# Characterising Top Seal in the Vulcan Sub-Basin, North West Shelf, Australia

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# Abstract

The occurrence of palaeo-oil columns in Late Jurassic and Cretaceous reservoirs in the Vulcan sub-basin indicates that hydrocarbon accumulations have leaked. It is unclear whether accumulations have leaked through breach of top seal or fault seal. This study evaluates the top seal potential for hydrocarbon accumulations in the Vulcan Sub-basin. For this purpose a top seal potential assessment methodology was developed.

Seal potential (SP) combines seal capacity (the hydrocarbon column height that can physically be held back by seal), seal geometry (the areal extent and thickness of the seal) and seal integrity (rock mechanical properties of the seal). Seal capacities are measured using mercury injection capillary pressure calculations. Areal extent is evaluated using sedimentological and sequence stratigraphic principles. Thickness is determined empirically from well logs and seismic data. Seal integrity is derived from a brittleness index. In addition, a component relating to data quality and quantity is included in seal potential evaluation.

The main sample set for this study is composed of drill cuttings. For this reason a comparison of seal capacity results measured from cuttings and cores has verified that cuttings samples provide accurate seal capacity measurements.

Lower Vulcan Formation SP ranges from low to high due to variations in seal capacity and thickness risks as well as data quality and quantity. High SP occurs in the main depocentres and low SP occurs on the palaeo-highs and basin margins. Upper Vulcan Formations SP ranges from low to moderate due to variations in seal capacity. Moderate SP occurs in the depocentres and low SP on the basin margins. In the Echuca Shoals Formations seal capacity,

seal extent and integrity as well as data quality and quantity are good. However seal thickness is inconsistent, resulting in SP variations from good to poor as a function of thickness. Jamieson Formation has high seal capacities, is thick and areally extensive, however the seal potential is locally moderate (for example on the Ashmore Platform) due to seal integrity risk. SP for the Jamieson Formation is controlled by the thickness and the amount of calcite present in the rock, which affects the brittleness of the formation and hence the seal integrity. The Woolaston, Gibson and Fenelon (WGF) Formations are grouped together as a regional seal and in this group SP varies from low to high. The WGF rocks generally have high seal capacities, are areally extensive and thick with good data quality and quantity sample set wise. Where the WGF is predominantly marl and calcilutite some of the highest brittleness index values were recorded and hence the WGF has a low SP in these areas.

Based on the overall seal potential analysis, almost all seals in the area are capable of holding back hydrocarbon columns greater then present or palaeocolums recorded. This suggests that hydrocarbon leakage in the Vulcan Sub-Basin did not occur as a result of top seal capillary failure.

# Declaration of Authenticity

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university of other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by any other person, except where due reference is made in the text.

I give consent to this copy of my thesis, when deposited in the University Library, being available for loan and photocopy.

Tom Kivior

15 June 2005

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# Chapter 1 Introduction and General Geology

## 1.1 General Geology

The Vulcan Sub-Basin is part of the Australian North West Shelf (Figure 1-1), which is currently the main hydrocarbon province in Australia. Over the last 20 years, intensive petroleum exploration has been undertaken in the Vulcan Sub-Basin, which has resulted in several discoveries. However, by modern standards, the commercial success rate in the Vulcan Sub-Basin is low and has been estimated at less than 2% or 1 discovery in 50 wells drilled (Lisk and Eadington, 1998; Shuster et al., 1998).

Many of the petroleum plays tested within the Vulcan Sub-Basin have residual or palaeo-oil columns (Lisk and Eadington, 1998 and O'Brien et al., 1996). O'Brien et al (1998) measured seepage and showed the existence of Hydrocarbon Related Diagenetic Zones (HRDZ) above some breached or partially breached petroleum traps in the Vulcan Sub-Basin. The presence of HRDZs, formed via the oxidation of leaking hydrocarbons, suggests that these traps were charged and then subsequently breached by either top seal or bounding fault seal failure. Many published papers have attributed this trap failure to the Neogene reactivation of older faults induced by the collision of the Australian and Eurasian plates in the late Miocene to Early Pliocene (AGSO North West Shelf Study Group 1994; Lisk and Eadington 1998; Nelson 1989; O'Brien et al. 1993; Pattillo and Nicholls 1990; Shuster et al. 1998 and Woods 1992). To date, however, little work has investigated top seal potential of the key sealing units in the Vulcan Sub-Basin.

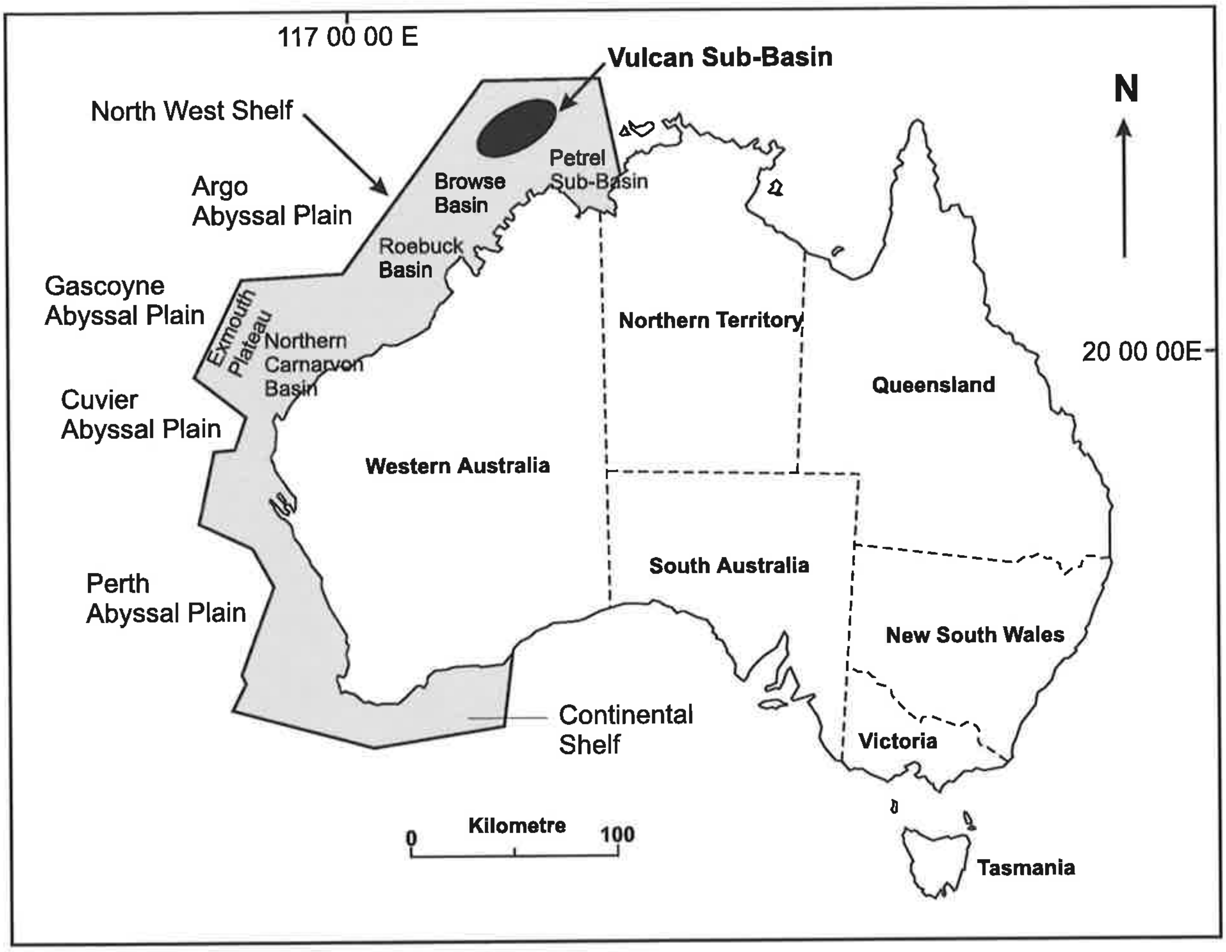



Figure 1-1 Location map of the Vulcan Sub-Basin situated on the Australian North West Shelf, with the shaded area showing the extent of Western Australian Basins.

## 1.2 Introduction and Objectives

The concept for this thesis comes directly from the fact that the Vulcan Sub-Basin has been disappointing as a petroleum province. Commercially the high number of dry holes has proven painful for explorers in the area. Many of the tested traps have clearly contained hydrocarbon columns at one point in the past and have subsequently leaks.

Early success in the Vulcan Sub-Basin, namely the Skua, Challis and Jabiru discoveries, has proven the sub-basin is a valid petroleum system with reservoir, structure, seals and a source rock that generated hydrocarbons and filled the traps post structure. The top seal effectiveness is the focus of this study due to the logical extension that at some point in the past hydrocarbon accumulations have leaked to form the palaeo-oil column seen in the sub-basin today. Thereby the seal component of the petroleum system appears to be the weakest component in the Vulcan Sub-Basin.

The objective of the present study is to develop a quantitative understanding of the top seal potential in the Vulcan Sub-Basin. The study aims to develop a top seal risk assessment on a regional scale and over various play types and incorporate the assessment into a ranking of top seals. As such it has focussed on top seal capacity, areal extent, thickness variation and integrity and was undertaken to determine whether top seal failure might be the cause of hydrocarbon leakage in the Vulcan Sub-Basin.

# 1.3 Geological setting of the Vulcan Sub-Basin

## 1.3.1 Structural Configuration

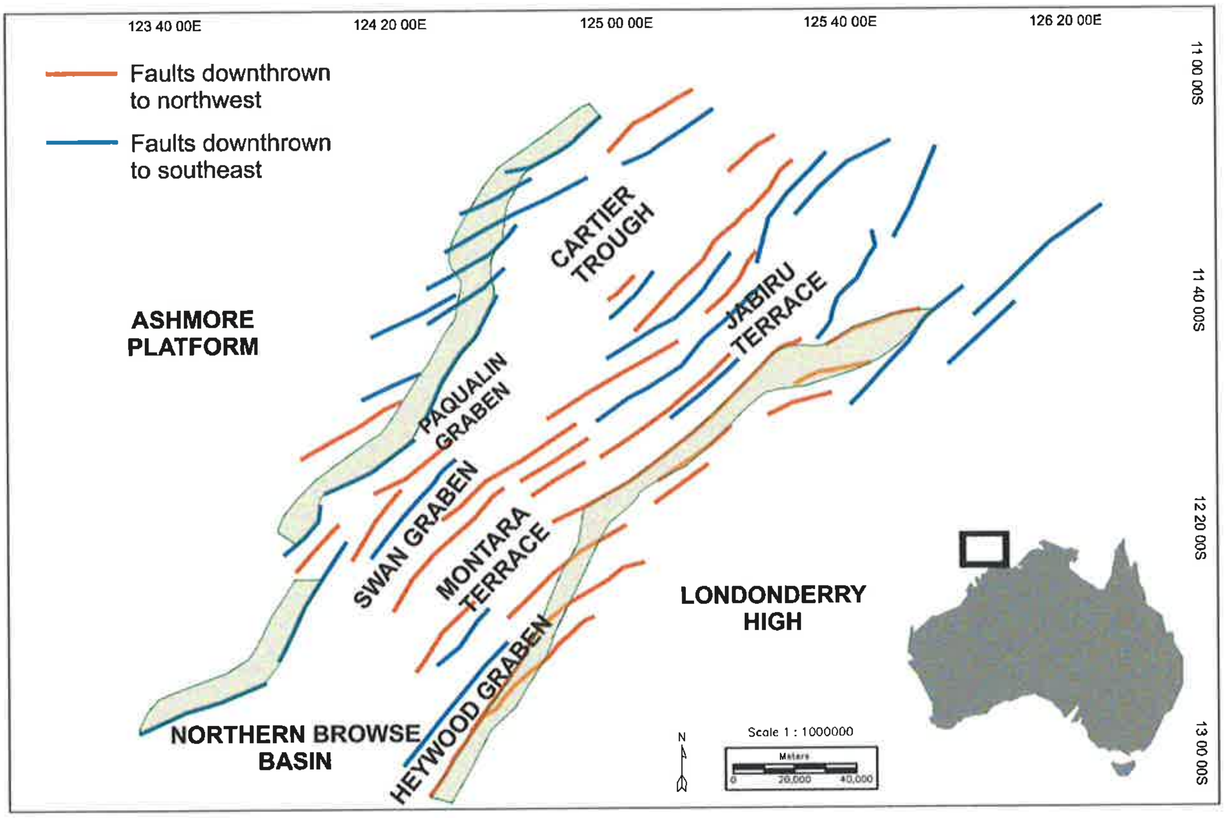



Figure 1-2 Structural elements of the Vulcan Sub-Basin

The Vulcan Sub-Basin is composed of a series of northeast-southwest-trending structural elements (Figure 1-2). The Ashmore Platform, on the western shoulder of the Vulcan Sub-Basin, is a large elevated block with relatively flat lying Cretaceous sediments unconformably overlying a thick section of Triassic rocks. The Londonderry High lies on the eastern margin of the Vulcan Sub-Basin and separates it from the Petrel Sub-Basin. The Londonderry High consists of tilted fault blocks and a peneplanated Triassic section overlain by Late Jurassic and younger sediments (MacDaniel 1988a). To the north of the Vulcan Sub-Basin lies the Sahul Syncline and the Timor

Trough and to the south the Browse Basin. Between the Ashmore Platform and the Londonderry High are a number of northeast-southwest trending structural elements, which include the Heywood, Swan and Paqualin Grabens, the Montarra and Jabiru Terraces and the Carter Trough.

### 1.3.2 Tectonic Evolution

As part of Gondwana, Australia was joined to Antarctica on the southern margin, India on the western margin and Argo Land and Burma on the northwestern margin (Muller et al. 1998 and Veevers, 1991a). Three major tectonic events affecting the western and southwestern margins of Australia have been recognised (Muller et al. 1998; Powell et al. 1988 and Veevers, 1991b). Firstly, the Argo Land and Burma continental blocks separated from Australia at approximately 156 Ma (Callovian). Secondly, separation between the Indian and Australian continents began at 132.5 Ma (Valanginian). Thirdly, the onset of rifting between Australia and Antarctica commenced in the mid-Cretaceous (96 Ma).

The breakup of the Gondwana continent occurred progressively as a southward propagating rift, which started in the Oxfordian and ended in the Valanginian. Thus, breakup between Argo Land and Australia was the first phase of propagation that lead to the breakup of Australia and India (Mihut and Muller 1998 and Muller et al. 1998). The fragmentation of East Gonwana is outlined with progressive reconstructions through time in Figure 1-3.

At the onset of sea floor spreading in the Argo Abysal Plain, the initial outline of East Gondwana contained Greater India, Antarctica and Australia (a). Muller et al. (1998) estimate the onset of sea floor spreading in Argo Abysal

Plain at about 156Ma, after which Argo Land started to rapidly move northwest relative to Australia.

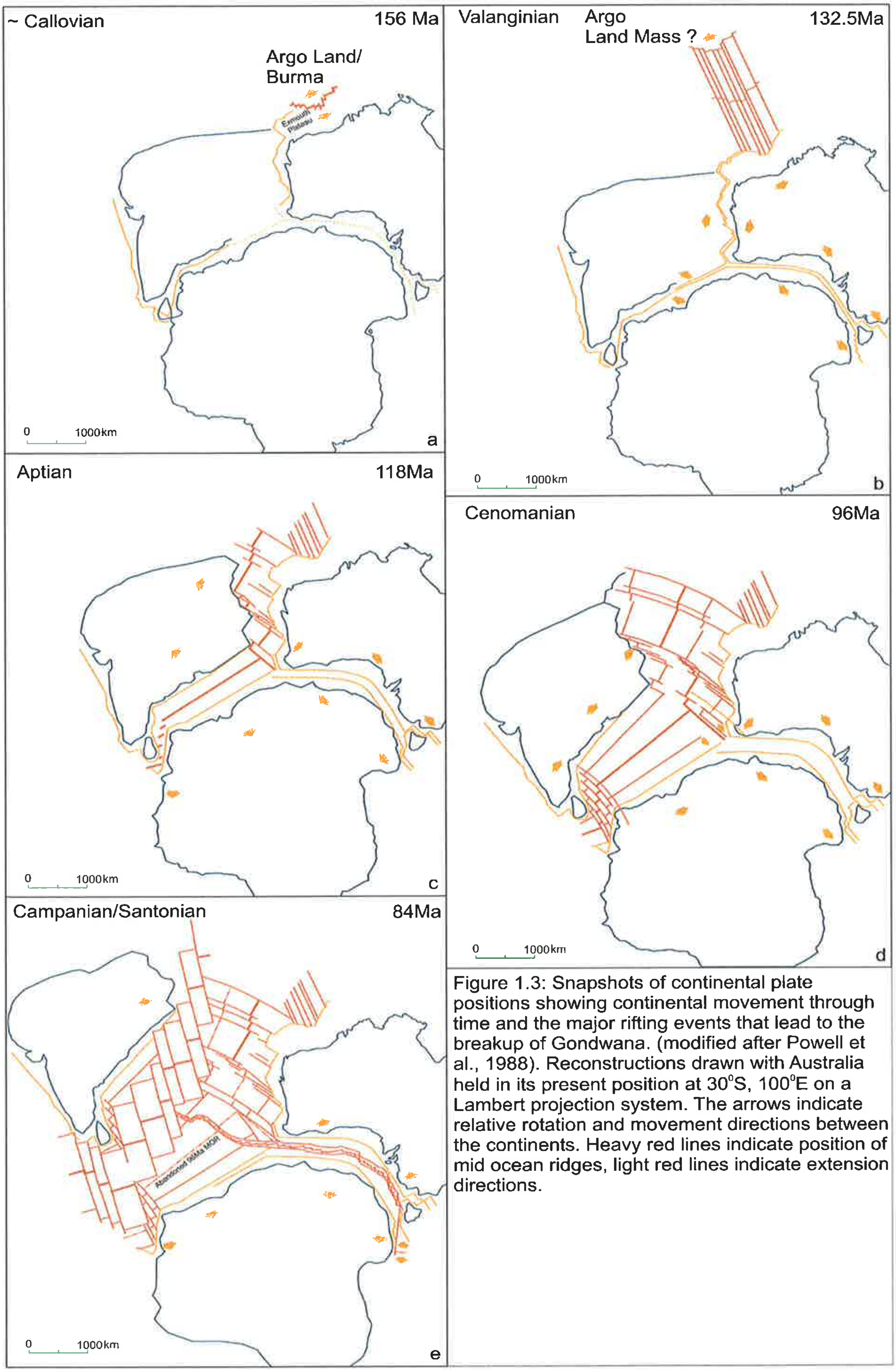



Figure 1.3: Snapshots of continental plate positions showing continental movement through time and the major rifting events that lead to the breakup of Gondwana. (modified after Powell et al., 1988). Reconstructions drawn with Australia held in its present position at 30°S, 100°E on a Lambert projection system. The arrows indicate relative rotation and movement directions between the continents. Heavy red lines indicate position of mid ocean ridges, light red lines indicate extension directions.

By the Early Valanginian (132-135Ma), Argo Land had rifted away and rifting had started between Australia and India (Figure 1.3b). At this time, sea floor spreading had started west of Australia in the Gascoyne, Cuvier and Perth Abysal plains (Muller et al. 1998 and Powell et al., 1988). Furthermore Muller et al., (1998) believe that drifting between India and Antarctica remained slow until breakup in the Aptian (120Ma). The model they use postulates that a transform fault separated northern Greater India and southern Greater India between 135Ma and 120Ma, after which both plates moved together (Figure 1.3c).

Powell et al. (1988) note that a major change in spreading pattern occurred during the Cenomanian (96Ma). In the Indian Ocean, a new spreading ridge was established closer to India and the continent began to move north rapidly at this time. Also at this time, a new spreading ridge formed between India and Australia, and the two continents drifted apart at a low spreading rate (Baillie et al. 1994 and Powell et al., 1988). The plate reconstructions (Figuer 1.3d and Figure 1.3e) show East Gondwana at the end of the first phase of sea floor spreading in the Cenomanian (96Ma) and the northward drift of the Indian continent in the Campanian/Santonian (84Ma).

The Australian plate continued to migrate northward until it collided with the Pacific Plate in the middle Miocene (Baillie et al. 1994). The interaction of the westward moving Pacific Plate and the northward moving Australian Plate produced two tectonic events. Firstly, there was a buckling of the Australian lithosphere as Australia passed over an oceanic subduction zone (Baillie et al. 1994). Secondly, a counter-clockwise rotation was induced on the Australian Plate by the collision, causing dextral transcurrent movements along preexisting fractures near the continent-ocean boundary around Australia (Veevers and Powell 1984). This collision was responsible for the extensive reactivation of faults in the Timor Sea area.

## 1.4 Stratigraphic Evolution

The stratigraphic succession (Figure 1-4) in the Vulcan Sub-Basin can be broadly catagorised into two major sequences, separated by a regional unconformity of Callovian age (MacDaniel 1988a). Pattillo and Nicholls (1990) further subdivide the stratigraphic sequence into an Early Jurassic, Triassic and Permian pre-rift megasequence. These are a) pre-Callovian sediments, b) a syn-rift megasequence (Callovian to Valanginian unconformities) and c) a post-rift megasequence (Valanginian unconformity to present day passive margin evolution).

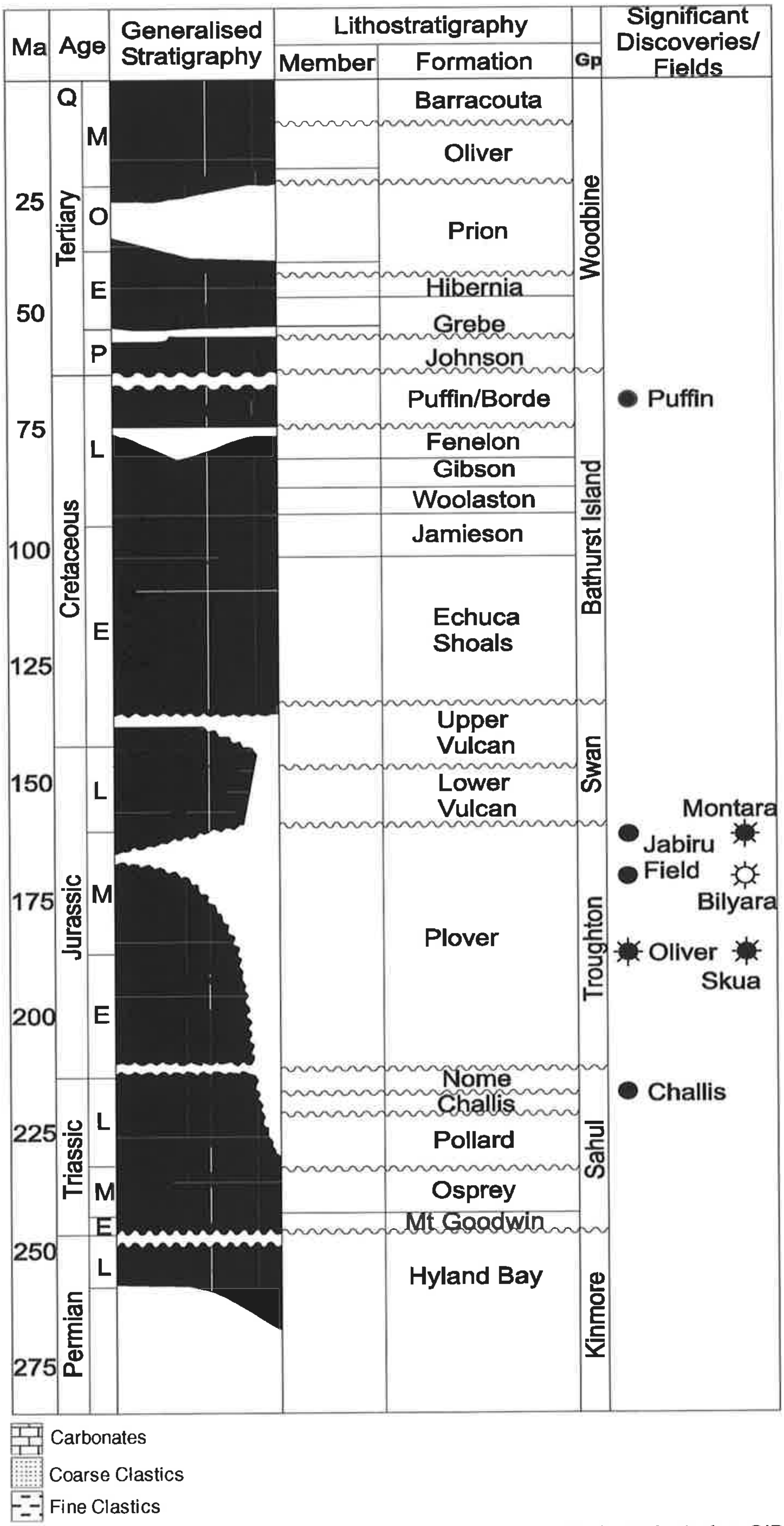



Figure 1-4: Stratigraphic column for the Vulcan Sub-Basin (modified after O'Brien et al., (1996)

### 1.4.1 Stratigraphic Evolution – Permian to mid-Jurassic

Intra-cratonic movement on the Gondwana continent began during the Carboniferous and culminated with basin subsidence during the Permian, which led to the formation of the 'Westralian Superbasin' (Yeates et al. 1987). Pre-Middle Jurassic sediments in the Vulcan Sub-Basin were deposited as part of the greater 'Westralian Superbasin'.

The Late Permian Hyland Bay formation is the oldest section penetrated to date and consists of a lower clastic member and an upper carbonate member (MacDaniel 1988a). The upper carbonate member is a laterally extensive shallow marine carbonate that was deposited on a broad carbonate platform on the ancient Tethyan margin of Australia (MacDaniel 1988a and Pattillo and Nicholls 1990). Reservoir potential in the carbonate is restricted to the possibility of natural fractures being present in the Hyland Bay Formation. The reservoir for Petrel and Tern gas condensate fields is the lower Hyland Bay clastic member.

The Mount Goodwin Formation unconformably overlies the Hyland Bay Formation and consists of thin basal transgressive sandstones, which fine upwards to thick mudstones (Pattillo and Nicholls 1990).

The mudstones of the Mount Goodwin Formation grade vertically into basin-floor turbidites, pro-delta slope to delta front and finally to delta plain facies of the Middle Triassic Osprey Formation (Pattillo and Nicholls 1990). MacDaniel (1988a) noted that the carbonate content of this regressive sequence increases to the north-west, which indicates that more marine conditions existed in that direction. The deltaic facies of this formation exhibit good reservoir potential, which is restricted to the Londonderry High area (Pattillo and Nicholls 1990).

The base of the Late Triassic Pollard Formation is defined by thin transgressive shale and carbonate facies, which unconformably overly the Osprey Formation. The shale and carbonate facies grade vertically into thick deltaic sandstones, which are potential reservoirs. However, these sandstones pass laterally into marine mudstones over the Ashmore Platform (Pattillo and Nicholls 1990).

Pattillo and Nicholls (1990) interpreted the base of the Challis Formation as disconformable, with transgressive clastic/carbonate lithologies overlying the regressive clastics of the Pollard Formation. The sequence passes vertically into mixed carbonate and shoreface clastic facies, which become thick coeval platform carbonates towards the west.

Characteristic lithologies of the Nome Formation are massive delta front to lower delta plain lithologies, which grade vertically to channelised upper delta plain deposits (Mory 1988 and Pattillo and Nicholls 1990). These deltaic sandstones are the main reservoir interval for the Challis discovery. Pattillo and Nicholls (1990) suggest that the Nome Formation represents a major phase of clastic delta progradation across the Late Triassic carbonate platform.

The Plover Formation is an important reservoir in the Vulcan Sub-Basin. Erosion during Late Jurassic rifting may have had significant control over the distribution of this formation and only remnants remain under the Callovian Unconformity (Pattillo and Nicholls 1990). Up to 600m of the Plover Formation is preserved within the Vulcan Sub-Basin. The Plover Formation is absent over the Ashmore Platform and only partially preserved along parts of the Londonderry High (MacDaniel 1988a). Pattillo and Nicholls (1990) subdivided the Plover Formation into three depositional sequences. The oldest sequence (Hettangian to Toarcian) consists of massive, medium to coarse grained quartzarenites deposited in fluvial and deltaic environments. The middle sequence (Toarcian) is characterised by marginal marine facies, consisting of carbonaceous mudrocks interbedded with fine-grained sandstones containing rootlets. The youngest sequence is made up of thick, sub-mature quartzarenites and thin mudstones. This sequence was deposited in a high energy, accretionary delta front environment. The sandstones of the youngest sequence are the main reservoir of the Skua Field (Osborne 1990).

### 1.4.2 Stratigraphic Evolution – mid Jurassic to Cretaceous

With the Argo Land drifting away in the late Callovian, the Vulcan Sub Basin entered a syn-rift depositional stage (Pattillo and Nicholls 1990). This phase of deposition extended from the Callovian unconformity to the Valanginian unconformity and has been subdivided into the Lower Vulcan and Upper Vulcan formations; these are separated by the intra Kimmeridgian unconformity.

#### 1.4.2.1 Lower Vulcan Formation

This sequence was deposited during the Callovian to Kimmeridgian. The Callovian unconformity forms the basal sequence boundary to the Lower Vulcan Formation. Accommodation space, created by Callovian faulting, formed broad gentle grabens and accumulation of this sequence represents the initial rift infill and subsequent drowning (MacDaniel 1988a; Pattillo and Nicholls 1990).

An Early Oxfordian stacked lowstand delta, deposited predominantly along the Montara Terrace and basin margin, was slowly drowned during the Late Oxfordian to Kimmeridgian and is overlain by Late Oxfordian interbedded siltstones and claystones and Kimmeridgian claystones (Baxter et al. 1997; Pattillo and Nicholls 1990). Deposition in the main basin grabens was dominated by claystones laid down in a low energy restricted marine setting (Pattillo and Nicholls 1990). Further rift development occurred during the Late Kimmeridgian/Tithonian, during which time the Lower Vulcan Formation was eroded significantly in places.

#### 1.4.2.2 Upper Vulcan Formation

This sequence was deposited from the Tithonian to Early Valanginian. During the Kimmeridgian and Tithonian, the Vulcan Sub-basin underwent a renewed phase of intense rifting. At this time, east-northeast faulting combined with the Callovian northeast fault pattern, formed regional *en-echelon* horst and Late Kimmeridgian/Tithonian graben structures (Pattillo and Nicholls 1990).

The Upper Vulcan is restricted to the major depocentres such as the Swan Graben and is missing from the Ashmore Platform, Londonderry High, Montara and Jabiru Terraces. This formation is characterised by thick, restricted marine mudrocks and coarse clastic submarine fan deposits depositied near intra-graben highs (Baxter et al. 1997; Pattillo and Nicholls 1990).

### 1.4.2.3 Echuca Shoals

At the end of tectonism in the Valanginian, the area became a thermally subsiding passive margin. A rapid transgression occurred at this time, which shifted the palaeo-shoreline to the southeast (MacDaniel 1988a; Pattillo and Nicholls 1990) and accumulation of the Echuca Shoals Formation commenced. This interval represents a transgressive condensed sequence, which was deposited over a period of 14Ma (Pattillo and Nicholls 1990), with thin basal sandstones along the Londonderry High that fine sharply upwards to glauconitic claystones.

### 1.4.2.4 Jamieson Formation

The base of the Jamieson Formation is the Aptian disconformity. Bathyal dark gray to black claystones are typical lithofacies within this unit. In many deeper parts of the sub-basin, a thin radiolarian siltstone occurs at the base of this interval (Pattillo and Nicholls 1990). However, this facies is generally less than 10m thick in this area and is thus included with the overlying claystones.

### 1.4.2.5 Woolaston, Gibson and Fenelon Formations

Widespread carbonate sedimentation commenced in the Vulcan Sub-Basin during the Cenomanian. The Woolaston, Gibson and Fenelon Formations (WGF) form a thick, hemipelagic slope depositional sequence (MacDaniel 1988a; Pattillo and Nicholls 1990). The Late Albian/Cenomanian disconformity at the base of this interval separates the claystones of the underlying Jamieson Formation from predominantly marls and cacilutites above the disconformity. The calcareous claystone, marl and calcilutite depositional cycles, which make up the WGF, were interpreted by Pattillo and Nicholls (1990) as a distal, deep-water stratigraphic response to eustatic fluctuations.

#### 1.4.2.6 Puffin/Borde Formations

During the Late Campanian clastic sediment deposition recommenced on what had been a developing carbonate shelf (Pattillo and Nicholls 1990). Clastic deposition consisted of massive submarine fan complexes that were sourced from the southeast and are today prevalent in the south-central Vulcan Sub-basin. Pattillo and Nicholls (1990) noted that over the northern Ashmore Platform and Jabiru Terrace this facies is characterised by a condensed marl/calcilutite facies with sand stringers, which are thought to be the distal parts of the submarine fan complexes.

### 1.4.3 Stratigraphic Evolution – Paleocene to Recent

The lower boundary of the Paleocene to Miocene sequence is marked by a regional unconformity. This stage has been referred to as the 'mature marine stage' of basin development during which time a thick carbonate wedge prograded in a northwestern direction. Pattillo and Nicholls (1990) identified six depositional sequences in which carbonates predominated and are interbedded with Paleocene and Eocene sands. Mory (1988); Pattillo and Nicholls (1990) and MacDaniel (1988a) provide a more comprehensive description of these sediments.

Renewed faulting and tectonic movement, which began in the Late Miocene, controlled the thickness and distribution of Upper Miocene to Recent sediments (MacDaniel 1988a). Pattillo and Nicholls (1990) noted that the Late Miocene Barracouta Formation is thickest in the Cartier Trough, in which accommodation space developed in response to the collision and ongoing subduction of the Australian Plate under Indonesia. Many of the fault dependant traps in the northern Timor Sea were reactivated by this Neogene Plate collision (Shuster et al. 1998).

## 1.5 Petroleum Plays in the Vulcan Sub-Basin

The majority of hydrocarbon discoveries in the western Timor Sea are in traps beneath the Valanginian Unconformity (MacDaniel 1988a). Jurassic faulting formed fault block traps that were eroded during the Late Jurassic and Early Cretaceous and structural closure is commonly fault dependant (MacDaniel 1988b). The main extensional rift phase in the Vulcan Sub-Basin began in the Late Callovian with the development of northeast-southwest trending grabens. A second phase of tectonism occurred during the middle Kimmeridgian and modified the earlier Callovian structural grain to form narrower, *en-echelon* grabens with intra-graben horsts and rotated fault blocks (Pattillo and Nicholls 1990). MacDaniel (1988a) proposed that Lower Cretaceous and Upper Jurassic claystones are the main seals for many of these traps.
Significant reservoir sands are also present in the Lower Vulcan Formation (Pattillo and Nicholls 1990), where coarse clastics prograded into the developing grabens. These sediments provide potential reservoirs adjacent to the Londonderry High along the Montara Terrace in the southeastern Vulcan Sub-Basin (Figure 1-2). The seals for this play are predominantly siltstones and claystones of the Lower Vulcan Formation. Within the Upper Vulcan Formation, submarine fan plays are present in grabens created by intra-Kimmeridgian tectonism (Pattillo and Nicholls 1990).

Upper Cretaceous sandstones of the Puffin Formation also have reservoir potential (MacDaniel 1988a). The Puffin Formation sandstones are restricted to the southern Vulcan Sub-Basin. Overlying Late Maastrichtian to Early Tertiary marls and limestones seal the Campanian and Maastrichtian sandstones, which are the reservoirs for the Puffin Field.

# Chapter 2 Methodology

## 2.1 Project Aim

The aim of this study is to gain a quantitative and qualitative understanding of the top seal potential of the Vulcan Sub-Basin. In order to achieve this, it was necessary to subdivide the succession into a series of genetically related packages of known age, to map their spatial distribution and to sample and perform a full suite of seal analysis on each respective package. Ultimately, the goal was to develop and apply a holistic seal risk methodology over the entire Vulcan Sub-Basin. Thus, a seal potential methodology was developed based on work by Kaldi and Atkinson (1997) and Kaldi (2000).

The Callovian to Maastrichtian section was subdivided into major units using biostratigraphic data. This allowed a chronostratigraphic framework to be constructed for the Vulcan Sub-Basin and defined the time occurrence of major basin-forming events. In turn, these events were transferred to seismic and mapped on a regional scale.

Known seals and potential seals were defined on well logs based on underlying hydrocarbon discoveries and reservoir sands targeted when drilling. Samples of core and cuttings were collected from identified sealing intervals.

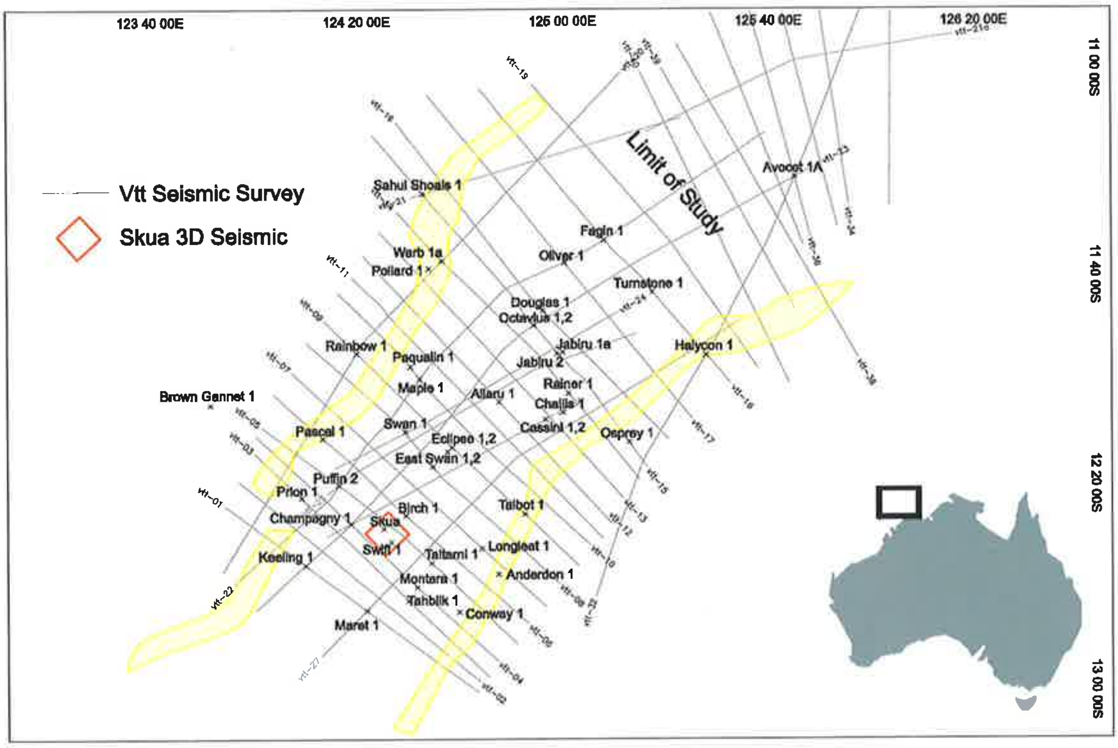



Figure 2-1: Vulcan Sub-Basin showing wells and seismic lines used in this study.

## 2.2 Database

Data for this study are derived from 44 wells distributed throughout the Vulcan Sub-Basin (Figure 2-1). Geoscience Australia provided biostratigraphic data for some of the wells, while the majority of data were obtained from well completion reports. Wiltshire Geophysical supplied the wireline log data used in this study. These were predominantly gamma ray, sonic, density, neutron and deep, shallow and micro-resistivity logs. The majority of the wells had gamma, sonic, neutron and density logs and these logs were selected where possible. Table 2-1 lists the wells that were incorporated in the study. The 2D seismic data for the study area were supplied by Geoscience Australia and consisted of digital data from the Geoscience Australia VTT seismic survey. The location of the regional 'VTT' seismic survey is shown in Figure 2-1.

| Well Name | # MICP Run | # XRD Run | # SEM Run |
|---|---|---|---|
| Allaru 1 | 2 | 1 | 0 |
| Anderdon 1 | 4 | 4 | 0 |
| Avocet 1a | 5 | 2 | 1 |
| Brown Gannet 1 | 2 | 2 | 2 |
| Challis 1 | 6 | 5 | 3 |
| Challis 2A | 0 | 0 | 0 |
| Challis 7 | 0 | 1 | 6 |
| Douglas 1 | 4 | 4 | 2 |
| East Swan 1 | 3 | 3 | 2 |
| Eclipse 1 | 2 | 2 | 1 |
| Jabiru 1a | 4 | 4 | 2 |
| Jabiru 2 | 4 | 4 | 4 |
| Kalyptea 1 | 2 | 0 | 0 |
| Maple 1 | 1 | 0 | 1 |
| Medusa 1 | 1 | 0 | 0 |
| Montara 1 | 5 | 3 | 2 |
| Octavius 1 | 0 | 0 | 0 |
| Octavius 1 ST1 | 5 | 3 | 0 |
| Oliver 1 | 3 | 1 | 0 |
| Osprey 1 | 3 | 3 | 0 |
| Pascal 1 | 3 | 3 | 1 |
| Pengana 1 | 0 | 0 | 0 |
| Pollard 1 | 2 | 2 | 0 |
| Prion 1 | 2 | 3 | 2 |
| Puffin 2 | 11 | 4 | 3 |
| Rainbow 1 | 0 | 0 | 0 |
| Rainier 1 | 8 | 3 | 1 |
| Rowan 1 | 4 | 6 | 1 |
| Sahul Shoals 1 | 11 | 4 | 0 |
| Skua 1 | 8 | 9 | 6 |
| Skua 3 | 2 | 2 | 2 |
| Skua 4 | 2 | 1 | 1 |
| Skua 5 | 1 | 1 | 0 |
| Skua 6 | 2 | 2 | 1 |
| Skua 8 | 2 | 2 | 2 |
| Skua 9 | 1 | 1 | 2 |
| Skua 9 ST1 | 0 | 0 | 0 |
| Sunset 1 | 2 | 0 | 1 |
| Swan 1 | 1 | 1 | 1 |
| Swift 1 | 4 | 4 | 3 |
| Taltami 1 | 0 | 0 | 0 |
| Tenacious West 1 | 17 | 11 | 10 |
| Warb 1a | 5 | 5 | 0 |

Table 2-1: Summary of wells from which data were collected and analysed

Sample intervals were selected for analysis based on a combination of biostratigraphic data and wireline log character as well as regional reservoir distribution. Table 2-1 lists Mercury Injection Capillary Pressure (MICP) analyses, X-Ray Diffraction (XRD) scans and Scanning Electron Microscope (SEM) images, which were prepared and analysed for each well in the study area. In many wells, samples were taken above the local sealing interval to provide a picture of the regional character of the younger top seal intervals, which are important in other areas of the Vulcan Sub-Basin.

## 2.3 Biostratigraphic, wireline log and seismic interpretation

The Callovian to Maastrichtian section is generally well sampled by sidewall cores, allowing a reasonable coverage for biostratigraphic information. Wireline logs provide the most complete dataset with which to sub-divide the section. When combined with biostratigraphic data, these provide a chronostratigraphic framework for the deposition of seal lithologies throughout the Vulcan Sub-Basin. Formation names were retained, though the stratigraphic section was sub-divided based on biostratigraphic data in each well. For example, any reference to the Lower Vulcan, Upper Vulcan, Echuca Shoals, Jamieson or WGF formations in the following chapters refer to time-equivalent stratigraphic sections based on biostratigraphic sub-division outlined in this chapter.

### 2.3.1 Biostratigraphic data

Biostratigraphic data were extracted from well completion reports (WCR) for 44 wells in the Vulcan Sub-Basin. The biostratigraphic data for wells consist predominantly of palynological data for the Maastrichtian and older section. The foraminiferal data covers the Albian to Recent section (Table 2-2). As this study is primarily focused on the Maastrichtian and older section, palynological data were more useful over the interval of interest than were the foraminiferal data.

| Well Name | Biozone Type | Number of Zones | Minimum Depth | Maximum Depth |
|---|---|---|---|---|
| Allaru 1 | Dinocysts & Acritarchs | 8 | 2304 | 2946 |
| Anderdon 1 | Foraminifera | 7 | 1000 | 1427 |
| Anderdon 1 | Dinocysts & Acritarchs | 1 | 1320 | 1410 |
| Anderdon 1 | Spores & Pollen | 4 | 1458 | 2895.5 |
| Avocet 1a | Nanoplankton | 11 | 1224 | 1703 |
| Avocet 1a | Planctic Foraminiferida | 1 | 1539 | 1539 |
| Avocet 1a | Dinocysts & Acritarchs | 11 | 1686 | 1908 |
| Brown Garnet 1 | Foraminifera | 10 | 275.5 | 2118.4 |
| Brown Garnet 1 | Spores & Pollen | 1 | 1769.7 | 1769.7 |
| Challis 1 | Foraminifera | 19 | 633 | 1383.6 |
| Challis 1 | Dinocysts & Acritarchs | 5 | 952 | 1380.8 |
| Challis 1 | Spores & Pollen | 2 | 1387.2 | 1927.9 |
| Challis 2a | Foraminifera | 18 | 454.5 | 1375.5 |
| Challis 2a | Dinocysts & Acritarchs | 3 | 1349 | 1381.5 |
| Challis 2a | Spores & Pollen | 1 | 1419.9 | 1648 |
| Challis 7 | Foraminifera | 8 | 1259 | 1334 |
| Champagny 1 | Planctic Foraminiferida | 2 | 2080 | 2440 |
| Champagny 1 | Nanoplankton | 12 | 2130 | 2995 |
| Champagny 1 | Dinocysts & Acritarchs | 14 | 2940 | 3395 |
| Conway 1 | Dinocysts & Acritarchs | 7 | 1619.5 | 2568.5 |
| Douglas 1 | Nanoplankton | 15 | 1760 | 2332.5 |
| Douglas 1 | Planctic Foraminiferida | 8 | 1950 | 2332.5 |
| Douglas 1 | Dinocysts & Acritarchs | 7 | 2347.5 | 2462.5 |
| Douglas 1 | Spores & Pollen | 3 | 2487.3 | 2748 |
| East Swan 2 | Nanoplankton | 9 | 1302.5 | 2000 |
| East Swan 2 | Dinocysts & Acritarchs | 4 | 2299 | 2635.5 |
| Eclipse 1 | Foraminifera | 7 | 1826 | 2203.5 |
| Eclipse 1 | Dinocysts & Acritarchs | 12 | 1927.5 | 2570.6 |
| Fagin 1 | Dinocysts & Acritarchs | 9 | 2646 | 3105 |
| Halycon 1 | Foraminifera | 12 | 615 | 1311 |
| Halycon 1 | Dinocysts & Acritarchs | 8 | 1010 | 1739 |
| Jabiru 2 | Dinocysts & Acritarchs | 9 | 1246 | 2342 |
| Kalyptea 1 | Nanoplankton | 18 | 1800 | 4060 |
| Kalyptea 1 | Foraminifera | 3 | 2388 | 2988 |
| Kalyptea 1 | Dinocysts & Acritarchs | 8 | 3682 | 4572 |
| Keeling 1 | Dinocysts & Acritarchs | 4 | 2990 | 3116 |
| Maple 1 | Planctic Foraminiferida | 1 | 2524 | 2524 |
| Maple 1 | Dinocysts & Acritarchs | 13 | 2552 | 3681.9 |
| Maple 1 | Nanoplankton | 1 | 2552 | 2552 |
| Maple 1 | Spores & Pollen | 2 | 3682.8 | 4087.58 |
| Medusa 1 | Dinocysts & Acritarchs | 4 | 1479 | 1785 |
| Medusa 1 | Nanoplankton | 7 | 1479 | 1785 |
| Medusa 1 | Spores & Pollen | 2 | 1836 | 1930 |
| Montara 1 | Foraminifera | 16 | 460 | 2340 |
| Montara 1 | Planctic Foraminiferida | 9 | 2049 | 2382 |

| Well Name | Biozone Type | Number of Zones | Minimum Depth | Maximum Depth |
|---|---|---|---|---|
| Montara 1 | Dinocysts & Acritarchs | 7 | 2326 | 3199 |
| Montara 1 | Spores & Pollen | 2 | 3175 | 3396 |
| Octavius 1 | Dinocysts & Acritarchs | 1 | 1847 | 1847 |
| Oliver 1 | Nanoplankton | 19 | 666.5 | 2900 |
| Oliver 1 | Foraminifera | 15 | 990 | 2840 |
| Oliver 1 | Planctic Foraminiferida | 1 | 1993.5 | 1993.5 |
| Oliver 1 | Dinocysts & Acritarchs | 13 | 2534 | 2943 |
| Osprey 1 | Foraminifera | 13 | 283 | 2365 |
| Paqualin 1 | Foraminifera | 7 | 1535 | 4218 |
| Paqualin 1 | Nanoplankton | 2 | 2286 | 2295 |
| Paqualin 1 | Dinocysts & Acritarchs | 12 | 2290 | 3789 |
| Pascal 1 | Planctic Foraminiferida | 7 | 2200.5 | 2498 |
| Pascal 1 | Dinocysts & Acritarchs | 1 | 2536 | 2557 |
| Pascal 1 | Spores & Pollen | 1 | 2692 | 2843 |
| Pengana 1 | Dinocysts & Acritarchs | 9 | 1385 | 1639 |
| Pengana 1 | Spores & Pollen | 2 | 1644.3 | 2046 |
| Puffin 2 | Planctic Foraminiferida | 11 | 1660 | 2432 |
| Puffin 2 | Spores & Pollen | 3 | 1986 | 2555 |
| Puffin 2 | Dinocysts & Acritarchs | 2 | 2035 | 2349 |
| Puffin 2 | Nanoplankton | 2 | 2240 | 2380 |
| Rainbow 1 | Planctic Foraminiferida | 12 | 1888 | 2380 |
| Rainbow 1 | Dinocysts & Acritarchs | 3 | 2360 | 2390 |
| Rainbow 1 | Spores & Pollen | 1 | 2399 | 2610 |
| Rainer 1 | Dinocysts & Acritarchs | 8 | 1647 | 2115 |
| Rainer 1 | Spores & Pollen | 4 | 2120 | 2361 |
| Rainier 1 | Dinocysts & Acritarchs | 8 | 1647 | 2115 |
| Rainier 1 | Spores & Pollen | 4 | 2120 | 2361 |
| Rowan 1 | Foraminifera | 5 | 1515 | 2819 |
| Rowan 1 | Planctic Foraminiferida | 3 | 1525 | 1926 |
| Rowan 1 | Nanoplankton | 16 | 1950 | 2817 |
| Rowan 1 | Dinocysts & Acritarchs | 3 | 2808 | 3183 |
| Rowan 1 | Spores & Pollen | 3 | 3193 | 3316 |
| Snowmass 1 | Nanoplankton | 17 | 867.5 | 1254.5 |
| Snowmass 1 | Foraminifera | 4 | 1260 | 1277 |
| Snowmass 1 | Dinocysts & Acritarchs | 6 | 1265 | 1653 |
| Swan 1 | Planctic Foraminiferida | 7 | 2138 | 2581 |
| Swan 1 | Dinocysts & Acritarchs | 12 | 2304 | 3259 |
| Warb 1a | Nanoplankton | 11 | 1603 | 2345 |
| Warb 1a | Planctic Foraminiferida | 5 | 2150 | 2346 |
| Warb 1a | Dinocysts & Acritarchs | 8 | 2210 | 2380 |
| Warb 1a | Spores & Pollen | 1 | 2381 | 2573 |

Table 2-2: Biostratigraphic types and amount of data in each well studied.

Biostratigraphic reports, contained in well completion reports, describe the planktonic foraminifera, dinocysts and acritach and spore and pollen assemblages present in sidewall cores and cuttings. The biostratigraphic assemblages found in samples were assigned to biozones, which are summarised for the Phanerozoic by (AGSO North West Shelf Study Group 1994). The biozones presented in Figure 2-2 are based on this summary chart. The biostratigraphic reports also identify missing biozones in the stratigraphic record, as well as providing an interpretation of the depositional environment for the assemblage.

Absolute ages of the foraminiferal zones have been defined for the North West Shelf by Young and Laurie (1996), who correlated these zones to international biozones. This collection of biostratigraphic data, including biozone name, age and depositional environment, was entered into a database, which was used for cross-referencing biozones between wells in the Vulcan Sub-Basin

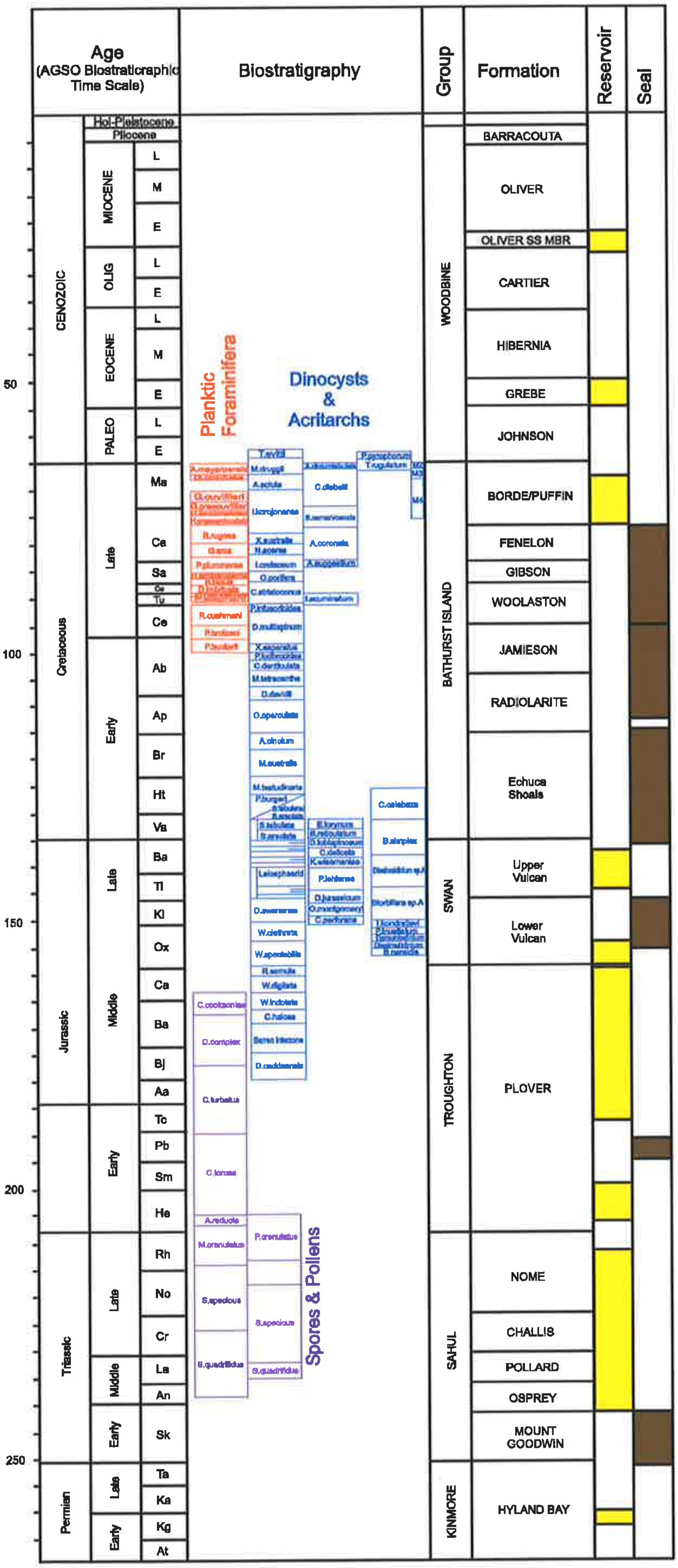



Figure 2-2: Biostratigraphic chart with biostratigraphic zones defined by AGSO Timescale Calibration and Development Project Team (1997)

### 2.3.2 Wireline Log Data

Most boreholes in this study contained extensive logging suites, consisting at least of gamma ray, sonic, density, neutron porosity as well as micro, shallow and deep induction/resistivity log. These wireline logging runs covered most of the Cretaceous and older lithologies. In order to integrate wireline logs with lithology, biostratigraphy and seismic data, a default template was set as shown in Figure 2-3.

### 2.3.3 Integration of biostratigraphic and wireline log data

The Triassic to Paleocene section of the Vulcan Sub-Basin was initially subdivided on the basis of major unconformities, evidenced by missing section observed on biostratigraphic and wireline logs. Biostratigraphic reports, the majority of which were obtained from well completion reports, were used to determine the age and time extent of the missing sections in the sub-basin.

Changes in wireline log signature are commonly associated with large hiatuses (Figure 2-3). Major hiatuses are correlated regionally over the Vulcan Sub-Basin, the results for which are presented in Chapter 4. Based primarily on biostratigraphic data, and supplemented by wireline log correlation, major hiatuses were correlated regionally over the Vulcan Sub-Basin.

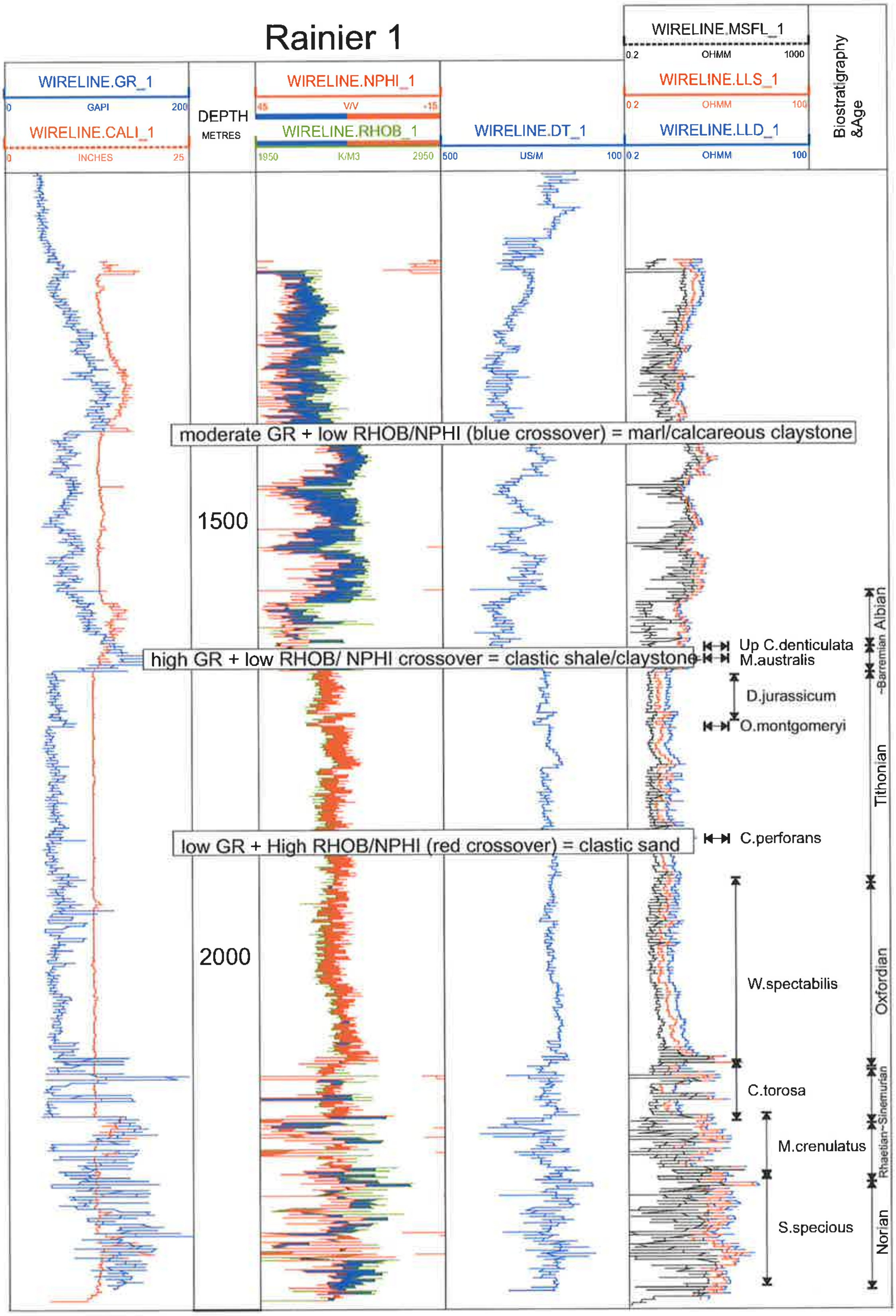



Figure 2-3: Lithology log template based on Rider (1996). Lithology interpretation of wireline logs is based on cuttings descriptions and well composite logs. This type section is from the Rainier 1 well in the central Vulcan Sub-Basin.

### 2.3.4 Seismic Interpretation

A regional grid of seismic data, the 2D seismic survey described in section 2.2, was loaded into Schlumberger's GeoFrame software for interpretation. Well locations, wireline log data and checkshot data were also loaded into GeoFrame along with biostratigraphic data and regional hiatuses, which were defined during wireline and biostratigraphic analysis. The distribution of sealing intervals was included with the seismic mapping in order to define the three dimensional nature of each sealing facies. By using a series of two-way time maps and isochron maps, it was possible to investigate how seal thickness and lateral extent change areally.

#### 2.3.4.1 Mapping Methodology

Wireline logs, biostratigraphy and associated formation picks were posted on the seismic data in order to identify the seismic character of events. Synthetic seismographs were generated where sonic and density logs were available to tie the well data to the seismic section.

A standard synthetic generation workflow was used, which included minimal editing of sonic and density logs for logging spikes and cycle skipping, calibration of the sonic log to checkshot data. The sonic log was blocked (averaged) to highlight the main trends in velocity variation. Wavelet extraction from the seismic and synthetics were bulk shifted if required to match the synthetic to the seismic trace.

A seismic pick was made on the synthetic at the corresponding peak, trough or crossover to the geological marker. This event was then mapped throughout the area to check that it tied to other wells in the area. The seismic picks were iteratively adjusted and reinterpreted until the interpretation tied on a regional scale. The event was then mapped over the extent of the study area, utilising standard interpretation techniques.

The Top Paleocene reflector is prominent in the southern and central Vulcan Sub-Basin and was auto-tracked over large areas. In areas with little well control and/or complex Miocene structures, the seismic section was flattened on the Top Paleocene reflector to aid interpretation.

#### 2.3.4.2 Two way time, isochron maps

A series of two way time and isochron maps were generated to investigate the thickness and lateral distribution of seal deposition from the Late Jurassic to Paleocene section in the Vulcan Sub-Basin. Regional two way time and isochron horizon grids were generated from 2D seismic lines. These grids were used to determine the present day spatial configuration of sealing intervals. Two way time maps were also used to identify structural trends in the sub-basin.

Variations in sediment thickness were determined by generating a series of time-thickness maps (isochron maps) for each stratigraphic unit: this was done by subtracting the top horizon from the bottom horizon and gridding the final result.

# Chapter 3 Seal Analysis

## 3.1 Introduction

This chapter outlines the methodology for determining seal capacities, a comparison of threshold pressure results from cuttings and core samples, and a discussion on evaluating seal potential (i.e. seal risk).

