overlying (or an unknown underlying) source. DSTs run in the McArthur Basin in the Bessie Creek in the Friendship #1 and Borrowdale #2 wells recovered 80 and 360 meters of water respectively and both had initial and final Shut-in-Pressures that were equal, and of sufficient pressure to indicate good reservoir quality. The implication is that the Bessie Creek in the Beetaloo Basin has excellent potential to be an economic and hydrocarbon charged reservoir where trapping geometries existed prior to hydrocarbon generation.

The upper contact of the Bessie Creek with the lower Velkerri Shale is discussed above. The contact with the Corcoran Formation beneath appears to be transitional and conformable.

Corcoran Formation In the Beetaloo Basin the only penetration of the Corcoran Formation is in the Altree #2 well. Here it is described as a siltstone and claystone of various shades of gray, and very indurated. The Corcoran is considered to have little importance economically either as a source rock, reservoir, or seal.

Older Sedimentary Units of the Beetaloo and McArthur Basins

No other reservoir units are known to be present in the Beetaloo Basin. However, as much as 10,000 meters of Precambrian sediment may be present. Coherent seismic reflectors are seen on the seismic records to over 4 seconds. Sediments beneath the Roper Group would be of questionable economic significance due to their great depth and unknown source-reservoir-seal relationships. Any source rocks within them would almost certainly be over-mature.

Tawallah Group Oldest sediments and related layered rocks in the overall McArthur Basin area are found in the Tawallah Group. These 1,700 to 1,800 Ma ancient rocks from oldest to youngest consist of the Yiyintyi Sandstone, the Siegal Volcanics, the Sly Creek Sandstone, the Settlement Creek Volcanics, the Wununmantyala Sandstone, the Wollogorang Formation and the Gold Creek Volcanics. The Tawallah Group as a whole can be up to 4,500 meters thick.

McArthur Group Unconformably overlying the Tawalla Group is the McArthur Group. Within the McArthur Group from base upward are the Masterton Sandstone, the Mallapunyah Formation, the Amelia Dolomite, the Tatoola Sandstone, the Toogannie Formation, the Myrtle Shale, the Emmerugga Dolomite, the Teena Dolomite, the lacustrine Barney Creek Formation with source rocks present, the Reward Dolomite, the Lynott Formation, the Yalco Formation, the Stretton Sandstone and the Looking Glass Formation. Whether or not the carbonates or sandstones within the McArthur Group are of reservoir quality is unknown.

Nathan Group The Nathan Group combined with the McArthur Group can reach up to 5,500 meters thick in the Batten Trough. Age of these groups is considered to be 1,400 to 1,500 Ma. The Nathan Group consists of the Balbirini Dolomite overlain by the Dungaminnie Formation which consists of a basal sandstone and an upper dolomite.

Lower Roper Group Unconformably above the Nathan Group, from oldest to youngest, the lower strata of the Roper Group consist of the Limmen Sandstone, the Mainoru Formation with the Mountain Valley Limestone Member and the Wooden Duck Member, the Crawford Formation, the Arnold Sandstone, the Jalboi Member, the Hodgson Sandstone and underlying the Corcoran Formation, the Munyi Member. Like the McArthur Group, the quality of the potential reservoirs in the lower Roper Group is unknown.

Intrusive Igneous Rocks

Dolerite (Diabase) sills are common in the pre-McMinn Formation portion of the sedimentary column. Their significance may be as occasional seals as noted in the McArthur Basin in the Borrowdale #2 well where the Bessie Creek Sandstone was found to contain good shows immediately beneath a sill. Also, these sills do locally effect the thermal history of the contact sediments. Zones of contact metamorphism have been noted for over 100 meters adjacent to the sills on both the top and bottom surfaces.

The dolerite sills have been K-Ar dated using plagioclase at 1220 and 1280 Ma, making them younger than the Kyalla Shale of the McMinn Formation. Yet within the Beetaloo Basin from present sub-surface control, the sills do not intrude sediments younger than the Velkerri Fromation.

These sills, where they occur, may negatively impact seismic acquisition, processing and interpretation.

The sills are nowhere found to have connected porosity or been described as fractured where they may be considered potential reservoirs. In the McArthur Basin, in the Friendship #1 well, some non-interconnected “vuggy porosity” is noted containing hydrocarbon shows.

Unconformities

Major unconformities occur within the Roper Group and younger sediments discussed previously. The primary impact they have is to eliminate potentially commercially important strata. On the Walton High the McMinn Formation is all but absent in the three wells drilled by Pacific Oil & Gas there. Yet the Antrim Plateau Volcanics and Tindall Limestone are both present. This demonstrates pre-Antrim Plateau Volcanic structural movement on the Walton High. It may also signal the formation of structures within the Beetaloo Basin prior to the Cambrian extrusive event. If these structures pre-date maturation of the major source strata, they would have been available for early charge and entrapment plus probable preservation of original matrix porosity.

Unconformities may also provide sub-crop trap opportunities. Reprocessing and reinterpretation of the available seismic should reveal these geometries. Future seismic acquisition may also be appropriate for defining these traps.

III. Petroleum Geology

The Beetaloo Basin offers a unique opportunity to discover giant petroleum accumulations in a basin with a documented hydrocarbon system. Within the basin of 7 million acres, enormous volumes of oil and gas were generated and migrated into reservoirs. Large untested structures exist in the Beetaloo Basin which contain these reservoirs. Interbedded organic-rich, world class source rocks act as both source and seal and the three major reservoir sandstones all have overlying thick seal facies. Additionally, the potential for sub-crop traps exists beneath the unconformities present in the Precambrian Roper Group sediments. An examination of previous exploration efforts reveals that most or all previous wells were drilled in less than explorationally optimal locations. The operator of these wells did not have the benefit of modern geophysical acquisition or processing techniques.

Conventional Reservoirs

The three principal reservoir units, the Bessie Creek Sandstone Formation, and in the McMinn Formation, the Moroak Sandstone Member and Jamison Sandstone Member, present the opportunity for giant on-structure oil and gas reserves. Each had basin-wide and even regional extent when deposited. Reservoir properties of each are variable, and off-structure, the risk of finding potentially economic reservoir quality diminishes substantially. However, on-structure, there is good evidence of preservation of porosity and permeability. Even with reduced reservoir quality, application of modern technology including improved drilling techniques such as horizontal drilling and fracturing techniques, enhance the prospectiveness of all reservoirs in the Beetaloo Basin.

Jamison Sandstone

The Jamison Sandstone of the Roper Group, McMinn Formation, is the youngest potential major reservoir unit in the Beetaloo Basin (refer to Figure II-1 and Enclosure

3.) In the Jamison #1 well, the Jamison exhibited not only excellent shows, indicative of migration of oil and gas into the sandstone, but also tested over 1000 meters of formation fluid in one DST and hundreds of meters of fluid plus free oil in two other DSTs (see Appendix I.) Also, the Jamison Sandstone is present near surface in the Pacific Oil and Gas, Shea #1 in the McArthur Basin north of the Beetaloo Basin (see Appendix I.) This is evidence of the regional depositional extent of the Jamison Sandstone.

The Jamison Sandstone is overlain by the Hayfield Mudstone, an excellent regional seal. Beneath the Jamison Sandstone are two source units. Immediately beneath the Jamison is the Kyalla Shale with two separate organic rich zones which average in excess of 2% TOC and occasionally reach as much as nearly 9%. One of these two zones is approximately fifty meters thick and lies just beneath the contact between the Jamison Sandstone and the Kyalla Shale offering a direct migration path for hydrocarbons generated from this unit. The Velkerri Shale Formation of the Roper Group is the second organic rich zone available to charge the Jamison. It lies beneath the Moroak Sandstone which is overlain by the Kyalla. The Velkerri TOC levels in the three twenty-five to thirty meter organic rich beds commonly exceed 4% and reach up to 8% or more. Both the Kyalla and Velkerri are mature in the Beetaloo Basin.

Core analysis in the Jamison #1 well of the Jamison Sandstone from 895 to 901 meters averages 11% porosity and 47 millidarcies of permeability.

Moroak Sandstone

The Moroak Sandstone of the McMinn Formation is the middle of the three primary reservoir targets in the Beetaloo Basin. Like the Jamison Sandstone, the Moroak retains good reservoir quality on-structure. In the Ronald #1 well, located on the prominent Arnold Arch in the northeastern portion of the Beetaloo Basin, a DST of the Moroak from 1044 to 1070 meters yielded 3108 liters of formation water in an eighteen minute flow period, or a calculated rate of 3000 barrels per day. This is actually a minimum rate since the flow began to kill itself due to reaching hydrostatic head. In the southern portion of the Beetaloo Basin in the Elliott #1 well, the Moroak tested 5200 liters of formation fluid from the 1330 to 1349 meter interval.

Both the Ronald #1 and the Elliott #1 are on relative structural highs, contributing to evidence of preservation of good reservoir quality on-structure in the Beetaloo Basin.

Shows are common in the Moroak Sandstone with excellent fluorescence noted in the upper Moroak in the Elliott #1 well and in the Alexander #1 well in the McArthur Basin, the Moroak was described as having “bitumen infilling of pores” which is evidence of hydrocarbon charge to the Moroak prior to formation of diagenetic pore filling cement. Therefore it can be expected that porosity and permeability will be preserved on-structure and in hydrocarbon filled traps in the Moroak Sandstone.

In the Walton #2 well on the Walton High, core porosity and permeability in the Moroak averaged 13.7% and 18.2 millidarcies respectively.

Bessie Creek Sandstone

The Bessie Creek Sandstone formation of the Roper Group is the oldest of the three documented major regional sandstone units in the Beetaloo Basin. Though not penetrated within the outline of the Beetaloo Basin south of the Walton High, evidence of the Bessie Creek’s prospectiveness is present.

In the McArthur Basin north of the Walton High, the Bessie Creek is known to contain “bitumen infilling of pores” in the Pacific Oil and Gas, Alexander #1. Some minor visible porosity and fair oil shows are found in the Altree #2 well on the Walton High. Therefore, much like the Jamison Sandstone and the Moroak Sandstone of the McMinn Formation, good preservation of reservoir quality can be expected where the Bessie

Creek is found charged, on structure or in other trap geometry within the Beetaloo Basin.

Charge to the Bessie Creek Sandstone likely came from the lower Velkerri organic rich shale. This would require downward migration of hydrocarbons, but the sandstone clearly received charge as in the Alexander #1 and the Altree #2.

Beneath the Bessie Creek Sandstone in the Beetaloo Basin, almost nothing is known about the sedimentary section other than a very thick section of what appears to be sedimentary strata on the seismic records. Some note of organic rich sediments in the Barney Creek Formation of the McArthur Group is made in the literature, but it is speculative to consider it a significant source for the Bessie Creek or younger strata.

Other Potential Reservoirs

A number of additional reservoirs of secondary potential exist in the Beetaloo Basin. A sandstone in the lower portion of the Hayfield Mudstone was found to contain good hydrocarbon shows in the Jamison #1. This sandstone was drill stem tested in the Jamison #1 and yielded a gas flow too small to measure plus thirteen liters of mud.

Other possible secondary potential reservoirs are found in the Kyalla Shale. These would be ideally situated as they are actually within one of the two major source units in the Beetaloo Basin. Sandstone within the Kyalla Shale appears to increase southward in the Beetaloo Basin and is best developed in the Elliott well where a DST of a sandy zone from 787.54 to 807.5 meters yielded 17.2 liters of mud without mention of recovered hydrocarbons.

If shale-encased sandstones are encountered within the Kyalla or Velkerri Shales in the Beetaloo Basin, and they are of sufficient porosity and permeability, there is potential to use a technique being employed in the Williston Basin of North America to economically recover hydrocarbons. In the Williston Basin, the Bakken Formation encases a modestly porous and permeable very fine-grained carbonate. Conventional vertical wells completed in this zone were not capable of producing hydrocarbons in paying quantities. However, with the application of horizontal drilling, this has become a highly economic play and, as of the writing of this report, is the focus of much intense activity in the Williston Basin. Application of similar technology to Beetaloo Basin reservoirs should greatly expand the resource base of this rich hydrocarbon system.

Source Rocks, Thermal History, and Migration

The presence of many shows of oil and gas in the wells that have been drilled in the Beetaloo Basin, the organic content of two black shales, and the thermal maturity of these shales support the generation of oil and gas from Proterozoic source rocks in the basin. Although Proterozoic sediments are frequently assumed to be non-perspective due to lack of organic matter, deep burial, complex tectonic and thermal histories, and the time elapsed since deposition, economic production from Proterozoic rocks offers encouragement for exploration in these older sedimentary provinces. Although source rocks of this age are not common, they have contributed significant amounts of economically recoverable hydrocarbons in areas such as Eastern Siberia and Oman.

In the Lena-Tunguska Basin north of Lake Baykal, several large fields produce oil and gas from Proterozoic (Ediacaran and Riphean age) and Lower Cambrian strata (Clarke, 1985). One of the largest fields in this region is Verkhnevilyuy, with estimated ultimate reserves of 10.5 TCFG and 250 million barrels of liquids sourced from Proterozoic rocks (Meyerhoff, 1980). Total reserves for this area approach 6 TCF of gas and 149 million barrels of liquids. Clarke (1985) estimated that the undiscovered potential of this basin may be as high as 189 TCFG and 11 billion barrels of oil. In Oman, 12 billion barrels of economically recoverable oil have been generated from the Late Proterozoic Huqf Group, a sequence of carbonates and evaporites (Grantham et al., 1987.)

The presence of a large basin complex in the Northern Territory, Australia with minimal structural disturbance and moderate depths of burial, make the Beetaloo and McArthur basins attractive for hydrocarbon exploration. Documentation of organic rich rock at relatively low thermal maturity has encouraged exploration in the basins. The first report of hydrocarbons in this area was in 1924 when bitumen in a basalt overlying a sandstone was described (Lanigan et al., 1994). In 1979, a gas blowout occurred in a Kennecott mineral corehole in the McArthur Group (Lanigan et al., 1994). As a result of this blowout, Kennecott and Amoco took exploration permits and Amoco, as operator, drilled the #1 Broadmere well in 1984 to a total depth of 2174 m. This well penetrated middle to lower Roper Group sediments and encountered no significant shows (Lanigan et al., 1994) and was plugged.

Stratigraphic drilling by the Bureau of Mineral Resources (BMR) in the 1980's confirmed the presence of upper Roper Group (Middle Velkerri) source rocks in the McArthur and Beetaloo basins. Rocks in the older McArthur Group may also be capable of generating hydrocarbons. In 1985, "live" oil was encountered in one of the stratigraphic holes drilled by BMR and, as reported by Langin et al. (1994), it had a major impact on perception of hydrocarbon potential in this area.

Source Rock Quality and Characteristics

Pre-Roper Group Source Rocks

Several studies of geochemistry and source rock potential have been conducted in the McArthur and Beetaloo basins. The oldest documented source rock in this area is the Barney Creek Formation, a shale sequence up to 200 meters thick west of the Beetaloo Basin in the Batten Trough of the McArthur Basin. Here it contains immature to over mature, oil-prone organic matter. Total organic carbon content expressed as a weight percent (TOC%) varies up to 10.4% (Jackson et al., 1988). The Batten Trough is a rift-related, asymmetric, north-south graben with facies that vary dramatically over short distances. This source rock is restricted to relatively small fault-bounded areas, and was probably deposited in relatively deep lakes or lagoons. Two other potential source rocks occur in the McArthur Group. The Caranbirini Member of the Lynott Formation has TOC contents as high as 3.4%, an adequate source rock and, where it has been sampled, it is mature to over mature (Jackson et al., 1988). This unit, probably deposited in relatively deep water, may have limited geographic distribution. The Yalco Formation was penetrated in one well, the Amoco 82-6, where it contained a 3 meter-thick shale with up to 6% TOC (Jackson et al., 1988). This unit is also interpreted to have a limited geographic distribution.

Stratigraphically equivalent source rocks may exist in grabens below the Roper Group in the Beetaloo Basin. As has been discussed previously in this report, gravity and seismic data support the presence of thick pre-Roper Group sediments in fault-bounded blocks within the Beetaloo Basin. If source rocks equivalent to those that have been identified in the McArthur Basin region are present as far west as the Beetaloo Basin, the depth of burial and tectonic history suggests that they would be over-mature and any hydrocarbons generated have been destroyed or lost.

Roper Group Source Rocks

Within the Roper Group, the Kyalla and the Middle Velkerri are the two dominate source rocks. Organic matter in these fine-grained sediments consists primarily of bacteria, cyanobacteria, and algae (Summons et al., 1994). The lack of bio-diversity at this time is not mirrored in the volume of organic material preserved in the sediment as the high TOC values confirm. The organic matter for both the Middle Velkerri and Kyalla shales is typed by Rock Eval pyrolosis as various mixtures of Type I and II (Taylor et al., 1994).

Middle Velkerri Shale In the Velkerri Formation, thick glauconitic shales with interbedded siltstones, have been penetrated in wells on the Walton High at the north end of the Beetaloo Basin and in the McArthur Basin to the northeast. Based on the stratigraphic framework and seismic correlations, the Velkerri Formation is expected to be present throughout the Basin (Figures III-1 and III-2.)

The Velkerri Formation has been informally divided into three units by Lanigan et al. (1994). Although the entire formation contains organic matter, the middle interval has three organic-rich zones clearly identified by high values on the gamma ray log and supported by geochemistry. TOC content in the more organic-rich zones varies generally from 4 to 6% but values as high as 12.5% have been measured (Taylor et al., 1994). The organic matter is generally composed of bacteria, cyanobacteria, and algae and is oil prone (Type I and II). The Middle Velkerri is an excellent source rock.

The environment of deposition was deep marine to prodelta (Warren et al., 1998) and the water chemistry was relatively high in sulphates resulting in kerogen with relatively high sulfur content (Taylor et al., 1994). These organic-rich shales contain pyrite.

Kyalla Member, McMinn Formation The Kyalla Member of the McMinn Formation has been penetrated in nine of the wells in the Beetaloo Basin. It has been removed by erosion in the Altree #2 and the Walton #2 wells on the Walton High. The Kyalla has two organic-rich intervals as shown in Figure III-3. In the Jamison #1 well, one zone, about 50 meters thick near the top of the shale, has TOC contents ranging from 2-3% and a 200-meter zone near the base of the shale has an average of about 2% TOC (Taylor et al., 1994). The remainder of the 800-meter thick shale has a TOC content of about 1%. The organic matter is also composed of bacteria, cyanobacteria, and algae and is oil prone (Type I and II). The Kyalla is a good source rock.

The environment of deposition of the Kyalla must have been different than that of the Middle Velkerri based on the differing TOC contents and chemistry. The Kyalla shale and kerogens contain very little sulfur and only minor amounts of pyrite.

Thermal and Burial History

The thermal history influencing the Roper Group sediments in the Beetaloo Basin has been influenced by depth of burial and subsequent uplift. The Beetaloo Basin is an intracratonic sag basin and its long history of relative stability produced a geologically simple thermal and source rock maturity history. Two burial history graphs have been generated to illustrate the differences in geologic history between the deeper basin and the marginal uplifts. Figure III-4 shows the relatively rapid burial of the Roper Group in the Jamison #1 well. Although this well did not penetrate the Velkerri shales, the section below the Moroak Sandstone has been projected from the Walton High. Figure III-5 shows a detail of the burial history from 1540 to 1200 Ma. Based on stratigraphy in the Jamison well, the lack of unconformities suggests continued burial without uplift. In contrast, the burial history for the McManus #1 well (Figure III-6) shows rapid burial with several episodes of major uplift that are more clearly shown on the detail of the burial history from 1500 to 1300 Ma (Figure III-7). In the Jamison well, the Middle Velkerri reached a depth of 2400 meters at the end of Hayfield deposition and, with Cambrian deposition, it reached its deepest burial of 3200 m. Since Cambrian time, the Roper Group has experienced nearly 200 meters of uplift associated with surface erosion. In the McManus well, the Middle Velkerri reached a depth of 1750 meters but unconformities document a series of uplifts contemporaneous with Roper deposition.

The Beetaloo Basin has experienced relatively low, consistant heat flow from Roper Group deposition though the present time, reflecting its stable intracratonic position. Although in some areas the intrusion of dolerite (diabase) sills has had a very local influence, these intrusions have not had a major impact on the history of hydrocarbon generation.

Maturation

Evaluation of the thermal maturity of Proterozoic organic matter has some uncertainty due to the relatively old ages and lack of organic bio-diversity. The lack of understanding of the maturation behavior of organic matter subjected to gentle heating over very long periods of time presents a challenge. We also do not fully understand the application of the tools that we generally use to measure maturity in organic matter of this age. One of the primary methods of evaluating the thermal maturity of younger organic matter is vitrinite reflectance. This method is not useful in Proterozoic sediments because the sediments and associated organic matter predate the evolution of terrestrial land plants, the source of vitinite. Amorphous microbial debris preserved with the sediment has been shown to experience physical changes very similar to vitrinite as temperature increases (Summons et al., 1994) and the change in reflectance of this material is referred to as R_o alg (alginite.) R_o alg behaves very much like the conventional vitrinite reflectance.

Geochemical tools are also useful in analyzing thermal maturity. As increasing temperature continues to break kerogen down, the ratio of hydrogen to carbon decreases as hydrocarbons are expelled (Tissot and Welte, 1984). From Rock Eval pyrolysis, T_{max} data and the Hydrogen Index (HI) may also be used as measures of thermal maturity (Summons et al., 1994).

Generation, Expulsion, and Migration

BasinMod, basin-modeling software developed by Platte River Associates, Boulder, Colorado, was used to model burial history, maturity, and timing of hydrocarbon generation and expulsion. 1-D modeling was performed on the McManus

#1 well located on the Walton High and the Jamison #1 well located near the center of the basin. These wells show very different hydrocarbon generation histories.

These models must be used with an appreciation for a variety of variables that are present in the data and assumptions. The values used are considered conservative and the results are also conservative and can be used as a guide to the timing of generation and the volumes of hydrocarbons generated and expelled. These values were selected from Pollack et al. (1993) as available in the compilation incorporated into BasinMod by Platte River Associates, Inc. Given the quiet nature of the geologic history of the north central part of Australia (refer to Tectonic Setting section in the INTRODUCTION) since deposition of the Roper Group, use of a consistent heat flow since Roper Group deposition is appropriate. This also minimizes the impact in any uncertainty with ages. The Middle Velkerri shale has been dated at approximately 1430 Ma by Warren et al. (1998) and this date was used as a guideline in building the depositional history for these source rocks.

Other parameters used in the modeling included the use of transient heat flow and expulsion by saturation method. We assumed that expulsion began when 0.15% of the pore space was filled with hydrocarbons before generation began. This value varies based on lithology, concentration of organic matter, and geologic history. Higher concentrations of organic matter have been shown to provide for more effective expulsion. The source rock of the Middle Velkerri has been described by Warren et al. (1998) as being composed of millimeter-scale couplets of black, highly organic-rich shales (4-6% and greater) and gray-green shales with lower organic content (<2%).

Specific stratigraphic information for each well is shown in Tables III-1 and III-2. The “Kyalla” lithology was defined in the modeling program to reflect the organic-rich nature of the rock and the “Velkerri” kerogen was defined as a mix of 60% Type I and 40% Type II kerogen.

McManus #1 Model

The McManus #1 well penetrated both the Kyalla and the Middle Velkerri source rocks on the Walton High. Table III-1 shows the stratigraphic and source rock data that were used to build the model for this well. For the purpose of modeling thermal history and hydrocarbon generation for this well, a surface temperature of 40° C and a heat flow value of 63 mW/m^2 (milliwatts per meter squared) were used.

To calibrate the model, measured maturity values are compared to the modeled maturity from BasinMod. In Figure III-8, the green line is the modeled maturity as measured by vitrinite reflectance and measured R_o alg and T_{max} data are posted as discrete points. The model fits the measured data well suggesting that the parameters selected for the model (heat flow, stratigraphy, etc.) adequately reflect basin history.

Timing and relative magnitude of generation for the Kyalla source rock (Figure III-9) and the Velkerri source rock (Figure III-10) are shown on graphs of age versus cumulative hydrocarbon generation per milligrams per gram of TOC. The Kyalla source rock, based on this model, began significant generation with deposition of the Cambrian sediments and volcanics but has not yet begun to expel hydrocarbons. As the maturity data indicate, the Kyalla is immature to marginally mature in the McManus well. The Velkerri, in contrast, began generation and expulsion during Hayfield deposition (Figures III-6 and III-7) and, with Cambrian deposition, experienced an increase in rate of generation. The Velkerri source rock is late mature. Figure III-11 superimposes maturation as barrels per acre rock on to the burial history diagram. This diagram reinforces the immature maturation of the Kyalla and suggests that the Velkerri has generated and expelled as much as 300,000 barrels of hydrocarbons per acre rock.

Event	Age	Top (m)	Thickness (m)	Eroded (m)	Lithology	Kerogen	TOC %
Surf Erosion	500			-150			
Tindall	510	0	126		Limestone		
Erosion	525			-73			
Antrim	530	126	143		Igneous		
Erosion	1400			-20			
Hayfield	1410	269	284		Shale		
Erosion	1412			-100			
Jamison	1415			100	Sandstone		
Erosion	1420			-570			
Kyalla	1427			570	Shale		
Kyalla	1429	553	114		Kyalla	Velkerri	2.31
Erosion	1447			-330			
Moroak	1448	667	73		Sandstone		
U Velkerri	1448.6	740	470		Shale		
M Velkerri	1449.4	1210	340		Kyalla	Velkerri	4
L Velkerri	1450	1550	286.8		Shale		

Table III-1: *Parameters used to build the McManus #1 model in BasinMod*. A lithology was created for the organic rich shales in the Kyalla and Velkerri to reflect the organic matter and is termed “Kyalla”. The kerogen type used in the model and termed “Velkerri” is a mix of 60% Type I and 40% Type II. The Saturation Threshold is measured as the percent of pore space filled with hydrocarbons before expulsion begins.

Jamison #1 Model

The Jamison #1 well reached TD in the Moroak Sandstone and drilled through the Kyalla shale but did not penetrate the Velkerri Formation. To model generation and expulsion for the Velkerri source rock in the Basin center, thicknesses and burial history below the Moroak Sandstone are projected into the Jamison well from the McManus well. Seismic interpretations and regional geology support the presence of Velkerri shales of equal or greater thicknesses and organic content in the Basin center. For the purpose of modeling thermal history and generation for the McManus #1 and the Jamison #1, a surface temperature of 40° C and a heat flow value of 70 mW/m^2 (milliwatts per meter squared) were used.

To calibrate the model, measured maturity values are compared to the modeled maturity from BasinMod. In Figure III-12, the green line is the modeled maturity as measured by vitrinite reflectance and measured R_o alg and T_{max} data are posted as discrete points. The model fits the measured data relatively well suggesting that the parameters selected for the model (heat flow, stratigraphy, etc.) adequately reflect basin history. The low R_o alg values at about 900 meters are interpreted to be anomalous.

Timing and relative magnitude of generation for the Kyalla source rock (Figure III-13) and the Velkerri source rock below the total depth of the well (Figure III-14) are shown on graphs of age versus cumulative hydrocarbon generation per milligrams per gram of TOC. The Kyalla source rock, based on this model, began significant generation and expulsion with deposition of the youngest Roper Group sediments. As the maturity data indicate, the Kyalla is peak mature to gas in the Jamison well. As expected, the Velkerri, projected into the Jamison well, began generation and expulsion during Hayfield deposition (Figures III-4 and III-5). The source rock quickly reached peak maturity with basin subsidence and sedimentation and entered the gas window. The Velkerri source rock is in the gas window. Figures III-15 and III-16 superimpose maturation as barrels per acre rock on to the burial history diagram and the Kyalla has generated and expelled between 100,000 and 150,000 barrels of hydrocarbon per acre of rock and suggests that the Velkerri has generated and expelled as much as 250,000 barrels of hydrocarbon equivalent per acre rock. Hydrocarbons that are retained in the Basin have been converted to gas.

Event	Age (my)	Top (m)	Thickness (m)	Eroded (m)	Lithology	Kerogen	TOC %	Saturation Threshold
Surf Erosion	500			-150				
Tindall	510	0	370		Limestone			
Erosion	525			-115				
Antrim	530	370	105		Igneous			
Erosion	1400			-2				
Bukalara	1407	475	25		Sandstone			
Erosion	1409			-26				
Hayfield	1410	500	370		Shale			
Jamison	1415	870	98		Sandstone			
Kyalla	1429	968	746		Shale	Velkerri	2.31	0.15
Moroak	1448	1714	410		Kyalla			
U Velkerri*	1448.6	2124	423		Shale			
M Velkerri*	1449.4	2547	306		Kyalla	Vlekerri	4	0.15
L Velkerri*	1450	2853	260		Shale			

Table III-2: *Parameters used to build the Jamison #1 model in BasinMod*. A lithology was created for the organic rich shales in the Kyalla and Velkerri to reflect the increase in organic content in these shales and is termed "Kyalla." The kerogen type used in the model and termed "Velkerri" is a mix of 60% Type I and 40% Type II. The Saturation Threshold is measured as the percent of pore space filled with hydrocarbons before expulsion begins. The Velkerri was not penetrated in the Jamison well but has been projected in from wells on the Walton High to allow modeling of generation in the Basin center.

Figure III-17 summarizes the generation potential of the Kyalla and the Velkerri source rocks in both the McManus #1 and the Jamison #1 wells as Cumulative Hydrocarbon/TOC (mg/gm) TOC versus depth. Although the specific values and original data could be debated, the Kyalla source rock is basically immature at the McManus well and mature in the Jamison well. The Velkerri source rock is mature in the McManus well and is post-mature (gas window) at the Jamison location.

Unconventional Reservoirs

Fractured Reservoirs

Fractures are noted in several core descriptions within the Kyalla Shale and the Moroak Sandstone as in the Elliott #1 well, and very rarely in the Jamison Sandstone. The exceptional fluid recovery in the Ronald #1 from the Moroak Sandstone may have been enhanced by fracturing in the DST interval. Thus, it is likely that where associated with fault zones, fractured reservoir potential may be significant. However, no subsurface evidence exists for extensive fracturing, and in fact mention of healed fractures (usually with carbonate or anhydrite) is noted. Interpretation of fracturing from seismic data as noted in the section on Seismic Data and Interpretation, especially on seismic line ME91-64, may indicate more wide-spread and potentially commercial fractured reservoirs. However, at this time, fractured reservoirs are not considered a major exploration target.

Basin-Centered or Continuous Phase Accumulations

It is unknown whether continuous, relatively water-free hydrocarbon accumulations occur within the Beetaloo Basin. Most drill stem test recoveries indicated the presence of water or simply tight reservoirs. With the hundreds of meters of highly organic rich source sediments in the Kyalla and especially the Velkerri Shales, the occurrence of such accumulations is possible. With the very large volumes of hydrocarbons generated from these rich source packages finding areas of preserved continuous phase commercial reserves would not be unusual. However, like fractured reservoirs, continuous phase accumulations cannot be considered primary targets.

IV. GEOPHYSICS

Gravity Data

Gravity data were obtained from the GeoScience Australia "Australian National Gravity Database" (March 2004 Edition). Nine hundred ninety-one (991) gravity stations exist in the Exploration Permits area (Figure IV-1). These stations are distributed both as a quasi-grid with approximately 10 km spacing and as detailed profiles along selected roads. Sweetpea does not anticipate the acquisition of additional gravity data at this time.

Gravity data reveal a pronounced low defining the Beetaloo Basin. This is probably due to the presence of the thick, relatively low-density sedimentary package that comprises the basin. These data provide the best indication of the true extent of the basin at this time. Certain structures internal to the basin such as the Daly Waters arch show up clearly on gravity data, while others, notably the Arnold Arch, have no expression (Enclosure 4). We hypothesize that a thicker sequence of sedimentary rocks exists below the present Arnold Arch than immediately on either side. This situation could result from the structural inversion of an early graben into the present Arch.

Aeromagnetic Data

Beetaloo Basin aeromagnetic data were reviewed using a total magnetic intensity image file (NT2004TMICol.ecw) provided by the Northern Territory Geological Survey (Figure IV-2). The image is compiled from a variety of constituent surveys of different vintages and acquisition parameters. The differences in the constituent surveys are quite pronounced. For instance, the bulk of EP 98 is covered by the regional McArthur Basin survey, acquired in 1977 using a 3000 m line spacing, while the northeast corner of EP 98 is covered by the 1994-vintage Urapunga survey, using a 400 m line spacing.

The latter high-quality survey shows high-frequency features, probably related to late-stage faulting, that are poorly imaged on the early survey.

Broadly, the aeromagnetic data depict a total magnetic intensity high trending roughly east-west through the Exploration Permit area. It is possible that this high is related to the Cambrian-aged Antrim Plateau volcanics, but current well control suggests this relationship is not one-to-one.

Only early, regional surveys cover most of the license area. The acquisition of a high-quality aeromagnetic survey over the Beetaloo Basin might reveal many details of late-stage faulting in the area and should be considered at some point in the future.

Seismic Data and Interpretation

Introduction and Summary

Approximately 1800 kilometers of 2425 kilometers of available 2D seismic data were interpreted to delineate prospective petroleum plays and trap leads (Table IV-1 and Appendix III.) Approximately 625 km of available data were not interpreted for several reasons. These lines were either outside the main area of interest, of very poor quality, adjacent to other lines that were interpreted, or some combination of these reasons. The uninterpreted seismic lines are in gray on Enclosures 6, 7, and 8. Of the 1800 km, 109 km are good quality data and the rest of the data vary from fair to poor. The best seismic data show structural features reliably. None of the data in the Beetaloo Basin area are entirely unusable, but the interpretation of these data is severely limited. Interpretation is speculative even in close proximity to wells.

The data were interpreted on hard copies and on a PC-based workstation. Ten structural trap leads were identified, with potential for large reserves. Prospect delineation will require reprocessing of some of the existing data and acquisition of new data. Sweetpea reprocessed two lines from different surveys and in different data quality settings. This shows that significant improvements can be made to the original processing of all lines in the study area.

Future seismic acquisition should use an explosive, rather than vibroseis, energy source. The desire to minimize environmental impact argues against the use of vibroseis trucks. Explosive energy sources can also improve the seismic resolution of the reservoir and hydrocarbon source section. The use of 3D seismic data should be considered in a later exploration phase.

Data and Data Quality

A total of 2425 kilometers of 2D seismic data were available for interpretation. The data were stored at both DBIRD and Veritas/Guardian in Perth. Australian Seismic Brokers Ltd. was very helpful in locating some of the data that was not archived. Considerable delays were encountered in assembling the data from both DBIRD and Veritas/Guardian, because all the data was not stored in one location and had not been retrieved in several years.

In most cases, the location data required editing before it was useable in the seismic interpretation workstation. A few important line location files contained noise that prohibited their use in the geographic interpretation base, so they were interpreted on hardcopy and the correlations added to the interpretation database separately.