A seal is any rock that impedes the movement of hydrocarbons, whereas a reservoir is any porous and permeable rock that is capable of holding hydrocarbon (Downey 1984; Kaldi and Atkinson 1997), this definition is widely accepted in literature and estimating seal capacity is in effect solving basic capillary pressure equations as outlined by Schowalter (1979). A top seal is a rock that overlies a reservoir and forms a barrier to the vertical migration of hydrocarbons. Seal capacity is defined as the hydrocarbon column height that a seal can support.

## 3.2 Capillary Seals

The forces acting on a seal overlying a hydrocarbon-bearing reservoir are shown in Figure 3-1. The main driving force for hydrocarbon migration is buoyancy, or pressure caused by the density difference between hydrocarbons and formation water. Buoyancy pressure is dependent on the hydrocarbon column height (h), the density of the hydrocarbons ($\rho_{hc}$) and the density of formation water ($\rho_w$) (Figure 3-1, Equation 1).

The main resistive force to hydrocarbons entering the seal is capillary pressure. Capillary pressure (Pc) is dependant on interfacial tension ($\sigma$: the forces acting between hydrocarbons and formation water), wettability ($\theta$: the forces acting between the fluids and the rock) and the radius ® of the largest pore throats in the sealing rock (Figure 3-1, Equation 2).

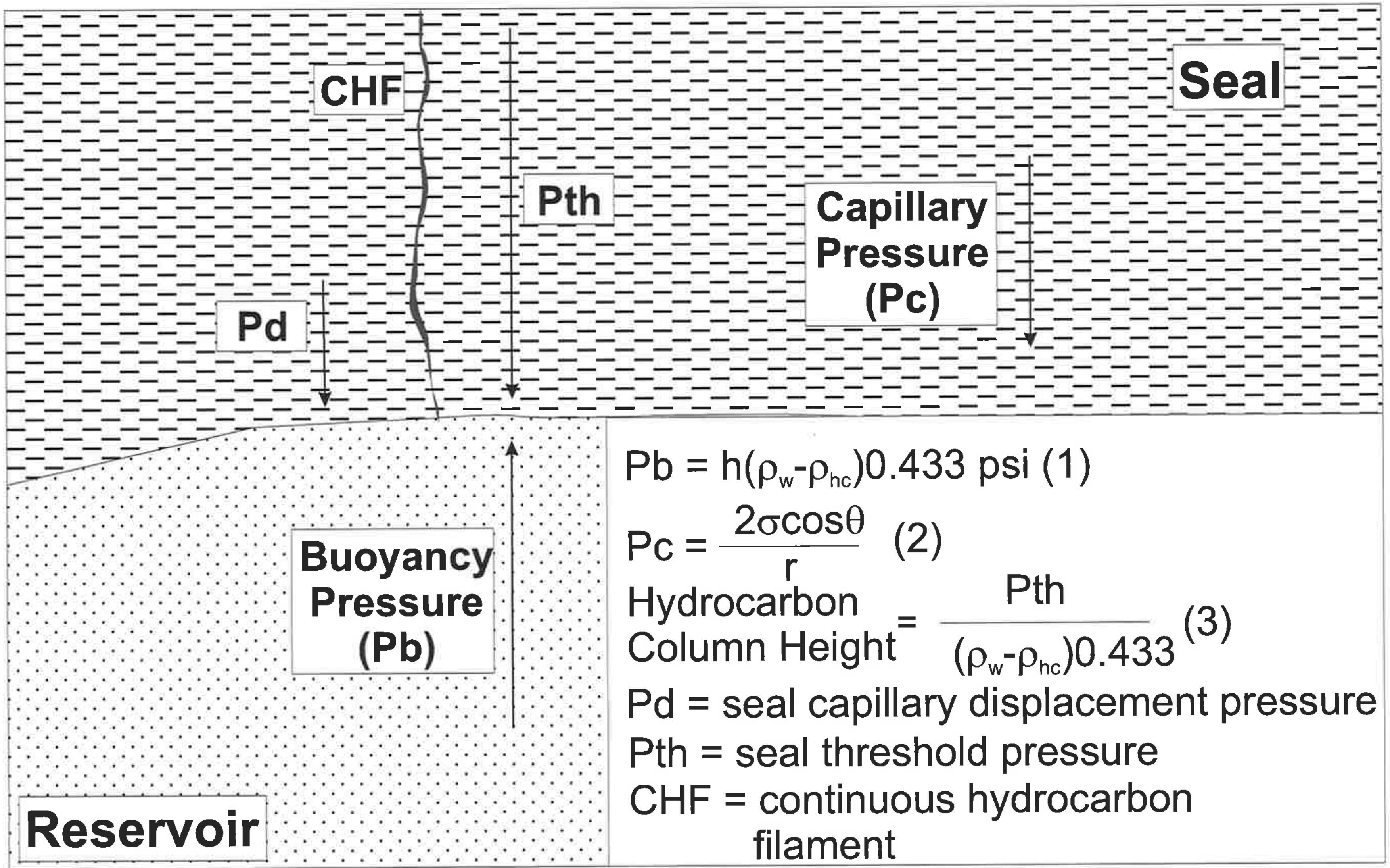



Figure 3-1: Schematic showing the forces controlling hydrocarbon entrapment and equations for those forces. Pb = buoyancy pressure (psi), the driving force for hydrocarbon migration is dependant on h(ft) = the height of the hydrocarbon column and (w-hc) = the density difference between the hydrocarbon and formation water (g/cc) (Equation 1). Pc = capillary pressure (psi), the resistive force is dependant on = interfacial tension (dynes/cm), = contact angle (degrees) and r = the size of the largest interconnected pore throats (Equation 2). Pc has two components, Pd = capillary displacement pressure (psi) (pressure at which hydrocarbons enter the seal) and Pth = threshold pressure (psi). Pb > Pd hydrocarbons enter the seal. Pb > Pth a continuous hydrocarbon filament (CHF) is present through the seal. The seal will

### 3.2.1 Buoyancy Pressure

The driving force for hydrocarbon migration is buoyancy (or the buoyant force), which is caused by the density difference between the water phase and the hydrocarbon phase (Schowalter 1979; Smith 1966; Smith 1980; Vavra et al. 1992; Watts 1987).

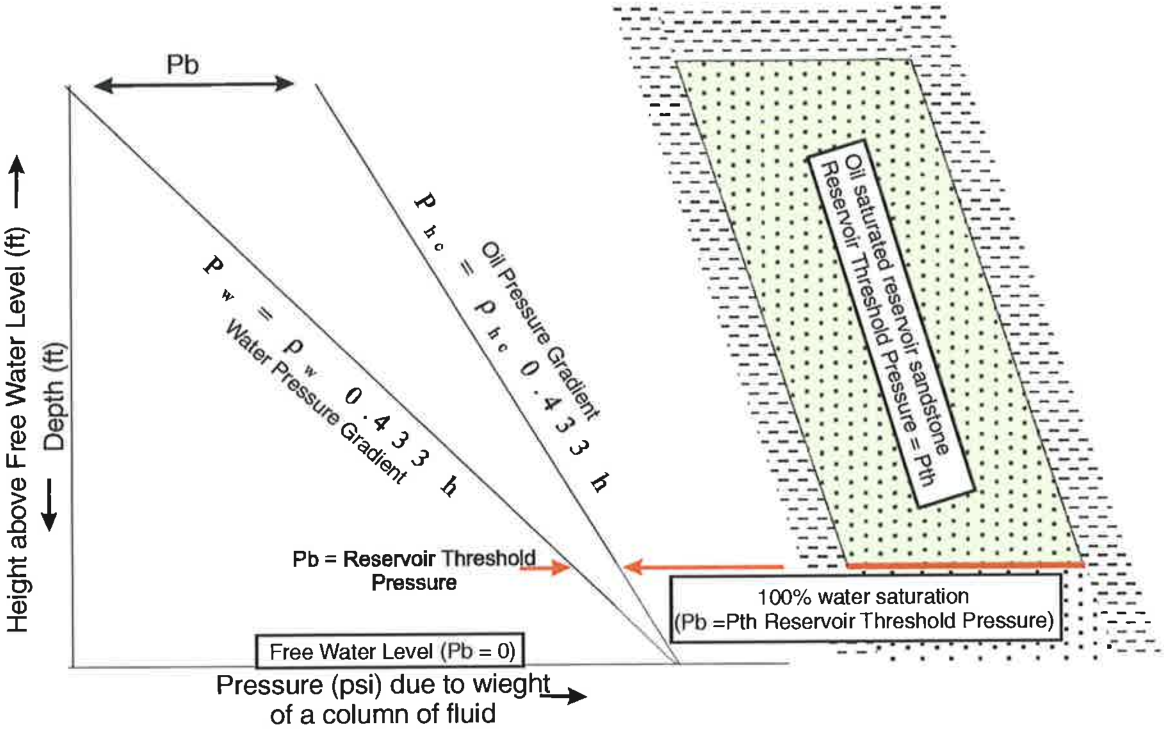



Figure 3-2: Buoyancy pressure of an oil filled reservoir under static conditions (after Schowalter 1979).

For a continuous hydrocarbon column, the buoyant force increases upward through the column. Figure 3-2 illustrates the increase in the buoyant force (Pb) (psi) of a hydrocarbon column trapped in a porous sandstone reservoir on a pressure vs. depth (ft) plot. Pw represents the water pressure (psi) gradient above the free water level (FWL = no buoyant force) and Phc represents the hydrocarbon pressure (psi) gradient above the FWL. The density of the respective fluids times 0.433 determines the slopes of the water gradient and oil gradient. At any height (ft) of hydrocarbon column above the FWL, the buoyant force is equal to the difference between Phc and Pw (Schowalter 1979).

Figure 3-2 shows a line called the '100% water saturation depth' which is determined by the reservoir threshold pressure. No hydrocarbons are present between the FWL and the 100% water saturation line because the reservoir threshold pressure must be overcome for hydrocarbons to enter the pore network of a rock.

The buoyant force can be calculated if the density of the hydrocarbons, density of the wetting phase fluids and the height of the hydrocarbon column is known using (1).

Pressure (psi) due to the buoyant force (Pb) can be written as:

$$Pb = (\rho_w - \rho_{hc})\ g\ \ h(m) \qquad (1)$$

Or

$$Pb = (\rho_w - \rho_{hc})\ 0.433\ h(ft)\ \text{(for PSI/ft conversion)} \qquad (2)$$

Where $\rho_w$ (g/cc) and $\rho_{hc}$ (g/cc) are the densities of water and hydrocarbons respectively, g is the gravitational constant (9.8 m/s) and h is the height of the hydrocarbon column above the free water level (FWL). Pb is the buoyancy pressure (psi) defined as the pressure exerted on the seal, by a hydrocarbon column, under hydrostatic conditions.

Subsurface densities of hydrocarbons and water need to be determined in order to perform the calculations for buoyancy pressure. For the purpose of this study, the range of brine and hydrocarbon densities defined in Table 3-1 were used. The low and high hydrocarbon density values were picked based on empirical data from the Jabiru, Challis and Skua fields, whereas the low and high values for water densities were picked to encompass a wide range of possible brine densities in the Vulcan Sub-Basin.

| Sensitivities | Low | | High |
|---|---|---|---|
| Interfacial Tension (dynes/cm) | 10 | 20 | 30 |
| Oil Densities (API) | 37 | 39 | 42 |
| Water Densities (g/cc) | 1 | 1.05 | 1.1 |

Table 3-1: Range in values used to calculate seal capacity sensitivities (shown as error bars on seal capacity results figures).

### 3.2.2 Entry Pressure, Displacement Pressure and Threshold Pressure

It is important to note the difference in Figure 3-1 between capillary displacement pressure (Pd), which is defined as the pressure at which the non-wetting phase first enters the pore system, and capillary threshold pressure (Pth), which is defined as the pressure at which a continuous hydrocarbon filament (CHF) first exists through the pore network of the seal. Pressure units used throughout this thesis are pounds per square inch (psi).

$$Pth = \frac{2\sigma\cos\theta}{r} \qquad (3)$$

Pth is considered to be the resistive force to hydrocarbon migration. Put another way, for hydrocarbons to migrate through a seal, Pb of the hydrocarbon has to be greater than Pth of the seal. As shown in Equation (3) Pth increases as interfacial tension ($\sigma$) increases, wettability contact angle ($\theta$ deg) decreases and the radius r of the largest interconnected pore throats in the rock decreases.

### 3.2.3 Interfacial Tension

Interfacial tension between oil and water was defined by Schowalter (1979) as the work required to enlarge by unit area the interface between two immiscible fluids and is a measure of the attraction of 'like' molecules within a fluid and the repulsion of 'dissimilar' molecules between different fluids.

Schowalter (1979) suggests a sub-surface interfacial tension range of 5 to 35 dynes/cm for an oil-water system and 30 to 70 dynes/cm for gas-water system.

O'Connor (2000) documented the discrepancy in published recommendations of values appropriate for interfacial tension estimates and referenced results of empirical back calculations of interfacial tension (based on fill to leak hydrocarbon accumulations) ranging between 26 and 30 dynes/cm.

For the purpose of this study, a range of interfacial tension was applied to all seal capacity calculations (values in Table 3-1).

### 3.2.4 Wettability

Wettability is defined as the work necessary to separate a wetting fluid from a solid (ie water from grains of quartz) (Schowalter 1979). Wettability is normally expressed as the contact angle (θ) of the oil-water interface against the rock, as measured through the denser fluid. For contact angles between 0 and 90 degrees, rocks are generally considered water wet, whereas for contact angles of between 90 and 180 degrees, the rocks are considered to be oil wet (Schowalter 1979).

The significance of wettability is that oil would preferentially adhere to grain surfaces in oil wet rocks, while water wet rocks would have grain surfaces covered by water. (Schowalter 1979) points out that whereas angles of greater than 90 degrees are generally considered oil wet, the contact angle may need to be as high as 140 degrees for oil to be preferentially absorbed over water.

Generally speaking, sedimentary rocks are considered to be water wet because of the initial depositional exposure of pore surfaces to water and the strong attraction of water to most rock surfaces. Furthermore, water is an excellent wetting fluid and it is often assumed that a thin film of water coats all grain surfaces, thus making the contact angle θ close to 0 (Equation 3). (Schowalter 1979) suggests that rocks rich in organic matter (source rocks) may not be water wet in the sub-surface.

For this study pores and pore throats are assumed to be water wet.

### 3.2.5 Pore Throat Radius

The third factor required to estimate Pth is the radius of the largest interconnected pore throats in the rock. From Equation 3, it can be seen that Pth is inversely proportion to the radius of the interconnected pore throats.

### 3.2.6 MICP

Capillary pressure properties of rocks (specifically Pth) can be evaluated by using mercury injection capillary pressure analysis (MICP) (Purcell 1948; Schowalter 1979; Vavra et al. 1992).

MICP data are acquired by injecting mercury into evacuated, cleaned and extracted core or cuttings samples. Mercury injection pressure is increased incrementally and the percentage of rock pore volume saturated by mercury is measured after allowing sufficient time for equilibrium to be reached. The injection pressure is increased incrementally until the mercury pressure reaches a predetermined value (60 000 psi in this study). The pressure is then graphed against mercury saturation as shown in Figure 3.3 (A and B).

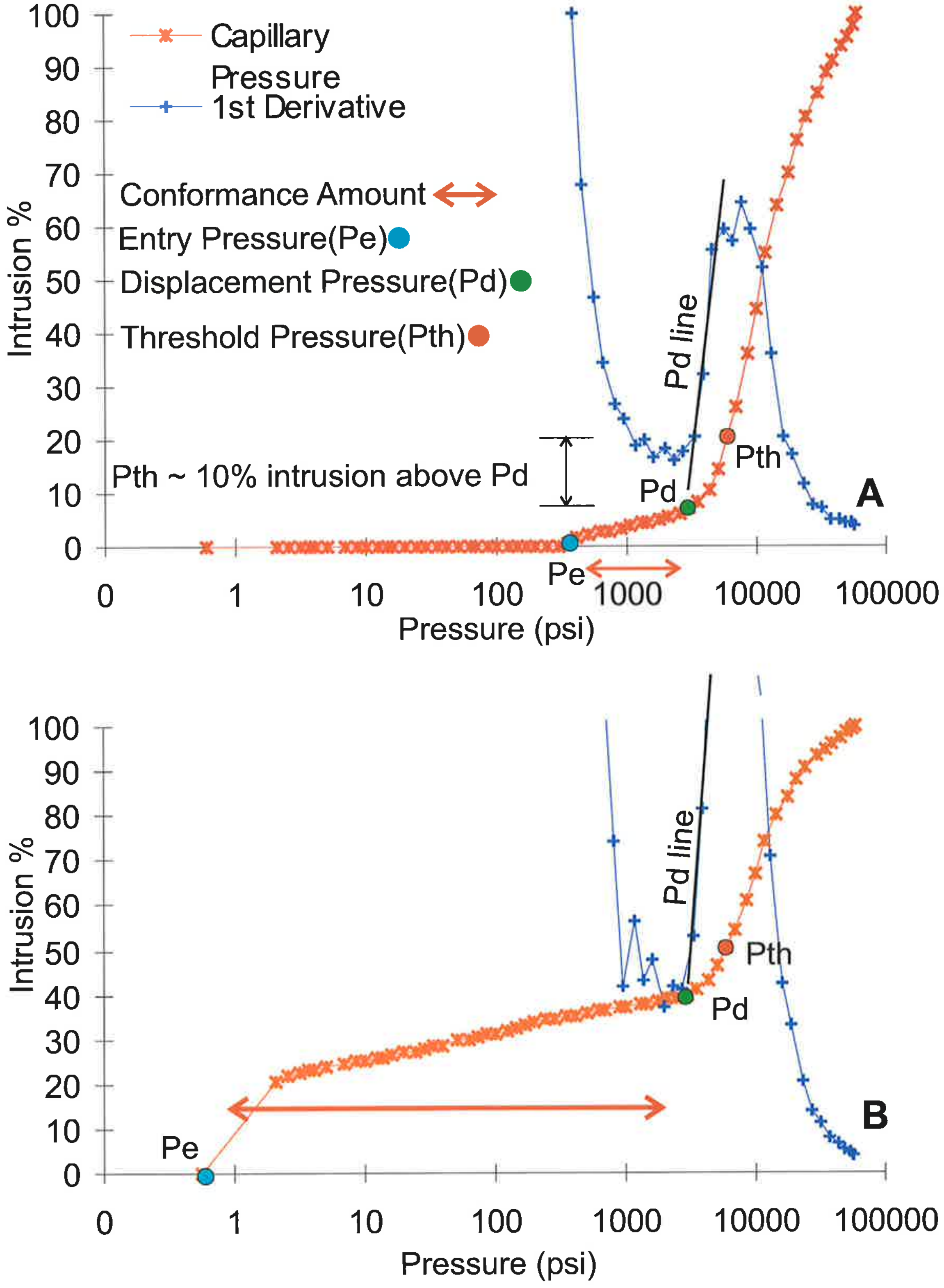



Figure 3-3 Mercury injection capillary pressure curve and 1st derivative for a claystone sample (A) and synthetic cuttings sample (B) showing entry pressure Pe, displacement pressure Pd, threshold pressure Pth and conformance effects. Y-axis values of the 1st derivative curve are scaled to plot on the same scale as the MICP curve. The first derivative of the intrusion curve is effectively the rate of intrusion of mercury with increase in pressure or the flow of mercury with change in pressure. The displacement pressure (Pd) is taken to be point at which the 1st derivative increases - indicated by the line of best-fit intersecting the MICP curve. The threshold pressure (Pth) is then estimated at 10% intrusion above the displacement pressure point. See text for details.

### 3.2.7 Threshold pressure

Schowalter (1979) experimentally detected critical saturations of mercury at Pth and has shown that the non-wetting phase saturation, required for a continuous hydrocarbon filament, has a range of 4.5 to 17%. Schowalter (1979) suggested that by determining the mercury pressure on the capillary pressure curve at 10% non-wetting phase, saturation Pth could be estimated. Sneider et al. (1997) compared observed hydrocarbon column heights in the field to column heights calculated from capillary pressure curves, and observed that seal capacity measurements approximated empirical hydrocarbon column heights where Pth was determined at a non-wetting phase saturation of 7.5%. Based on numerical simulation of bond percolation processes in a 3D 10x10x10 lattice, Schlomer and Krooss (1997) documented that the onset of percolation, equivalent to the first interconnected pathway, corresponds to 13% non-wetting phase saturation.

Seal capacities calculated using Pd instead of Pth will underestimate true seal capacity by between 4.5 and 17%. When calculating seal capacities for this thesis a 10% sensitivity was applied to the Pd determined from capillary pressure plots to determine the error underestimating Pth would introduce.

### 3.2.8 Conformance

Conformance is defined as the difference (in PSI) between the entry pressure (Pe) and the displacement pressure (Pd). In order to determine Pth from a MICP curve, Pe and Pd must be determined first. Before entering the pore network, mercury conforms around the sample, filling surface irregularities. This 'conformance' appears as apparent mercury intrusion on the MICP curve and can make picking Pd difficult. Figure 3.3 shows MICP results for a claystone core plug and synthetic cuttings made from the same core. The conformance, highlighted by the red arrow, is negligible for the core plug MICP curve (Figure 3.3A). However, for cuttings, the sample size is smaller, with a more irregular surface causing conformance effects to increase significantly (Figure 3.3B).

The cause of the extra conformance seen in both the real and synthetic cuttings samples (Figure 3.3) is most likely due to micro fractures and surface effects created by physical damage. As the volume of mercury intruded into a seal lithology is at least an order of magnitude smaller than the volume of mercury injected into a reservoir sample, the conformance affects are appear more pronounced for seal lithologies as these effects make up a larger proportion of the intruded mercury volume.

Conformance must be accounted for before determining Pd and Pth. Previous studies have removed conformance by visual inspection of the MICP curve (Schowalter 1979; Sneider et al. 1997). While visual inspection may be appropriate for removing conformance in samples with clear inflection points and low conformance effects, many MICP curves for cuttings samples have large conformance effects, as exemplified in Figure 3.3B, and a more robust method for finding the displacement pressure is required.

### 3.2.9 1$^{st}$ derivative – a consistent way of removing conformance

The 1$^{st}$ derivative of the MICP curve effectively shows the rate of intrusion of mercury with increasing pressure. The y-axis values of the 1$^{st}$ derivative curve were multiplied by a constant, so as to plot on the same scale as the MICP curve. This shape of the first derivative curve consistently shows a decreasing amount of mercury intrusion decreases with increasing pressure and decreasing conformance affects (Figure 3.3'1'). When the mercury enters the sample, the first derivative curve, which represents the rate of mercury intrusion into the MICP vessel, can be seen to increase significantly (Figure 3.3 points at the base of the 'Pd line').

Displacement pressure (Pd) is interpreted to be the point at which the rate of mercury intrusion increases significantly. A practical way of determining Pd is to extend of the line of best fit ('Pd line' in Figure 3.3) to the MICP curve. Pth is then interpreted to be 10% non-wetting phase intrusion above Pd.

The first derivative curve is scaled so that the points just before the rate of mercury intrusion into the sample (Figure 3.3 '1') overlie the MICP curve. In this way Pd can be picked consistently on different samples as the pressure where mercury intrusion into the sample increases significantly. The error in picking the true Pd of a sample is accounted for by taking using a +/-10% range of Pth when calculating seal capacity. Throughout this study a line of best fit was drawn graphically to fit the points associated with the increase in the rate of mercury intrusion into the sample. The line of best fit is used as a guide to determine the MICP reading closest to the beginning of high rates of mercury intrusion into the sample.

This methodology was developed and tested for this study to remove conformance effects from cuttings MICP results.

## 3.3 Seal Capacity (Column Height)

$$Pth_{hw} = \frac{\sigma_{hw}.\cos(\theta_{hw})}{\sigma_{ma}.\cos(\theta_{ma})}(Pth_{ma}) \qquad (4)$$

Quantitative application of MICP data to subsurface conditions requires the conversion of MICP values to subsurface hydrocarbon-water capillary pressure values. The conversion factor is shown in Equation 4, where $Pth_{hw}$ is the threshold pressure for the hydrocarbon water system, $Pth_{ma}$ is the threshold pressure for the mercury air system, $\sigma_{hw}$ is the interfacial tension of the hydrocarbon water system (dynes/cm), $\sigma_{ma}$ is the interfacial tension of the mercury air system, $\theta_{hw}$ is the contact angle of hydrocarbon and water, $\theta_{ma}$ is the contact angle of mercury and air against the rock (Purcell 1948; Schowalter 1979; Vavra et al. 1992).

The sensitivities due to variation of subsurface interfacial tension values and the assumption that subsurface seals are water wet have been discussed in previous sections. Thus, as $\theta_{hw}$ is taken to be zero, cos ($\theta_{hw}$) = 1. The interfacial tension of mercury and air is 480 dynes/cm (at standard temperature and pressure) and the contact angle between mercury and air is 140 degrees.

$$HC(ft) = \frac{Pth_{seal} - Pth_{res}}{(\rho_w - \rho_{hc})0.433} \qquad (5)$$

The seal capacity (HC(ft)), defined as the amount of hydrocarbon column a seal can hold, is calculated using Pth (converted for a hydrocarbon water system) and Equation 5, where $Pth_{seal}$ is the threshold pressure of the seal, $Pth_{res}$ is the threshold pressure of the reservoir, $\rho_{hc}$ is the density of hydrocarbons and $\rho_w$ is the density of formation water (Purcell 1948).

As outlined in Chapter 3.2.1, in order to model the uncertainty of various variables used to calculated seal capacity, a range of values was used for each input variable show in Equation 5.

## 3.4 Cuttings vs Core

### 3.4.1 Introduction

Many top seal studies face the problem of acquiring enough rock sample for MICP measurements, which are essential for determining seal capacities. Samples can consist of core, sidewall cores and/or cuttings; core of the top seal is the most desirable but the least commonly obtained. Cuttings, on the other hand, are the most commonly available sample type, but provide the least “reliable” measurement. One component of this study, therefore, investigates the viability of using cuttings to determine top seal capacity.

Relatively few authors have investigated the use of cuttings in MICP analysis. Purcell (1948), in one of the original papers dealing with capillary pressures, mentioned the usefulness of cuttings where no core is available for MICP analysis. Schowalter (1979) evaluated the reliability of drill cuttings-derived MICP curves on two sandstone samples, an interbedded sand/shale sample and a chalk sample by crushing cores to various sized, simulated cuttings. He suggested that capillary properties of irregular rocks, which are of drill cuttings size, can be measured with accuracy. However, he noted that the smaller the sample the more likely the estimated Pth will be less than that measured from a full size core plug.

A comprehensive paper on estimating seal capacities from cuttings was published by Sneider et al. (1997) in which they evaluated seals with Pth ranging from approximately 100psi to 5000psi. Sneider et al. (1997) further determined empirical adjustment factors (EAF), which are added to Pth interpreted from cuttings-derived MICP curves. For seals with Pth ranges between 1400psi to 6900psi, the EAF range was between 923psi and 4009psi, with an average EAF of 1810psi. The EAF represents a significant error in estimating Pth between cuttings and core samples. Sneider et al. (1997) acknowledged the importance of removing conformance before Pth could be determined; the authors however, did not outline a method for doing this. The large variance in EAF values provided by Sneider et al. (1997) may be explained by the large amounts of conformance associated with cuttings-derived MICP curves.

### 3.4.2 Sample Preparation

Three types of samples were used for this study: drill cuttings, synthetic cuttings and core. Drill cuttings were prepared by removing particles smaller than 0.8mm using a 1mm sieve. This was done because samples smaller than 1mm may clog the MICP machine. Synthetic cuttings were prepared by crushing bulk core into cuttings-sized particles and then filtering these through a 1mm sieve.

All core plugs used in this study were oriented with respect to vertical and were prepared in three ways. Figure 3-4 illustrates the various types of mercury intrusion into a vertically oriented (plug length parallel to core) epoxy-coated sample. For vertical intrusion samples were coated with epoxy on all sides, leaving only the top and bottom open. Samples for horizontal intrusion were coated on the top and bottom leaving the sides open. Bulk core samples were not coated at all.

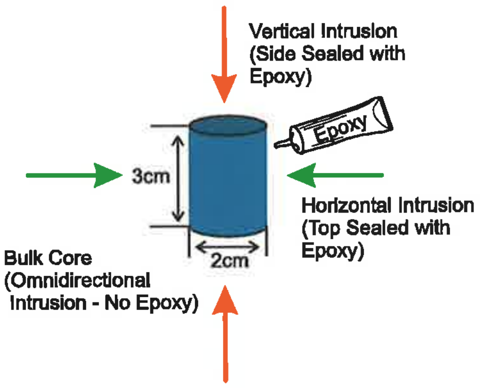



Figure 3-4: Core plugs are oriented in a vertical direction; this example is of a vertical core plug. For mercury intrusion into the sample in a vertical direction, the sides of the core plug are coated with epoxy. For mercury intrusion in a horizontal direction, the top and bottom of the core plug are coated with epoxy. A bulk core sample has no epoxy coating and mercury enters the pore network form all directions. (modified after (Sneider et al. 1997))

### 3.4.2.1 Cuttings vs. Core Results

Four sets of results, which compare MICP curves of epoxy sealed core, bulk core, synthetic cuttings and, where possible, real cuttings obtained from just above or below the cored interval, are shown in Figure 3-5. Pd values, interpreted using the 1st derivative, are shown as green dots and Pth, taken at 10% above Pd, are shown as red dots on the MICP curves. Conformance increase due to cuttings irregularities is highlighted using red arrows. Scanning electron microscope (SEM) images for each sample in Figure 3-5 are shown in Figure 3-6.

It is clear from Figure 3-5A and Figure 3-5B that real cuttings curves and synthetics cuttings curves are very similar in shape and conformance effects. This suggests that MICP curves derived from synthetic cuttings are comparable to MICP curves derived from real cuttings. Thus synthetic cuttings have a valid MICP intrusion curve. Figure 3-5C and Figure 3-5D compare synthetic cuttings and core only as no cuttings could be obtained from the same lithology above the core sample.

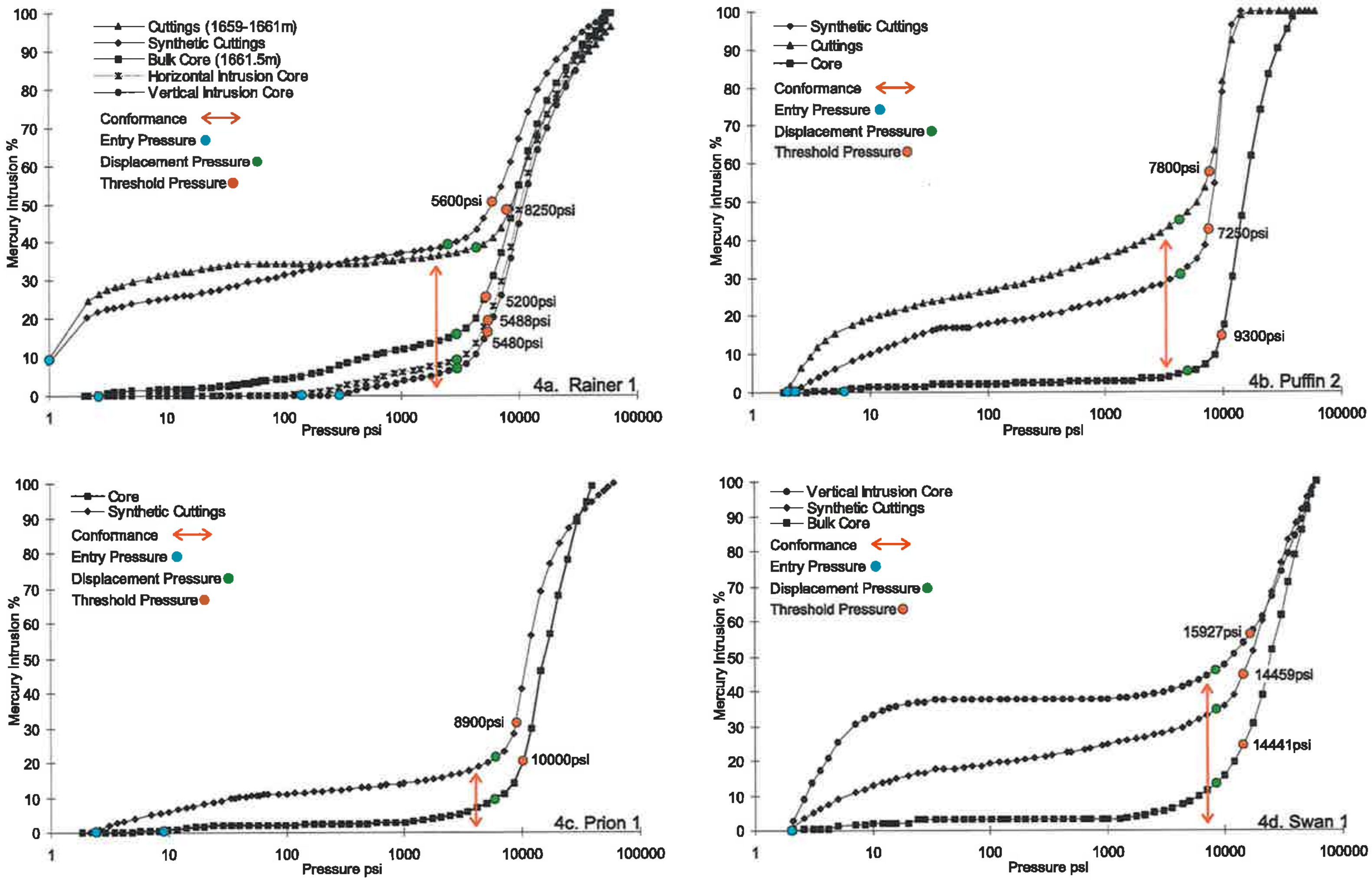



Figure 3-5: Capillary pressure curves for four comparison studies on cuttings and core. Entry pressures, determined using first derivative, are marked with green dots and threshold pressures, taken at 10% intrusion above the entry pressure, are marked with red dots. Note the increase in conformance due to the greater surface area and undulation of cuttings samples.

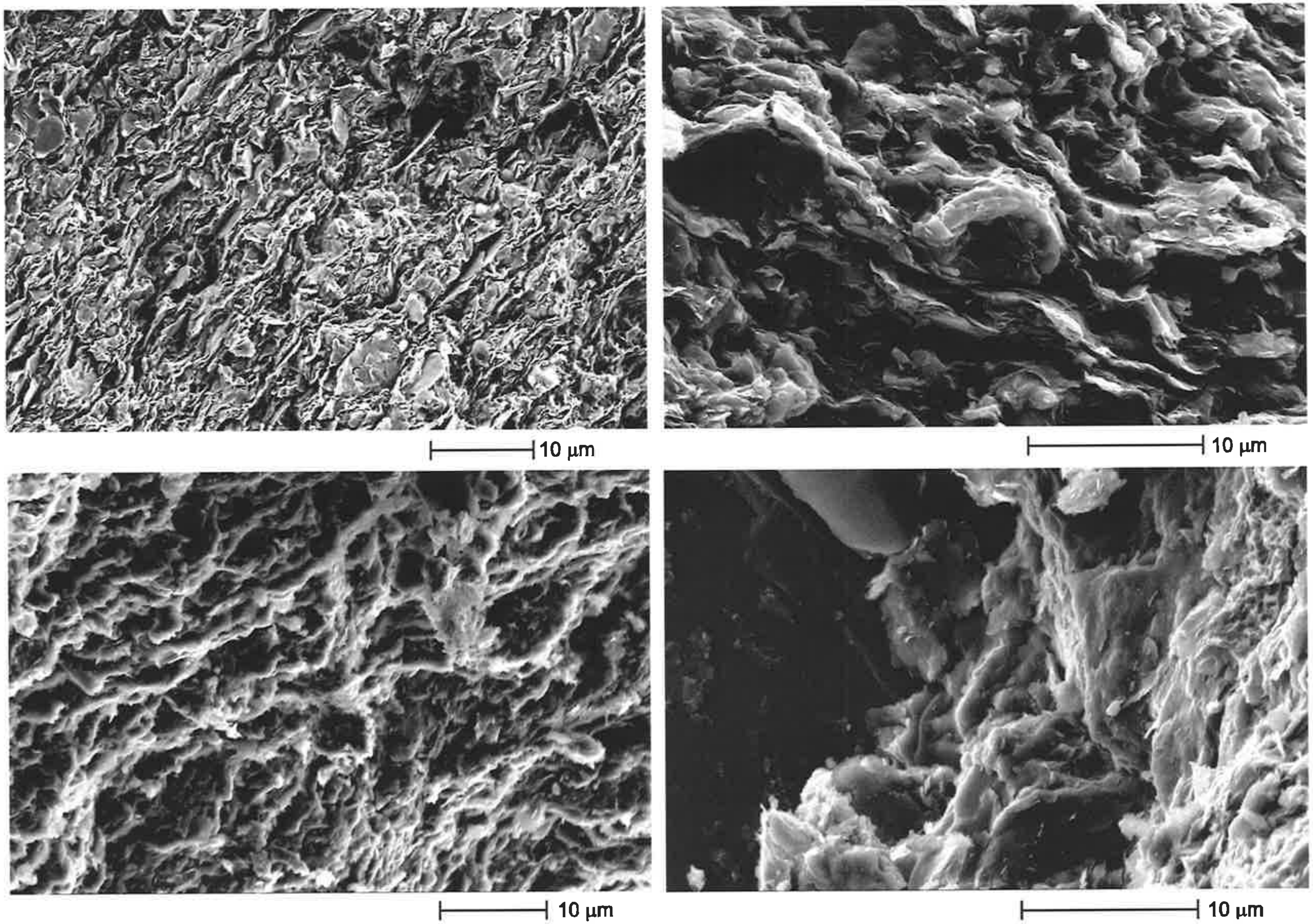



Figure 3-6: SEM images correspond to the mercury injection capillary pressure graphs in Figure 3-5 (e.g. Image A corresponds to Graph A in Figure 3-5. All four images show predominantly detrital clay fabric. The seals shown in Images B, C and D also contain some carbonate grain support in the clay fabric.

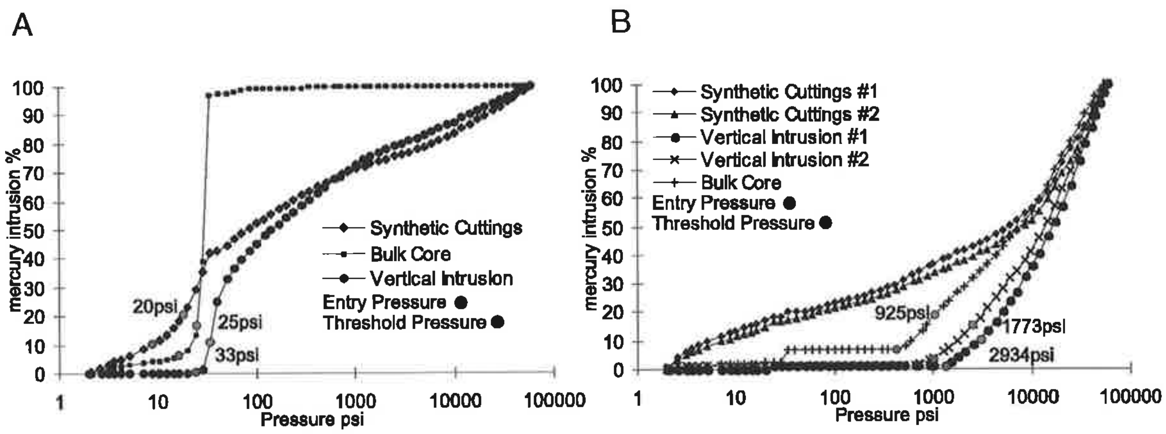



Figure 3-7: Mercury injection capillary pressure (MICP) curves for core and cuttings samples of a sandstone (A) and a sandy mudstone (B). At low pressures conformance effects make it difficult to pick entry and threshold pressures. There is a distinct increase in conformance when comparing the core and cuttings MICP curves for sample A. It is not possible to pick an entry or threshold pressure for the cuttings sample MICP curves shown in B.

It is not possible to reliably estimate Pd or Pth from cuttings curves shown in Figure 3-7. In both cases synthetic cuttings exhibit the most conformance and the lowest Pd and Pth values. Bulk core plugs have the next highest conformance and next lowest Pd and Pth. By contrast, vertical intrusion core samples had the least conformance effects, thus allowing the most reliable Pd and Pth interpretation.

Low Pd and Pth, shown in Figure 3-7A, are characteristic of sandstone samples. Due to the brittle nature and relatively large grain sizes of many types of sandstone, the integrity of the pore networks is commonly not preserved in real or synthetic cuttings. Hence, the Pd and Pth interpreted from cuttings MICP curves are lower than the actual Pd and Pth.

Figure 3-7B illustrates a seal with interbedded claystone and siltstone beds. Pd and Pth interpreted for bulk core and vertical intrusion core samples show a variance of over 1000psi. These results indicate heterogeneity on a core scale as there is a larger interconnected pore throat network in the horizontal direction than in the vertical. Consequently Pd and Pth is lower for the bulk core and much higher for vertically intruded core. It was not possible to interpret Pd and Pth from the MICP curves of the cuttings.

The results in Figure 3-7 suggest that Pd and Pth interpretation is not always possible on cuttings-derived MICP curves. However, where a clear inflection exists and where cuttings are representative of the sub-surface rocks, as with the results shown in Figure 3-5, cuttings-derived MICP curves can provide valid Pd and Pth values.

Pd and Pth values interpreted from MICP curves in Figure 3-5 and Figure 3-7 are displayed in Figure 3-8. The sample type and MICP reference are displayed at the base of each bar in the graph with the pressure value shown at the top of each bar. The percentage difference between Pd and Pth values for different types of core and cuttings samples, normalized to the bulk core sample, are displayed in Figure 3-9.

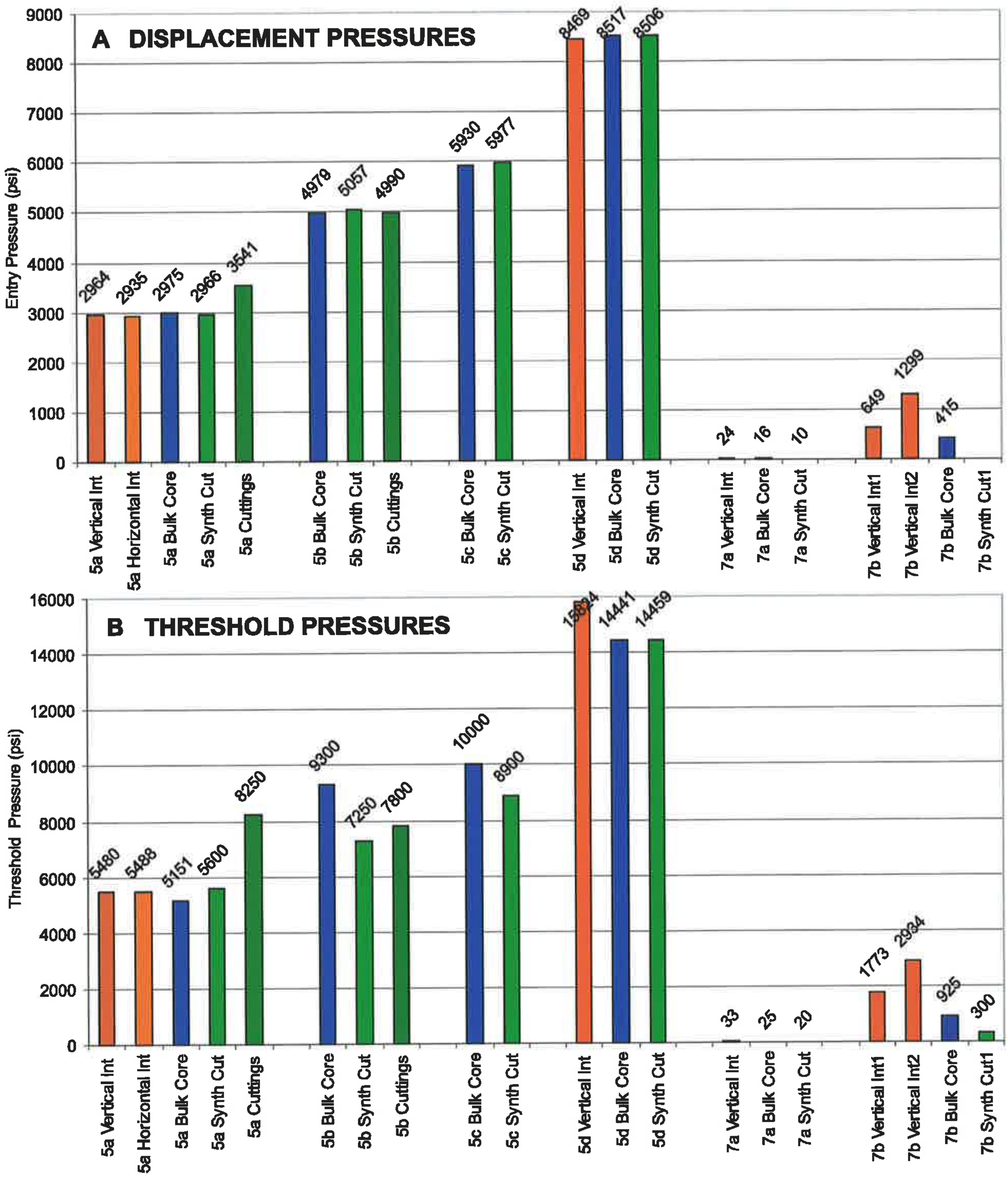



Figure 3-8: Displacement pressure differences (A) and threshold pressure differences (B) are show for different types of sample. Pressure values are printed at the top and the sample type is printed at the base of each bar. Samples with prefix '5' correspond to MICP curves in Figure 3-5 while samples with prefix '7' correspond to MICP curves in Figure 3-7. Displacement pressures were determined using the first derivative; threshold pressures were taken at 10% intrusion above the entry pressure.

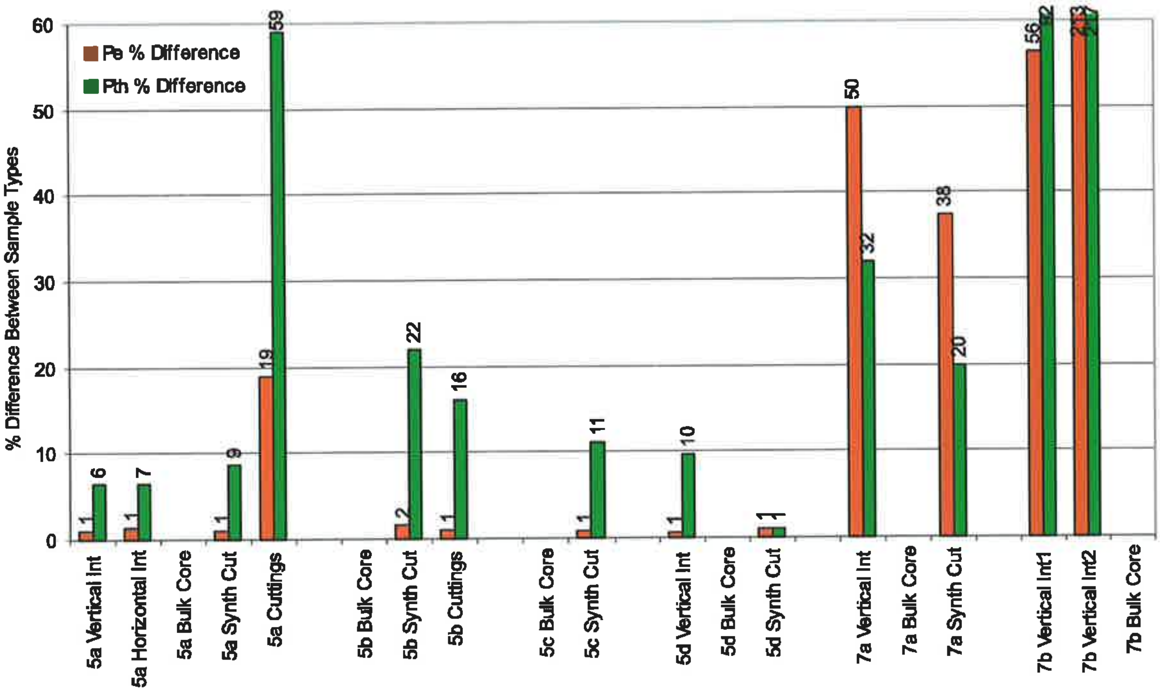



Figure 3-9: For each sample the difference in displacement pressure (red bars) and threshold pressure (green bars) is show as a percentage relative to the 'Bulk Core' displacement pressure and threshold pressure. The sample reference number and sample type are printed at the base of each bar. Sample 5a is a sandstone and the higher difference in Pd and Pth values between core and synthetic cuttings is largely attributed to conformance effects. It was not possible to pick either Pd or Pth on the synthetic cuttings curves for sample 5b, the large difference in pressure values between 'Vertical Intrusion' and 'Bulk Core' is attributed to the presence of lower Pd and Pth (bigger interconnected pore throat paths) with omnidirectional intrusion.

The four seal samples for which synthetic and real cuttings provided valid results (prefix '5' in Figure 3-8 and Figure 3-9) showed a difference in Pd of less than 3%. However, the difference in Pth ranged from 6% to 20% for core and synthetic cuttings. The greater difference in Pth variance may be explained by considering that the shape of the MICP curve is smoothed with increasing conformance. The curvature of the MICP curve influences the Pth value taken at 10% non-wetting phase saturation above Pd.

The two samples for which it was not possible to interpret Pd and Pth values (prefix '7' in Figure 3-8 and Figure 3-9) from cuttings derived MICP curves clearly show large differences in interpreted Pd and Pth.

### 3.4.2.2 Cuttings vs. Core Discussion

This study demonstrates that, under certain circumstances, cuttings can provide valid results in MICP analysis. Where invalid results are obtained, it is not possible to determine Pd and thus interpret Pth. Where valid results are obtained and Pd is determined using the 1$^{st}$ derivative, the difference in Pd between core and synthetic cuttings samples is less than 3%. Estimated Pth values have a greater variance than Pd due to the shape of the MICP curve changing with increased conformance. The error in seal capacity calculations, based on Pth obtained from cuttings, ranges between 6 and 20%.

Following the conclusion that cuttings can provide valid seal capacity results, sampling for a regional analysis of seal capacity in the Vulcan Sub-Basin was undertaken, with top seal cuttings sampled from over 40 wells.

## 3.5 Analytical Techniques

### 3.5.1 Sampling Strategy

Regional seals were defined based on integrated geological and geophysical criteria outlined in Chapter 2. Cuttings samples representative of the seal in a particular well were collected from a range of depth intervals determined from wireline logs.

All sample collection was undertaken at the Geoscience Australia core library in Canberra, Australia. Cuttings were obtained from sample bags representing 3 to 5m intervals. Due to government restrictions, no more than ¼ of the sample weight could be taken for analysis. Multiple samples were collected over the base of the seal interval and from intervals higher in the section that were thought to be equivalent to seals in other parts of the basin.

These samples were collected to build up the data base for basin wide seal characterisation and to test regional variation.

## 3.5.2 Preparation of Samples for MICP

In order to run MICP analysis, the cuttings are placed in a powder penetrometer (Figure 3-10), which is sealed and evacuated to a vacuum before mercury is allowed to enter the chamber containing the sample. Due to design constraints, cuttings smaller than 0.8mm in diameter will clog the penetrometer and must be sieved out. There was often residual dried drilling mud coating the cuttings. The following procedure was followed for MICP sample preparation:

Cuttings samples were washed with methylated spirits to remove any coating drilling mud. The cuttings were then dried in an 80°C oven for 10 minutes after which the sample was sieved using a 0.8mm sieve. Cuttings that were larger than 0.8mm were then dried in an oven at 80°C for 24 hours. The cuttings sample set was then examined at 10x magnification and any obvious cavings were removed.

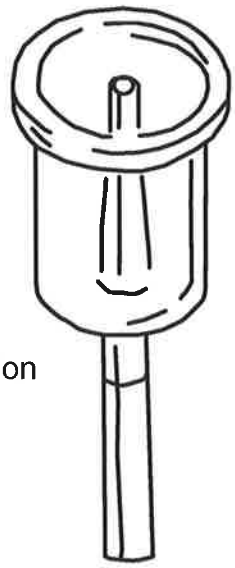


Figure 3-10: Schematic of a powder penetrometer. The rock sample is placed inside the cavity in MICP analysis.

### 3.5.3 SEM Preparation and Methodology

Scanning electron microscope (SEM) samples were prepared by sticking individual cuttings to an epoxy-coated stub. Once the epoxy had dried the cuttings were broken, usually using tweezers, so as to provide a fresh rock surface.

A standard 1 micron thin gold coating was applied to the SEM stub samples and the cuttings were analysed using a Philips XL-30 Field Emission Scanning Electron Microscope (1-30 kV field emission SEM, nominal resolution < 2.0 nm at high kV, < 8nm at 1 kV.), with an integrated EDAX Energy Dispersive X-ray analyser package.

Minerals were initially identified using the integrated EDAX x-ray analyser package for each formation and subsequent identification was performed by visual inspection.

### 3.5.4 XRD Preparation

The standard x-ray diffraction method was employed, which consisted of crushing a small amount of sample with distilled water using a mortar and pestle. The samples were then sent for analysis using a Philips P W 1050 Diffractometer with a Cobalt K$\alpha$ radiation source.

Sample results were then plotted in the XRD analysis software, which contained mineral spectrums for kaolinite, quartz, calcite, mixed illite/smectite, and chlorite. As the size of the peaks in an XRD graph is relative to the concentration of the sample preparation, it is common practice to normalise the results measuring the half area of each mineral peak and dividing this by the half area of the quartz peak found at $25^{o}2\theta$.

## 3.6 Seal Potential

Seal potential (SP) comprises the following geological components (Kaldi and Atkinson 1997):

- the calculated amount of hydrocarbon column height supported relative to trap height (seal capacity);
- the areal extent of the seal lithology (lateral seal capacity continuity) relative to trap size (seal geometry);
- the thickness of the seal relative to fault throw offset in the top seal (seal thickness); and
- the propensity of the rock to brittle failure (seal integrity).

### 3.6.1 Seal Capacity

The seal capacity component of SP was determined by comparing the seal capacity to the vertical structural closure drilled by each well. Where the evaluated seal capacity was greater than vertical structural closure, the seal capacity component was considered to have a low risk of hydrocarbon leakage via to top seal.

Seal capacity depends on Pth, interfacial tension, wettability, formation water density and hydrocarbon density (Figure 3-1 Equation 3). Mercury injection capillary pressure (MICP) analysis and the variables used in calculating seal capacity have been discussed in previous sections.

### 3.6.2 Areal Extent of the Seal

The areal extent component was estimated by comparing areal extent of the seal to the estimated areal extent of the trap closure. Where the seal lithology covers the closure, and the seal capacity does not vary laterally, a low risk was assigned to the areal extent component.

### 3.6.3 Seal Thickness

The risk of the top seal being offset by fault throw was included in the seal potential evaluation. The seal thickness component was assessed by comparing seal thickness to fault throws in the top seal and where seal thickness was significantly greater than fault throws in the top seal, a low risk was assigned to the seal thickness component. For a complete seal evaluation, where the structure is dependant on fault seal, fault seal risk should be evaluated together with top seal potential. However, as the aim of this study is to assess whether hydrocarbon leakage in the Vulcan Sub-Basin is top seal dependant, fault seals have not been addressed.

### 3.6.4 Seal Integrity

Seal integrity can be considered as the propensity of a seal rock to develop structural permeability (Sibson 1996) and is related to the presence or absence of fluid-conducting fractures.

Seal integrity is a function of lithology and regional stresses. A summary of the ductile nature of various lithologies is presented in Figure 3-11 (Kaldi 2000). Based on the assumption that conductive fractures are less likely to form in ductile lithologies, rocks such as halite and organic shale are the most ductile and the least likely to develop structural permeability. As the carbonate content or the siliciclastic grainsize of the seal lithology increases, the propensity to develop structural permeability also increases.

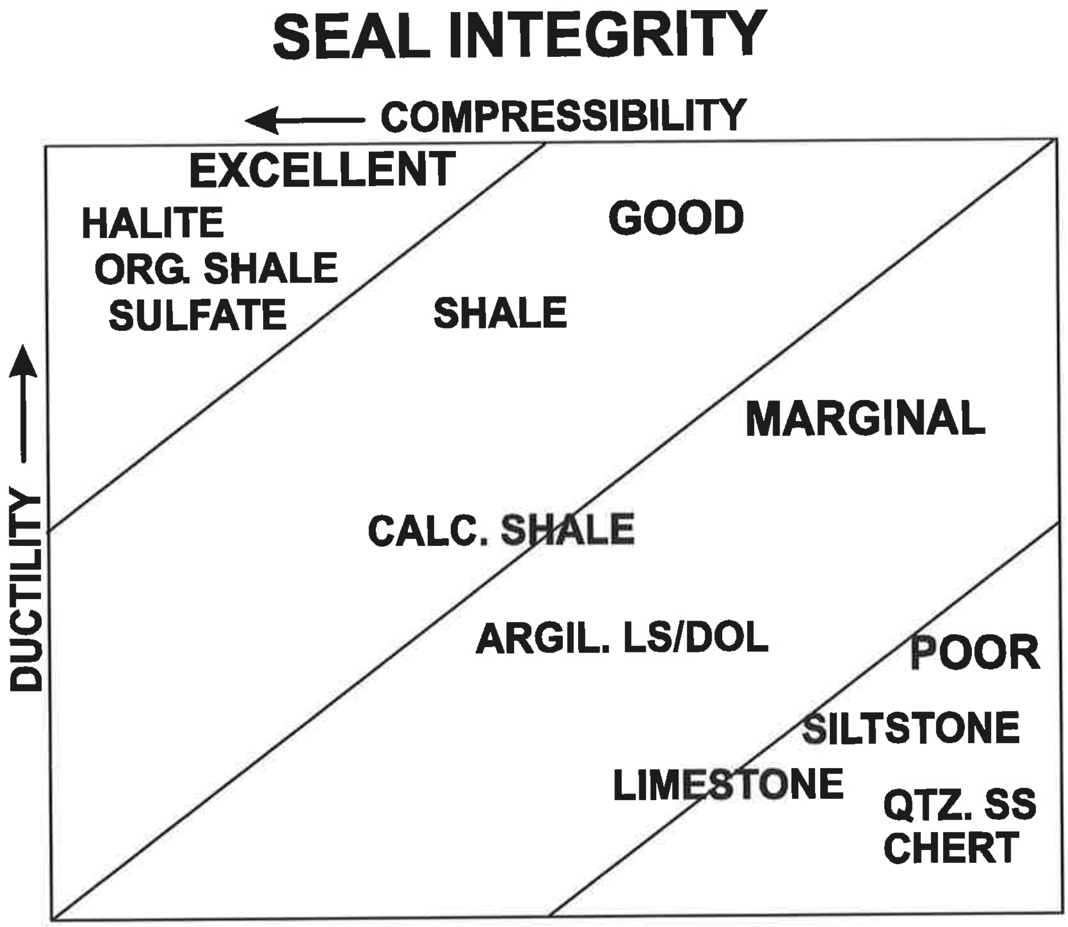



Figure 3-11: Schematic showing the relative ductility and compressibility of various lithologies. (Kaldi 2000)

The presence of conducting fractures is a qualitative assessment that should incorporate data such as core analysis, sidewall core petrographic analysis, well bore image data (FMS/FMI) and, ultimately, a combined stress field and rock strength evaluation.

Kovack et al. (2004) have investigated several techniques for estimating seal strength for the Muderong Shale in the Carnarvon  Basin, which is part of Australia's North West Shelf. Most of the five algorithms tested by Kovack et al. (2004) describe unconfined compressive strength (UCS) of a rock as a function of P- and S- wave derived elastic moduli. Based on work done by Dewhurst et al. (2002), who measured the UCS of the Muderong Shale, Kovack et al. (2004) compared this measurement to log-derived methods and found a match between the measured UCS of Dewhurst et al. (2002) and the wireline log methods used to calculate UCS. The Kovack et al. (2004) study further calculated the minimum pressure change P (buoyancy pressure) required to initiate brittle failure, by incorporating the UCS, frictional co-efficients of lithologies and *in-situ* stress conditions. This preliminary study found a correlation between fracture density observed in image logs and the average minimum capillary pressure required to initiate brittle seal failure. This study has taken a regional seal comparison approach as proposed by Ingram and Urai (1999), which estimates the UCS of a rock from p-wave velocity. Based on the UCS, a relative brittleness index of rocks in the Vulcan Sub-Basin was calculated, the methodology for which is outlined in Section 3.7.4.

## 3.7 Practical Seal Potential Assessment

Nakanishi and Lang (2002) presented an approach to prospect risk analysis using the risk assessment matrix shown in Figure 3-12. This matrix is equally applicable to assigning confidence values for regional seal potential evaluation. To estimate SP, a confidence value has to be allocated for each risk component of SP using Figure 3-12.

**expression of the existence of seal potential components**

| quality & quantity of information | very bad | bad | even | good | very good |
|---|---|---|---|---|---|
| plentiful | 0.000 | 0.250 | | 0.750 | 1.000 |
| enough | 0.125 | 0.313 | | 0.688 | 0.875 |
| moderate | 0.250 | 0.375 | 0.500 | 0.625 | 0.750 |
| poor | 0.375 | 0.438 | 0.500 | 0.563 | 0.625 |
| very poor | | | 0.500 | | |

Figure 3-12: Risk matrix for expression of the existence of seal potential components and quality and quantity of information (Nakanishi and Lang 2001).

The confidence value is assessed by the expression of the presence of each component based on a geological interpretation and the quantity and quality of the data supporting the interpretation (Nakanishi and Lang 2001, 2002; Rose 2001). For each component used to determine SP, a geological expression is determined (e.g. 'good' or 'bad') and data quality and quantity is assigned (e.g. 'moderate' or 'enough'). Hence, a value is determined for each SP component using the risk matrix (Figure 3-12). SP is calculated at each well by multiplying the values determined for the four components outlined above because all components are considered necessary for an effective top seal.

SP has been defined and applied to provide a basin-scale seal ranking. Changes in seal properties are highlighted and seal properties can be compared regionally and between intervals. The SP value represents a relative ranking and does not necessarily represent the probability of an effective seal. Top seal and lateral seal risk should be assessed on a prospect by prospect basis using the factors in SP as a guide to seal properties.

The following sections outline the methods employed to determine SP for top seals in the Vulcan Sub-Basin.

### 3.7.1 Seal Capacity

| | |
|---|---|
| Very Good | Seal holds back in excess of structural closure. |
| Good | Seal holds back between 50 and 100% of structural closure. |
| Bad | Seal holds back less than half of structural closure. |
| Very Bad | Not a sealing lithology (i.e. sandstone) |

Table 3-2: Geological component definitions for seal capacity.

The criteria for seal capacity assessment are presented in Table 3-2. The data quality and quantity criteria are presented in Table 3-3. Based upon these, the risk of seal failure due to seal capacity was obtained from Figure 3-12.

| | |
|---|---|
| Plentiful | Measured MICP value for seal capacity |
| Enough | Side wall core, cuttings descriptions and well log motifs suggest the type of seal present is the same as a directly measured seal from the same formation in a different well (analogue, rock catalogues). |
| Moderate | Existing well data are not enough to confidently estimate seal capacity. |
| Poor | There is no well data and seal capacity measurement comes from a general geological concept of the area |
| Very Poor | No data & no geological concept – pure guess |

Table 3-3: Seal capacity component data quality and quantity definitions.

Seal capacity was measured for numerous samples in the sealing interval. Based on MICP measurements, sidewall core descriptions, cuttings descriptions and well log character in known wells, the seal capacities were estimated for each seal lithology in other wells. Vertical closure estimates were taken from well completion reports and seismic structure maps. Where no vertical structural closure data were available, a value of 111m was used. This value is based on averaging 22 known vertical structural closures in the Vulcan Sub-Basin.

### 3.7.2 Areal Extent

The definitions of the geological criteria applied to the areal extent of a seal are listed in Table 3-4. The areal extent of the top seal was estimated based on well log correlations, seismic interpretation as well as sequence stratigraphic depositional models. The criteria used to evaluate the data quality and quantity of the areal extent component are listed in Table 3-5.

| | |
|---|---|
| Very Good | Seal covers entire structural closure and seal lithology is uniform and homogeneous over structure |
| Good | Seal covers top of closure and most of structure and minimal lateral change in seal lithology |
| Bad | Seal does not cover structure and/or significant lateral variation in lithology |
| Very Bad | No seal lithology is present on top of structure |

Table 3-4: Areal extent geological component definitions.

| | |
|---|---|
| Plentiful | Well and seismic data prove the existence of the geological factor. |
| Enough | Well and seismic data suggest existence of geological factor. |
| Moderate | Existing well and seismic data are not enough to provide confidence of existence of geological factor. |
| Poor | No well or seismic data, the expression of the geological factor comes from a general geological concept of the region. |
| Very Poor | No data & no geological concept – pure guess |

Table 3-5: Data quality and quantity definitions (Nakanishi and Lang 2001).

### 3.7.3 Seal Thickness

The criteria for evaluating seal thickness are listed in Table 3-6. Seal thickness was determined from well logs, biostratigraphy, cuttings descriptions and seismic data. Minor fault throws were estimated from seismic data, well completion reports and published structure maps (Gorman 1990). The same criteria used to evaluate the data quality and quantity of the areal extent component was applied to the seal thickness component (Table 3-5). In areas where seal thickness was less than seismic resolution and no information was available on sub-seismic faults, a 'poor' data quality and quantity was used to estimate the seal thickness risk component.

| | |
|---|---|
| Very Good | Seal thickness significantly greater than any fault throws observed in top seal. |
| Good | Faults in top seal offset the top seal (fault throw ~ 25% and 75% of top seal thickness) |
| Bad | Fault throws significantly offset top seal (fault throw >75% of seal thickness) |
| Very Bad | Fault throw is greater than seal thickness. |

Table 3-6: Geological component definitions for seal thickness and fault throw.

### 3.7.4 Seal Integrity

Based on the assumption that a brittle mudrock is anomalously strong compared to normally consolidated rocks at the same depth, Ingram and Urai (1999) presented a method for determining a brittleness index (BRI). This method was applied to estimate the brittleness of seal rocks in the Vulcan Sub-Basin and is outlined below.

Ingram and Urai (1999) defined a ductile mudrock as one that can deform without dilatency and the associated creation of fracture permeability, whereas a brittle mudrock was defined as one that dilates during deformation and allows fracture permeability to develop. Thus, a brittle mudrock was assumed to be anomalously strong compared to normally consolidated rocks at the same depth. Based on this assumption, the brittle or ductile nature of a rock can be estimated from a rock's unconfined compressive strength.

The BRI is calculated as a ratio (Equation 6) of the estimated *in-situ* unconfined compressive rock strength of the seal lithology (UCS) and the unconfined compressive strength of a normally consolidated rock at the same depth $UCS_{NC}$.

$$BRI = \frac{UCS}{UCS_{NC}} \quad (6)$$

(Ingram and Urai 1999) presented empirical data that correlate a mudrock's unconfined compressive strength to p-wave velocity data. The resulting correlation is shown in Equation 7, where UCS is the unconfined compressive strength of a rock and $v_p$ is the p-wave velocity.

$$\log UCS = -6.36 + 2.45 \log(0.86 v_p - 1172) \quad (7)$$

The effective pressure corresponding to normal consolidation at depth estimates $UCS_{NC}$ (Ingram and Urai 1999). The effective vertical stress, which is the vertical stress minus the pore pressure, was used to calculate $UCS_{NC}$. Mildren (1997) determined the relationship of vertical stress ($\sigma_v$) to depth (Equation 8) for the Vulcan Sub-Basin. In order to calculate the effective vertical stress, all formations were assumed to be normally pressured and pore pressure was calculated from a hydrostatic pressure gradient, or the normal pressure gradient, of 10MPa/km that van Ruth et al. (2000) estimated for the Vulcan Sub-Basin.

$$\sigma_v = 10\wedge\left(\frac{\log\left(\frac{depth}{62.759}\right)}{0.9197}\right) \quad (8)$$

In order to calculate BRI for seal rocks, the empirically derived equation relating unconfined compressive strength to p-wave velocity was assumed to hold for the Vulcan Sub-Basin.

1. A BRI value can be calculated from a sonic (DT) wireline logs as follows:

2. Calculate the pore pressure at depth by applying a pressure gradient of 10MPa/km. If depth is in meters then divide by 1000 to convert to kilometers and multiply by 10 which is the normal pressure gradient as specified by van Ruth et al. (2000).

3. Calculate the vertical stress by applying the vertical stress formula shown in Equation 8.

4. Calculate the effective vertical stress by subtracting the pore pressure calculated in 1) from the vertical stress calculated in 2). The effective vertical stress is used as an approximation for UCSnc, which is the denominator in the BRI equation (Equation 6).

5. Calculate the velocity in meters per second from the sonic log where velocity = (1/DT)*1000000)

6. Calculate UCS using Equation 7, with the velocity calculated in step 4 substituted for $v_p$. UCS is the numerator for the BRI equation (Equation 6).

7. Calculate BRI by dividing UCS calculated in step 5 by UCSnc calculated in step 3.

An example of a BRI log is shown in Figure 3-13. The Echuca Shoals interval between the Sahul_Group_top marker and the Echuca_Shoals_top marker, is a clastic interval in this well. Two sandstones can be seen at the base of this interval (low GR between 3025 and 3050m), which fine up into a claystone (high GR). For the sandstones at the base of the Echuca Shoals interval, BRI values range between 3 and 6, whereas for the overlying claystones BRI values are 1. The base of the Jamieson Formation interval has a 10m radiolarite, for which BRI values of 3 to 4 have been calculated. The rest of the Jamieson Formation interval consists of claystone and calcareous claystone, with claystones having a BRI of 1 and the more calcareous sediments have a BRI of 2 to 3. The WGF interval is predominantly marl to calcareous claystone and has BRI values of 4 to 8.

To determine the seal integrity of an interval the mean BRI was calculated for a particular interval. For the example shown in Figure 3-13, a mean BRI value of 1.2 was calculated for the claystones between 3000m and 3025m of the Echuca Shoals Formation and a mean BRI value of 5.68 was calculated for the WGF interval between 2760 and 2890m.

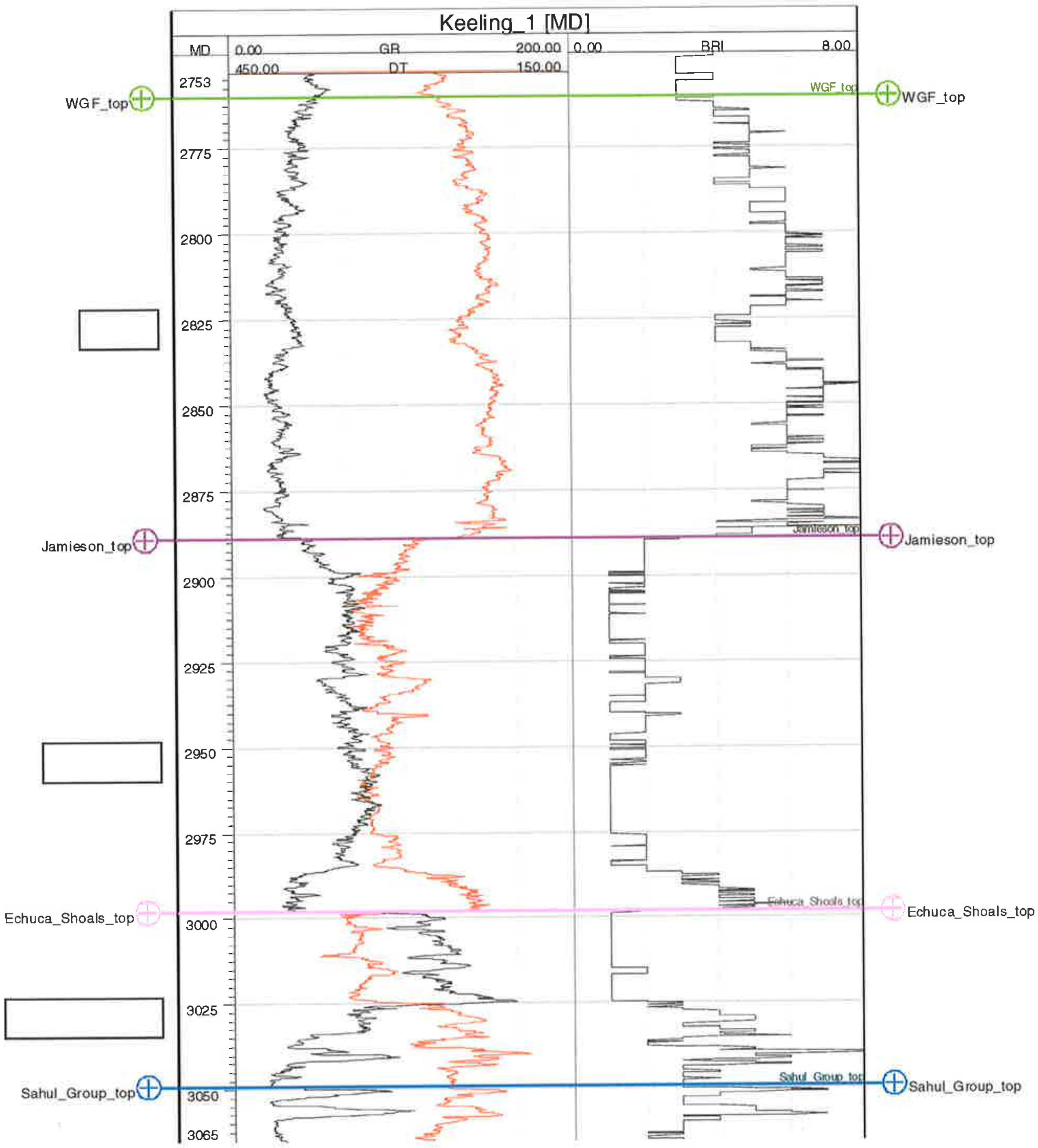



Figure 3-13: GR, DT and BRI log showing BRI results for Keeling 1.

| | |
|---|---|
| Very Good | 1<BRI<2 |
| Good | 2<BRI<4 |
| Bad | 4<BRI<6 |
| Very Bad | 6<BRI<8 |

Table 3-7: Geological component definitions for the brittle index (BRI) used to estimate rock strength and risk seal integrity.

| | |
|---|---|
| Plentiful | Data prove that fluid conducting fractures either exist or do not exist. |
| Enough | Data suggest that fluid conducting fractures either exist or do not exist. |
| Moderate | Data provide information on the rock properties, such as propensity of the seal to fracture, but no information on the actual existence of fractures. |
| Poor | The propensity of the seal to either contain or not contain fluid conducting fractures comes from a general geological concept of the region. |
| Very Poor | No data & no geological concept – pure guess |

Table 3-8: Data quality and quantity definitions for seal integrity.

Seal integrity was estimated for the Vulcan Sub-basin by taking the mean BRI for each seal interval where well logs were available. BRI values above 4 are considered to be brittle (Ingram and Urai 1999), with BRI values greater than 2 already having some risk of brittle failure. The definitions for seal integrity component geological and data quality and quantity criteria are presented in Table 3-7 and Table 3-8 respectively. Based upon these criteria, a seal integrity component value was obtained from Figure 3-12.

It should be noted that Ingram and Urai (1999) developed the brittleness index from soil mechanics measurements made on mudstones, with this study extending this approach to mixed carbonate clastic lithologies. A BRI value does not necessarily indicate the presence of open fluid conducting fractures and thus a brittle rock may retain a hydrocarbon column (Ingram and Urai 1999). The data quality and quantity level used for estimating seal integrity based on BRI values were, at best, 'moderate' (Table 3-8). Thus, the highest overall SP value possible is 0.75.

### 3.7.5 Practical Seal Potential

Fairway maps were created for each seal interval by grouping low (0.0-0.24), moderate (0.24-0.48) and high (0.48-0.75) SP values and hand contouring the data. Seal potential results and SP fairway maps are presented in Chapter 6. Furthermore Chapter 6 outlines an example of Seal Potential as it has been applied in this study.

Seal potential fairway maps for each seal interval were used to highlight areas of top seal risk in the Vulcan Sub-Basin. Each seal interval was also compared qualitatively and quantitatively other seal interval influencing each hydrocarbon play type.

# Chapter 4 Biostratigraphy, wireline and seismic interpretation – Results and Discussion

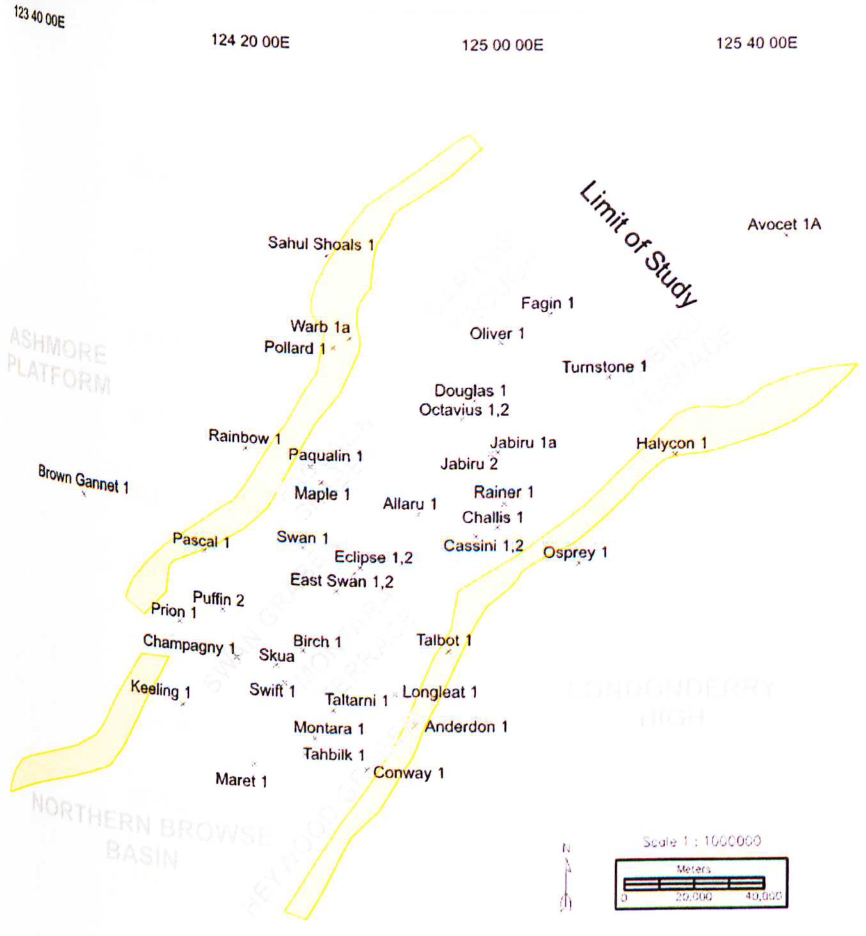
## 4.1 Introduction

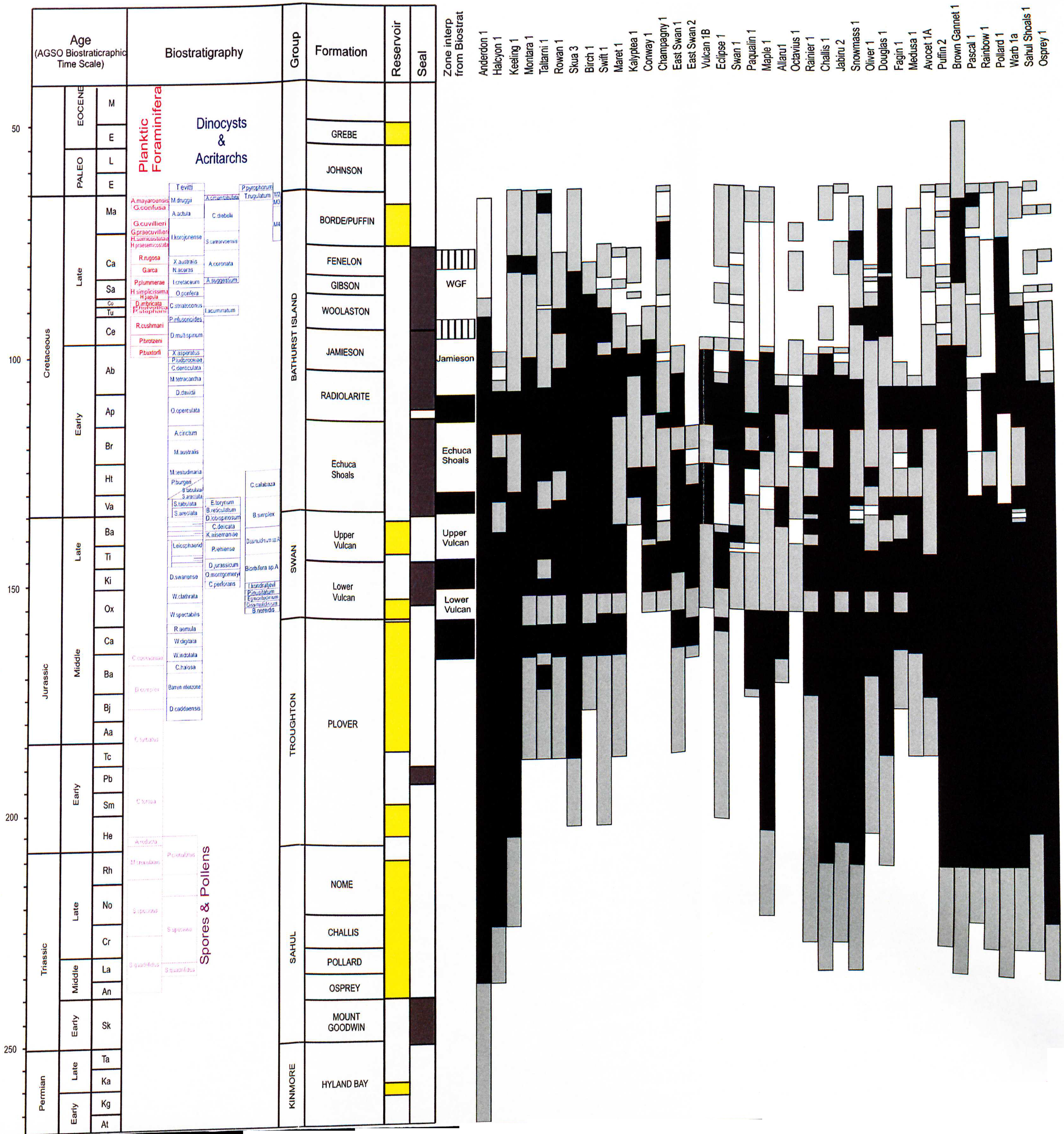
Using the methodology outlined in Chapter 2, the Callovian to Maastrichtian section of the Vulcan Sub-Basin was subdivided into major stratigraphic units which were bound by regionally significant biostratigraphic events. This subdivision was based predominantly on wireline log motifs and all available biostratigraphic data.

## 4.2 Biostratigraphic Analysis

### 4.2.1 Biostratigraphy Introduction

The Callovian to Maastrichtian succession of the Vulcan Sub-basin has been subdivided into a series of sequences, which are separated by basin-wide episodes of missing section. The missing section was defined from biostratigraphic reports. Within the reports, missing section is identified where sediments of a particular biozone have not been identified in a well. In biostratigraphic reports from wells with good quality samples and sample density, the identification and accurate dating of a missing section is relatively simple and is often stated in the well completion report. In wells with a low biostratigraphic sample density, it is often unclear whether sediments of a particular age are actually missing or have not been sampled adequately. In wells containing ambiguous biostratigraphic results, the nature of the missing section has been determined on the basis of geological information from surrounding wells and by wireline log character. By collating the intervals of missing section across the basin, regionally significant events can be distinguished from more localised ones.




Sediments of this age have been positively identified from the presence of diagnostic assemblages.

Missing section - the absence of any diagnostic assemblage of this age have been identified.

Undifferentiated - diagnostic age determinations have not been possible. This can either be due to poor sample recovery rates in which case stage names are normally only defined or due to poor sampling resolution in which case it is not possible to determine the absence or presence of a biozone

Biostratigraphic reports contain no mention of the presence or absence of assemblages of this age.

Figure 4.1 (above) Location map showing the distribution of wells which have been used in this biostratigraphic study.

Figure 4.2 (opposite) Summary diagram illustrating the age of sedimentary packages in the Vulcan Sub-Basin as determined from biostratigraphic data. Major unconformities are clearly shown on this diagram by the presence of laterally extensive missing section.

### 4.2.2 Biostratigraphic Results

The present study uses biostratigraphic data from thirty-nine wells to subdivide the section into sequences and to later constrain the wireline log interpretation. Figure 4-1 shows the location of the wells used for the biostratigraphic study and Figure 4-2 summarises the biostratigraphic age of sediments contained within these wells. Missing section is shown in black in Figure 4-2, present section is identified in dark grey and sediments of undefined age are show in light grey. Figure 4-2 shows several periods of missing section that occur in the majority of the wells in the study area.

The section was subdivided into genetically related units, which were separated by major episodes of missing section of Callovian, Kimmeridgian, Valanginian and Aptian age (Figure 4-2 missing sections are highlighted in black in the zone interpretation from biostratigraphy column). Two other episodes of missing section of Cenomanian and Campanian age (shown in Figure 4-2 as vertical striped segments in zone interpretation from biostratigraphy column) are suggested by the biostratigraphic data however, these events are not as accurately defined from the biostratigraphy or appear to be as regionally extensive as those events listed above. The Callovian, Kimmeridgian, Valanginian and Aptian intervals of missing section have been interpreted as regional unconformities and so can be interpreted as sequence boundaries. Due to localised tectonics and sub-basin palaeo-topography, the duration of some of these events varies throughout the sub-basin.

Well sequences were interpreted based predominantly on biostratigraphic data, with wireline log motif correlation being used where the biostratigraphic data were incomplete. For the purposes of this study, formation names already established in the Vulcan Sub-Basin have been assigned to intervals determined by biostratigraphy (Figure 4-2). For example, the Echuca Shoals Formation has been interpreted consistently in all wells in this study based on an oldest biozone of S.aerolata and youngest biozone of A.cinctum.

## 4.3 Geological Interpretation of Wireline Log Motifs

### 4.3.1 Lower Vulcan

The Callovian to Kimmeridgian Lower Vulcan Formation has a characteristic wireline log response in the Vulcan Sub-basin. Type sections of the Lower Vulcan Formation from Montara 1, Oliver 1 and Swan 1 are presented in Figure 4-3 and Figure 4-4. The section shown in Figure 4-3 for the Montara 1 is dominated by stacked coarsening upward deltaic sand packages. This log signature is typical for the Lower Vulcan Formation in the south eastern Vulcan Sub-Basin. In Montara 1, these sands are capped by over 200m of siltstone and claystone, which form a local seal.

The section shown in Montara 1 has been interpreted as a proximal deltaic system deposited during early Lower Vulcan deposition, which was progressively flooded, and with time, the section became dominated by fine grained sediment.

The sections presented for Oliver 1 and Swan 1 in Figure 4-4 are typical of the more distal depositional environments of the south western and northern Vulcan Sub-basin. The Oliver 1 section is characterised by relatively thin basal transgressive sand that fines into predominantly claystone sediments deposited in distal neritic to open marine depositional environments.

The Swan 1 section is from the central Vulcan Sub-basin and represents sedimentation in the deep Swan Graben. There is no basal transgressive sandstone and the entire section is characterised by siltstone and claystone deposits.

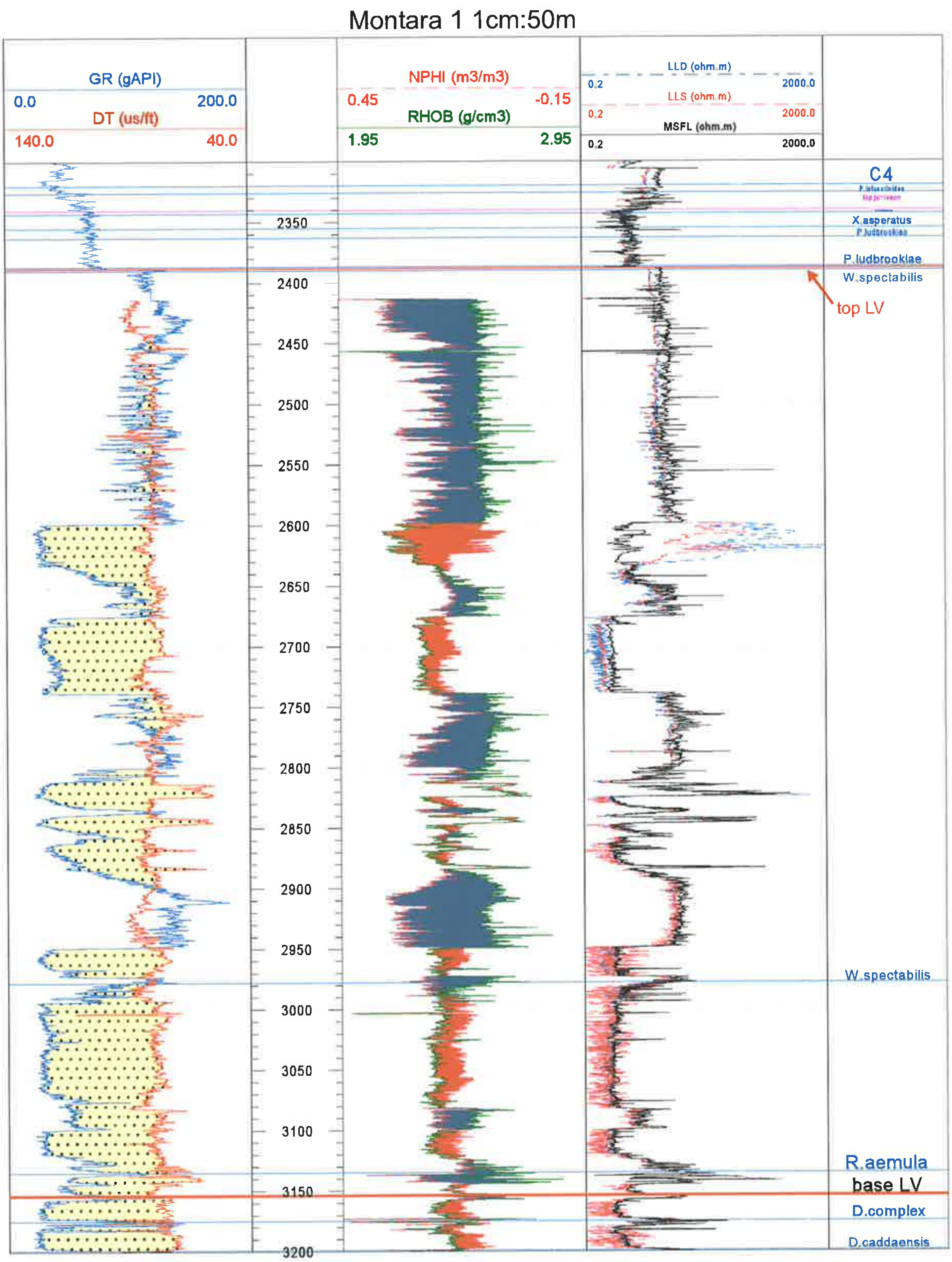



Figure 4-3: Lower Vulcan section for Montara 1.

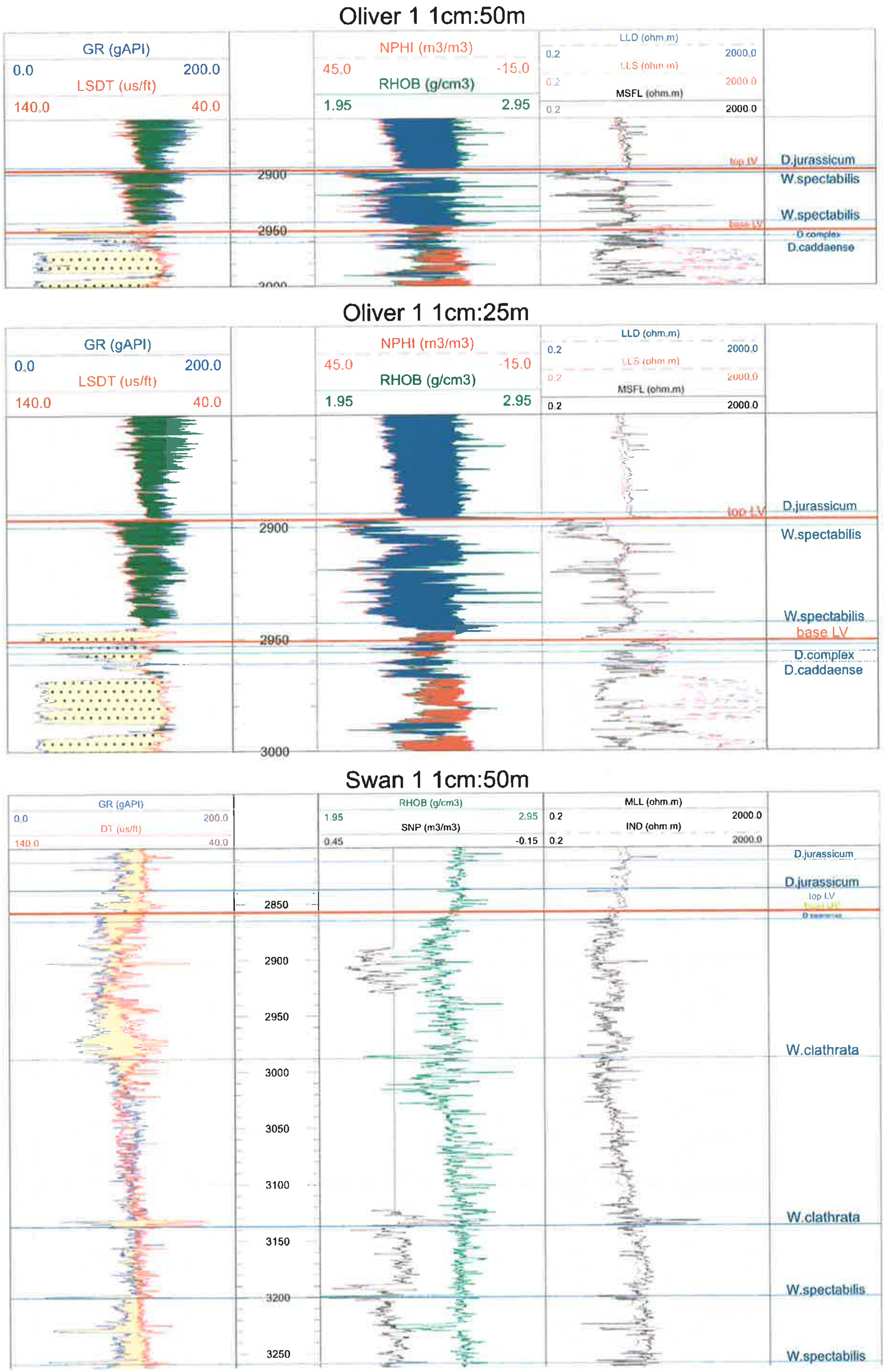



Figure 4-4: Lower Vulcan section for Oliver 1 and Swan 1. The Oliver 1 section is shown at both 1cm:50m and 1cm:25m scale.

### 4.3.2 Upper Vulcan

Type sections for the Upper Vulcan formations are presented for Octavius 1 (Figure 4-5), Fagin 1 (Figure 4-6), Swan 1 (Figure 4-6) and Oliver 1 (Figure 4-7).

The Kimmeridgian unconformity, which separates the Lower and Upper Vulcan Formations, is highlighted by missing section in Figure 4-2. The wireline log response that characterises the Kimmeridgian unconformity can be seen at the base LV marker in Fagin 1 (Figure 4-6) and Oliver 1 (Figure 4-7) as an identifiable log shift that separates Lower Vulcan from Upper Vulcan sediments of the Vulcan Sub-basin.

The Valanginian boundary between the Upper Vulcan Formation and overlying sediments is readily identifiable by a change in wireline log signature. Examples of this boundary can be seen at the top UV marker in all type sections shown for the Upper Vulcan Formation. Where the Echuca Shoals Formation overlies the Upper Vulcan Formation, there is a distinct change in the sonic velocity over the boundary. A faster sonic response can be seen in the Upper Vulcan Formation (below top UV marker in Figure 4-5) as opposed to a slower sonic response and greater sonic to gamma ray log separation in the Echuca Shoals Formation (above the top UV marker in Figure 4-5). Where the Jamieson Formation overlies the Upper Vulcan Formation there is a decrease in gamma ray values from high values in the Upper Vulcan to lower values in the Jamieson Formation, as well as a decrease in the density across the boundary (top UV marker in Figure 4-6 Swan 1).

Sandstone interpreted in the middle of the Upper Vulcan section Octavius 1 (2750-2900m Figure 4-5) and Fagin 1 (2865-2870m Figure 4-6) are turbidite sand deposits based on cuttings descriptions and core descriptions for Tithonian sands intersected in Tenacious West 1 and predominantly occur in wells near the eastern margin of the Vulcan Sub-Basin.

The majority of the interval in Octavius 1 and Fagin 1, and the entire sections shown in Swan 1 and Oliver 1, are predominantly siltstones and claystones. These sediments are characterised by high gamma ray values and a shale type separation of the neutron porosity and density logs (shaded in blue in all figures).

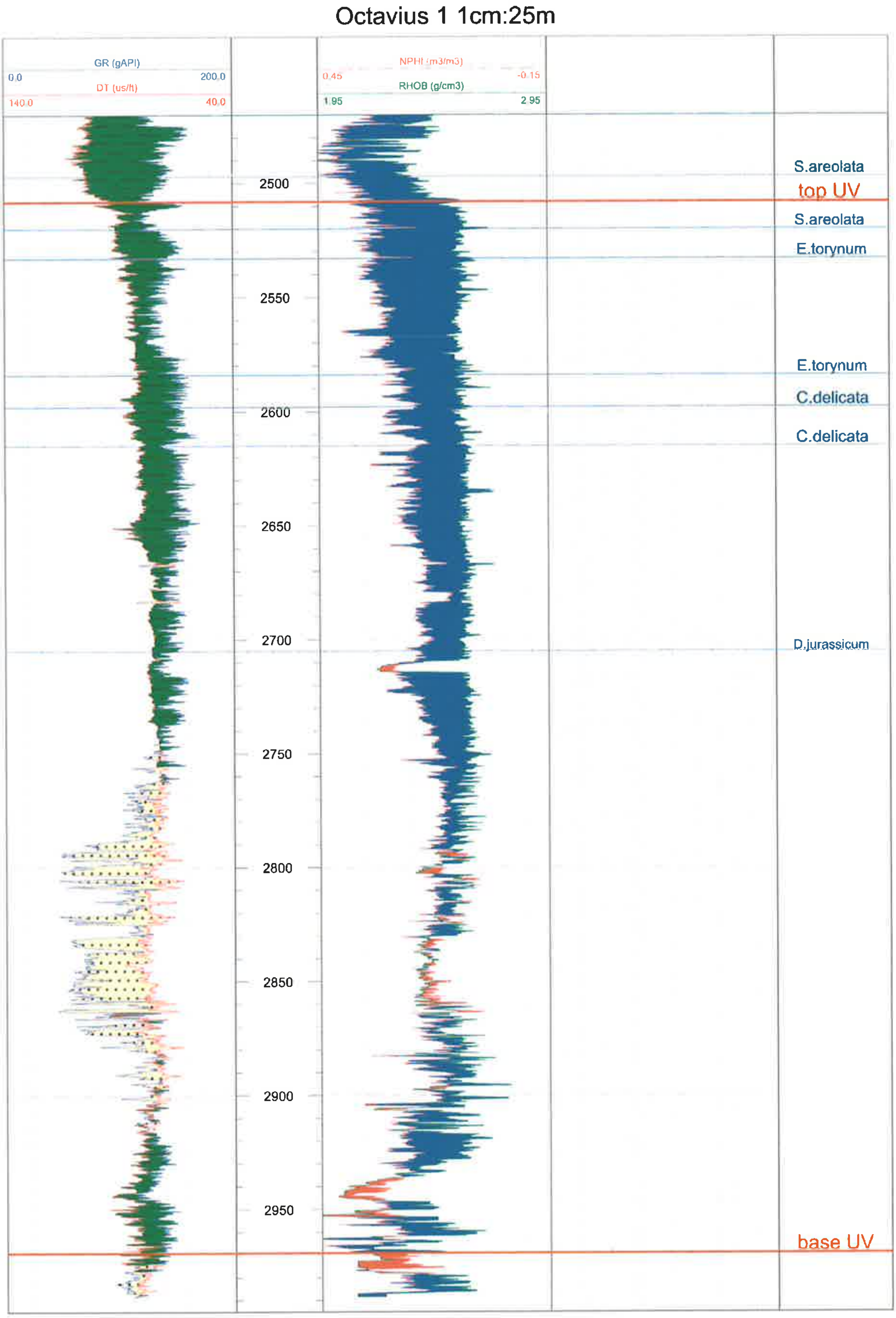



Figure 4-5: Upper Vulcan section for Octavius 1.

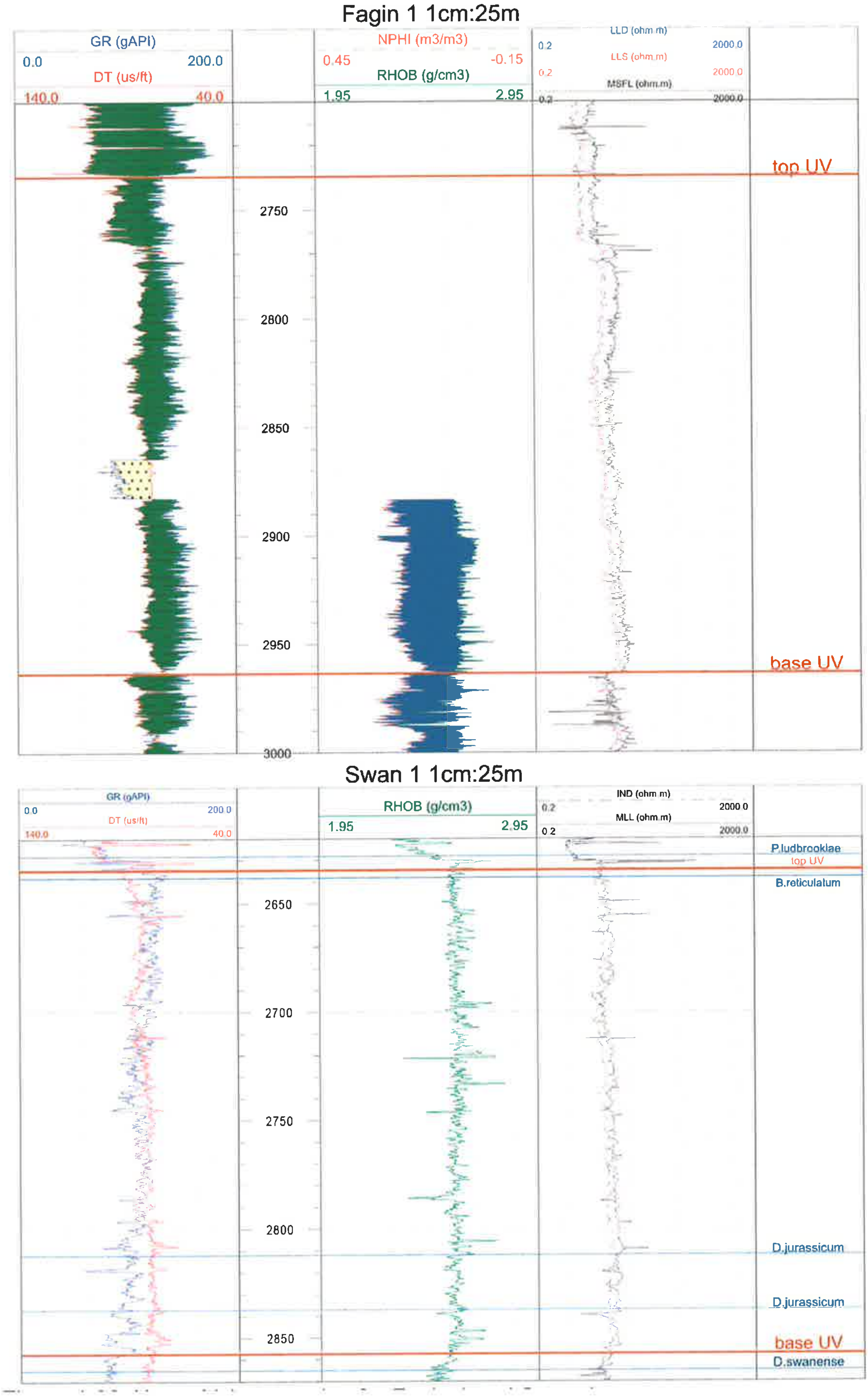
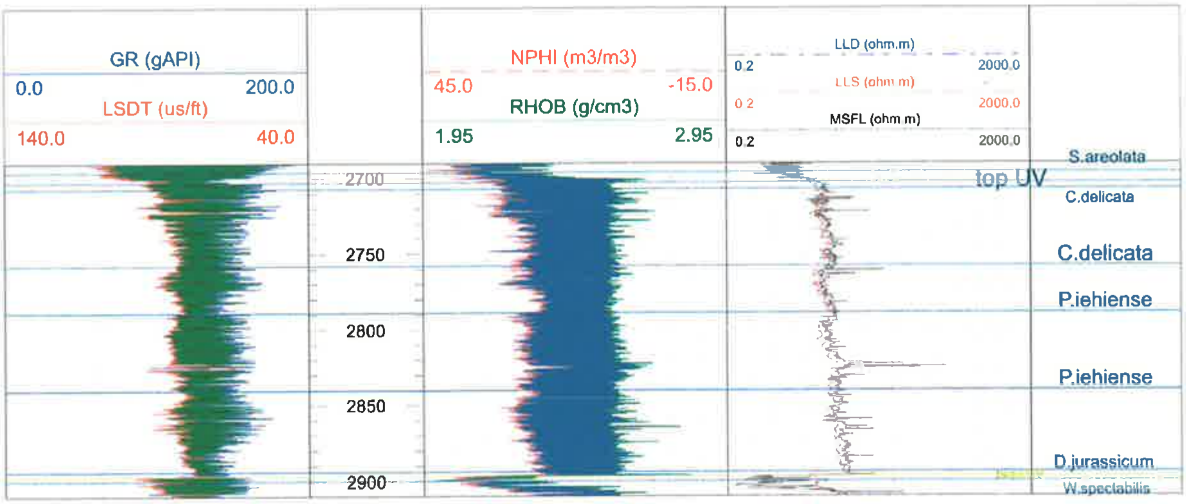



Figure 4-6: Upper Vulcan section for Fagin 1 and Swan 1.

Oliver 1 1cm:50m




Oliver 1 1cm:25m

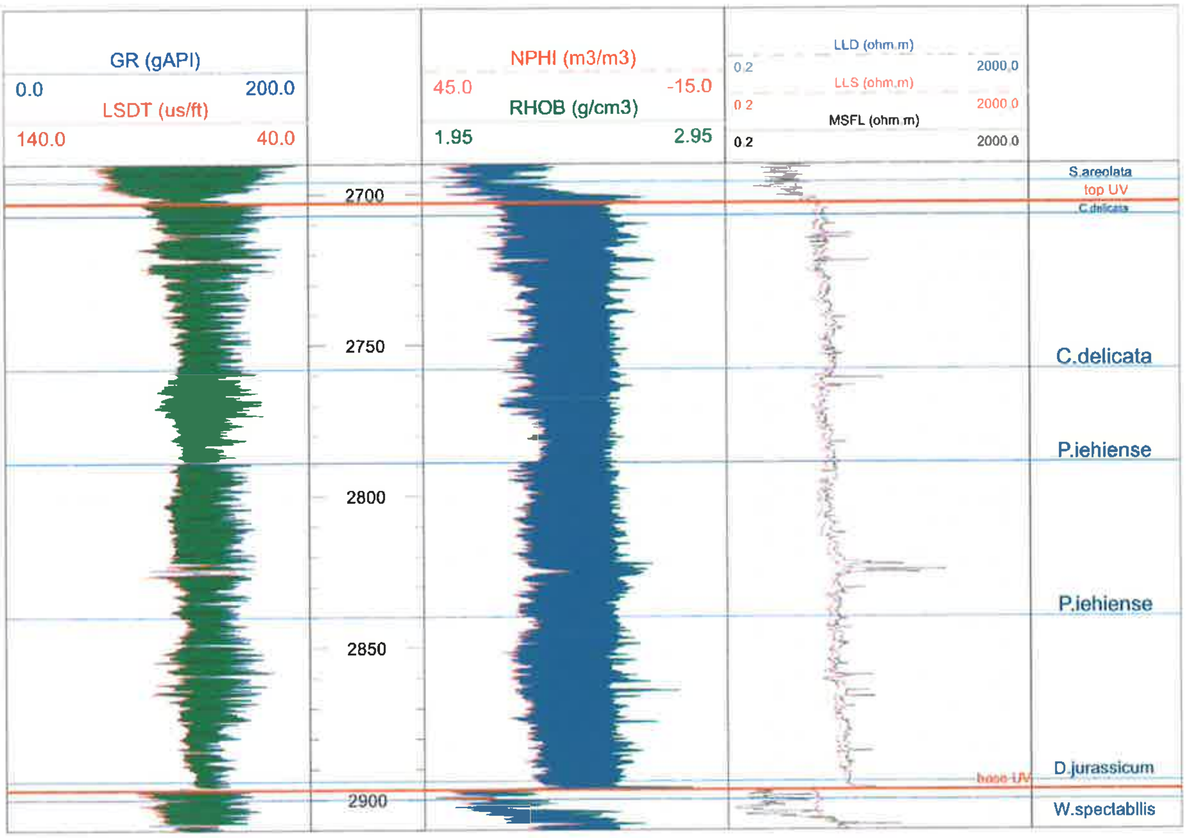



Figure 4-7: Upper Vulcan section for Oliver 1.

### 4.3.3 Echuca Shoals Formation

Type sections for the Echuca Shoals Formation are presented in Elm 1 (Figure 4-8), Oliver 1 (Figure 4-9) and Keeling 1(Figure 4-10). Section are shown in two scales in these figures, the 1cm:50m scale is included to compare thickness relative to the succession above and below the Echuca Shoals.

The Echuca Shoals Formation is predominantly claystone and glauconitic claystone. The well logs from Elm 1 and Oliver 1 are typical for the central Vulcan Sub-Basin. In the southern Vulcan Sub-Basin and along the eastern bounding Londonderry High, the base of the Echuca Shoals Formation has a basal sandstone. Keeling 1 is the type section from the southern Vulcan Sub-Basin where a thicker deposit is present in the central sub-basin. The basal sands evident in Keeling 1 fine upwards into claystones.

The boundary between the Echuca Shoals Formation and the overlying Jamieson Formation is charaterised by a change in log character from high gamma values in the Echuca Shoals Formation to low gamma values in the Jamieson Formation. The 'top echuca' marker is placed at the intersection of the Echuca Shoals and Jamieson formation in Figure 4-8, Figure 4-9 and Figure 4-10.

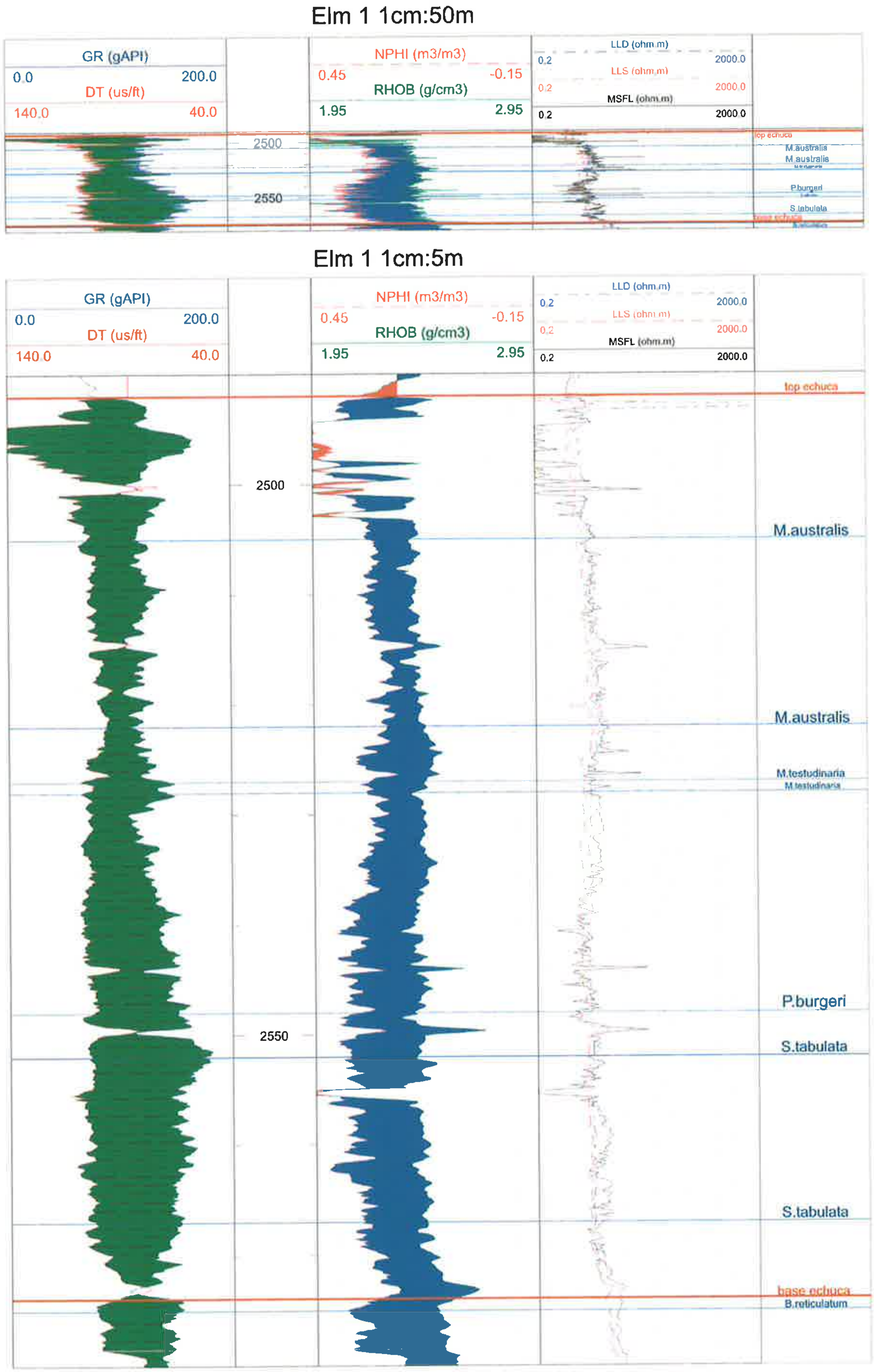



Figure 4-8: Echuca Shoals section for Elm 1.

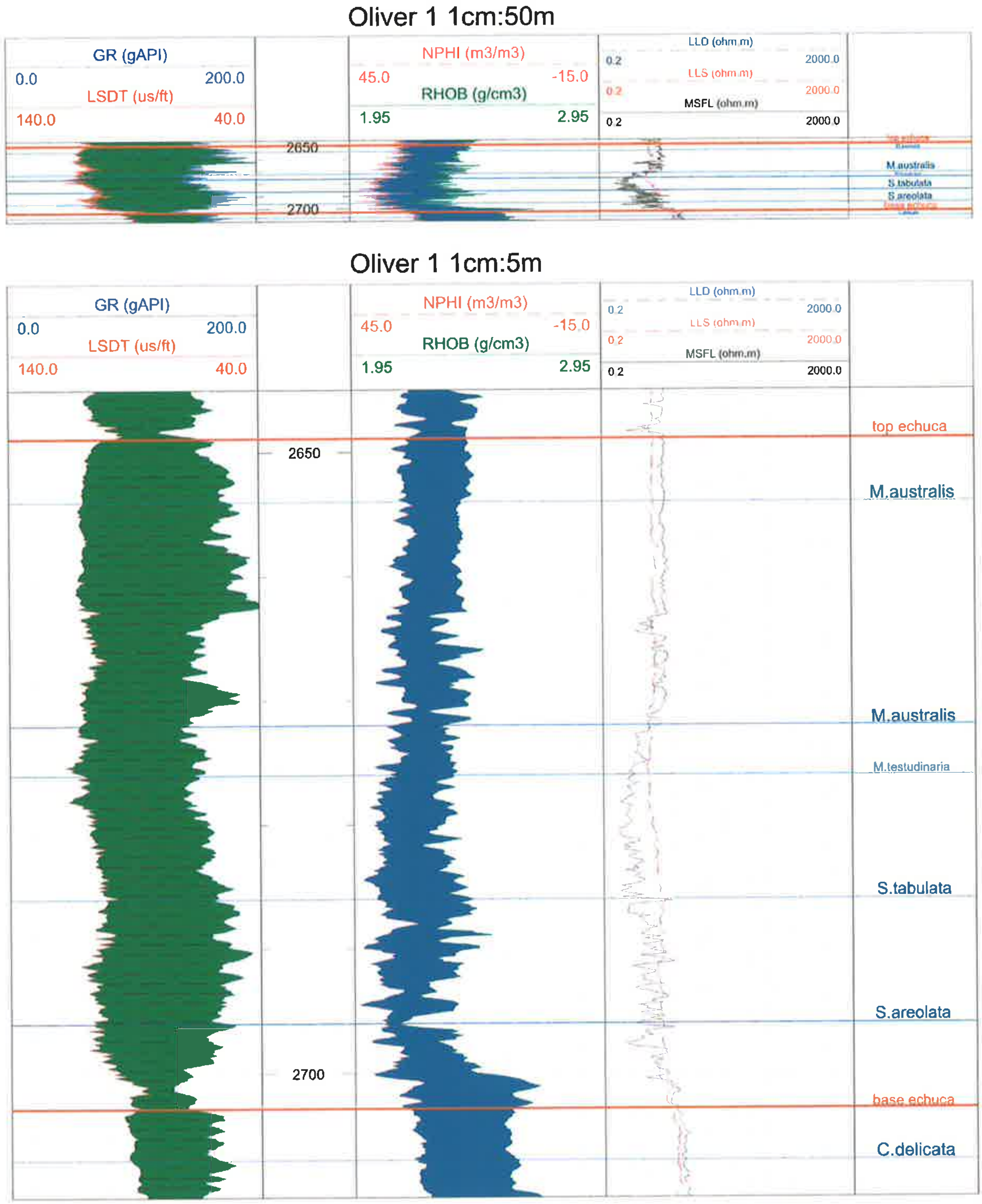



Figure 4-9: Echuca Shoals section for Oliver 1.

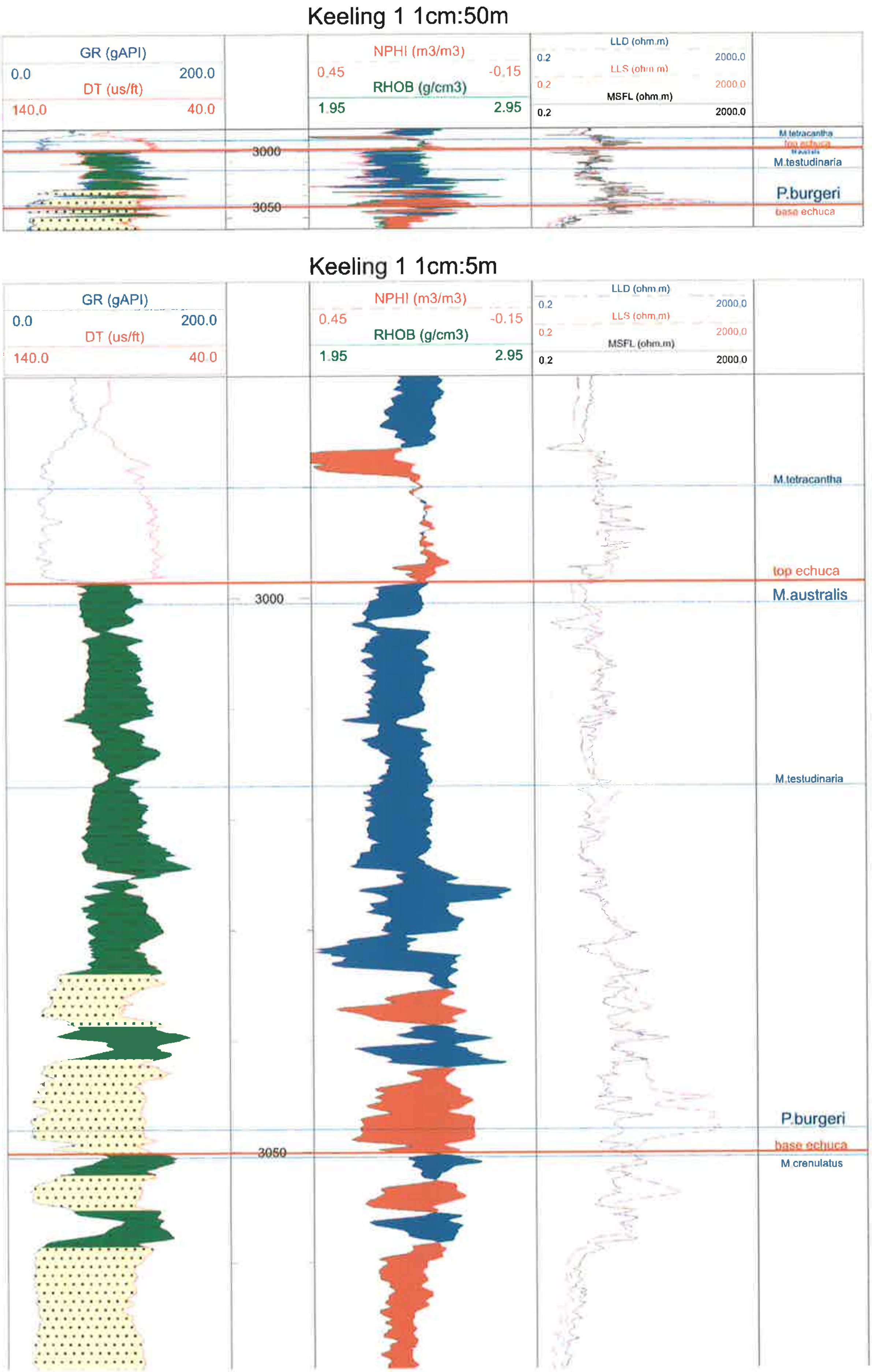



Figure 4-10: Echuca Shoals section for Keeling 1.

### 4.3.4 Jamieson Formation

The type sections for the Jamieson Formation are presented for Osprey 1 (Figure 4-11), Elm 1 (Figure 4-12), Rainbow 1 (Figure 4-13) and Brown Gannet 1 (Figure 4-14).

In the central Vulcan Sub-Basin, the base of the Jamieson Formation is typically characterised by a thin interval of radiolarite. A typical low gamma and fast sonic response from the radiolarite can be seen clearly at the base of Elm 1 (Figure 4-12) between 2475m and the base Jamieson marker.

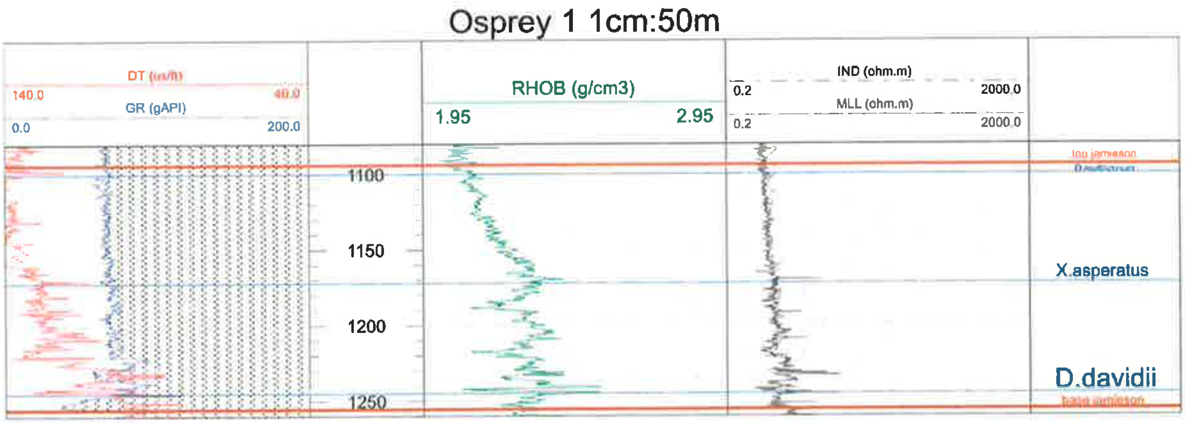
Apart from the relatively thin radiolarite found in some wells, the Jamieson Formation is predominantly made up of calcareous claystones and marls. Osprey 1 (Figure 4-11) has one of the thickest sections of Jamieson Formation. The low gamma response over the basal 10m is due to the radiolarite. The rest of the interval has a fairly uniform GR log response of around 80 API, with corresponding slow sonic log response.

Elm 1 (Figure 4-12) is located in the central Vulcan Sub-Basin. The section shown in Figure 4-12 has approximately 16m of radiolarite at the base with 90m of overlying calcareous claystone. The GR log has a relatively constant value of around 100 API and the RHOB/NPHI cross over lithology indicator is typical of a clastic claystone (shaded in blue on Figure 4-12).

Rainbow 1 (Figure 4-13) is located near the western boundary of the Ashmore Platfrom (high block) and the Vulcan Sub-Basin. The type section shown here has approximately 12m of radiolarite at the base with 35m of overlying calcareous claystone/marl. The GR response shows lower values relative to the more proximal type section seen in Elm 1 mainly because the rocks contian a higher carbonate content.