The interpreted Beetaloo seismic data were gathered in six surveys from 1989 to 1992 (Table 1: Seismic Database). Great differences in data quality exist between surveys, between different lines within the same survey (Figure IV-3), and along single lines.

BEETALOO BASIN SEISMIC DATABASE				
Line	*Year Acquired*	*Line Length (km)*	*Data Quality*	*Interpreted Kilometers*
89-098	1989		1=Low	0
89-100	1989			0
89-103	1989			0
89-105	1989			0
89-107	1989			0
89-109	1989			0
89-113	1989			0
89-203	1989	77	3	77
EL90-201	1990	60		0
MA91-090	1991	81	1	81
MA91-093	1991	65	1	65
MA91-098	1991	63	1	63
MA91-099	1991	30		0
MA91-103	1991	121	2	121
MA91-109	1991	30	1	30
MA91-200	1991	22		0
MA91-210	1991	45	1	45
MA91-211	1991	10		0
MA91-213	1991	17		0
MA91-215	1991	10		0
MA91-217	1991	16		0
MA91-220	1991	23		0
MA91-221	1991	23		0
MA91-223	1991	23		0
MA91-225	1991	15		0
MA91-227	1991	23		0
MA91-230	1991	34		0
MA91-241	1991	20		0
MA91-250	1991	45	1	45
MA91-251	1991	20	1	20
MA91-254	1991	20	1	20
MA91-261	1991	17		0
MA91-271	1991	14		0
MA91-296	1991	18		0
MA91-600	1991	81		0

Table 1: *Seismic Database, page 1*. All the seismic surveys used vibroseis as the energy source, although different energy source-point intervals, geophone arrays, and intervals were used. The most recent data is not necessarily the best quality, and there is no clear best source-geophone geometry.

Line	Year	Length *(km)*	*Quality*	*Interpreted Kilometers*
MC92-100	1992	26	1	26
MC92-102	1992	46	2	46
MC92-104	1992	85	2	85
MC92-104W	1992	26	2	26
MC92-123	1992	30	2	30
MC92-202	1992	10	2	10
MC92-251	1992	85	1	85
MC92-281	1992	26	1	26
MC92-43	1992	70	2	70
MC92-53	1992	64	1	64
MC92-61	1992	22		0
MC92-63	1992	51	1	51
MC92-73	1992	72	1	72
MC92-73N	1992	12	1	12
MC92-83	1992	28	1	28
MC92-93	1992	32	2	32
MD92-106	1992	32	1	32
MD92-225	1992	21		0
MD92-229	1992	20		0
MD92-250	1992	45	2	45
MD92-49	1992	31		0
MD92-50	1992	22	3	22
MD92-55	1992	31	2	31
MD92-58	1992	18		0
MD92-59	1992	31		0
MD92-67	1992	15		0
ME91-123	1991	38	2	38
ME91-130	1991	30	2	30
ME91-40	1991	20		0
ME91-64	1991	10	3	10
ME91-83	1991	50	1	50
ME91-90	1991	58	1	58
SH90-100	1990	40	1	40
SH90-102	1990	46	2	46
SH90-103	1990	100	2	100
SH90-105	1990	30	2	30
SH90-107	1990	20	2	20
SH90-109	1990	10		0
Line km	total	2,426	total	1783

Table 1: Seismic Database, page 2

There is seismic evidence for fracture-enhanced porosity and permeability in the identified structural traps. Some fracture zones are distinctly visible (Appendix III: Line

ME91-64), but most show as a decrease in reflection continuity across positive compressional structures that are interpreted to be wrench-fault-induced.

Seismic Reprocessing

The variation in data quality in the Beetaloo area is attributable to topographic features, near-surface unconsolidated sediments, shallow volcanics, shallow karsted limestones, and acquisition and processing parameters. Thus, it is important to determine what can be done to improve the quality and moderate the variations along existing seismic lines, as well as to establish improved reprocessing and acquisition techniques for future work in the area.

Two lines, MA91-103 and SH90-103 (Appendix III), were selected for reprocessing, which was carried out by Pulsonix, Inc. of Englewood, Colorado, U.S.A. Pulsonix has extensive experience with acquisition and processing of onshore Australian seismic data. The selected lines run south-to-north between the Elliott 1 well on the southern basin margin, through the Jamison 1 well in the basin center, to the Altree 2 well on the Walton High to the north. The results (Enclosure 5) were favorable, showing overall increases in reflection continuity. Resolution was increased everywhere except relative to the highest-quality segment of MA91-103.

Several differences between the original processing and reprocessing by Pulsonix contributed to the improvement:

1) Hand-editing to remove bad shots and traces. This was moderately effective, due to the high fold of the data: bad source points and traces are largely over-ridden by the large number of source points in each stacking gather.
2) Longer deconvolution operator to remove more reverberations.
3) Spectral whitening to increase the amplitude of both low and high frequency portions of the signal bandwidth.
4) Closely spaced velocity analyses due to rapidly changing near-surface lithologies.

5) Velocity analyses performed four times instead of once: first after initial refraction static correction, then after each of two auto-static corrections, and finally after Dip MoveOut (DMO). Each of these processes changes the velocity field enough to warrant re-picking the velocities along the lines.
6) Signal enhancement using FK and FX filters instead of TAU-P: TAU-P typically produces a more mixed, smoothed appearance than either FK or FX filters, which retain trace-to-trace individuality necessary for identifying fractures.

A detailed comparison is shown in Tables IV-2a, IV- 2b and IV3a, 3b.

Comparison of the original processing and the Pulsonix reprocessing done for Sweetpea shows these significant differences:

1) The reprocessing involved more editing and noise filtration before stacking the data.
2) Pulsonix performed four velocity analyses, before and after calculating residual static corrections, after trim statics, and after Dip MoveOut correction. This increases the accuracy of the F-K noise rejection filter. The velocity analyses were made every 1.5 km, considerably more closely spaced than standard production processing.
3) The vibroseis energy source-point spacing (45 and 25 meters) is extremely close, which is appropriate for very high-frequency data, but closer than can be utilized with the vibration sweep frequencies of 10-66 and 8-80 Hz., much less the filtered frequency windows of 10-40 Hz and 8-55 Hz. For this reason, it was possible to mix and sum adjacent traces with no loss of signal, using a running weighted-trace mix, then to sum every two traces to further increase noise cancellation.

The primary sources for the high noise levels observed in the Beetaloo Basin data are unconsolidated, slow-velocity sediments at the surface, which absorb acoustic energy, and interbedded shales and volcanic deposits in the section above the Jamison sandstone, with strongly-contrasting velocities that further absorb and reflect the seismic signal. Future processing in the Beetaloo area should provide for similar intensive editing and noise-distribution analysis to achieve maximum results in this difficult area.

MA91-103
Recorded by WGC
INSTRUMENTS: SERCEL 368
Energy source: Vibroseis: 8-80 HZ; Sweeps per source point: 2; Source Int: 25M
Geophone group Int.: 25M; Groups: 300
Geophone spread: 3787.5—62.5-VP-62.5—3787.5
Fold: 150
Processing By DIGICON:
1) Format conversion @ 4ms.
2) Zero to minimum phase conversion.
3) Trace Balance.
4) F-K Filter: Pass Signal
5) Deconvolution
    - Spiking
    - 160ms Operator
    - 1.0% White Noise
6) Refraction first arrival tied to upholes.
7) First pass velocities using constant velocity stacking techniques.
8) Residual statics
    - Surface consistent
    - +/- 12ms shift
9) Dip MoveOut
10) Velocity Analysis
11) NMO
12) Mute
13) Trace Scaling: 500ms AGC
14) Trim statics
    - CDP Consistent
    - +/- 8ms shift
15) Stack – 150 fold
16) Filter: Approx. 8-55 HZ
17) Correction from floating datum to final datum
    - 200M above sea level
18) Migration
    - Wave Equation Finite Difference
    - Smoothed velocities @ 95%
19) TAU-P Filter
20) Trace Scaling

Table IV-2a. MA91-103 original processing

MA91-103
Recorded by WGC INSTRUMENTS: SERCEL 368
Energy source: Vibroseis: 8-80 HZ; Sweeps per source point: 2; Source Int: 25M
Geophone group Int.: 25M; Groups: 300
Geophone spread: 3787.5—62.5-VP-62.5—3787.5
Fold: 150
Processed by PULSONIX, INC. (November 2004):
1) SEGY input – data at 4ms sample rate
2) Geometry and trace edits
3) Refraction Statics
    - 500M datum
    - 4000M/S replacement velocity.
4) F-K Filter: Reject Noise
5) Spiking Deconvolution
    - Minimum phase
    - 220MS Operator
    - 0.1% White noise
6) Spectral Whitening
    - 10-70 HZ
7) Trace Balance
8) Velocity Analysis
    - 1 Every 1.6 km
9) Residual Statics
    - +/-24 ms shift
10) Trim Statics
    - +/- 6 ms shift
11) Dip MoveOut
12) DMO velocity analysis
    - 1 Every 1.6 km
13) NMO/MUTE
14) AGC
    - 500 ms
15) Stack
    - 120 Fold nominal
16) Steep-Dip Finite-Difference Time Migration
    - 100% Smoothed stacking velocities
17) Post-stack enhancement filter
18) Bandpass Filter
    - 10/12-50/60 HZ/DB
19) FX Deconvolution
20) FK Filter
21) AGC
    - 500 ms
22) Trace mix
    - Weighted 1:2:1
23) 2-1 Trace Sum

Display

Table IV-2b. MA91-103; Pulsonix reprocessing

SH90-103
Recorded by Geosystems INSTRUMENTS: GEOCOR IV (16 Sign-bit)
Energy source: Vibroseis: 10-66 HZ; Sweeps per source point: 7 Varisweeps per VP
Source Interval: 45M
Receiver Group Interval.: 15M; Groups: 500
Geophone Spread: 3742.5—7.5-VP-7.5—3742.5
Fold: 83.3
Processing By SIMON HORIZON:
1) Format conversion & Re-sample to 4ms.
2) Amplitude Recovery.
3) Trace Summing 1:2:1 O/P 250 traces.
4) F-K Filter: Reject Noise
5) Deconvolution

- Predictive 20 ms
- 120 ms Operator
- 1.0% White noise
- Refraction Calibrated First Arrival to Upholes.
- Preliminary Constant Velocity Stack Analysis using 21 trace @ approx. 2km intervals.
- Residual Statics
- Surface Consistent
- +/- 20ms shift
- DMO
- Velocity Analysis @ approx. 1km intervals.
- NMO
- Correction from floating datum to final datum
- 200M above sea level
- Trim statics
- CDP consistent
- +/- 12ms shift
- Stack (41.667%)
- Spectral Equalization
- Zero phase deconvolution after stack
- Filter

TIME	FREQ
200-1000ms	12-45 HZ
1300-1700ms	10-45 HZ
2000-2800ms	10-40 HZ

- Scaling
- TAU-P Enhancement
- Time varying Dip & Coherency Filter
- 70% original data
- Migration
- Wave Equation Finite Difference

Smoothed velocities @ 95%

Table IV-3a. SH90-103: Original processing

SH90-103

Recorded by Geosystems INSTRUMENTS: GEOCOR IV (16 Sign-bit)
Energy source: Vibroseis: 10-66 HZ; Sweeps per source point: 7 Varisweeps per VP
Source Interval: 45M
Receiver Group Interval.: 15M; Groups: 500
Geophone Spread: 3742.5—7.5-VP-7.5—3742.5
Fold: 83.3

Processed by PULSONIX, INC. (November 2004):

1) SEGY input/resample to 4ms
2) Geometry and trace edits
3) 2D Convolutional Filter (Array Forming)
    - Weighted: 1,2,1
4) Refraction Statics
    - 500M datum
    - 4000M/S replacement vel.
5) F-K Filter: Reject Noise
6) Spiking Deconvolution
    - Minimum phase
    - 220MS Operator
    - 0.1% White noise
7) Spectral Whitening
    - 10-70 HZ
8) Trace Balance
9) Velocity Analysis
    - 1 Every 1.5 KM
10) Residual Statics
    - +/- 24 ms shift
11) Trim statics
    - +/- 6 ms shift
12) DMO
13) DMO velocity analysis
    - 1 every 1.5 km
14) NMO/MUTE
15) AGC
    - 500 ms
16) Stack
    - 83.3 Fold nominal
17) Steep-Dip Finite Difference Time Migration
    - 100% Smoothed stacking velocities
18) Post-stack enhancement filter
19) Bandpass filter
    - 10/12-50/60 HZ/DB
20) FX Deconvolution
21) FK Filter
22) AGC
    - 500 ms
23) Trace mix
    - Weighted 1:2:1
24) 2-1 Trace sum
25) Display

TableIV-3b. SH990-103: Pulsonix reprocessing

Seismic Interpretation

Methodology Interpretation was carried out on both a PC-based workstation and on color prints of the lines. This allowed maximum flexibility in viewing the very long 2D lines (long lines are not ideally displayed on PC monitors) and in correlating horizons across areas of data loss. Variable-area wiggle trace sections were not used because they do not accurately image small fault offsets or small amplitude variations. These variations are important in the identification of small-offset faults and joint systems (Appendix III).

The MA91 survey was originally processed to a lower elevation datum than the other surveys, and required a bulk shift of +0.200 seconds to tie the other surveys. Because of this low datum, near-surface reflections were lost, and in some cases this compromised the correlation of the Hayfield Mudstone reflection.

Because of the poor overall data quality, synthetic seismograms were not useful for tying well markers to seismic reflection character, except at the Jamison #1 well, nor as a basis for conversion from depth to seismic travel time. Figures IV-4, 5, 6 and 7 are the synthetics for the Altree #2, Burdo #1, Elliott #1, and Jamison #1 wells. In order to make the ties where no synthetic seismograms were available, sonic log transit time values from the above listed wells were used to calculate average transit times ("delta-t"; in microseconds per foot) for the major stratigraphic intervals. These were used to convert the thickness for each unit measured in the wells to 2-way reflection time thickness, then summed to give the total reflection time from the surface to each of the stratigraphic markers. The calculations are shown in Figure IV-8. These were plotted in depth (Figure IV-9) and then plotted in time at the same vertical scale as the seismic displays (Figure IV-10.)

Conversion of time maps to depth used the calculated average velocities to produce contour maps of average velocity to the Hayfield, Jamison and Moroak seismic markers. The contours were digitized to produce velocity grids, which in turn were multiplied by the time structure map grids to produce depth structure maps.

Structure The primary goals of the seismic interpretation were to identify viable plays and trap leads in the Beetaloo Basin, and to provide insight into the reasons for lack of success in each of the existing wells located on the seismic grid. Enclosure 6 is a structure map of the Jamison Sandstone and Enclosure 7 is a structure map of the Moroak Sandstone as interpreted from the seismic data. As a general rule, none of the wells were drilled on true structural closure based on the seismic data. The single exception may be the Ronald #1 well, which could have been drilled on a closure based on very poor quality seismic data within the structurally complex crest of the Arnold Arch. Even that well appears to be at least 100 m low to the apex of the Arch.

The Moroak and Jamison sandstone reflections are the basis for the structural interpretation. Other reflections are too discontinuous to correlate over the study area, although the Hayfield was mapped to add control to the basin burial history.

Dominant positive structural features in the Beetaloo Basin are the basin margins and the intra-basin Arnold Arch. Lines MA91-103 and SH90-103 form a basin-wide north-south transect, crossing well onto the structural highs. Lines MA90-90 and MD92-250 delineate the eastern basin margin. The western basin margin is crossed only by line ME91-90, which is of very poor quality.

The Jamison, Kyalla, Moroak, and upper Velkerri are widely identifiable as high-amplitude, continuous reflections on seismic data. Although the Bessie Creek and Corcoran are penetrated by wells on the Walton High, they cannot be traced with any reliability off-structure into the basin areas. An angular unconformity at the top of the Kyalla Shale is visible on a few lines, usually one or two cycles below the Jamison marker (Appendix III, Line MA91-109), where data quality is good enough to resolve this. The Jamison section appears to maintain uniform thickness across the basin areas, thinning only on prominent structural highs.

Due to the poor overall data quality, the Kyalla and Velkerri horizons were not correlated over the study area. Well data indicates that the Jamison Sandstone and Moroak Sandstone do not vary significantly in thickness, so no important structural control is lost by restricting mapping to the Jamison and Moroak.

The Hayfield Mudstone was correlated over the area, although it is a very unreliable pick. It lies in the near-surface section where seismic data are least reliable. In many cases, the pick follows seismic events that may be real, but cannot be consistently distinguished from reverberations from the ground surface. On the MA91 survey, processed to a lower datum, the Hayfield marker often appears to be above the datum and is therefore lost.

Overall data quality is not good enough to interpret internal bedding geometry, so seismic facies interpretations are not possible. The seismic acquisition program planned for 2005 should include tests to determine the best acquisition and processing parameters to optimize structural and stratigraphic resolution.

Isochron The isochron of the interval from the Jamison Sandstone to the Moroak Sandstone is shown on Enclosure 8. There is a major unconformity documented at the base of the Jamsion Sandstone as shown on Enclosures 1 and 2. This marks the major structural readjustment in the Basin and the isochron shows the truncation of the pre-Jamison sediments on the Basin’s margins and the Arnold Arch.

Exploration Plays

Structure Structural mapping of the Jamison and Moroak Sandstones defined the geometry of the main part of the Beetaloo Basin and resulted in the identification of 10 structural leads.

Within the basin and along the basin margins, there are positive structures that appear to be related to late-Proterozoic lateral-slip faulting (e.g. line SH90-104, shot points 4000 to 4400, Appendix III). Although these structures are either too small or too deep to be primary exploration targets at this time, with success in the Basin, these structures may become attractive leads. In most cases, these structures are associated with a decrease in seismic reflection continuity, which may be due to fracturing. The only seismic line of high enough quality to accurately image fracturing is line ME91-64 (Appendix III), which crosses east-west through the Jamison well. Reflection discontinuity and amplitude changes visible along near-vertical lines may be due to wrench-fault related faults and fractures.

Color displays show amplitude as color in a vertical line directly below the seismic trace's surface location, instead of variable-area trace displacement laterally away from the surface location. Therefore, these color displays depict small changes in amplitude and small fault displacements more accurately and more visibly than variable-area displays. Many abrupt changes in amplitude may be observed where there is no visible offset of reflections. This is often associated with pore-fluid pressure changes across fracture zones. It should be noted that the fractures on ME91-64 do not appear to penetrate above the Hayfield Mudstone, and therefore do not represent significant risk of trap breach. Elsewhere, the data quality is not good enough to be sure of the upper extent of the faults.

Fracture-enhanced porosity and permeability may be important to improve reservoir quality and performance in sandstones or possibly create the reservoir. Direct seismic evidence for fracturing and degeneration of seismic reflection continuity over positive structural features are plotted on the Moroak structure map (Enclosure 7.)

Subcrops Along the basin margins and the flanks of the Arnold Arch, truncations of the Kyalla Shale under the Jamison Sandstone are visible on better-quality seismic lines. Where there is a structural reversal associated with truncation, fractures may enhance reservoir charge and productivity. Due to the poor seismic data quality, the interpretation of subcrop trends is not reliable. For this reason, and because subcrop traps are higher risk than pure structural-closure traps, they are not considered primary exploration targets at this time.

Future Work and Recommendations

Sweetpea plans a program of 2-D seismic data acquisition of 333 km in 2005. This program will focus on delineating the leads on the Arnold Arch and other leads in the Basin. At present, considerable uncertainty exists regarding the smaller structural closures due to wide data spacing and to poor data quality. Before any new drilling is attempted, existing data should be reprocessed and new data acquired. The use of 3D seismic should be considered for a second phase of data acquisition.

Increasing sensitivity to environmental impact and the need to restrict public access to private lands puts more burden on vibroseis energy sources with their large, heavy vehicles. Although the cost of explosive sources is high, associated costs may be much lower, because explosive surveys can use smaller, relatively lightweight all-terrain vehicles.

Extensive field tests of explosive sources should be carried out to determine the shallowest shot-hole depths that will provide consistent energy transfer to the subsurface. Costlier shaped charges may actually be more cost-effective, since they can be used in shallower holes than conventional explosive charges.

Previous surveys used very closely spaced source points (25 and 45 meters) to increase the “fold” or multiplicity of the data in an effort to increase the signal-to-noise ratio. Although this is an effective method, it is expensive in terms of surface damage. The use of higher-energy explosives instead of vibroseis sources may provide the relatively high data quality with fewer shot points (one third to one fourth the shot points of vibroseis), hence less surface impact.

The most effective procedure employed in the reprocessing Sweetpea completed in 2004 was exhaustive editing of the input records and of each processing step to determine optimum processing methods. Although automated refraction-static and velocity analysis methods were used, they were edited closely. Editing is an expensive processing procedure, and is therefore held to a minimum by processors on large surveys such as in the Beetaloo Basin. The very close source point spacing effectively increases the size of the surveys relative to the actual coverage in surface line distance. However, it should be stressed that the total processing cost is small relative to the cost of acquisition, and the cost of seismic acquisition is small relative to the cost of exploration drilling.

V. BEETALOO BASIN LEADS

Arnold Arch, Structural Trend – Eastern EP 98 and Northern EP 76

The Arnold Arch (Enclosures 6 and 7) has only one well drilled on this very prominent structural feature which has been present since early in the depositional history of the Beetaloo Basin. This feature is at least fifty kilometers long and trends NNW in the northeastern portion of the Beetaloo Basin. What adds significantly to the intrigue of the Arnold Arch is the Pacific Oil and Gas, Ronald #1 well which tested fluid from the Moroak Sandstone at an estimated rate of 3000 barrels of water per day. This provides evidence of good reservoir adjacent to a large anticline.

The Arnold Arch was present during generation of hydrocarbons from the Velkerri and Kyalla organic-rich shales. Therefore, the Arch has a high probability of receiving very large volumes of hydrocarbons to fill reservoirs present including the Bessie Creek Sandstone (which was not penetrated in the Ronald #1), the Moroak Sandstone and the Jamison Sandstone. Additional reservoirs in the Hayfield Mudstone may also be present and should be evaluated in any well drilled.

Genetically, the Arnold Arch appears to be an uplifted older graben. In detail the Arch appears to have eastward and westward parallel culminations with a structural sag between them. The "Cooee Hill" lead (p. 60), occupies the western culmination and the "Hemley" lead (p. 61) occupies the eastern culmination.

Structural Leads

Examination of the existing seismic lines reveals a number of unevaluated possible structural leads. Data quality does not allow further evaluation without reprocessing critical un-reprocessed lines associated with these structures. These leads are discussed below in approximate order of exploration priority.

EP 98: COOEE HILL – Lines MC92-202 and MC92-102 both transect a strong culmination centered at approximately shot point 600 on line MC92-102. This feature is also defined by lines MD92-59, MD92-55 and MA91-250. The lead is the western culmination of the parallel highs on the Arnold Arch. It is approximately forty-five kilometers long and eight-plus kilometers wide. On both the Jamison and Moroak structure maps, the structure is the western-most culmination on the Arnold Arch. This structure would be the first major barrier to hydrocarbon migration from the oil "kitchen" in the Beetaloo Basin. The wrench fault-related "flower" structure would then have been one of the first large reversals to be filled. This Arnold Arch Prospect is worthy of immediate follow-up and may lead to major reserves. The Ronald #1 well north of this structure, had the best fluid recovery of any well in the Beetaloo Basin and was calculated to have yielded as much as 3000 barrels of fluid per day from the Moroak on a DST. The good reservoir properties seen in the Moroak on the Arnold Arch may also be preserved in the Jamison and Bessie Creek Sandstones, especially where the hydrocarbon charge preceded diagenesis.

EP 98: 80 METER TOWER - Seismic Line SH90-102: Despite very poor data quality, there appears to be an anticlinal feature at the Jamison and Moroak level and likely at the Bessie Creek as well. The anomaly is located between shot points 1200 and 1700. This feature could be very large extending to the southwest as mapped on Enclosures 6 and 7, where it is confirmed by lines MC92-93, SH90-103 and even at the western end of line SH90-100. It is ideally located in the central portion of the Beetaloo Basin to receive charge from generating Velkerri and Kyalla source rocks. As mapped, the feature is broad and further seismic definition is necessary to adequately determine the geometry of, and an initial drill-site on, this very large feature.

EP 117: NEWCASTLE CREEK - Seismic Line ME91-123: An anticline is visible just north of the line intersection with line MA91-090. The feature is broad and looks convincing at the Jamison reflector, but has no expression at the Moroak and deeper Bessie Creek. The anomaly is centered between shot points 1000 and 1700. On the

Jamison time-structure map the feature lines MA91-103 and ME91-83 confirm the feature. Newcastle Creek may be a positive flower structure and maps out as an E-W fold at least thirty kilometers long and ten kilometers wide. The eastern end of the feature lies approximately ten kilometers north of the Elliott #1 well. This is an excellent lead for the Jamison reservoir which should be charged by the Kyalla and Velkerri at this location.

EP 98: HODGSON - Seismic Line MC92-104W: Located north of the Chanin well and south of the Walton High, there appears a sharp, almost horst-like feature between shot points 1200 and 2000. As with all other leads, improved seismic data would clarify this anomaly.

EP 117: ORANGETREE - Seismic Line MD92-50: A very sharp anticlinal feature occurrs between shot points 1000 and 1450. The feature appears to involve the Jamison, Moroak and Bessie Creek horizons. The structure is located in the southern end of the Beetaloo Basin, southeast of the Elliott #1 well, which had hydrocarbon shows.

EP 98: HEMLEY - A large prominent anticlinal feature is visible on the Moroak structure and Jamison to Moroak Isochron maps (see Enclosure 7 and 8). It is located on line MC92-102, centered near shot point 2100. This structure is approximately fifteen kilometers long and five to eight kilometers wide. The trend is NW-SE and is supported by the interpretation on lines MC92-43 and MC92-53. This anticlinal feature is the eastern of the parallel anticlines on the Arnold Arch and may represent a flower structure like Cooee Hill. It could have received charge from the satellite basin immediately east of the Arnold Arch.

EP 76: YAROO CREEK - Line 89-203 between shot points 600 and 1350. A good anticlinal reversal occurs on the southern end of the known Arnold Arch. This is a one-line anomaly but does appear to involve both the Jamison and Moroak sandstones.

Further delineation through additional seismic acquisition may reveal a very intriguing feature, placed ideally to receive excellent hydrocarbon charge from the greater Beetaloo Basin. Gravity data suggest that a very large feature at this location, may link this feature to a slight anticlinal reversal at shot point 2150 on line MD92-250.

EP 98: TURKEY CREEK - Line MC92-53 exhibits an anticlinal reversal centered at shot point 4400. This reversal involves the Moroak and likely the Bessie Creek as well, but is not expressed at the Jamison level. It is on the northern end of the Arnold Arch and is located less than ten kilometers north of the Ronald #1 well which had an estimated fluid flow of 3000 barrels per day from the Moroak.

EP 117: NORTH JINGALOO - On seismic line MC92-123, just south of the Shortland #1 and southwest of the Jamison #1 wells, a good anticlinal reversal is seen centered between shot points 2150 and 2850. This feature involves both the Jamison and Moroak sandstones. It also occupies a very good fetch area where it could directly receive hydrocarbon charge from the Velkerri and Kyalla source rocks. The Jamison #1 well had perhaps the best hydrocarbon shows of any well in the Beetaloo Basin (see appendix I, Well Summaries, Jamison #1 well), including two separate DSTs with free oil recovery and fluid recoveries of over 1000 meters from the Jamison Sandstone. This is an indication that the Jamison #1 is close to a significant intact trap. It is repeatedly demonstrable that reservoir quality of the sandstones on anticlinal features is far superior to those off-structure.

EP 117: SOUTH MARTYRS TREE - Seismic Line MA91-090: There appears to be good anticlinal reversal between shot points 2250 and 2600 at the Moroak and deeper Bessie Creek. However, at the Kyalla/Jamison level, reversal is diminished or non-existent.

EP 98 & EP 117: DUNMARRA – A closed high, based on gravity data, appears on the southern end of the Daly Waters Arch on the western side of the Beetaloo Basin. It is located in the southwestern portion of EP 98 and a portion of EP 117. Dunmarra is approximately fifty kilometers long and is roughly north-south in trend. This lead is worthy of further investigation.

EP 99 occupies the southernmost end of the Beetaloo Basin and includes the Helen Springs High visible on the southern end of seismic line MA91-103. The Helen Springs High is totally unevaluated. It will be structurally complex but may offer excellent potential. More seismic acquisition will be necessary to clarify the geometry of the Helen Springs High.

Southeastern Beetaloo Basin – Eastern EP 117 and Central EP 76

The southeastern portion of the Beetaloo Basin, occupying a large area between leads "South Martyrs Tree" and "Yaroo Creek," in the eastern portion of EP 117 and portions of EP 76, is ideally located to receive large volumes of hydrocarbons migrating from the center of the Beetaloo Basin. This basin flank would likely have received some of the earliest charge, with an excellent chance that early structures would have become filled and retain excellent reservoir quality. There is effectively no seismic control in the area, and this is an ideal location for further exploration seismic in later phases of the exploration program.

All of the above seismic leads are un-drilled and unevaluated. One form of ranking before any attempt to reprocess seismic data would be whether all potential horizons are involved in the apparent anticlinal structure.

Leads in which the Moroak and Bessie Creek Sandstones appear favorably structured, while the Jamison Sandstone is not, indicate early structural deformation as in Newcastle Creek and Turkey Creek. This could be favorable to early receipt of hydrocarbon charge resulting in good preservation of reservoir quality.

The possibility of sub-crop traps should also be considered. Truncation of the Moroak and Bessie Creek on both the Walton High and the Helen Springs High, as well as possibly on the Daly Waters Arch, offer potential. The truncation of the Moroak and Bessie Creek can be interpreted with a fair amount of certainty on the northern (Walton High) and southern (Helen Springs High) ends of seismic line MA91-103. A complicating factor in sub-crop traps in the Beetaloo Basin is the seeming universal presence of the Jamison Sandstone. The Jamison is the basal unit of the uppermost Roper Group, resting on the sub-crop surface and it would not provide a seal for migrating hydrocarbons.

Considering factors most significant to hydrocarbon charge and reservoir quality preservation, timing, size of potential recoverable reserves and multiplicity of reservoir targets, the top three leads are ranked: #1 – Cooee Hill, #2 – 80 Meter Tower, and: #3 – Newcastle Creek.

ACTION PLAN AND EXPLORATION APPROACH

Seismic Reprocessing and Acquisition

Within and adjacent to the Beetaloo Basin, Pacific Oil and Gas acquired 2662.8 kilometers of seismic. Seismic line SH90-103 and the northern portion of MA90-103 (177 km) have been reprocessed, which shows the effectiveness of using modern processing techniques to enhance the quality of vintage seismic. Sweetpea has acquired digital seismic data for 2425.6 kilometers of seismic data in the Beetaloo Basin. In addition, Sweetpea has 237.2 kilometers of 1989 vintage data along and north of the Walton Arch, currently available as standard variable-area presentation (approximately 2:1 horizontal exaggeration at 10 traces/centimeter), and in a horizontally-compressed presentation (approximately 2:1 vertical exaggeration at 40 traces/centimeter) in print form only. The data quality is consistently fair, making it better than much of the data across the Beetaloo Basin.

The Beetaloo Basin contains very large anticlinal features and trends. The leads defined in this report are almost certainly only a fraction of those present in this relatively vast and clearly under-explored basin. Further examination of the currently available seismic may reveal additional structural leads which will require additional seismic acquisition.

Arnold Arch Lead Area: In order to further investigate current leads, it is recommended that lines MC92-102, MC92-104, MD92-49, MD92-55, MD92-106 be considered for reprocessing to refine the geometry of the Arnold Arch. Once the reprocessing and interpretation are complete, a follow-up 2D and/or 3D seismic acquisition program will likely be necessary to define the optimum locations to test the Arnold Arch major tectonic feature.

Jamison Lead Area: The Jamison well had excellent shows in all of the penetrated major reservoir targets and within the Kyalla Shale source section. Line SH90-103 has been reprocessed. Interpretation of the reprocessed data clearly shows that the Jamison #1 well was not optimally located. The Jamison #1 was also drilled as a one-line anomaly at the time it was drilled. Later shooting of east-west line MA91-098 revealed nothing to support the Jamison #1 location. Further seismic acquisition, most likely a 3D survey, is necessary to detail the geometry of this lead area. If a drillsite is confidently defined, preparation for a wildcat test could begin at once.

Additional Lines Recommended for Reprocessing to Follow-up Leads

1. Line MA91-090
2. Line MC92-102
3. Line MC92-104
4. Line MC92-50
5. Line MC92-50
6. Line ME91-83
7. Line ME91-123

Description of the leads associated with this recommended reprocessing is discussed in Chapter V. “Beetaloo Basin – Leads”.

Seismic Acquisition Timing and Costs

Sweetpea plans to acquire 333 km of seismic data in 2003 and the program is shown on Figure VI-1. It is anticipated that seismic acquisition costs will be in line with normal regional experience. There will be some limitation on timing of acquisition, due to dry vs. wet season constraints. It is not anticipated that any unusually expensive methods like helicopter support will be necessary, unless extraordinary weather hampers normal acquisition.

Land Status and Drilling

Sweetpea Corporation Proprietary Limited holds license to the following Exploration Permits (EP) which constitute effectively all of the Beetaloo Basin: EP 76, EP 98, EP 99 and EP117. Sweetpea is bound by Australian and Northern Territory law in the exploration of the Beetaloo Basin. None of these laws will inhibit a careful and responsible execution of normal exploration operations. No other lands are anticipated to be necessary in the exploration of the Beetaloo Basin.

Drilling activities, especially initial wildcat drilling, should be planned for the dry season to minimize access problems and expense. Also, an examination of drilling records of previous wells reveals that lost circulation problems can be anticipated in the shallow, Cambrian and younger section, especially in the Tindall Limestone and the Antrim Plateau Volcanics. No significant lost circulation problems are anticipated in drilling the Precambrian section.

Overpressure has not been reported in the Beetaloo Basin drilling activities to date. Many wells drilled by Pacific Oil and Gas in the Beetaloo Basin were cored rather than drilled with conventional bits.

The Shortland #1 was conventionally drilled without coring to 1020 meters in twenty days, while the Jamison #1 was drilled to a depth of 410 meters then continuously cored from 410 meters to a T.D. of 1767 meters. Total drilling time from spud to rig release was sixty-six days. It is anticipated that in any development drilling program that continuous coring will not be necessary, greatly reducing the rig time and thus drilling cost.

VI. CONCLUSIONS AND RECOMMENDATIONS

The Beetaloo Basin offers a unique opportunity to discover major, world-class oil and natural gas reserves. It is an under-explored basin, and since the mid-1990s, largely ignored. Several attractive features come together in this Basin:

- Excellent geologic setting for billion+ barrel traps.
- Ten lead areas defined on 2D seismic data.
- Rich, thick, thermally-mature source rocks.
- Three good-quality reservoir sections with regional seals.
- Favorable timing for episodic hydrocarbon charge and ongoing generation.
- Favorable political and cultural setting.
- Predictable operations costs.