Brown Gannet 1 (Figure 4-14) lies on the outer Ashmore Platform and thus is the most distal section shown. There is a 10m radiolarite layer at the base overlain by a fairly calcareous marl.

The type section for Elm 1 (Figure 4-12), Rainbow 1 (Figure 4-13) and Brown Gannet 1 (Figure 4-14) show how the Jamieson formation log responses change from southeast to the northwest. The rocks change from siliclastic dominated in the southeast to carbonate-dominated claystones towards the northwest. The probably clastic sediment source was to the south east of the present day Vulcan Sub-Basin.



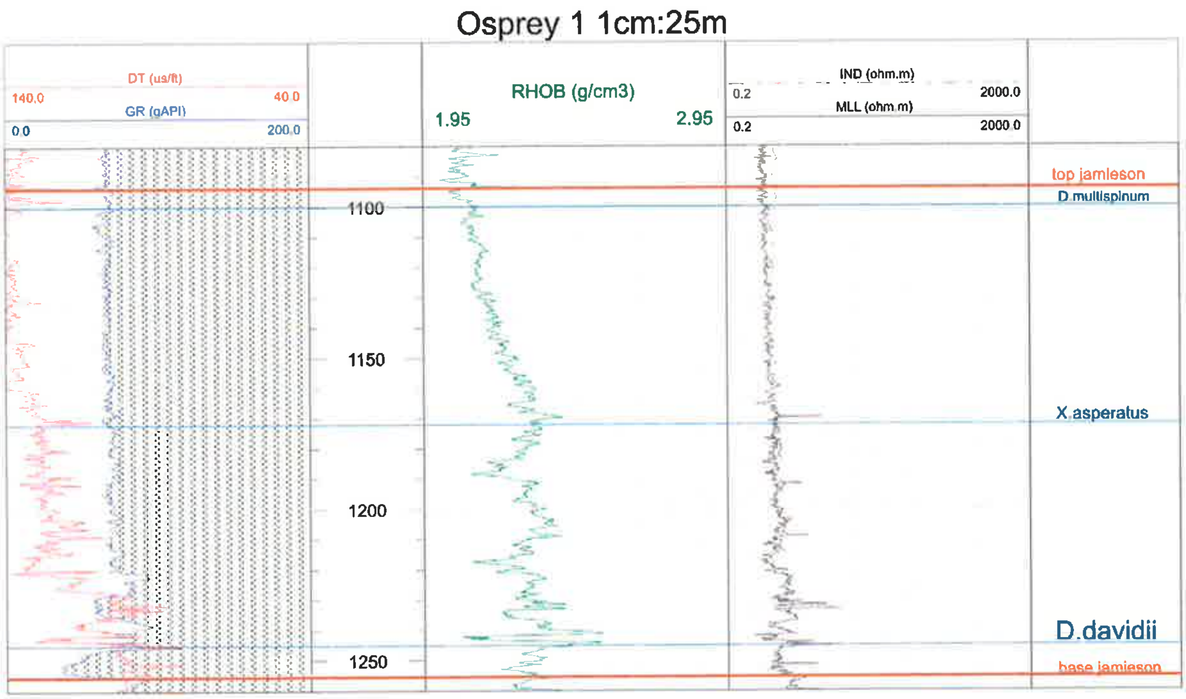




Figure 4-11: Jamieson section for Osprey 1.

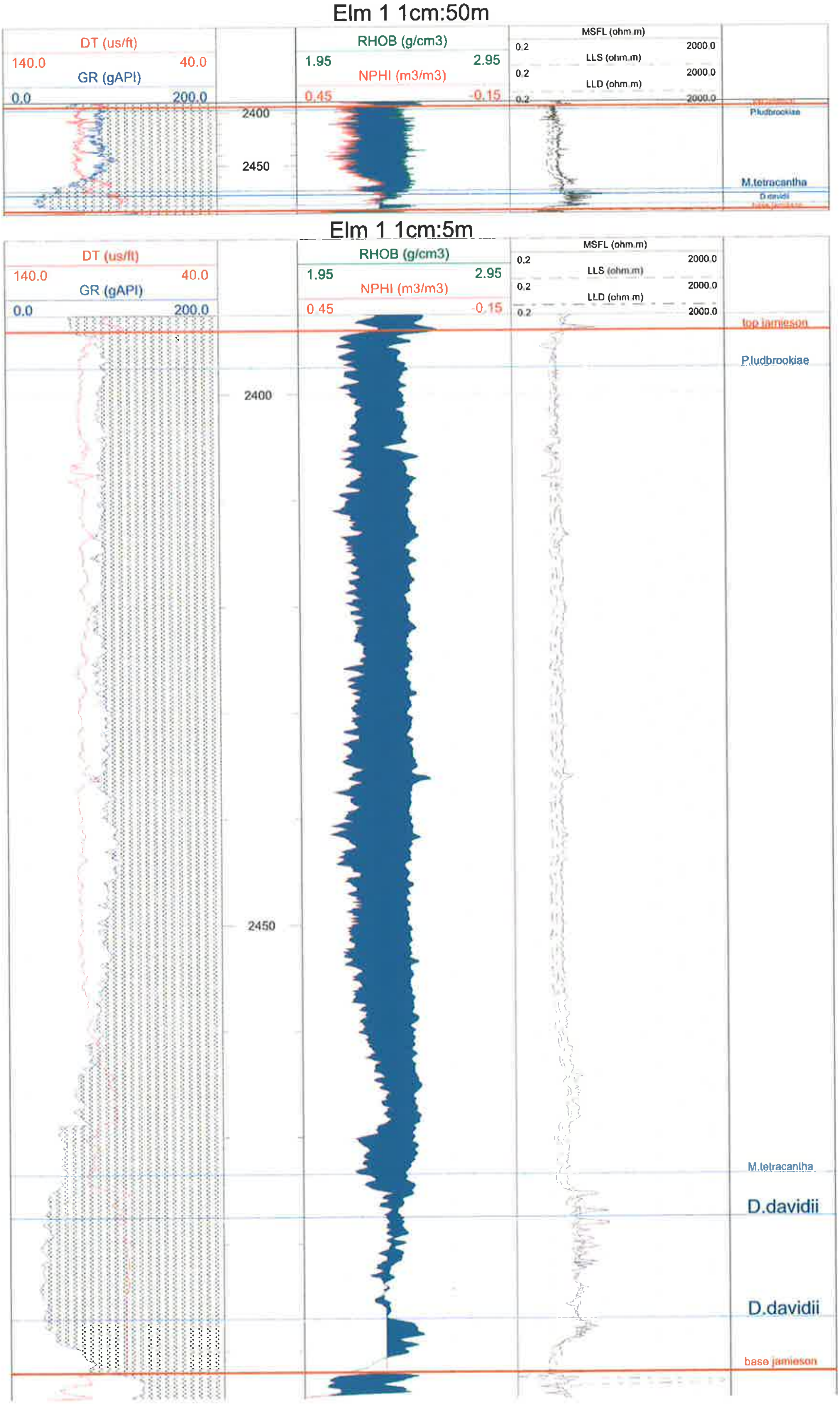
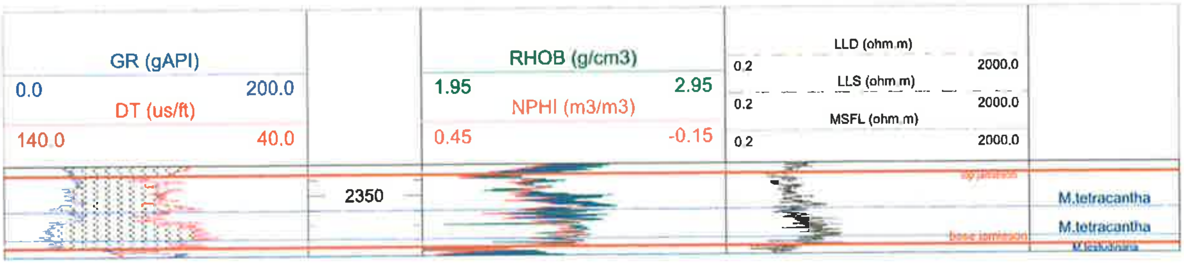



Figure 4-12: Jamieson section for Elm 1.

Rainbow 1 1cm:50m




Rainbow 1 1cm:5m

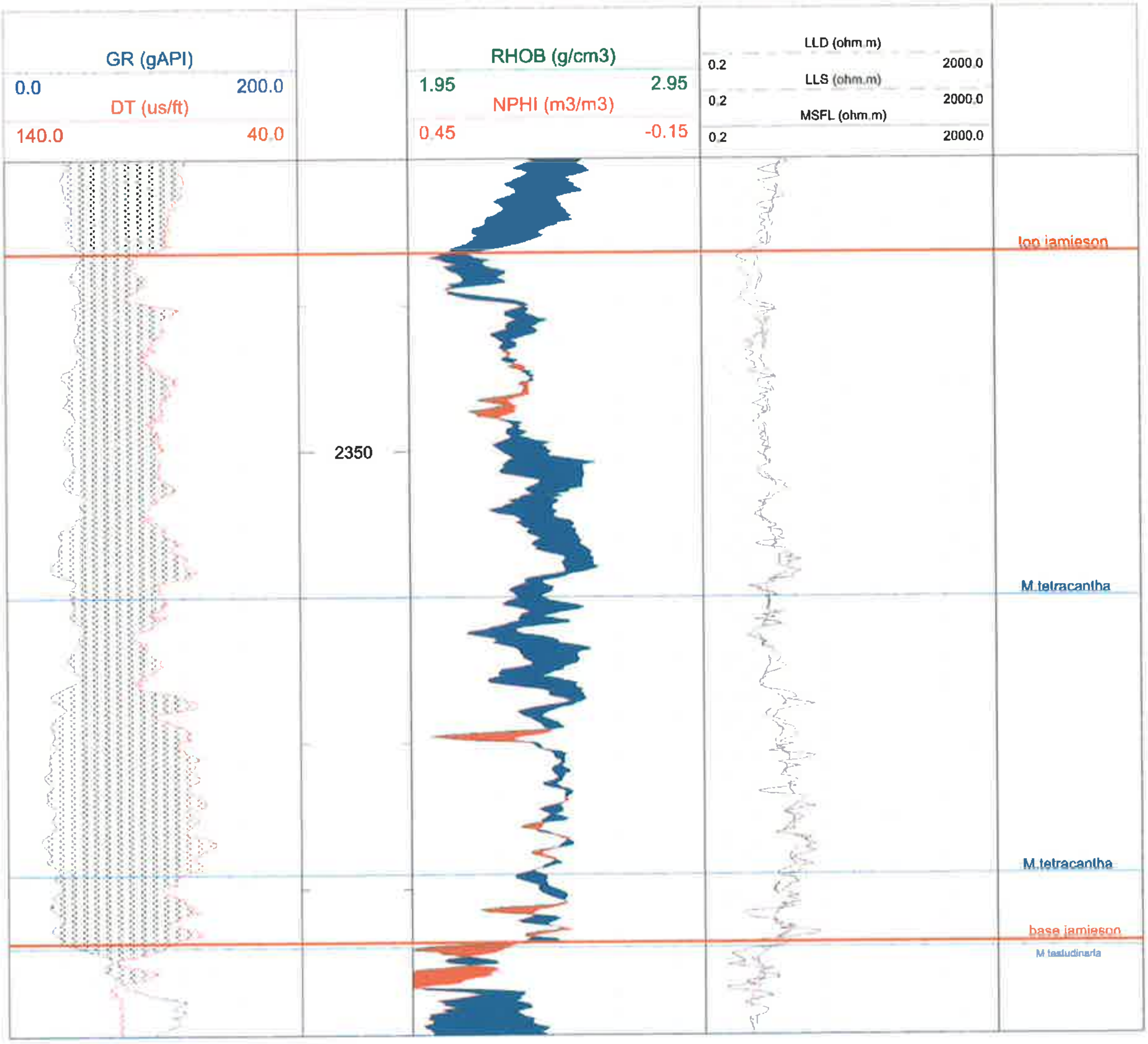



Figure 4-13: Jamieson section for Rainbow 1.

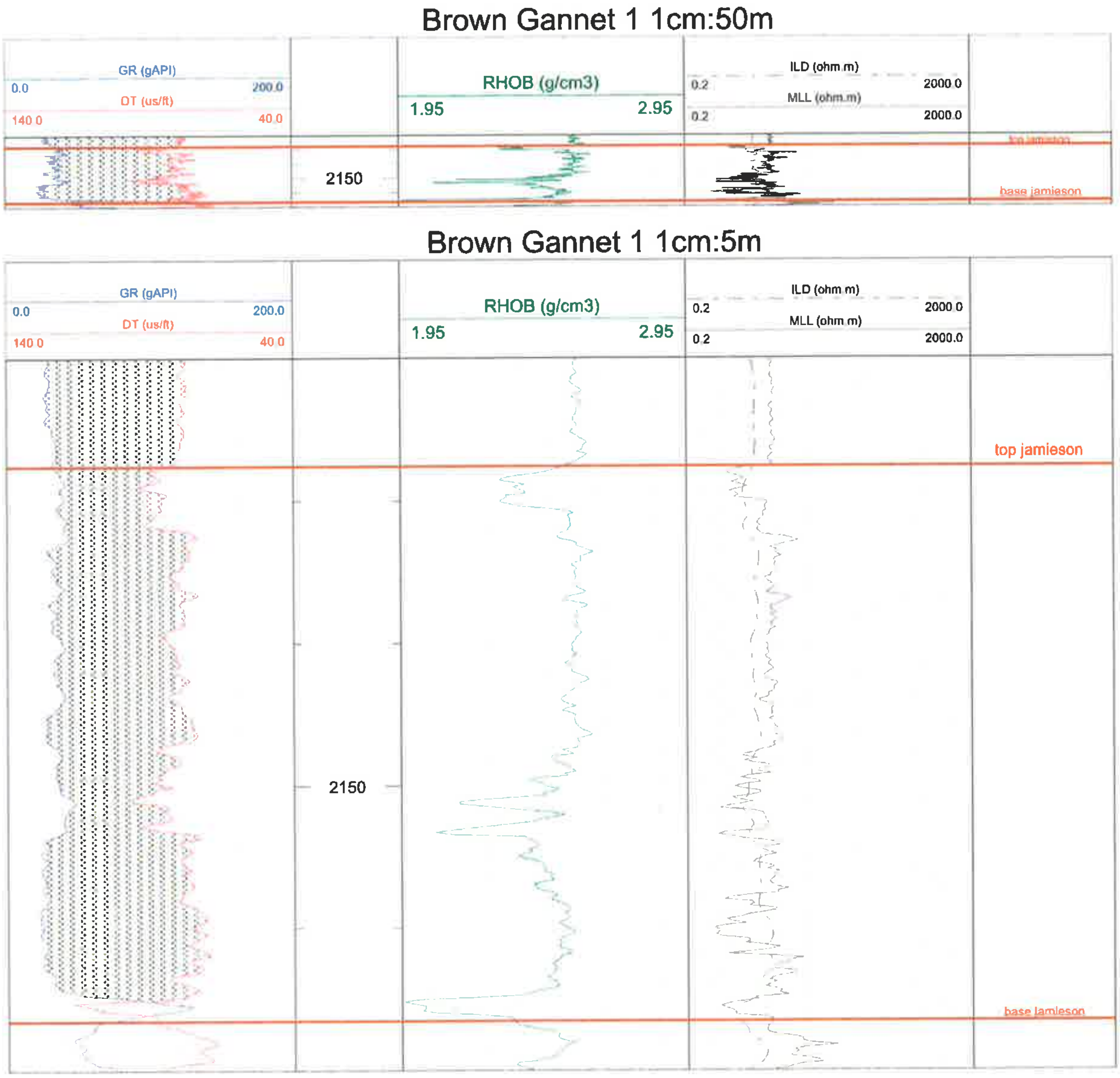



Figure 4-14: Jamieson section for Brown Gannet 1.

### 4.3.5 Woolaston, Gibson and Fenelon Formations

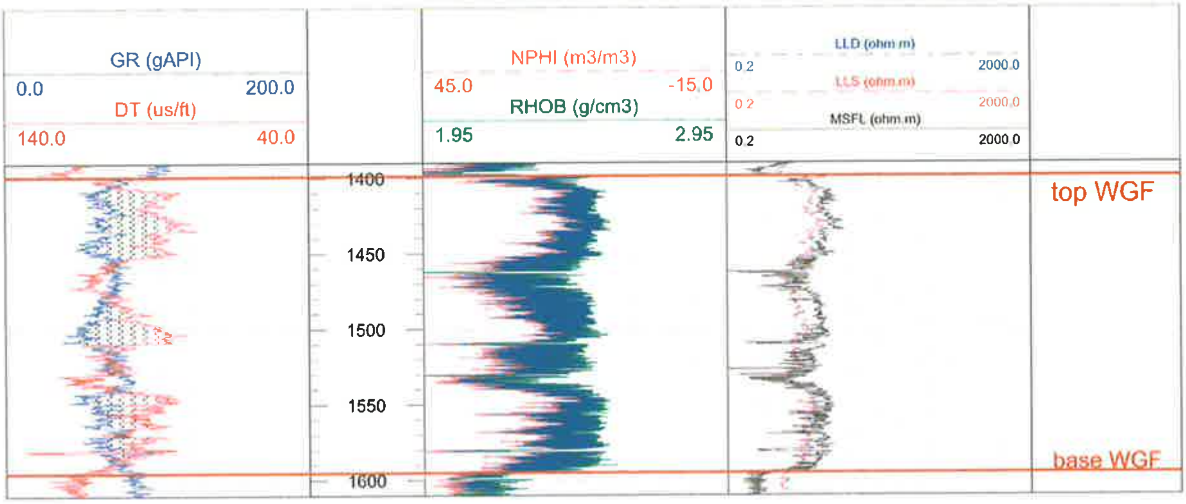
Representative sections for the Woolaston, Gibson and Fenelon Formations (WGF) are presented in Rainier 1 (Figure 4-15), Skua 8 (Figure 4-16), Swan 1 (Figure 4-17), Brown Gannet 1 (Figure 4-18) and Sahul Shoals 1 (Figure 4-19).

The section shown in Rainier 1 is typical of WGF sediments along the Londonderry High and eastern Vulcan Sub-Basin. The Rainier 1 section in particular shows layers of calcareous claystone and marl with the calcareous claystone layers corresponding to a slightly higher GR and slower DT response (no shading in Figure 4-15), while the sections of marl have a lower GR and a faster DT response (shaded with marl lithology in Figure 4-15). Overall, the WGF succession in Rainier 1 is a carbonate-dominated claystone.

The Skua 8 (Figure 4-16) and Swan 1 (Figure 4-17) succession are representative of the WGF from the central part of the Vulcan Sub-Basin and are interpreted as a distal equivalent of the Rainier 1 section. The WGF section in both Skua 8 and Swan 1 wells is characterised by a relatively low and uniform GR response and a relatively fast DT log response. In the WGF section, based on well completion report cuttings descriptions and cuttings sample analysis, these log responses are indicative of marls and calcareous claystones.

Brown Gannet 1 (Figure 4-18) and Sahul Shoals 1 (Figure 4-19) sections are representative of WGF sediments on the distal Ashmore Platform. Both sections have very low GR response and relatively quick DT response. The WGF formation becomes more calcareous distally and this is reflected in the GR and DT response in these wells.

Rainier 1 1cm:50m




Rainier 1 1cm:25m

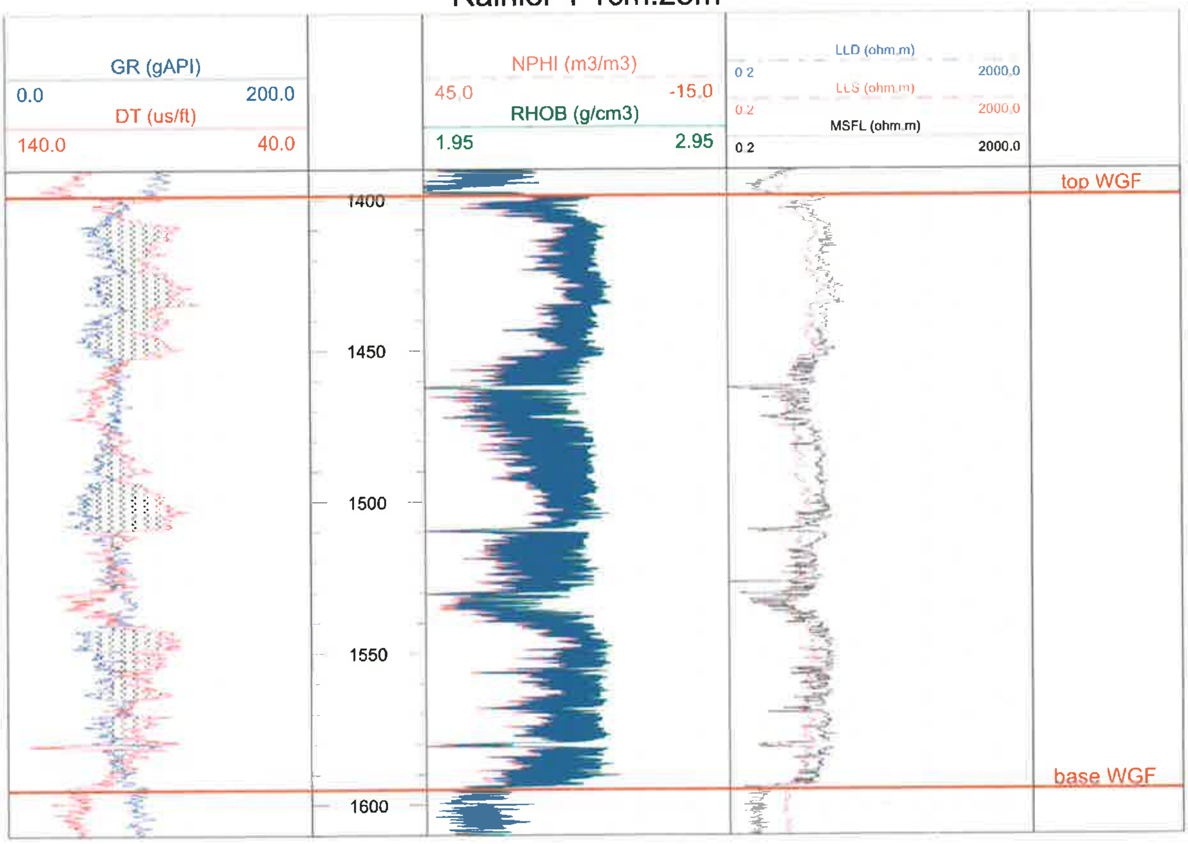



Figure 4-15: WGF section for Rainier 1.

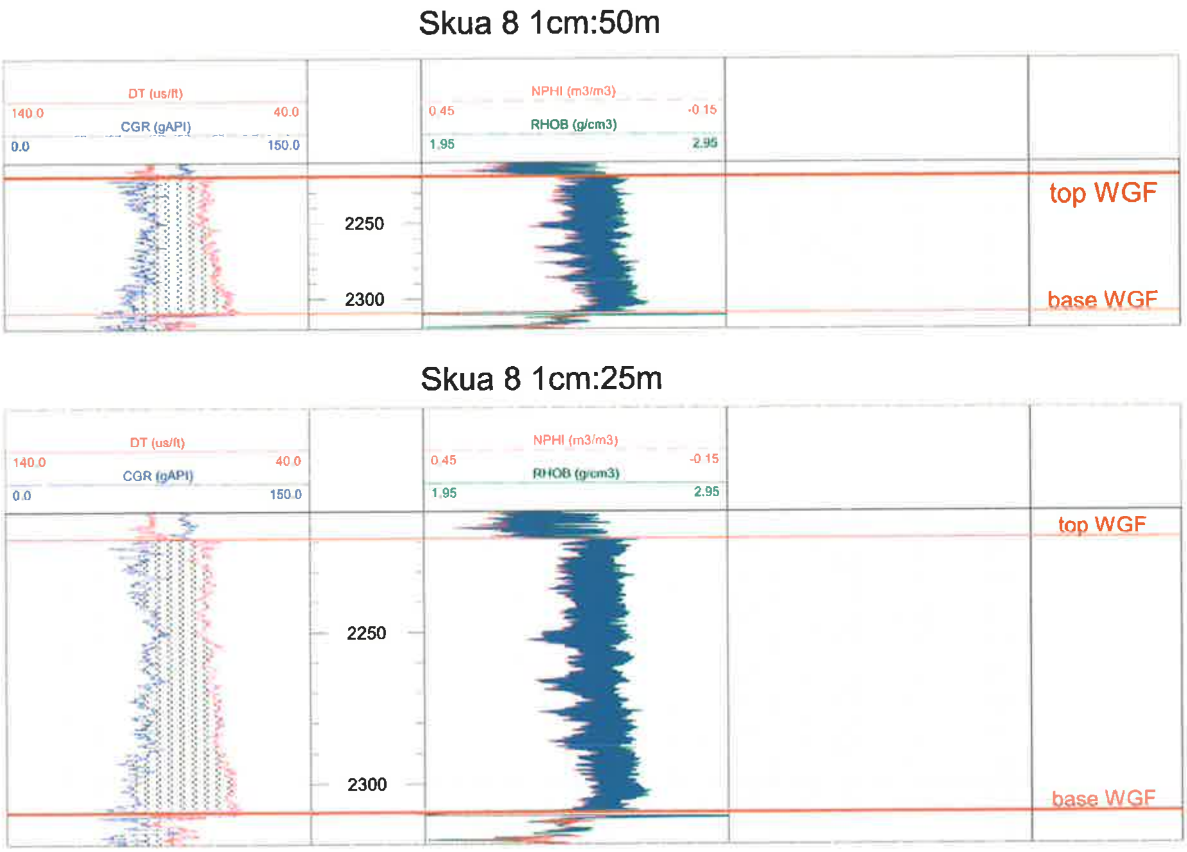
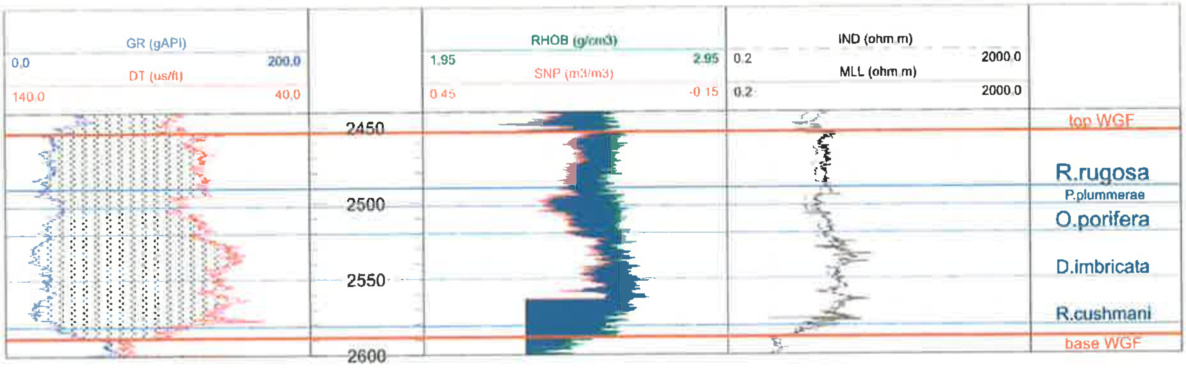



Figure 4-16: WGF section for Skua 8.

Swan 1 1cm:50m




Swan 1 1cm:25m

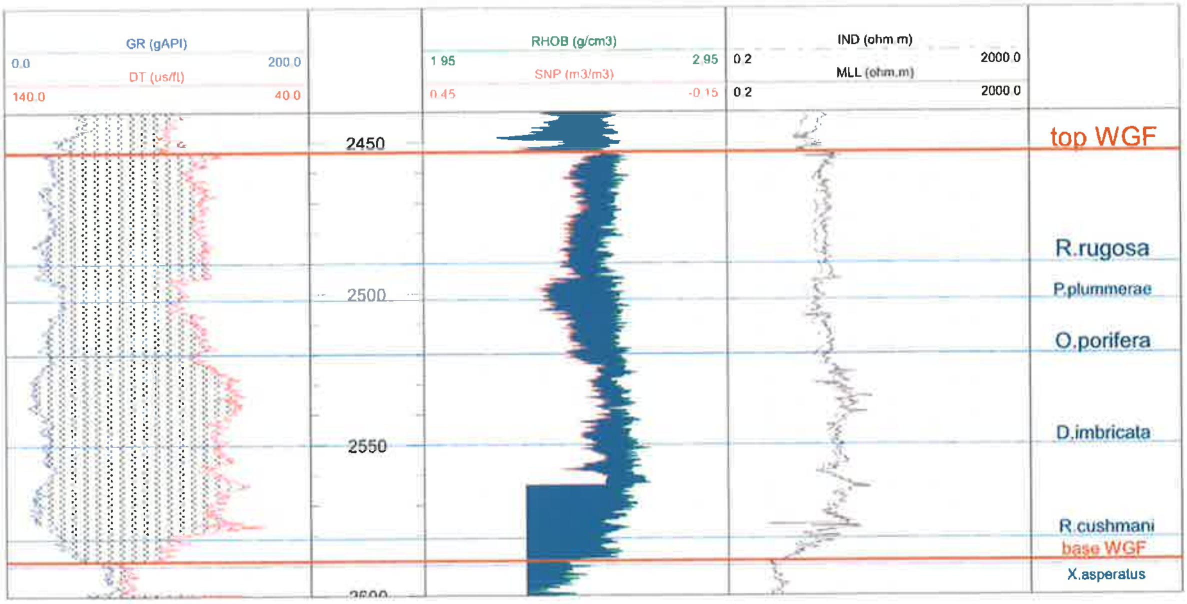



Figure 4-17: WGF section for Swan 1.

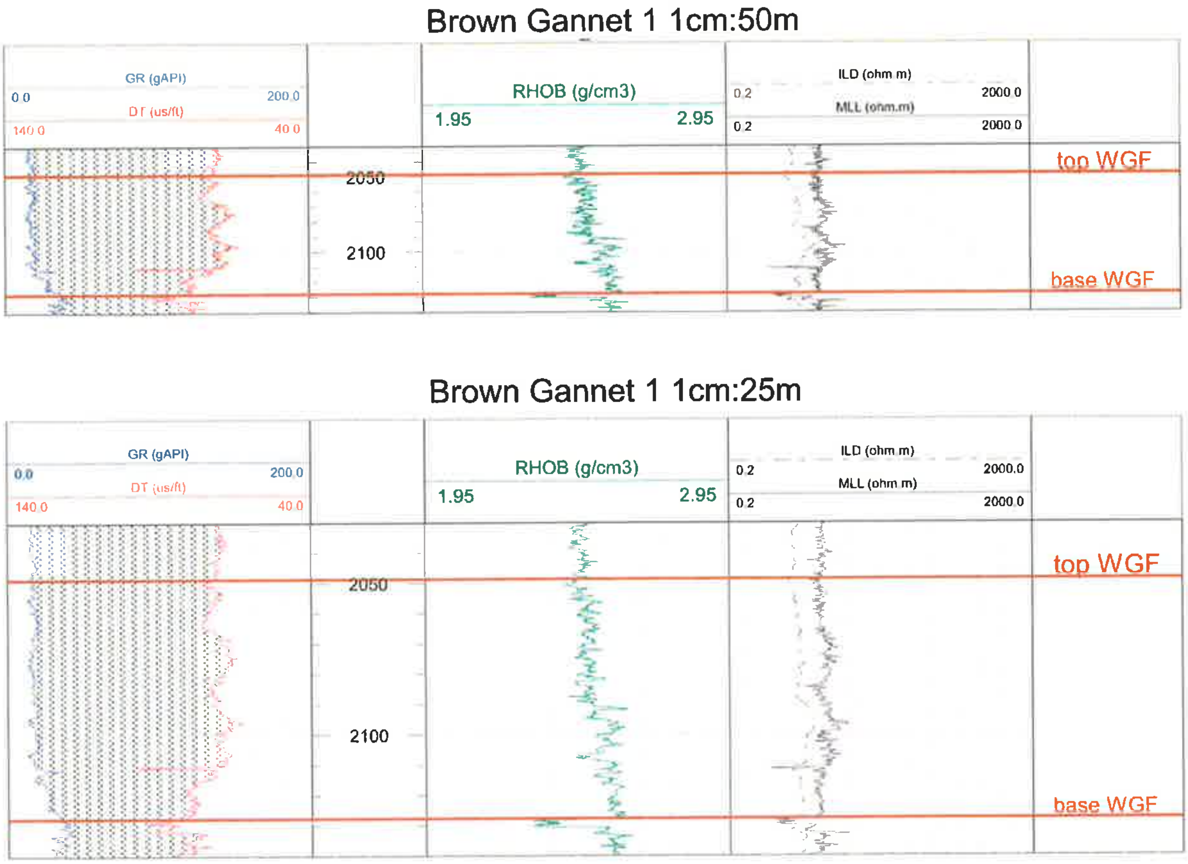



Figure 4-18: WGF section for Brown Gannet 1.

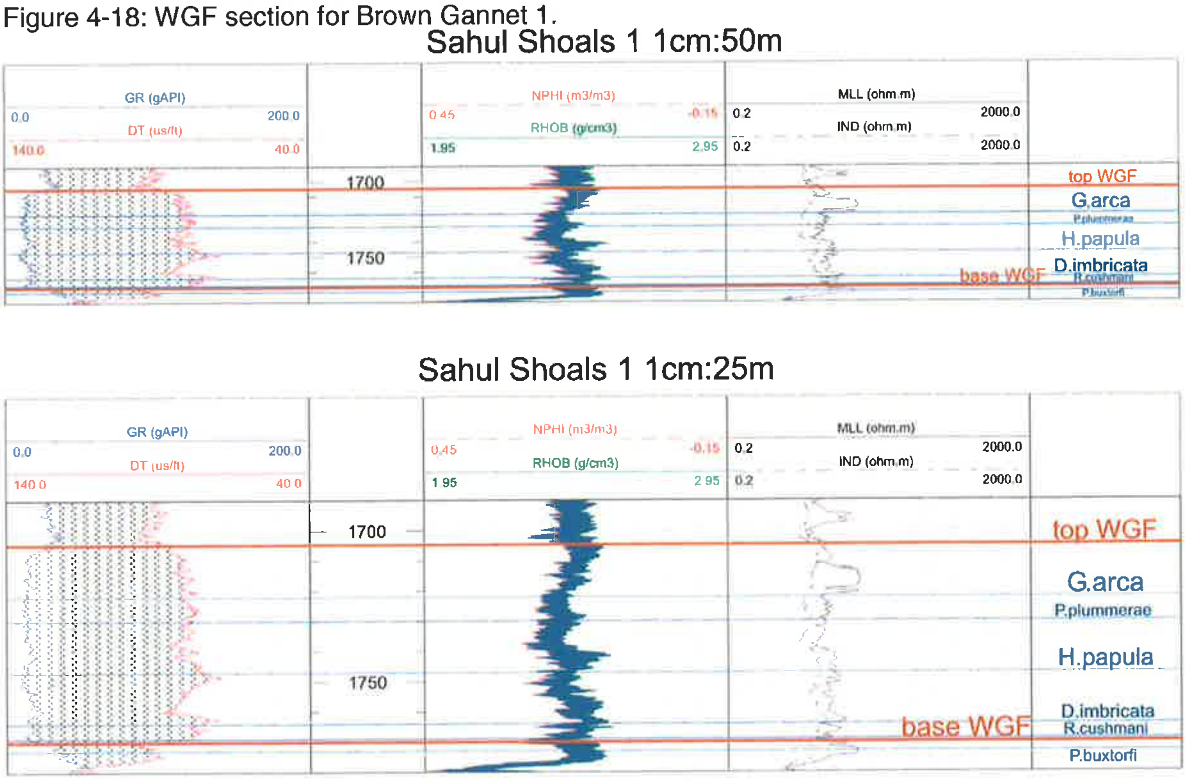



Figure 4-19: WGF section for Sahul Shoals 1.

## 4.4 Seismic Interpretation

The seismic interpretation methodologies used to generate the results presented in this section have been outlined in Chapter 2.

### 4.4.1 Seismic expression of wireline events

Synthetic seismograms were generated for wells that have good sonic data. Two examples are presented in this section showing well ties for Talbot 1 and Maret 1. Figure 4-20 and Figure 4-21 show synthetic seismograms for Maret 1 and Talbot 1 respectively.

The panels in both figures show the elements necessary for the generation of a synthetic seismic trace. The tracks described below are present in both figures and are numbered for reference in Figure 4-20:

1) Depth track (DvsT),

2) Sonic log track,

3) Scale track,

4) Reflection coefficient track,

5) Extracted wavelet track

6) Synthetic seismic track,

7) Seismic trace track showing seismic in the vicinity of the well,

8) Marker track and,

9) A track containing other log curves in the same well.

Seismic section from lines vtt-01 (closest seismic line to Maret 1) and vtt-09 (closest seismic line to Talbot 1) are shown in Figure 4-22 and Figure 4-23 respectively.

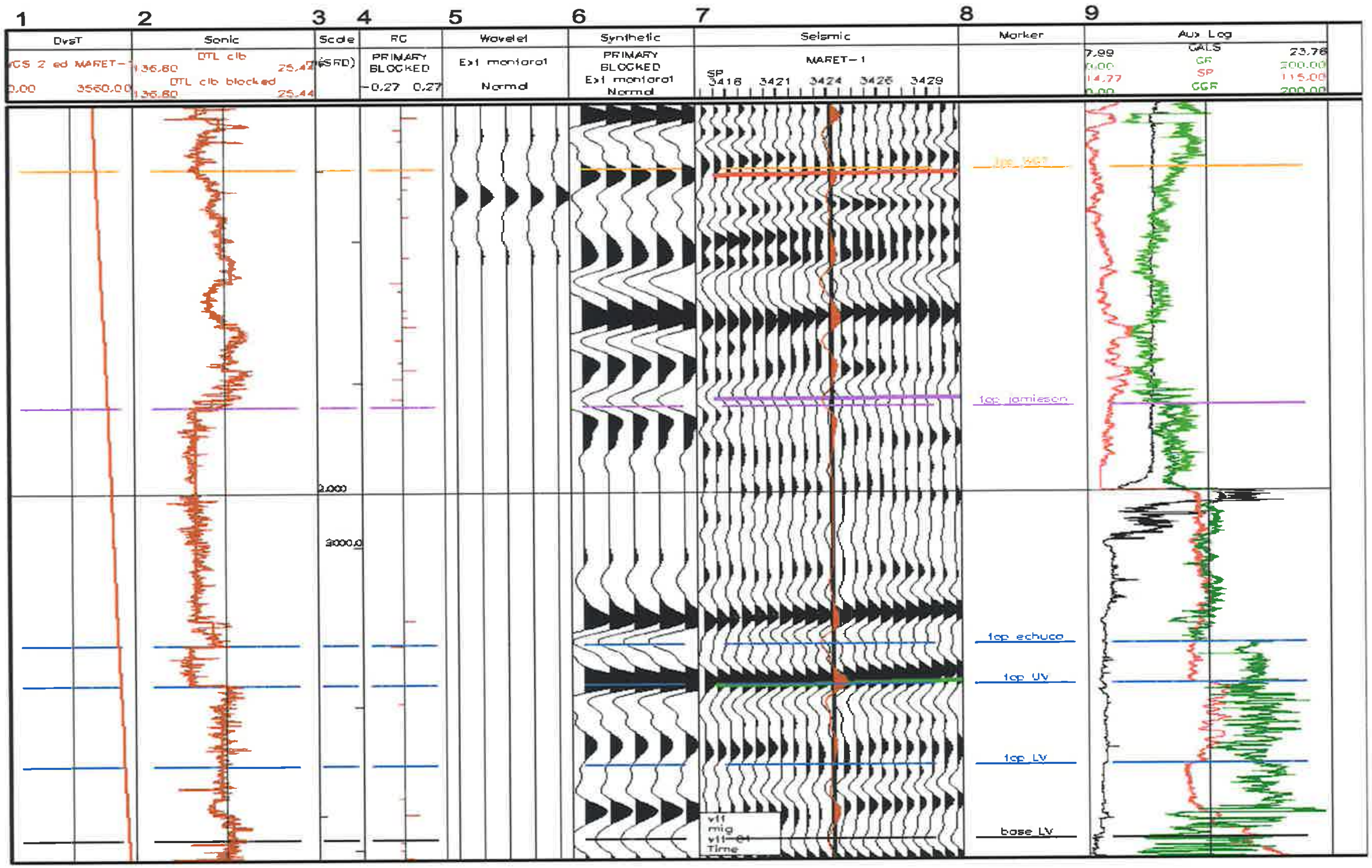



Figure 4-20: Synthetic seismic section for Maret 1.

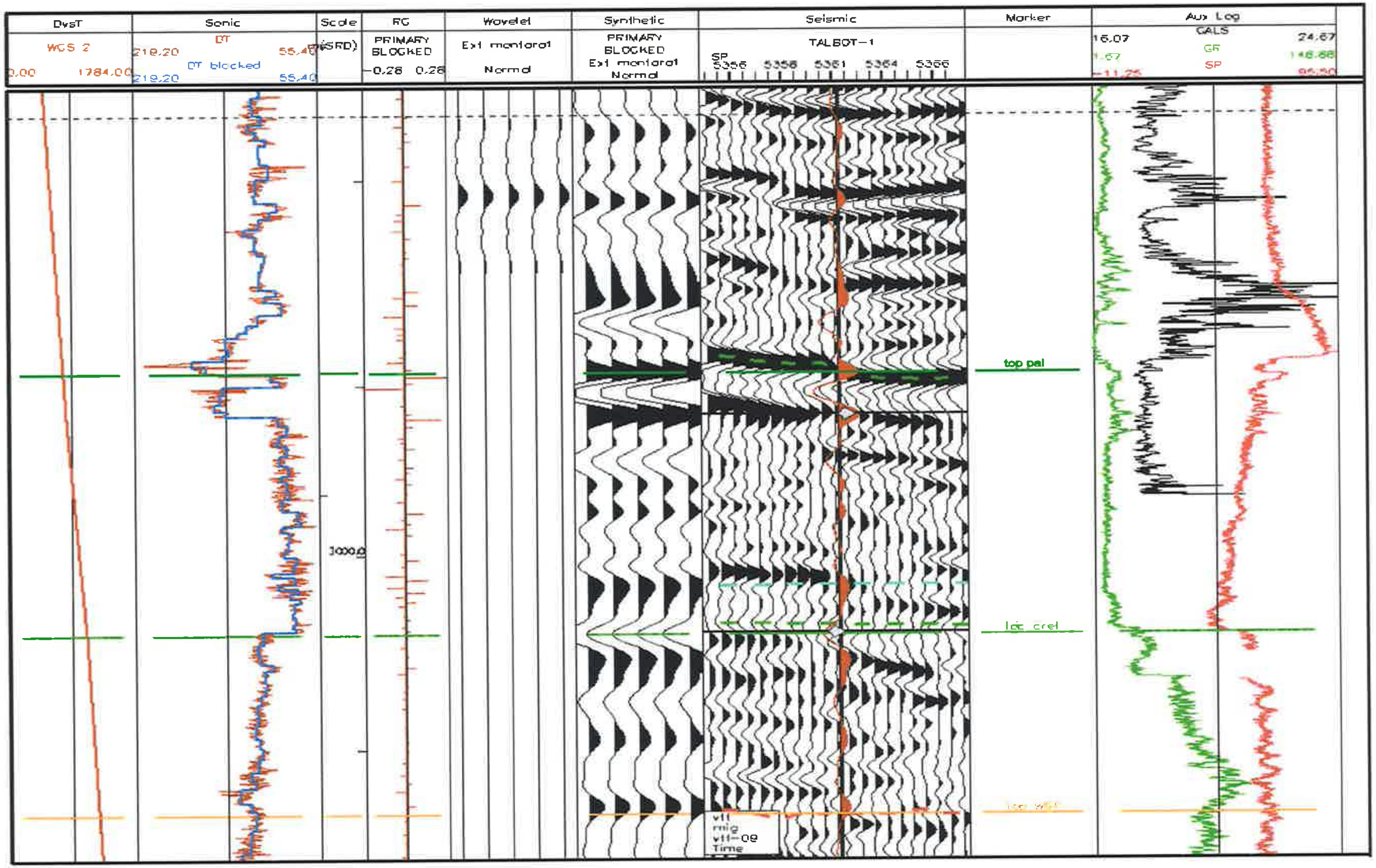



Figure 4-21: Synthetic seismic section for Talbot 1.

Two-way time maps of the Kimmeridgian unconformity (Figure 4-2), which forms the boundary between the Upper Vulcan and the Lower Vulcan formations, and the Callovian Unconformity, equivalent to the base Lower Vulcan Formation, were supplied by the Geoscience Australia.

The 'top UV' marker in Figure 4-20 corresponds to the top of the Upper Vulcan Formation in Maret 1, where the top of the formation is characterisied by shifts in the sonic log (from fast to slow) and a deflection in the SP log. The top UV marker in Figure 4-20 corresponds to a positive amplitude event. The horizon interpreted at the top UV marker in Figure 4-20 corresponds to the Valanginian Unconformity in Maret 1. In other parts of the study area, where the Upper and Lower Vulcan formations are missing, this horizon may represent an unconformity ranging from the Callovian to the Aptian epochs; in other words, as this horizon represents the main sequence boundary between the Jurassic and Cretaceous sediments in the Vulcan Sub-Basin. The top of the Echuca Shoals Formation ('top echuca' in Figure 4-20) exhibits a sonic shift from slow above the marker to fast below the marker (DT_aux in track 2 of Figure 4-20). There is also a distinct gamma ray log shift from low values above the marker to high values below the marker (GR log in track 9 of Figure 4-20), due to a much higher carbonate content in rocks above the marker. The sonic shift from slow (claystones) to fast (marl/calcareous claystone) across the top of the formation corresponds to a negative reflection coefficient and thus the top of the Echuca Shoals formation corresponds to a negative amplitude event. A relatively thick section of the Echuca Shoals Formation was intersected in Maret 1. Line vtt-01 and the Maret 1 synthetic seismogram and markers are shown in Figure 4-22. Note the excellent correlation between the synthetic and the seismic trace at the top Echuca marker.

Where seismically resolvable in the study area the top of the Echuca Shoals Formation is interpreted as a negative amplitude event.

The top of the Jamieson Formation is marked by the 'top Jamieson' marker in Figure 4-20. There is a shift in sonic log response from a generally slow sonic response below the top Jamieson marker (track 2 Figure 4-20) to a faster sonic response above the top Jamieson marker, which is consistent with a higher carbonate content above the top Jamieson marker. This shift in sonic response results in a negative reflection coefficient. Thus the top Jamieson marker corresponds to a negative amplitude on the synthetic seismic trace shown in track 6 of Figure 4-20. The top Jamieson horizon has been interpreted as a negative amplitude event on the sections shown in Figure 4-22 and Figure 4-23; this interpretation extends throughout the study area.

The top of the zone of interest in this study is represented by the 'top WGF' marker in Figure 4-20 and Figure 4-21. The top WGF marker corresponds to the top of the Woolaston, Gibson and Fenelon formations. Based on the log response, the top WGF marker generally correlates to a positive amplitude event however, this event does not have a strong log response, with only a small shift in sonic over the boundary evident in both Figure 4-20 and Figure 4-21. The top WGF is characterized by a weak positive amplitude in both sections shown in Figure 4-22 or Figure 4-23. Throughout the study area the WGF horizon, red horizon near 1750ms in Figure 4-22 and near 1000ms in Figure 4-23, was interpreted, with the aid of well ties, as a positive seismic event.

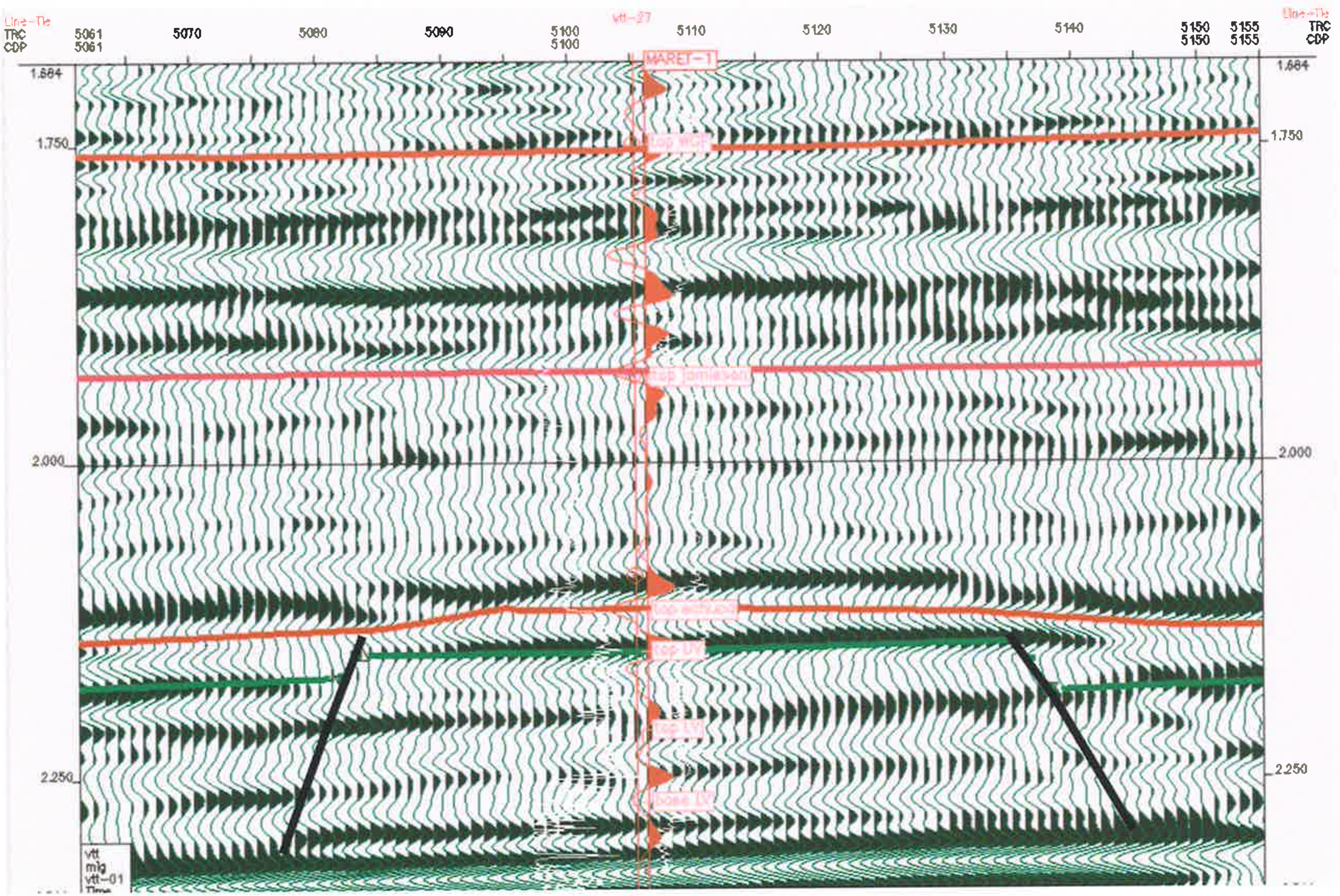



Figure 4-22: 2D seismic line vtt-01 showing the Maret 1 well synthetic well tie (with markers). Interpretation shows has been interpreted over the entire study area.

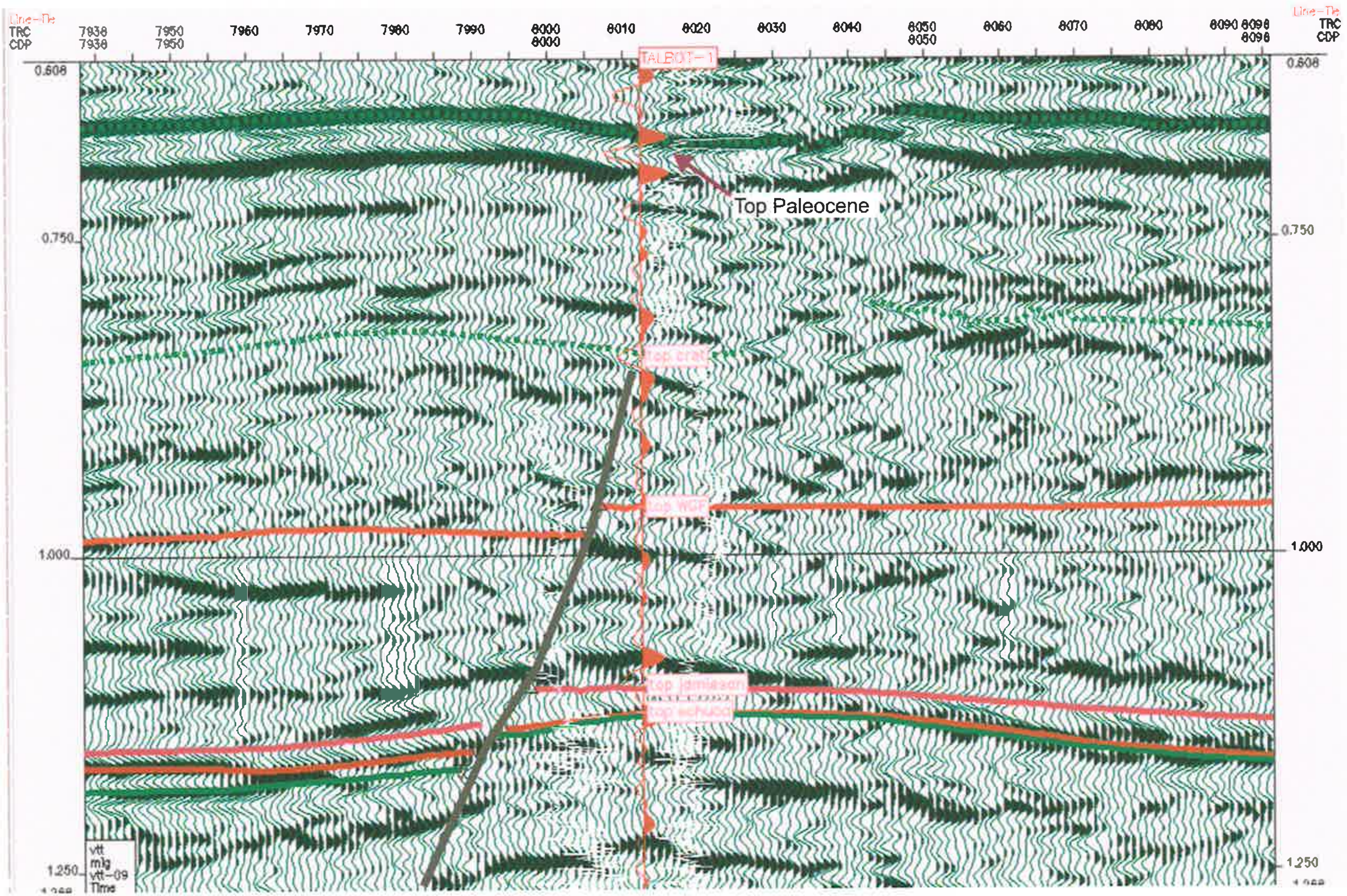



Figure 4-23: 2D seismic line vtt-09 showing the Talbot 1 well synthetic well tie (with markers). Interpretation shows has been interpreted over the entire study area.

The top Cretaceous marker, labelled as 'top cret' in Talbot 1 (Figure 4-21), generally correlates to a negative amplitude event. The top Cretaceous does not correspond to a strong seismic event (Figure 4-23) however, based on well ties, the 'top cret' horizon was interpreted as a reference horizon over the study area.

The youngest horizon interpreted is the top Paleocene reflector show in Talbot 1 (Figure 4-21) as marker 'top pal'. The top pal marker corresponds to a log break in both the sonic and SP logs however, there is little response in the gamma ray log. The seismic panel in Figure 4-21 shows seismic line vtt-09 ($7^{th}$ panel from left) with the Talbot 1 well path and synthetic seismic trace as a red wiggle. The top pal marker correlates with a positive amplitude event in the seismic section. The positive amplitude that was interpreted as the top Paleocene seismic event corresponds to the horizon between 0.6 and 0.75 ms shown in Figure 4-23.

### 4.4.2 Results & Discussion – Log Signature Maps

The following sections present wireline log signature maps for the Lower Vulcan, Upper Vulcan, Echuca Shoals, Jamieson and WGF intervals. The aim of this section is to highlight the facies types and distribution within each interval. Log signatures are shown with the same vertical and horizontal scale on all maps and consist of a gamma ray log (black trace) and a sonic log (red trace). For each interval, a map (twt to base of interval or interval isochron thickness) is presented, wireline log signatures for every well that intersected the interval of interest are shown surrounding the map.

#### 4.4.2.1 Lower Vulcan

The Lower Vulcan Formation log signature map is presented in Figure 4-24, with a two way time to the Callovian unconformity map shown for reference. The two-way time map of the Callovian unconformity was supplied by Geoscience Australia; (pers com, John Kennard 1999).

The extent of the Callovian Unconformity in the Vulcan sub-basin as shown in Figure 4-24, is representative of the extent of the Lower Vulcan Formation sediments. Where the Callovian unconformity is cut by the younger Kimmeridgian unconformity, the Lower Vulcan formation is missing. The Callovian and Kimmeridgian unconformities occurred during Late Jurassic to Early Cretaceous rifting (Pattillo and Nicholls 1990).

All sediments of the Vulcan Formation are clastic. The well logs presented in Figure 4-24 can be grouped into two main facies types. In the southeastern Vulcan Sub-Basin (area 1 in Figure 4-24), the log character seen in Montara 1, Tahbilk 1 and Taltarni 1 is characteristic of coarsening upwards deltaic sands. All three wells also have over 100m of claystone overlying the shallowest sands. This early infill, comprising coarse clastic sediments, was described by (Pattillo and Nicholls 1990) as a fan-delta depositional system that occurs predominantly at the graben margins in the southeastern part of the Vulcan Sub-Basin.

The Lower Vulcan formation is relatively thin along the northeastern terraces of the Vulcan Sub-Basin (area 3 in Figure 4-24), either because of non-deposition or erosion. In the deeper parts of the Vulcan Sub-Basin, represented by the colder colours in Figure 4-24 (area 2), the Lower Vulcan Formation is over 500m thick and is primarily composed of restricted marine mudstones. With continued graben development, these mudstones were deposited progressively over the entire Vulcan Sub-Basin after fan-delta progradation had ceased in the southeastern part of the sub-basin.

The log signature maps, suggests that the Lower Vulcan Formation proximal clastic sediments (mainly sands) dominate the eastern Vulcan Sub-Basin. The rocks become finer grained towards the west and are interpreted as more distal sediments.

A basal transgressive sand overlying the Callovian unconformity is present in almost all wells which intersect the Lower Vulcan formation.

The main potential reservoirs of the Lower Vulcan formation are the proximal deltaic sandstones along the eastern margins of the Sub-Basin. This Lower Vulcan Formation specific deltaic play type is predominantly sealed by intra-formational Lower Vulcan claystones and siltstones, with younger regional seals having minimal impact in sealing the reservoir.

In the deeper parts of the Vulcan Sub-Basin, the distal claystones of the Lower Vulcan Formation provide seals to reservoir sandstones of the Plover Formation, which is one of the main reservoir targets. However, due to Kimmeridgian and Valanginian uplift and erosion the Lower Vulcan formation is most often eroded from structural highs proximal to the basin margins.

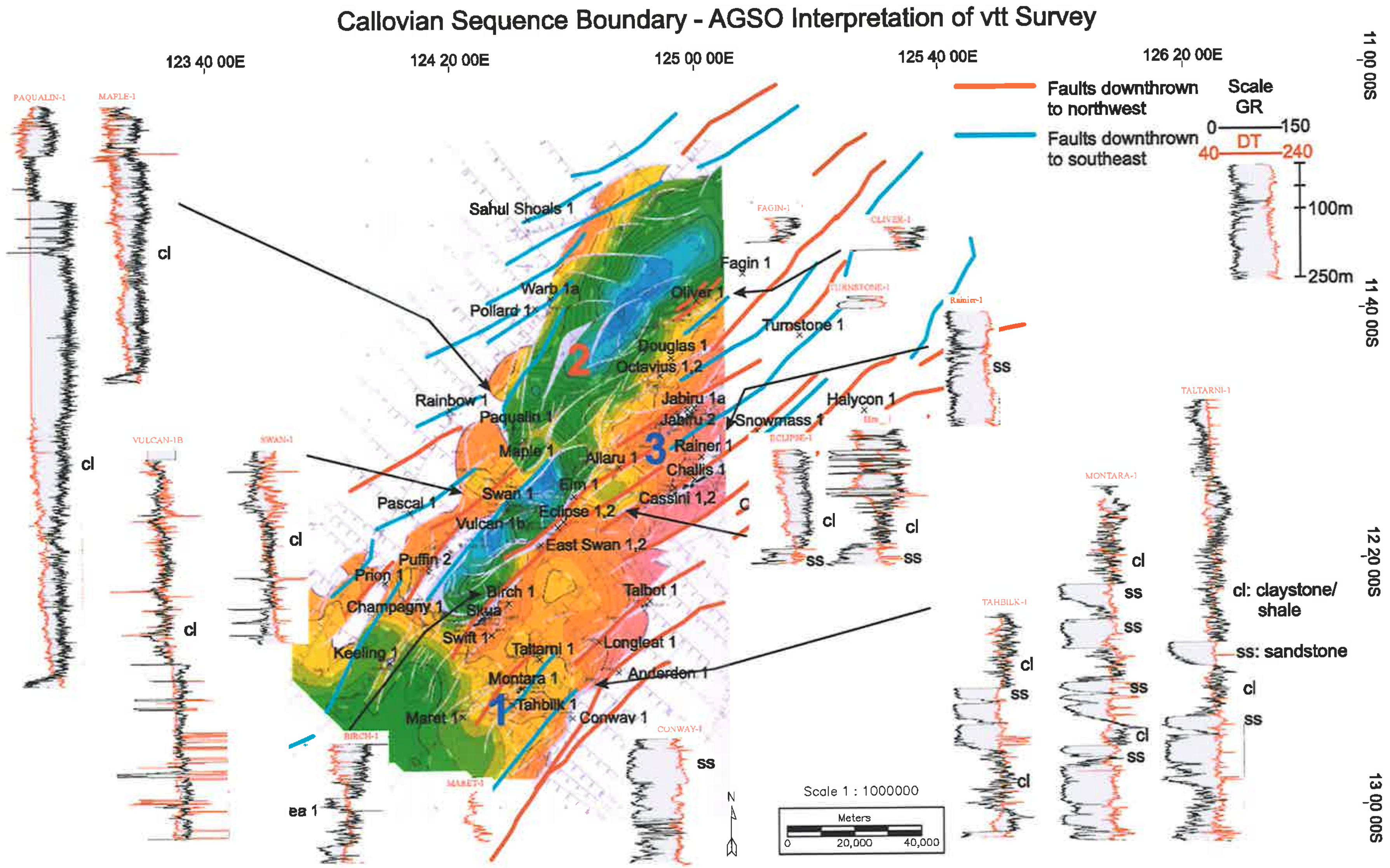



Figure 4-24: Two way time map of the Callovian unconformity showing the lateral extent of the Lower Vulcan Formation. GR/DT log signature plots are posted for each well showing facies distribution and thickness.

#### 4.4.2.2 Upper Vulcan

The Upper Vulcan formation log signature map and the Kimmeridgian Unconformity two-way time map are presented in Figure 4-25. The Kimmeridgian Unconformity is an erosional unconformity which resulted from Late Jurassic to Early Cretaceous rifting; it is the basal bounding surface to the Upper Vulcan Formation. The two-way time map of the Kimmeridgian unconformity was supplied by GeoScience Australia (pers com John Kennard 1999).

The extent of the Kimmeridgian Unconformity in the Vulcan Sub-Basin, as shown in Figure 4-25, is representative of the extent of the Upper Vulcan Sub-Basin sediments. Where the Kimmeridgian Unconformity is coincident with the younger Valanginian Unconformity, the Upper Vulcan Formation is missing. (Pattillo and Nicholls 1990) describe the Kimmeridgian Unconformity as the expression of the final, most intense stage of rifting in the Vulcan Sub-Basin. In many palaeo high areas, such as the basin-bounding Londonderry High and Ashmore Platforms, the Kimmeridgian and Callovian unconformities amalgamate.

The Upper Vulcan sediments are restricted to the deeper parts of the Vulcan Sub-Basin and consist primarily of claystone and siltstone sediments. Turbiditic sands occur in Rainier 1, Octavius 1 (Figure 4-5), Fagin 1 (Figure 4-6), Snowmass 1 and Halcyon 1 on the Jabiru Terrace in the northeastern Vulcan Sub-Basin (area 1 in Figure 4-25). These sands were most likely proximal sub-marine fan deposits laid down locally adjacent to newly developed horsts (Pattillo and Nicholls 1990).

Overall, the Upper Vulcan Formation section is restricted to the Vulcan Sub-Basin depocentres and was either not deposited, or was eroded from most of the horsts within the Vulcan Sub-Basin and high surrounding areas.

The afore mentioned turbiditic fan sandstones sealed by overlying claystones is an intra-formation stratigraphic play type within the Upper Vulcan Formation, the seal potential of which is dependant on localised seals. Hence regional seal effectiveness will have no effect on top seal risk for this play type. As with the Lower Vulcan Formation, the Upper Vulcan Formation claystones, where they are present on intra-basin highs, may provide top seal for the underlying Late Triassic Challis and Early Jurassic Plover clastic reservoir plays. The Valanginian uplift and erosion event has, in all but the main basin depocenters, eroded the Upper Vulcan Formation and thus the Upper Vulcan claystones cannot be considered as a regional seal.

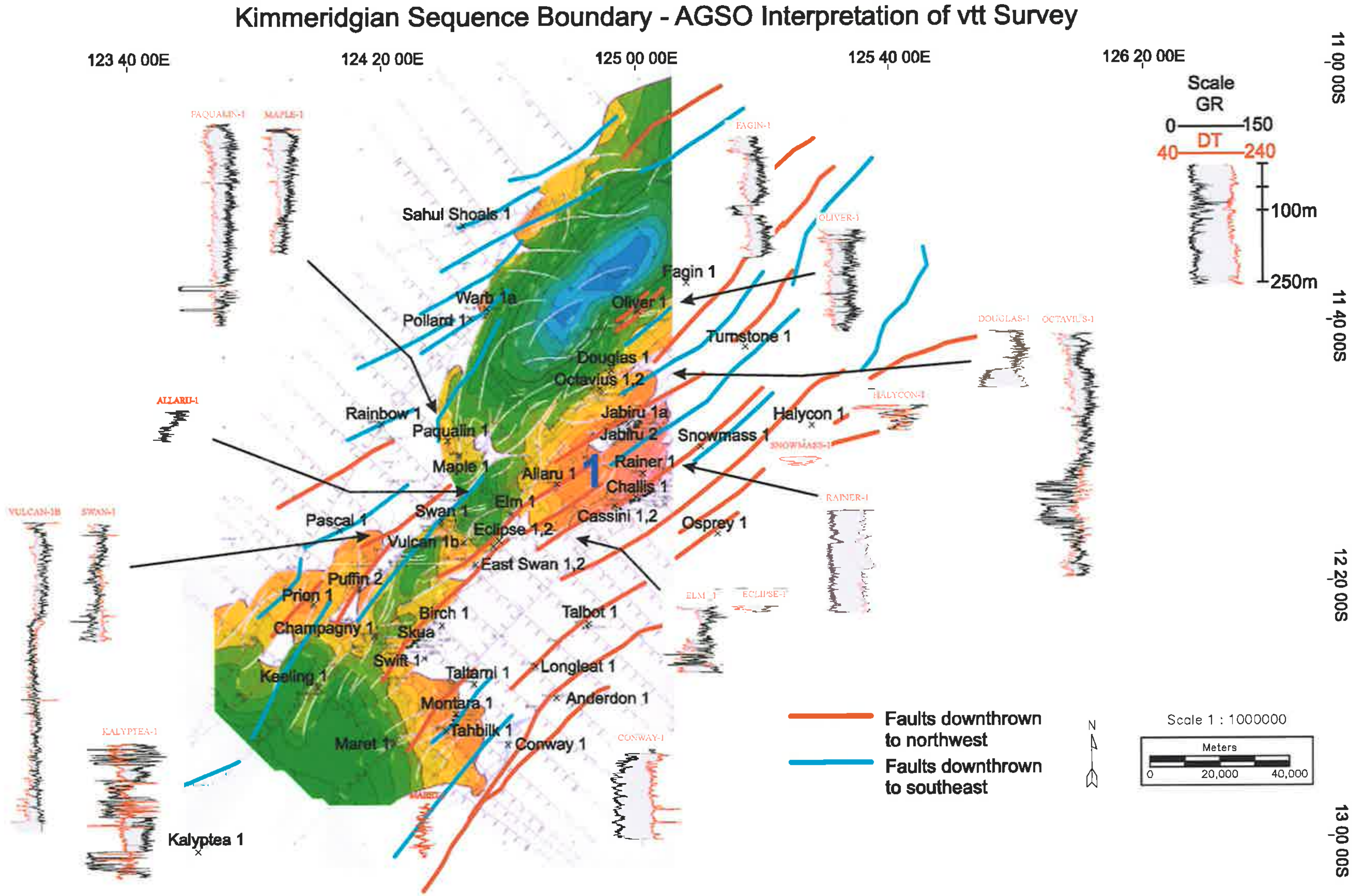



Figure 4-25: Two way time map of the Kimmeridgian unconformity showing the lateral extent of the Upper Vulcan Formation. GR/DT log signature plots are posted for each well showing facies distribution and thickness.

#### 4.4.2.3 Echuca Shoals

The Echuca Shoals Formation isochron map over the study area is presented in Figure 4-26, along with well logs signatures. The Echuca Shoals Formation is absent from the Londonderry High (area 1 in Figure 4-26) and the Ashmore Platform (area 2 in Figure 4-26), which form the southeastern and northwestern boundaries of the Vulcan Sub-Basin.

This interval is thin to absent over palaeo-high areas such as the Skua, Jabiru and Puffin Horsts, the Montara Terrace and much of the Londonderry High. The Echuca Shoals Formation ranges from less than 10m thick along parts of the Ashmore Platform and Londonderry High to more than 50m in the vicinity of the Cartier Trough. A 50m section of Echuca Shoals Formation occurs in Oliver 1 and is the maximum thickness of this formation within the Vulcan Sub-Basin. The Echuca Shoals Formation thickens in the major depocentres of the Vulcan Sub-Basin (area 3 in Figure 4-26). Away from the depocentres, the Echuca Shoals Formation is less than 25 meters thick; this is highlighted by the thin section seen on logs (Figure 4-26). Although the Echuca Shoals Formation is relatively thin, it is composed primarily of clastic claystones and represents a condensed section in the Vulcan Sub-Basin. Pattillo and Nicholls (1990) have interpreted the intra-Valanginian disconformity as a regional transgressive surface representing the base of post-rift sedimentation. The Echuca Shoals Formation sediments represent a period of transgression, with thin basal sandstones that fine upwards to condensed sections of claystones and glaucontic claystones, which were deposited in a clastic starved shelfal environment. The condensed claystones of the Echuca Shoals Formation most likely are the maximum flooding event for the post Late Jurassic rift sequence in the Vulcan Sub-Basin.

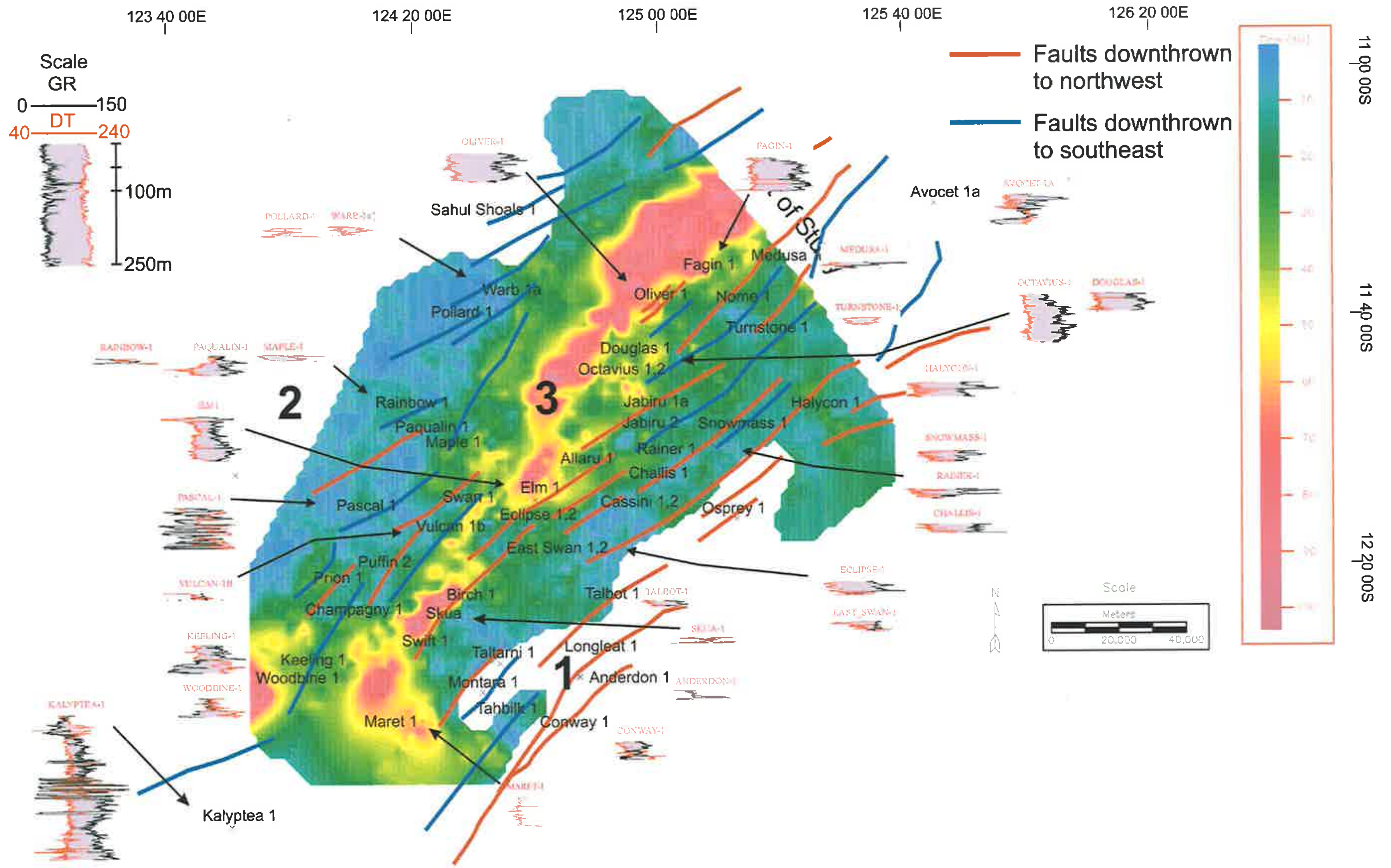



Figure 4-26: Isochron map of the Echuca Shoals Formation showing thickness and lateral extent of the formation. GR/DT log signature plots are posted for each well showing facies distribution and thickness.

### 4.4.2.4 Jamieson

The Jamieson Formation well logs are presented in Figure 4-27 together with an isochron map of the Jamieson Formation over the study area.

This is the lowest interval of mixed calcareous and clastic sediments desposited in a deep-water, clastic starved environment. In the central Vulcan Sub-Basin, the basal 10m of this formation is commonly made up of radiolarite. A a type section for radiolarite is shown in Kalyptea 1 well, which lies in the northern Browse basin. The bottom 50m of the Kalyptea 1 well log section (Figure 4-27) shows a typical log response of radiolarite, which has a very low gamma ray response and a very slow sonic log response.

Well log signatures in Figure 4-27 have predominantly high gamma-ray responses of over 75 API and indicate that claystones and calcareous claystones dominate the Jamieson Formation. The thickest section, of 200 to 500m in Osprey 1 and Halcyon 1, occurs in the central Londonderry High, which forms the eastern boundary of the Vulcan Sub-Basin (Area 1 in Figure 4-27).

The depositional thickness of the Jamieson Formation is controlled by paleotopography in the central and western Vulcan Sub-Basin. A thicker, deep-water progradational wedge increases the thickness of the Jamieson Formation along the eastern most Londonderry High (Area 1 in Figure 4-27).

The Jamieson Formation thins from east to west and is less than 25m in thickness on the Ashmore Platform (Area 2 in Figure 4-27). There is also a facies change evident on the logs, with the thicker, eastern sediments being dominated by claystones whereas the thinner western sediments are composed of marls and very calcareous claystones. The difference in carbonate content may be due to less fine grained clastic sediments being deposited in the more distal areas such as the Ashmore Platform.

Area 3 in Figure 4-27 shows the Jamieson Formation thickening significantly into the adjacent Browse Basin, which lies to the south of Vulcan Sub-Basin.

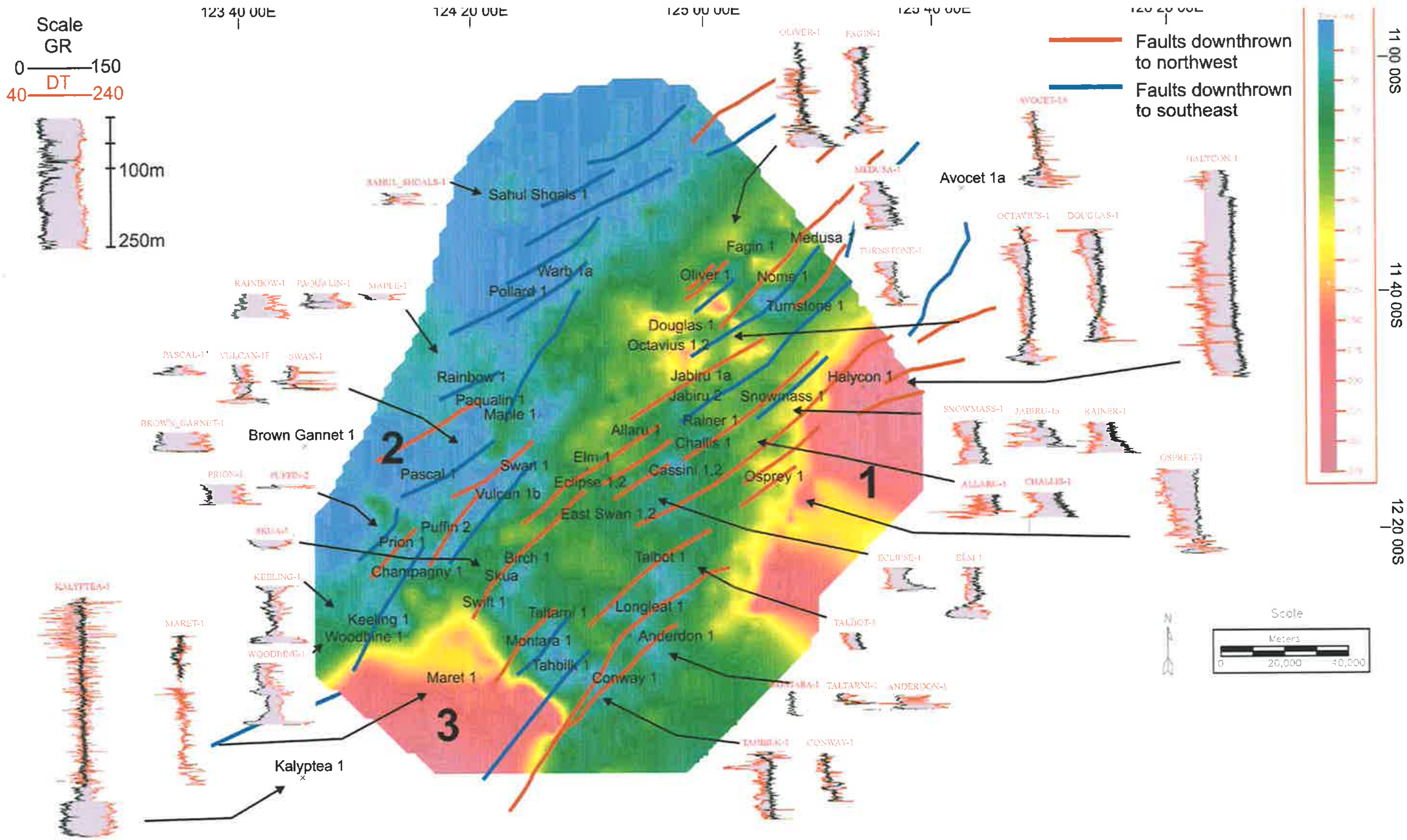



Figure 4-27: Isochron map of the Jamieson Formation showing thickness and lateral extent of the formation. GR/DT log signature plots are posted for each well showing facies distribution and thickness.

#### 4.4.2.5 WGF

An isochron map of the WGF interval is presented in Figure 4-28, together with well log signatures.

The thickness of the WGF interval ranges from over 250m on the Londonderry High (area 1 in Figure 4-28) to 70m to 100m on the Ashmore Platform (area 2 in Figure 4-28). There is a distinct variation in log signatures between area 1 and area 2. The WGF interval on the Londonderry High is made up of interbedded intervals of calcareous claystone and marl, thus as the carbonate content of the rock increases the gamma ray value decreases and the sonic log slows. The distinct zig-zag patterns that can be seen in the logs of Allaru 1, Rainier 1, Challis 1 and Jabiru 1a are due to interbedded sections of calcareous claystones and marls.

Along the western side of the Vulcan Sub-Basin, marls and deepwater carbonates dominate the sediments. A type section of a distal carbonate-dominated interval of the WGF Formation is shown for Brown Gannet 1 (Figure 4-18) and for Sahul Shoals 1 (Figure 4-19). These wells show typical low gamma ray values and slow sonic log values indicative of high carbonate content in non-clastic environments. Log signature for wells along the Ashmore Platform (Figure 4-28) have similar log characteristics to those seen in Figure 4-18 and Figure 4-19.

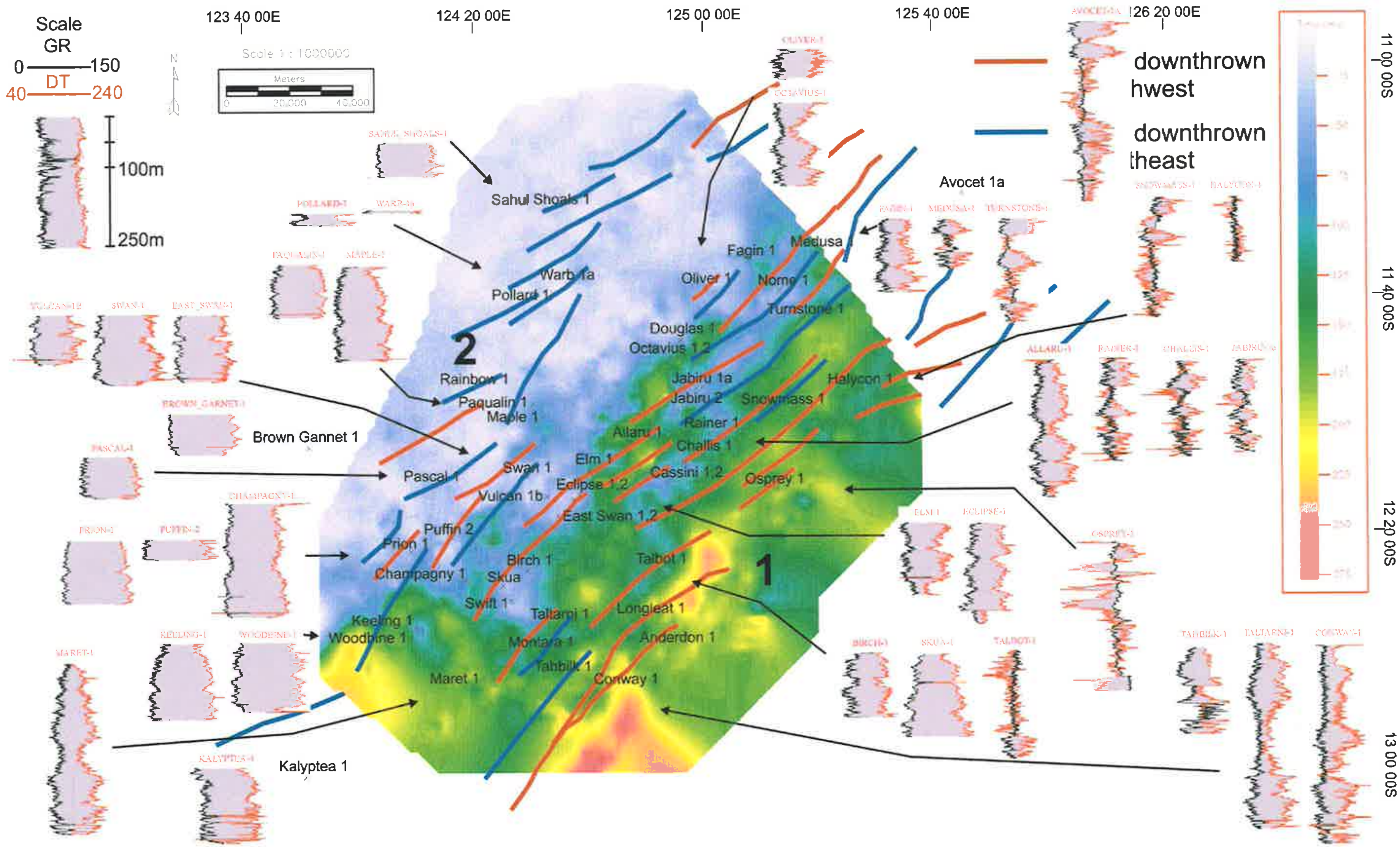



Figure 4-28: Ishochron map of the Woolaston, Gibson and Fenelon (WGF) Formations. WGF thickness ranges from 70 to 100m along the Ashmore Platform to over 200m along the Londonderry High. GR/DT log signature plotted showing facies distribution and thickness

### 4.4.3 Log Signature Maps Discussion

Of the five intervals studied, the Lower Vulcan and Upper Vulcan formations both contain reservoir facies and sealing facies however, any sands found within these formations represent minor stratigraphic plays in the Vulcan Sub-Basin.

The most successful play type in the Vulcan Sub-Basin is composed of Let Triassic to Early Jurassic reservoir (Challis and Plover Formations), with structural relief created by Late Jurassic (Kimmeridgian to Valanginian) rifting and sealed by regionally extensive combinations of the Echuca Shoals, Jamieson and WGF Formations.

The Echuca Shoals Formation, although thin, is the youngest regionally extensive sealing interval in the section and represents a condensed section deposited during an early transgression. The Echuca Shoals Formation may contain the post rift maximum flooding surface. In many areas, the Echuca Shoals formation lies under the Jamieson and WGF formations, with all three forming the seal. However, each interval has unique sealing properties and variations in those properties; therefore the intervals have been analysed individually.

# Chapter 5 Sample Analysis - Seal Capacity, SEM & XRD

## 5.1 Introduction

The general sampling methodology for this section has been outlined in Chapter 3. For each interval defined in Chapter 4, a set of capillary pressure results, with accompanying x-ray diffraction mineralogy and scanning electron microscope images are presented below. Examples of seal character variation are also highlighted within the regionally extensive intervals.

For each sample tested the results are presented, as multi component figures comprising:

A) A wireline log composite of GR and DT logs, with each top seal interval studied identified next to the well. The location of the sample in the well is shown as a red dot on the log plot and associated depths over which the samples were taken as well as seal capacity (oil retention) are noted next to the location,

B) MICP results showing pressure vs. mercury saturation, from which threshold pressure has been derived. The intrusion curve is shown in black and the slope of the curve, which was used to remove conformance effects, is shown as a blue dashed line. The sample depth, threshold pressure and calculated seal capacity (oil retention) have been noted above each intrusion graph,

C) Pore throat size distributions derived from MICP intrusion data,

D) X-ray diffraction analysis results,

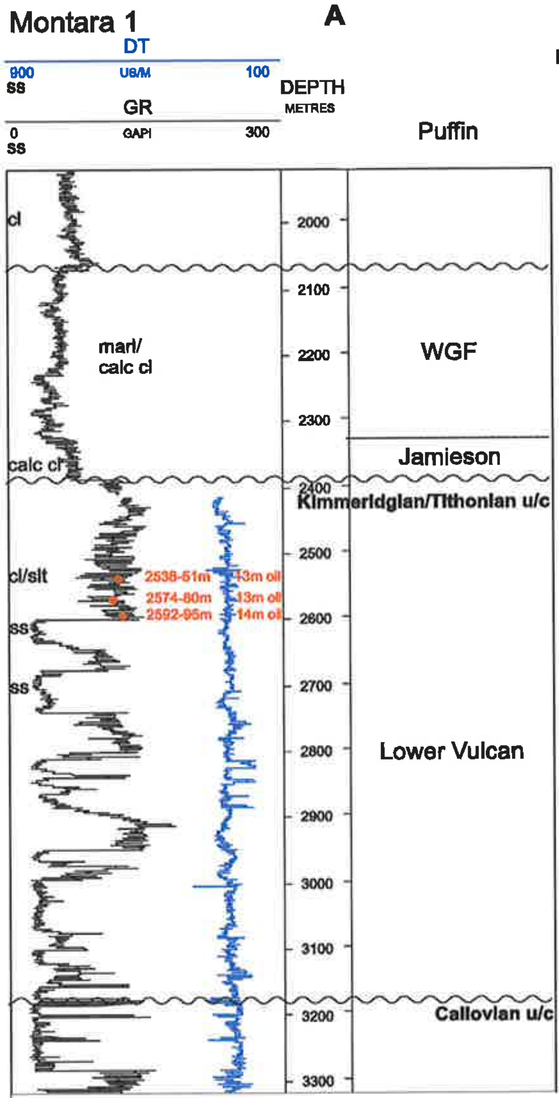
E) Scanning electron microscope image of the sample.

Seal capacity results have been presented with error ranges, which show how sensitivities in the seal capacity equation input variable affect the seal capacity column height. Input variable sensitivity has been outlines in Chapter 3 and specifically Table 3.1.

### 5.1.1 Lower Vulcan

The Montara 1 well (Figure 5-1) is situated on the southern Montara Terrace (Figure 4-1) near the transition zone between the Vulcan Sub-Basin and Browse Basin. This well contains a Late Callovian to Early Oxfordian lowstand deltaic sand section (Figure 5-1 A), which represents initial rift infill at the base of the Lower Vulcan Formation. Cuttings were sampled from three intervals above a hydrocarbon bearing sandstone at 2600m; the sampled intervals are shown as red dots in Figure 5-1A. Very similar results were obtained for all three samples. Results for the interval sampled between 2358m to 2341m are presented in Figure 5-1. A threshold pressure of 85psi was measured and corresponds to a seal capacity of 13m oil column (Figure 5-1B). Smectite clays are clearly visible clogging pore throats in the SEM image shown in Figure 5-1D, in what is most likely a deltaic siltstone. The smectite clays coat silt sized quartz grains in the image.

In contrast to the above sample, the Lower Vulcan Formation sampled in Jabiru 2 at 1637m is a claystone (Figure 5-2). Jabiru 2 lithologies consist of claystones overlying a basal transgressive sandstone. This sample has a threshold pressure of 3917psi which corresponds to a seal capacity of 340m oil column (Figure 5-2B). The XRD results (Figure 5-2D) indicate that the sample mineralogy is predominantly kaolinite clay with minor illite and calcite. Kaolinite, illite and a suspended coccolith have been highlighted on the SEM image (Figure 5-2E).



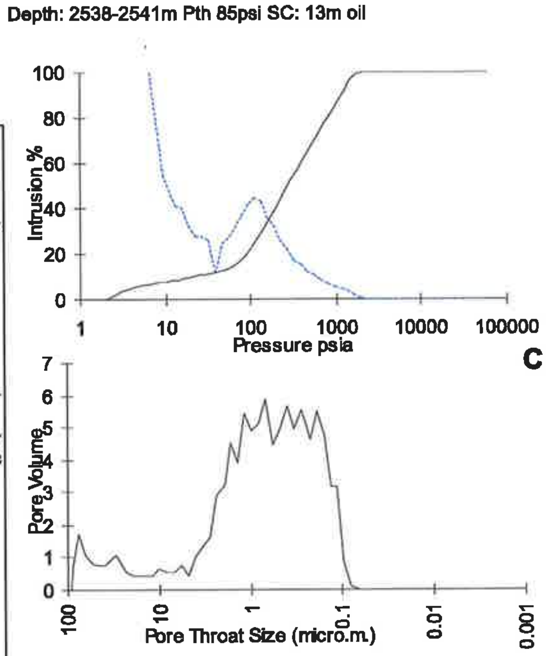
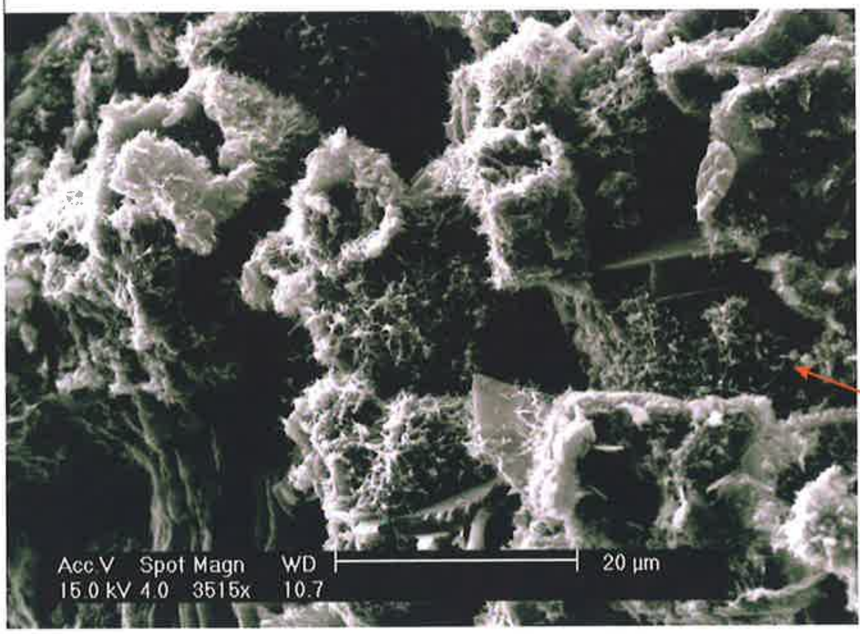
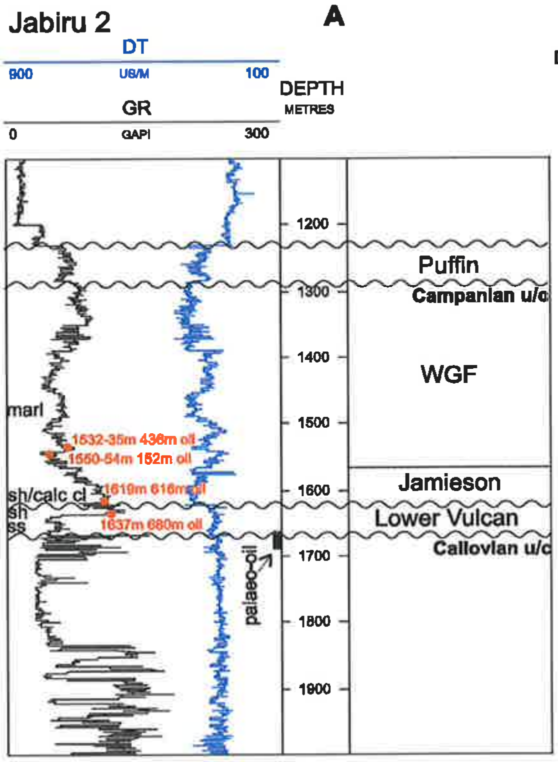




Figure 5-1: Results for Montara 1 Lower Vulcan cuttings samples from a depth between 2538-2541m. A well log composite is show in A with the locations of the sample indicated by the red dot. The capillary pressure intrusion profile is shown in B (black curve) with the change in slope of this curve plotted as the dashed blue line. The pore throat size distributions is shown in C. X-ray diffraction results with peak interpretations are presented in D and an scanning electron microscope image of the sample is presented in E.




D

smectite coating quartz grians



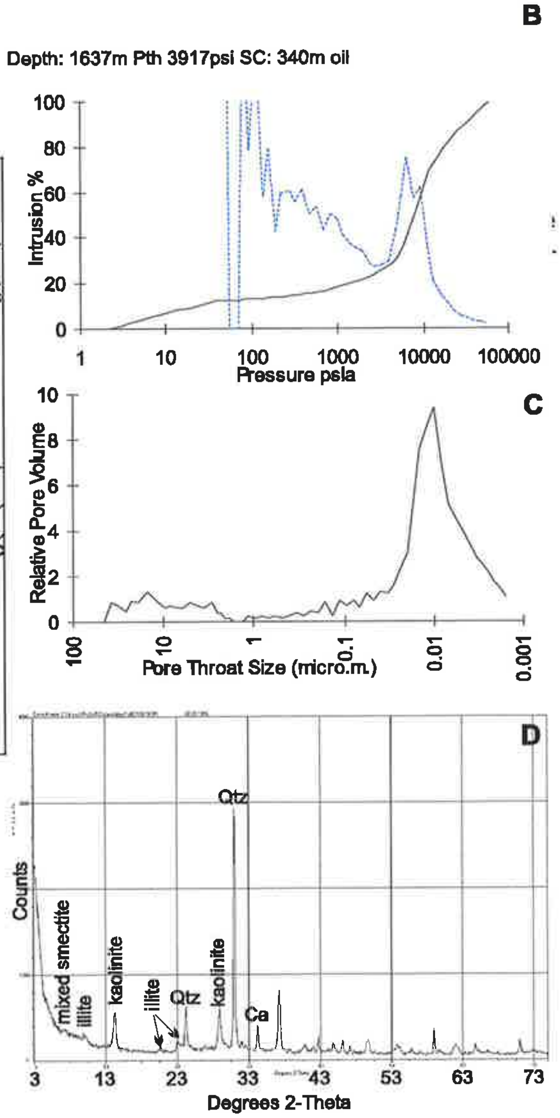
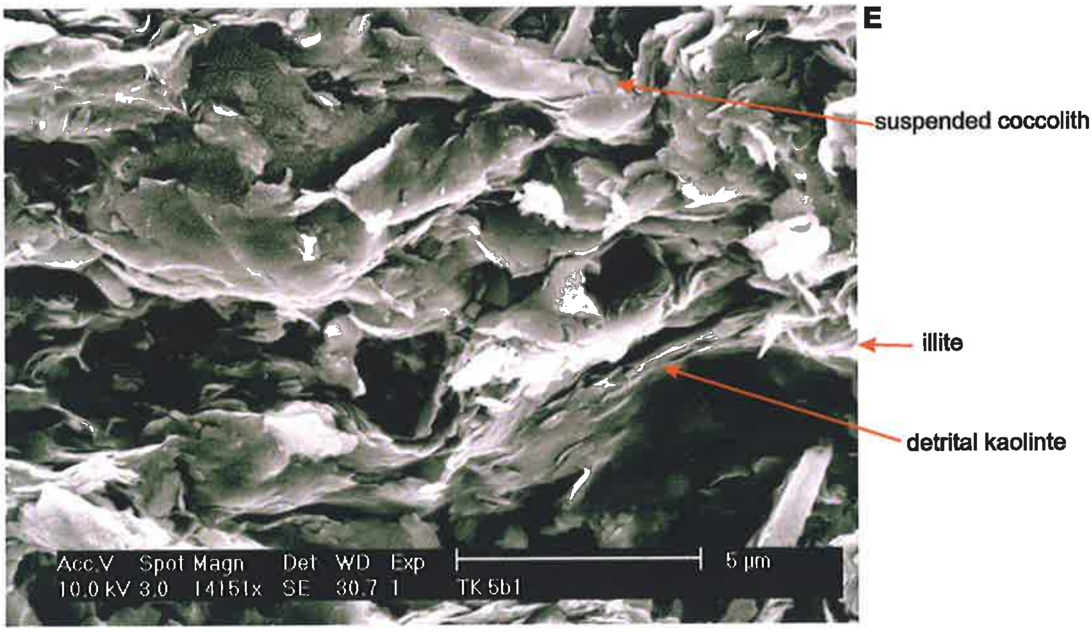




Figure 5-2: Results for Jabiru 2 Lower Vulcan cuttings samples from a depth between 1532-1535m. A well log composite is show in A with the locations of the sample indicated by the red dot. The capillary pressure intrusion profile is shown in B (black curve) with the change in slope of this curve plotted as the dashed blue line. The pore throat size distributions is shown in C. X-ray diffraction results with peak interpretations are presented in D and an scanning electron microscope image of the sample is presented in E.



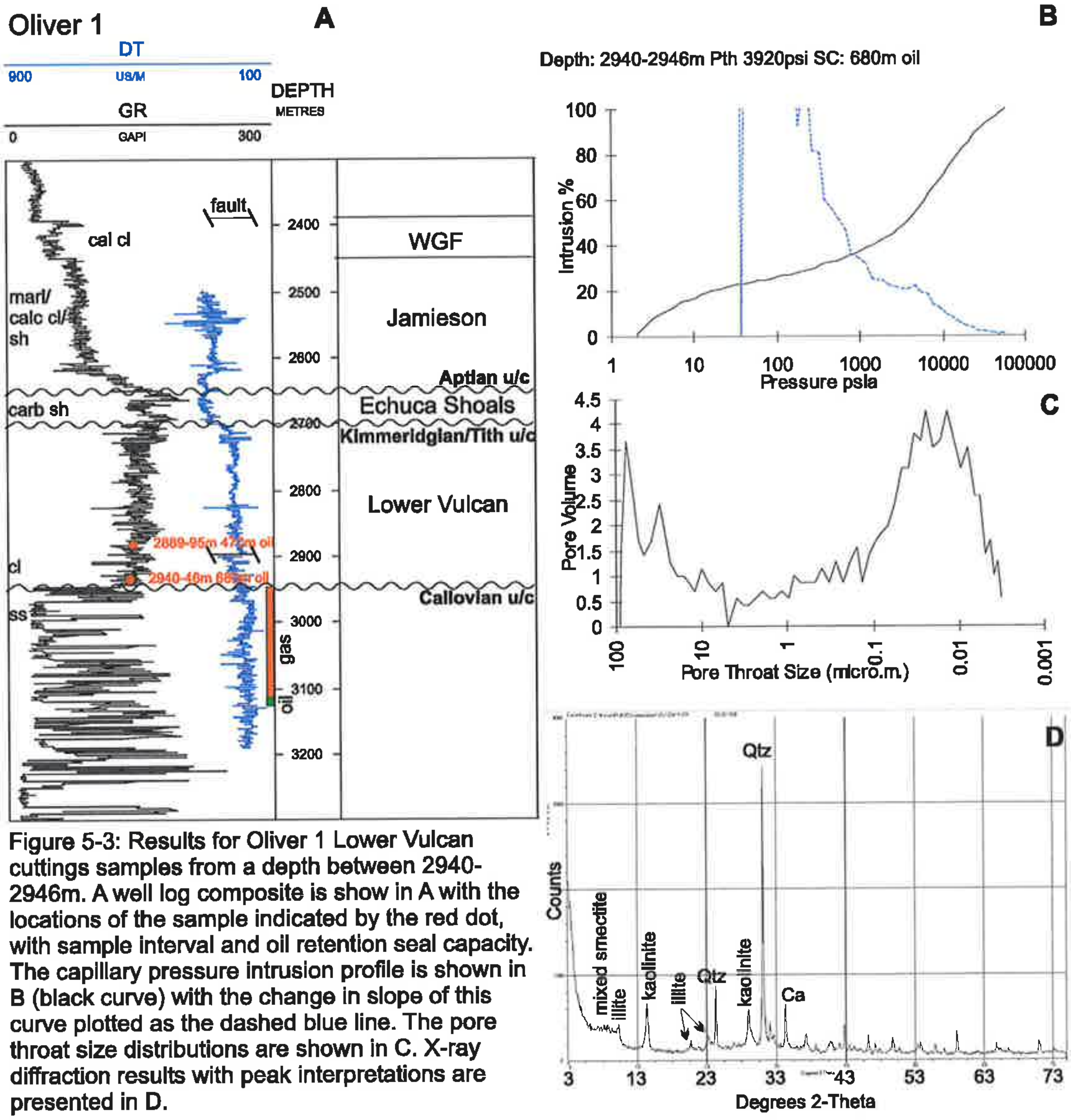



Figure 5-3: Results for Oliver 1 Lower Vulcan cuttings samples from a depth between 2940-2946m. A well log composite is show in A with the locations of the sample indicated by the red dot, with sample interval and oil retention seal capacity. The capillary pressure intrusion profile is shown in B (black curve) with the change in slope of this curve plotted as the dashed blue line. The pore throat size distributions are shown in C. X-ray diffraction results with peak interpretations are presented in D.

The Oliver 1 well intersected a gross gas column of 162.7m. The clays from Lower Vulcan Formation interval are interpreted to be the seal and were sampled between 2940-2946m and 2889-2895m (Figure 5-3A). Both samples measured high seal capacities. Results for the 2940-2946m sample are presented in Figure 5-3. The Lower Vulcan Formation in Oliver 1 is dominated by Oxfordian aged claystones, which are medium grey to grey brown, firm, subfissile, micromicaeous and contain, disseminated carbonaceous specks (Oliver 1 Well Completion Report). A threshold pressure of 3920psi was measured for this sample (Figure 5-3B), which corresponds to a seal capacity of 680m oil column or a gas column in the order of 400m. The XRD results (Figure 5-3D) show high kaolinite and illite peaks, with no calcareous materials present. Overall, the Lower Vulcan Formation is a fining upwards sequence. Seal capacities were difficult to obtain from cuttings in this interval. However, in areas away from the Montara Terrace, especially in the central Vulcan Sub-Basin, the thick claystones of the Late Oxfordian to Kimmerigian age have high seal capacities, as seen in the Oliver 1 samples. In contrast, in the south eastern Vulcan Sub-basin, along the Montara Terrace, the Lower Vulcan Formation is a deltaic system prograding out into the sub-basin. As can be seen from the Montara 1 sample analysis (Figure 5-1), the top seal capacity of the deltaic sediments is low and can vary significantly.

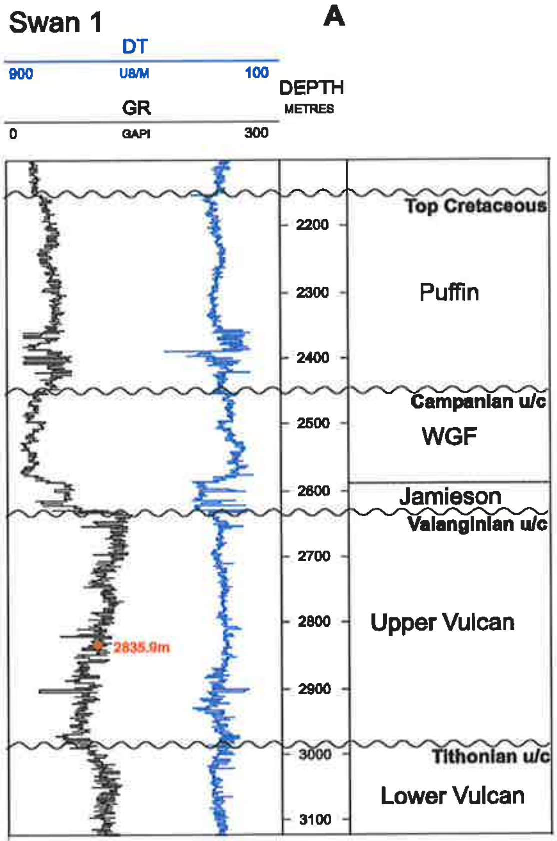
The Lower Vulcan Formation is a proven seal across with the technical success at Montara 1 proving that intra-Lower Vulcan Formation statigraphic plays have all the components for an oil accumulation. The Oliver 1 gas discovery is also sealed by a thick section of Lower Vulcan Formation claystones. On a prospect scale the, if the existence of a Lower Vulcan Formation claystone as a top seal can be proven, then a relatively low risk can be assigned to top seal effectiveness.

### 5.1.2 Upper Vulcan

The Upper Vulcan Formation is characterised by thick, restricted marine mudrocks and coarse clastic submarine fan deposits near intra-graben highs. Seal analysis results for samples from Swan 1 and Octavius 1 are presented below.

Results for Upper Vulcan Formation rocks sampled from Swan 1 at 2835.9m are presented in Figure 5-4. A threshold pressure of 8500psi was measured and corresponds to a seal capacity for oil of over 1400m oil column (Figure 5-4B). XRD results show that this sample is dominated by kaolinite, illite and smectite clays with almost no calcite present (Figure 5-4D). The SEM image shows undulating clay layers (Figure 5-4E).

The Octavius 1 well (Figure 5-5) is situated on the flank of the Cartier Trough (Figure 4-1). The lower part of the Upper Vulcan Formation in this well contains Tithonian submarine fan channel sands (between 2800m and 2900m in Figure 5-5A), overlain by a potential seal of interbedded siltstones and claystones. A threshold pressure of 3245psi (Figure 5-5B), which corresponds to a seal capacity of 563m oil column, was measured near the top of the Lower Vulcan Formation. XRD analysis (Figure 5-5D) shows that this sample contains a mixture of kaolinte, illite and smectite clays.



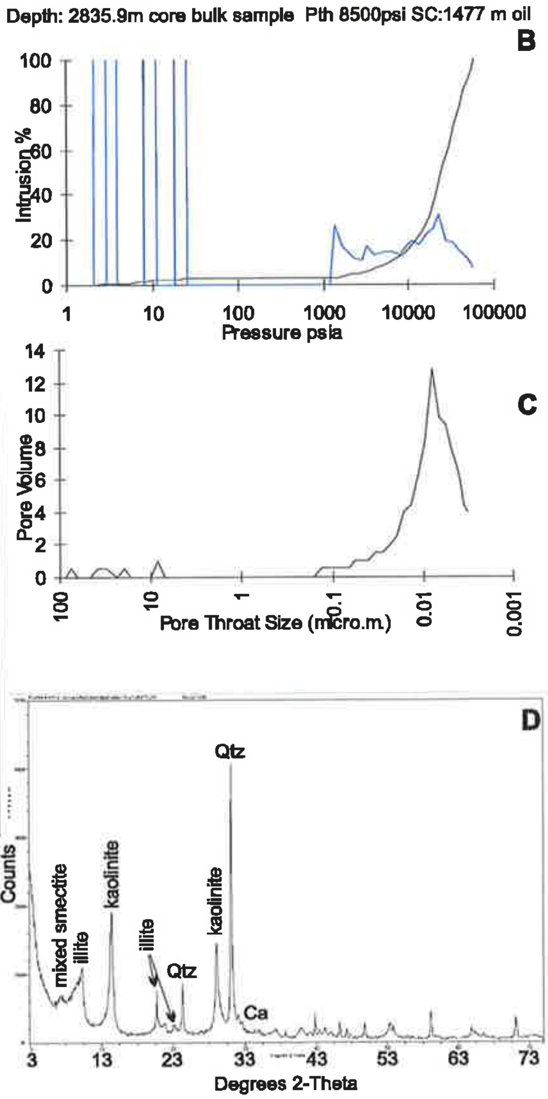
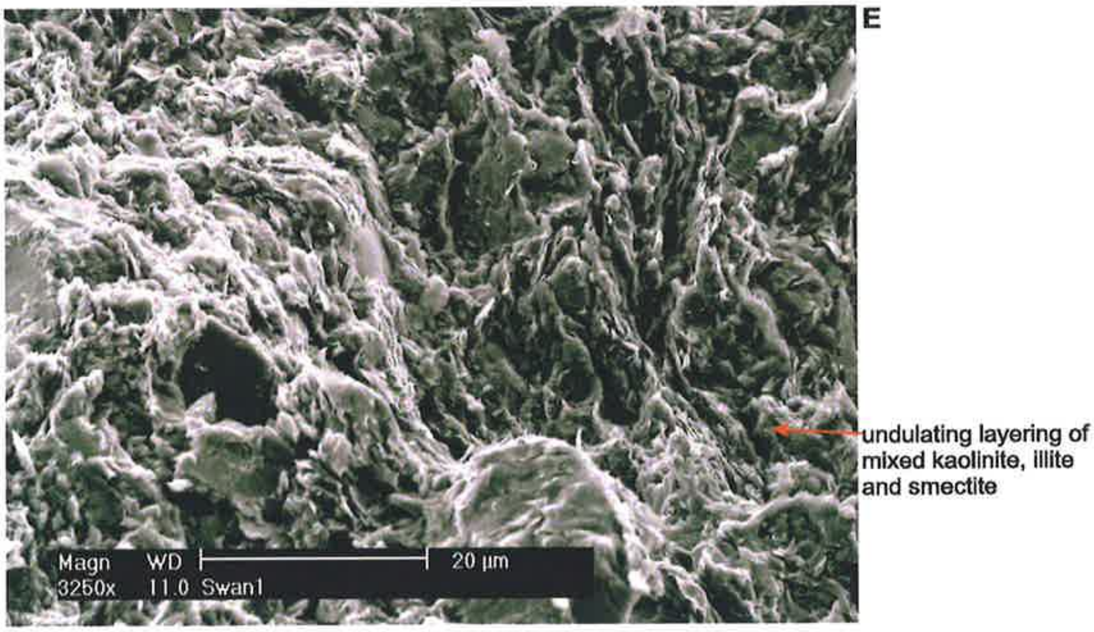
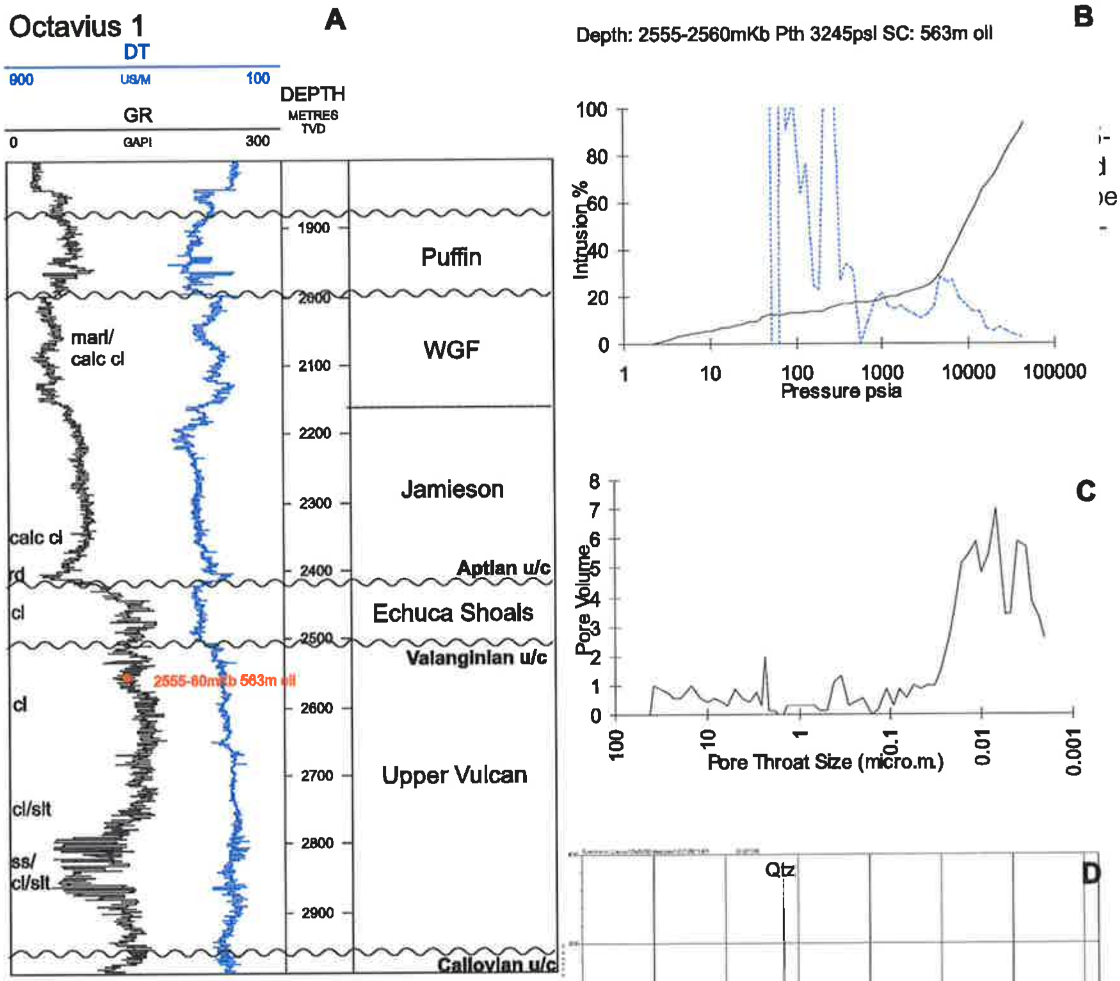




Figure 5-4: Results for Swan 1 Upper Vulcan core from a depth between 2835.9m. A well log composite is show in A with the locations of the sample indicated by the red dot. The capillary pressure intrusion profile is shown in B (black curve) with the change in slope of this curve plotted as the dashed blue line. The pore throat size distributions is shown in C. X-ray diffraction results with peak interpretations are presented in D and an scanning electron microscope image of the sample is presented in E.





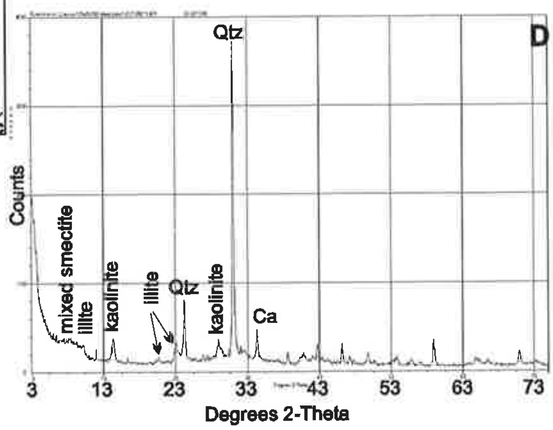




Figure 5-5: Results for Octavius 1 Upper Vulcan cuttings samples from a depth between 2555-2560m. A well log composite is show in A with the locations of the sample indicated by the red dot. The capillary pressure intrusion profile is shown in B (black curve) with the change in slope of this curve plotted as the dashed blue line. The pore throat size distributions is shown in C. X-ray diffraction results with peak interpretations are presented in D.

### 5.1.3 Echuca Shoals

Samples analysed for this interval are listed in Table 5-1 with well name, sample depth range, sample type, MICP analysis threshold pressure, calculated seal capacity for oil (including interfacial tension ranges high, normal and low) and calculated seal capacity for gas. Analysis of seals sampled in East Swan 1, Eclipses 1, Octavius 1 and Skua 1 are presented in detail below and highlight the variability of regional seal properties within the Echuca Shoals Formation.

| Well Name | Depth From (m) | Depth To (m) | Sample Type | Threshod Pressure MICP(psi) | Oil Column Height (high) (m) | Oil Column Height (norm) (m) | Oil Column Height (low) (m) | Gas Column Height (m) |
|---|---|---|---|---|---|---|---|---|
| Allaru 1 | 2313 | 2319 | Cuttings | 1765.00 | 458 | 305 | 153 | 275 |
| Challis 1 | 1378 | 1381 | Cuttings | 2936.00 | 764 | 509 | 255 | 458 |
| Challis 1 | 1384 | 1387 | Cuttings | 2954.00 | 650 | 433 | 217 | 390 |
| Douglas 1 | 2370 | 2375 | Cuttings | 3244.00 | 844 | 562 | 281 | 507 |
| East Swan 1 | 2329 | 2332 | Cuttings | 2949.00 | 767 | 511 | 256 | 460 |
| Eclipse 1 | 2319 | 2321 | Cuttings | 3906.00 | 1017 | 678 | 339 | 610 |
| Octavius 1 ST1 | 2455 | 2460 | Cuttings | 3558.00 | 926 | 617 | 309 | 556 |
| Octavius 1 ST1 | 2490 | 2495 | Cuttings | 3568.00 | 928 | 619 | 309 | 557 |
| Pascal 1 | 2517 | 2520 | Cuttings | 1610.00 | 418 | 278 | 139 | 251 |
| Rainier 1 | 1659 | 1661 | Cuttings | 4330.00 | 1433 | 1024 | 683 | 341 |
| Rainier 1 | 1661.5 | 1661.8 | Core | 3555.00 | 925 | 617 | 308 | 555 |
| Rainier 1 | 1661.5 | 1661.8 | cuttings (synthetic) | 3560.00 | 926 | 618 | 309 | 556 |
| Rainier 1 | 1661.5 | 1661.8 | core (top sealed) | 3556.00 | 925 | 617 | 308 | 555 |
| Rainier 1 | 1661.5 | 1661.8 | core (side sealed) | 3564.00 | 927 | 618 | 309 | 557 |
| Skua 1 | 2407 | 2414 | Cuttings | 8465.00 | 2206 | 1471 | 735 | 910 |
| Tenacious West 1 | 2440 | 2445 | Cuttings | 7140.00 | 1861 | 1240 | 620 | 768 |
| Tenacious West 1 | 2460 | 2465 | Cuttings | 7140.00 | 1861 | 1240 | 620 | 1117 |
| Tenacious West 1 | 2470 | 2475 | Cuttings | 8445.00 | 2201 | 1467 | 734 | 1321 |
| Warb 1a | 2350 | 2355 | Cuttings | 2481.00 | 764 | 509 | 255 | 458 |

Table 5-1:Echuca Shoals seal capacity results.

Threshold pressures in the Echuca Shoals Formation range from 1765psi to over 8000psi and correspond to seal capacities of 300m to over 1400m oil column (Table 5-1). Threshold pressures measured in the Echuca Shoals formation rocks are consistently the highest in the Vulcan Sub-Basin. A plot with seal capacity ranges (oil column) is shown in Figure 5-6. The error bars in Figure 5-6 show the uncertainties in the variables used to calculate seal capacities.

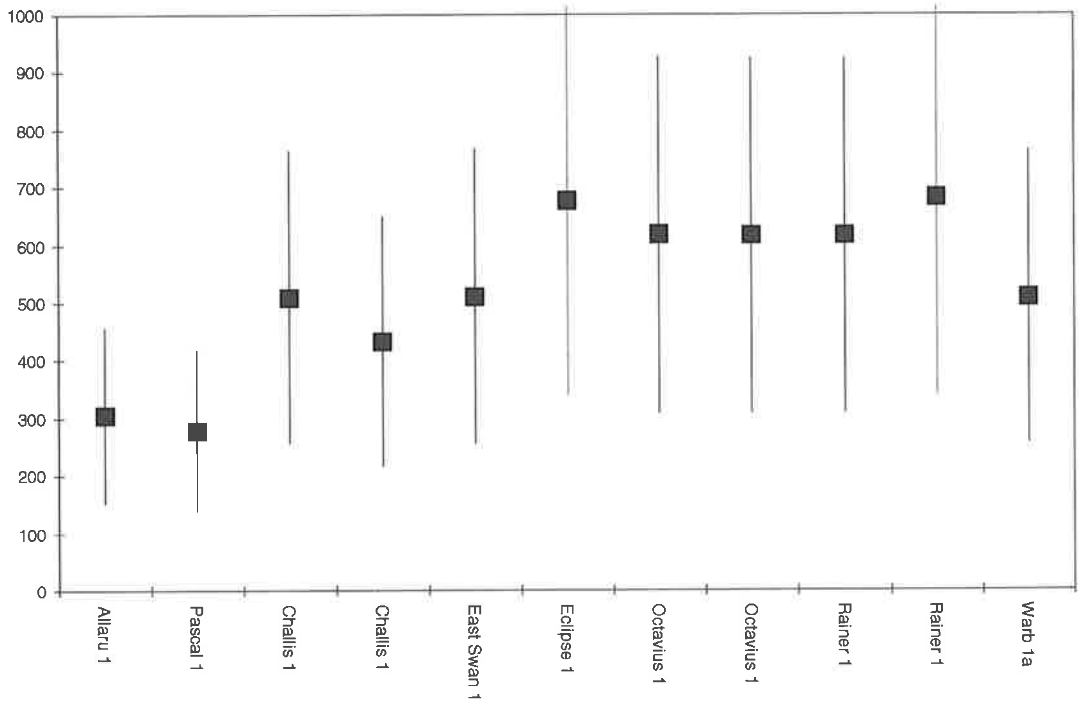
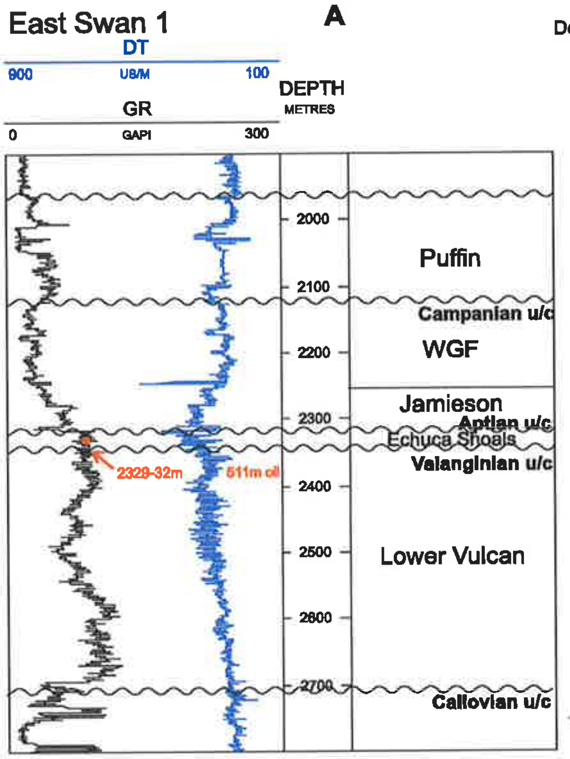



Figure 5-6: Seal capacities in meters of oil that the Echuca Shoals Formation samples can retain are shown on the y-axis. Error bars have been added to account for variability in interfacial tension. Wells, shown on the x-axis, are ordered from proximal on the left to distal on the right.