Eleven wells and ~2400 km of existing seismic data define source rocks, reservoir, seal, and timing that create several leads defined in this Report, offering Sweetpea the basis for a highly profitable exploration effort. Sweetpea Corporation controls all of the known prospective lands in the basin. Geologically similar basins globally have produced enormous amounts of commercial oil and gas. The Beetaloo Basin may be the site of similar major discoveries following a concerted exploration effort.

The future exploration approach is discussed at length at Chapter V in the section entitled “Beetaloo Basin Leads”. Naturally, the flow of any exploration program will be dictated by the results of that program. This approach simply offers a logical step in further evaluation of this extremely attractive basin.

Through the course of detailing the leads recognized in this Report, as well as through acquisition of additional regional data, it is a virtual certainty that additional prospective areas will become apparent. However, evaluation of the structural leads identified in Figure VI-1 should be the first step in realizing the exploration potential of the Beetaloo Basin.

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LIST OF APPENDICES

APPENDIX I.

Beetaloo Basin Well Summaries

ALTREE #2

Spud Date: October 5, 1988

Rig Release: December 10, 1988

Well Sequence Number: 1

Total Depth: 1699.85 meters; Cored interval: 208.7 to 1699.85 meters (TD)

DSTs: None

Elevation: DF = 214.8 m

Tops:

Tindall Limestone	near surface	
Antrim Plateau Volcanics	91.0 meters	
Moroak Sandstone	320.0 meters	(McMinn Formation)
Velkerri Shale (upper)	391.5 meters	(Velkerri Formation)
Velkerri Shale (lower)	948.0 meters	
Bessie Creek Sandstone	1229.5 meters	
Corcoran Formation	1658.0 meters	
Dolerite Sill	1689.5 meters	

Hydrocarbon Shows: Minor oil shows were found in the “Middle Velkerri”. Poor oil shows were encountered below that until the “basal sandstone” which by geologists call is just above the Bessie Creek Sandstone but is in fact the upper Bessie Creek. In this basal sandstone, fair oil shows were encountered.

Geological Summary: The Altree 2 was drilled after the rig was skidded off of the Altree 1 due to mechanical problems early in the drilling of the Altree 1. The well was drilled to test the northern margin of the Beetaloo Basin for Roper Group sediments. Also, the intent was to test for reservoir quality sandstones. No visible porosity was encountered in the Moroak or Corcoran Sandstones. The Bessie Creek Sandstone had only sparse fair visible porosity. A few sandstones inter-beds in the lower Velkerri Shale had some poor porosity. These also exhibited occasional fineing upward texture and scoured bases. A possible fault was encountered at 1128.5 to 1129.5 meters where dips in the core were 60 degrees.
Source rock geochemistry by Analabs is avaliable.

Comments: Generally poor shows and an almost total lack of visible porosity, and none that would justify further evaluation, bodes poorly for the sands in this well.

BALMAIN #1

Spud Date: October 8, 1992

Rig Release: November 7, 1992

Well Sequence Number: 8

Total Depth: 1050 meters — Cored Interval: apparently continuously cored - top unknown

DSTs: DST #1 - 777.55 — 790.5 meters DST #2 - 879.78 — 887.07 meters

Rec. 4.5 liters OIL + 24.5 liters o&wcm Rec. 80.5 liters sw (formation water)

Test of Sand in Hayfield Mudstone Test of Jamison Sandstone

Elevation: DF = 230.3 meters

Tops:

Jindukin Formation	52.5 meters
Tindall Limestone	81.5 meters
Antrim Plateau Volcanics	263.0 meters
Bukalara Sandstone	346.0 meters
Hayfield Mudstone	404.0 meters
Jamison Sandstone	854.0 meters
Kyalla Shale	938.5 meters

Hydrocarbon Shows: DST #1 recovered free oil, and oil was recovered from the water of DST #2. The core description of the Kyalla shale (938.35 to +1050 meters) contains numerous notations of hydrocarbons including fluorescence, oil bleeds, gas bleeds. Basically the Kyalla has lots of oil and gas held within the rocks. Most bleeds were from fractures and laminations.

Geological Summary: The Balmain #1 was to test a “lateral resistivity anomaly identified using the compensated transient electromagnetic (CETM) technique.” Primary target was the Jamison Sandstone with the secondary objective the sandy portion of the Hayfield Mudstone. Tests apparently proved unsatisfactory for further evaluation. The DSTs had very small volumes of fluid recovered indicating poor reservoir properties.

Source rock analysis is available. The Kyalla is thought to be marginally mature to mature for liquids generation. Organic richness varied from 0.96% to 2.72%.

Comments: The Balmain #1 was drilled on the anomaly noted above and to follow-up leads from the Jamison #1 well where free oil recoveries were obtained.

BURDO #1

Spud Date: August 26, 1993

Rig Release: September 13, 1993

Well Sequence Number: 12 (last)

Total Depth: 1239 meters in Moroak Sandstone. Cored Interval: one 1027.0 to 1034.5 meters — the rest of the hole was rotary air drilled

DSTs: none

Elevation: KB = 271.9 meters

Tops:		
	Mullman Beds	surface
	Tindall Limestone	103.8 meters
	Antrim Plateau Volcanics	184.9 meters
	Hayfield Mudstone	454.9 meters
	Jamison Sandstone	587.6 meters
	Kyalla Shale	749.4 meters
	Moroak Sandstone	1144.6 meters

Hydrocarbon Shows: Burdo #1 had significant gas shows with some oil shows. Dry gas was regularly flared at the surface prior to unloading water from the hole while making connections. However, detailed show evaluation was impossible with air drilling.

Geological Summary: The Burdo #1 was located near the NE margin of the Beetaloo Basin and was to designed to test a large wrench fault.

Comments: Had good water fill-up while drilling the Moroak Sandstone which may indicate good reservoir properties. The Jamison Sandstone was much thicker than normal and is felt by Pacific's geologist to be possibly conformable with the underlying Kyalla. However, log profile has a very sharp contact and this is likely an unconformity. The Jamison is thicker here but this well is a significant step-out from the Ronald 1 to the west.

Source rock analysis of the Kyalla done. "The Kyalla is mature for hydrocarbon generation."

CHANIN #1

Spud Date: June 26, 1993

Rig Release Date: July 20, 1993

Well Sequence Number: 10

Total Depth: 1411.0 meters in Moroak Sandstone; Cored Interval: none. Well air drilled and switched to mist/foam. This switch improved sample quality.

DSTs: none

Elevation: KB = 244.9 meters

Tops:

Mullman Beds		Surface
Tindall Limestone	76.5 meters	
Antrim Plateau Volcanics	182.3 meters	
Hayfield Mudstone	622.4 meters	
Jamison Sandstone	875.0 meters	
Kyalla Shale	948.4 meters	
Moroak Sandstone	1328.0 meters	

Hydrocarbon Shows: A sample from the basal Jamison Sandstone exhibited weak fluorescence. Otherwise "very poor hydrocarbon shows (were) encountered in the well".

Geological Summary: The Chanin #1 was designed to test a seismically-inferred structural closure. The prognosis (revised) proved to be quite accurate and if a four-way closure was tested as interpreted, the paucity of shows was discouraging to Pacific Oil & Gas as to timing of the development of the structure relative to generation and migration of hydrocarbons. Re-interpretation of the seismic may be prudent to confirm, if possible, the four-way closure.

Comments: Water analysis done on a Moroak Sandstone sample recovered while drilling (no DSTs). Total dissolved solids 216,000 mg/l. Chloride 140,000 mg/l (or 231,000 mg/l NaCl).

MASON #1

Spud Date: November 27, 1991

Rig Release: December 22, 1991

Well Sequence Number: 7

Total Depth: 1103 meters (driller), 1106 meters (logger); Cored interval(s): 809.2-818.2 meters; 875.8-884.8 meters; 893.9-902.9 meters

DSTs:
DST #1, 805.14 — 818.0 meters (Sand lens in Hayfield Mudstone)
Rec. 45.8 liters of mud (suspect small gas inflow)
SIPs 158.8-820.47 psi
FHP 1244.81 psi

DST #2, 894.3 — 902.9 meters (Jamison Sandstone)
Rec. 54.7 liters of mud
SIPs 140.16 - 1139.0 psi
FHP 1377.04 psi

Elevation: DF = 265.7 meters

Tops:

Mullman Beds?		Surface
Jindukin Formation	63.2 meters	
Tindall Limestone	121.5 meters	
Antirm Plateau Volcanics	346 meters	
Hayfield Mudstone	472.3 meters	
Jamison Sandstone	876.5 meters	
Kyalla Shale	973.7 meters	

Hydrocarbon Shows: Some fluorescence in core #1 from a sandstone in the Hayfield Mudstone. No visible porosity was noted in description. Similarly, core #3 had shows in sandstone (Jamison) and was tested.

Geological Summary: Although not stated on any information available in the well file, the Mason #1 was clearly located seismically. It is near the Shortland #1 which was designed to test an unfaulted structural closure (seismic?), and the Jamison #1 which had excellent shows and fair fluid recoveries including free oil. The Mason #1 encountered relatively poor shows and the sandstones drilled and cored had "nil visible porosity" to occasional "poor visible porosity". The sandstones were commonly clay filled and occasionally quartz cemented. The DSTs also were relatively tight and recovered only drilling mud.

Comments: Examination of seismic should reveal the rationale for drilling the Mason #1.

ELLIOTT #1

Spud Date: August 20,1991

Rig Release: October 24, 1991

Well Sequence Number: 6

Total Depth: 1729.2 meters (driller) in Moroak Sandstone; Cored interval: 594.92 meters to TD

DST's:

DST #1 787.54 -- 807.5 meters
(Sandy zone in Kyalla)
Rec. 17.2 liters of mud

DST #2 1006.95 — 1029.3 meters
(Sandy zone in Kyalla)
Rec. 6.0 liters of mud

DST #3 & #4 1101.35 — 1141.05 m
#3 Rec. 98.3 liters of mud + 15 ml oil
#4 Rec. 30.57 liters of mud (Kyalla ss test)

DST #5 1330.0 — 1349.3 meters
(Top Moroak S.S.)
Rec. 5200 liters of formation water

Elevation: DF = 246.3 meters

Tops:

Jindukin Fm.	surface
Tindall Limestone	323.0 meters
Jamison Sandstone	590.0 meters
Kyalla Shale	665.0 meters
Moroak Sandstone	1323.0 meters
Velkerri Shale (?)	1583.0 to 1685.3 meters

Hydrocarbon Shows: Both gas shows and fluorescence were very common in the Elliott #1. Some minor oil bleeds were also reported. Gas shows began below 710 meters and were nearly 100% methane, increasing in heavies downward where below 1100 meters some C5 was occasionally detected. A complete description of lithology is available in Appendix V.

Geological Summary: The Elliott #1 is the southernmost well in the Beetaloo Basin and is key to documenting the presence of the Kyalla, and likely the Velkerri sections this far south. The core description notes the possible top of the upper Velkarri between 1583 and 1685 meters. The well was also based on the southern end of the regional N-S seismic line MA91-103, where the reservoir potential of the Moroak Sandstone was of interest. The Elliott #1 was also designed to investigate the nature of the subcrop of the Moroak sandstone beneath the Cambrian unconformity. The Kyalla saw increased sand content and lower organic content than wells to the north. This may help confirm the south to north sediment transport direction for the Kyalla inferred in other wells. Several of these sandstone inter-beds were tested without encouragement for commercial reservoir quality. However, the Moroak yielded 5200 liters of formation (saline) water on a DST.

Source Rock: Kyalla was leanest near top with a maximum of 0.8% TOC and somewhat richer near the base with up to 2.5% TOC. Kyalla was immature at top to over mature at the base.

JAMISON #1

Spud Date: October 18, 1990

Rig Release Date: December 23, 1990

Well Sequence Number: 5

Total Depth: 1766.0 meters (logger); Cored interval: from 410.2 meters to 1766.85 meters

DSTs:

DST #1- 804.8 — 818.8 meters
Rec. 13 liters M + gas TSTM
Sandstone in Hayfield Mudstone

DST #2 - 868 — 895 meters
Rec. 1004 meters sli GCMW + gas TSTM
Upper Jamison (Bukalorkmi) Sandstone

DST #3 - 865.94 — 930.45 meters
Rec. 448 m fm. w, 1.5 m OIL + gas TSTM
Upper Jamison Sandstone

DST #4 - 889.3 — 904.6 meters
Rec. 687 meters SW + 5 cm OIL
Upper Jamison Sandstone

Elevation: DF = 263.4 meters

Tops:

Tindall Limestone	77.0 meters
Antrim Plateau Volcanics	372.0 meters
Bukalara Sandstone	475.62 meters
Hayfield Mudstone (Chambers River)	501.46 meters
Jamison Sandstone (Bukalorkmi SS)	871.04 meters
Kyalla Shale	968.8 meters
Moroak Sandstone	1714.32 meters

Hydrocarbon Shows: Good staining and fluorescence in a sandstone in the lower Hayfield Mudstone and excellent stain and fluorescence in the upper Jamison Sandstone. Pin point oil bleeds are reported in sandstones where fluorescence is noted. All DSTs had gas and two had small amounts of free oil. The oil was 34.6 degrees API.

Geological Summary: The Jamison #1 was drilled to test, at that time, the southern extension of the Beetaloo Basin. The well confirmed a good thickness of Upper Roper Group sediments with modest source rock potential and some reservoir potential in the Jamison Sandstone. It is likely that the Jamison Sandstone is conformable with the Kyalla.

Comments: The final flow periods and final shut in times are extreme, up to 1644 and 1980 minutes respectively.

McMANUS #1

Spud Date: September 28, 1989

Rig Released: November 18, 1989

Well Sequence Number: 3

Total Depth: 1617.4 meters (logger); Cored interval: 272 meters to T.D.

DSTs: DST #1 - 1171.46 — 1319.9 meters
Middle Velkerri Formation
Rec. (misrun) 632 meters of mud

Elevation: DF = 192.0 meters

Tops:

Tindall Limestone	12 meters
Antrim Plateau Volcanics	126 meters
Hayfield Mudstone	270.5 meters
Jamison Sandstone	467.3 meters
Kyalla Shale	552.5 meters
Moroak Sandstone	669.5 meters
Velkerri Shale (upper)	740.0 meters
Velkerri Shale (lower)	1551.0 meters

Hydrocarbon Shows: Dead oil was found in the Jamison Sandstone. Live oil shows including good oil bleeds and pin-prick oil bleeds and stains in the upper Velkerri. Some gas shows were found in the upper Velkerri and some excellent gas shows in the lower Velkerri.

Geological Report: The McManus #1 was drilled on the northern margin of the Beetaloo Basin and was the third well drilled on the "Walton High". Presumably the well was to test encouragement seen in the Altree #2 and Walton #2.

Comments: The McManus #1 was drilled immediately following the Walton #2.

WALTON #2

Spud Date: August 13, 1989

Rig Released: September 14, 1989

Well Sequence Number: 2

Total Depth: 1017 (logger); Cored interval: 191.6 meters to T.D.

DSTs: DST #1 & #2- 755.86 — 778.5 meters
Rec. 15 meters mud & 7.5 liters sli ocm respectively
Lower Velkerri Formation

Elevation: KB = 192.0 meters

Tops:

Tindall Limestone	36.0 meters
Antrim Plateau Volcanics	86.0 meters
Moroak Sandstone	195.5 meters
Velkerri Shale (upper)	258.0 meters
Velkerri Shale (lower)	556.5 meters
Thin Dolerite Sill	660.8 to 667.0 meters
Thick Dolerite Sill	840.0 to 955.0 meters
Bessie Creek Sandstone	971.5 meters

Hydrocarbon Shows: Some spotty light brown oil stain and oil bleeds in lower Moroak Sandstone. Some patchy fluorescence in Velkerri. The lower Velkerri exhibited abundant fluorescence between 650 and 660 meters and from 760 to about 800 meters. Effectively the Bessie Creek Sandstone was without shows.

Geological Summary: The rig was skidded ten meters south of the Walton 1. This is another well intended to test the "Walton High". The well encountered a thick intrusive (Dolerite Sill) which probably impacted the prospectivity of the Walton #2. Core plugs of the Moroak sandstone were taken with porosities up to 20.7% and permeabilities up to 896 millidarcies. Average permeability, with the exception of the 896 md reading is 18.2 md. Average porosity of seven core plugs tested is 13.7%. Plugs were also taken in the lower Velkerri in some sandstone interbeds. A maximum of 0.26 md K and 12.3% porosity was recorded. Most porosities were in the 5% to 8% range and permeablilties were 0.1 md or less.

RONALD #1

Spud Date: July 30, 1993

Rig Release Date: August 17, 1993

Well Sequence Number: 11

Total Depth: 1150.0 meters (driller & logger); Cored Interval: none

DSTs: DST # 1 - 1044-1070 meters
Rec. 3108 liters of formation water
(estimated flow rate about 3000 bf/d)
Tested Moroak Sandstone

Elevation: KB = 254.3 meters

Tops:

Jinduckin Formation	64.3 meters
Tindall Limestone	80.5 meters
Antrim Plateau Volcanics	187.0 meters
Hayfield Mudstone	559.5 meters
Jamison Sandstone	773.0 meters
Kyalla Shale	872.0 meters
Moroak Sandstone	1042.0 meters

Hydrocarbon Shows: Some minor fluorescence was noted in the lower Jamison Sandstone and a few other zones, but no stain or cut was seen in the cuttings. In the original geologists report, the Ronald #1 is described as having “a lack of hydrocarbons”. This could be in part because the Ronald #1 was not cored.

Geological Summary: The Ronald #1 is the eastern-most well in the Beetaloo Basin proper. The Amoco Broadmere #1 is east of the Ronald #1 but the Amoco well cannot be considered to be a test of the Beetaloo Basin. The Kyalla formation correlates fairly well with other Beetaloo Basin wells. The well was designed to test a structure on the “Arnold Arch”, thought to be seismically defined and “fault independent” (seismic line MD 92-255). Primary targets were the Jamison and Moroak Sandstones. The most encouraging factor of the Ronald #1 was the large amount of formation water recovered from the Moroak Sandstone.

SEVER #1

Spud Date: August 30, 1990

Rig Release Date: October 10 1990

Well Sequence Number: 4

Total Depth: 1260 meters; Cored Interval: 276.5 meters to TD

DSTs: None

Elevation: DF = 175.3 meters

Tops:

Tindall Limestone	28 meters
Antrim Plateau Volcanics	46 meters
McMinn Formation (undiff.)	151.5 meters
Velkerri Formation (upper)	331.35 meters
Dolerite Sill	757.78 to 839.97 meters
Bessie Creek Sandstone	1166.96 meters
Corcoran Formation	1227.64 meters

Hydrocarbon Shows: None

Geological Summary: The Sever #1 was drilled northwest of the Beetaloo Basin. The intrusion of the Dolerite Sill is thought to have "over-cooked" the source rocks of the Velkerri. The absence of the Moroak Sandstone was not anticipated and the Bessie Creek Sandstone was extensively silicified.

SHORTLAND #1

Spud Date: November 13, 1992

Rig Release Date: December 3, 1992

Well Sequence Number: 9

Total Depth: 1020 meters (driller), 1018 meters (logger); Cored Interval: None

DSTs: DST #1 - 817.9 — 836.0 meters
Rec. 8 liters of formation water cut mud
some gas was in the test tool
Test was in a sandstone in the lower Hayfield Mudstone

Elevation: DF = 267.7 meters

Tops:

Jindukin Formation	surface
Tindall Limestone	124.0 meters
Antrim Plateau Volcanics	355.5 meters
Bukalara Sandstone	487.0 meters
Hayfield Mudstone	490.5 meters
Jamison Sandstone	870.0 meters
Kyalla Shale	981.0 meters

Geological Summary: The Shortland #1 was drilled in an area of relatively dense seismic coverage and southwest of and relatively close to the Mason #1. It was designed to test a seismic closure. Results were considered similar to those in the Mason #1.

Overall the well was not a significant contribution beyond that of the Mason #1. The structure anticipated was concluded to not be present. Variable velocity was considered to be the culprit.

APPENDIX II.

McArthur Basin Well Summaries

(Wells listed in order drilled – all wells P&A)

Pacific Oil & Gas – Alexander #1

Spud Date: July 31, 1987
Rig Release Date: July 31 1987

T.D. 689.6 meters

Summary: Well spudded in Moroak Sandstone and rotary drilled to 46 meters, where it was then cored to TD.

Shows were encountered in all formations drilled. Of significance is a note that there was “bitumen infilling” of pores in both the Moroak and especially the Bessie Creek sandstones, where in the Bessie Creek, the pore filling was noted as “throughout”. Clearly Velkerri generated oil migrated into these reservoirs, both upward into Moroak and downward into Bessie Creek.

Additionally, the Moroak is described to contain coarse to medium grains. If, as has been suggested by previous authors, the source for clastics is from the south or southwest, this would complicate the regional depositional model. No mention is made of channel related depositional indicators.

Pacific Oil & Gas – Supply #1

Spud Date: October 1, 1987
Rig Release Date: October 9, 1987

T.D. 182.5 meters

Summary: Well spudded in Velkerri Shale and TD’d in Velkerri. No logs were run? The well was cored, with a simple core description available. Most notable is the extensive fracturing in the core. Many fractures are described as healed.

Pacific Oil & Gas – Lady Penrhyn #1

Spud Date: October 16, 1987
Rig Release Date: November 9, 1987

T.D. 745 meters (driller), 743 meters (logger)

Summary: Spudded unexpectedly in the Kyalla Shale. Well was cored from the surface to 81.5 meters, then rotary drilled to 101 meters and again cored to T.D.
The Kyalla Shale was about 100 meters thick and the Moroak Sandstone was 71 meters thick. We can assume less than a full section of Kyalla since it was at the surface. Depositionally significant comments about the Moroak Sandstone are, that it contained compactional sandstone dikes, and much soft sediment deformation features.

Common shows in both the Moroak and Velkerri and Bessie Creek Sandstone attest to the generation and migration of oil into reservoirs and potential reservoirs. The Corcoran Formation was penetrated for 36 meters at T.D.

Additionally significant, the Lady Penrhyn #1 demonstrates the presence of both Kyalla and Moroak north of the "Walton High"

Pacific Oil & Gas – Lady Penrhyn #2

Spud and Rig Release Dates not available in file, but presumed to follow soon after the Lady Penrhyn #1.

T.D. 449 meters

Summary: Spudded in Lower Kyalla Shale and topped the Moroak Sandstone at 45 meters and the Velkerri at 87 meters. The Moroak was therefore 42 meters thick. The Moroak in the Lady Penrhyn #1 was 71 meters thick and the difference between the wells, near twins of each other, is unclear.

The Lady Penrhyn #2 was cored from 73 meters to T.D.

Pacific Oil & Gas – Prince of Wales #1

Spud Date: November 11, 1987
Rig Release Date: November 25, 1987

T.D. 532 meters

Summary: The Prince of Wales #1 spudded in the Velkerri Shale. It encountered a 65 meter thick dolerite (diabase) sill in the middle of the Bessie Creek Sandstone. No DSTs were run and no shows were reported.

Pacific Oil & Gas – Friendship #1

Spud Date: June 11, 1988
Rig Release Date: June 25, 1988

T.D. 395 meters (cored from 55 meters to T.D.)

Summary: the Friendship #1 was spudded in the middle Velkerri Shale. Of significance was the finding of good Bessie Creek Sandstone reservoir quality in the upper six meters immediately beneath a dolerite (diabase) sill. This porous interval also contained good oil shows as did the upper few(?) meters of the sill. The sill was described as “vuggy”with non-interconnected porosity. A DST of the sill recovered only mud. However, a DST of the upper Bessie Creek recovered 80 meters of water and significantly the initial and final SIP were equal at 562.3 psi.

As is true of many McArthur Basin wells, the Friendship #1 was designed to test an anticlinal structure which after drilling was considered breached by faulting and subsequent loss of seal integrity. Core description indicated extensive fracturing with universal fracture in-filling.

Pacific Oil & Gas – Borrowdale #2
(Borrowdale #1 abandoned due to hole problems at 116.3 meters and rig skidded 3 meters)

Spud Date: July 7, 1988
Rig Release Date: July 29, 1988

T.D. 614.5 meters

Summary: The Borrowdale #2 was cored from 10 meters to T.D. and spudded in the Velkerri Shale. It penetrated the Bessie Creek Sandstone beneath a dolerite sill at 526 meters. A DST was run after encountering good shows in the Bessie Creek’s upper 21 meters. The DST recovered 360 meters of water and initial and final SIPs were near equal at 741 psi.

The Borrowdale #2 demonstrates that hydrocarbons were trapped on structure, the dolerite sill appears to have acted as a seal, and timing for entrapment/expulsion of oil was favorable. It should also be noted that for the Bessie Creek porosity and permeability were low in the core analysis. Also, the core was described as fractured. The geological report suggests that trap integrity was compromised by faulting and fracturing resulting in failure to find an accumulation on this structural test.

Pacific Oil & Gas – Golden Grove #1

Spud Date: July 31, 1988
Rig Release Date: August 13, 1988

T.D. 439 meters

Summary: The file is incomplete on this well. There were no shows or DSTs run. It was cored from a depth of ten meters to T.D.

Pacific Oil & Gas – Broughton #1

Spud Date: August 18, 1988
Rig Release Date: September 18, 1988

T.D. 1000 meters

Summary: The Broughton #1 was spudded in the Corcoran Formation. All of the Roper Group above is not present. Minor oil shows were reported in the Hodgson and Limmen Sandstones of the lower Roper Group. No DSTs were run. The Broughton #1 is northern-most Pacific Oil and Gas test in the McArthur Basin.

Pacific Oil & Gas – Lawrence #1

Spud Date: September 22, 1988
Rig Release Date: October 11, 1988

T.D. 530.5 meters (driller and logger)

Summary: The Lawrence #1 was cored from a depth of ten meters to T.D. Of most significance, the Bessie Creek Sandstone had excellent visible porosity in the lower portion of the section. Core analysis lists porosity up to 15%. A 106 meter dolerite (diabase) sill was encountered just above the Bessie Creek. On mechanical logs, the porosity in the Bessie Creek appears to be about five meters thick. There were no shows reported in the Lawrence #1.

Pacific Oil & Gas – Shea #1

Spud Date: July 7, 1991
Rig Release Date: July 25, 1991

T.D. 616 meters

Summary: the Shea #1 spudded in the Bukalorkmi Sandstone (Called Jamison Sandstone in the Beetaloo Basin), and was cored from 72 meters to T.D. The Bukalorkmi (Jamison) is the only report of this unit in the McArthur Basin. The Shea #1 entered the Kyalla Shale at 20 meters and topped the Moroak Sandstone at 245 meters. The Moroak was 40 meters thick and the Velkerri was topped at 285 meters and drilled in to T.D.

Hydrocarbon shows in the Shea #1 were very weak with some “pin point” oil bleeds reported tn the Velkerri and weak to moderate hydrocarbon odor in the Kyalla Shale and Moroak Sandstone.

The Shea #1 is important in the understanding of original regional stratigraphic distribution of the McMinn Formation including the Jamison, Kyalla and Moroak Sandstones in this portion of the McArthur Basin.

APPENDIX IV.

Beetaloo Basin Existing Well Postmortem

Every well drilled within the Beetaloo Basin was located, on, or very near to a seismic line. Generally very poor original data quality likely contributed to increasing the risk of well locations of most of the tests within the basin. Refinement of existing seismic data through re-processing and detailing of both structural and stratigraphic leads determined following that reprocessing, should result in lower risk prospects. The following is a summary of each well and the possible reasons for non-economic results.

A summary of drilling results including tops, total depth, DSTs, and shows relative to these wells is available in Appendix I.

ALTREE #2: The first well drilled in the Beetaloo Basin, "designed as a stratigraphic test to determine the presence of upper Roper Group Sediments below the Cambrian volcanics" (quote from well file), was drilled (cored) on the "Walton High" on the northern edge of the Beetaloo Basin. It was drilled on seismic line 89-105. The well was abandoned after encountering a dolerite (diabase) sill at 1689.5 meters. The main anticipated reservoirs in the Altree #2, the Moroak Sandstone and the Bessie Creek Sandstone (no Jamison Sandstone present) were both found to be tight. The Corcoran Formation was the deepest sedimentary unit penetrated.

Although the Altree #2 was drilled on a prominent high, actual structural closure at the well location cannot be confirmed, particularly at the complicated structural position on the Walton High. Seismic line 89-105 is roughly normal to the Walton High and the drillsite where the Altree #2 is located does not have a tie line at this location to confirm four-way closure. Thus, with the Jamison Sandstone missing, and no confirmable early structural closure, and lack of shows judged worthy of a DST by the operator, the Altree #2 was plugged and abandoned. Clearly more geophysical control may have avoided drilling the Altree #2 at this location.

WALTON #2: The Bessie Creek Sandstone was the primary reservoir target in the Walton #2. Additionally, several sills were encountered in the well. The Walton #2 was drilled on line 89-109, on the "Walton High".

Seismic interpretation was that at this location the well would test “a large thrust faulted anticline in the Roper Group section”.

The Walton #2 was drilled in an area of several seismic lines, yet was located on one line, without the benefit of a crossing confirming line. Once again poor seismic data quality contributed to increasing the risk at the location of the Walton #2. Additionally, the numerous intrusive sills complicated the interpretation. The Bessie Creek Sandstone was the formation at total depth.

Better seismic data quality and an understanding of the distribution of the most prospective reservoirs, will greatly reduce the risk of new drilling in the Beetaloo Basin.

McMANUS #1: The McManus #1 was drilled at the end on line MC92-251 where seismic events are rising sharply onto the Walton High, and considerable isochron thinning is seen in the Jamison Sandstone and Kyalla shale section, at the intersection with seismic line SH90-109. The McManus #1 was a test of an interpreted anticline on the structurally complex Walton High.

The lower Velkerri Shale is the formation at total depth.

The presence of dead oil in the Jamison Sandstone indicates that post-Jamison erosion or faulting has allowed trapped hydrocarbons to re-migrate out or become degraded, or possibly that this location was a migration path with the Jamison Sandstone acting as a migration “pipeline”.

Refinement of existing seismic would better reveal the true nature of the structural geometry at the location of the McManus #1. Also, drilling where there is increased risk of loss of potential seals for the primary reservoirs, greatly increases risk. Such data refinement, and understanding the distribution of key reservoirs will avoid the reasons for failure in the McManus #1.

SEVER #1: The Sever #1 was drilled approximately 85 kilometers NW of the Walton High, outside the confines of the Beetaloo Basin. Although it was located on seismic line EL90-201, it encountered a very complex section of McMinn Formation sediments and a thick dolerite sill. Confining exploration efforts to the Beetaloo Basin where the multiplicity of potential reservoirs and mature, rich, thick source rocks exist will reduce the risks of drilling at locations similar to those at the Sever #1.

At total depth the Sever #1 was drilling the Corcoran Formation.

JAMISON #1: The Jamison #1 was drilled on seismic line SH90-103 without the benefit of a cross line. The shows in the Jamison well may have stimulated the relatively intense seismic acquisition in the area of the well, and particularly immediately to the north. Also, follow-up drilling of the Mason #1 at least in part may be the result of trying to confirm the lead the shows in the Jamison well provided. Since the Jamison #1 was drilled on a one line anomaly, whether or not the location is truly a crestal position could not have been verified at the time it was drilled.

The Jamison #1 was drilling the Moroak Sandstone at total depth.

More accurate seismic interpretation through re-processing of current lines and additional modern acquisition, perhaps a 3D survey, should resolve the structural geometry in the area of the Jamison location. The good shows encountered in the well in the sands in the Hayfield Mudstone and Jamison Sandstone indicate that the Jamison is in fact a good lead for further exploration in the Beetaloo Basin.

ELLIOTT #1: The Elliott #1 was drilled at the intersection of seismic lines ME91-64 and MA91-103. An anticlinal reversal is seen at the Moroak level in both lines but at the Jamison level, the structure appears to be flattened out on line MA91-103 and may well indicate non-closure to the south. DSTs in the lower portion of the Kyalla yielded mud plus some small amounts of oil and appeared to test tight rock. The top of the Moroak did yield 5200 liters of water and had shows. This is very encouraging for improved reservoir quality in the Moroak on Beetaloo Basin structures.

The Elliott #1 was in the lower Moroak Sandstone or uppermost Velkerri Shale at total depth.

MASON #1: The Mason #1 was drilled on seismic line MA91-223 and near line MA91-210. The location on the original seismic appears to be slightly synclinal and reason for the location is an explorational puzzle. Even using original records the well seems poorly located. The excellent shows encountered in the Jamison #1, may in part at least, have been a stimulus for selecting the Mason #1 location.

The Mason #1 was drilling the Kyalla Shale at total depth.

BALMAIN #1: Like the Mason #1, location of the Balmain #1 is puzzling geophysically. It was drilled on the intersection of seismic line MC92-100 and line MC92-251. Possible but very questionable reversal is seen at the Jamison level on line MC92-100 but the location on line MC92-251 dip is regional.

Careful interpretation of structural attitudes and seismic data improvements will avoid locating wells as was the case in the Balmain #1.

The Balmain #1 was drilling the Kyalla shale at total depth.

SHORTLAND #1: The Shortland #1 again is located on or very near lines MA91-109 and MA91-098. Possible reversal is seen at the Moroak level, but this is slight at best on MA91-109. On line MA91-098 the well appears to be on the flank of a syncline. It is difficult to understand the well location from a structural interpretation point of view.

Better structural interpretation and explorational rationale will avoid failures like the Shortland #1.

The Shortland #1 was drilling the Kyalla Shale at total depth.

CHANIN #1: The Chanin #1 was drilled on seismic line MD92-225 and near seismic line SH90-103. The well may be on a structural high on line SH90-103 at the Jamison and Moroak levels and deeper, but it is located within an area of very poor seismic data. Attempts at interpreting data in such areas are fraught with risk.

Once again, a clearer interpretation of seismic should avoid drilling in Chanin #1 like locations.

The Chanin #1 was drilling the Moroak Sandstone at total depth.

RONALD #1: The Ronald #1 is the only well in the Beetaloo Basin drilled on the prominent Arnold Arch near the eastern side of the Basin. It was drilled on seismic line MD92-55 which does show a prominent structure with isochron thinning between the Moroak and Jamison sandstones. However, the Ronald #1 may point up the risks of drilling on single line seismic anomalies, even if on a prominent regional high.

Thick sections of Tindall Limestone and Antrim Plateau Volcanics also undoubtedly complicated geophysical interpretation. Also the Ronald #1 was not cored and show evaluation was more difficult. However, the DST of the Moroak yielding an estimated 3000 BFPD is very encouraging for preservation of porosity on true structural culminations.

Although the Ronald #1 was drilled on a prominent one-line high, it was also drilled immediately north of a synclinal sag at the Jamison Sandstone level. If this sag was present during hydrocarbon migration, it could have acted as a migration dam to potential reservoirs to the north where the Ronald #1 was drilled.

The Ronald #1 was drilling the Moroak Sandstone at total depth.

BURDO #1: The Burdo #1 was drilled on seismic line 89-203. Data quality at the location is very poor and could easily be misinterpreted. It does appear to be located on a prominent horst block but closure is extremely speculative. Again, it is located on one seismic line.

Selection of locations in very poor data areas and especially on single lines is very risky and must be avoided in intelligent wildcat well location selection.

The Burdo #1 was drilling the Moroak Sandstone at total depth.

BROADMERE #1: The Amoco Broadmere #1 was drilled in the “Batten Trough” region, a complex north-south graben system of the southern McArthur Basin, nearly 100 kilometers west of the Beetaloo Basin. It was drilled following an extensive field program and 333 line kilometers of seismic acquisition. The Broadmere #1 was to test a structural reversal interpreted to be present from intersecting seismic lines. According to the “Post Drilling Appraisal” report by Amoco dated June 1985, the Broadmere #1 was plugged and abandoned at a depth of 2175 meters in Roper Group sediments. It was plugged “due to a lack of shows, extremely poor reservoir quality and indications that the oil floor may lie above 4000 feet” (1220 meters). It is important to note that according to a map in the Amoco report, the location is surrounded by Lower Roper Group and McArthur and Nathan Group sediments.

The Broadmere #1 was drilling in “Roper Group Sediments” at total depth.

APPENDIX V.

GEOLOGICAL DESCRIPTION
ELLITOT #1

INTERVAL - CUTTING DESCRIPTIONS

Surface – 12 m MUDSTONE, grayish pink to very pale orange.

12 – 21 m MUDSTONE, moderate orange pink.

21- 48 m MUDSTONE with minor SANDSTONE. Mudstone is pale yellowish brown to dark yellow orange. Sands are fine to medium grained, moderate to well sorted, clear frosted quartz grains.

48 – 117 m CLAYSTONE, olive black to brown black, silty in part with occasional glauconite, trace mica. Occasional to common fine to very fine quarts sand grains.

117 – 127 m CLAYSTONE, off white to brown, firm, blocky.

127 – 133 m Ttoal circulation lost in large caverns, suspect limestone.

133 – 156 m SANDSTONE, very fine to coarse grained, moderately sorted, subrounded to rounded, clear to frosted quartz grains, trace argillaceous matrix.

156 – 170 m SANDSTONE & SILTSTONE. Silts are pale brown to moderate red brown, dolomitic. Sands are very fine go coarse grained, moderately sorted, subrounded to rounded, clear to frosted quartz grains, trace argillaceous matrix.

170 – 195 m SANDSTONE, very fine to coarse grained, moderately to poorly sorted, subrounded to rounded, clear to frosted quartz grains, trace argillaceous matrix, trace dolomite cement.

195 – 210 m SANDSTONE, grading into underlying SILTSTONE. Sands are moderate grey to pale grown, very fine grained grading to siltstone places, sub-angular to rounded, hard to very hard, common siliceous cement. Silts are off-white to light grey, blocky, hard dolomitic.

210 – 216 m DOLOMITIC SILTSTONE, pale yellow brown to light grey, blocky, very hard, common mica, grades to very fine sandstone.

216 – 234 m DOLOMITE, dark yellow orange to pale brown, hard, blocky, microcrystalline with occasional very thin chert bands.

234 – 260 m DOLOMITIC SILTSTONE, moderate to dark reddish brown, hard, sub-blocky, arenaceous, micro-micaceous.

260 – 267 m DOLOMITIC LIMESTONE grading to DOLOMITIC SILTSTONE, pale yellow brown, moderately hard to blocky.

267 – 274 m DOLOMITIC SILTSTONE, light bluish grey arenaceous, micro-micaceous, moderately hard to blocky.

274 – 294 m Lost circulation

294 – 309 m LIMESTONE, yellowish grey to white, blocky to sub-fissile, hard, microcrystalline, occasionally dolomitic.

309 – 314 m DOLOMITIC SILTSTONE, red brown and light bluish grey, moderately hard, blocky.

314 – 320 m LIMESTONE, yellowish grey to white, blocky to sub-fissile, hard, microcrystalline, dolomitic.

320 – 324 m DOLOMITIC SILTSTONE, light bluish grey, moderately hard, blocky.

324 – 404 m DOLOMITIC LIMESTONE, pale yellow brown to moderate yellow grown, blocky to sub-fissile, hard, microcrystalline, trace pyrite. Dolomite content varied between 30% and 90%.

404 – 409 m DOLOMITIC LIMESTONE with DOLOMITIC SILTSTONE. Limestones are pale yellow brown to moderate yellow brown, blocky to sub fissile, hard, microcrystalline, trace pyrite. Siltstones are light bluish grey, moderately hard, blocky, very calcareous.

409 – 595 m Lost Circulation

CORE DESCRIPTION

594.92 – 663.43 m JAMISON SANDSTONE

Very light to light grey, tending to slightly greenish grey in places. Grain size ranges from very fine to medium, but is dominantly fine, and moderately to well sorted, with most grains sub-angular to rounded. Most primary porosity is now taken up by quartz overgrowths and (authigenic?) clays with variable, but usually minor carbonate cement (calcite with minor dolomite?), resulting in low porosity and permeablilty.

Stratification is generally poorly defined throughout, dominated by apparently “massive” to vague chaotic bedding, which seems to have been rapidly deposited and/or subsequently remobilized (fluidized?). infrequently within this sequence subintervals of better defined stratification occur, delineated by the presence of greenish grey silty mudstone, which occurs in various forms.

Most commonly this mudstone appears as very fine (whispy, hair-like) planar to slightly wavy laminae which define a sub-horizontal to low-angle planar stratification and generally pass gradationally to “massive” intervals above and below. In some cases these wispy laminae also delineate very fine cross-lamination (eg. 605.15 – 605.75 m, 617.6 – 618.18 m,637.18 – 637.90 m) and broader-scale, more diffuse cross-bedding towards the base (eg. 647.70 to 648.60 m). Various sized clasts of greenish grey mudstone occur spasmodically throughout; smaller clasts as part of planar laminated intervals and larger clasts occurring sparsely distributed through “massive” and chatoic intervals, occasionally in sufficient proportions over 10 – 20 cm sib-intervals to produce breccias of distorted mud clasts (eg. 611.60 *- 611.80 m, 650.93 – 651.13 m). Wispy, high angle streaks of greenish grey mudstone occur in many of the thicker “massive”/chatoic beds below 627 meters, in some cases seeming to cross-cut bedding. These may have resulted from a post-depositional fluidization of the sand.

Greenish grey silty mudstone also occurs as “massive” to chatoically bedded units ranging form 1 cm (possibly just a large clast) to 30 cm, usually with very sharp (planar to wavy planar) tops and bases. The thicker examples tend to occur at the top of a sequence passing from “massive”/chaotic sandstone, through finely planar laminated (and cross-laminated) sandstone to 10 – 30 cm mudstone units, and thus may be interpreted to represent the last phase in a waning depositional cycle.

Pyrite, both as fine crystals and nodules (up to 1 cm) occurs sparsely through the entire interval, mostly associated with the greenish grey mudstone beds, clasts and laminae. Between 610.00 – 610.12 m large patches of pyretic cement fill 20% of sandstone matrix.

Down to about 610 meters dark grey “spots” of clastic material up to 1 cm occur sporadically, but below this carbonate is only observed as a sparse patchy cement spread diffusely through the sandstone matrix.

Towards the base of this interval a reddish brown alteration (oxidation) becomes increasingly common. This is first observed as a few patchy light reddish brown bands around 644 meters and at 659 meters, then below 660.18 meters this oxidation becomes more common, including two bands (660.48- 660.58 m, 660.61 – 660.69 m) and scattered patches. A chaotic sandstone bed from 661.97 – 662.43 m has a matrix of dark reddish brown and greenish grey cements irregularly mixed.

Sharp, wavy planar sub-horizontal contact; from fine light grey sandstone with abundant patches of reddish brown cement to poorly sorted, muddy, dark greenish grey, very fine sandstone.

662.43 – 663.25 meters SANDSTONE with minor crudely inter-bedded MUDSTONE

Very fine to fine, poorly sorted(locally muddy) mostly dark greenish grey (minor light greenish grey) sandstone which shows crude planar to wavy planar bedding with minor, thin (< 5 mm) mudstone laminae.

Approximately 40% of this unit shows a dark reddish brown alteration in poorly defined sub-horizontal bands and patches (similar to the base of the overlying interval). The lowermost 40 cm hosts common to abundant, 1-3 mm poorly defined carbonate (calcite) nodules.

Contact at 663.25 meters

Sub-horizontal, wavy/irregular but sharp contact, due to “massive” fine sandstone draping over clasts of the underlying conglomerate.

663.25 – 664.73 meters CONGLOMERATE (Base Jamison Sandstone)

This interval comprises a diverse array of colours, types and sizes of pebbles and cobbles within a predominantly very fine to medium sand matrix.

Clasts are of two main types: (i) various rounded to subangular sandstone clasts ranging from 0.5 cm to (at least) 5.0 cm and made up of clean, very fine to coarse sand, rounded to angular, some poorly sorted, others well sorted. Colour of these sandstone clasts ranges form light greenish grey to dark yellowish orange (most with patchy dark yellowish brown) to dark reddish brown. (ii) platy to lenticular to irregularly shaped clasts of mudstone (some with sand grains entrained), largely of either a very light or very dark greenish grey or dark reddish brown colour. These platy elongate clasts range form 12 mm up to (at least) 5 cm long and up to 1 cm thick.

Although very poorly sorted and only very crudely bedded, there is a pronounced sub-horizontal fabric evident in this interval, defined by the larger elongate pebbles and clasts being mostly sub-horizontal. However, there are no internal subdivisions, suggesting one continuous depositional episode for this unit.

Contact at 664.73 meters TOP KYALLA SHALE

Contact is sharp, horizontal and slightly wavy planar. Medium to coarse sand grains from the matrix of the conglomerate can be seen embedded up to a few millimeters into the underlying mudstone, possibly suggesting the mudstone was quite lithified, but just soft enough to allow some sand grains to be pressed into it under lithostatic compaction. Small fragments of the mudstone can be seen in the conglomerate and are not significantly squashed or deformed, suggesting that the mudstone was competent/lithified at the time the conglomerate was deposited.

These observations are interpreted to indicate that the mudstone was deposited and became largely indurated before the conglomerate was deposited, suggesting an hiatus and erosional unconformity of unknown duration or extent.

664.73 – 728.3 meters SILTY MUDSTONE w/ inter-bedded SANDSTONE & SILTSTONE

Silty mudstone is medium grey to grayish black and variably silty; generally "massive" to very finely laminated with sparse to common specks of mostly very fine (<0.5 mm) carbonaceous material.

Sandstone is mostly very fine to occasionally fine, light to very light grey, with internal stratification ranging from very finely planar laminated (and very rarely cross-laminated) through to "massive" and frequently chatoically bedded, and very infrequently showing a "mottled" character. Siltstone occurs in between the sandstone and mudstone, and is light to medium grey in colour, with internal stratification ranging from "massive" to planar laminated to chaotic.

Overall, the interval shows broadly planar to wavy planar stratification consisting of a stack of variably complete upward fining sequences ranging from millimeters to tens of centimeters thick.

The basic sequence begins with a sharp (erosional) base to fine to very fine sandstone, which is massive to very finely planar and rarely cross-laminated. This passes gradationally up through siltstone to a silty (and sometimes finer) mudstone, which appears mostly massive, but is occasionally vaguely planar laminated. Usually either the sandstone or mudstone component dominates and the intervening siltstone remains relatively minor, so that the gradual transition from sandstone up into mudstone often occurs over less than 10-20% of the cycle's thickness. Both the sandstone and the mudstone parts are mostly 2 mm to 10 cm thick, ranging infrequently up to 25 cm. approximate percentages of sandstone are estimated to be 25-40% down to 696 m, 10-20% form 696 m to 711 m, and 50 -70% form 711 m to 728.3 m.

The entire interval appears to have been deposited under conditions of instability since almost every cycle appears to have undergone soft sediment deformation to some extent. This deformation is of two main types:

(1) "Molar" Structures. This informal descriptive term refers to sub-vertical, squiggly sandstone features within mudstone beds which display a downward tapering profile, and a thin elongate plan view. These structures have been previously referred to (including in published literature) as sandstone injections/dykes, but this genetic term is probably incorrect. Instead, it is thought that they form as the result of gravitational infilling of sand into cracks developed in quasi-solid (or semi-plastic) mud layers, probably due to dewatering/syneresis of differential mass flow. Injection of the sand is discounted because it only appears to happen downward, hence the interpretation of gravitational processes. These molar structures are ubiquitous throughout much of the Kyalla Member, but have also been observed in similar facies of other Roper Group units.

(2) Hydroplastic structures. This group occurs on a scale of millimeters to tens of centimeters and provides the most visible disruption to original planar stratification. It produces mainly irregular/distorted contacts as sediments are folded, slumped and/or injected into adjacent layers, producing anything from wavy contacts, to dish structures, to tongues of intruded sediment (often retaining internal lamination), to slump folds and faults, and chaotically mixed/contorted beds.

Both of these groups of structures are clearly due to remobilization of sediment shortly after its deposition, and thus, are thought to be caused (at least in part) by relatively rapid deposition causing continual loading of wet sediment which becomes locally unstable until bed failure occurs. This sediment loading appears to comprise a multitude of small, variable movements, suggesting continual readjustment during deposition.

As with the conglomerate and the base of the overlying sandstone, the top of this interval displays a variable alteration to dark and light grayish green and dark reddish brown which broadly follows bedding (forming alternating bands), as well as the reddish brown forming irregular patches and streaks within some grayish green bands. This is thought to have resulted form diagenetic fluid flow through the conglomerate.

Lithologic contact at 728.30 meters

Rapid transition (across a 2 cm very fine sandstone bed) form dark grey mudstone to greenish grey mudstone. Apparently the upper limit of a greenish alteration zone around the underlying sandier interval.

728.30 – 737.04 meters SANDSTONE w/ inter-bedded SILTSTONE & MUDSTONE

Similar overall sequence as above, but generally much sandier, and locally coarser, including some "pseudo-oolithic" beds. Sandstone is light and medium light grey, light pinkish grey and light greenish grey. Over 1 -05 cm intervals it is occasionally medium to coarse and frequently contains platy clasts and wavy laminae of mudstone.

Siltstone and mudstone layers are as above, but greenish grey in colour, and rarely more than 5 cm thick, especially below 729 meters. The 1 -3 cm mudstones commonly contain numerous molar structures. Some sands show incipient discs of sandstone over 15 – 40 cm zones (eg. 731.45 -731.60 m and 732.20 – 732.60 m).

The thickest single sandstone bed (734.53 – 734.94 m) shows a vague, wavy, high-angle stratification reminiscent of either chaotic slumping or fluidization.

The most notable lithological difference in this interval is the presence of several beds (ranging 0.5 – 20 cm) of medium to coarse (and minor very coarse), subrounded to well rounded grains ("pseudo-oolites"). These beds have a matrix containing variable proportions of very fine sand, clays (both light pinkish grey and grayish green), minor quartz overgrowths and patchy authigenic calcite and pyrite cements. The thicker examples also have a patchy dark reddish brown (iron oxide?) cement in places. Most grains are white to light grey quartz, but some are grayish black (smoky quartz?). Bounding contacts of these beds tend to be sharp, sub-horizontal and planar to slightly wavy, but internally they are crudely bedded, ranging from massive to chaotically bedded (the latter sparsely delineated by distorted layers of grayish green silty mudstone).

These beds are quite distinctive and are thought to represent deposition in a shallow marine environment of moderate to high energy where tide and/or wave action have moved grains back and forth over a limited area.

Lithologic Contact at 737.04 meters

Rapid transition (across a few centimeters of sandstone with very thin mudstone laminae) form greenish grey mudstone to dark and medium dark grey mudstone.

737.04 – 746.90 meters SILTY MUDSTONE w/ variably interbedded SANDSTONE and minor SILTSTONE

Similar to the silty mudstone of the interval above, except that mudstones are nto quite as dark, ranging medium grey to dark grey (and very slightly bluish/greenish in places). Thickness of individual mudstone units ranges from millimeters up to 10 cm.

Sandstones are also similar to the 665 – 728 m interval, being light to very light grey, and ranging mostly form millimeters to 10 cm thick (less commonly up to 20 cm) and occupying 15% to 50% of the interval. Grain size ranges form very fine to (mostly) fine to medium. Infrequently, 1 – 5 cm beds of well rounded, medium to coarse grains occur, which appear to be less well developed examples of the "pseudo-oolites" described above. In fact, they comprise a bimodal sand population with a framework of well rounded, medium to coarse grains in a matrix of very fine sand and a light pinkish grey clayey cement.

Stratification is broadly planar to slightly wavy, and consists of variable complete upward fining cycles which frequently show slumping (and the resulting chaotic bedding), especially in and below the thicker sandstones, as well as ubiquitous molar structures within the mudstones. Most of the incipient pseudo-oolite beds have sharp, planar bases and tops.

Lithologic Contact at 746.90 meters

Approximate mid-point of transitional contact between interval above and mujch sandier zone below.

746.90 – 751.36 meters

As above, but much higher sand content (ranging 85 – 95%). Sandstone is light to very light grey, mostly fine to medium (with minor coarse component), subrounded. Individual beds range mostly 2 mm – 15 cm (with one 55 cm thick at 747.15 – 747.70 m), and all appear massive to vaguely planar bedded. Occlusion of primary porosity is extreme, due mostly to silicification, with a variable, but lesser contribution form calcite (and sometimes associated pyrite, eg. 747.28 – 747.90 m, which may be due to a sub-vertical fracture).

Thicker sands often have very fine sub-vertical fractures (eg. 747.20 – 747.90 m) and some show incipient horizontal "scallop-like" sets of fractures (1 – 2 cm apart over 15 cm zone, 749.10 – 749.25 m).

Mudstone beds are dark grey to grayish black, mostly thin (2 mm – 5 cm) and massive, but sometimes contain 2 -4 mm beds of incipient pseudo-oolites, and ubiquitous "molar" structures.

Lithologic Contact at 751.36 meters

Approximate mid-point of transitional contact with underlying muddier interval

751.36 – 788.80 meters SILTY MUDSTONE w/ variably interbedded SANDSTONE & minor SILTSTONE

Similar to the 737 – 746 m interval, except that sandstone percentages lower, ranging mostly 5 – 15%, except for the sandy subintervals which range 40% - 70% (ie. 752.10 – 753.25 m, 760.93 – 762.10 m, 766.40 – 767.10 m, 768.30 – 768.75 m, 780.50 – 781.90 m and 783.10 – 783.50 m).

Sandstones are generally of two main types:

1) very fine to fine grained, thinly bedded (from <1 mm – 10 cm) with massive/chaotic to planar (and rarely cross-) laminated stratification. These have commonly undergone at least minor soft sediment deformation (sometimes major) and usually have a sharp base, then grade through siltstone to mudstone in variably complete upward fining cycles.

2) medium to very coarse sand sized (with minor percentage of granules) framework within a medium grey clayey matrix with a minor percentage of very fine sand. These beds range from 3 mm – 25 cm thick, are internally massive, and have very sharp planar to wavy planar 9and rarely very irregular/slumped) top and bottom contacts. Most grains are white to light grey quartz, but a high proportion of the medium sized grains are dark grey to black (smoky quartz?). No calcite or pyrite was detected in these pseudo-oolites, unlike those above. These pseudo-oolitic beds generally occur in groups (eg. Form 766.40 – 767.10 m) with intervening mudstone beds, and only very rarely as single beds within the sequence of interbedded silty mudstone and fine sandstone. Also, some of these medium to well rounded grains appear singly or in sparse trains through some adjacent mudstone beds.

Overall stratification is as above, broadly planar to wavy planar, with common (but variable) slumping and dewatering structures.

Lithologic Contact at 788.80 meters

Approximate boundary within the transition between the interval above and the underlying sandier interval.

788.80 – 801.17 m SANDSTONE with variably interbedded SILTY MUDSTONE

Sandstone is of the two types described in previous intervals, but the proportion of beds containing medium to very coarse, well rounded grains (“pseudo-oolites”) is now much greated than the very fine to fine sandstone beds, estimated to be 80% and 20% respectively. Overall, the proportion of total sandstone throughout ranges 60 – 90%, with thicknesses mostly 0.5 -15 cm, occasionally up to 40 cm.

The pseudo-oolitic beds have a variable matrix ranging from medium (slightly greenish grey clay (with or without very fine sand grains), to very light grey clay and quartz overgrowths and sporadic, very patchy calcite cement.

Overall stratification is the same as for the previous intervals, broadly planar to wavy planar with minor slumping and dewatering effects, dominantly common sandstone molar structures within mudstones, and less slumping due to the lack of thicker mudstone beds.

Lithologic Contact at 801.17 meters

Contact with underlying interval taken at vase of a thick sandstone which marks the bottom of the dominantly sandstone interval above.

801.17 – 881.70 m SILTY MUDSTONE w/ variably intervedded SANDSTONE & SILTSTONE

Silty mudstone ranges medium dark to dark grey, commonly with a greenish black tinge (with one anomalous light grey mudstone at 859.52 – 859.58 m). Often this greenish color comes and goes on a scale of millimeter, especially in the uppermost and lowermost parts of this interval. Also, the silt content varies appreciably, producing some very fine mudstone beds (claystones?) and elsewhere some subtle gradations into siltstone.

Sandstones are mostly very fine to fine, with colors ranging medium light to light (slightly yellowish) grey to light olive and greenish grey. Overall, they comprise 5 – 20% of this interval, but locally can account for up to 855 (eg. 859 – 860m). Grain size is dominantly very fine to fine, with 0.5 – 15 cm beds of medium to very coarse pseudo-oolitic sands occurring above 802 m, and frequently below 843 m to the base of the interval. The near total porosity occlusion in these sands appears to be due to silicification and clays, with minor dolomitic cement in a single yellowish grey 8 cm thick very fine sand unit at 812.70 m.

Many sands less than 5 cm show basal slumping, internal fluidization 9wavy fractures and faults, eg. 860.11 – 860.16 m) and occasionally unusual patterns (ie. 861.0 – 861.11 m).

Some intervals almost completely devoid of sandstone interbeds (sand <5%) occur (830.60 – 834.60 m, 835.10 – 840.05 m, 841.60 – 843.0 m) and the latter of these is very poorly sorted (containing medium to coarse pseudo-oolite grains) over its lowermost 0.5 m, dividing subintervals with (below) and without (above) pseudo-oolitic sand units.

Stratification is essentially the same as intervals described above, being predominantly planar to wavy planar with varying degrees of subsequent slumping (producing folds, chaotic bedding etc.), dewatering, and molar structures.

The largely finer grained character of this interval has produced a more finely interbedded (planar) sequence with deformational events being more episodic (related to deposition of sandstone beds). It is also noteworthy that some of the very fine sandstone beds have a finely laminated, occasionally crenulated internal stratification somewhat reminiscent of very shallow water algal-mat structures.

Lithologic Contact at 881.70 meters

Somewhat arbitrary contact, chosen at the top of a dominantly (>95%) sandstone interval.

881.70 – 892.19 m SANDSTONE with minor interbedded SILTY MUDSTONE

Similar to the dominantly sandy intervals described above. Sandstone is light to medium light grey (often slightly brownish) and slightly greenish in the pseudo-oolitic beds. It comprises 90 – 98% of the interval, of which most (>90%) is very fine to fine grained, massive to vaguely planar laminated variety which occurs mostly in beds 1 – 30 cm thick (and rarely up to one meter). Pseudo-oolitic units are generally finer than above, ranging medium to coarse with minor very coarse grains, and beds of 0.5 – 5 cm, occasionally up to 20 cm thick. As well as the ubiquitous silicification filling pore space in both types of sands, these pseudo-oolites also have a light grey clayey matrix.

The mudstone is also similar to above, medium to dark grey and massive to vaguely planar laminated with ubiquitous molar structures and toher minor deformation associated with loading by sands.

One noticeable difference is that the mudstones within this sandy interval are generally less silty and contain clays which are more reactive to water (they are breaking up faster, and in smaller pieces, than above or below).

Lithologic Contact at 892.19 meters

Approximate base of dominantly sandy interval.

892.19 – 1008.75 m SILTY CLAYSTONE/MUDSTONE with variably interbedded SILTSTONE AND SANDSTONE

The sediments of this interval differ appreciably from the overlying sequence in that they are overall finer-grained, with the mudstones tending towards claystone and the sandstones tending towards siltstone. This coupled with some apparent changes to the clay mineralogy, produces some changes in the color and stratification as outlined below.

Mudstone/claystone ranges from medium grey to dark grey, dark greenish grey and greenish black, with the greenish tinge being more prevalent in the more clayey sediments. Specks of mostly very fine (<< 1 mm) carbonaceous material also affect color, ranging form sparse (lighter) to common (darker).

Prolonged wetting and drying of the core has shown that much of the mudstone/claystone, particularly the finer and more greenish type/s, tend to crackle when wetted, then crumble and break up relatively rapidly into very small pieces. This would seem to indicate that highly water-sensitive clays occur in this interval and are either absent or of much lower abundance in the overlying sequence.

Sandstones and siltstones throughout this interval range mostly between light and medium light grey, commonly with a slight greenish tinge, occasionally slightly yellowish/olive and very rarely tending to very light grey. Grain size ranges form (dominantly?) siltstone up to very fine sandstone, with no coarser beds observed throughout the entire interval. Thickness of these siltstone/sandstone layers ranges from much less than 1 mm (micro-laminae) very commonly up to 2 cm, less commonly up to 8 cm and infrequently up to 20 cm. they mostly comprise 5 – 40% of any given interval, but may be locally more abundant (eg. 60% over 939 – 942 m).

Stratification is still broadly planar with minor to locally severe soft sediment deformation effects, sometimes forming trains of very small discontinuous lenses (< 0.5 mm thick) within mudstones.

The mudstone and claystone layers appear massive, except where micro-laminae and thin beds of siltstone and sandstone are interspersed within them, usually defining planar to wavy planar lamination which shows commonly minor (to rarely major) subsequent distortion. In some cases this distortion has proceeded to the point of chaotic mixing, resulting in a “mottled” appearance eg. 911.75 – 911.80 m).

Sandstone and siltstone laminae and beds commonly show a very, very fine planar lamination, which is frequently wavy or rippled on a very small scale sometimes forming trains of very small discontinuous lenses (< 0.5 mm thick) within mudstones. Planar lamination is apparent in all but some of the thickest sandstone beds (12 – 20 cm), which either never had any discernible laminae, or have subsequently had their stratification masked by post-depositional effects. Most of the sandstone/siltstone beds show at least some basal slumping or differential loading which occasionally progresses to extremes, producing dish structures, tongues, flame structures, etc.

The molar structures which were so ubiquitous in the inter-bedded mudstone/sandstone intervals above are both much less common and generally much smaller in this interval. In contrast to this, most sandstone/siltstone beds (especially those thicker than 1 cm) show sparse to very common sub-vertical, wavy fractures or veins which appear to have been structures delineating water escape pathways from the underlying mudstone. These features commonly show (usually minor) subsequent vertical and (less commonly) horizontal displacement.

This very fined grained interval appears to be essentially devoid of any porosity or permeability, with most sands/silts being very well indurated, probably due to extensive silicification. Evidence of the carbonate cements is very sparse, with only a minor dolomitic cement being detected in a few sandstone beds (usually those with a pinkish-yellowish tinge eg. 960.12 – 960.26 m, 982.20 – 982.26 m), and no pyrite was observed.

Below 1001 meters some slightly coarser (fine sand-sized) units 1 – 5 cm thick begin to appear, possibly representing a subtle transition to the sandier interval below.

Lithologic contact at 1008.70 meters

Nominal contact (which is actually somewhat transitional) to the underlying sandy interval.

1008.70 – 1035.52 m Inter-bedded SANDSTONE AND MUDSTONE

Similar to the interval above, with the major difference being the relative increase in average grain size due mainly to the large increase in the proportion of sandstone and (much less so) to the increase in silt percentage within the mudstone. Throughout this interval the combined percentage of the sandstone/siltstone fraction ranges 40% - 95%, averaging about 75% overall.

Sandstones (and clean silt beds) are very light to medium light grey and range mostly from silt to fine sand, occasionally with medium sand-sized (and very rarely coarse) grains scattered through the latter. Many sands have sparse, very fine to fine rounded grains of a moderate to dark yellowish green material (glauconite?).

Internal stratification within the sandstone/siltstone beds is dominantly vaguely to well defined planar and cross-lamination, with less numbers of massive and chatoic beds (usually the coarser sands).

Many of the coarser beds exhibit a spotty to patchy light brown to brownish grey staining which largely follows the bedding planes. This staining coincides with areas where fluorescence was recorded in U.V. light photography and thus is inferred to be relict oil. Further comment on hydrocarbon shows will be made elsewhere.

Sub-vertical water escape fractures/veins (as described in the interval above) occur commonly within the sandstones of this interval. Many appear to show a genetic affinity with the sandstone molar structures within the mudstone which was not so apparent in previously described intervals. In some cases (eg. 1022.70 – 1022.80 m) a succession of fractures and molar structures can be seen to line up, delineating one continuous wavy planar conduit (10 cm long), passing through a series of thinly inter-bedded sandstone and mudstone beds.

All sands appear very tight, mainly due to extensive silicification, with minor contributions to occlusion from clays and very minor calcite cement.

The mudstones of this interval are mostly dark grey to grayish black, and are noticeably siltier than much of the mudstone in the interval immediately above. They are generally thin (< 1 mm up to 3 cm), but occasionally occur up to 12 cm thick. The mudstones frequently contain sandstone molar structures, but are otherwise apparently massive to vaguely planar laminated. As with all the overlying intervals the mudstone mostly occurs as the top of a variably complete upwar5d fining sequence, which starts from a sharp-based sandstone and grades rapidly through siltstone to mudstone (which has a gradational base and sharp top). Apart from some localized exceptions these mudstones don't tend to disintegrate as rapidly or extensively as those in the interval above when wetted. (Whether this is due to a different clay mineralogy, or simply due to the increased silt content is unclear).

Lithologic contact at 1035.52 meters

Approximate base of the overlying sandier (chosen nominally at the sharp base of a 4 cm thick light grey sandstone with none thicker or coarser below).

1035.52 – 1052.70 m SILTY MUDSTONE with minor, variable inter-bedded SANDSTONE and MUDSTONE

Similar lithologies and stratification to the interval above, but with generally much lower proportion of coarser (sandstone and siltstone) inter-beds. Silty mudstone is dark grey to grayish black with siltstones and sandstones ranging light grey to medium grey 9some slightly brownish). Grain size mostly ranges up to very fine sand sized (rarely up to fine). Silts and sands comprise 5% - 20% of most of this interval with sands being subordinate, but in the few sub-intervals with 40% - 60% combined (eg. 1037.20 – 1037.74 m, 1043.60 – 1044.10 m, 1052.30 – 1052.70 m) very fine sand dominates silt.

Some of the mudstone beds show sighs of crumbling due to adverse reaction to wetting. This is similar, but less pronounced than in the interval above 1000 meters.

Very fine grained glauconite occurs sporadically throughout, often common in very fine laminae adjacent to and dispersed within sandstones. Pyrite is observed sporadically, both as very finely disseminated crystals through some sand, silt and mud laminae, and also filling some of the vertical water escape fractures in some sands/silts. No carbonate was detected.

Stratification is broadly planar to wavy planar (as above) with common to abundant sandstone molar structures in muds and sub-vertical de-watering fractures in silts and sands. Slumping features are present, but relatively minor, probably due to the lower abundance and thickness of the sandstone beds.

Lithologic contact at 1052.70 meters

Chosen at the base of a dominantly sandy 0.5 m interval of the above section, which contrasts with a 30 cm water-reactive mud at the top of the interval below.

1052.70 – 111.58 m SILTY MUDSTONE (and CLAYSTONE) W/ MINOR INTER-BEDDED siltstone and SANDSTONE

Similar to interval above, but with even lower proportions of siltstone and sandstone. Mudstone is still dominantly silty, but locally it fines to claystone (especially above 1066 meters) and color ranges mostly between dark grey and black, with minor proportions of medium dark grey. Above 1066 meters and below 1095 meters, mudstone which crumbles extensively when wetted becomes prominent.

Sandstone and siltstone inter-beds/laminae within this interval are generally sparse (comprising < 10%) and thin (< 2 cm), but over some sub-intervals they approach 505 (eg. 1067 – 1073 m) and bed thicknesses of up to 45 cm are observed sporadically (eg. 1075.58 – 1075.73 m, 1103.58 – 1103.70 m, 1105.90 – 1106.35m). These largely consist of siltstone and to a lesser extent, very fine sandstone and frequently pass gradationally upward into silty mudstone.

Stratification is broadly planar and occasionally wavy planar, but with numerous units up to 50 cm thick of massive to subtly upward fining character, especially below 1087.20 m.

The sub-intervals 1059 meters to 1066 meters and 1076 meters to 1084 meters are largely devoid of sandstone/siltstone inter-beds, appearing mostly massive to vaguely planar bedded, the latter delineated by thin (< 1 cm) laminae and discontinuous lenses of sand/silt.

Sandstone molar structures are common to abundant around 9below) almost all sand/silt beds down to 1087.20 m, but then become less common with depth, and only occur infrequently below 1090.2 m.

Throughout much of this interval (especially above 1080 m) pyrite occurs commonly as very thin circular nodules (up to 3 mm in diameter) on bedding planes. Above 1067 meters these features are frequently larger (up to approximately 10 mm), very irregularly shaped and can often be traced to sub-vertical, pyrite-filled micro-fractures. Pyrite was observed to occur patchily within longer sub-vertical fractures (eg. In a very well silicified, very fine sandstone at 1105.90 – 1106.35 m).

No carbonate was detected, but some thin (< 2 mm) sub-horizontal veins of anhydrite occur in and adjacent to sand units around 1103.40 – 1103.70 and 1107.00 – 1107.15 m. carbonaceous specks are commonly to locally abundant within the darker mudstones.

Below 1102 meters planar fractured trending 30-40 degrees TCA (to core axis) occur.

Lithologic contact at 1111.58 meters

Sharp, sub-horizontal, planar contact between grayish black mudstone and underlying medium-light grey fine sandstone.

1111.58 – 1145.76 m SANDSTONE and minor inter-bedded SILTY MUDSTONE

Sandstone is medium grey to light grey with darker types tending to be slightly brownish-olive. The lighter colored (and generally coarser) sands begin below about 1129 meters and become more common with depth. Patchy grayish-brownish staining, often along bedding planes is locally common and appears to be oil staining. Grain size is mostly very fine to fine, with some medium (and rarely coarse)(sand units occurring towards the base (especially below 1135 meters), many of which contain small (< 1 cm) platy clasts of mudstone/claystone, often abundantly (eg. 1145.05 – 1145.27 m).