Seal capacity results and associated data for cuttings sampled from East Swan 1 between 2329m and 2332m are presented in Figure 5-7. A threshold pressure of 2949psi for this sample corresponds to a seal capacity of 511m (Figure 5-7B). Results of XRD analysis (Figure 5-7D) show that this sample is a calcareous claystone composed predominantly of kaolinite, illite with some smectite clays and minor calcite. Detrital clay layers are the predominant minerals visible in the SEM image (Figure 5-7E).



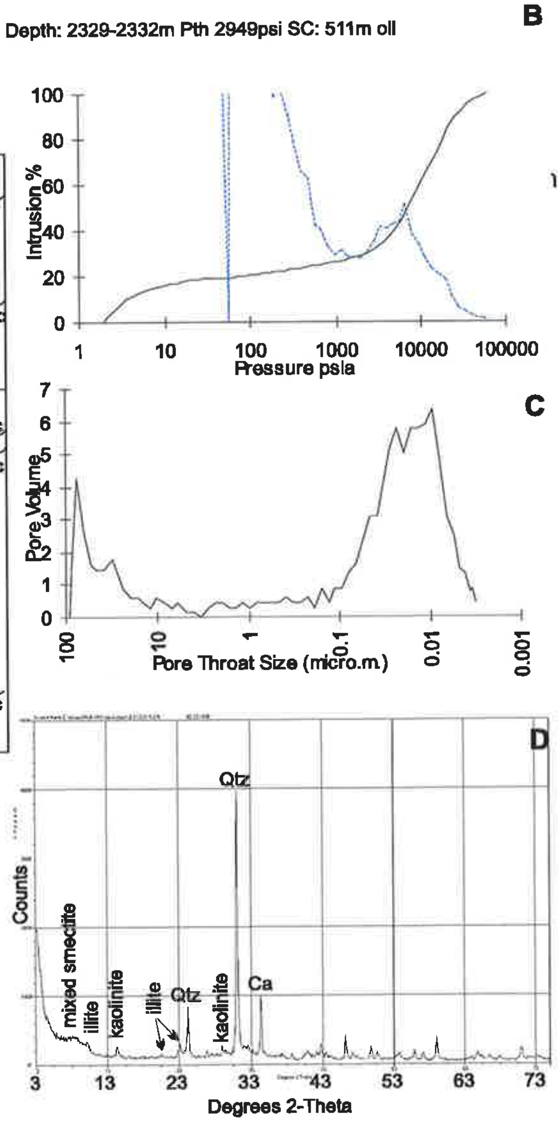
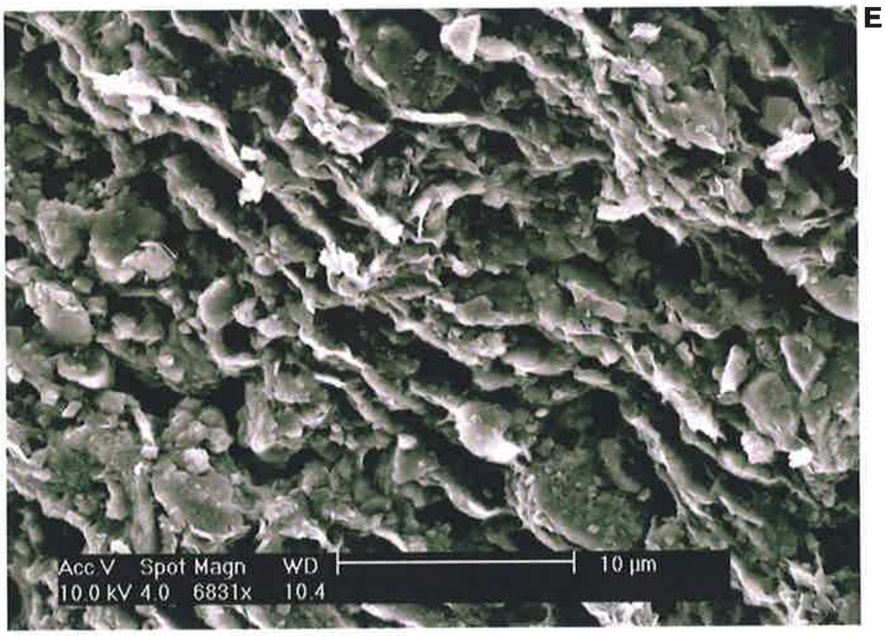




Figure 5-7: Results for East Swan 1 Echuca Shoals cuttings samples from a depth between 2329-2332m. A well log composite is show in A with the locations of the sample indicated by the red dot. The capillary pressure intrusion profile is shown in B (black curve) with the change in slope of this curve plotted as the dashed blue line. The pore throat size distributions is shown in C. X-ray diffraction results with peak interpretations are presented in D and an scanning electron microscope image of the sample is presented in E.



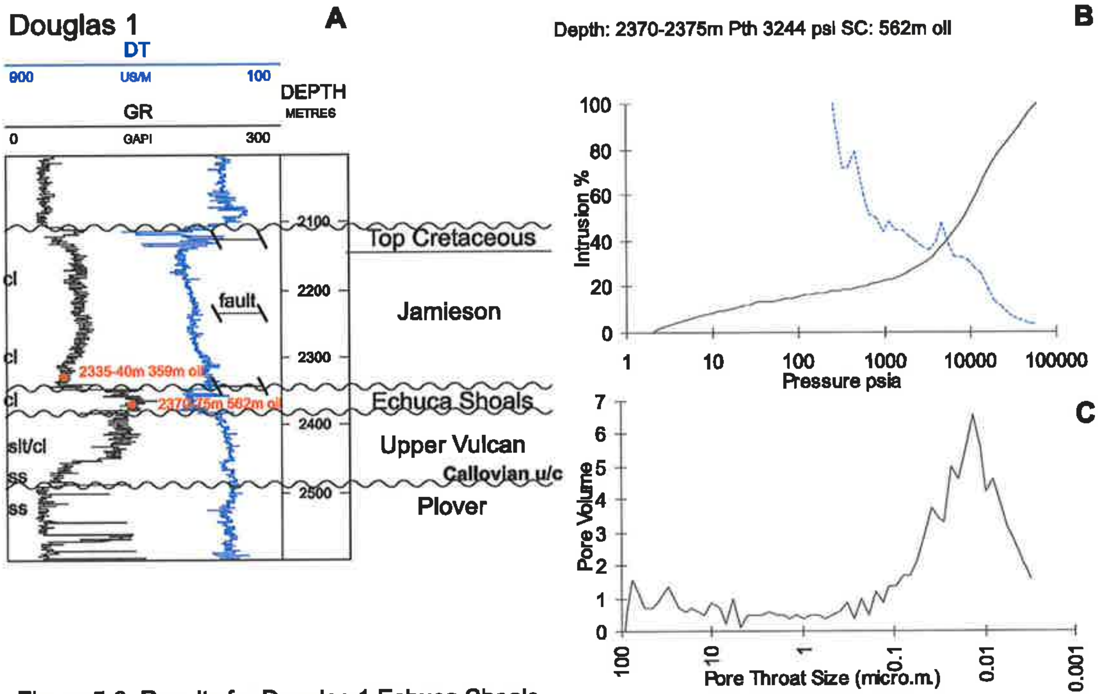
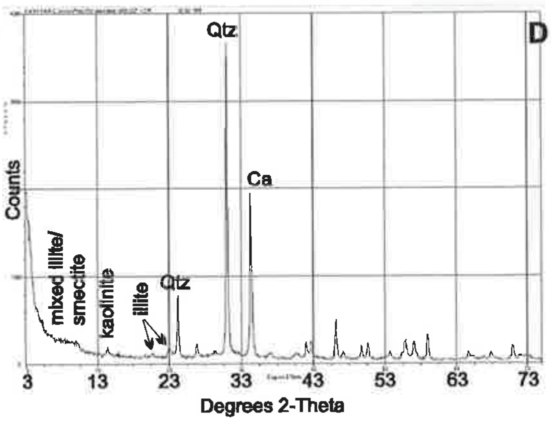
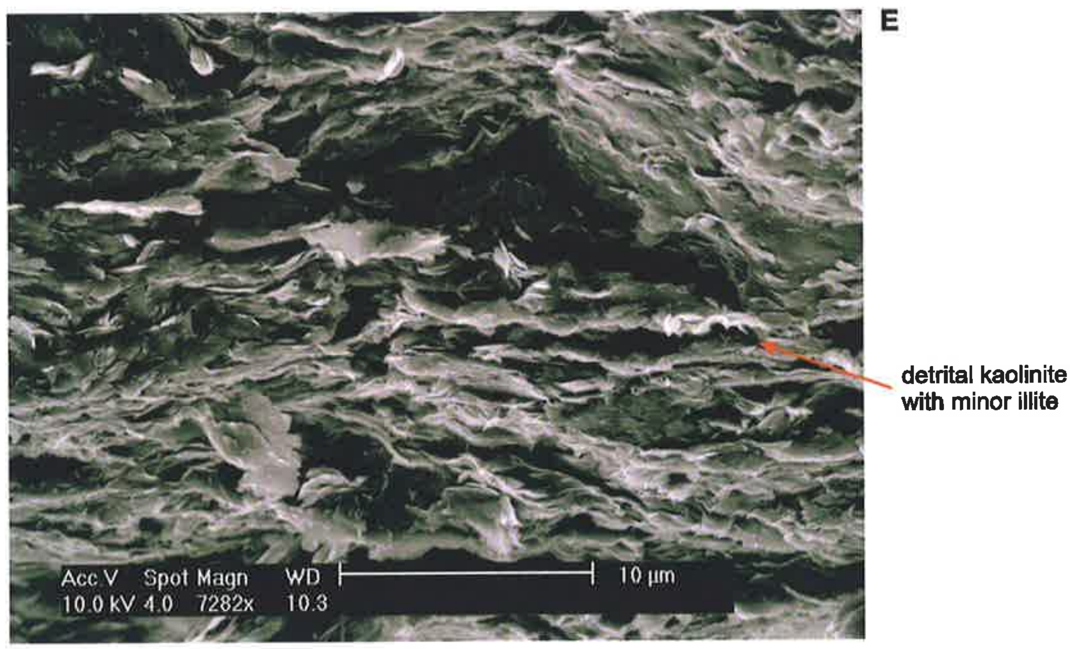
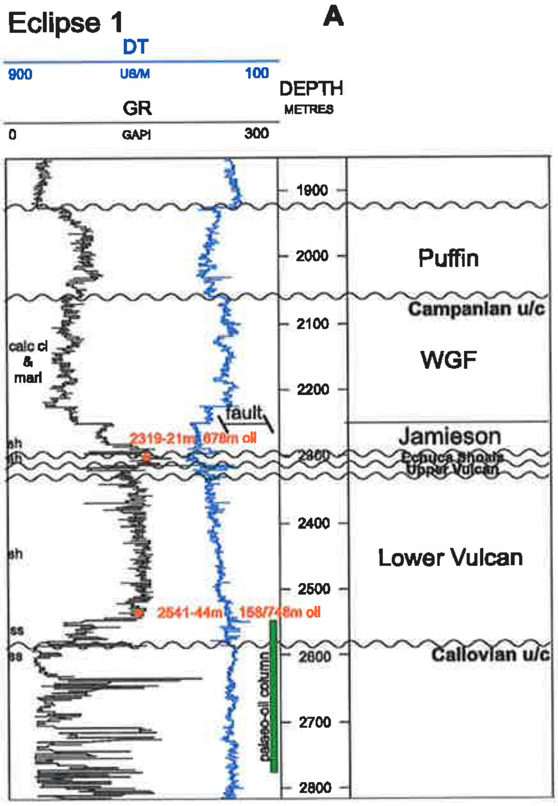



Figure 5-8: Results for Douglas 1 Echuca Shoals cuttings samples from a depth between 2370-2375m. A well log composite is show in A with the locations of the sample indicated by the red dot. The capillary pressure intrusion profile is shown in B (black curve) with the change in slope of this curve plotted as the dashed blue line. The pore throat size distributions is shown in C. X-ray diffraction results with peak interpretations are presented in D and an scanning electron microscope image of the sample is presented in E.





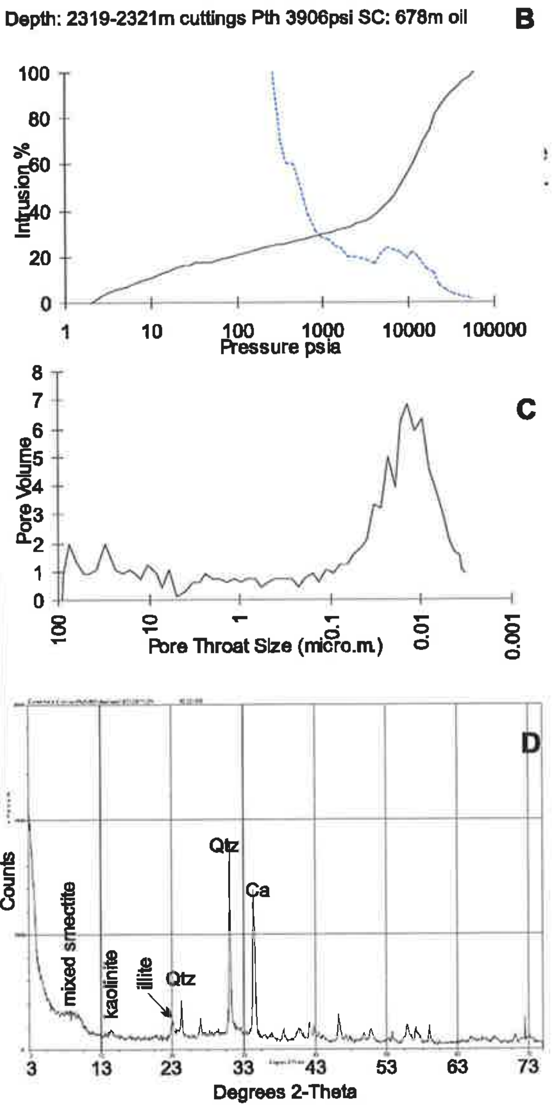
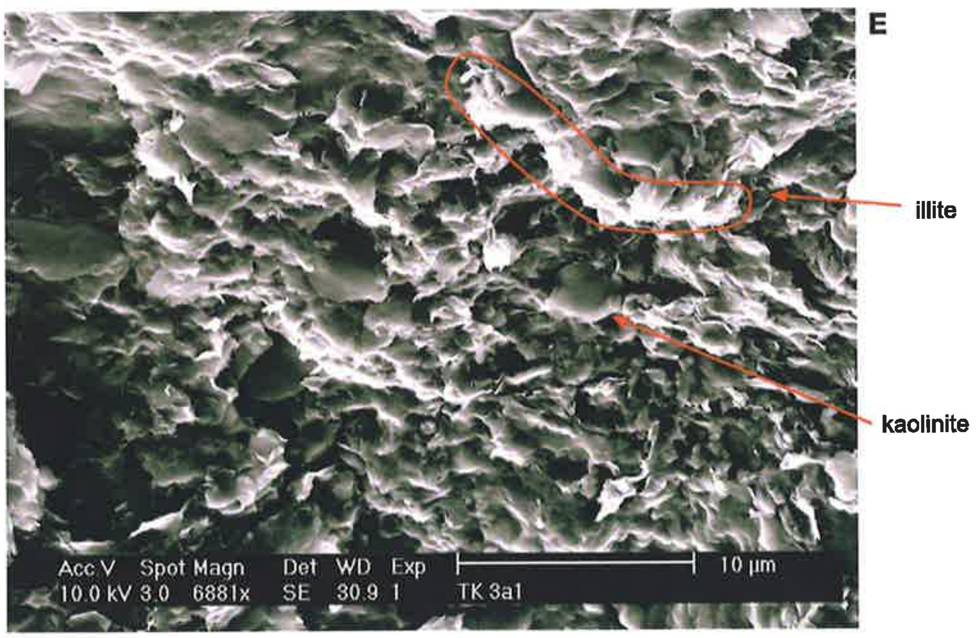




Figure 5-9: Results for Eclipse 1 Echuca Shoals cuttings samples from a depth between 2319-2321m. A well log composite is show in A with the locations of the sample indicated by the red dot. The capillary pressure intrusion profile is shown in B (black curve) with the change in slope of this curve plotted as the dashed blue line. The pore throat size distributions is shown in C. X-ray diffraction results with peak interpretations are presented in D and an scanning electron microscope image of the sample is presented in E.



Seal capacity results for cuttings sampled between 2370m to 2375m from Douglas 1 are presented in Figure 5-8. This claystone has a measured threshold pressure of 3244psi, which corresponds to a 562m oil column seal capacity (Figure 5-8B). XRD analysis (Figure 5-8D) indicate that this sample is primarily composed of siliciclastic sediments. The SEM image (Figure 5-8E) shows predominantly kaolinites with some minor illite.

Seal capacity results for cuttings sampled from Eclipse 1 between 2319m and 2321m are presented in Figure 5-9. A threshold pressure of 3906psi was measured and corresponds to a seal capacity of 678m oil column (Figure 5-9B). XRD results (Figure 5-9D) show this sample to be a mixture of kaolinite, illite and smectite with calcite also present. Kaolinite and illite clays are clearly visible on the SEM image (Figure 5-9E) however; the calcite crystals are not visible on the SEM image, and probably make up only a minor component of the sample.

Other Echuca Shoals results are presented in Appendix A and show similar facies to those shown in Figure 5-7 and Figure 5-8.

From a top seal capacity perspective the claystones of the Echuca Shoals Formations have the potential to make some of the tightest seals in the Vulcan Sub-Basin. As with the older clastic seals of the Upper and Lower Vulcan Formations, if one can prove on a prospect scale that the claystones of he Echuca Shoals formations are present on structure then a low risk of top seal failure can be assigned to seal risk prospect evaluation component.

### 5.1.4 Jamieson

Sample analysed for this interval is listed in Table 5-2 with well name, sample depth range, sample type, MICP analysis threshold pressure, calculated seal capacity for oil (including interfacial tension ranges high, normal and low) and calculated seal capacity for gas retention. A range of seal capacities for oil are plotted in Figure 5-10. Analysis of seals sampled in Jabiru 1a, Challis 1, Brown Gannet 1 and Skua 1 are presented in detail below and highlight the seal variability within the Jamieson Formation.

| Well Name | Depth From (m) | Depth To (m) | Sample Type | Threshold Pressure MICP (psi) | Oil Column Height (high) (m) | Oil Column Height (norm) (m) | Oil Column Height (low) (m) | Gas Column Height (m) |
|---|---|---|---|---|---|---|---|---|
| Avocet 1a | 1705 | 1707 | Cuttings - radiolarite | 241.00 | 20 | 40 | 52 | 25 |
| Avocet 1a | 1708.1 | 1708.1 | core - radiolarite | 345.00 | 87 | 58 | 29 | 36 |
| Avocet 1a | 1709.3 | 1709.3 | core - radiolarite | 588.00 | 151 | 101 | 50 | 62 |
| Avocet 1a | 1710 | 1710 | core - radiolarite | 202.00 | 50 | 33 | 17 | 21 |
| Brown Gannet 1 | 2146 | 2149 | Cuttings | 1043.00 | 270 | 180 | 90 | 162 |
| Brown Gannet 1 | 2152 | 2155 | Cuttings | 1270.00 | 329 | 219 | 110 | 197 |
| Challis 1 | 1324 | 1327 | Cuttings | 711.00 | 183 | 122 | 61 | 110 |
| Challis 1 | 1363 | 1366 | Cuttings | 4282.00 | 1114 | 743 | 372 | 669 |
| Douglas 1 | 2335 | 2340 | Cuttings | 2075.00 | 539 | 359 | 180 | 323 |
| Jabiru 1a | 1586 | 1592 | Cuttings | 3569.00 | 929 | 619 | 310 | 557 |
| Jabiru 2 | 1619 | 1619 | Cuttings | 3552.00 | 924 | 616 | 308 | 555 |
| Osprey 1 | 1188 | 1191 | Cuttings | 3522.00 | 1024 | 682 | 341 | 614 |
| Osprey 1 | 1226 | 1229 | Cuttings | 120.00 | 23 | 16 | 8 | 14 |
| Osprey 1 | 1249 | 1252 | Cuttings | 1290.00 | 258 | 172 | 86 | 155 |
| Rainier 1 | 1623 | 1626 | Cuttings | 3237.00 | 842 | 561 | 281 | 505 |
| Rainier 1 | 1641 | 1647 | Cuttings | 3538.00 | 921 | 614 | 307 | 553 |
| Rowan 1 | 2700 | 2703 | Cuttings | 1443.00 | 374 | 249 | 125 | 224 |
| Sahul Shoals 1 | 1777 | 1780 | Cuttings | 922.00 | 238 | 159 | 79 | 144 |
| Sahul Shoals 1 | 1783 | 1786 | Cuttings | 700.00 | 180 | 120 | 60 | 109 |
| Sahul Shoals 1 | 1786 | 1789 | Cuttings | 962.00 | 248 | 166 | 83 | 150 |
| Sahul Shoals 1 | 1789 | 1792 | Cuttings | 839.00 | 216 | 144 | 72 | 130 |
| Skua 1 | 2398 | 2401 | Cuttings | 8515.00 | 2219 | 1480 | 740 | 916 |
| Skua 1 | 2404 | 2407 | Cuttings | 8525.00 | 2222 | 1481 | 741 | 917 |
| Skua 3 | 2371 | 2374 | Cuttings | 1256.00 | 325 | 217 | 108 | 195 |
| Skua 6 | 2352 | 2355 | Cuttings | 900.00 | 163 | 96 | 48 | 122 |

Table 5-2: Jamieson seal capacity results.

Threshold pressures measured in the Jamieson Formation seal lithologies range from 200psi to over 8000psi and correspond to seal capacities of 30m to over 1400m oil column (Table 5-2). The results in Table 5-2 can be grouped into three lithology-based subsets.

The first subset is comprised of Osprey 1 1226-1229m cuttings, which are from a 5m thick sandstone bed near the base of the Jamieson Formation. A low seal capacity (16m oil column) was measured for this sample. This sand is part of the basal transgressive surface over the Callovian unconformity and is part of a reservoir interval.

Samples composed of radiolarite make up the second lithological subset in Table 5-2. Seal capacities ranging from 30 to 100m oil column have been measured in core and cuttings from the radiolarite found at the base of the Jamieson Formation in Avocet 1A. These are relatively low seal capacities when compared to seal capacities of the Jamieson Formation calcareous claystones. Radiolarite is commonly less than 10m thick at the base of the Jamieson Formation in the central Vulcan Sub-Basin (Chapter 4.2.2) depocenters and so is not a significant control on the sealing potential of the Jamieson Formation.

The third subset makes up the majority of the samples analysed from the Jamieson Formation. These rocks are composed of claystones and calcareous claystones, with threshold pressures that range from 900psi to over 8500psi and correspond to seal capacities (Figure 5-10) of 100m to 1000m oil column (Table 5-2).

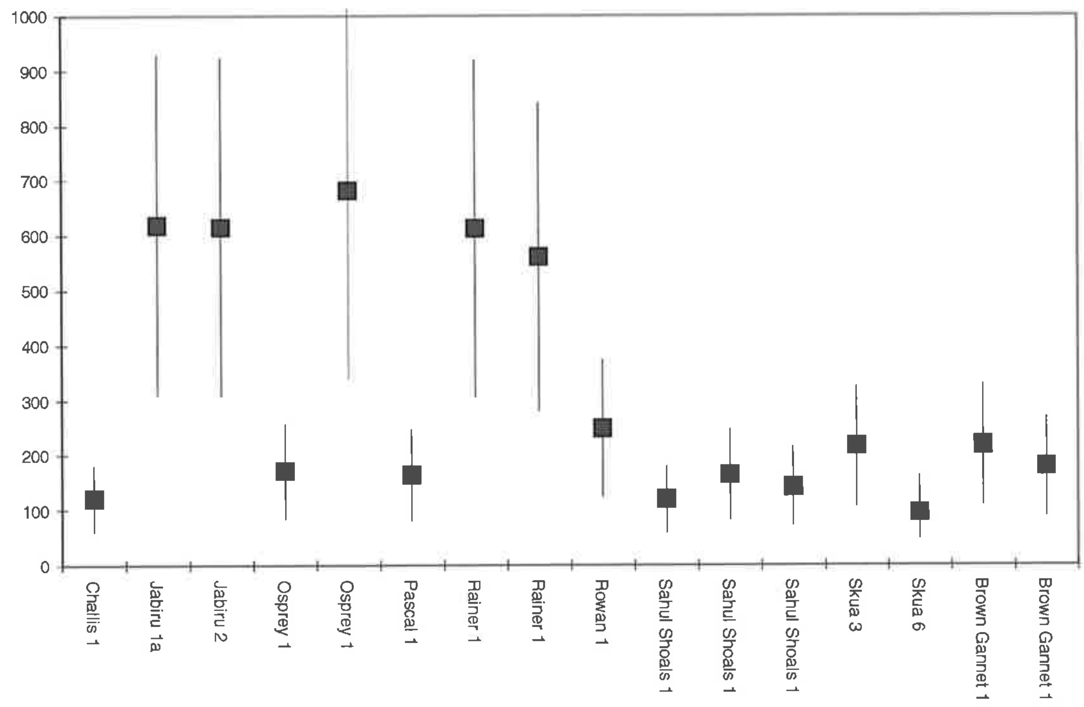



Figure 5-10: Seal capacities in meters of oil that the Jamieson Formation samples can retain are shown on the y-axis. Error bars have been added to account for variability in interfacial tension. Wells, shown on the x-axis, are ordered from proximal on the left to distal on the right.

Seal capacity and facies analysis results for the Jabiru oil field seal are presented in Figure 5-11, and include results for cuttings samples from Jabiru 1a (1586-1592m). The seal was sampled just above an oil-bearing reservoir (Figure 5-11A), which contains a 57m present day oil column. There is also evidence of a 56m palaeo oil-column (Lisk and Eadington 1998). A threshold pressure of 3569psi was measured (Figure 5-11B), which corresponds to a seal capacity of 619m oil column. XRD results (Figure 5-11D) indicate that this claystone seal is composed primarily of kaolinite and illite clays (Figure 5-11E).

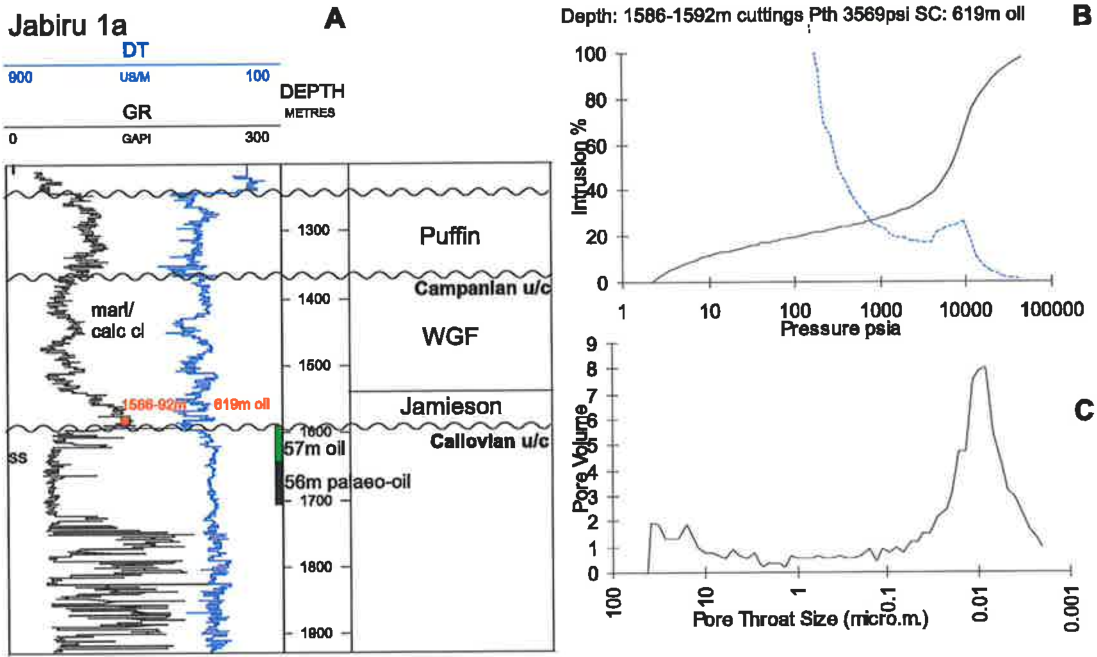
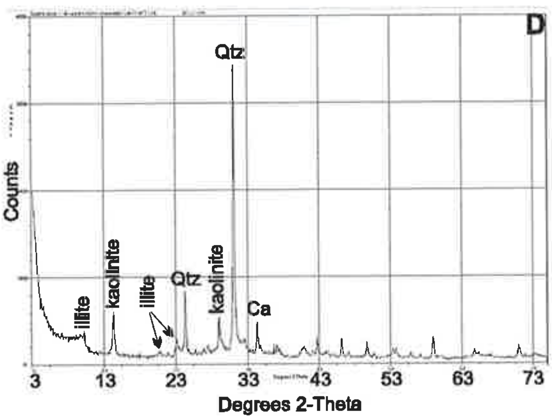
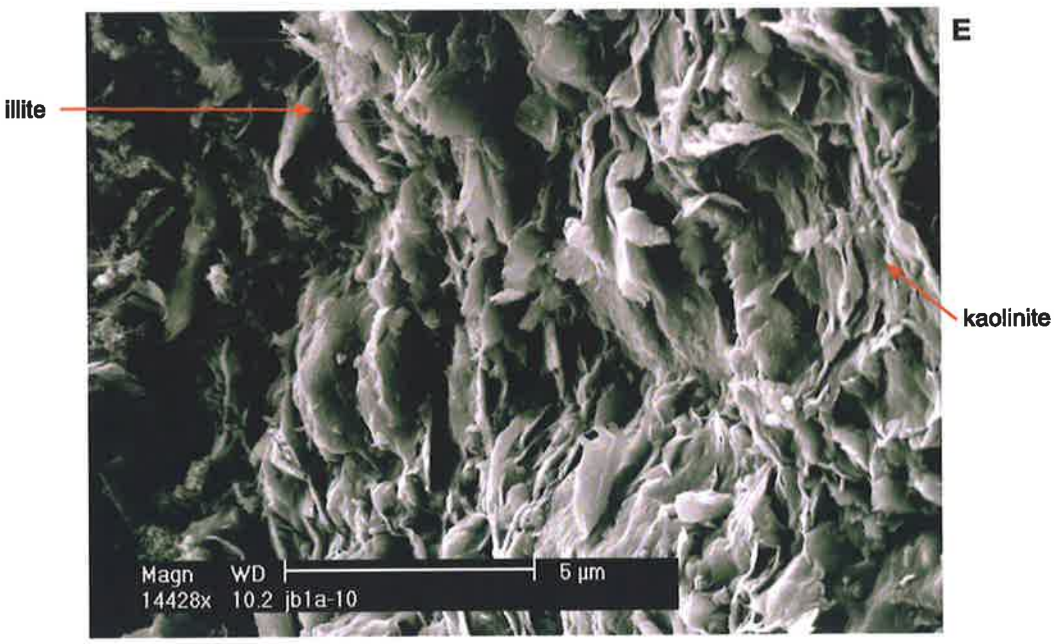
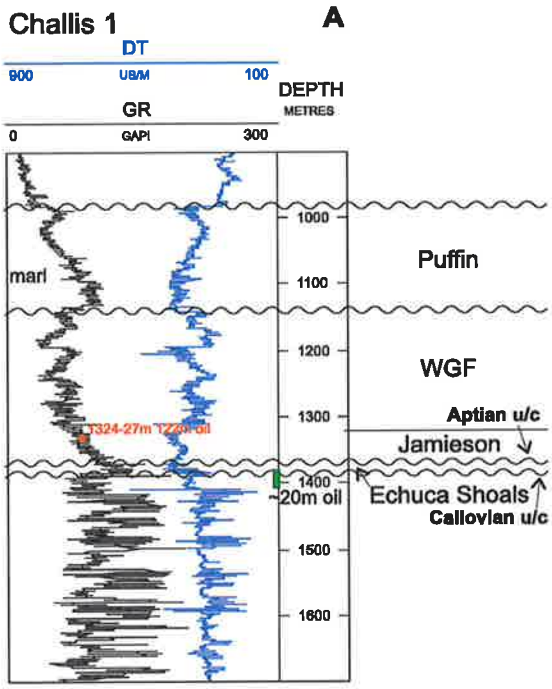
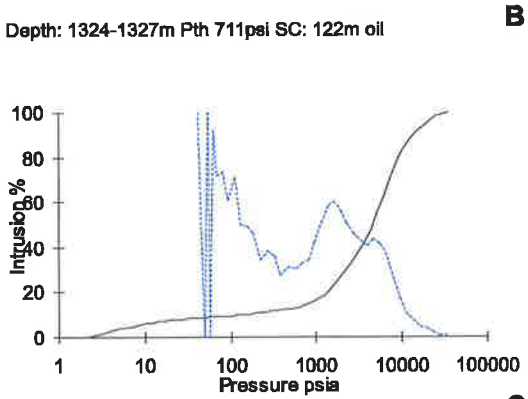


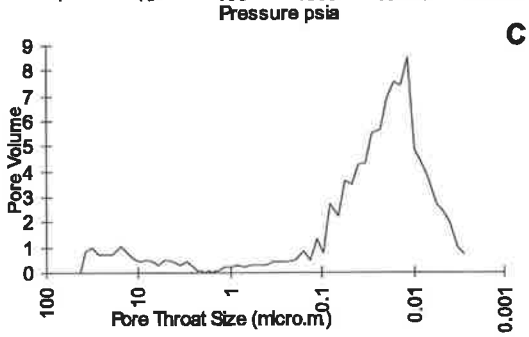

Figure 5-11: Results for Jabiru 1a Jamieson cuttings samples from a depth between 1586-1592m. A well log composite is show in A with the locations of the sample indicated by the red dot. The capillary pressure intrusion profile is shown in B (black curve) with the change in slope of this curve plotted as the dashed blue line. The pore throat size distributions is shown in C. X-ray diffraction results with peak interpretations are presented in D and an scanning electron microscope image of the sample is presented in E.





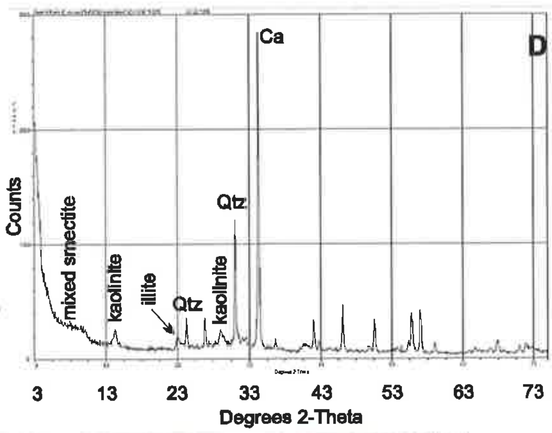
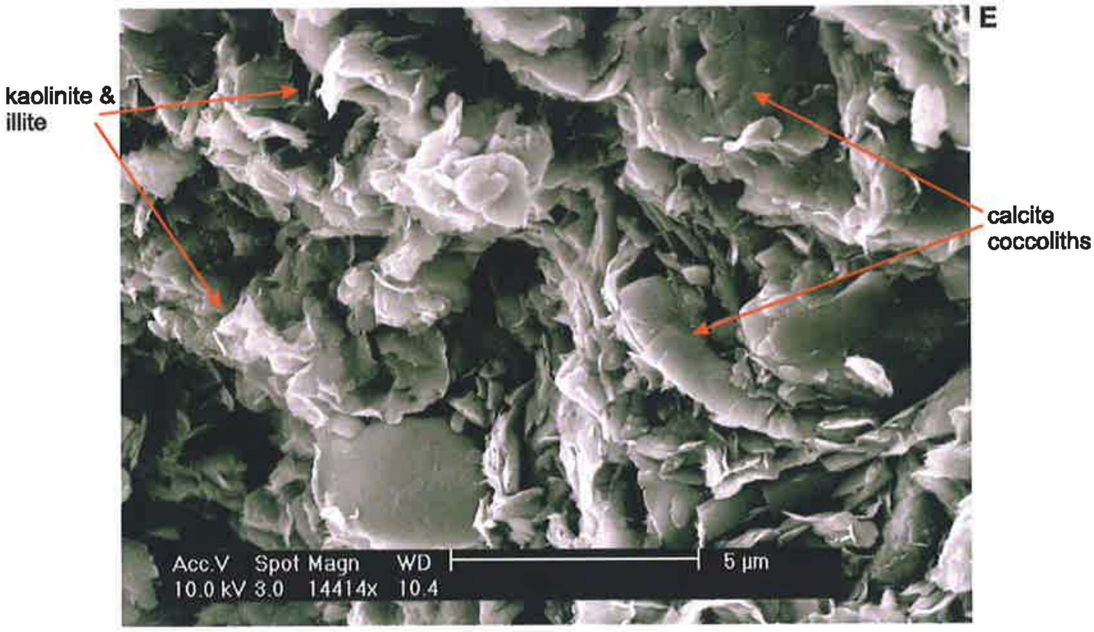




Figure 5-12: Results for Challis 1 Jamieson cuttings samples from a depth between 1324-1327m. A well log composite is show in A with the locations of the sample indicated by the red dot. The capillary pressure intrusion profile is shown in B (black curve) with the change in slope of this curve plotted as the dashed blue line. The pore throat size distributions is shown in C. X-ray diffraction results with peak interpretations are presented in D and an scanning electron microscope image of the sample is presented in E.



Results for the Jamieson Formation in Challis 1 are presented in Figure 5-12. Cuttings from the interval between 1324 and 1327m (shown as red dot in Figure 5-12A) have a threshold pressure of 711psi, (Figure 5-12B) corresponding to a seal capacity of 122m oil column. XRD results indicate that these samples are dominated by calcite, with a minor clay fraction (Figure 5-12D). Fragments of coccoliths, as well as individual calcite crystals (Figure 5-12E) with detrital kaolinite and illite make up the siliciclastic component of the rock.

Both the Jabiru 1a and Challis 1 samples described above come from the Jabiru Terraces along the eastern boundary of the Vulcan Sub-Basin (Figure 4.1). In this area, the lithology of the Jamieson Formation varies within the section. Based on cuttings analysis, XRD results and supported by the wireline log responses (Figure 5-11A and Figure 5-12A), it can be concluded that the Jabiru 1a (Figure 5-11) sample was taken from a claystone lithology, whereas the Challis 1 (Figure 5-12) was sampled in a marl to calcareous claystone.

Seal capacity and mineralogy results for Skua 1, 2404-2407m, are presented in Figure 5-13. A threshold pressure of 8525psi was measured, which corresponds to a seal capacity of 1481m oil column (Figure 5-13 B). The Jamieson Formation in Skua 1 is a thin claystone (Figure 5-13 A) composed primarily of kaolinite and illite clays, with some traces of calcite (Figure 5-13 D). Kaolinite clay layers with illite clays rimming some of the kaolinite can be seen on the SEM image shown in Figure 5-13 E.

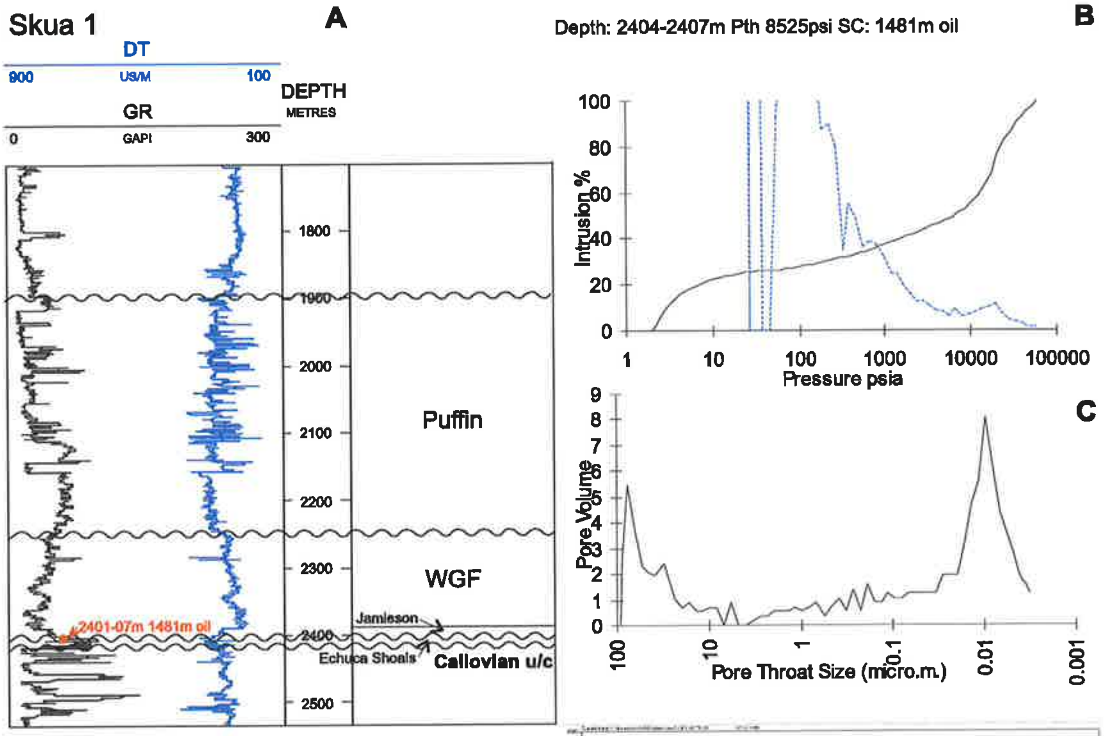
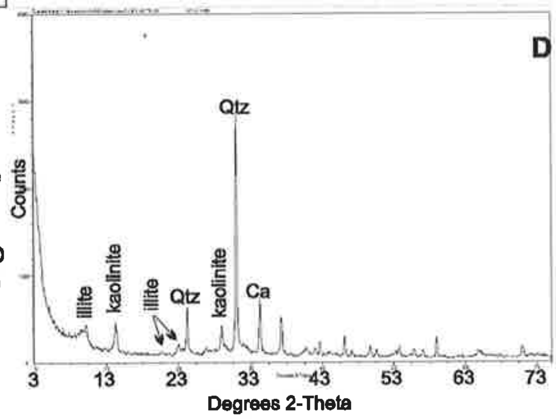
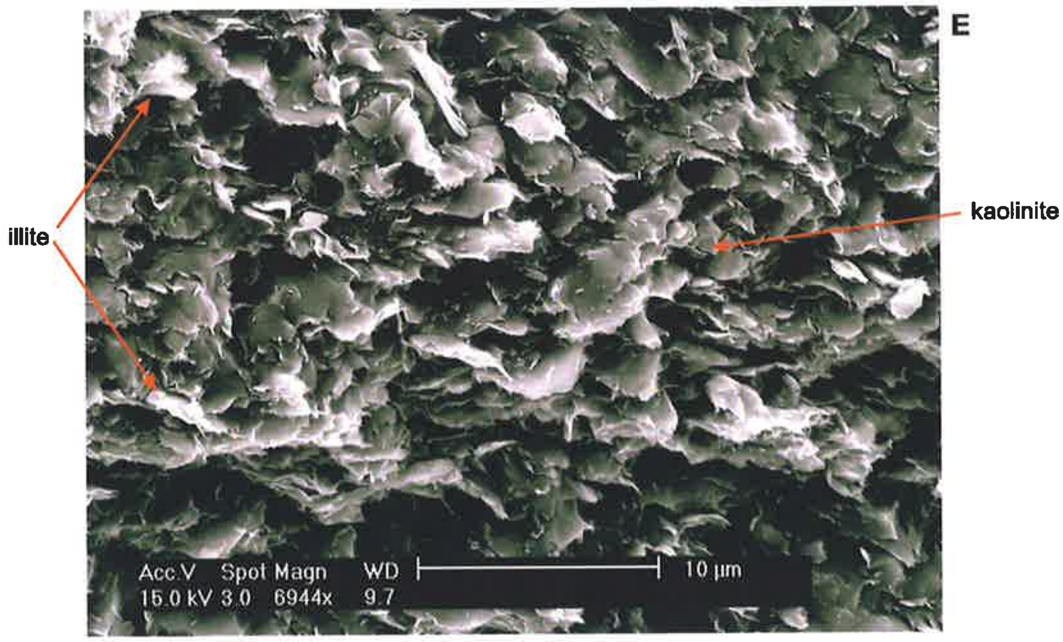
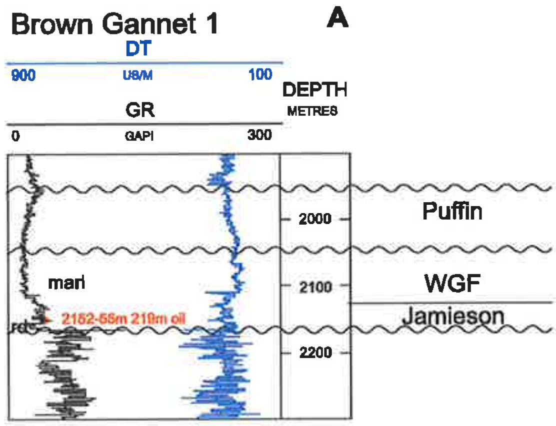



Figure 5-13: Results for Skua 1 Jamieson cuttings samples from a depth between 2404-2407m. A well log composite is show in A with the locations of the sample indicated by the red dot. The capillary pressure intrusion profile is shown in B (black curve) with the change in slope of this curve plotted as the dashed blue line. The pore throat size distributions is shown in C. X-ray diffraction results with peak interpretations are presented in D and an scanning electron microscope image of the sample is presented in E.





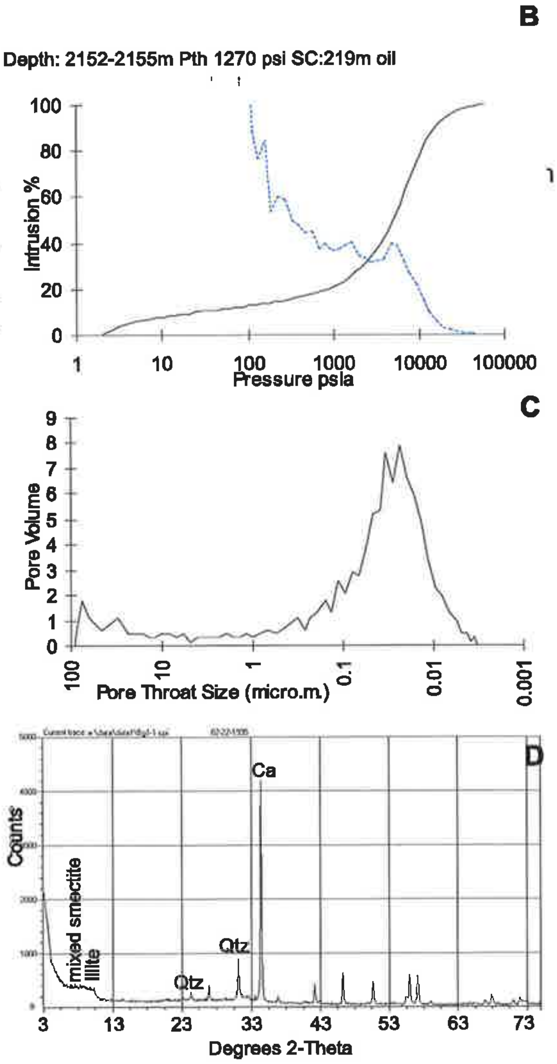
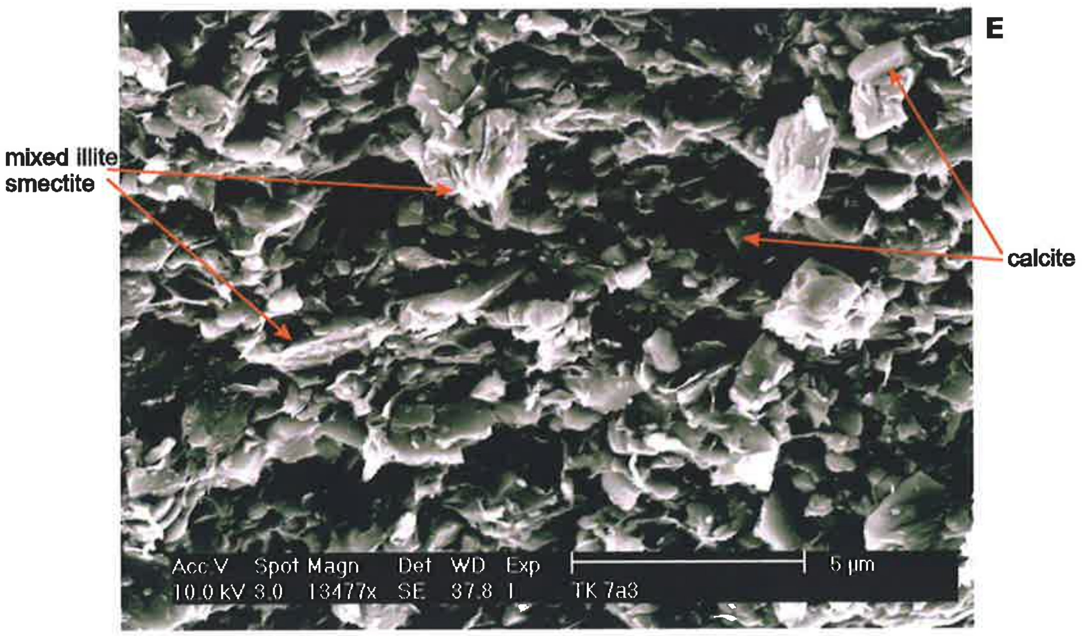




Figure 5-14: Results for Brown Gannet 1 Jamieson cuttings samples from a depth between 2152-2155m. A well log composite is show in A with the locations of the sample indicated by the red dot. The capillary pressure intrusion profile is shown in B (black curve) with the change in slope of this curve plotted as the dashed blue line. The pore throat size distributions is shown in C. X-ray diffraction results with peak interpretations are presented in D and an scanning electron microscope image of the sample is presented in E.



Seal capacity results for Brown Gannet 1, 2152-2155m, are presented in Figure 5-14. A 1270psi threshold pressure was measured for this sample and corresponds to a seal capacity of 219m oil column. The Jamieson Formation in Brown Gannet 1 is predominantly marl and the XRD results show that this sample is dominated by calcite (Figure 5-14D) with some illite and smectite present; kaolinite is absent. Abundant rhombic calcite crystals and illite clays are also present (Figure 5-14E).

Skua 1 is located in the southern Vulcan Sub-Basin, whereas Brown Gannet 1 is located on the Ashmore Platform to the west of the sub-basin proper (Figure 4.1). As with the Jabiru 1a and Challis 1 samples above, the difference in seal capacity between the Skua 1 and Brown Gannet 1 samples can be explained by the amount of calcite present. The lithological variation within the Jamieson Formation ranges from claystone to calcareous claystone to marl. As the amount of calcite increases the seal capacity decreases.

Results for all MICP, XRD and SEM analyses from samples in the Jamieson Formation are contained in Appendix A, these results have been tabulated in Table 5-2.

The Jamieson Formation marls and claystones provide top seals to the Jabiru and Challis fields, which were significant early discoveries. Of particular interest is that even where the Jamieson Formation is predominantly made up of marls, the seal capacity is in excess of 100m and considering that the Jabiru field had a vertical oil column of 57m, the Jamieson Formation can be considered as an excellent seal from a seal capacity perspective.

### 5.1.5 Woolaston/Gibson/Fenelon – WGF

Seal capacity results for the WGF interval are tabulated in Table 5-3. Seal capacities (oil column heights) are graphed in Figure 5-15. Table 5-3 presents the well name, sample depth range, sample type, MICP analysis threshold pressure, calculated seal capacity for an oil column (including interfacial tension ranges high, normal and low) and calculated seal capacity for a gas column. Four sample analyse from three wells (Challis 1 1140-1150m, Jabiru 2 1532-1535m & 1550-1554m and Skua 8 2301-2307m) are presented in detail, highlighting the regional seal variation within the WGF interval.

| Well Name | Depth From (m) | Depth To (m) | Sample Type | Threshold Pressure MICP (psi) | Column Height (high) (m) | Column Height (norm) (m) | Column Height (low) (m) | Gas Column Height (m) |
|---|---|---|---|---|---|---|---|---|
| Anderdon 1 | 1410 | 1420 | cuttings | 2953.00 | 768 | 512 | 256 | 461 |
| Anderdon 1 | 1390 | 1400 | cuttings | 3540.00 | 921 | 614 | 307 | 553 |
| Challis 1 | 1140 | 1150 | cuttings | 2083.00 | 541 | 361 | 180 | 325 |
| Challis 1 | 1260 | 1270 | cuttings | 4309.00 | 1122 | 748 | 374 | 463 |
| Jabiru 2 | 1550 | 1554 | cuttings | 885.00 | 228 | 152 | 76 | 137 |
| Jabiru 2 | 1532 | 1535 | cuttings | 2515.00 | 654 | 436 | 218 | 392 |
| Pascal 1 | 2475 | 2478 | cuttings | 600.00 | 154 | 103 | 51 | 92 |
| Pascal 1 | 2493 | 2496 | cuttings | 958.00 | 247 | 165 | 82 | 148 |
| Pollard 1 | 2031 | 2034 | cuttings | 2962.00 | 770 | 514 | 257 | 462 |
| Rainier 1 | 1542 | 1545 | cuttings | 1004.00 | 259 | 173 | 86 | 107 |
| Sahul Shoals 1 | 1755 | 1758 | cuttings | 464.00 | 118 | 79 | 39 | 71 |
| Sahul Shoals 1 | 1770 | 1773 | cuttings | 513.00 | 131 | 88 | 44 | 80 |
| Sahul Shoals 1 | 1762 | 1765 | cuttings | 566.00 | 145 | 97 | 48 | 88 |
| Sahul Shoals 1 | 1746 | 1749.5 | cuttings | 643.00 | 165 | 110 | 55 | 100 |
| Sahul Shoals 1 | 1713 | 1716 | cuttings | 670.00 | 172 | 115 | 57 | 104 |
| Skua 1 | 2313 | 2316 | cuttings | 809.00 | 208 | 139 | 69 | 125 |
| Skua 1 | 2380.5 | 2383.5 | cuttings | 2068.00 | 537 | 358 | 179 | 222 |
| Skua 3 | 2365 | 2371 | cuttings | 675.00 | 174 | 116 | 58 | 104 |
| Skua 4 | 2280 | 2283 | cuttings | 750.00 | | | | |
| Skua 5 | 2343 | 2346 | cuttings | 491.00 | 126 | 84 | 42 | 52 |
| Skua 8 | 2301 | 2307 | cuttings | 900.00 | 232 | 155 | 77 | 139 |
| Skua 8 | 2307 | 2310 | cuttings | 1251.00 | 324 | 216 | 108 | 134 |
| Skua 9 | 2301 | 2304 | cuttings | 801.00 | 206 | 138 | 69 | 85 |
| Skua 9 | 2310 | 2313 | cuttings | 1026.00 | 265 | 177 | 88 | 159 |
| Tenacious West 1 | 2200 | 2210 | cuttings-white carbonate | 1300.00 | 337 | 224 | 112 | 139 |
| Tenacious West 1 | 2160 | 2165 | cuttings-white | 1438.00 | 373 | 248 | 124 | 154 |
| Tenacious West 1 | 2200 | 2210 | cuttings-dark (marl) | 1598.00 | 414 | 276 | 138 | 171 |
| Tenacious West 1 | 2200 | 2210 | cuttings-black shale | 5005.00 | 1303 | 869 | 434 | 538 |
| Tenacious West 1 | 2160 | 2165 | cuttings-dark marl | 5984.00 | 1559 | 1039 | 520 | 643 |
| Warb 1a | 2340 | 2345 | Cuttings | 1236.00 | 320 | 213 | 107 | 192 |
| Warb 1a | 2345 | 2350 | cuttings | 1771.00 | 460 | 306 | 153 | 276 |

Table 5-3: WGF interval seal capacity results.

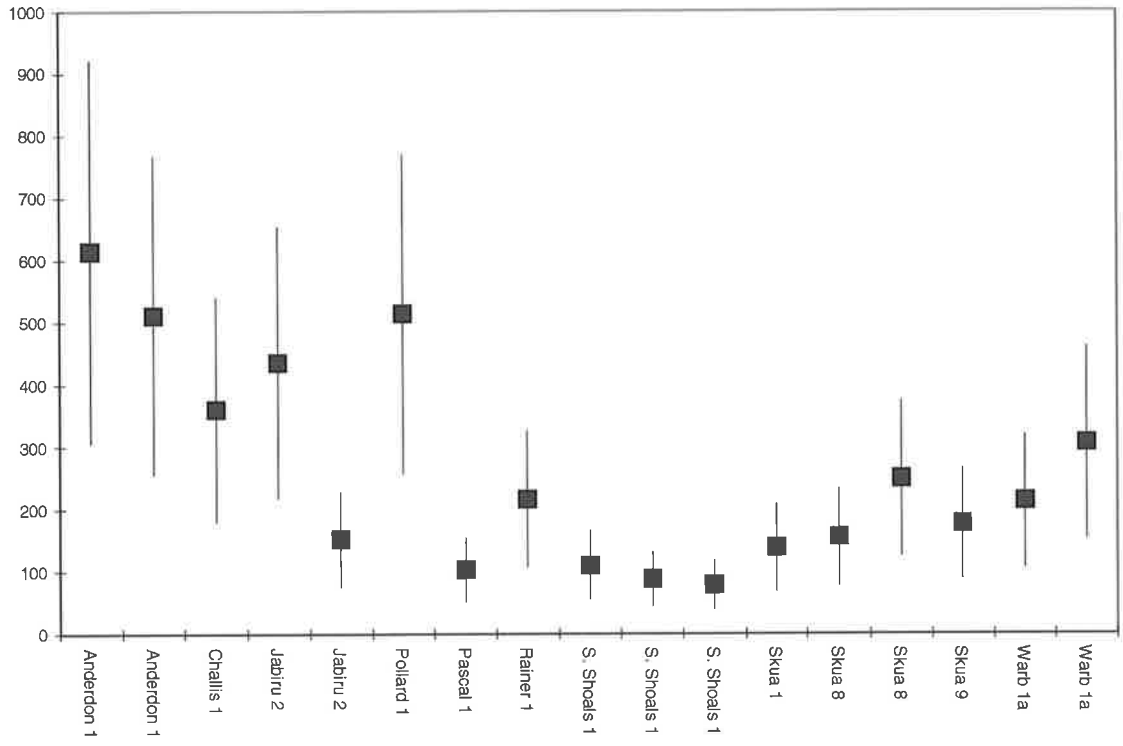
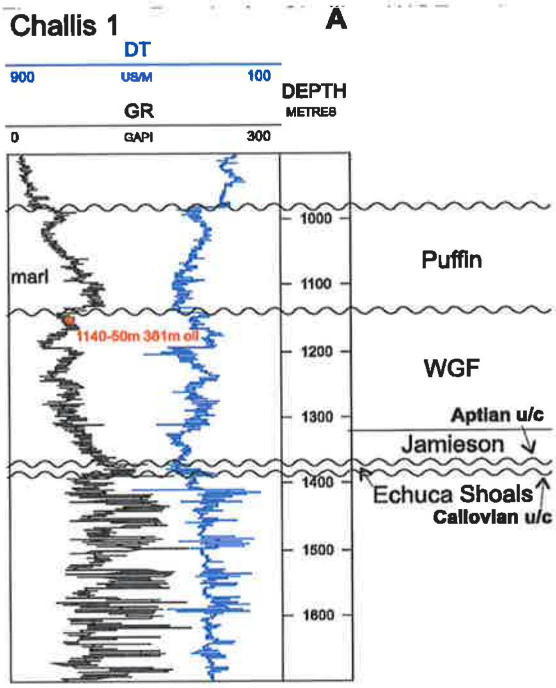



Figure 5-15: Seal capacity (in meters of oil) that the WGF interval can retain is shown on the y-axis. Error bars have been added to account for variability in interfacial tension. Wells, shown on the x-axis, are ordered from proximal on the left to distal on the right.

Threshold pressures measured in the WGF interval range from 460psi to over 5000psi, which correspond to oil column seal capacities ranging from 79m to over 870m (Table 5-3). This variation in seal capacities is highlighted in Figure 5-15. This range in seal capacities is exemplified by samples analysed from Challis 1, Jabiru 2 and Skua 8, which are presented and discussed below.

As outlined previously the range in seal capacity is predominantly due to uncertainty in the interfacial tension used in calculating seal capacity. Interfacial tension is a fluid dependant property and hence different rock types would be influenced in a similar manner as interfacial tension changes. This means that if the interfacial tension causes the seal capacity calculated above to be on the low side of the error bar, all seal capacities shown in Figure 5-15 will be affected in a similar way.