Stratification within sandstones is mostly planar lamination, which becomes slightly wavy and apparently massive in places, but only rarely exhibits cross-bedding 9eg. 1138.72 – 1138.77 m). occasionally beds of platy sandstone/siltstone clasts are observed, ranging from a silty example now altered to siderite (1115.03 – 1115.15 m) to those containing medium sands and 1 – 3 mm muddy clasts (1131.03 – 1131.06 m, 1138.51 – 1138.62 m and 1145.05 – 1145.27 m).

Sandstones comprise 80% - 95% of this interval, with the exception of the sub-interval 1113.50 – 1118.40 m, where silty mudstone (60% - 80%) and siltstone (35% - 45%) dominate.

Silty mudstone is dark grey to grayish black (locally slightly brownish) and mostly occurs in beds 0.5 – 10 cm thick which are generally massive to vaguely planar 9some slightly wavy) laminated. Squiggly sandstone molar structures occur sparsely to commonly throughout, such that some mudstones are riddled with them and adjacent units may be completely devoid of them. They are particularly abundant in the interval 1115.75 – 1120.25 m, which is dominantly sandy at the base and becomes gradationally more muddy upward.

Stylolites (incipient to locally well developed) are common in the thicker sand units. Within the mudstones (particularly at sharp contacts with the sandstones) sub-horizontal partings with a vitreous luster and incipient slicken-siding become common with depth.

Pyrite occurs occasionally as finely disseminated crystals and rounded nodules up to 3 mm, patchily developed within the mudstones (especially over 1112.00 – 1118.40 m) and within coarser sands. Carbonate cement occurs patchily in most sandstone/siltstone beds, mostly as calcite, but with significant siderite between approximately 1112.00 m and 1115.50 m, especially between thin sandstone beds down to 1113.40 m and as replacement of elongate silty clasts in a clast breccia at 1105.03 – 1105.16 m.

Lithologic contact at 1145.76 meters

Nominally chosen as the dividing contact between the overlying sandy interval and the muddier section below. Contact is the sharp planar base of a fine sandstone bed.

1145.76 – 1310.30 m SILTY MUDSTONE with commonly inter-bedded SANDSTONE and minor SILTSTONE

Similar to the dominantly silty mudstone intervals above, but with a slightly higher overall proportion of sandstone inter-beds. As described previously the sequence largely consists of variably complete upward fining sequences (from fine to very fine sandstone, through minor siltstone to silty mudstone) and is broadly planar to slightly wavy planar stratified.

Silty mudstone is dark grey to grayish black, as above, in beds from millimeters to 30 cm thick, which exhibit a massive to vaguely planar laminated (and occasionally chaotic) internal stratification, generally with a sharp (erosional) upper contact (to sandstone).

Sandstones are very light to medium light grey and are mostly very fine, occasionally coarsening to fine. They generally exhibit fine planar lamination which occasionally grades to massive, and very rarely cross-lamination. Bed thickness ranges form millimeters commonly up to 10 cm, and much less frequently up to 20 cm. the proportion of sandstone 9and greatly subordinate siltstone) mostly ranges 25% - 60%, but is slightly lower over 1239 – 1243 m and 1253 – 1260 m and begins to increase steadily with depth form 60% at about 1277 m to 80% at 1290 m, 90% at 1297 m, then varies sporadically to the base of the interval.

Post-depositional structures are (as above) dominated by common to abundant sandstone molar structures in the mudstones and slumping/dewatering features in the sandstones. These include slump folds, dish structures, tongue structures (some of which occasionally progress to chaotic bedding) and then sub-vertical “veins” in the many sandstones, which can usually be seen to lead up from the underlying sandstone molar structures (indicating a water escape pathway?). A large mudstone dike with sandstone molar structures within it occurs between 1208.50 m to 1208.63 m.

Calcite cement occurs very patchily throughout this interval, mostly as a very minor cement in some (usually coarser) sandstone beds.

Other noteworthy features include; sideritic/dolomitic replacement/invasion of a very fine sandstone, producing a fine, irregular vein network and a slightly pinkish tinge to the medium grey color (1177.48 – 1177.62 m) – a pinkish grey band of chatoically bedded, sub-rounded clasts with alteration to dolomite (and minor calcite) with small to locally large intrusions of coarse crystalline pyrite (1209.47 – 1209.54 m) – thin (<1 mm) high angle (10 degrees TCA) anhydrite vein (1242.06 -1242.15 m) – from 125290 m to 1256.10 m a zone of mostly thin (<2 mm), sub-vertical anhydrite (with minor calcite) veins, one of which thickens to (at least) 1.5 cm between 1255.10 and 1255.30 m and contains large, fibrous/acicular anhydrite crystals, brecciated mudstone pieces (up to 5 cm long) and minor calcite – other very thin (<1 mm), high angle (1- - 20 degrees TCA) anhydrite veins occur at 1258.10 – 1258.25 m and even thinner examples occur spasmodically down to 1291 meters.

Lithologic contact at 1310.30 meters

Sharp, planar sub-horizontal contact chosen nominally at the base of a 20 cm thick inter-bedded silty mudstone and sandstone unit with abundant sandstone molar structures. Below this sandstone remains dominant (>70%)(but overall, contact is transitional, with minor silty mudstone units below and some thick (up to 40 cm) sandstone beds above (eg. 1297,50 – 1297.90 m).

1310.30 – 1322.28 m SANDSTONE with minor inter-beds of SILTY MUDSTONE

Basically a transition zone between the overlying interval (silty mudstone with variable sandstone inter-beds) and the thick sandstone interval below. The interval comprises dominantly sandstone with small sub-intervals (down to single laminae) of silty mudstone with abundant associated dewatering structures. The incidence of these muddy unity is greatly reduced below 1316.50 m (from 10% - 20%) to less than 2% of core down to 1321 m, but then increasing to 40% of the lowermost subinterval.

All lithologies are very well lithified (almost cherty), probably because of proximity to anhydrite veining, silicification and pressure solution effects.

Sandstone ranges in color between very light grey and dark grey (mostly the latter over 1316.70 – 1320.90 m) with some bands/beds displaying a dark greenish grey or slightly reddish/brownish grey tinge. Grain size is masked somewhat by the dark matrix and extreme silicifcation, but is almost all very fine to fine, with minor medium grains (which tend to be light grey and rounded). Some sand beds (especially basal parts) have small (< 1 cm), thin (< 2 mm) platy clasts of mudstone entrained within them, sometimes in beds up to 3 cm thick (at 1312 m), but mostly as sparse trains of clasts delineating bedding.

Stratification is broadly planar to wavy planar, with largely minor to occasionally major slumping and folding. Within the sandstones bedding is often masked by color and silcification; where apparent it shows planar and cross-bedding, but most of the beds now appear massive.

Deformation in this interval is dominated by; 1) brittle fracturing of a zone from 1314.70 m to 1315.08 m, which shows various sized, very angular fragments of the adjacent sandstone in a vein of anhydrite (with minor calcite?). 2) antoher zone of brittle fracture from 1321.10 m continuing down to 1322.85 m. This zone features sub-vertical veins of anhydrite (and minor calcite) which vary from 1 – 10 mm thick and contain angular fragments of the adjacent sediments. Vertical displacement across these fractures is up to 3 cm.

Only very sparse traces of pyrite were observed, usually associated with the anhydrite (minor calcite) veining.

Lithologic contact at 1322.28 meters

Sharp planar sub-horizontal contact from very fine, slightly greenish sandstone to medium to coarse sandstone with rounded grains and dark grey matrix. This contact has a small, sub-vertical brittle fault though it.

1322.28 – 1495.30 m SANDSTONE: TOP OF MOROAK SANDSTONE MEMBER

Mostly medium to light grey, locally brownish, pinkish and yellow with increasingly common bands of reddish brown below 1428 meters. Mostly fine to coarse grained throughout with infrequent silty and muddy bands, becoming more frequent toward the base.

This sandstone readily divides into the following sub-intervals:

1322.28 – 1349.30 m SANDSTONE

Mostly medium to dark grey (frequently slightly brownish), mostly fine to medium, but with frequent coarse grains. Sometimes crudely stratified into layers of fine, medium and coarse grains which appear mostly sub-rounded to well rounded (especially coarser grains), but units of mixed (poorly sorted) fine to coarse grains are not uncommon. Thus, stratification varies between vaguely defined (often crude) planar to cross-bedding and massive to chaotically bedded.

The fine sands appear to be completely silicified while the medium and coarse sands still have a very low inter-granular porosity, which locally appears vuggy (possibly due to plucking of grains during drilling).

Overall, color changes gradationally form mostly medium and dark grey at the top to medium grey through 1333 – 1338 meters, to medium-light and light grey to the base. Sparsely below 1334.50 and commonly below 1338.90 meters, 10 – 80 cm patches of the core are stained with a diffuse brownish oil staining. Also, below 1335 m some 5 – 40 cm intervals of very light grey sandstone occur, sometimes with a patchy dark grey matrix accentuating bedding.

Within this interval some brittle deformation occurs, most notable of which are two anhydrite veins. 1) 1327.55 – 1330.15 m. Very coarse crystalline anhydrite vein with small (< 1 mm) to very large (> 10 cm) angular fragments of the adjacent sandstone included, and with very irregular upper and lower contacts. 2) 1346.90 – 1347.65 m. Sub-vertical 3 cm thick vein of anhydrite (very coarse crystals) with a matrix of soft fine grained mineral (gypsum?) and abundant, variably sized angular fragments of the adjacent sandstone. Minor carbonate cement?

Above and below these larger veins, numerous thinner (and mostly sub-vertical) 1 – 2 mm veins of anhydrite occur (joining with veins in the interval above and down to 1349.10 meters). Other closed (ie. Non-lined) fractures occur throughout (becoming more common with depth) and stylolites occur commonly, but with variable frequency.

Lithologic contact at 1427.78 meters

Nominal contact at the top of the first band of dark reddish brown. Apart from the occurrence of the reddish brown bands in this interval the sandstone here is much the same as that described above.

1427.78 – 1495.3 m SANDSTONE

Very similar to the intervals above, with the main difference being the periodic occurrence of sub-intervals of dark reddish brown and minor greenish grey.

Greyish orange, yellowish grey and pinkish grey with common 1 – 4 m sub-intervals of pale, moderate and dark reddish brown (frequently with 1 – 15 cm bands of light greenish grey, usually associated with clayey material).

Grain size ranges from very fine to very coarse, but is mostly medium to coarse and grains mainly appear to be sub-rounded to well rounded. Sorting ranges from very good to very poor, dominantly tending towards the latter.

Stratification appears to largely consist of crude, poorly defined planar and cross-bedding, with lesser sub-intervals of massive to chaotic bedding. Also, diagenetic changes (especially silicification and pressure solution effects) have masked/modified primary structures to varying extents.

Finer-grained sub-intervals/bands become increasingly common with depth and usually comprise a fine to very fine sandstone with a clayey matrix, siltstone inter-beds, and fine (but wavy to very irregular) laminae of claystone and/or silty mudstone.

The wavy/irregular character of many of these clay/mud laminae is due mainly to the presence of sandstone molar structures within them, and subsequent compactional effects.

Because these finer intervals are associated with much of the reddish and light greenish grey color changes, the mud/clay layers (which were presumably originally dark grey to black) have been bleached and/or stained to their present color. One small sub-interval (1462.79 – 1462.91 m) of this inter-bedded silty mudstone and fine sandstone with abundant dewatering structures has retained its black/dark grey color, somehow avoiding the adjacent alteration. Dark reddish brown alteration is also associated with coarse to very coarse beds of sub-rounded to rounded, light grey to white quartz grains, which may represent very poorly developed examples of the pseudo-oolites encountered much higher in the section.

Fractures (mostly sub-vertical to high angle) and stylolites appear commonly, but with variable frequency throughout, being more abundant in the finer sands and around the muddy/clayey sub-intervals.

Some poorly developed incipient examples of “scallop-like” fractures occur around 1453, 1461 – 1465, 1471, and 1489 meters.

Apart form any secondary porosity created by these fractures, effective porosity and permeability appears extremely low, with virtually all primary pore space seemingly occluded by silsicification and authigenic clays.

Lithologic contact at 1495.30 meters

Sharp, planar sub-horizontal contact, nominally chosen at the abrupt change from moderate reddish brown to dark grey. This contact is obviously based on alteration effects more than primary sedimentary character, since lithology (crudely inter-bedded muddy sandstone and mudstone) is the same immediately above and below. The significance is more in the reappearance of dark grwy color and the (associated) increasing abundance of silty mudstone inter-beds below.

1495.30 – 1729.05 m Alterations of SANDSTONE and thinly inter-bedded SILTY MUDSTONE and SANDSTONE

This interval consists of alternations between fine to very coarse sandstone (as in the interval above) and silty mudstone with thinly inter-bedded/laminated fine sandstone 9similar to that described higher in the section).

The thicknesses of these alternating sub-intervals varies, with the thickness and relative proportion of silty mudstone increasing with depth. Sandstone dominates the section down to 1563.90 meters (mostly > 90%) with silty mudstone intervals ranging from 2 cm up to one meter. From 1563.90 – 1613.50 m sandstone and silty mudstone occur in near equal proportions, each tending to dominate over 2 - 6 meter sub-intervals. Below 1613.50 m silty mudstone dominates, with thicker sandstone intervals being restricted to 1633.15 – 1635.10 m, 1643.40 – 1652.10 m, 1662.63 – 1669.45 m, 1672.15 – 1673.10 m, 1692.70 – 1699.80 m and 1725.80 – 1729.05 m (T.D.).

Sandstone is mostly light to medium grey with diffuse zones of pale reddish brown and light greenish grey and occasional 3 – 15 cm bands of dark reddish brown. Grain size varies fine to very coarse, usually with good sorting in the finer sandstones and moderate to poor sorting in the dominantly coarse to very coarse beds. Some very coarse to granule sized grains dominate sand beds between 1590.10 m and 1591.80 m. Most medium and coarser grains appear sub-rounded to well rounded. Occasionally sand units have clasts (mostly platy/elongate) of mudstone, some bleached white to very light grey.

Stratification within the sandstone subintervals ranges (as above) between crudely planar and cross-bedded and massive to chaotically bedded; commonly masked by silicification and pressure solution effects.

Occlusion of pore space appears essentially complete and is largely taken up by quartz over-growths and minor authigenic clays. Even thin, bleached clayey laminae sparsely distributed through the sands have a cherty (silicified) appearance. Calcite cement seems to occur very sparsely and patchily, as a minor matrix component in coarser sand units and as a very fine film lining fractures. Pyrite is only observed as very sparse patches within the matrix of very coarse sand units and infrequently replacing parts of some mudstone clasts.

The reddish and greenish coloration seems to be due to selective bands of oxidation and reduction (respectively) of matrix clays (with the dark reddish brown being more extreme oxidation which has resulted in a softer, relatively friable matrix). These bands usually occur in and around each other and don't persist below 1532.10 meters (the top of a 20 cm silty mudstone unit).

Sets of scallop-like sub-horizontal fractures occur infrequently within the sandstone intervals, usually within the fine to medium parts (eg 1509.40 – 1509.70 m, 1510.60 – 1510.90 m, 1513.50 – 1`513.80 m, 1534.90 – 1535.10 m, 1535.70 – 1536.10 m, 1587.20 – 1587.90 m and 1588.80 – 1589.40 m). Stylolites and sub-vertical to high angle fractures (all from pressure solution?) occur frequently, occasionally highlighted as the sharp contact between two distinctly different colors (eg.1501.79 m and 1528.45 m).

Silty mudstone is essentially the same as described in the interval above 1290 meters. It ranges dark grey to grayish black in color with very fine to fine (and rarely medium and coarse) light to medium grey sandstone inter-beds 0.5 – 4 cm thick.

Stratification within these sub-intervals is planar to wavy planar inter-lamination and thin inter-bedding of silty mudstone and sandstone, with occasional to locally common slumping and soft sediment deformation. Squiggly sandstone molar structures are ubiquitous throughout almost all of these mudstone beds, but they gradually become less abundant with depth, and start to become noticeably less common (<50% of mudstone) below 1583 meters, being replaced by units (up to 10 cm thick) of grayish black silty mudstone with massive to vaguely planar laminated stratification. Below about 1630 – 1640 meters the proportion of mudstone displaying molar structures is down to 5 – 10% of the total silty mudstone sub-interval and with depth they become even more infrequent.

Also below about 1640 meters, the mudstone tends to be darker colored (mostly grayish black) with lower proportions of slightly darker (mostly medium-dark grey), and finer(?) inter-bedded sandstones.

Below 1685.30 meters the squiggly sandstone molar structures become very sparse and infrequent. This appears to be due to a change in character of the mudstone, which becomes devoid of sandy or silty inter-beds over length ranging from 10 cm to more than 2 meters (eg. 1685.56 – 1687.62 m). These units appear to be massive and locally siltier (slightly lighter colored and more gritty), but still frequently have units of thinly planar inter-bedded silty mudstone and sandstone within and around them. The decreasing incidence of the thinly inter-bedded mudstone and sandstone with squiggly molar structures may embody the gradational transition form the basal McMinn Formation into the Upper Velkerri Formation. If this is the case this formation boundary could be placed between 1583.0 – 1685.3 meters.

Below about 1592 meters all sands range very fine to medium, are planar to slightly wavy planar (and rarely cross-) laminated, and very well silicified. Some thicker sands show slumping and chaotic bedding, while many thinner ones show water escape veins (even without accompanying sandstone molar structures in adjacent mudstones), indicating infrequent and mostly sub-vertical to high angle.

Sparse occurrences of a dark green mineral (glauconite?) in sands were observed, including a fine inter-laminae in a 5 cm sandstone bed (1722.76 – 1722.81 m).

1729.05 meters END OF HOLE (Driller).

LIST OF ENCLOSURES

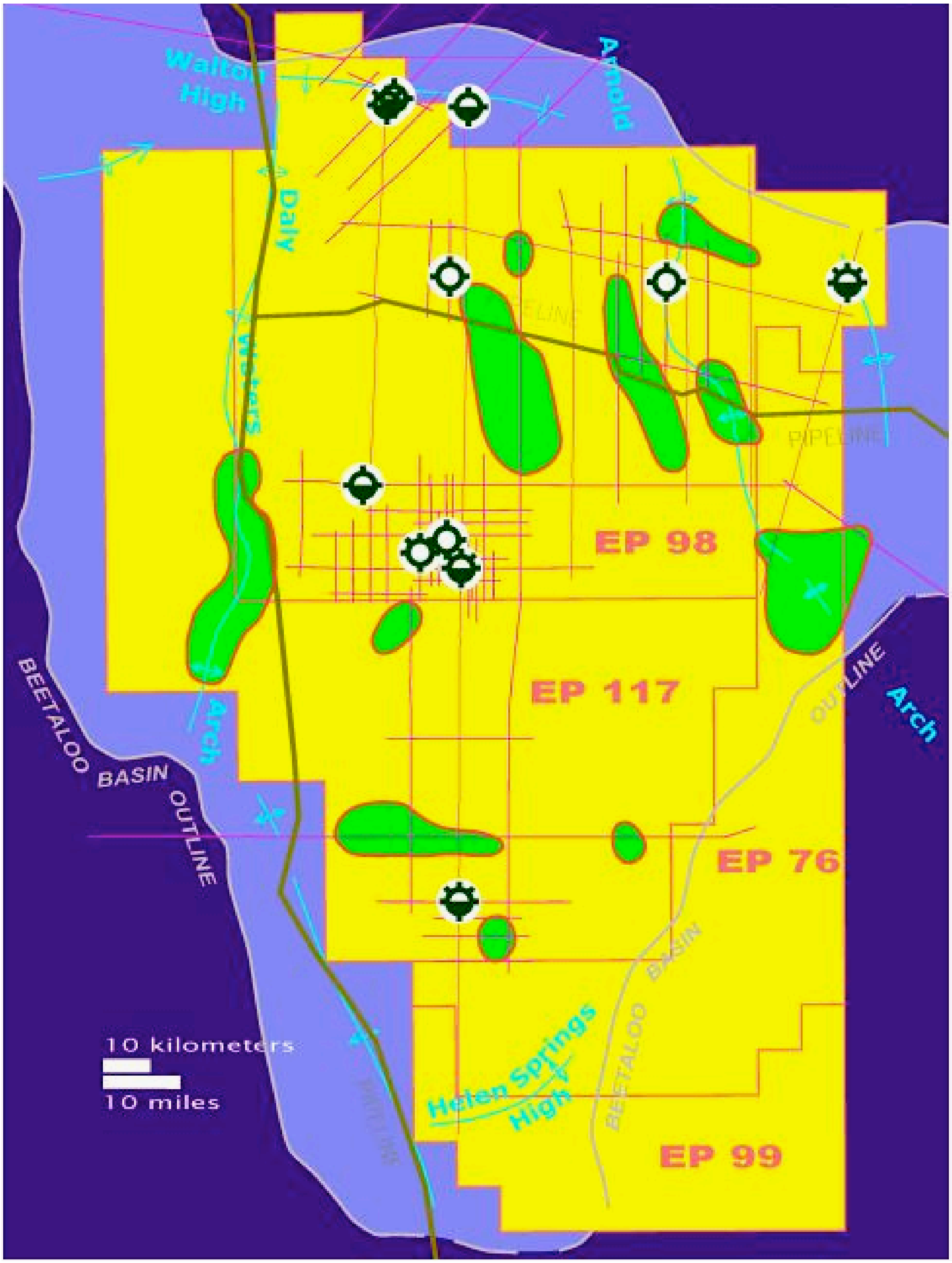


Figure 1. Summary map of the Beetaloo Basin. The outline of the Beetaloo Basin is highlighted in light blue and Sweetpea's exploration permits are shown in yellow. Leads mapped from seismic and gravity are shaded in green with the seismic grid in red. The dark green lines are gas pipelines following major transportation corridors.

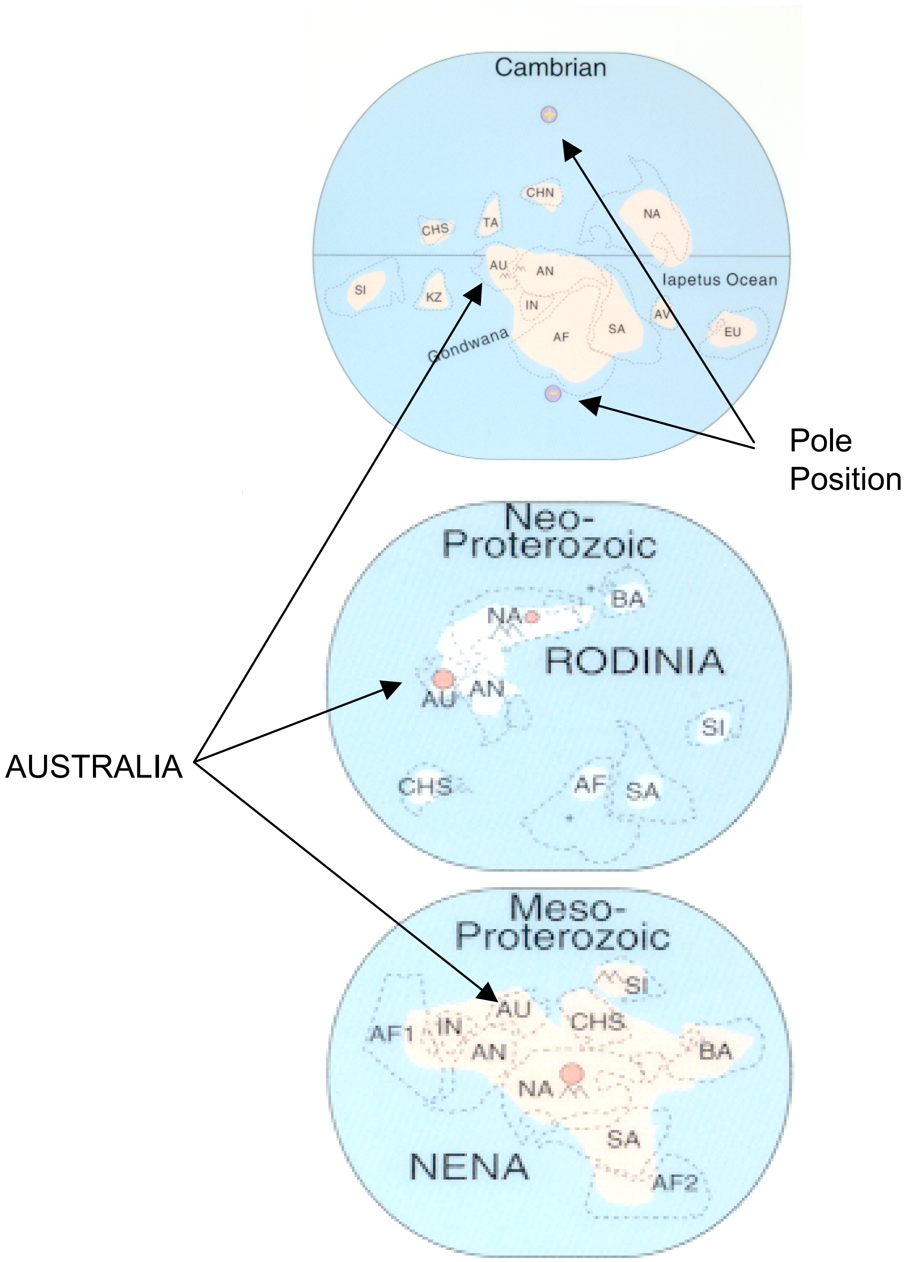


Figure I-1 Interpreted plate positions showing Australia from Mesoproterozoic through Cambrian time. Orange circles are impact features. White cover during the Neoproterozoic represents extent of glaciation. Maps are adapted from Janke (2002.)

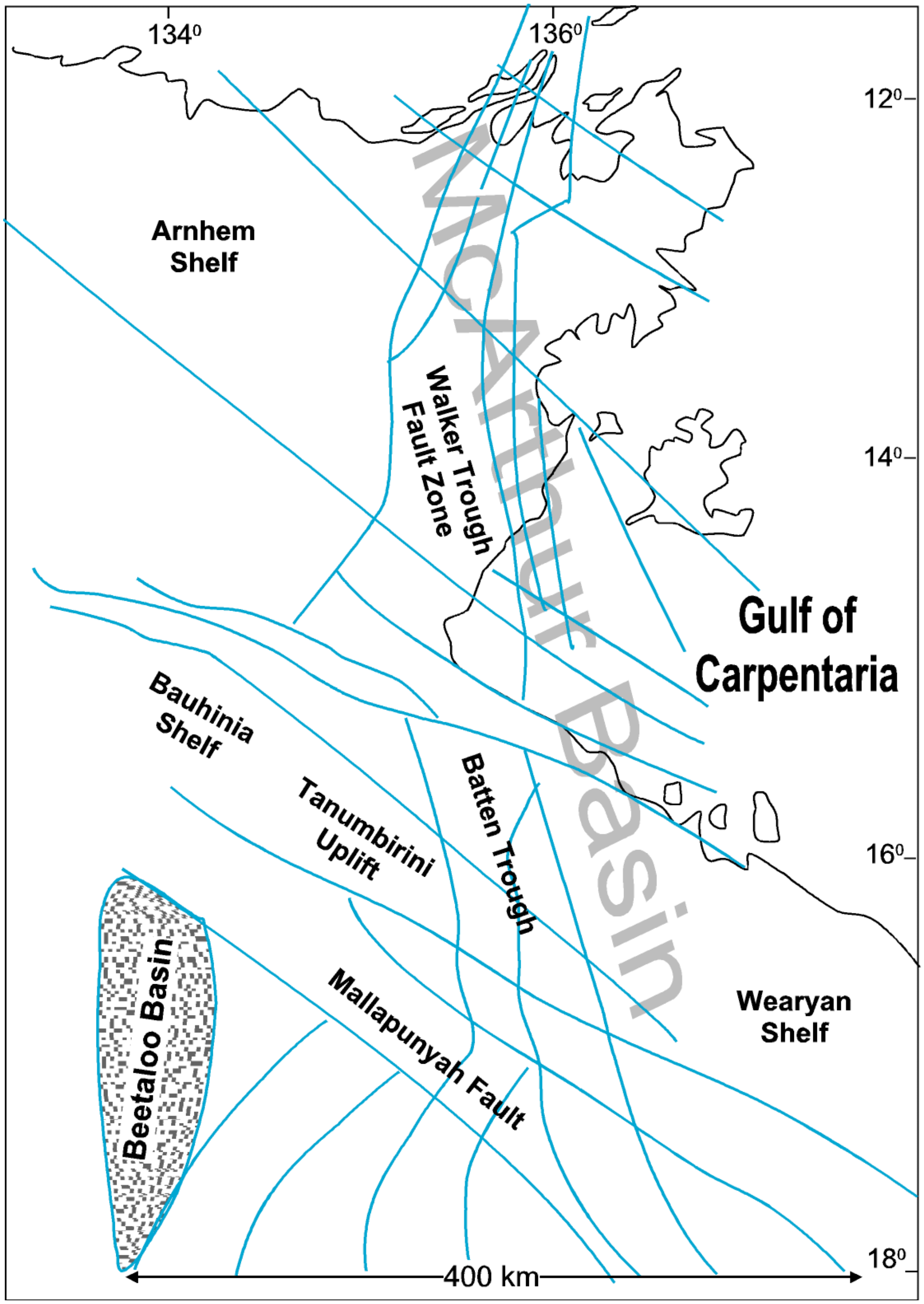


Figure I-2. The regional tectonic setting of the Beetaloo Basin showing the older structural features of the McArthur Basin. Adapted from Plumb, 1994.

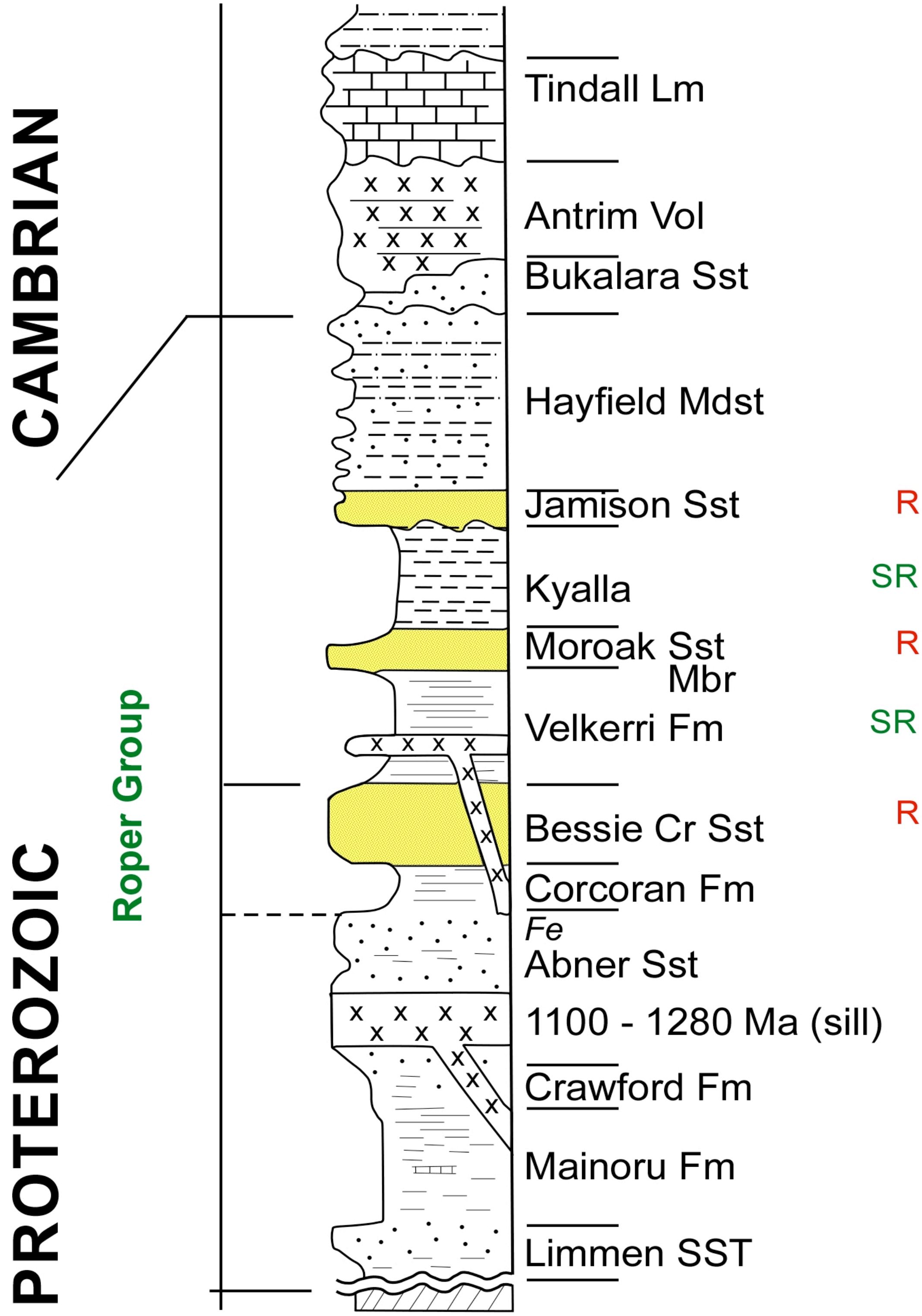
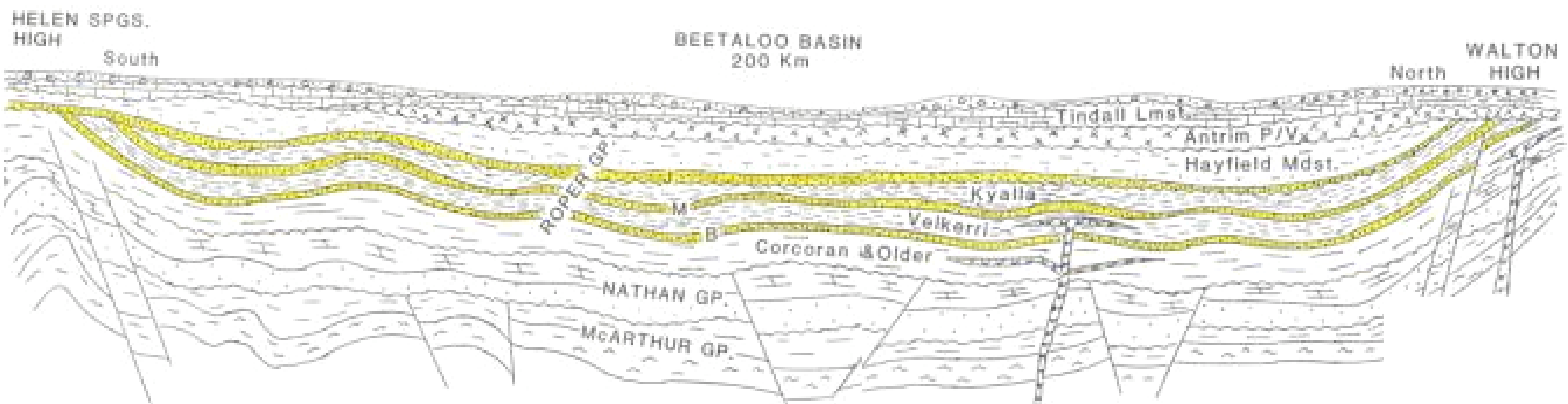


Figure II-1. Stratigraphic Column for the Beetaloo Basin. The source rock intervals in the Roger Group are indicated by **SR** and the potential conventional reservoirs are indicated by **R**.



J Jamison Ss
M Moroak Ss
B Bessie Creek Ss

Figure III-1. South to north schematic structural cross section.

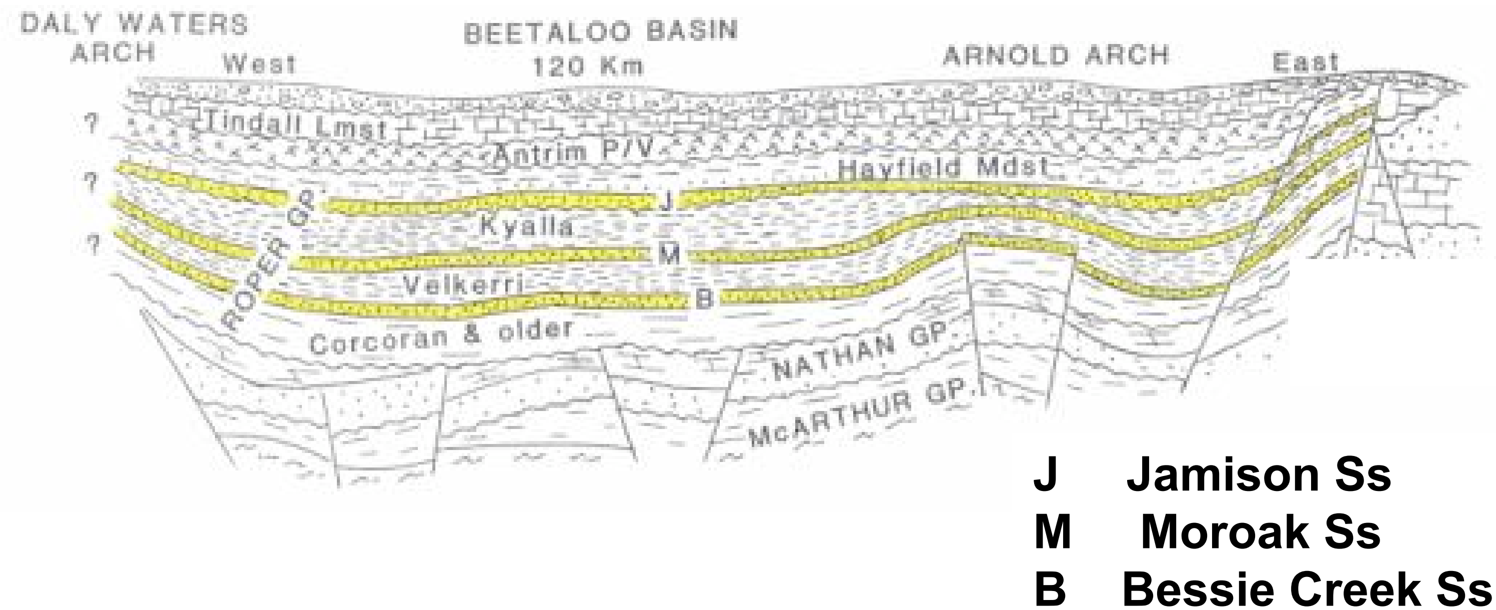


Figure III-2. West to east schematic structural cross section showing the intrabasinal Arnold Arch. The Kyalla and Velkerri source rock.

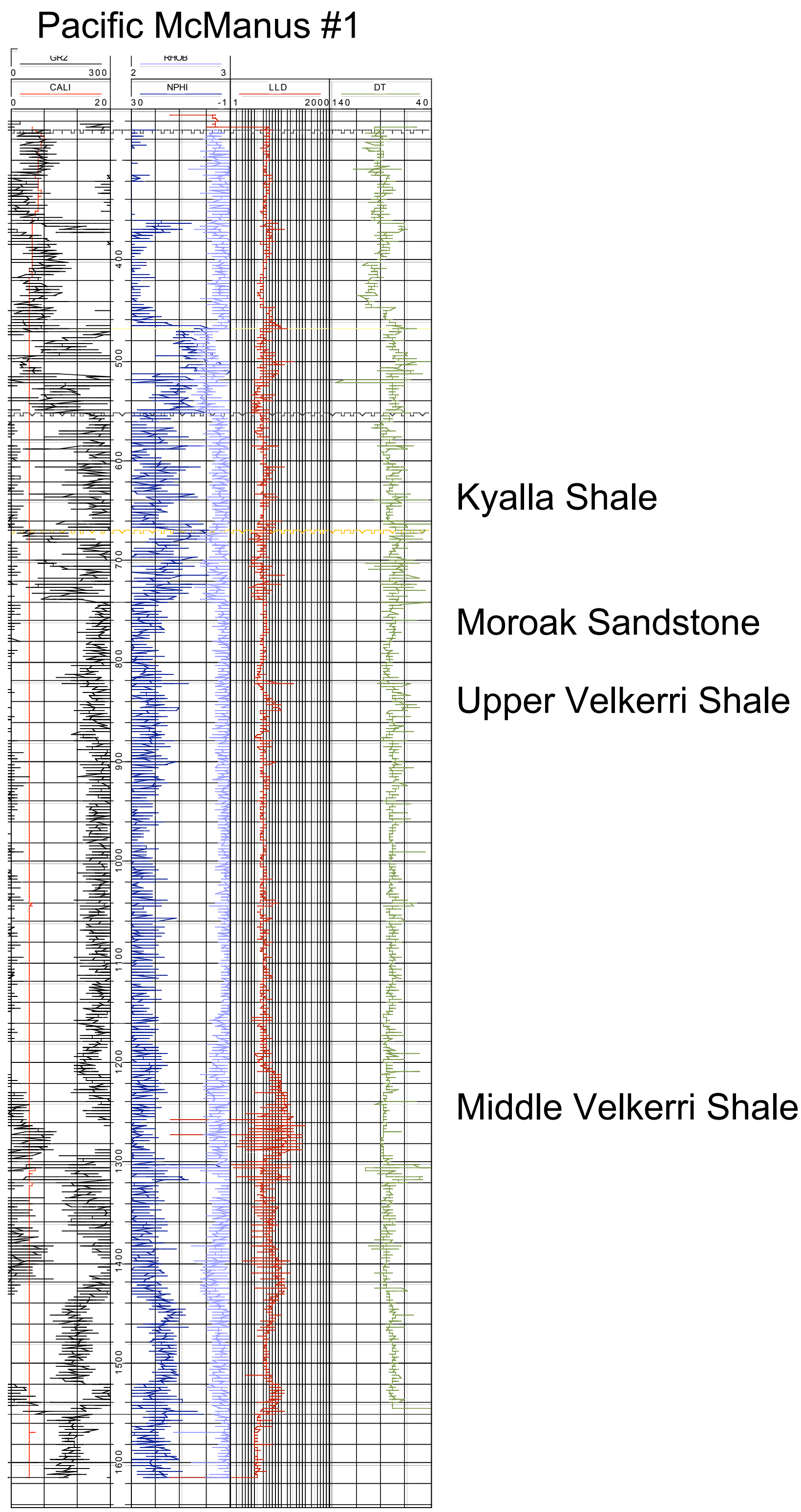


Figure III-3 Log detail of the Upper and Middle Velkerri Shale in the McManus #1 well. The three high gamma ray zones in the Middle Velkerri have high TOC contents (4-12%.) Enclosure 11 compares the log signature to the measured TOC contents

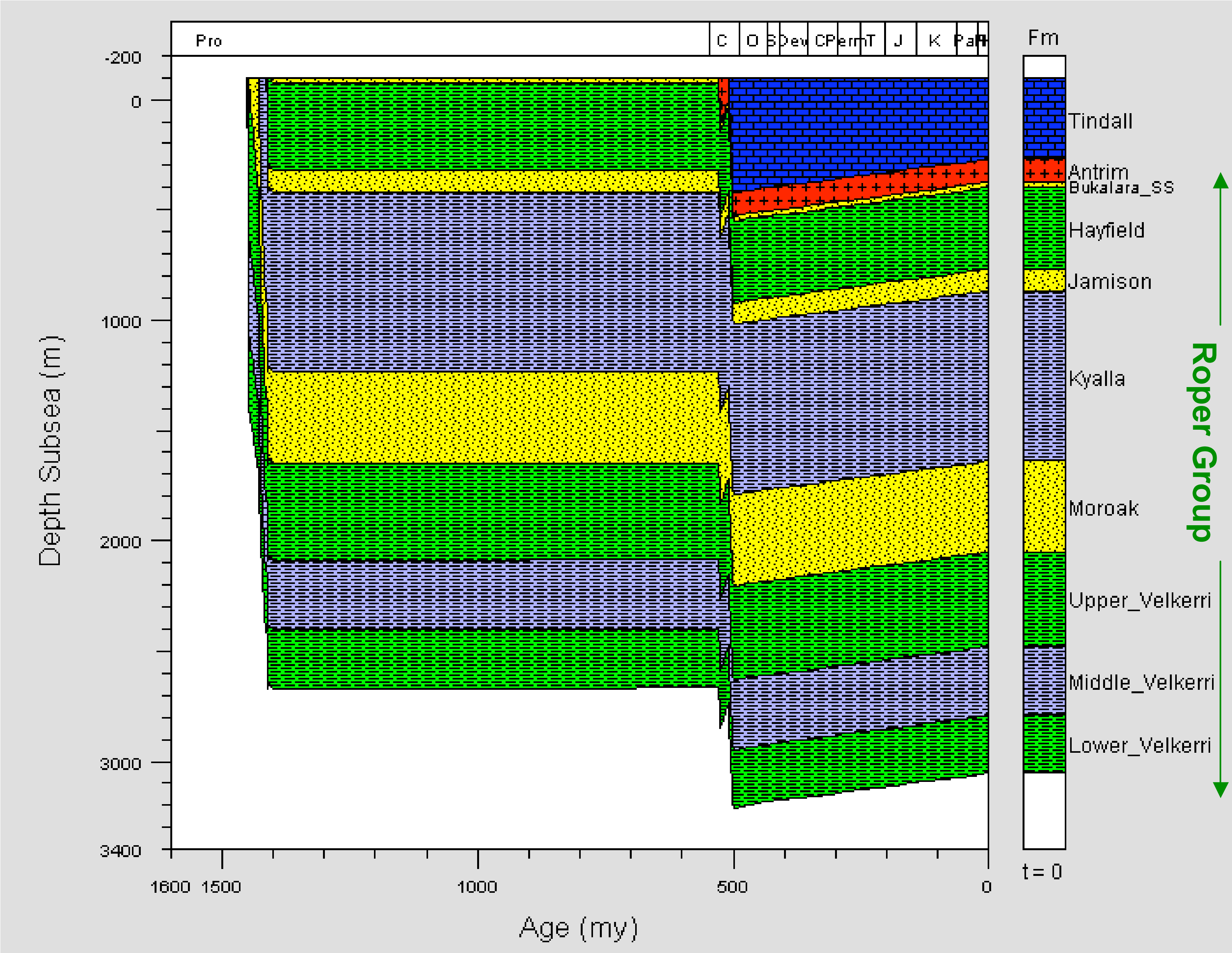


Figure III-4. Burial History Graph for the Jamison #1 well in the Beetaloo Basin. The graph shows the relatively rapid deposition of the pre-Bukalara sediments and the impact of deposition of Cambrian units on depth of burial for the Roper Group.

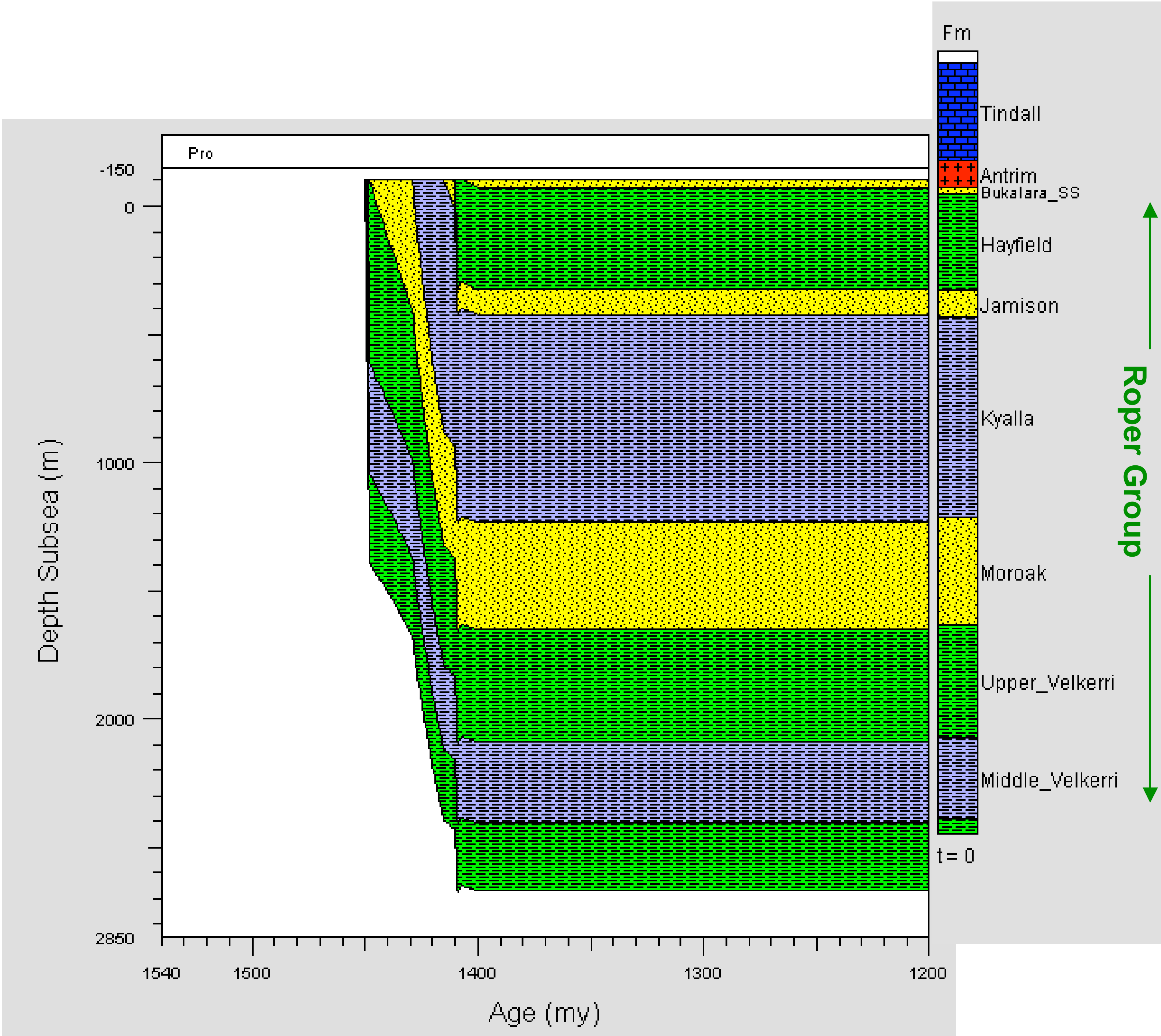


Figure III-5. Detail of the Jamison #1Burial History Graph for the period from 1450 to 1200my showing the the deposition of the Roper Group as modeled from the stratigraphy in the Jamison #1 well. No uplift is documented during this time.

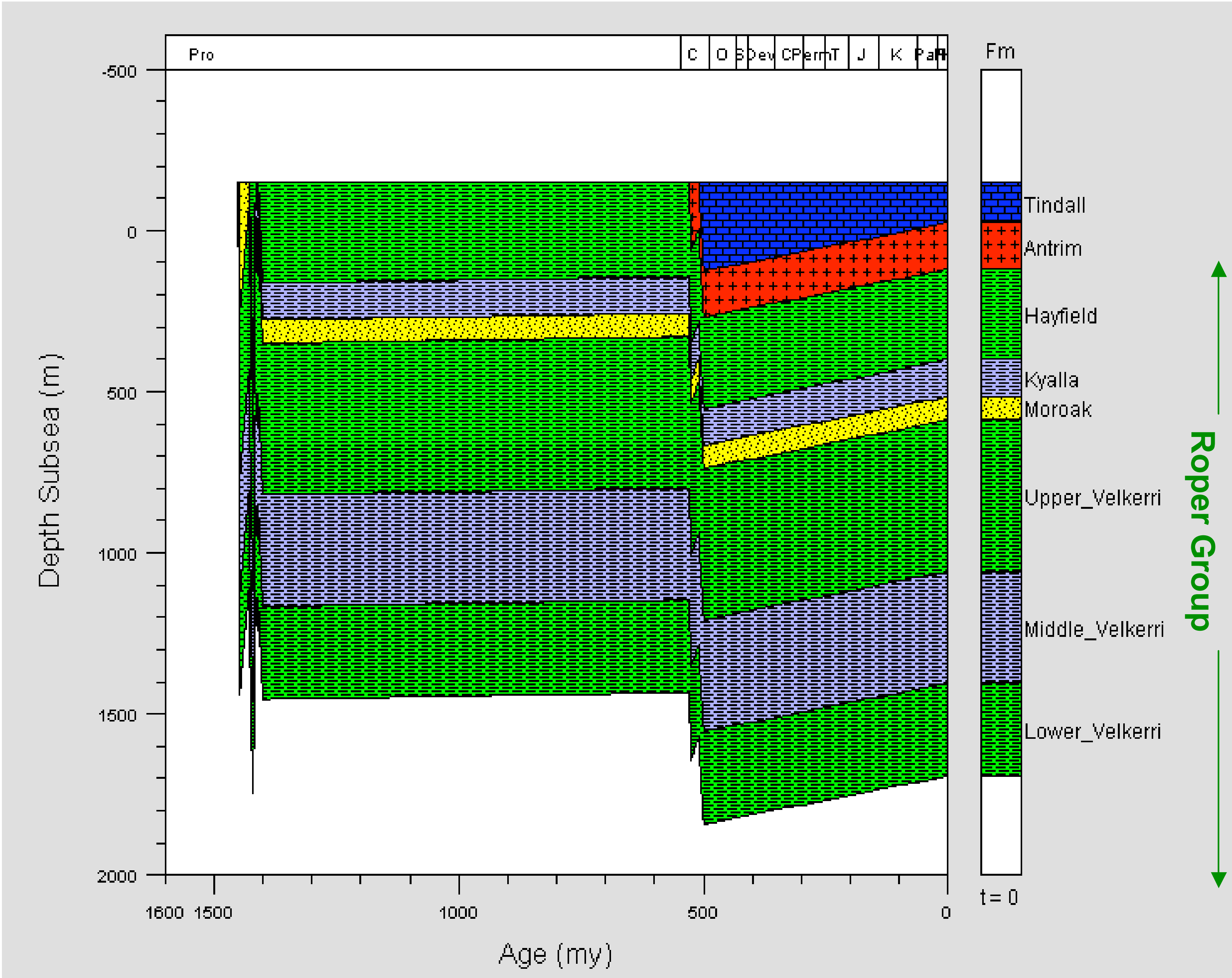


Figure III-6. Burial History Graph for the McManus #1. Roper sediments were deposited fairly rapidly early in the history of the Beetaloo Basin but the presence of unconformities in the McManus #1 documents early uplift. See the next figure for a detailed burial history graph for this early period.

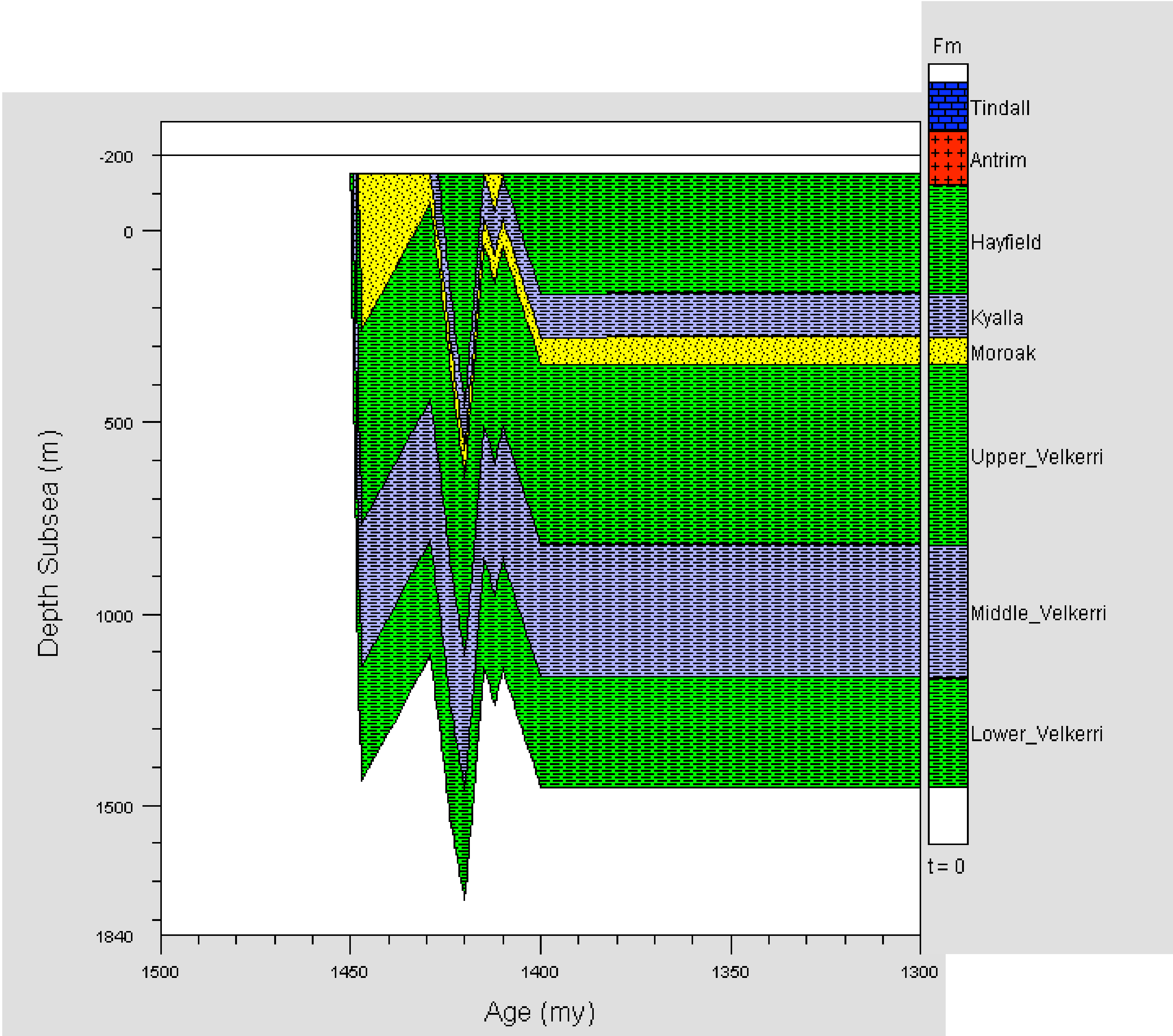


Figure III-7. Detail of the Burial History Graph from 1450 to 1300my showing two episodes of uplift in the Walton High region based on unconformities in the stratigraphic section.

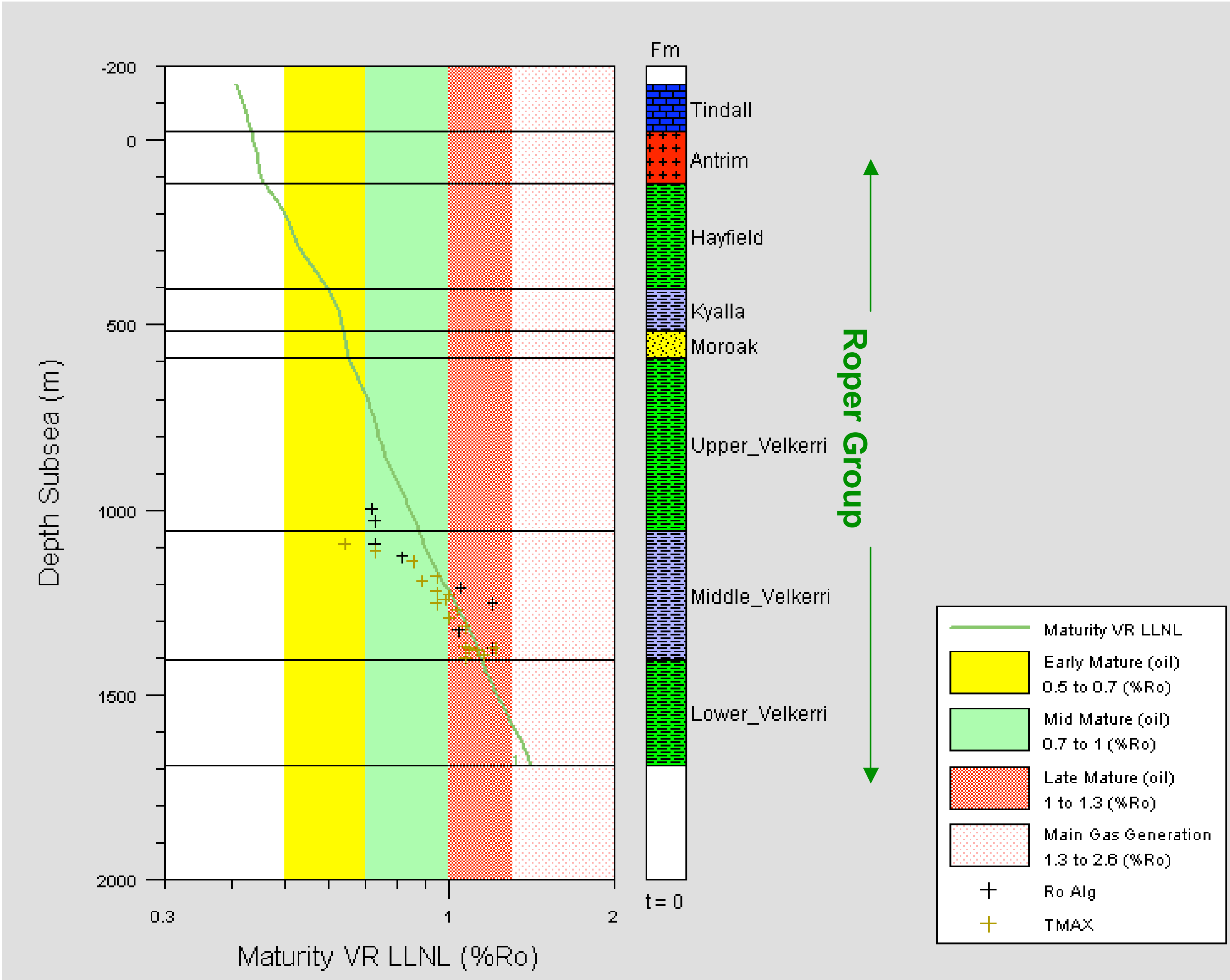


Figure III-8. Calibration of measured maturity with modeled maturity. Measured Ro Alg and Tmax data from the McManus #1 well are compared to the modeled maturity as calculated by the model with a good fit.

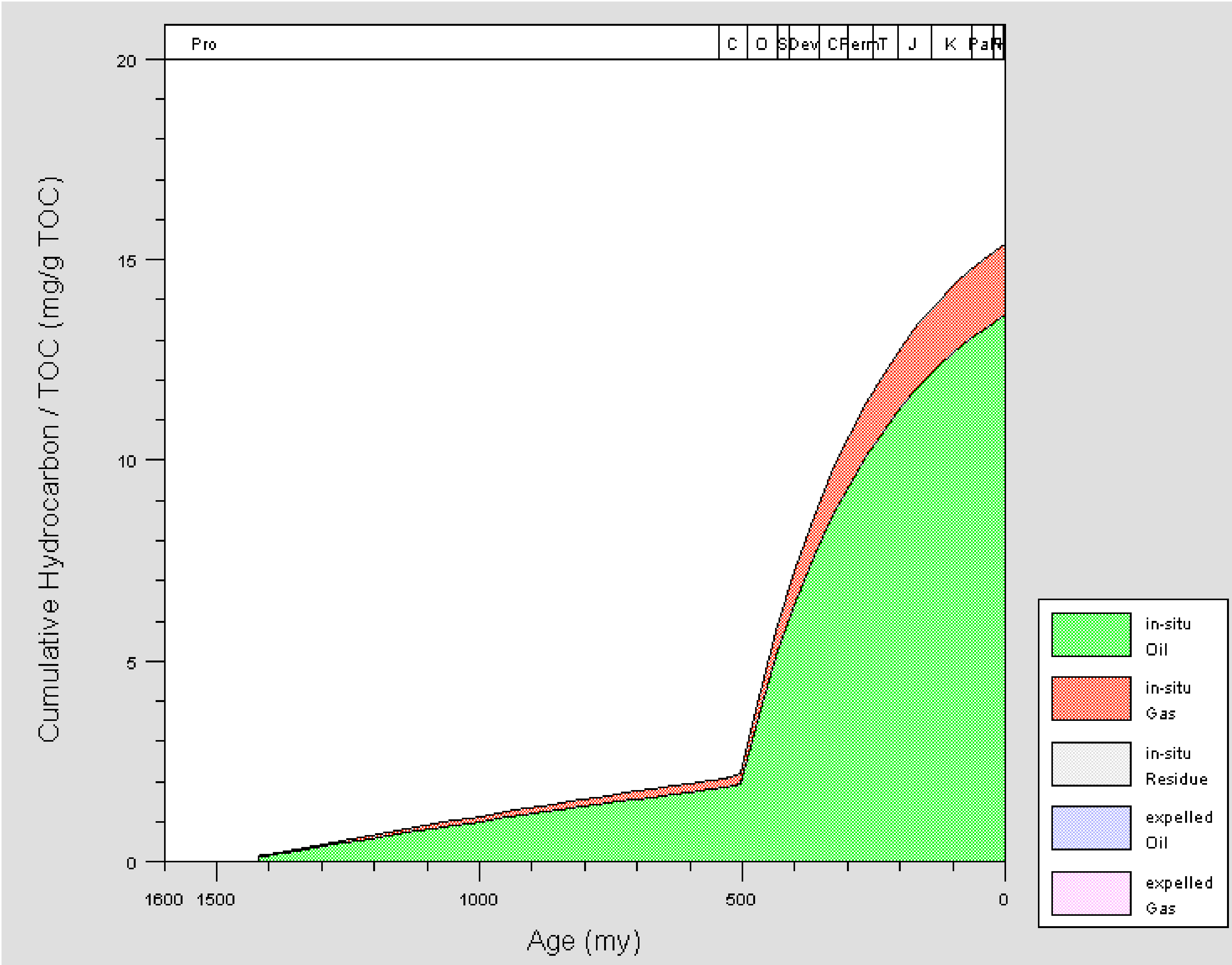


Figure III-9. Modeled generation for the Kyalla source rock in the McManus #1.