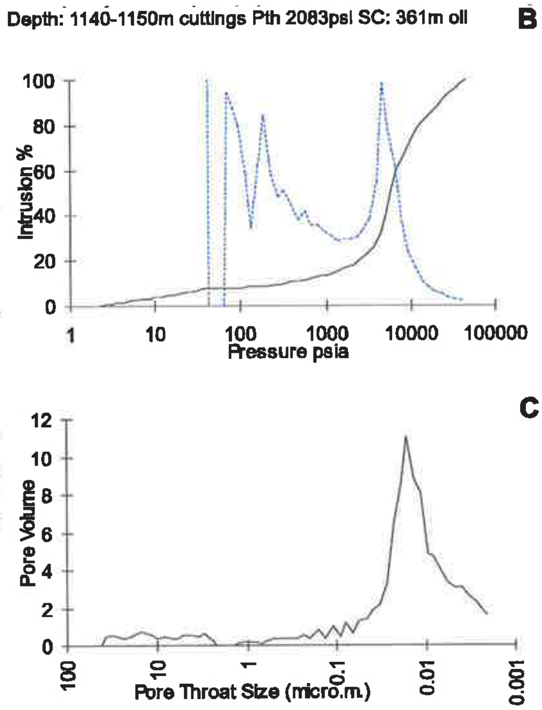
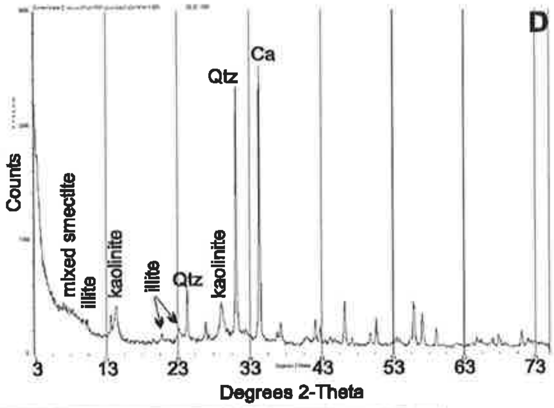
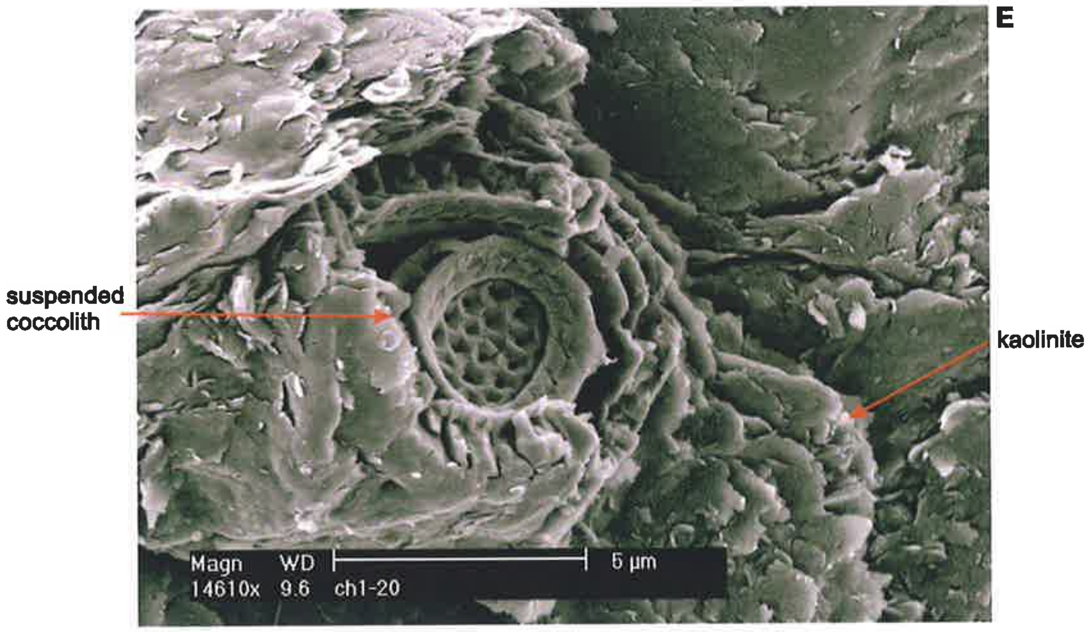
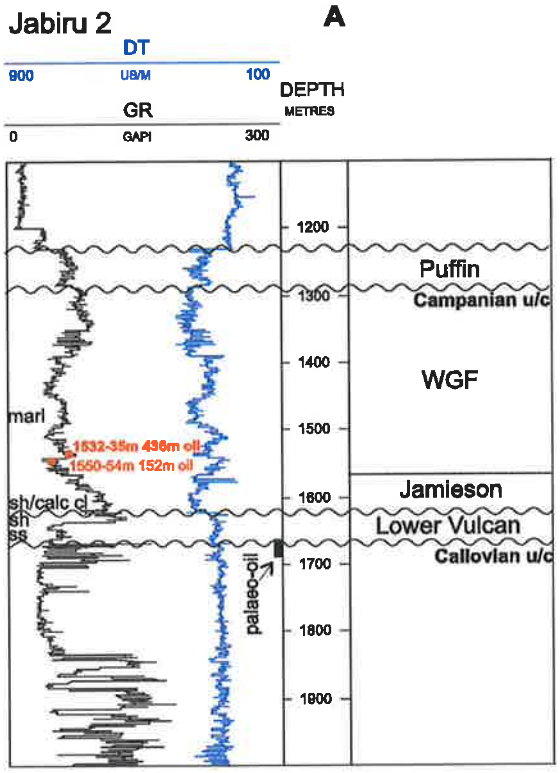
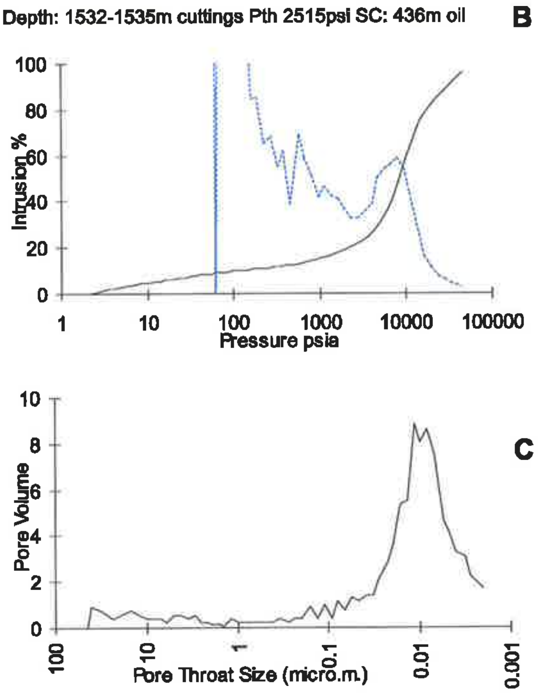




Figure 5-16: Results for Challis 1 WGF cuttings samples from a depth between 1140-1150m. A well log composite is show in A with the locations of the sample indicated by the red dot. The capillary pressure intrusion profile is shown in B (black curve) with the change in slope of this curve plotted as the dashed blue line. The pore throat size distributions is shown in C. X-ray diffraction results with peak interpretations are presented in D and an scanning electron microscope image of the sample is presented in E.





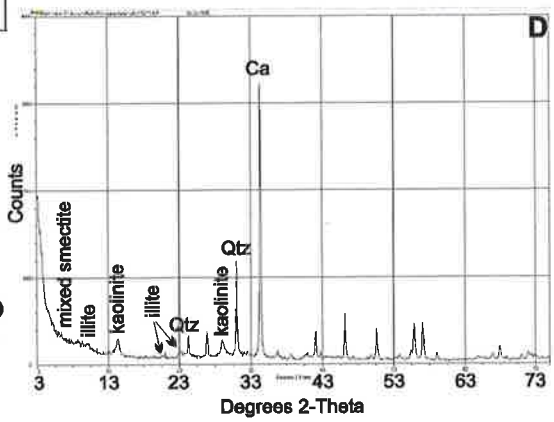
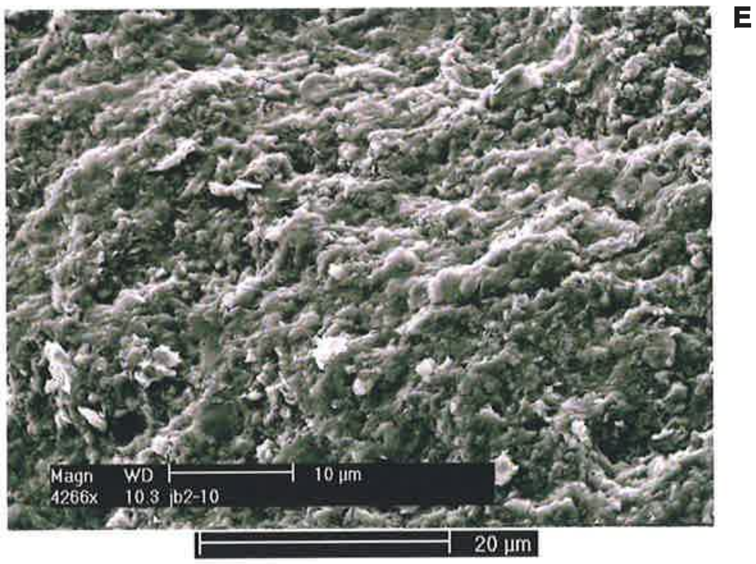




Figure 5-17: Results for Jabiru 2 WGF cuttings samples from a depth between 1532-1534m. A well log composite is show in A with the locations of the sample indicated by the red dot. The capillary pressure intrusion profile is shown in B (black curve) with the change in slope of this curve plotted as the dashed blue line. The pore throat size distributions Is shown In C. X-ray diffraction results with peak interpretations are presented in D and an scanning electron microscope image of the sample is presented in E.

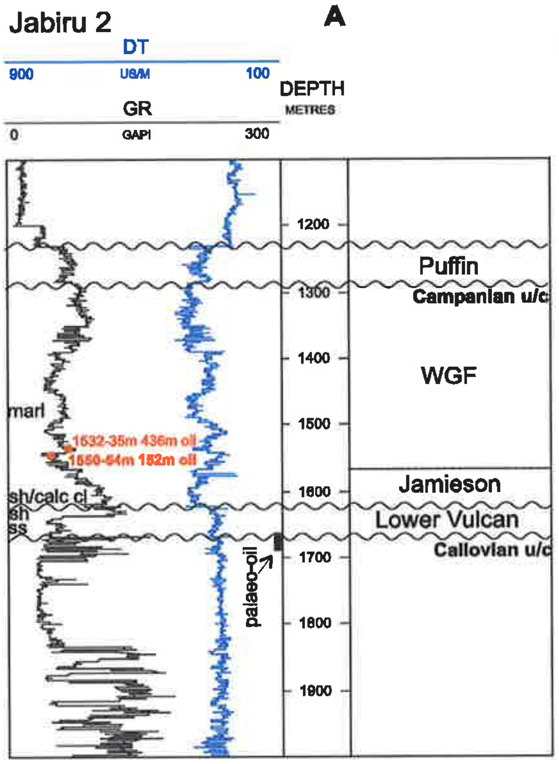


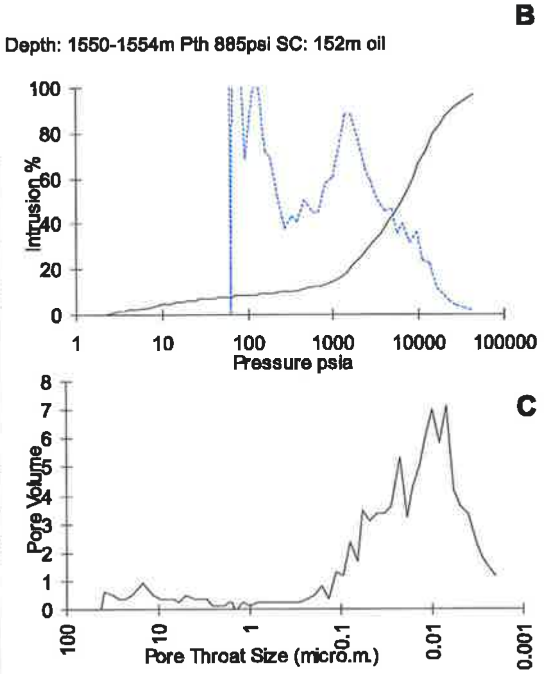
Challis 1 cuttings samples from between 1140 and 1150m have a threshold pressure of 2083psi (Figure 5-16 A), which can seal an oil column of 321m. The XRD and SEM results show that this sample is composed predominantly of kaolinite clays, with some calcite. The SEM image (Figure 5-16 E) indicates that the calcite in the sample is surrounded by clay, an example of which is the coccolith surrounded by kaolinite that can be seen in the centre of the image.

Cuttings from Jabiru 2 (1532-1535m) have a 2515psi threshold pressure, which corresponds to a seal capacity of 436m oil column (Figure 5-17B). The XRD results (Figure 5-17D) indicate this sample is kaolinite and calcite rich, with minor smectite and illite. The SEM image (Figure 5-17E) shows predominantly kaolinite with very little obvious porosity. Of note is that calcite is generally absent.

Cuttings from Jabiru 2 (1550-1554m) have a 885psi threshold pressure, which corresponds to a seal capacity of 152m oil column (Figure 5-18B). The XRD results (Figure 5-18D) indicate that this sample is dominated by calcite, with some kaolinite and minor illite. Numerous calcite crystals dominate the SEM image (Figure 5-18E). Relatively extensive porosity between the packed calcite crystals, which make up the bulk of the sample, is evident in the SEM image.

In summary, calcite poor samples (Jabiru 2 1532-1535m & Challis 1 1140-1150m) have higher seal capacities than calcite rich samples (Jabiru 2 1550-1554m).



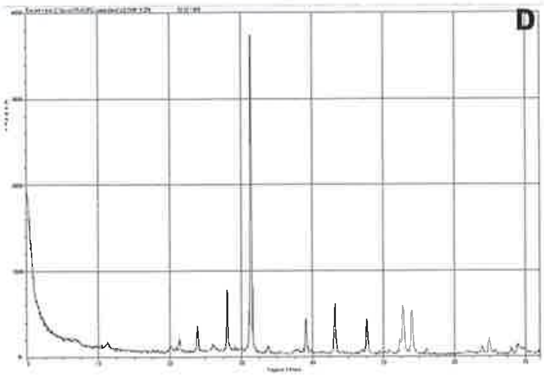
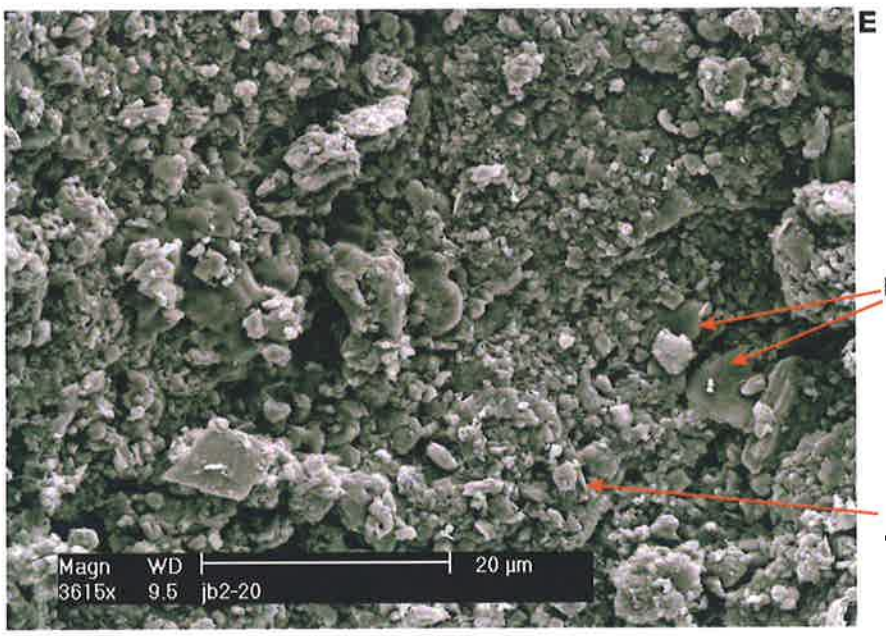




Figure 5-18: Results for Jabiru 2 WGF cuttings samples from a depth between 1550-1554m. A well log composite is show in A with the locations of the sample indicated by the red dot. The capillary pressure intrusion profile is shown in B (black curve) with the change in slope of this curve plotted as the dashed blue line. The pore throat size distributions is shown in C. X-ray diffraction results with peak interpretations are presented in D and an scanning electron microscope image of the sample is presented in E.



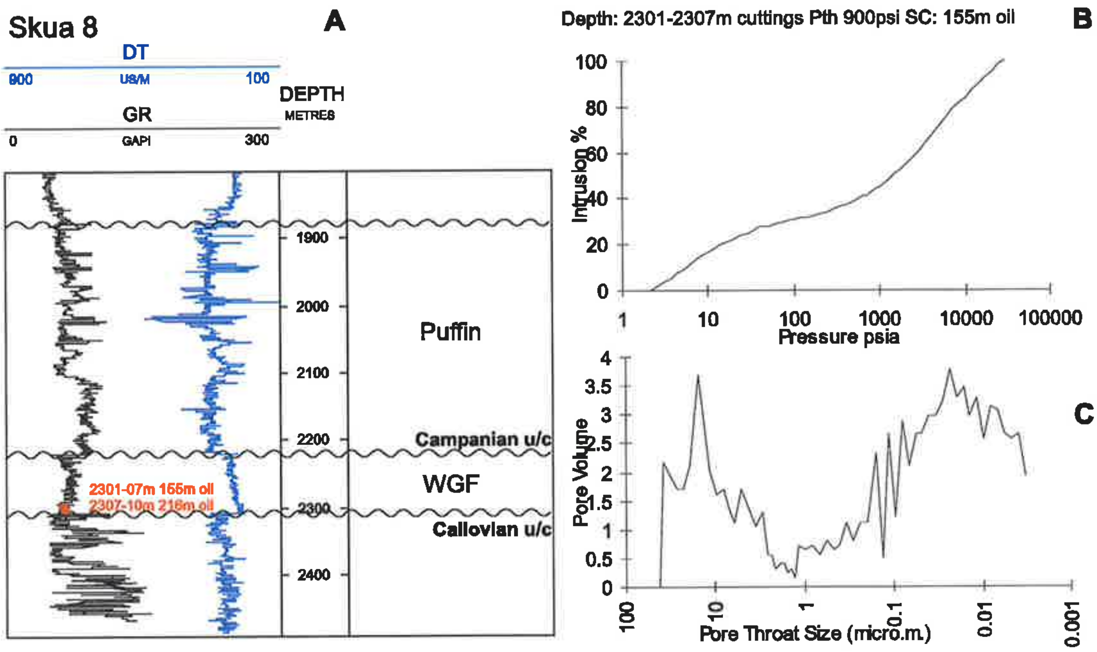
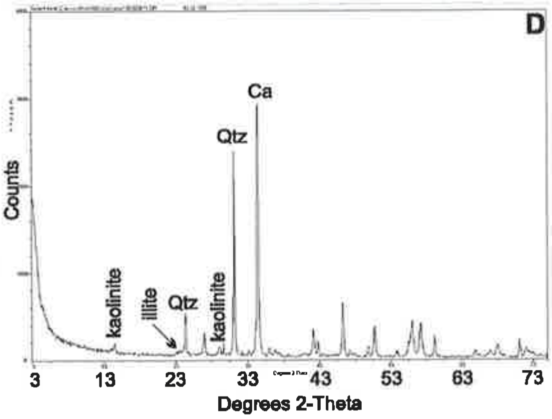
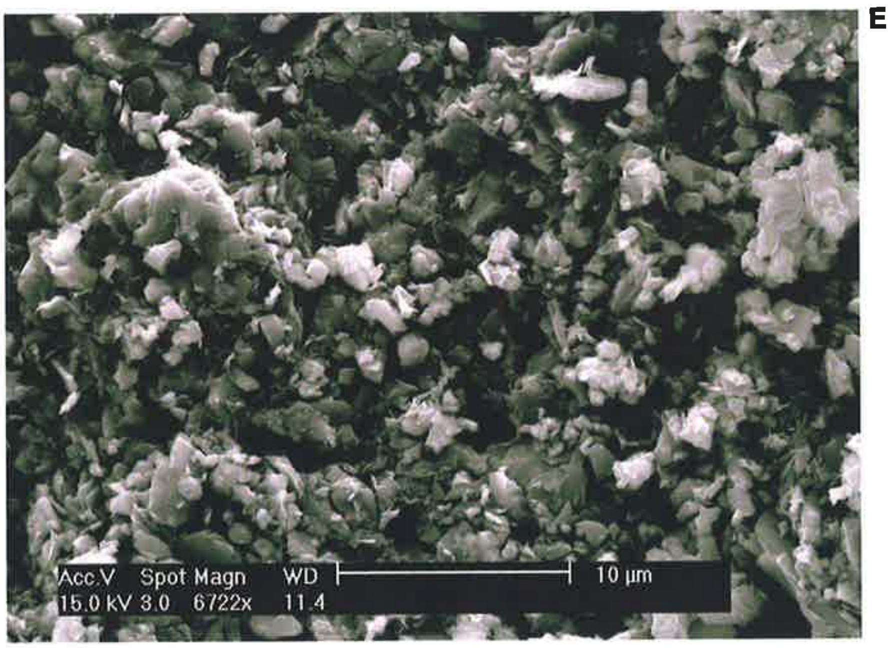



Figure 5-19: Results for Skua 8 WGF cuttings samples from a depth between 2301-2307m. A well log composite is show in A with the locations of the sample indicated by the red dot. The capillary pressure intrusion profile is shown in B (black curve) with the change in slope of this curve plotted as the dashed blue line. The pore throat size distributions is shown in C. X-ray diffraction results with peak interpretations are presented in D and an scanning electron microscope image of the sample is presented in E.



Cuttings from Skua 8 (2301-2307m) have a threshold pressure of 900psi (Figure 5-19A), which equates to a seal capacity of 155m oil column. The XRD results (Figure 5-19D) show that the sample contains predominantly calcite, with some kaolinite clays. The SEM image of the sample (Figure 5-19E) clearly shows the sample is dominated by calcite crystals intermixed with minor clay. The rhombic, fragmented nature of the calcite-dominant mineralogy of this marl creates a bigger interconnected pore throat network and thus a lower threshold pressure than in the claystone.

The threshold pressure difference and the corresponding seal capacity difference between the four samples are a function of the interconnected pore throats within the rock itself. As can be seen from the SEM images and XRD analysis, the Challis 1, 1140-1150m and Jabiru 2, 1532-1535m samples are predominantly composed of clay, which has very little intergranular porosity and relatively small (0.01-0.02 micron) pore throats. The Jabiru 2, 1550-1554m and Skua 8, 2301-2307m samples are composed of rhomboidal calcite crystals (micrite) that are not as tightly packed as the clay minerals, with much more visible porosity. The difference between the predominantly kaolinite and predominantly calcite samples is that the calcite-rich samples have bigger pore throats that form a more interconnected path. Hence, the difference in threshold pressure and seal capacity for the WGF interval is dependant on the composition of rocks in the interval.

As such, even the most calcareous parts of the WGF interval still hold back over 70m of oil column and so from a top seal capacity risk can be considered as a low risk top seal.

# Chapter 6 Seal Potential – Results and Discussion

The methodology used to determine seal potential (SP) has been outlined in Chapter 3 (sections 3.5, 3.6 and 3.7). SP results and fairway maps for the Lower Vulcan, Upper Vulcan, Echuca Shoals, Jamieson and Woolaston/Gibson/Fenelon (WGF) Formations are presented in the following sections.

For reference, the location and name of the major structural features in the Vulcan Sub-Basin are shown in Figure 6-1.

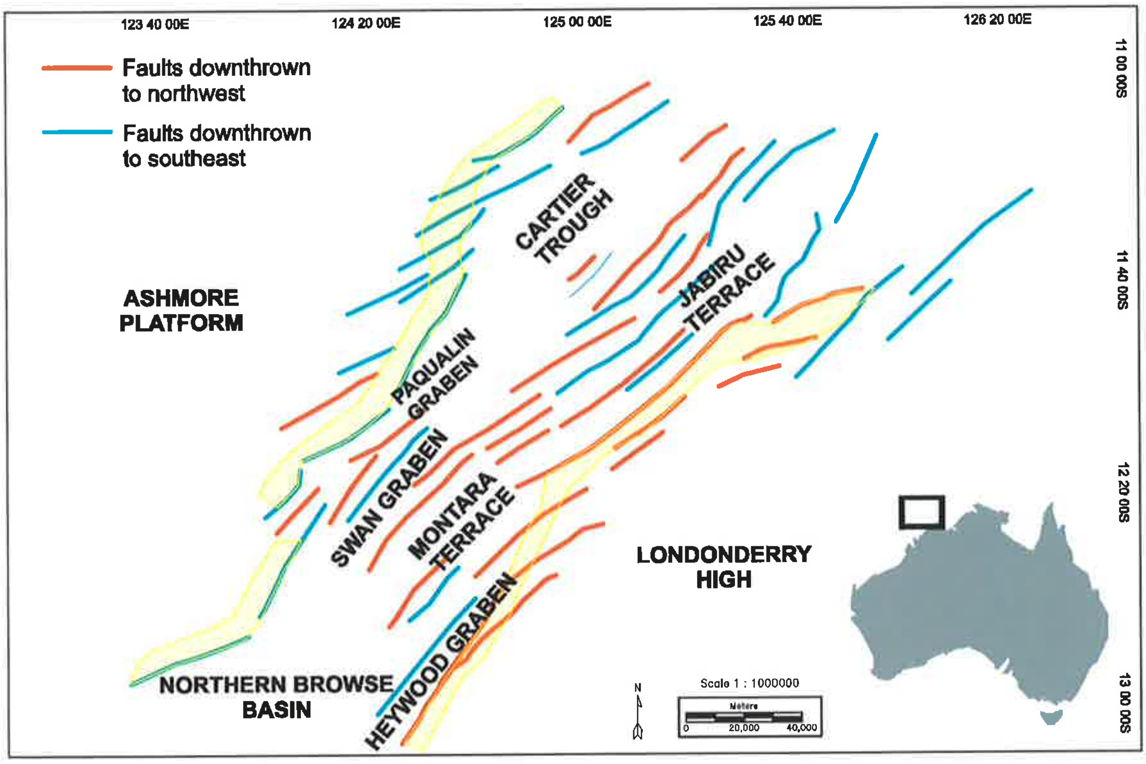



Figure 6-1: Names and locations of major features in the Vulcan Sub-Basin.

## 6.1 Lower Vulcan

### 6.1.1 Results

An example workflow for evaluating the SP of the Lower Vulcan Formation is shown for Eclipse 1 and Jabiru 2 in Table 6-1. The assessment of each SP component (seal capacity, seal thickness, areal extent and seal integrity) is described below using examples from Eclipse 1 and Jabiru 2.

#### 6.1.1.1 Seal Capacity Risk Evaluation Example

The results for the seal capacity part of SP for Eclipse 1 and Jabiru 2 are shown in Table 6-1 (1).

The seal capacity of the Lower Vulcan Formation shales in Eclipse 1 is 76m (oil column). Eclipse 1 was drilled on a structural closure with a vertical height of 110m. Using the methodology outlined in Chapter 3.7.1, the seal capacity risk for Eclipse 1 is assigned a geological factor of good (seal holds back between 50 and 100% seal capacity) and a data quality and quantity factor of plentiful (MICP measurements for seal capacity are available). Using the risk matrix shown in Figure 3-12, a risk value of 0.75 (Table 6-1 (1) – Risk Matrix Value) was assessed for the Eclipse 1 seal capacity risk.

A seal capacity of 680m (oil column) was measured for Jabiru 2 and the Jabiru structure has a vertical structural closure of approximately 250m. Using the methodology outlined in Chapter 3.7.1, the seal capacity risk for Jabiru 2 is assigned a geological factor of very good (seal holds back in excess of structural closure) and a data quality and quantity factor of plentiful (MICP measurements for seal capacity exist). Using the risk matrix shown in Figure

3-12, a risk value of 1.0 (Table 6-1 (1) – Risk Matrix Value) was assessed for the Jabiru 1 seal capacity risk.

Seal capacity results were presented with error bars in Chapter 5. For the purpose of seal potential evaluation, the seal capacity calculated from the most likely input variables was used. This approach is considered to be valid as the seal capacity input variable contributing the majority of the error is interfacial tension. As such the effect interfacial tension has on the calculated seal capacity is proportional to the threshold pressure, with high seal capacity sample showing a much greater error variation than low seal capacity samples. For example from Figure 5.6, a seal capacity of 500m will have an error of 250m and will still be considered to be an excellent seal from a seal potential evaluation perspective, while from figure 5.10, a seal with a capacity of 100m will have an associated uncertainty error of only 30m.

#### 6.1.1.2 Seal Thickness Risk Evaluation Example

Results for the seal thickness component of SP are tabulated in Table 6-1 (2). The criteria for determining the geological factor of seal thickness are outlined in Chapter 3.7.3.

The seal thickness in the Lower Vulcan Formation section in Eclipse 1 is 215m. For Eclipse 1, the seal thickness geological factor is "very good" (seal thickness significantly greater than any fault throws in the top seal) based on enough data (existing well and seismic data are not enough to provide confidence of existence of geological factor). Using the risk matrix (Figure 3-12) a risk value of 0.875 (Table 6-1 (2) – Seal Thickness Risk Matrix Value) was assessed for the Jabiru 1 seal thickness risk.

The seal thickness geological factor for Jabiru 2 is "bad" (seal does not cover structure and/or there is significant lateral variation in lithology) based on moderate data (existing well and seismic data are not enough to provide confidence of existence of geological factor). The measured seal thickness for the Lower Vulcan Formation in Jabiru 2 is only 11m, which is below seismic resolution and so at best a moderate data confidence can be used for seal thickness risk. Using the risk matrix (Figure 3-12) (Table 6-1 (2) – Seal Thickness Risk Matrix Value) Jabiru 1 has a seal thickness risk of 0.375.

#### 6.1.1.3 Areal Extent Risk Evaluation Example

Results for the areal extent part of SP are tabulated in Table 6-1 (2). The criteria for determining the geological factor of areal extent are outlined in Chapter 3.7.2.

The areal extent geological factor for Eclipse 1 is "very good" (seal covers entire structural closure and seal lithology is uniform and homogeneous over structure) as the seal is thick and correlated to nearby wells and is based on plentiful data (well and seismic data prove the existence of the geological factor). Using the risk matrix (Figure 3-12) (Table 6-1 (2) – Areal Extent Risk Matrix Value) the Eclipse 1 areal extent risk is 0.375.

Seal areal extent for Jabiru 2 is "bad" (seal does not cover structure and/or significant lateral variation in lithology) as this seal is not present in Jabiru 1a, which is on the structure, whereas Jabiru 2 was drilled just off structure. The geological risk assessment of areal extent in Jabiru 2 is based on plentiful data (well and seismic data prove the existence of the geological factor). Using the risk matrix (Figure 3-12) (Table 6-1 (2) – Areal Extent Risk Matrix Value) the Jabiru 2 areal extent risk is 0.25.

#### 6.1.1.4 Seal Integrity Risk Evaluation Example

The results for the seal integrity part of SP for Eclipse 1 and Jabiru 2 are shown in Table 6-1 (3). The criteria for determining the geological factor (Table 3.7) and data confidence (Table 3.8) of seal integrity are outlined in Chapter 3.7.4.

For the Lower Vulcan formation in Eclipse 1, the brittleness index (BRI) ranged from values of 2 to 4, with a BRI mean of 2.92. Using Table 3.7, a BRI mean of 2.92 gives a geological risk of "good" (BRI mean value is between 2 and 4) based on moderate data certainty (data provide information on the rock properties, such as propensity of the seal to fracture, but no information on the actual existence of fractures). Using the risk matrix (Figure 3-12) (Table 6-1 (3) – Seal Integrity Risk Matrix Value) the Eclipse 1 seal integrity risk is 0.625. The Lower Vulcan formation seal lithology in Jabiru 2 has a BRI mean value of 4.06. Using Table 3.7 from Chapter 3.7.4, a BRI mean of 4.06 is equivalent to a geological risk factor of bad (BRI mean value is between 4 and 6) based on moderate data certainty (data provide information on the rock properties, such as propensity of the seal to fracture, but no information on the actual existence of fractures). Using the risk matrix (Figure 3-12), a risk value of 0.375 (Table 6-1 (3) – Seal Integrity Risk Matrix Value) was assessed for the Eclipse 1 seal integrity risk.

#### 6.1.1.5 Seal Potential Evaluation Example

Two values for SP are shown. The first SP value is shown in the last column in Table 6-1 (2) and is calculated using only seal capacity, seal thickness and areal extent. The second value is in the last column of Table 6-1 (3) and is calculated using all seal capacity, seal thickness, areal extent and seal integrity components.

The seal potential is calculated by multiplying the risk matrix values (RMV) of each of the seal potential parts. Taking Eclipse 1 as an example:

Seal Capacity RMV (0.75) * Seal Thickness RMV (0.875) * Areal Extent RMV (1.0) * Seal Integrity RMV (0.625) = Seal Potential (0.41).

Summary tables of seal potential results are presented in the following sections of this chapter. Appendix B contains seal potential results for each well within each formation presented in the same format as Table 6-1 and Table 6-2.

Table 6-1 (1)

| | | Seal Capacity | | | | | |
|---|---|---|---|---|---|---|---|
| Well Name | Lithology Comments | Seal Capacity | Structural Closure | structure / seal capacity | Geological Factor | Data Quality and Quantity | Risk Matrix Value |
| Eclipse 1 | dark grey shales | | 110m | 0.69 | good | moderate | 0.75 |
| Jabiru 2 | Kimmeridgian claystone/ marl? | 680m | ~250m | 1 | very good | plentiful | 1 |

Table 6-1: Workflow used in determining seal potential for two wells in the Lower Vulcan Formation. Read the tables left to right starting with (1) Seal Capacity, (2) Seal Thickness and Areal Extent and (3) Seal Brittleness (BRI index) and Seal Potential. Parts (2) and (3) are on the next page. All Eclipse 1 data is display in black text and all Jabiru 2 data is displayed in red text.

Table 6-1 (2)

| Seal Thickness | | | | | Areal Extent | | | | Seal Potential (No BRI) |
|---|---|---|---|---|---|---|---|---|---|
| Seal Thickness (m) | fault throws in cap rock | Geological Factor | Data Quality and Quantity | Risk Matrix Value | Seal Areal Extent | Geological Factory | Data Quality and Quantity | Risk Matrix Value | Seal Cap *Thickness *Areal extent |
| 215 | very thick seal & no resolvable faults in top seal | very good | enough | 0.875 | correlates to East Swan1 and Eclipse 1 | very good | plentiful | 1 | 0.66 |
| 11 | no major top seal faults - if Challis Field is used as an analog field top seal fault throws are in the order of 10 to 15m | bad | moderate | 0.375 | no present on top of structure in Jabiru 1a | bad | plentiful | 0.25 | 0.09 |

Table 6-1 (3)

| Seal Integrity (based on brittleness index or BRI) | | | | | | | | | Seal Potential |
|---|---|---|---|---|---|---|---|---|---|
| Brittle Index Range | BRI mean | BRI StDev | depth from | depth to | BRI Count | Geological Factory | Data Quality and Quantity | Risk Matrix Value | Seal Cap *Thickness *Areal extent *BRI Index |
| 2 to 4 | 2.92 | 0.65 | 2330 | 2540 | 1378 | good | moderate | 0.625 | 0.41 |
| ~4 | 4.06 | 0.64 | 1623 | 1635 | 79 | bad | moderate | 0.375 | 0.04 |

SP results for the Lower Vulcan Formation are presented in Table 6-2. The SP of the Lower Vulcan Formation is shown in Figure 6-2 as well as hydrocarbon columns and paleo-oil columns within strata for which the Lower Vulcan Formation acted as a top seal. Using the SP assessment process outlined above SP was estimated for the Lower Vulcan Formation based on a data set of seal capacity measurements, cuttings and sidewall core descriptions, well log motifs, seismic structure and BRI data.

SP values shown in the 'Seal Potential + BRI' column of Table 6-3 were plotted at each well location and hand contoured to generate Figure 6-2.

| Well Name | Seal Capacity | | Seal Thickness | | Areal Extent | | Seal Potential | Seal Integrity | | | Seal Potential + BRI |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Geological Factor | Data Factor | Geological Factor | Data Factor | Geological Factor | Data Factor | | Mean BRI | Geological Factor | Data Factor | |
| Allaru 1 | G | M | VG | EN | VG | PL | 0.55 | - | G | P | 0.31 |
| Birch 1 | B | M | VG | EN | G | M | 0.21 | 2.8 | G | M | 0.13 |
| Champagny 1 | G | M | G | EN | VG | EN | 0.38 | - | G | P | 0.21 |
| Conway 1 | VB | EN | - | - | - | - | - | - | - | - | 0 |
| East Swan 1 | G | M | G | EN | VG | PL | 0.43 | 2.64 | G | M | 0.27 |
| East Swan 2 | G | M | G | EN | VG | PL | 0.43 | 2.82 | G | M | 0.27 |
| Eclipse 1 | G | P | VG | EN | VG | PL | 0.66 | 2.92 | G | M | 0.41 |
| Eclipse 2 | G | M | VG | EN | VG | PL | 0.55 | 3.23 | G | M | 0.34 |
| Fagin 1 | G | M | VG | EN | VG | PL | 0.55 | 3.18 | G | M | 0.34 |
| Jabiru 2 | VG | PL | B | M | B | PL | 0.09 | 4.06 | B | M | 0.04 |
| Longleat 1 | VB | EN | B | M | B | M | 0.02 | - | E | P | 0.01 |
| Maple 1 | VG | EN | VG | EN | VG | PL | 0.77 | 2.22 | G | M | 0.48 |
| Maret 1 | G | M | G | PL | G | EN | 0.32 | 2.52 | G | M | 0.2 |
| Montara 1 | B | PL | VG | PL | G | EN | 0.17 | 3.81 | G | M | 0.11 |
| Octavius 1 | G | M | VG | PL | G | PL | 0.48 | - | B | P | 0.21 |
| Octavius 2 | G | M | VG | M | G | PL | 0.48 | 4.26 | B | M | 0.18 |
| Oliver 1 | VG | PL | VG | EN | VG | PL | 0.88 | - | G | P | 0.49 |
| Paqualin 1 | VG | EN | VG | EN | VG | PL | 0.77 | 1.98 | VG | M | 0.57 |
| Rainier 1 | B | PL | B | PL | B | PL | 0.02 | - | E | P | 0.01 |
| Rowan 1 | G | PL | VG | EN | G | M | 0.41 | 2.82 | G | M | 0.26 |
| Swan 1 | G | M | VG | PL | VG | PL | 0.63 | 2.66 | G | M | 0.39 |
| Swift 1 | B | PL | - | - | - | - | - | - | - | - | 0 |
| Tahbilk 1 | B | EN | VG | PL | G | EN | 0.22 | 3.98 | G | M | 0.13 |
| Taltarni 1 | B | M | VG | EN | VG | M | 0.25 | 3.89 | G | M | 0.15 |
| Vulcan 1b | VG | M | VG | PL | VG | PL | 0.75 | 2.15 | G | M | 0.47 |

Expression of geological factor existence
- VG:very good
- G:good
- E:even
- B:bad
- VB:very bad

Quantity & quality of information
- PL:plentiful
- EN:enough
- M:moderate
- P:poor
- VP:very poor

Table 6-2 Seal potential values assessed for the Lower Vulcan Formation. Wells with a low seal potential are highlighted in red.

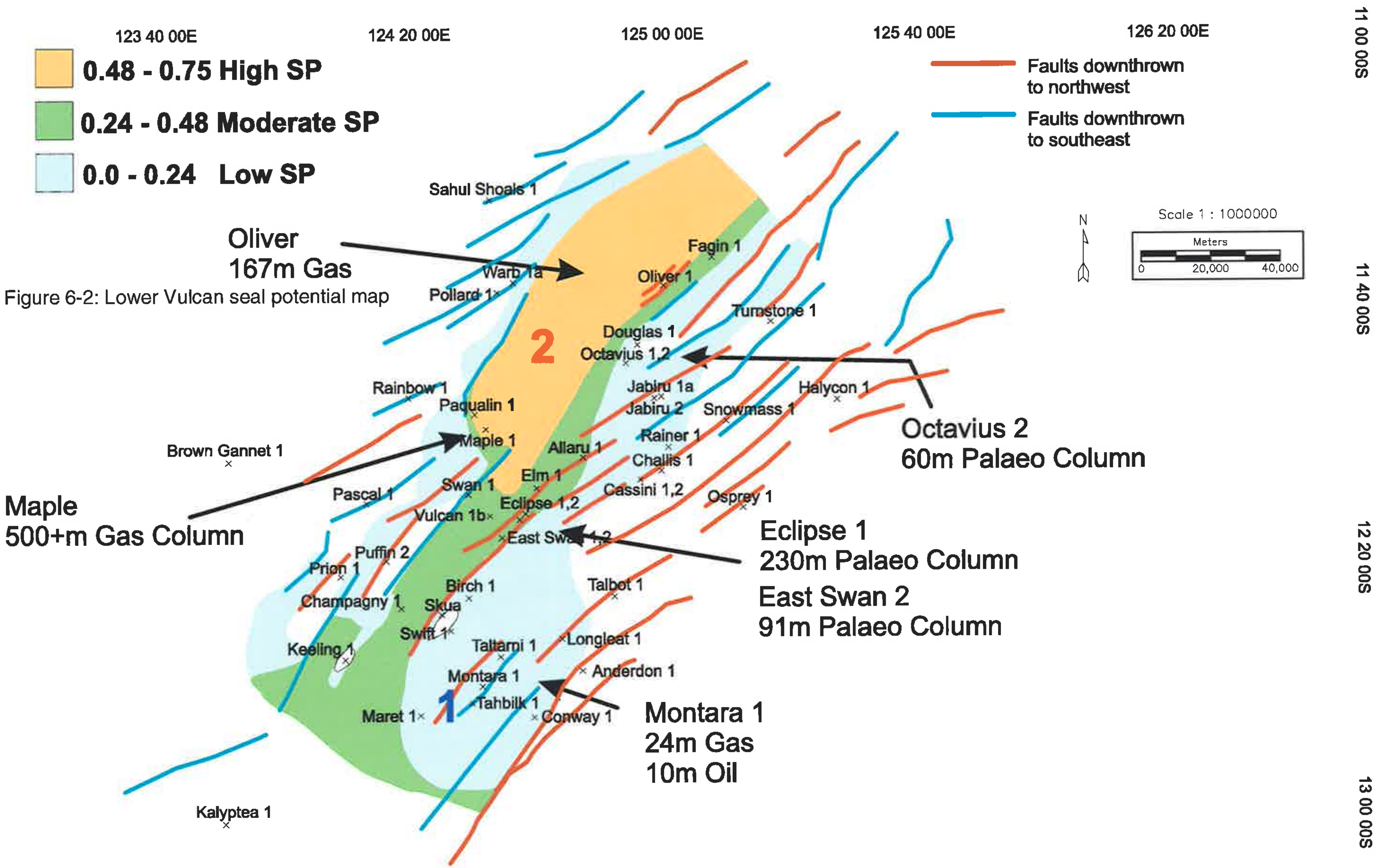



Figure 6-2: Lower Vulcan seal potential map

### 6.1.2 Analysis and Discussion

Mean BRI values for claystone seal rocks of the Lower Vulcan Formation are low (BRI<4). These rocks are relatively ductile and have high seal integrity. BRI mean values of approximately 4 were measured for seals containing high percentages of siltstones and claystone interbeds. These intervals are relatively brittle and have lower seal integrity. Seal integrity is 'good' in the Lower Vulcan Formation and does not decrease SP.

High SP (0.48-0.75) for this sequence occurs within the Late Oxfordian to Kimmeridgian-aged restricted marine claystone facies. This facies occurs in the main depocentres of the Vulcan Sub-Basin but was either eroded or not deposited on the Ashmore Platform, Londonderry High and intra-graben highs. Kimmeridgian claystones (Chapter 5.1.1) have seal capacities of over 600m (oil). The facies is over 500m thick in places and is regionally extensive in the Cartier Trough, resulting in high SP.

SP is moderate (0.24-0.48) in the northern Browse Bain, Swan Graben and southeastern edge of the Cartier Trough. Well log motifs (Figure 4-43), cuttings and sidewall core descriptions indicate that deposition consisted of predominantly claystones with some interbedded siltstones. A moderate SP has been interpreted in the Swan Graben and along the fringe of the Cartier Trough due to uncertainty in data quality and quantity. This uncertainty reduces the overall SP in these areas for Vulcan 1b, Eclipse 1&2, East Swan 1&2, Allaru 1 and Fagin 1.

Low SP (0.0-0.24) occurs in areas proximal to the basin margin such as the Montara Terrace, Jabiru Terrace. The Lower Vulcan Formation is missing from Londonderry High and Ashmore Platform. The regional extent and facies variation of the Lower Vulcan formation is discussed in Chatper 4.1.1.1. Where it is present along the sub-basin margins, (eg the Jabiru Terrace area) it is thin and sandstone-dominated. The Montara Terrace and surrounding area have a low SP because the section contains significant siltstone and sandstone (reservoirs) deposited in a prograding delta system. Hence, the SP in the Montara Terrace area is low because of low seal capacities.

Where the Upper Vulcan claystones have been preserved with some thickness this formation is an excellent top seal. This qualitative statement is supported by the empirical evidence in the Oliver and Maple gas accumulations, which are seal by Lower Vulcan Formation claystones and have over accumulations of 160m and 500m of gas column respectively.

## 6.2 Upper Vulcan

### 6.2.1 Results

SP results for the Upper Vulcan Formation are presented in Table 6-3. Definitions used to assess the geological factor and the data quality and quantity for each part of SP (ie seal capacity, seal thickness, areal extent and seal integrity) shown in Table 6-3 are defined in Chapter 3.7. An example seal potential evaluation workflow is outlined for the Lower Vulcan Formation sections Chapter 6.1.1.1 to Chapter 6.1.1.5.

SP of the Upper Vulcan Formation (Figure 6-3) is based on cuttings and sidewall core descriptions, interpreted well logs, a restricted data set of seal capacity measurement and mean BRI data. The SP values shown in the 'Seal Potential + BRI' column of Table 6-3 were plotted at each well location and hand contoured to generate Figure 6-3.

| Well Name | Seal Capacity | | Seal Thickness | | Areal Extent | | Seal Potential | Seal Integrity | | | Seal Potential + BRI |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Geological Factor | Data Factor | Geological Factor | Data Factor | Geological Factor | Data Factor | | Mean BRI | Geological Factor | Data Factor | |
| Allaru 1 | G | M | VG | EN | VG | EN | 0.48 | - | B | P | 0.27 |
| Champagny 1 | G | M | VG | PL | G | PL | 0.47 | - | G | P | 0.26 |
| Conway 1 | B | EN | VB | M | G | EN | 0.05 | 3.76 | G | M | 0.03 |
| Douglas 1 | VG | M | G | EN | G | M | 0.32 | 4.28 | B | M | 0.12 |
| East Swan 2 | E | M | G | M | G | M | 0.2 | 2.64 | G | M | 0.12 |
| Eclipse 1 | E | M | G | M | G | M | 0.2 | 2.36 | G | M | 0.12 |
| Eclipse 2 | E | M | G | M | G | M | 0.2 | 2.55 | G | M | 0.12 |
| Fagin 1 | G | EN | VG | EN | VG | EN | 0.53 | 3.01 | G | M | 0.33 |
| Halycon 1 | B | PL | VG | EN | B | PL | 0.05 | - | E | P | 0.03 |
| Maple 1 | G | M | VG | EN | VG | PL | 0.55 | 2.49 | G | M | 0.34 |
| Maret 1 | B | M | VG | EN | G | PL | 0.25 | 2.86 | G | M | 0.15 |
| Octavius 1 | G | M | VG | EN | G | M | 0.34 | 4.64 | B | M | 0.13 |
| Octavius 2 | G | M | VG | EN | G | M | 0.34 | 4.66 | B | M | 0.13 |
| Oliver 1 | G | PL | VG | EN | VG | EN | 0.57 | - | G | P | 0.32 |
| Paqualin 1 | G | M | VG | EN | VG | PL | 0.55 | 2.15 | G | M | 0.34 |
| Rainer 1 | B | PL | B | PL | B | PL | 0.02 | - | E | P | 0.01 |
| Swan 1 | VG | EN | VG | PL | VG | PL | 0.88 | 3.04 | G | M | 0.55 |
| Vulcan 1b | VG | EN | VG | PL | VG | PL | 0.88 | 2.31 | G | M | 0.55 |

Expression of geological factor existence: VG:very good, G:good, E:even, B:bad, VB:very bad

Quantity & quality of information: PL:plentiful, EN:enough, M:moderate, P:poor, VP:very poor

Table 6-3: Seal potential values assessed for the Upper Vulcan Formation. Wells with a low seal potential are highlighted in red.

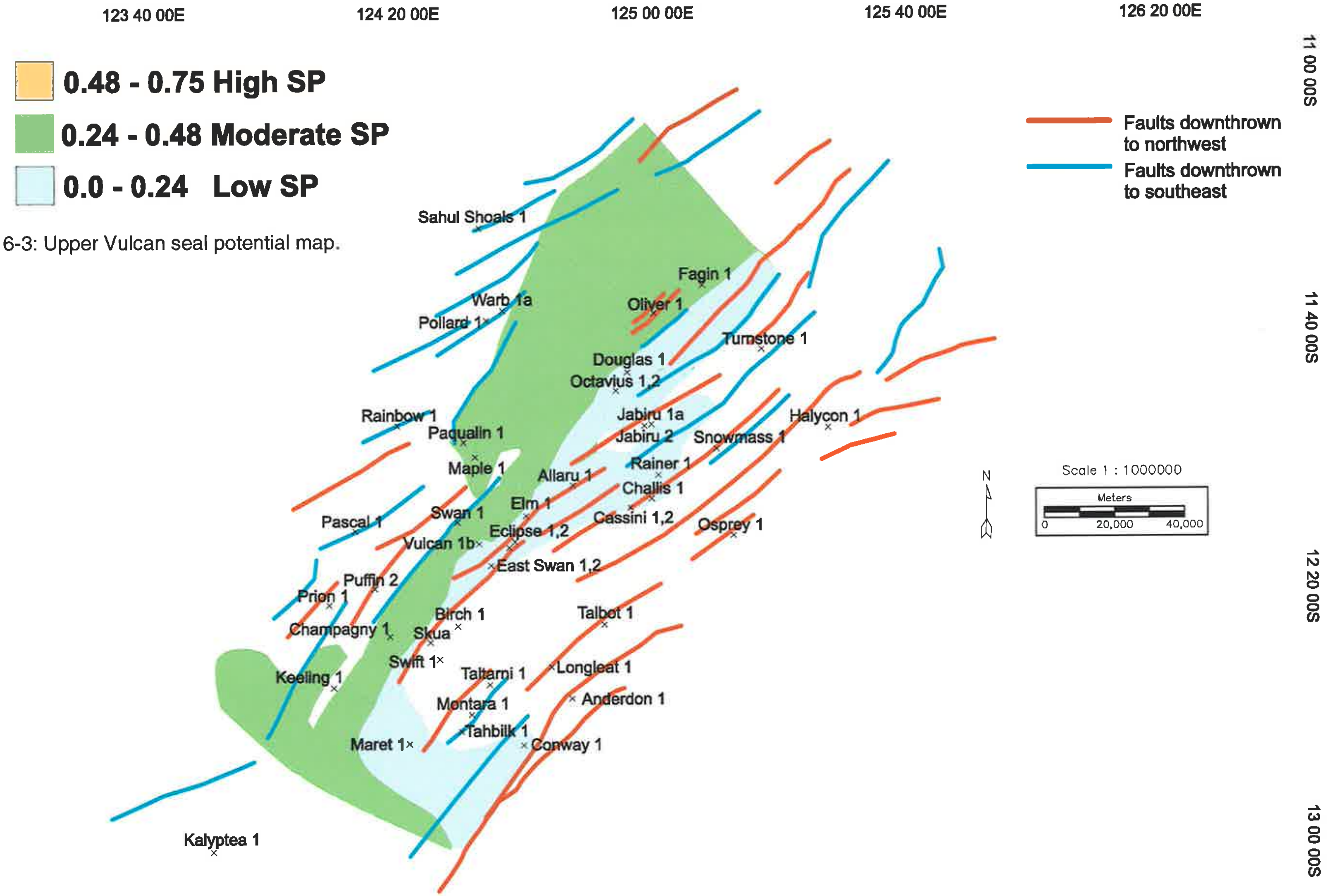



Figure 6-3: Upper Vulcan seal potential map.

### 6.2.2 Analysis and Discussion

Mean BRI values for the Upper Vulcan Formation range from 2 to 5 (Table 6-3). Seal integrity is "good" for the majority of this formation. Seals above turbidite channel sands (e.g. Octavius 1), which contain interbedded siltstones and claystones, have a 'bad' seal integrity (BRI > 4) and low SP.

The data quality and quantity available to estimate seal capacity, lateral extent and seal integrity are "moderate" (Table 3-5). For these rocks the existing well and seismic data are insufficient to provide confidence of existence of geological factor. Largely due to poor data quality and quantity, the SP for the Upper Vulcan Formation is "moderate" (0.24-0.48).

"Moderate" SP (0.24-0.48) occurs within the major depocentres where the Upper Vulcan Formation consists of thick (>200m) restricted marine claystones. As discussed in Chapter 4.4.2.2, the Lower Vulcan Formation is thick, regionally extensive and has high seal capacities (Chapter 5.1.2) within the major depocenters.

"Low" SP (0.0-0.24) occurs along the Jabiru Terrace, where the seal was either eroded or not deposited. Low SP also typifies submarine channel fans depositied near the Cartier Trough and Jabiru Terrace boundary (Octavius, Fagin and Rainier wells in Table 6-3).

The Upper Vulcan Formation is restricted to the major depocentres and contains both the seal and reservoir rocks for submarine fan plays in the Vulcan Sub-Basin. The SP results suggest that the Upper Vulcan Formation is capable of retaining large hydrocarbon columns. However, where submarine fan channel sands are present, the overlying seals contain a greater coarse clastic component resulting in lower seal capacity, more restricted areal extent and lower seal integrity than predominantly claystone intervals.

## 6.3 Echuca Shoals

SP results for the Echuca Shoals Formation are presented in Table 6-4. Wells with a "low" SP are shown red and the factors contributing to a "low" SP are in bold type.

Definitions used to assess the geological factor and the data quality and quantity for each part of SP (i.e. seal capacity, seal thickness, areal extent and seal integrity) shown in Table 6-4 are defined in Chapter 3.7. An example seal potential evaluation workflow is outlined for the Lower Vulcan Formation sections Chapter 6.1.1.1 to Chapter 6.1.1.5.

SP values for the Echuca Shoals Formation are presented in Figure 6-4. Seal capacities, hydrocarbon columns and paleo-oil columns, for which the Echuca Shoals Formation acted as a top seal, are also shown in Figure 6-4. SP for this interval is assessed based on numerous seal capacity measurements, regionally mapped isochron thickness and well data. The SP values shown in the 'Seal Potential + BRI' column of Table 6-4 were plotted at each well location and hand contoured to generate Figure 6-4.

| Well Name | Seal Capacity | | Seal Thickness | | Areal Extent | | Seal Potential | Seal Integrity | | | Seal Potential + BRI |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Geological Factor | Data Factor | Geological Factor | Data Factor | Geological Factor | Data Factor | | Mean BRI | Geological Factor | Data Factor | |
| Allaru 1 | VG | PL | B | PL | VG | P | 0.16 | - | VG | P | 0.1 |
| Brown Gannet 1 | VG | M | B | M | G | M | 0.18 | 1.31 | VG | M | 0.13 |
| Cassini 1 | VG | EN | B | EN | VG | PL | 0.27 | 1.55 | VG | M | 0.21 |
| Cassini 2 | VG | EN | B | EN | VG | PL | 0.27 | 1.44 | VG | M | 0.21 |
| Challis 1 | VG | PL | B | PL | VG | PL | 0.25 | 1.55 | VG | M | 0.19 |
| Champagny 1 | VG | EN | VG | PL | VG | PL | 0.88 | - | G | P | 0.49 |
| Conway 1 | VG | EN | VG | EN | G | EN | 0.53 | 1.59 | VG | M | 0.4 |
| Douglas 1 | VG | PL | B | P | VG | PL | 0.44 | 1.17 | VG | M | 0.33 |
| East Swan 1 | VG | PL | VG | EN | VG | EN | 0.77 | 1.06 | VG | M | 0.57 |
| East Swan 2 | VG | EN | VG | M | VG | PL | 0.66 | 1.62 | VG | M | 0.49 |
| Eclipse 1 | VG | PL | VG | EN | VG | PL | 0.88 | 1.53 | VG | M | 0.66 |
| Eclipse 2 | VG | EN | VG | EN | VG | PL | 0.77 | 1.49 | VG | M | 0.57 |
| Fagin 1 | VG | EN | VG | EN | VG | PL | 0.77 | 1.25 | VG | M | 0.57 |
| Halycon 1 | G | EN | VG | M | VG | M | 0.39 | 1.06 | VG | M | 0.29 |
| Keeling 1 | VG | EN | G | PL | VG | PL | 0.66 | 1.2 | VG | M | 0.49 |
| Maple 1 | VG | EN | G | P | VG | P | 0.31 | 1.49 | VG | M | 0.23 |
| Maret 1 | VG | EN | G | PL | VG | PL | 0.66 | 1.35 | VG | M | 0.49 |
| Medusa 1 | VG | EN | G | P | G | P | 0.28 | 2.37 | G | M | 0.17 |
| Octavius 1 | VG | PL | VG | EN | VG | PL | 0.88 | 1.29 | VG | M | 0.66 |
| Octavius 2 | VG | EN | VG | EN | VG | PL | 0.77 | 1.47 | VG | M | 0.57 |
| Oliver 1 | VG | EN | VG | EN | VG | PL | 0.77 | - | VG | P | 0.48 |
| Paqualin 1 | VG | EN | G | EN | VG | EN | 0.57 | - | VG | M | 0.43 |
| Pascal 1 | VG | PL | G | P | G | P | 0.32 | 1.59 | G | M | 0.2 |
| Pollard 1 | VG | EN | G | M | G | P | 0.31 | - | G | P | 0.17 |
| Prion 1 | VG | M | G | P | G | P | 0.24 | 2.49 | G | M | 0.15 |
| Rainbow 1 | VG | EN | G | P | G | P | 0.28 | 1.77 | VG | M | 0.21 |
| Rainer 1 | VG | PL | G | P | G | P | 0.32 | 1.54 | VG | M | 0.24 |
| Rowan 1 | B | PL | VG | EN | B | M | 0.08 | 3.1 | G | M | 0.05 |
| Skua 1 | G | PL | VG | M | B | PL | 0.14 | 2.62 | G | M | 0.09 |
| Snowmass 1 | VG | EN | G | P | G | P | 0.28 | 1.38 | VG | M | 0.21 |
| Talbot 1 | VG | EN | B | M | G | M | 0.21 | 1.7 | VG | M | 0.15 |
| Turnstone 1 | VG | EN | G | P | G | P | 0.28 | 1.72 | VG | M | 0.21 |
| Vulcan 1b | VG | PL | G | P | G | P | 0.32 | 2.77 | G | M | 0.2 |
| Warb 1a | VG | PL | G | P | G | P | 0.32 | 2.17 | G | M | 0.2 |
| Woodbine 1 | VG | EN | VG | M | VG | PL | 0.66 | 1.51 | VG | M | 0.49 |

| Expression of geological factor existence | | Quantity & quality of information | |
|---|---|---|---|
| | VG:very good | | PL:plentiful |
| | G:good | | EN:enough |
| | E:even | | M:moderate |
| | B:bad | | P:poor |
| | VB:very bad | | VP:very poor |

Table 6-4: Seal potential values assessed for the Echuca Shoals Formation

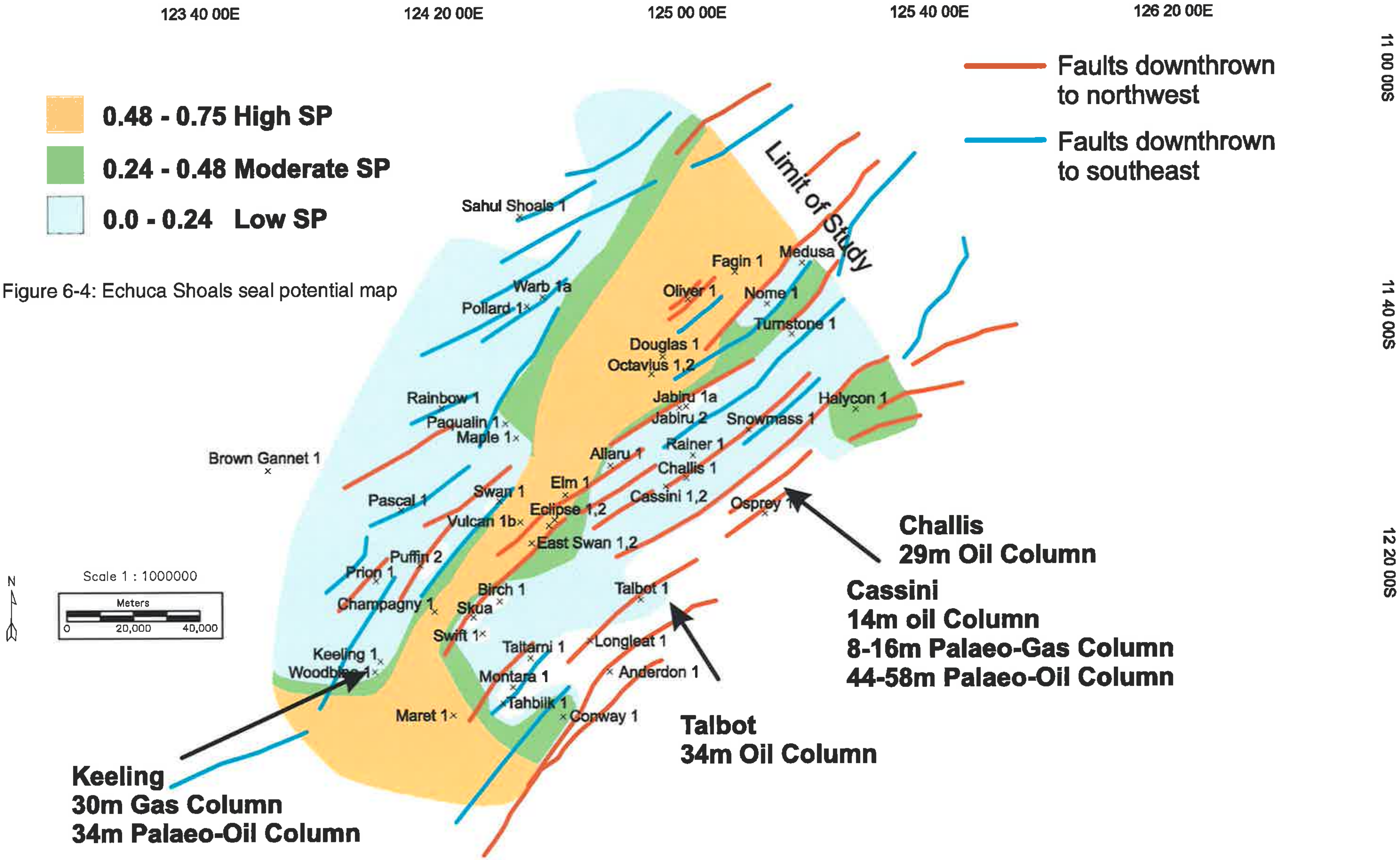



Figure 6-4: Echuca Shoals seal potential map

### 6.3.1 Analysis and Discussion

Mean BRI values for the Echuca Shoals Formation (Table 6-4) are generally less than 2, indicating ductile lithologies and high seal integrity. The rock properties analyses for this interval are summarised in section 5.1.3, where measured seal capacities to oil range between 300 and 600m. Scanning electron microscope images and capillary pressure results (section 5.1.3) show compaction-aligned claystones with poorly interconnected pore networks that result in the very high seal capacities.

A regional distribution map composed of an isochron thickness and regional log signature map of the Echuca Shoals Formation is shown in Figure 4-35. This interval is thin to absent over palaeo-high areas such as the Skua, Jabiru and Puffin Horsts, the Montara Terrace and much of the Londonderry High. The thickness of the Echuca Shoals ranges from less than 10m along parts of the Ashmore Platform and Londonderry High to more than 50m in the Cartier Trough, which is a major depocentre. Based mainly on biostratigraphic correlation and well logs, a thin Echuca Shoals sequence is interpreted to extend over the majority of the Ashmore Platform as a veneer overlying the Valanginian Unconformity (Figure 4-35).