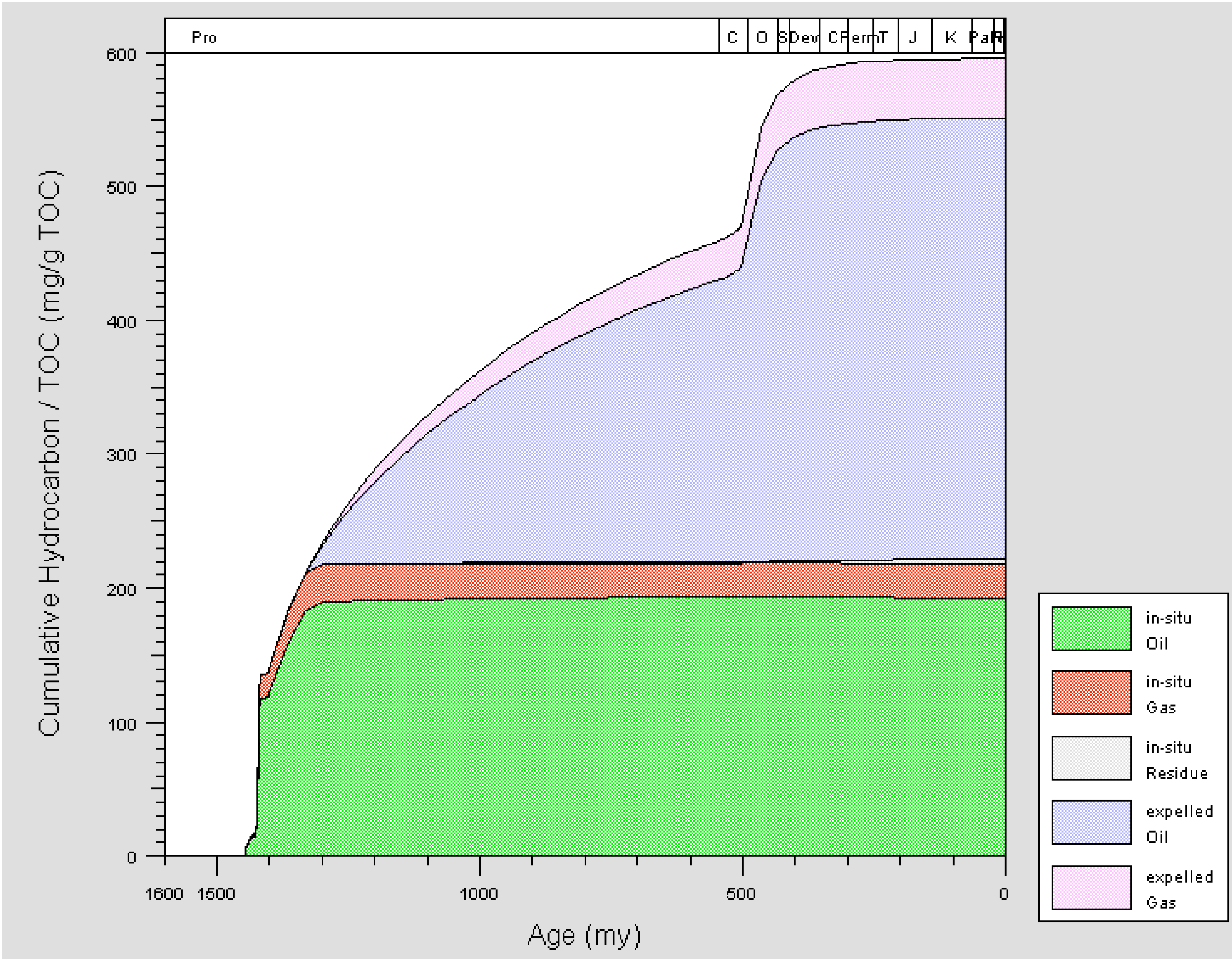


Figure III-10. Modeled generation for the Middle Velkerri in the Mc Manus #1

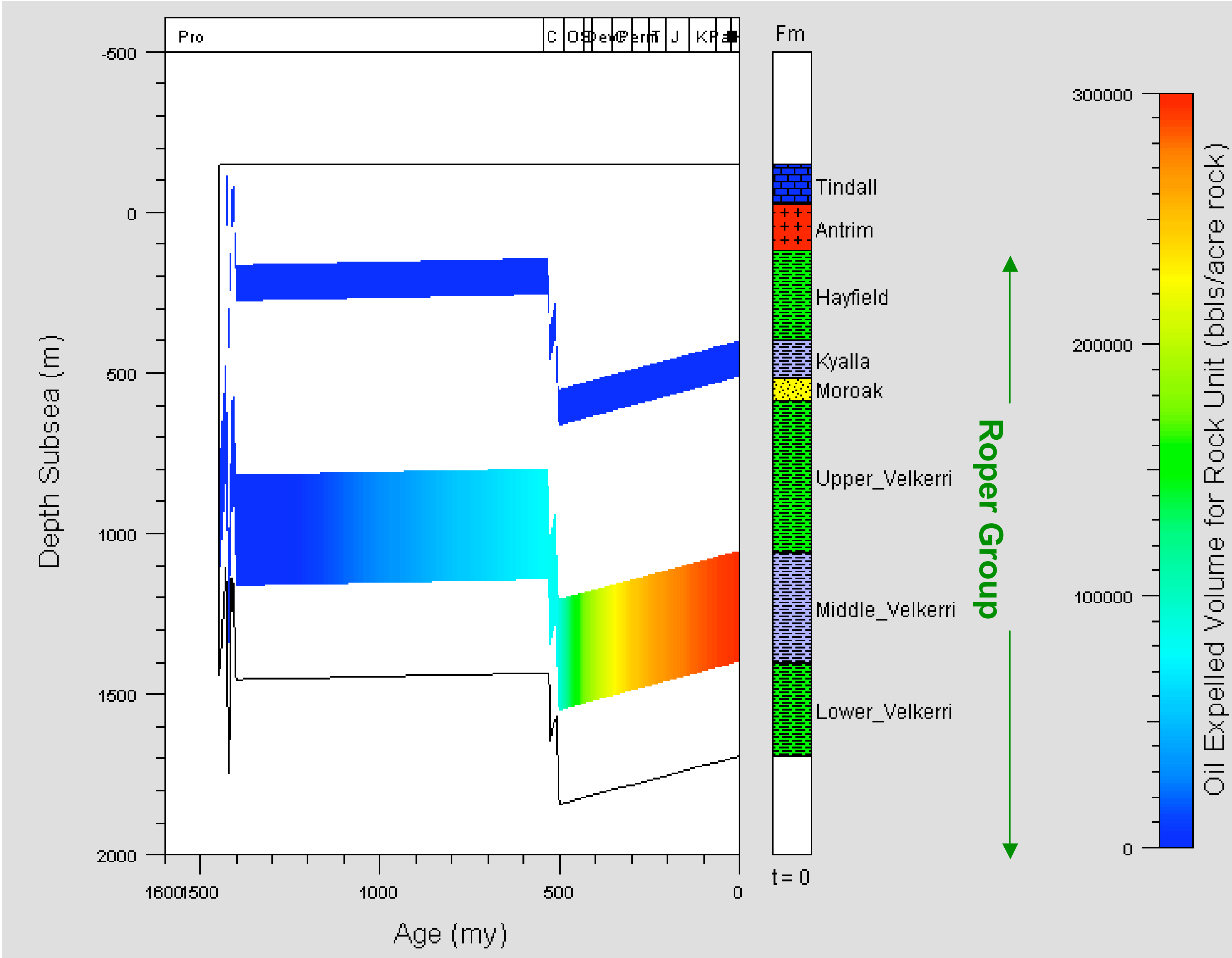


Figure III-11. Graph of depth versus oil expelled for rock unit in bbls\acre rock for the McManus #1 well on the Walton High. The deeper Middle Velkerri shale is shown to have generated and expelled a large volume of hydrocarbons since deeper burial as a result of Cambrian sedimentation. The Middle Velkerri, as modeled, has expelled roughly 300 MBBLS/acre rock since Cambrian time. The Kyalla is immature.

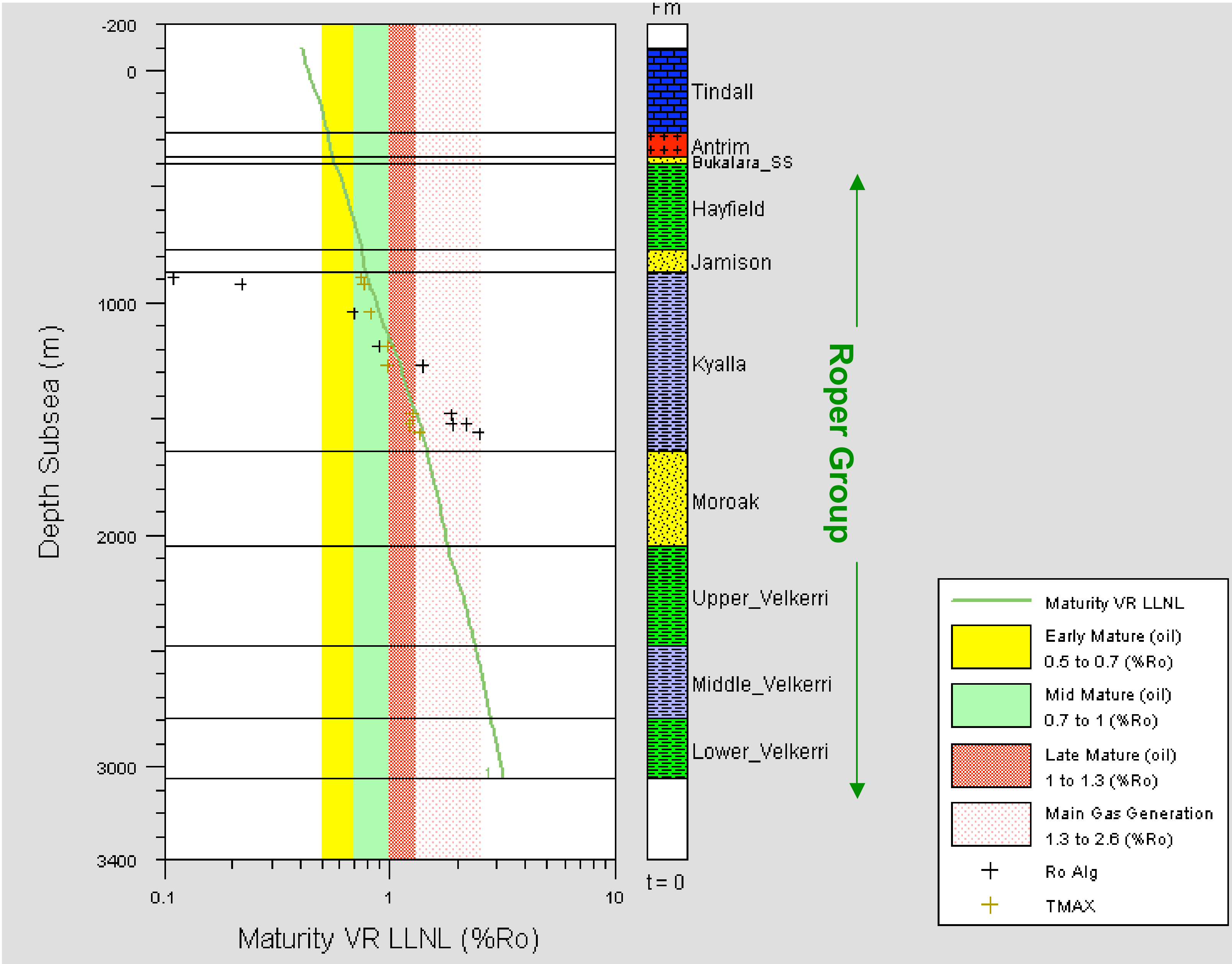


Figure III-12. Calibration of measured maturity and modeled maturity for the Jamison #1 well. Although the Velkerri Shale is not present in the well, it was projected in to allow modeling of hydrocarbon generation from the Basin center.

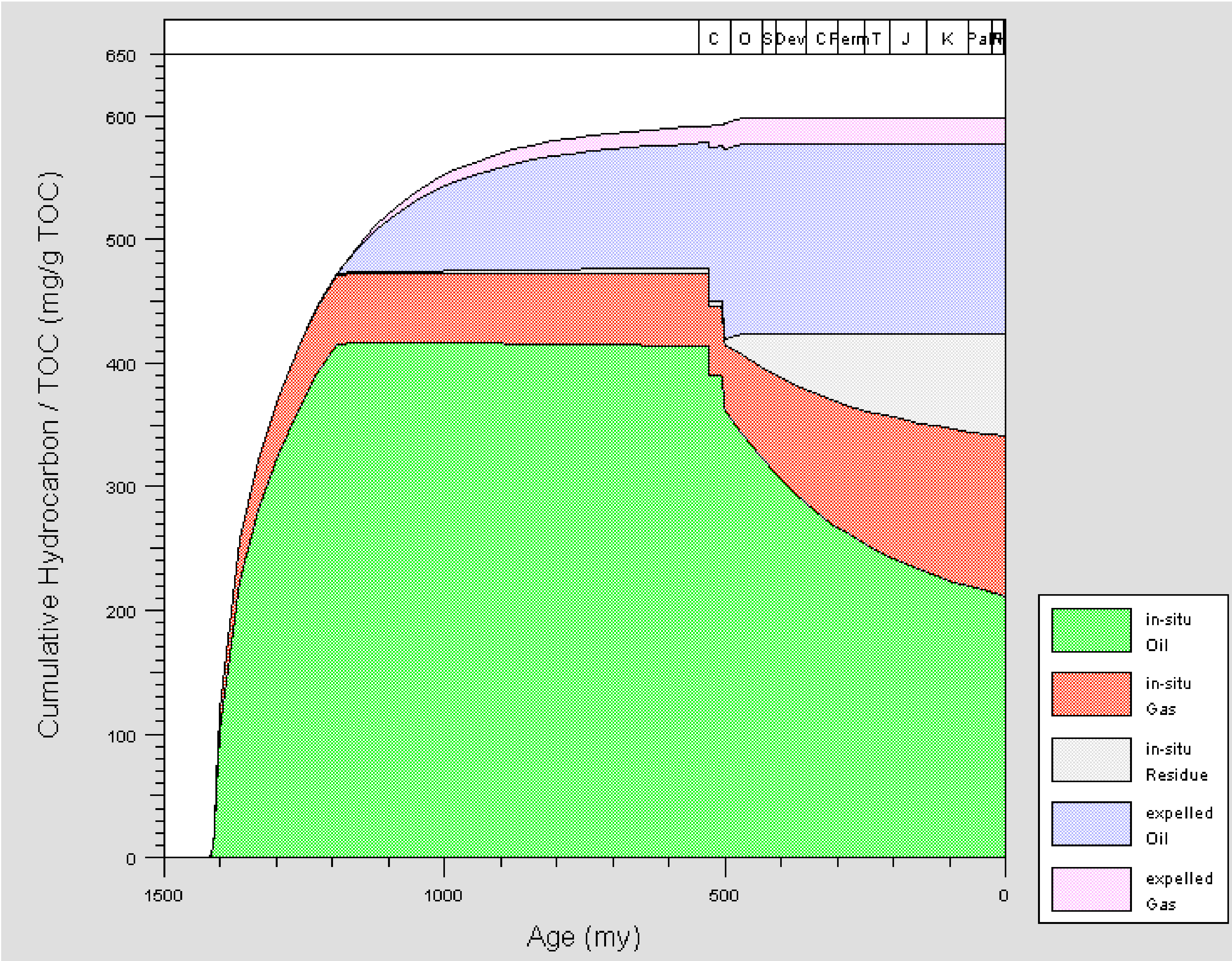


Figure III-13. Modeled generation for the Kyalla source rock in the Jamison #1

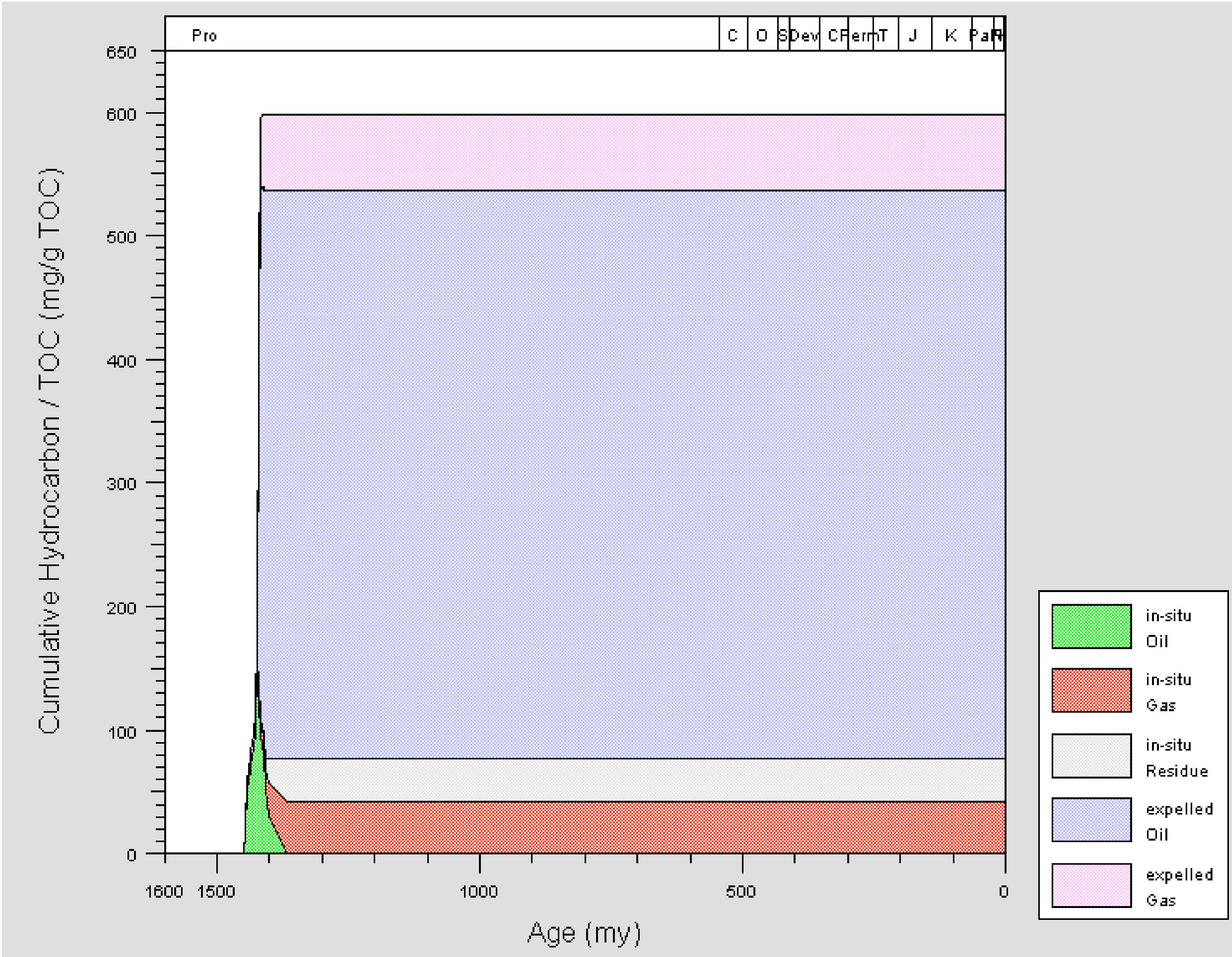


Figure III-14. Modeled generation for the Middle Velkerri source rock in the Jamison #1

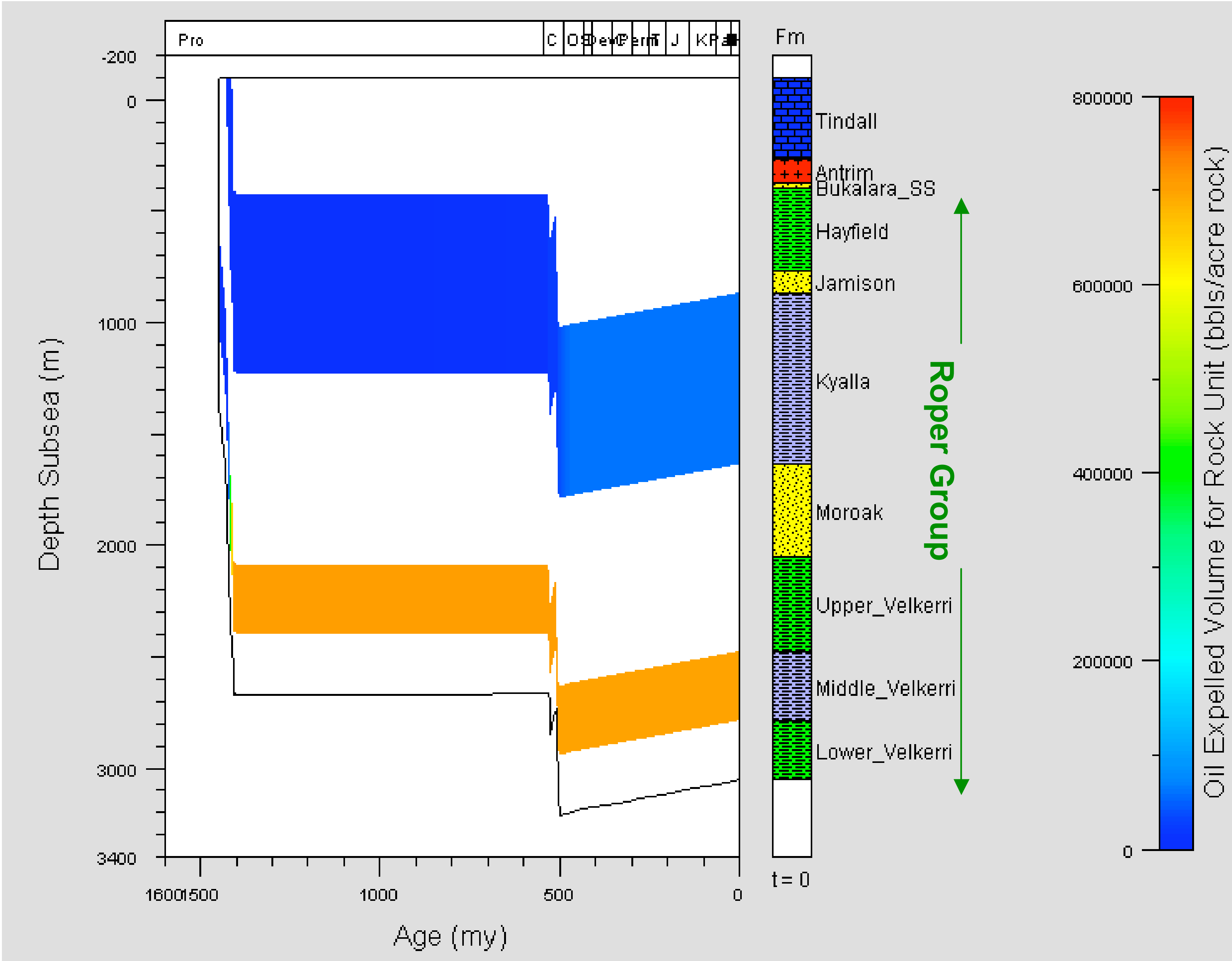


Figure III-15. Graph of depth versus oil expelled for rock unit in bbls\acre rock for the Jamison #1 well. The deeper Middle Velkerri shale is shown to have generated and expelled a very large volume of hydrocarbons very early while the shallower Kyalla began to expel hydrocarbons in the Cambrian.

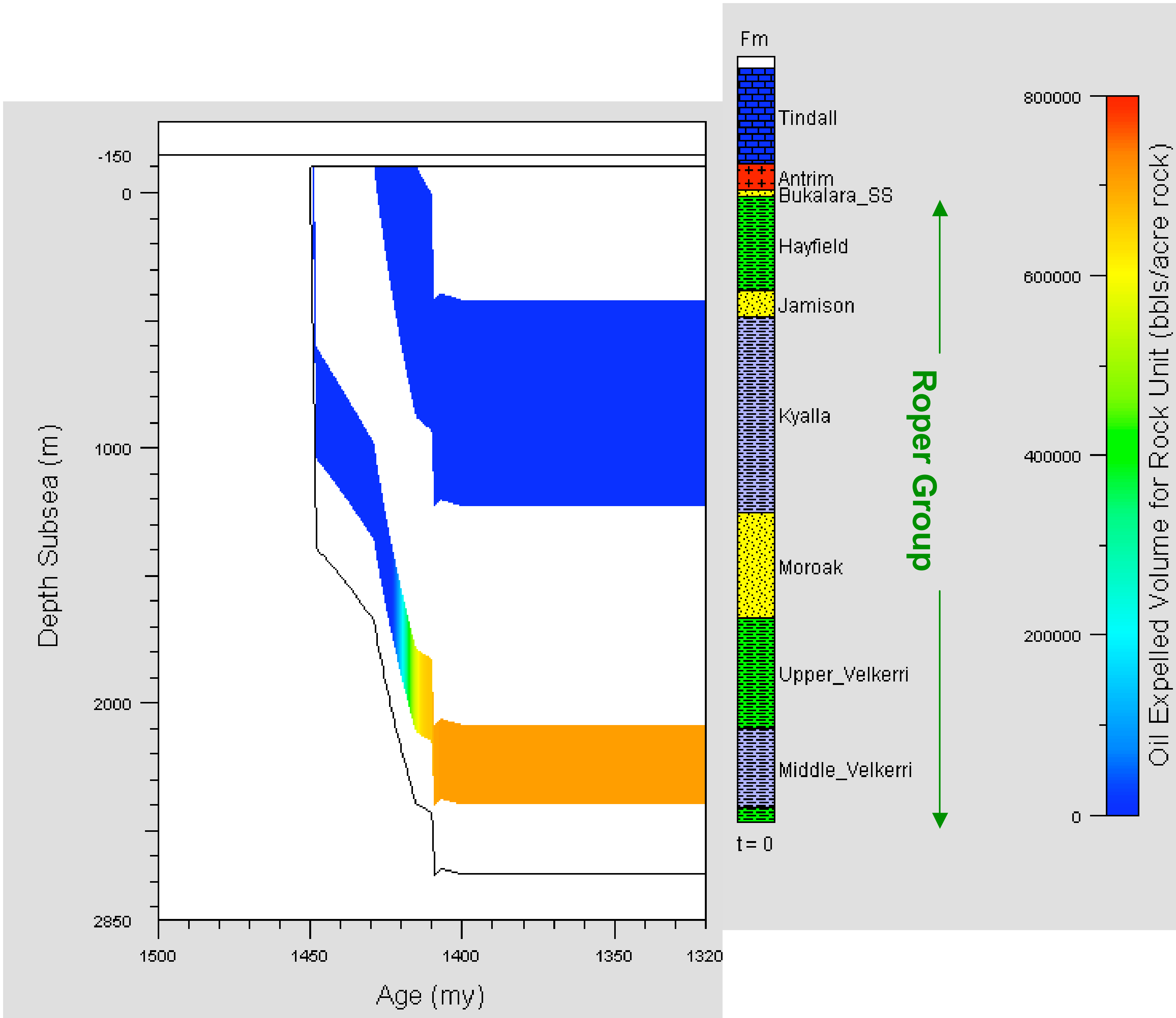


Figure III-16. Detail of the graph of depth versus oil expelled for rock unit in bbls\acre rock for the Jamison #1 well up to 1320 my. The deeper Middle Velkerri shale is shown to have generated and expelled a very large volume of hydrocarbons with expulsion starting about the time of Kyalla deposition. By Hayfield deposition, the Middle Velkerri has reached maximum generation and expulsion and has expelled roughly 640 MBBLS/acre rock.

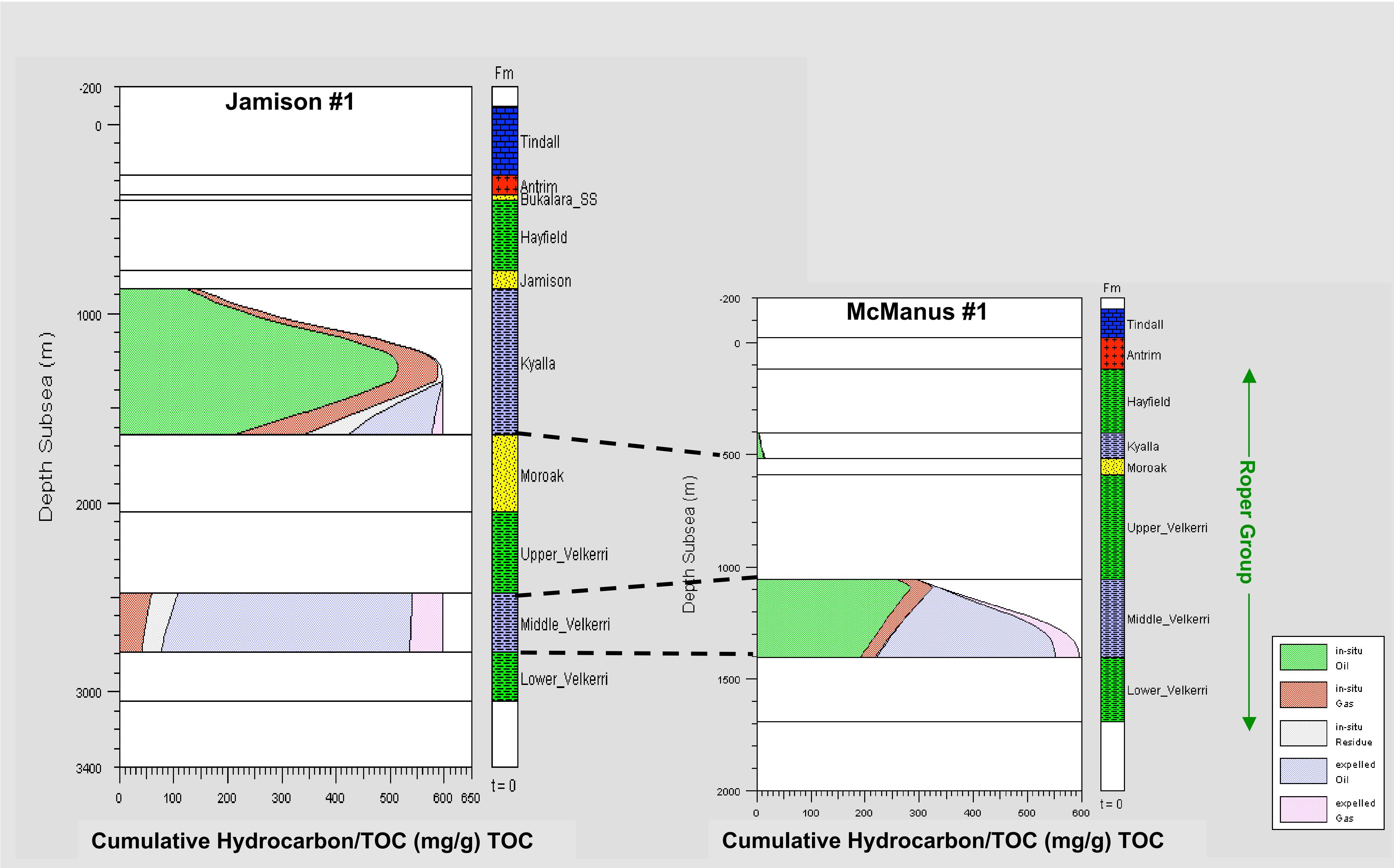


Figure III-17. Comparison of the generation potential (cumulative hydrocarbon/TOC) of the Middle Velkerri and the Kyalla in the Jamison #1 and the McManus #1

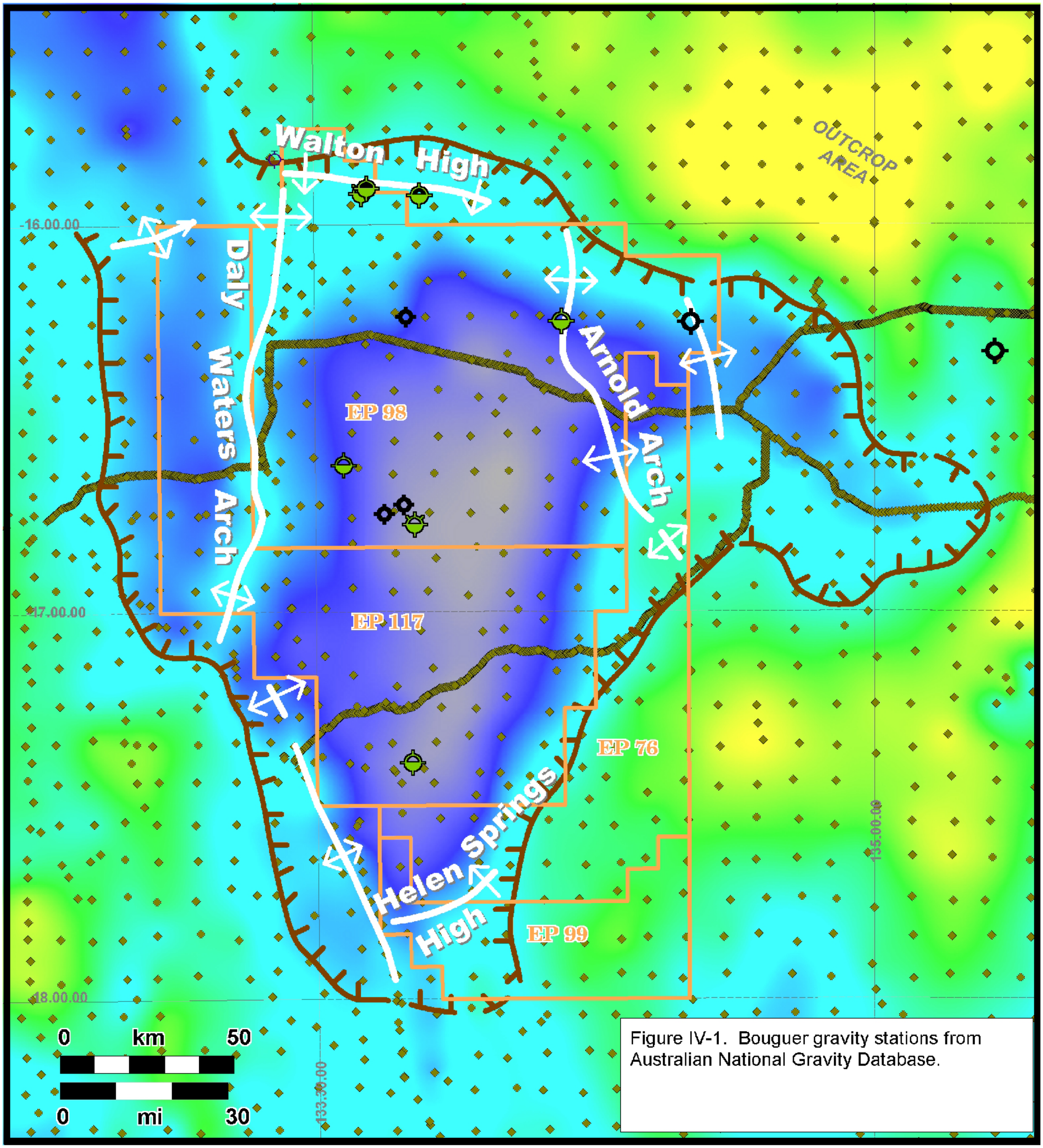


Figure IV-1. Bouguer gravity stations from Australian National Gravity Database.

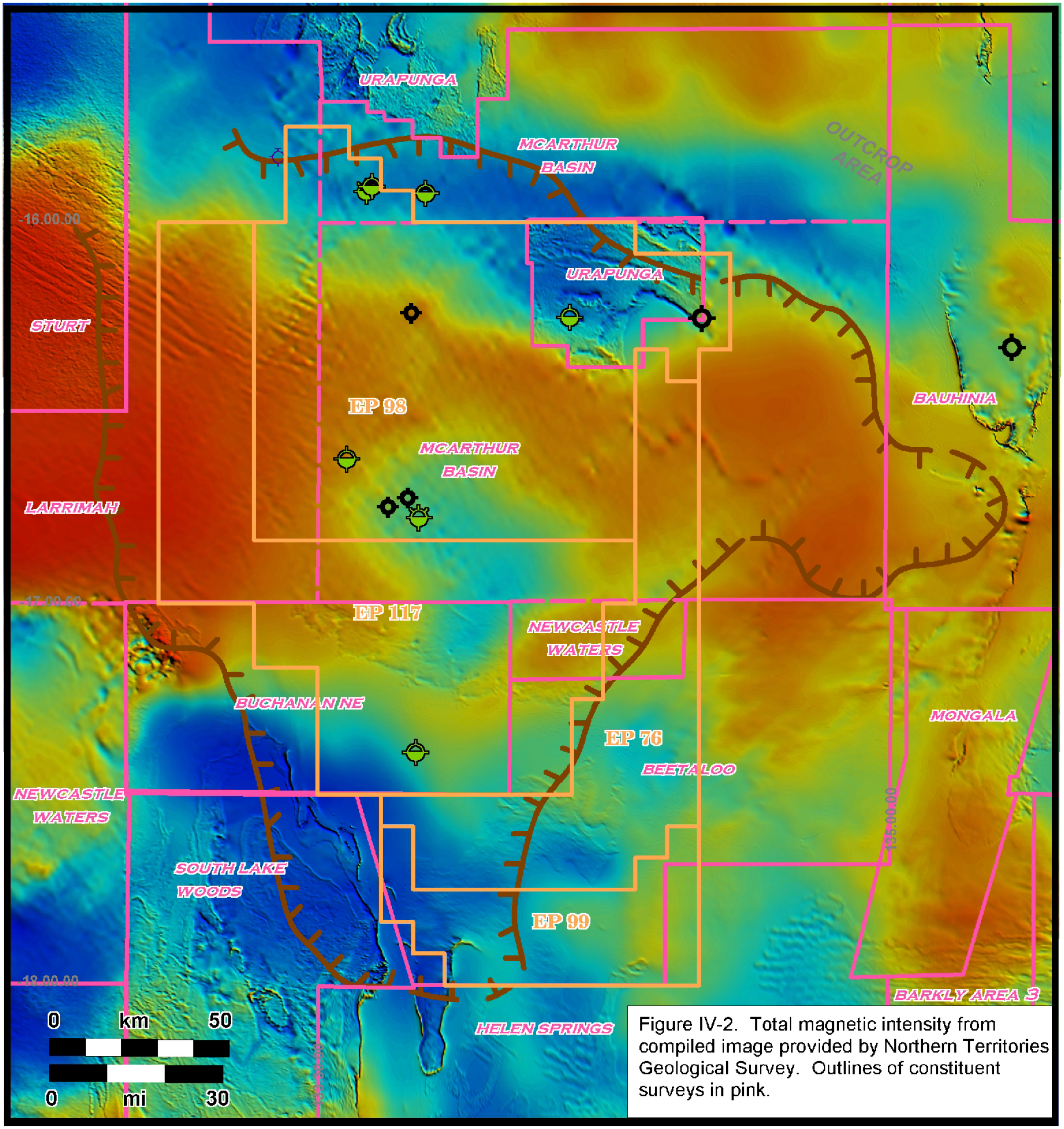
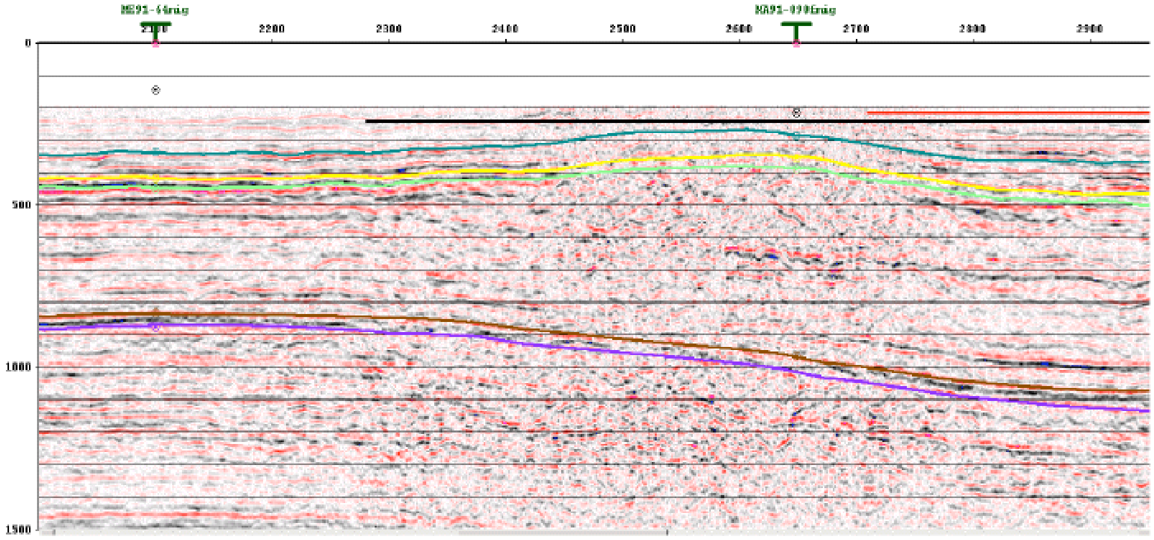
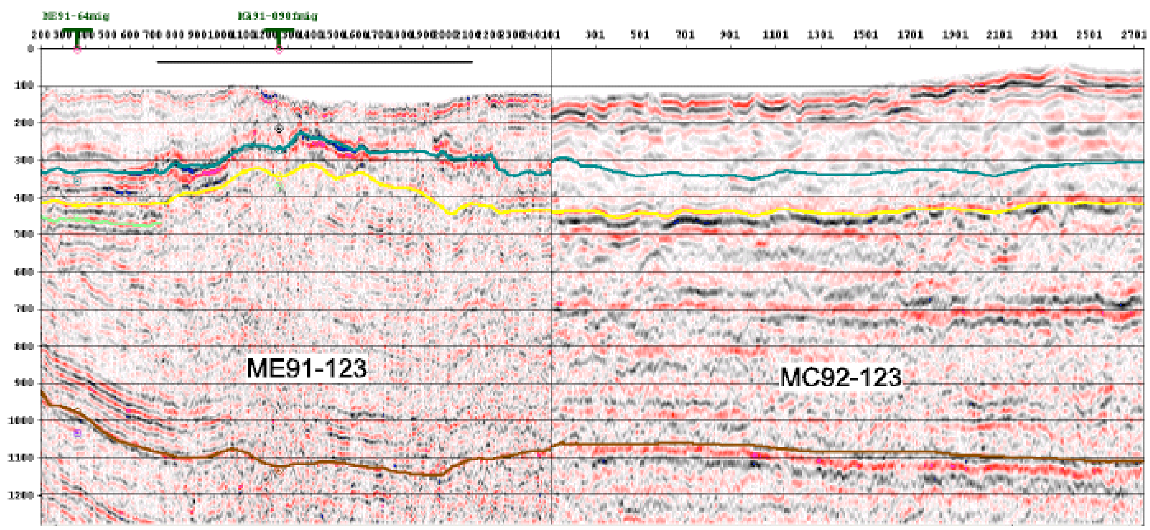


Figure IV-2. Total magnetic intensity from compiled image provided by Northern Territories Geological Survey. Outlines of constituent surveys in pink.



Data quality variation along line MA-91-103 (original processing)



Data quality variation between two connecting north-south lines from different surveys.

Figure IV-3: Seismic data quality comparisons.

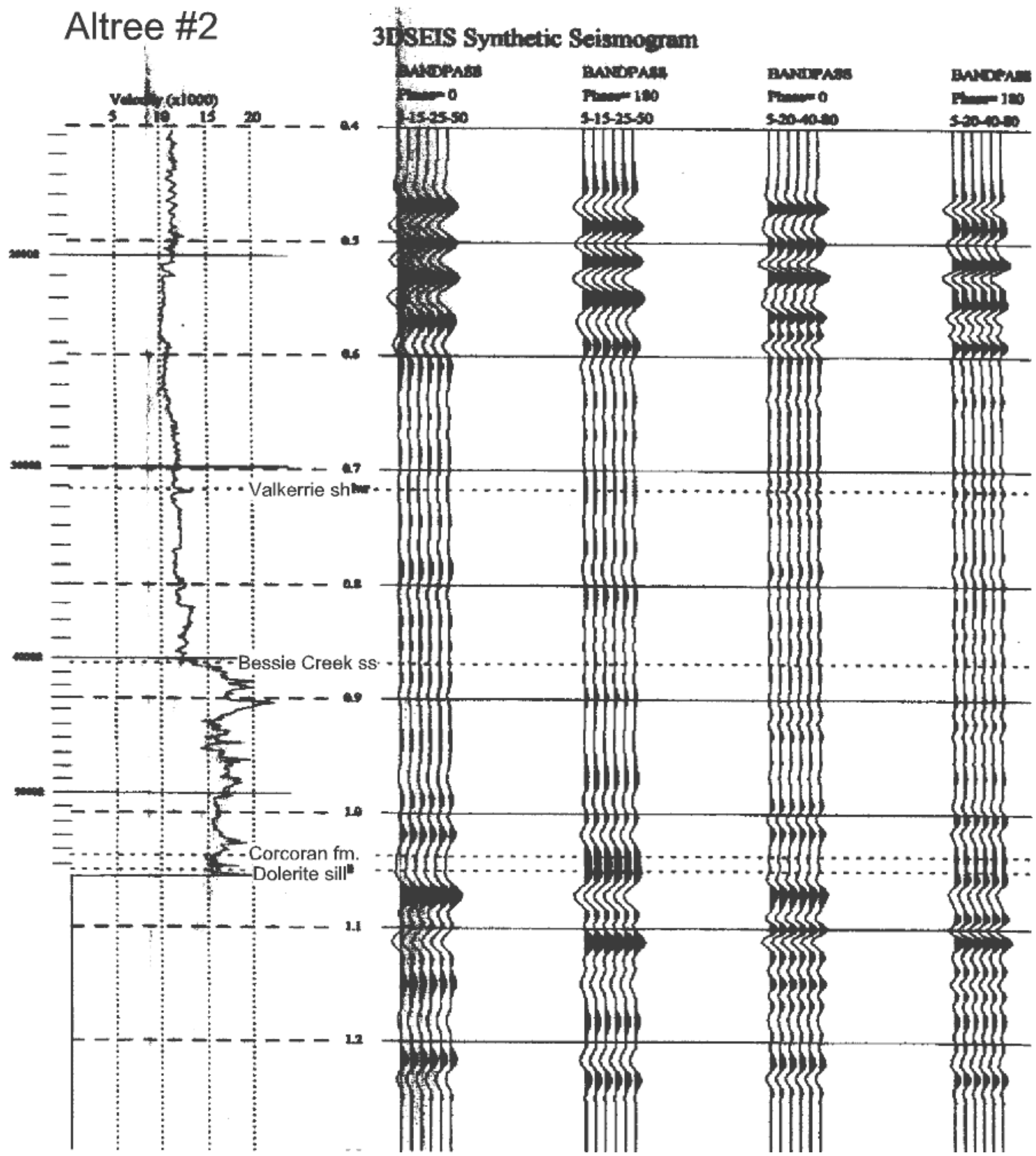


Figure IV-4. Synthetic seismogram for the Altree #2 well.

Burdo #1

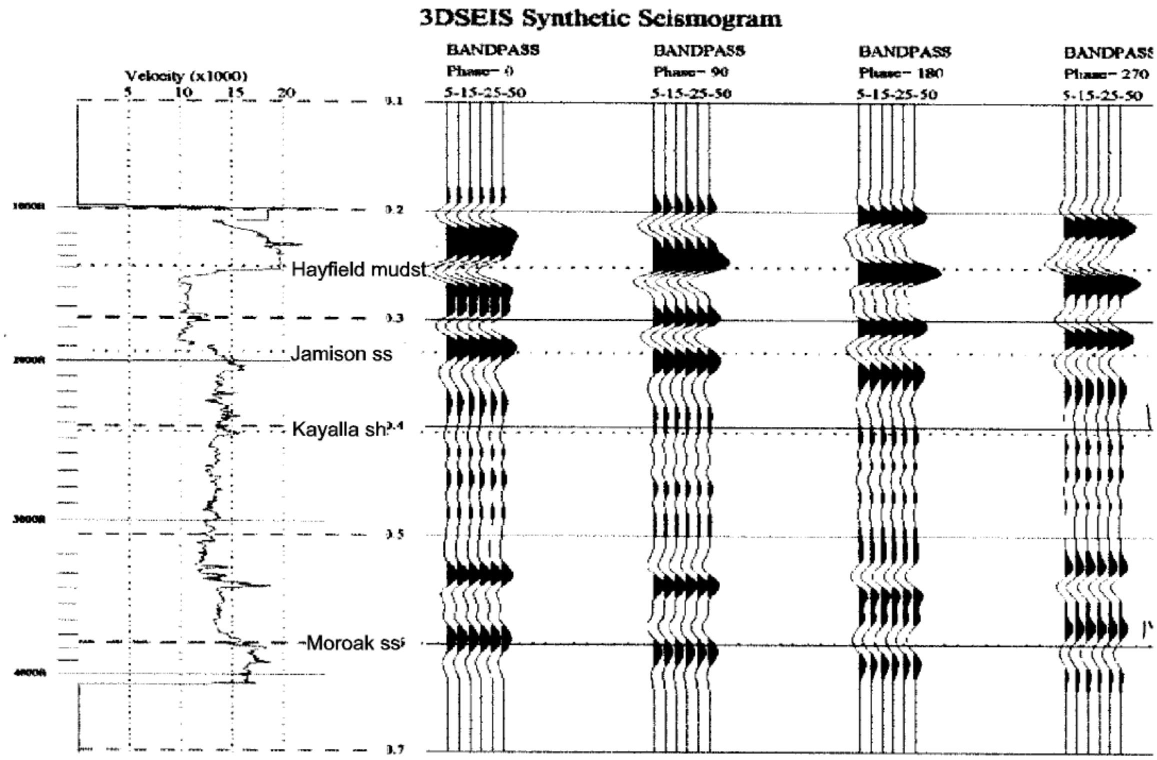


Figure IV-5. Synthetic seismogram for the Burdo #1 well.

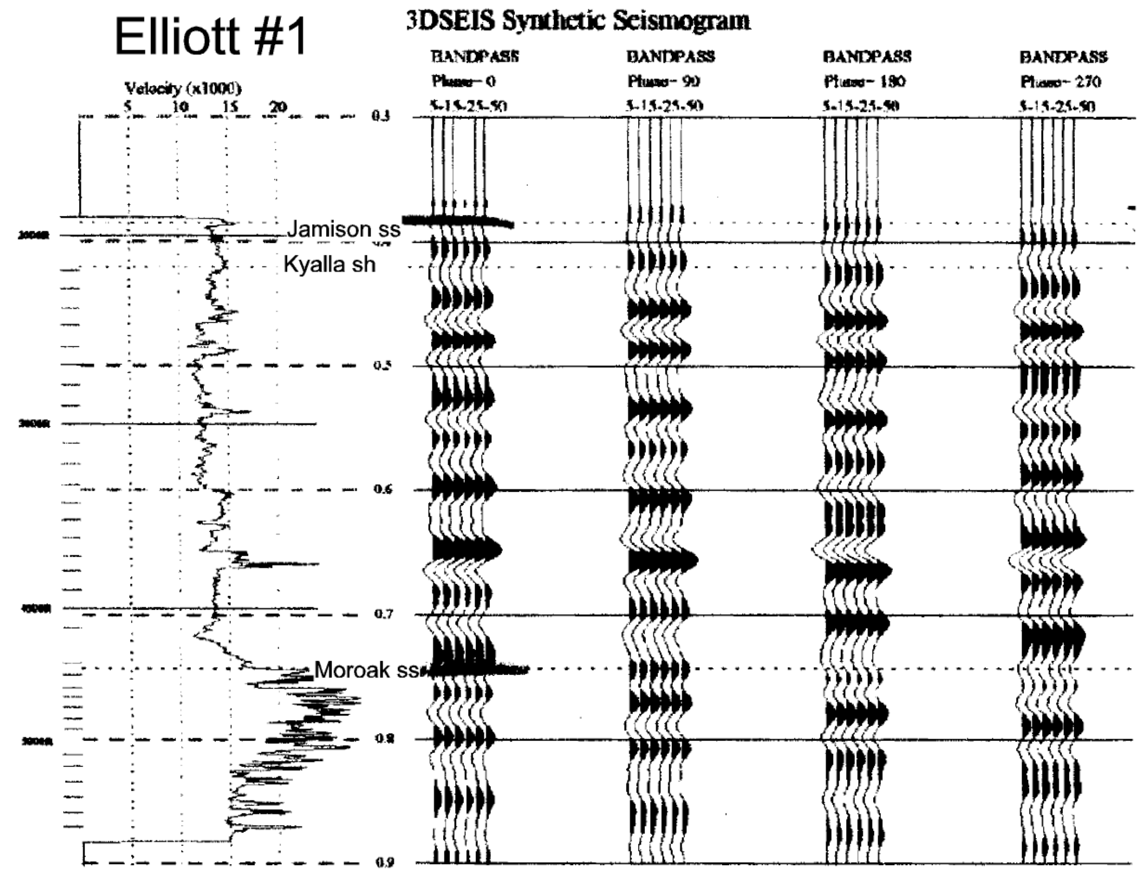


Figure IV-6. Synthetic seismogram for the Elliott #1 well.

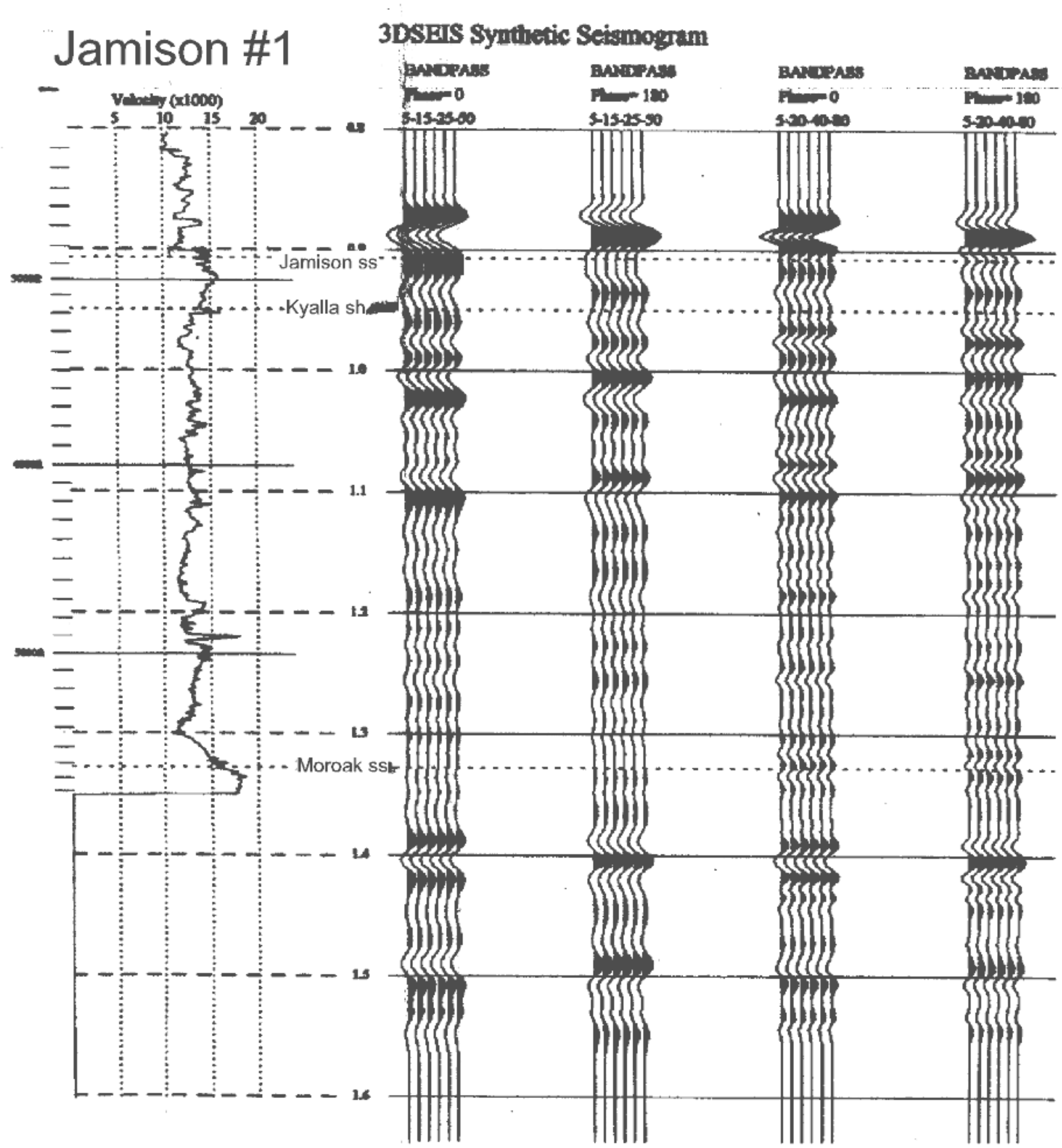


Figure IV-7. Synthetic seismogram for the Jamison #1 well.

Figure IV-8. Depth conversion calculations

			Elliott 1						Mason 1						Shortland 1						Jamison 1						Balmain 1					
	dT	Vi	Depth	dD	dT	TWT	Vint	Vave	Depth	dD	dT	TWT	Vint	Vave	Depth	dD	dT	TWT	Vint	Vave	Depth	dD	dT	TWT	Vint	Vave	Depth	dD	dT	TWT	Vint	Vave
Judkin	100	10000	0	1060	0.212	0.000	10000		0	400	0.080	0.000	10000		0	407	0.081	0.000	10000								0	266	0.053	0.000	10000	
Tindall LS	65	15385	1060	876	0.114	0.212	15385	10000	400	735	0.096	0.080	15385	10000	407	759	0.099	0.081	15385	10000	0	1214	0.158	0.000	15385		266	597	0.078	0.053	15385	10000
Antrim PV	55	18182							1135	415	0.046	0.176	18182	12931	1166	443	0.049	0.180	18182	12951	1214	431	0.047	0.158	18182	15385	863	462	0.051	0.131	18182	13196
Hayfield MST	90	11111							1550	1324	0.238	0.221	11111	14014	1609	1245	0.224	0.229	11111	14065	1645	1209	0.218	0.205	11111	16031	1325	1476	0.266	0.182	11111	14593
Jamison SS	68	14706	1936	246	0.033	0.326	14706	11882	2874	322	0.044	0.460	14706	12509	2854	445	0.061	0.453	14706	12603	2854	322	0.044	0.423	14706	13499	2801	279	0.038	0.447	14706	12525
Kayalla SH	75	13333	2182	2159	0.324	0.359	13333	12145	3196			0.503		12700	3299			0.513		12851	3176	2451	0.368	0.467	13333	13612	3080		0.000	0.485		12695
Moroak SS	60	16667	4341	1422	0.171	0.683	16667	12708													5627			0.834		13489						
U Valkerri SH	90	11111																														
L Valkerri SH	80	12500																														
Dolerite Sill	50	20000																														
	80	12500																														
Dolerite Sill	50	20000																														
	80	12500																														
Bessie Cr SS	60	16667																														
Corcoran SH	70	14286																														
Corcoran SS	50	20000																														
Dolerite Sill	50	20000																														
TD			5763			0.854		13499																								
			ME91-64; sp 1300						MA91-223; sp 580,																							
Seismic Crossing			MA91-103; sp 2100						MA91-210; sp 1300						MA91-109; sp 600						SH90-103; sp 470						MC92-100; sp 1700					

			McManus 1						Walton 2						Altree 2						Ronald 1						Burdo 1					
	dT	Vi	Depth	dD	dT	TWT	Vint	Vave	Depth	dD	dT	TWT	Vint	Vave	Depth	dD	dT	TWT	Vint	Vave	Depth	dD	dT	TWT	Vint	Vave	Depth	dD	dT	TWT	Vint	Vave
Judkin	100	10000																			0	264	0.053	0.000	10000		0	104	0.021	0.000	10000	
Tindall LS	65	15385													0	299	0.039	0.000	15385		264	351	0.046	0.053	15385	10000	104	81	0.011	0.021	15385	10000
Antrim PV	55	18182	0	888	0.098	0.000	18182		0	641	0.071	0.000	18182		299	751	0.083	0.039	18182	15385	615	1921	0.211	0.098	18182	12496	185	270	0.030	0.031	18182	11810
Hayfield MST	90	11111	888	647	0.116	0.098	11111	18182																			455	133	0.024	0.061	11111	14911
Jamison SS	68	14706	1535	278	0.038	0.214	14706	14336													2536	325	0.044	0.310	14706	16375	588	162	0.022	0.085	14706	13840
Kayalla SH	75	13333	1813	384	0.058	0.252	13333	14392													2861	558	0.084	0.354	13333	16167	750	395	0.059	0.107	13333	14018
Moroak SS	60	16667	2197	231	0.028	0.310	16667	14195	641	205	0.025	0.071	16667	18182	1050	235	0.028	0.121	16667	17287	3419			0.438		15625	1145			0.166		13774
U Valkerri SH	90	11111	2428	2661	0.479	0.337	11111	14398	846	980	0.176	0.095	11111	17790	1285	235	0.042	0.150	11111	17170												
L Valkerri SH	80	12500	5089			0.816		12469	1826	342	0.055	0.272	12500	13451	3229	2749	0.440	0.192	12500	33639												
Dolerite Sill	50	20000							2168	20	0.002	0.326	20000	13291																		
	80	12500							2188	568	0.091	0.328	12500	13332																		
Dolerite Sill	50	20000							2756	377	0.038	0.419	20000	13152																		
	80	12500							3133	54	0.009	0.457	12500	13717																		
Bessie Cr SS	60	16667							3187			0.465		13694	4034	1406	0.169	0.632	16667	12769												
Corcoran SH	70	14286													5440	102	0.014	0.801	14286	13591												
Corcoran SS	50	20000																														
Dolerite Sill	50														5542			0.815		13603												
TD																																
Seismic Crossing			MC92-251; 8380						close to McManus well						SH90-103; sp 6710						MD92-53; sp 1780						89-203; sp 5580					.

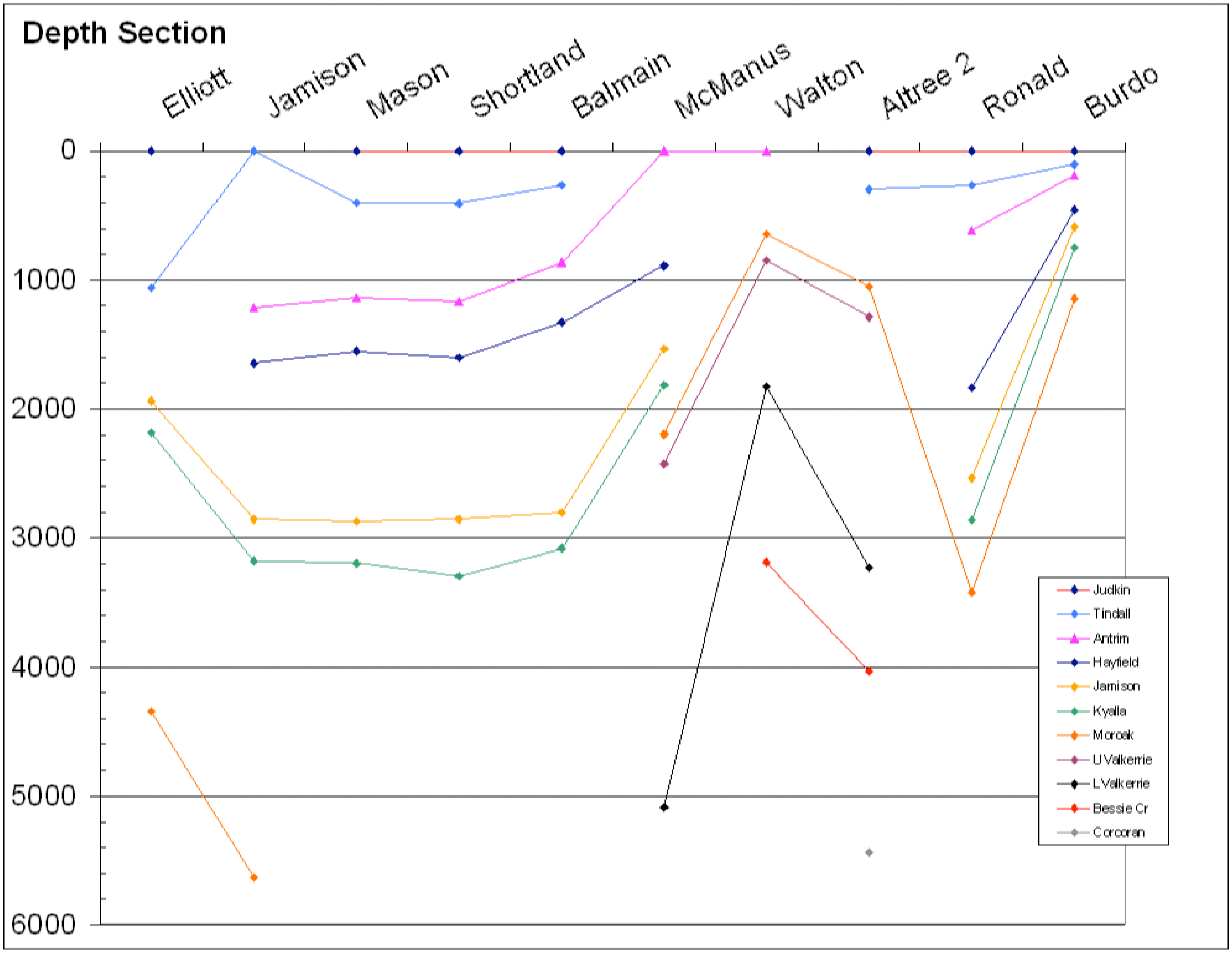


Figure IV-9. Depth correlation section

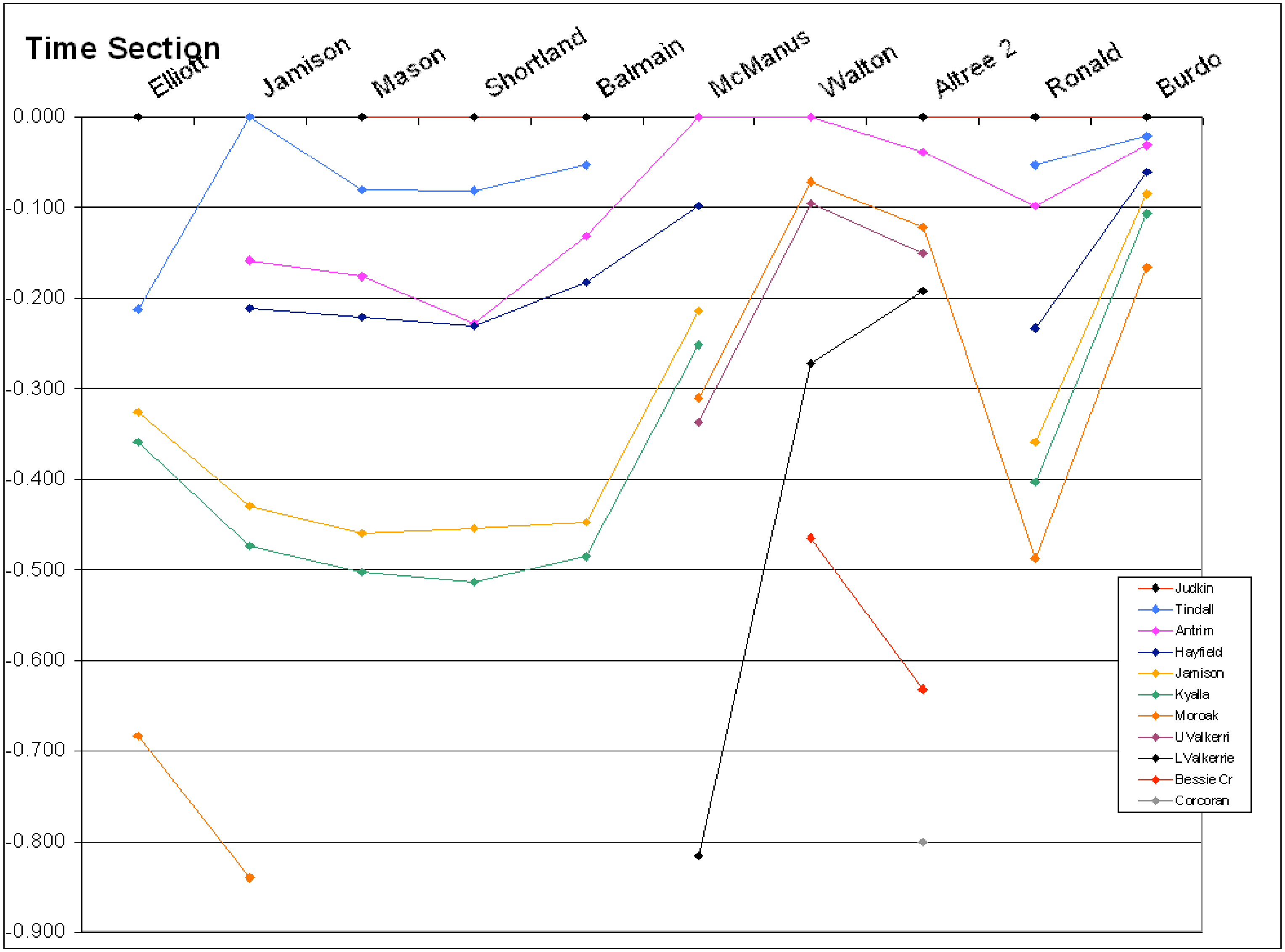


Figure IV-10. Time correlation section

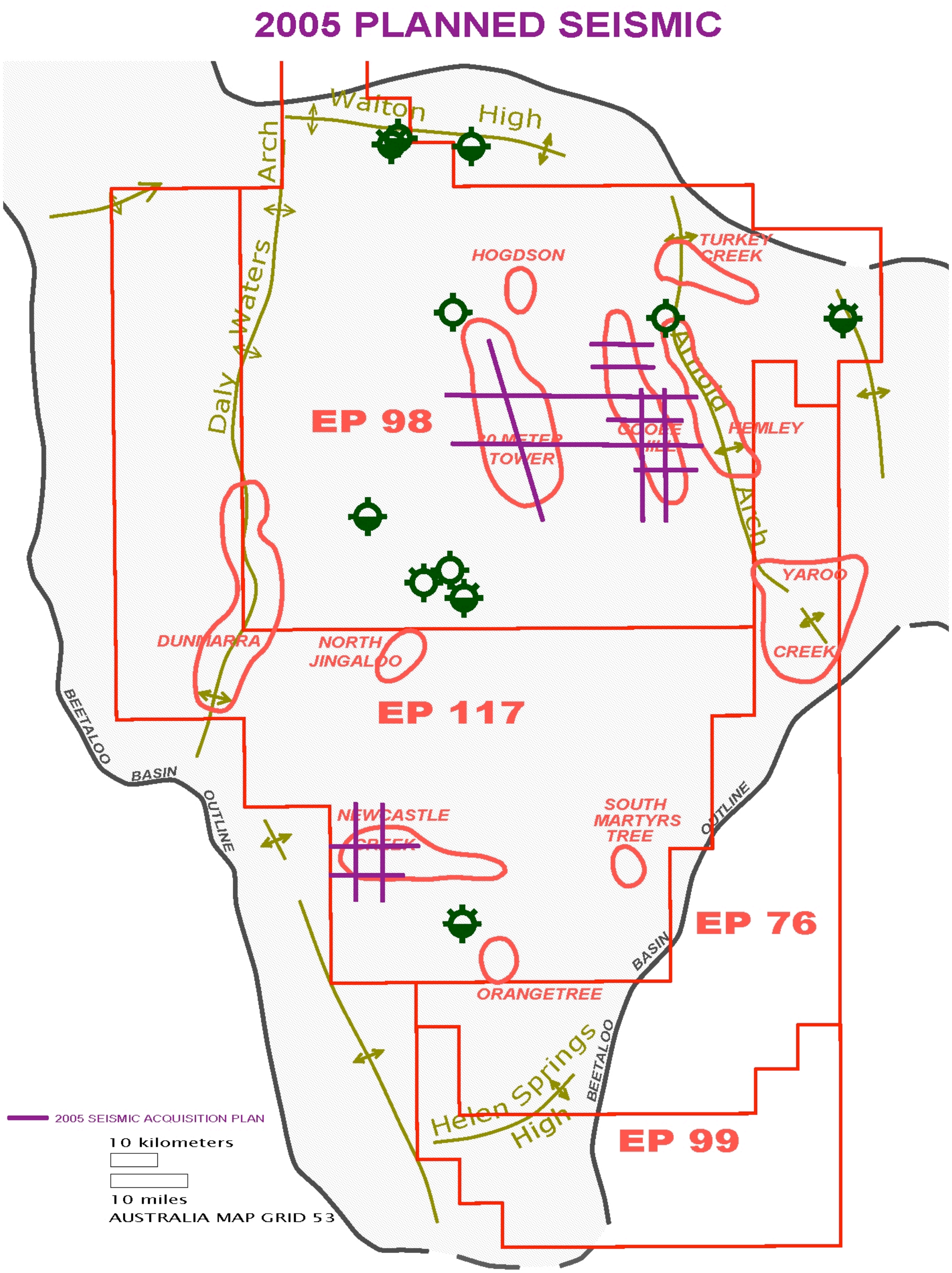


Figure VI-1 2005 Planned Seismic Acquisition Program