The high seal capacity, thick section, areal extent and high seal integrity of the Echuca Shoals in the Vulcan Sub-Basin depo-centres result in a “high” SP (0.48-0.75). The thickness of the Echuca Shoals Formation was influenced by palaeo-topography. Consequently a “moderate” SP (0.24-0.48) is evaluated along the Swan Graben and Cartier Trough margins because, as the Echuca Shoals Formation thins, the seal thickness and areal extent decreases.

The Ashmore Platform, Jabiru Terrace and Montara Terrace have “low” SP (0.0-0.24. Measured seal capacities in these areas are “high”. However the seal thickness is less than 10 metres on the Ashmore Platform and on palaeo-high horst blocks in the Jabiru Terrace area, resulting in increased risk of a breached Echuca Shoals Formation. SP results in Table 6-4, with the exception of Rowan 1 and Skua 1, indicate that the thickness of the Echuca Shoals formation is the main contributing factor to a low SP and hence is the main risk to an effective top seal.

A case in point is the SP evaluation for Challis 1, which intersected a 29m oil column sealed by a thin Echuca Shoals Formation. A seal capacity of over 400m was measured for this interval. However, fault throws of over 10m have been mapped on top of the Challis structure (Gorman, 1990) resulting in a high probability (high risk) of fault offset of the Echuca Shoals Formation seal. Thus, the seal thickness component was assessed as “bad”, resulting in the SP in Challis 1 being “low”. A similar situation occurs in the Cassini Field where Lisk et al, (1998) interpreted a 64m palaeo-hydrocarbon column. The Echuca Shoals Formation in Cassini 1 is 10m thick and is interpreted as a condensed section made up of predominantly glauconitic claystone. The Echuca Shoals interval over the Cassini Field is similar to the interval in Challis 1 which have seal capacities of over 400m. Fault offset in the top seal has been interpreted on Base Cretaceous structure by Gorman (1990). Based on this interpretation, the seal thickness component is “bad”, making the SP in Cassini 1 “low”. SP is also “low” for the thin Echuca Shoals Formation (~8m) in Talbot 1, which intersected a 34m oil column. The seal thickness component here is “bad” with a “moderate” value for data quality and quantity.

Even though the Echuca Shoals is very thin and does not cover palaeo-high areas, it is the lower-most interval with consistently high seal capacities to extend over the majority of the Vulcan Sub-Basin. The Echuca Shoals Formation is predominantly a condensed section, which is in parts glauconitic and in parts a slightly calcareous claystone with poor pore interconnectivity. Excellent seal capacities (300m to over 1400m) occur in the formation. The seal thickness component of SP is the main risk to an effective seal. The top seals in Challis 1, Cassini 1 and Talbot 1 all have “low” SP mainly due to the seal thickness and in each of these traps the top seal to the structure is dependant on the overlying formations.

From a prospect evaluation perspective the Echuca Shoals Formation is one of the best seals in the Vulcan Sub-Basin where it exists in sufficient thickness to be mapped with confidence over a structure. If the seal thickness and areal extent risk can be proven to be an insignificant component of seal potential then low risk of failure can be assigned to the top seal component when evaluation a prospect.

## 6.4 Jamieson Formation

SP results for the Jamieson Formation are presented in Table 6-5. Wells with a “low” SP are in red and the factors contributing to the “low” SP are highlighted in bold.

Definitions used to assess the geological factor and the data quality and quantity for each part of SP (ie seal capacity, seal thickness, areal extent and seal integrity) shown in Table 6-5 are defined in Chapter 3.7. An example, seal potential evaluation workflow is outlined for the Lower Vulcan Formation in Chapter 6.1.1.1 to Chapter 6.1.1.5.

The SP for the Jamieson Formation is presented in Figure 6-5. Seal capacities, hydrocarbon columns and palaeo-oil columns sealed by the Jamieson Formation are also shown in Figure 6-5. SP for this interval is assessed based on numerous seal capacity measurements, regionally mapped isochron thickness and well data. The SP values shown in the ‘Seal Potential + BRI’ column of Table 6-5 were plotted at each well location and hand contoured to generate Figure 6-5.

| Well Name | Seal Capacity | | Seal Thickness | | Areal Extent | | Seal Potential | Seal Integrity | | | Seal Potential + BRI |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Geological Factor | Data Factor | Geological Factor | Data Factor | Geological Factor | Data Factor | | Mean BRI | Geological Factor | Data Factor | |
| Allaru 1 | VG | EN | G | PL | VG | PL | 0.77 | - | VG | P | 0.41 |
| Brown Gannet 1 | VG | PL | VG | M | VG | PL | 0.75 | 4.49 | B | M | 0.28 |
| Cassini 1 | VG | EN | G | PL | VG | PL | 0.66 | 1.27 | VG | M | 0.49 |
| Cassini 2 | VG | EN | VG | EN | VG | PL | 0.77 | 1.39 | VG | M | 0.57 |
| Challis 1 | VG | PL | VG | PL | VG | PL | 1 | 1.28 | VG | M | 0.75 |
| Champagny 1 | VG | EN | VG | PL | VG | PL | 0.88 | - | VG | P | 0.55 |
| Conway 1 | VG | EN | VG | PL | VG | PL | 0.88 | 1.81 | VG | M | 0.66 |
| Douglas 1 | VG | PL | VG | M | VG | PL | 0.75 | 1.4 | VG | M | 0.56 |
| East Swan 1 | VG | EN | VG | EN | VG | PL | 0.77 | 1.71 | VG | M | 0.57 |
| East Swan 2 | VG | EN | VG | EN | VG | PL | 0.77 | 1.78 | VG | M | 0.57 |
| Eclipse 1 | VG | EN | VG | EN | VG | PL | 0.77 | 1.45 | VG | M | 0.57 |
| Eclipse 2 | VG | EN | VG | EN | VG | PL | 0.77 | 1.35 | VG | M | 0.57 |
| Fagin 1 | VG | EN | VG | PL | VG | PL | 0.88 | 1.59 | VG | M | 0.66 |
| Halycon 1 | VG | EN | VG | PL | VG | PL | 0.88 | - | VG | P | 0.55 |
| Jabiru 1a | VG | PL | VG | PL | VG | PL | 1 | 2.14 | G | M | 0.63 |
| Jabiru 2 | VG | PL | VG | PL | VG | PL | 1 | 2.33 | G | M | 0.63 |
| Keeling 1 | VG | EN | VG | PL | VG | PL | 0.88 | 1.56 | VG | M | 0.66 |
| Longleat 1 | VG | EN | G | M | G | M | 0.34 | - | G | P | 0.19 |
| Maple 1 | VG | EN | VG | M | VG | PL | 0.66 | 3.16 | G | M | 0.41 |
| Maret 1 | VG | EN | VG | PL | VG | PL | 0.88 | 1.73 | VG | M | 0.66 |
| Medusa 1 | VG | EN | VG | PL | VG | PL | 0.88 | 1.61 | VG | M | 0.66 |
| Montara 1 | VG | EN | VG | EN | VG | PL | 0.77 | - | VG | P | 0.48 |
| Octavius 1 | VG | EN | VG | PL | VG | PL | 0.88 | 1.48 | VG | M | 0.66 |
| Octavius 2 | VG | EN | VG | PL | VG | PL | 0.88 | 1.53 | VG | M | 0.66 |
| Oliver 1 | VG | EN | VG | PL | VG | PL | 0.88 | - | VG | P | 0.55 |
| Osprey 1 | VG | PL | VG | EN | VG | PL | 0.88 | 1.04 | VG | M | 0.66 |
| Paqualin 1 | VG | EN | VG | M | VG | PL | 0.66 | 3.44 | G | M | 0.41 |
| Pascal 1 | VG | PL | G | PL | VG | EN | 0.66 | 2.94 | G | M | 0.41 |
| Prion 1 | VG | EN | VG | PL | VG | EN | 0.77 | 3.24 | G | M | 0.48 |
| Puffin 1 | G | M | G | M | G | M | 0.24 | - | G | P | 0.14 |
| Puffin 2 | VG | EN | B | M | G | M | 0.21 | 3.81 | G | M | 0.13 |
| Rainbow 1 | VG | EN | G | PL | VG | PL | 0.66 | 3.09 | G | M | 0.41 |
| Rainer 1 | VG | PL | VG | PL | VG | PL | 1 | 1.38 | VG | M | 0.75 |
| Rowan 1 | VG | PL | VG | EN | VG | EN | 0.77 | 1.89 | VG | M | 0.57 |
| Sahul Shoals 1 | VG | PL | G | M | VG | PL | 0.63 | 2.31 | G | M | 0.39 |
| Skua 1 | VG | PL | VG | M | B | PL | 0.19 | 2.87 | G | M | 0.12 |
| Skua 6 | VG | PL | VG | M | B | PL | 0.19 | 3.04 | G | M | 0.12 |
| Snowmass 1 | VG | EN | VG | PL | VG | PL | 0.88 | 1.21 | VG | M | 0.66 |
| Swan 1 | VG | EN | VG | PL | VG | EN | 0.77 | 1.72 | VG | M | 0.57 |
| Swift 1 | VG | PL | G | EN | VG | PL | 0.88 | 2.29 | G | M | 0.47 |
| Tahbilk 1 | VG | EN | VG | PL | VG | PL | 0.88 | 1.36 | VG | M | 0.66 |
| Talbot 1 | VG | EN | G | M | VG | PL | 0.55 | 1.59 | VG | M | 0.41 |
| Taltarni 1 | VG | EN | VG | M | VG | PL | 0.66 | 2.03 | G | M | 0.41 |
| Turnstone 1 | VG | EN | VG | PL | VG | PL | 0.88 | 1.68 | VG | M | 0.66 |
| Vulcan 1b | VG | EN | VG | EN | VG | PL | 0.77 | 1.2 | VG | M | 0.57 |
| Woodbine 1 | VG | EN | VG | PL | VG | PL | 0.88 | 1.69 | VG | M | 0.66 |

Expression of geological factor existence: VG:very good; G:good; E:even; B:bad; VB:very bad

Quantity & quality of information: PL:plentiful; EN:enough; M:moderate; P:poor; VP:very poor

Table 6-5: Seal potential values assessed for the Jamieson Formation.

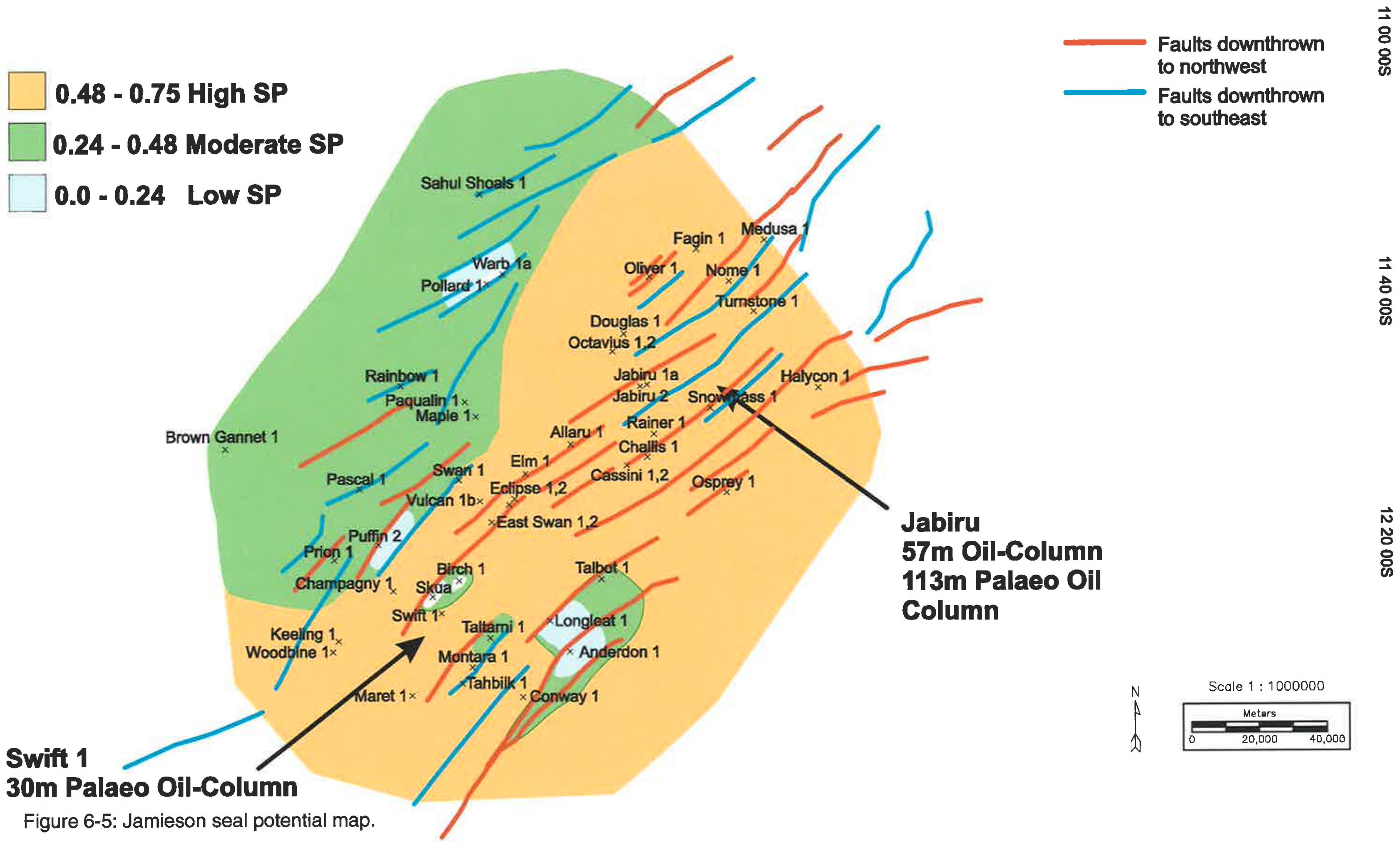


Figure 6-5: Jamieson seal potential map.

Mean BRI values for the Jamieson Formation are less than 2 in the Vulcan Sub-Basin and along the Londonderry High. This indicates that the rocks are ductile and have 'very good' seal integrity. Over the Ashmore Platform, however, mean BRI values vary between 3.5 and 4, resulting in a 'good' seal integrity value.

A regional thickness map of the Jamieson Formation is presented in Figure 4-37. This interval ranges in thickness from over 300m along the northeastern Londonderry High and in the northern Browse Basin, to between 20 and 40m on the Ashmore Platform. Within the Vulcan Sub-Basin, this unit thins over the many palaeo-highs, such as the Jabiru, Challis and Puffin horst, and is absent over the Skua horst. The Jamieson Formation is more than 100m thick within the major depocenters such the Swan Graben and the early Cartier Trough. Bathyal dark gray to black claystones are typical lithofacies within this unit. However, in many deeper parts of the sub-basin, a thin radiolarian siltstone occurs at the base of this interval. The radiolarite is generally less than 10m thick in the study area and is included with the overlying claystones in the SP analysis for the Jamieson Formation.

The Jamieson Formation seal rocks are summarised in Section 5.1.4. Seal capacities measured for claystones and calcareous claystones of the Jamieson Formation range from 100m to over 1000m oil column. As discussed in Section 5.1.4, the variation in seal capacity in the Jamieson Formation is dependant on the amount of calcite present in the analysed sample. The lithology of the Jamieson Formation ranges from claystone to calcareous claystone to marl. As the amount of calcite increases, the seal capacity decreases. In this formation, the presence of rhombic calcite crystals has increased the pore network interconnectivity, thereby reducing the seal capacity.

A "high" SP (0.48-0.75) is interpreted for the Jamieson Formation over the majority of the Vulcan Sub-Basin (Figure 6-5) and the Londonderry High, where the formation is thick, areally extensive and has high seal capacities.

A "moderate" SP (0.24-0.48) was assessed on the Ashmore Platform, where the Jamieson Formation is predominantly composed of calcareous claystones. This interval has 'very good' measured seal capacites and is areally extensive. However, it is thinner in this area and has lower mean BRI values (columns highlighted in blue in Table 6-5) seal integrity than in the Vulcan Sub-Basin and Londonderry High.

"Low" SP (0.0-0.24) occurs over several palaeo-high horst blocks (Puffin, Skua, Taltarni and Longleat/Anderdon wells in Figure 6-5), where the Jamieson Formation thins significantly.

The Jamieson Formation is the seal for a 113m palaeo-oil column below a 57m live oil column in Jabiru 1a (Figure 6-5). SP for the Jamieson Formation in Jabiru 1a is high with "very good" seal capacity of over 600m. The seal is also thick (50m), areally extensive and has "good" seal integrity. A 30m palaeo-oil column was encountered in Swift 1. The overlying Jamieson Formation seal is 28m thick and is composed of shales and calcareous claystones. SP for the Jamieson Formation in Swift 1 is high with seal capacity and areal extent estimated to be "very good" with a "good" seal thickness and seal integrity. The "high" SP interpreted for Jabiru 1a and Swift 1 suggest that the palaeo-column encountered in these wells did not form due to leakage from top seal failure. Thus, hydrocarbon leakage must have occurred due to some other cause.

“High” SP is interpreted in the Jamieson and underlying Echuca Shoals Formations that form the top seal for the Challis and Keeling hydrocarbon accumulations and the Cassini palaeo-oil column. A “high” SP suggests that any hydrocarbon loss from these traps did not occur through top seal leakage. The Jamieson Formation is extensive and has a “high” SP over the Jabiru Terrace, Swan Graben, Cartier Trough and the majority of the Londonderry High. The absence of the unit on top of horst structures in the southwestern Vulcan Sub-Basin indicates that palaeo-high areas influenced deposition and contributed to the “low” SP areas of this unit. The “moderate” SP on the Ashmore Platform is due to a higher mean BRI for the more calcareous sediments in this distal area. High BRI results in low seal integrity and hence lower SP.

As with the Echuca Shoals Formation discussed in the previous section, where the Jamieson Formation can be proven to exist on top structure, the top risk of top seal failure is low as the risks diminishing seal potential are predominantly lack of seal thickness or lack or areal extent on top of structures.

## 6.5 Woolaston/Gibson/Fenelon

SP results for the WGF Formation are presented in Table 6-6. Wells with a low SP are shown red and the factors contributing to a low SP are highlighted in bold.

The SP for the WGF Formation is presented in Figure 6.6. Seal capacities, hydrocarbon columns and paleo-oil columns, in reservoirs for which the WGF Formation is the top seal, are also shown in Figure 6.6. SP for this interval is assessed based on numerous seal capacity measurements, regionally mapped isochron thickness and well data. The SP values shown in the 'Seal Potential + BRI' column of Table 6-6 were plotted at each well location and hand contoured to generate Figure 6.6.

| Well Name | Seal Capacity | | Seal Thickness | | Areal Extent | | Seal Potential | Seal Integrity | | | Seal Potential + BRI |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Geological Factor | Data Factor | Geological Factor | Data Factor | Geological Factor | Data Factor | | Mean BRI | Geological Factor | Data Factor | |
| Allaru 1 | VG | EN | VG | PL | VG | PL | 0.88 | - | G | P | 0.49 |
| Anderdon 1 | VG | PL | VG | PL | VG | PL | 1 | - | G | P | 0.56 |
| Birch 1 | VG | EN | VG | PL | VG | PL | 0.88 | 4.51 | B | M | 0.33 |
| Brown Gannet 1 | VG | PL | VG | M | VG | PL | 0.75 | 8.03 | VB | M | 0.19 |
| Cassini 1 | VG | EN | VG | PL | VG | PL | 0.88 | 3.21 | G | M | 0.55 |
| Cassini 2 | VG | EN | VG | PL | VG | PL | 0.88 | 3.56 | G | M | 0.55 |
| Challis 1 | VG | PL | VG | PL | VG | PL | 1 | 3.19 | G | M | 0.63 |
| Champagny 1 | VG | EN | VG | PL | VG | PL | 0.88 | 5.65 | B | M | 0.33 |
| Conway 1 | VG | EN | VG | PL | VG | PL | 0.88 | 3.17 | G | M | 0.55 |
| Douglas 1 | VG | EN | VG | EN | VG | PL | 0.77 | - | G | P | 0.43 |
| East Swan 1 | VG | EN | VG | PL | VG | PL | 0.88 | 4.37 | B | M | 0.33 |
| East Swan 2 | VG | EN | VG | PL | VG | PL | 0.88 | 4.49 | B | M | 0.33 |
| Eclipse 1 | VG | EN | VG | PL | VG | PL | 0.88 | 5.44 | B | P | 0.38 |
| Eclipse 2 | VG | EN | VG | PL | VG | PL | 0.88 | 4.03 | B | M | 0.33 |
| Fagin 1 | VG | EN | VG | EN | VG | PL | 0.77 | 3.98 | G | M | 0.48 |
| Halycon 1 | VG | EN | VG | EN | VG | PL | 0.77 | 2.71 | G | M | 0.48 |
| Jabiru 1a | VG | PL | VG | PL | VG | PL | 1 | 2.88 | G | M | 0.63 |
| Jabiru 2 | VG | PL | VG | PL | VG | PL | 1 | 3.15 | G | M | 0.63 |
| Keeling 1 | VG | EN | VG | PL | VG | PL | 0.88 | 5.68 | B | M | 0.33 |
| Longleat 1 | VG | EN | VG | PL | VG | PL | 0.88 | - | G | P | 0.49 |
| Maple 1 | VG | EN | VG | EN | VG | PL | 0.77 | 5.75 | B | M | 0.29 |
| Maret 1 | VG | EN | VG | PL | VG | PL | 0.88 | 3.57 | G | M | 0.55 |
| Medusa 1 | VG | EN | VG | EN | VG | PL | 0.77 | 2.89 | G | M | 0.48 |
| Montara 1 | VG | EN | VG | PL | VG | PL | 0.88 | - | B | P | 0.38 |
| Octavius 1 | VG | EN | VG | PL | VG | PL | 0.88 | 3.28 | G | M | 0.55 |
| Octavius 2 | VG | EN | VG | PL | VG | PL | 0.88 | 3.72 | G | M | 0.55 |
| Oliver 1 | VG | EN | VG | EN | VG | PL | 0.77 | - | G | P | 0.43 |
| Osprey 1 | VG | EN | VG | EN | VG | PL | 0.77 | 2.37 | G | M | 0.48 |
| Paqualin 1 | VG | EN | VG | EN | VG | PL | 0.77 | 5.39 | B | M | 0.29 |
| Pascal 1 | VG | PL | VG | EN | VG | PL | 0.88 | 6.53 | VB | M | 0.22 |
| Pollard 1 | VG | PL | VG | M | VG | PL | 0.75 | 5.18 | B | M | 0.28 |
| Prion 1 | VG | EN | VG | PL | VG | PL | 0.88 | - | VB | M | 0.22 |
| Puffin 1 | VG | EN | G | PL | VG | PL | 0.66 | - | VB | P | 0.25 |
| Puffin 2 | VG | EN | G | PL | VG | PL | 0.66 | 7.47 | VB | M | 0.16 |
| Rainbow 1 | VG | EN | G | PL | VG | PL | 0.66 | 6.18 | VB | M | 0.16 |
| Rainer 1 | VG | PL | VG | PL | VG | PL | 1 | 3.48 | G | M | 0.63 |
| Rowan 1 | VG | EN | VG | PL | VG | PL | 0.88 | 5.04 | B | M | 0.33 |
| Sahul Shoals 1 | VG | PL | VG | EN | VG | PL | 0.88 | 6.21 | VB | M | 0.22 |
| Skua 1 | VG | PL | G | PL | VG | PL | 0.75 | 5.57 | B | M | 0.28 |
| Skua 3 | VG | PL | G | PL | VG | PL | 0.75 | - | B | P | 0.33 |
| Skua 5 | VG | PL | VG | PL | VG | PL | 1 | 5.63 | B | M | 0.38 |
| Skua 6 | VG | PL | G | PL | VG | PL | 0.75 | 6.18 | B | M | 0.19 |
| Skua 8 | VG | PL | G | PL | VG | PL | 0.75 | 6.83 | B | M | 0.19 |
| Skua 9 | VG | PL | G | PL | VG | PL | 0.75 | 5.64 | B | M | 0.28 |
| Snowmass 1 | VG | EN | VG | PL | VG | PL | 0.88 | 2.52 | G | M | 0.55 |
| Swan 1 | VG | EN | VG | PL | VG | PL | 0.88 | 5.73 | B | M | 0.33 |
| Swift 1 | VG | EN | VG | PL | VG | PL | 0.88 | 4.68 | B | M | 0.33 |
| Tahbilk 1 | G | M | VG | PL | VG | PL | 0.63 | - | E | P | 0.31 |
| Talbot 1 | VG | PL | VG | PL | VG | PL | 1 | 2.6 | G | M | 0.63 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Taltarni 1 | VG | EN | VG | PL | VG | PL | 0.88 | 3.23 | G | M | 0.55 |
| Turnstone 1 | VG | EN | VG | EN | VG | PL | 0.77 | 2.6 | G | M | 0.48 |
| Vulcan 1b | VG | EN | G | PL | VG | PL | 0.66 | 3.65 | G | M | 0.41 |
| Warb 1a | VG | PL | VG | M | VG | PL | 0.75 | 5.72 | B | M | 0.28 |
| Woodbine 1 | VG | EN | VG | PL | VG | PL | 0.88 | 5.89 | B | M | 0.33 |

| Expression of geological factor existence | | Quantity & quality of information | |
|---|---|---|---|
| | VG:very good | | PL:plentiful |
| | G:good | | EN:enough |
| | E:even | | M:moderate |
| | B:bad | | P:poor |
| | VB:very bad | | VP:very poor |

Table 6-6: Seal potential values assessed for the Woolaston, Gibson and Fenelon Formations (WGF).

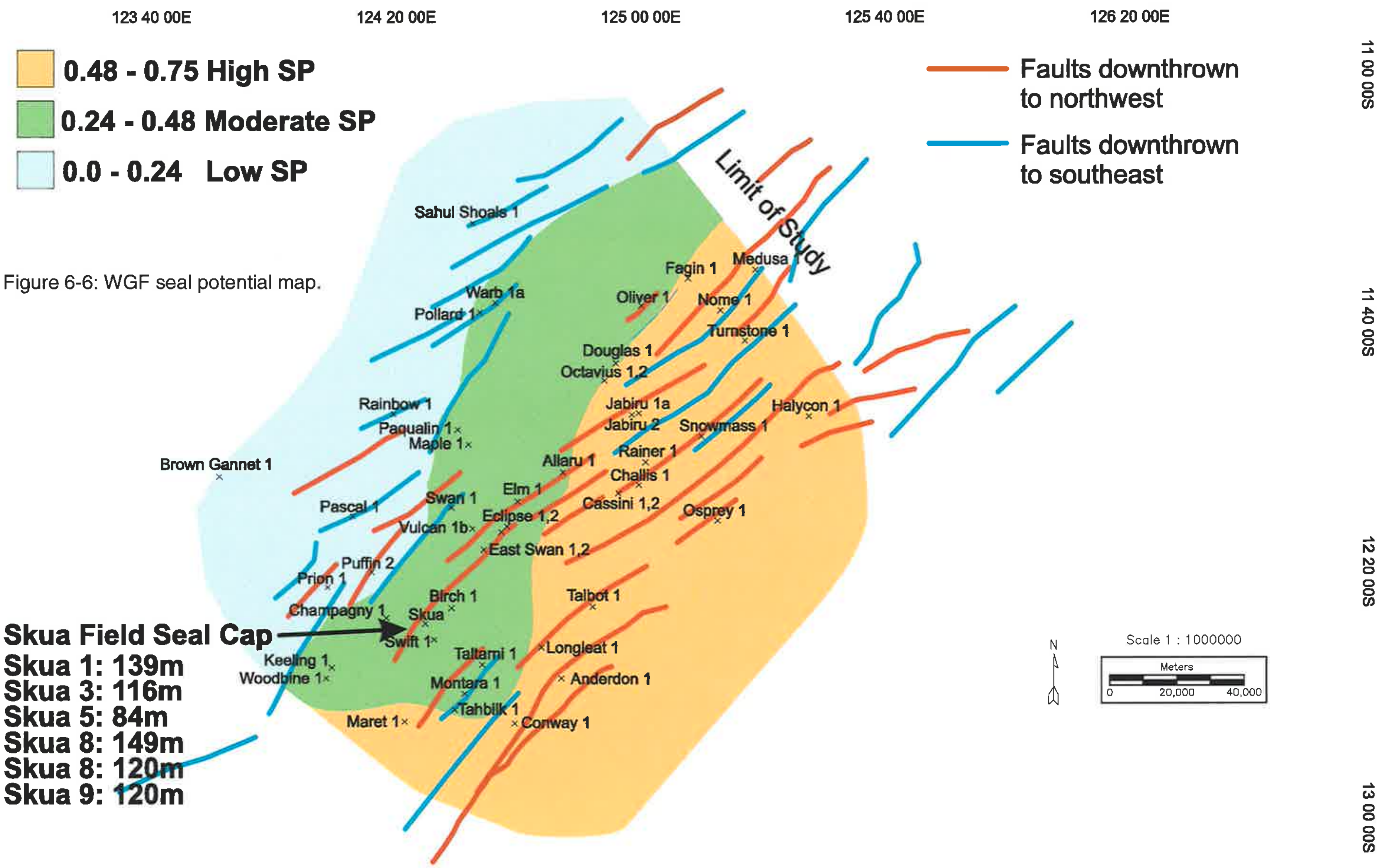



Figure 6-6: WGF seal potential map.

This WGF is the regional seal for the Vulcan Sub-Basin.

The seal rock properties for this interval are presented in Section 5.1.5. Seal capacities range from 79m to over 870m (oil column height). Rocks with lower seal capacities (100 to 200m) are predominantly marls and argillaceous calcilutites, while calcareous claystones, with a lower carbonate content, have higher seal capacities.

A regional thickness isochron and log signature map of the WGF Formation is presented in Section 4.1.1.5, Figure 4-38. The interval has a thickness of 300m along the Londonderry High and decreases to between 30 and 70m on the Ashmore platform. Over 100m of this unit is present in all wells within the Vulcan Sub-Basin, except for the Puffin 1 & 2 wells, on the Puffin Trend, where the thickness is only 35m. The increase in WGF thickness from the southeast to the northwest is not controlled by the location of main depocentres in the sub-basin, indicating that palaeo topography had minimal influence on deposition of this interval.

An SP fairway map for WGF Formation is presented in Figure 6.6. “High” SP (0.48-0.75) is interpreted on the Londonderry High, Jabiru Terrace and the Northern Browse Basin. “Moderate” SP (0.24-0.48) occurs in the Cartier Trough, Swan Graben and on the Montara Terrace. “Low” SP (0.0-0.24) occurs on the Ashmore Platform, where the interval is predominantly a condensed marl facies.

Mean BRI values range from 2 to 7 (Table 6-6) and significantly influence SP values of the WGF. Based only on seal capacity, seal thickness and areal extent, SP would be assessed as “high” for the entire WGF Formation.

However, the seal integrity lowers the SP for this interval over large areas of the Vulcan Sub-Basin.

The SP variation within the WGF across the sub-basin is probably due to the relative amount of calcareous claystone to marl and calcilutite in the section. Where the WGF is thick on the Londonderry High, calcareous claystone forms a significant part of the section. The claystone has a low BRI ("high" seal integrity) and thus "high" SP. On the Ashmore Platform, the WGF is predominantly composed of marl and calcilutite with high BRI values ("low" seal integrity) and, thus, a "low" SP.

Over 100m of WGF form the main seal for the Skua Field. Seal capacities are "very good" (over 116m) and the seal is thick and areally extensive over the Skua Structure. However, high BRI values (5 to 7), result in "bad" seal integrity and degrade the SP from what otherwise would have been "high" to "moderate".

It should be pointed out that mean BRI values used to estimate seal integrity only give an idea of the brittle or ductile nature of seal rocks and do not provide information on whether fluid conducting factures exist in the top seal. Thus, seal rocks with a high mean BRI (low seal integrity) may still be capable of holding hydrocarbon columns.

WGF regional seal rocks are relatively brittle in the Vulcan Sub-Basin and on the Ashmore Platform. Thus, the development of permeability through open fractures in the top seal in these areas is a risk to it being an effective top seal and requires further assessment.

From a prospect evaluation perspective the WGF formation has excellent seal thickness and lateral extent. As presented in Chapter 5.1.5, seal capacities measure for the formation are also greater than the hydrocarbon columns intersected in the Jabiru and Challis accumulations. Thus the real risk lies in the relative brittle nature of the marls and calcareous claystones. The risk of brittle failure would increase if there is evidence of Miocene fault reactivation in the vicinity of the prospect.

# Chapter 7 Conclusions

## 7.1 Introduction

A top seal risk assessment methodology, which has been applied on a regional scale and over various play types, has been developed to provide a quantitative understanding of top seal potential in the Vulcan Sub-Basin.

The study of top seal potential has focussed on top seal capacity, areal extent, thickness and integrity and was undertaken to determine whether top seal failure might be the cause of hydrocarbon leakage in the Vulcan Sub-Basin.

## 7.2 Mercury Intrusion Capillary Pressure

A methodology was determined for estimating and removing conformance from mercury intrusion capillary pressure (MICP) results and thus allowing a consistent determination of threshold pressure (Pth) for samples with different amounts of conformance (ie cuttings and core)

A comparison of MICP results from core, synthetic cuttings (made from core) and real cuttings have shown that the synthetic cuttings provide valid MICP intrusion results. The synthetic cuttings MICP results show similar threshold pressure and more conformance than the core sample results and are used as the basis for a comparison of MICP curves derived from drill cuttings and core.

Where a clear inflection exists on the MICP intrusion curve and where cuttings are representative of sub-surface rocks, the cuttings derived MICP curves provide valid Pd and Pth values.

Cuttings samples can provide valid capillary pressure measurements, often with errors of 10% or less.

## 7.3 Seal Potential

This study has developed a holistic seal risk methodology that can be used to identify specific seal risk factors over the entire Vulcan Sub-Basin. Specifically a seal risk matrix was used to determine the risk associated with each seal potential component. The methodology incorporates a brittleness index (BRI) that quantifies the seal integrity component of seal potential (SP).

In the southeastern Vulcan Sub-Basin, the early Lower Vulcan Formation was deposited as part of a prograding delta system and the seals contain a large siltstone component; therefore the SP is “low”. SP is highest where restricted marine claystone were deposited in the main basin depocentres.

The highest risk in each of the seal potential components was incorporated in determining overall seal potential for the Upper Vulcan Formation. Because of data quality, the highest seal potential in this formation was “moderate” and occurs in the major depocentres of the Vulcan Sub-Basin, where the Upper Vulcan Formation is thick and regionally extensive and has high seal capacities.

Low seal potential occurs in the Upper Vulcan Formation along the structurally higher terraces that border the southeastern margin of the Vulcan Sub-Basin. Here, the formation is mainly composed of sandstones and siltstones. Submarine fan sands were deposited along parts of the terraces; the seal to these sands has a “low” seal potential due to the coarse clastic component in the rock overlying the submarine fan sands.

The Echuca Shoals Formation seal potential is predominantly determined by the thickness and lateral extent of this formation. High seal potential occur in the basin depocenters, where the interval is thickest. Even though the Echuca Shoals Formation is regionally extensive, it is absent over many palaeo-highs resulting in “low” seal potential over the Ashmore Platform and Jabiru and Montara Terraces. Where the Echuca Shoals Formation is thick and has significant lateral extent it has high seal potential.

Seal potential for the Jamieson Formation is controlled by the thickness and the amount of calcite present. It is thin and more calcareous over the Ashmore Platform and around palaeo-high areas within the Vulcan Sub-Basin. Seal potential analysis has highlighted the following as the greatest risks for an effective Jamieson Formation seal: it thins on and around palaeo-high areas within the southeastern Vulcan Sub Basin and is thinner and more calcareous over the Ashmore Platform. An increase in calcareous content of the sediments increases the seal integrity risk.

Seal integrity is the controlling factor on seal potential for the WGF formation. Seal integrity poses the greatest risk on the Ashmore Platform, where the WGF is primarily composed of marl and calcilutite, which have some of the highest brittleness index values and thus have a low seal potential due to the higher risk of open fractures developing in the top seal.

## 7.4 Implications for Hydrocarbon Exploration

This study has identified the main sealing intervals in the Vulcan Sub-Basin, with the main regional seal being a combination of the Echuca Shoals Formation and the overlying Jamieson and WGF formations.

Generally the seal capacity of the cap rocks studied in the Vulcan Sub-Basin is high enough to hold back substantial hydrocarbon columns. For the major seals the greatest risk are: 1) seal thickness for the Echuca Shoals Formation, 2) thickness and seal integrity for the Jamieson Formation and 3) seal integrity for the WGF formations. The brittleness of a seal has been used to estimate the seal integrity component of a seal. Seal brittleness is important in the Vulcan Sub-Basin because of the Neogene reactivation of many faults. There is a higher risk of fracture development in brittle rocks (rocks with a high unconfined compressive strength). Ductile top seals have not been compromised by structural reactivation. For example the Echuca Shoals Formation has a low BRI indicating a relatively low unconfined compressive strength which suggests that it is ductile lithology. In contrast, the Jamieson and WGF formations have high BRI values, which indicate relatively brittle lithologies. Thus these formations are more likely to be compromised by the Neogene structural reactivation.

## 7.5 Recommendation for Future Work

This study empirically tests seal capacity results obtained from cuttings and compares them to seal capacity results obtained from core. Similar comparison of cuttings and core seal capacity should be tested in other sedimentary basins world wide so as to build up a database of different lithologies and geological settings.

This study also shows that seal integrity is critical in evaluating seal potential, especially when combining brittle top seals with fault reactivation in traps. Further studies to detail the impact of rock strength on seal integrity and to determine the methodologies available to determine in-situ seal integrity should be carried out. Such studies would provide a more robust assessment of the seal integrity component of seal potential.

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# Appendix A – Mercury Capillary Pressure, Scanning Electron Microscopy and X-Ray Diffraction Results for All Samples Tested

# Appendix A - Biostrat zones and depositional environment information for Upper and Lower Vulcan Formations

| well_name | biozone name | biozone range | biostrat depth top (m) | biostrat depth base (m) | biozone age from (Ma) | biozone age to (Ma) | age_code | notes on biozone age | depositional enviroment | formation name | formation top (m) | formation base (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Allaru 1 | D.swanense | | 2406 | 2421 | 146 | 150.3 | 525 | | open marine - The microplankton to spore-pollen ratio suggests open marine environments of deposition | Vulcan Lw | 2403 | 2850 |
| Allaru 1 | W.clathrata | | 2424 | 2448 | 150.3 | 153.8 | 525 | | open marine - shallowing downhole - The continued prominence of dinoflagellates suggests open marine conditions although there is a marked downhole increase in the spore-pollen to microplankton ratio suggesting shallowing relative to the overlying section | Vulcan Lw | 2403 | 2850 |
| Allaru 1 | W.spectabilis | | 2451 | 2946 | 153.8 | 158.5 | 425 | | open marine - shelfal - The prominence of microplankton suggests open marine environments of deposition although the increase in the vascular plant debris suggests shelfal influence | Vulcan Lw | 2403 | 2850 |
| East Swan 2 | R.aemula | | 2607 | 2635.5 | 158.5 | 160.3 | 325 | | shelfal marine | Vulcan Lw | 2390 | 2637 |
| Eclipse 1 | W.spectabilis | W.spectabilis Mid | 2332 | 2489.9 | 153.8 | 158.5 | 225 | | marine/shallow marine? - The environment of deposition is clearly marine, although characterised by substantial vascular plant debris. This association has been interpreted previously as shallow marine | Vulcan Lw | 2330 | 2585 |
| Eclipse 1 | W.spectabilis | W.spectabilis Lw | 2555.1 | 2561.3 | 153.8 | 158.5 | 425 | | marine | Vulcan Lw | 2330 | 2585 |
| Eclipse 1 | R.aemula | | 2570.6 | 2570.6 | 158.5 | 160.3 | 425 | | marine | Vulcan Lw | 2330 | 2585 |
| Eclipse 1 | C.cooksoniae | D.complex | 2580 | 2647.5 | 163.5 | 167.5 | 425 | | marginal marine - The absence of dinoflagellates and the pattern of acritarch occurences suggests a marginal marine environment of deposition, possibly with increasing marine influence towards the lower part of the interval | Vulcan Lw | 2330 | 2585 |
| Fagin 1 | W.spectabilis | | 2970 | 3009 | 153.8 | 158.5 | 425 | | shelfal to open marine | Vulcan Lw | 2964 | 3017 |
| Jabiru 2 | W.spectabilis | | 1625 | 1642.5 | 153.8 | 158.5 | 325 | | shelfal marine - environment of deposition is shelfal marine with substantial vascualr plant debris | Vulcan Lw | 1623 | 1667 |
| Maple 1 | O.montgomeryi | | 3069 | 3069 | 143.8 | 145.2 | 525 | | open marine | Vulcan Lw | 3060 | 3682 |
| Maple 1 | D.swanense | | 3087 | 3140 | 146 | 150.3 | 525 | | open marine | Vulcan Lw | 3060 | 3682 |
| Maple 1 | W.clathrata | | 3150 | 3150 | 150.3 | 153.8 | 525 | | open marine | Vulcan Lw | 3060 | 3682 |
| Maple 1 | W.spectabilis | | 3298.5 | 3600 | 153.8 | 158.5 | 425 | | shelfal to open marine | Vulcan Lw | 3060 | 3682 |
| Maple 1 | R.aemula | | 3680 | 3681.9 | 158.5 | 160.3 | 425 | | shelfal to open marine | Vulcan Lw | 3060 | 3682 |
| Montara 1 | W.spectabilis | | 2390 | 2978 | 153.8 | 158.5 | 425 | | shelfal to open marine - The spore-pollen to microplankton ratio, together with the nature and proportion of vascular plant debris suggests shelfal, open-marine environments of deposition | Vulcan Lw | 2389 | 3175 |
| Montara 1 | R.aemula | | 3135 | 3135 | 158.5 | 160.3 | 425 | | shelfal to open marine - The spore-pollen to microplankton ratio, together with the nature and proportion of vascular plant debris suggests shelfal, open-marine environments of deposition | Vulcan Lw | 2389 | 3175 |
| Oliver 1 | W.spectabilis | | 2900 | 2943 | 153.8 | 158.5 | 525 | | open maine - The environment of deposition is interpreted as open marine, the increasing proportion of vascular plant debris suggests a shallowing with depth | Vulcan Lw | 2897 | 2945 |
| Oliver 1 | E.communis | V.stradneri | 2900 | 2900 | | | 400 | lower late Kimmeridgian - Middle Oxfordian | distal neritic | Vulcan Lw | 2897 | 2945 |
| Paqualin 1 | W.clathrata | | 2961 | 3051 | 150.3 | 153.8 | 525 | | open marine | Vulcan Lw | 2935 | 4165 |

## Appendix A - Biostrat zones and depositional environment information for Upper and Lower Vulcan Formations

| well_name | biozone name | biozone range | biostrat depth top (m) | biostrat depth base (m) | biozone age from (Ma) | biozone age to (Ma) | age_code | notes on biozone age | depositional enviroment | formation name | formation top (m) | formation base (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Paqualin 1 | W.spectabilis | | 3060 | 3789 | 153.8 | 158.5 | 425 | | open marine to shelfal - The microplankton to spore-pollen ratio indicates open marine environments of deposition, although increased vascular plant debris indicate relatively high rates of deposition, some of which may derive from shelfal locations | Vulcan Lw | 2935 | 4165 |
| Paqualin 1 | indeterminate | | 4077 | 4131 | | | 250 | Sample lies well below W.spectabilis (3789m) and is at least 158.5MA | proximal neritic | Vulcan Lw | 2935 | 4165 |
| Rainier 1 | W.spectabilis | | 1923 | 2115 | 153.8 | 158.5 | 525 | | open marine, possibley shelfal | Vulcan Lw | 1890 | 21200 |
| Rainier 1 | C.turbatus | | 2120 | 2120 | 177 | 189.5 | 100 | | deltaic | Vulcan Lw | 1890 | 21200 |
| Rainier 1 | M.crenulatus | S.speciosus | 2190 | 2244 | 206.5 | 214 | 100 | | lower delta plain | Vulcan Lw | 1890 | 21200 |
| Rainier 1 | S.wigginsii | S.speciosus | 2262 | 2361 | 214 | 220.5 | 100 | | marginal marine, shallowing with depth | Vulcan Lw | 1890 | 21200 |
| Rowan 1 | W.spectabilis | | 2865 | 3110 | 153.8 | 158.5 | 325 | | shelfal marine - the prominence of vascular plant debris and the dominance of the palynomorph suite by spores-pollen, suggests a shelfal marine environment of deposition, although, possible transport of this material to deeper environments cannot be disco | Vulcan Lw | 2865 | 3185 |
| Rowan 1 | R.aemula | | 3133 | 3183 | 158.5 | 160.3 | 325 | | shelfal marine environment - the high proportions of vascular plant debris and the dominance of the playnomorph suites by spores and pollen above 3150m suggests shelfal marine environments of depostion. The increasing prominence fo microplankton below 315 | Vulcan Lw | 2865 | 3185 |
| Swan 1 | W.clathrata | | 2988 | 3137 | 150.3 | 153.8 | 425 | | top - marine environment of deposition relatively close to an active source of fluvial sediment - bottom - marine environment of depisition some distance removed from an active source of fluvial sedimentation | Vulcan Lw | 2988 | 3272 |
| Swan 1 | W.spectabilis | | 3200 | 3259 | 153.8 | 158.5 | 325 | | 10500 - marine environment of deposition some distance removed from an active fluvial sediment source | Vulcan Lw | 2988 | 3272 |
| Swift 1 | W.spectabilis | | 2394.9 | 2437.6 | 153.8 | 158.5 | 325 | | shelfal marine - with considerable terrestrial plant input | Vulcan Lw | 2394 | 2461 |
| Allaru 1 | P.iehiense | D.jurassicum | 2343 | 2403 | 140 | 142.5 | 525 | | open marine - The microplankton to spore-pollen ratio and the relatively low proportion of vascular plant debris in the residues suggest open marine environments | Vulcan Up | 2343 | 2403 |
| Douglas 1 | C.delicata | | 2380.5 | 2384 | 138 | 139 | 525 | | open marine | Vulcan Up | 2379 | 2485 |
| Douglas 1 | K.wisemaniae | | 2390 | 2390 | 139 | 140 | 525 | | open marine | Vulcan Up | 2379 | 2485 |
| Douglas 1 | P.iehiense | D.jurassicum | 2396.5 | 2450 | 140 | 142.5 | 525 | | open marine | Vulcan Up | 2379 | 2485 |
| Douglas 1 | D.jurassicum | | 2454.5 | 2462.5 | 142.5 | 143.8 | 425 | | open to shelfal marine | Vulcan Up | 2379 | 2485 |
| East Swan 2 | W.spectabilis | | 2319 | 2555 | 153.8 | 158.5 | 425 | | open marine, possibly shelfal - possibly shallowing downhole | Vulcan Up | 2317 | 2390 |
| Eclipse 1 | P.iehiense | | 2328 | 2328 | 140 | 142.5 | 425 | | marine - in view of the extent of reworking the environment is uncertain, although a marine setting is preferred | Vulcan Up | 2317 | 2330 |
| Fagin 1 | C.delicata | | 2759 | 2777.4 | 138 | 139 | 525 | | open marine | Vulcan Up | 2734 | 2964 |
| Fagin 1 | P.iehiense | | 2869.4 | 2902 | 140 | 142.5 | 525 | | open marine | Vulcan Up | 2734 | 2964 |
| Fagin 1 | P.iehiense | D.jurassicum | 2928 | 2949 | 140 | 142.5 | 525 | | open marine | Vulcan Up | 2734 | 2964 |
| Halycon 1 | S.areolata | | 1334 | 1337 | 133 | 135 | 425 | | marine | Vulcan Up | 1327 | 1374 |
| Halycon 1 | D.lobospinosum | | 1341 | 1341 | 137 | 138 | 425 | | marine | Vulcan Up | 1327 | 1374 |
| Halycon 1 | K.wisemaniae | | 1350 | 1353 | 139 | 140 | 425 | | marine | Vulcan Up | 1327 | 1374 |

## Appendix A - Biostrat zones and depositional environment information for Upper and Lower Vulcan Formations

| well_name | biozone name | biozone range | biostrat depth top (m) | biostrat depth base (m) | biozone age from (Ma) | biozone age to (Ma) | age_code | notes on biozone age | depositional enviroment | formation name | formation top (m) | formation base (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Kalyptea 1 | E.torynum | C.delicata | 4350 | 4572 | 135 | 136 | 325 | | shelfal - tentatively regarded as shelfal | Vulcan Up | 4303 | 4575 |
| Maple 1 | B.reticulatum | | 2846 | 2850 | 136 | 137 | 425 | | shelfal to open marine | Vulcan Up | 2846 | 3060 |
| Maple 1 | D.lobospinosum | C.delicata | 2859 | 2938 | 137 | 138 | 425 | | shelfal to open marine | Vulcan Up | 2846 | 3060 |
| Maple 1 | D.jurassicum | | 2975 | 3030 | 142.5 | 143.8 | 425 | | shelfal to open marine | Vulcan Up | 2846 | 3060 |
| Oliver 1 | C.delicata | | 2707 | 2758 | 138 | 139 | 325 | | shelfal marine | Vulcan Up | 2700 | 2897 |
| Oliver 1 | P.iehiense | | 2789 | 2840 | 140 | 142.5 | 325 | | shelfal marine or deeper | Vulcan Up | 2700 | 2897 |
| Oliver 1 | D.jurassicum | | 2874 | 2894 | 142.5 | 143.8 | 525 | | open marine | Vulcan Up | 2700 | 2897 |
| Paqualin 1 | K.wisemaniae | | 2619 | 2638 | 139 | 140 | 525 | | open marine | Vulcan Up | 2528 | 2935 |
| Paqualin 1 | P.iehiense | | 2633 | 2685 | 140 | 142.5 | 525 | | open marine - prominence of microplankton and scarcity of vascular plant debris suggest open marine environments of deposition | Vulcan Up | 2528 | 2935 |
| Paqualin 1 | D.jurassicum | | 2844 | 2907 | 142.5 | 143.8 | 525 | | open marine | Vulcan Up | 2528 | 2935 |
| Paqualin 1 | D.swanense | | 2925 | 2952 | 146 | 150.3 | 525 | | open marine | Vulcan Up | 2528 | 2935 |
| Swan 1 | B.reticulatum | | 2638 | 2638 | 136 | 137 | 325 | | marine environment of deposition relatively close to an active fluvial sediment source | Vulcan Up | 2635 | 2988 |
| Swan 1 | K.wisemaniae | | 2729 | 2729 | 139 | 140 | 225 | | marine environment of deposition relatively close to an active fluvial sediment source | Vulcan Up | 2635 | 2988 |
| Swan 1 | D.jurassicum | | 2812 | 2837 | 142.5 | 143.8 | 425 | | distinct marine environment of deposition | Vulcan Up | 2635 | 2988 |
| Swan 1 | D.swanense | | 2865 | 2865 | 146 | 150.3 | 425 | | marine environment of deposition relatively close to an active source of fluvial sediment - amount of wood and cuticle suggests this. | Vulcan Up | 2635 | 2988 |

## Appendix A - Biostrat zones and depositional environment information for Echuca Shoals Formation

| well_name | biozone name | biozone range | biostrat depth top (m) | biostrat depth base (m) | biozone age from (Ma) | biozone age to (Ma) | age_code | notes on biozone age | depositional enviroment | formation name | formation top (m) | formation base (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Allaru 1 | D.davidii | | 2304 | 2307 | 106.5 | 109 | 525 | | open marine - The predominance of dinoflagellates and the relatively low proportion and composition of vascular plant debris (mainly opaque and semi-opaque fragments) suggest and open marine environment of deposition | Echuca Shoals | 2310 | 2343 |
| Allaru 1 | A.cinctum | | 2310 | 2313 | 115 | 118 | 525 | | open marine - The abundance of dinoflagellates and the relatively low proportion of vascular plant debris suggest an open marine environment of deposition | Echuca Shoals | 2310 | 2343 |
| Allaru 1 | M.australis | M.australis Lw | 2319 | 2322 | 118 | 123 | 525 | | open marine - The abundance of dinoflagellates and the relatively low proportion of vascular plant debris suggest an open marine environment of deposition | Echuca Shoals | 2310 | 2343 |
| Allaru 1 | M.testudinaria | | 2328 | 2343 | 123 | 126.5 | 325 | | shelfal marine - The downhole increase in the vascular plant debris and increase in spore-pollen to microplankton ratio through this interval suggests some downhole shallowing to shelfal environments | Echuca Shoals | 2310 | 2343 |
| Allaru 1 | P.iehiense | D.jurassicum | 2343 | 2403 | 140 | 142.5 | 525 | | open marine - The microplankton to spore-pollen ratio and the relatively low proportion of vascular plant debris in the residues suggest open marine environments | Echuca Shoals | 2310 | 2343 |
| Allaru 1 | D.swanense | | 2406 | 2421 | 146 | 150.3 | 525 | | open marine - The microplankton to spore-pollen ratio suggests open marine environments of deposition | Echuca Shoals | 2310 | 2343 |
| Allaru 1 | W.clathrata | | 2424 | 2448 | 150.3 | 153.8 | 525 | | open marine - shallowing downhole - The continued prominence of dinoflagellates suggests open marine conditions although there is a marked downhole increase in the spore-pollen to microplankton ratio suggesting shallowing relative to the overlying section | Echuca Shoals | 2310 | 2343 |
| Allaru 1 | W.spectabilis | | 2451 | 2946 | 153.8 | 158.5 | 425 | | open marine - shelfal - The prominence of microplankton suggests open marine environments of deposition although the increase in the vascular plant debris suggests shelfal influence | Echuca Shoals | 2310 | 2343 |
| Anderdon 1 | P.helvetica | | 1410 | 1427 | 89 | 90.1 | 425 | Mid to Early Turonian interpreted by I.Deighton (WCR) | outer shelf - slope | Echuca Shoals | 1438 | 1457 |
| Anderdon 1 | P.infusorioides | A.suggestium | 1320 | 1410 | 91 | 92.5 | 525 | | Environment of deposition is interpreted as open marine on the basis of the prominence of chorate dinoflagellates and the relative absence of vascular plant debris and microfossils | Echuca Shoals | 1438 | 1457 |
| Anderdon 1 | T.playfordii | | 1458 | 1630 | 238.5 | 245 | 100 | | Environment of deposition is interpreted as deltiac to non-marine, with increasing marine influence towards the base of the sequence indicated by a marked increase in acritarchs. | Echuca Shoals | 1438 | 1457 |
| Anderdon 1 | P.samoilovichii | L.pellucidus? | 1740 | 2410 | 245 | 251 | 425 | | The prominence of acritarchs throughout the interval indicates a marine environment of deposition. | Echuca Shoals | 1438 | 1457 |
| Anderdon 1 | D.parvithola | D.playfordii | 2445 | 2752.8 | 257 | 268.5 | 425 | | The consistent and often prominent occurrence of acanthomorph acritarchs indicates marine environments of deposition | Echuca Shoals | 1438 | 1457 |
| Anderdon 1 | G.gansseri | G.falsostuarti | 1080 | 1135 | | | 225 | Age=Mid Maastrichtian - Foraminifera interpreted by I.Deighton (WCR) | inner shelf | Echuca Shoals | 1438 | 1457 |

## Appendix A - Biostrat zones and depositional environment information for Echuca Shoals Formation

| well_name | biozone name | biozone range | biostrat depth top (m) | biostrat depth base (m) | biozone age from (Ma) | biozone age to (Ma) | age_code | notes on biozone age | depositional enviroment | formation name | formation top (m) | formation base (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Anderdon 1 | G.calcarata | G.ventricosa | 1150 | 1190 | | | 225 | Late - Mid Campanian interprteted by I.Deighton (WCR) | inner shelf | Echuca Shoals | 1438 | 1457 |
| Anderdon 1 | G.elevata | | 1200 | 1310 | | | 325 | Early Campanian interpreted by I.Deighton (WCR) | inner shelf (1200-1270) to mid shelf (1270-1310) | Echuca Shoals | 1438 | 1457 |
| Anderdon 1 | D.assymetrica | | 1310 | 1320 | | | 325 | Late Santonian interpreted by I.Deighton (WCR) | outer shelf | Echuca Shoals | 1438 | 1457 |
| Anderdon 1 | G.gansseri | | 1000 | 1039.9 | | | 325 | | mid shelf | Echuca Shoals | 1438 | 1457 |
| Anderdon 1 | D.concavata | M.schneegansi | 1340 | 1400 | | | 325 | Early Santonian to Late Turonian interpreted by I.Deighton (WCR) | outer shelf | Echuca Shoals | 1438 | 1457 |
| Avocet 1a | KCN-3 | | 1224 | 1224 | 66.3 | 67.6 | 400 | Latest Early-Late Maastrichtian interpreted by Rexillius (WCR) | outer neritic | Echuca Shoals | 1725 | 1782 |
| Avocet 1a | KCN-11 | | 1245 | 1245 | 75.5 | 78.4 | 450 | basal Middle Campanian | outer neritic-upper bathyal | Echuca Shoals | 1725 | 1782 |
| Avocet 1a | KCN-16 | | 1310.5 | 1330 | 83 | 83.8 | 450 | upper Late Santonian | outer neritic-upper bathyal | Echuca Shoals | 1725 | 1782 |
| Avocet 1a | KCN-17 | | 1350 | 1350 | 83.8 | 85 | 450 | lower Late Santonian | outer neritic-upper bathyal | Echuca Shoals | 1725 | 1782 |
| Avocet 1a | KCN-18 | | 1369 | 1405 | 85 | 85.5 | 450 | upper Early Santonian | outer neritic-upper bathyal | Echuca Shoals | 1725 | 1782 |
| Avocet 1a | KCN-20 | | 1434 | 1492 | 86.2 | 88.1 | 450 | Coniacian | outer neritic-upper bathyal | Echuca Shoals | 1725 | 1782 |
| Avocet 1a | KCN-20 | KCN-21 | 1510 | 1510 | 86.2 | 88.1 | 500 | Turonian/Coniacian | upper bathyal | Echuca Shoals | 1725 | 1782 |
| Avocet 1a | KCN-25A | | 1560 | 1600 | 95.2 | 96.3 | 500 | upper middle-early Late Cenomanian | upper bathyal | Echuca Shoals | 1725 | 1782 |
| Avocet 1a | KCN-25B | KCN-25C | 1617.5 | 1638 | 96.3 | 97.6 | 500 | Late Albian-lower Middle Cenomanian | upper bathyal | Echuca Shoals | 1725 | 1782 |
| Avocet 1a | C.denticulata | P.ludbrookiae | 1686 | 1686 | 101.5 | 103.5 | 425 | | open marine possibley shelfal. | Echuca Shoals | 1725 | 1782 |
| Avocet 1a | M.tetracantha | | 1698 | 1714.5 | 103.5 | 106.5 | 525 | | open marine. | Echuca Shoals | 1725 | 1782 |
| Avocet 1a | KCN-28 | | 1686 | 1698 | 103.8 | 107.2 | 550 | upper Early-lower Middle Albian | middle-upper bathyal | Echuca Shoals | 1725 | 1782 |
| Avocet 1a | D.davidii | | 1718 | 1718 | 106.5 | 109 | 525 | | open marine | Echuca Shoals | 1725 | 1782 |
| Avocet 1a | KCN-30 | | 1702 | 1703 | 108.9 | 110.6 | 425 | lower Late Aptian | undifferentiated marine | Echuca Shoals | 1725 | 1782 |
| Avocet 1a | M.australis | | 1726 | 1734 | 118 | 123 | 325 | | shelfal marine | Echuca Shoals | 1725 | 1782 |
| Avocet 1a | M.testudinaria | P.burgeri | 1740 | 1742 | 123 | 126.5 | 325 | | shelfal marine | Echuca Shoals | 1725 | 1782 |
| Avocet 1a | S.tabulata | P.burgeri | 1746.4 | 1746.5 | 131 | 133 | 325 | | shelfal marine | Echuca Shoals | 1725 | 1782 |
| Avocet 1a | S.areolata | S.tabulata | 1749 | 1749 | 133 | 135 | 325 | | shelfal marine - The environment of deposition is interpreted as shelfal marine | Echuca Shoals | 1725 | 1782 |
| Avocet 1a | C.delicata | | 1751.5 | 1769.5 | 138 | 139 | 425 | | open marine, possible shelfal | Echuca Shoals | 1725 | 1782 |
| Avocet 1a | P.iehiense | | 1771.5 | 1771.5 | 140 | 142.5 | 525 | | open marine - The environment of deposition is interpreted as open marine, probably representing very slow rates of sedimentation. | Echuca Shoals | 1725 | 1782 |
| Avocet 1a | D.jurassicum | P.iehiense | 1773 | 1780 | 142.5 | 143.8 | 325 | | shelfal marine. | Echuca Shoals | 1725 | 1782 |
| Avocet 1a | C.torosa | C.turbatus | 1782 | 1908 | 189.5 | 204.5 | 100 | | distal fluvio-deltaic - The environment of deposition appears to be distal fluvio-deltaic. | Echuca Shoals | 1725 | 1782 |
| Avocet 1a | KPF-13 | | 1539 | 1539 | | | 600 | Early Turonian or older | undifferentiated bathyal (anoxic) | Echuca Shoals | 1725 | 1782 |
| Avocet 1a | | | 1704 | 1704 | | | 500 | This sample is younger than D.davidii (1718m) and has been assinged an age of 106MA | undifferentiated bathyal | Echuca Shoals | 1725 | 1782 |
| Avocet 1a | | | 1712 | 1723 | | | 400 | This sample is younger than D.davidii (1718m) and has been assinged an age of 106MA | outer neritic or deeper | Echuca Shoals | 1725 | 1782 |
| Avocet 1a | | | 1729 | 1746 | | | 350 | Sample is between M.australis(1726m) and M.testudinaria/P.burgeri(1740m) and thus has been assigned an age of 123MA | low energy middle - outer neritic (anoxic) | Echuca Shoals | 1725 | 1782 |

## Appendix A - Biostrat zones and depositional environment information for Echuca Shoals Formation

| well_name | biozone name | biozone range | biostrat depth top (m) | biostrat depth base (m) | biozone age from (Ma) | biozone age to (Ma) | age_code | notes on biozone age | depositional enviroment | formation name | formation top (m) | formation base (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Avocet 1a | | | 1749 | 1751.5 | | | 425 | Sample lies between S.areolata/S.tabulata (1749m) and C.delicata (1751.5m) and thus has been assigned an age of 135MA to 138MA | undifferentiated marine | Echuca Shoals | 1725 | 1782 |
| Challis 1 | A.mayaroensis | G.gansseri | 990 | 1037 | 65 | 67 | 325 | mid - late Maastrichtian | mid shelf (990) to inner shelf (1037) | Echuca Shoals | 1370 | 1387 |
| Challis 1 | C.diebelii | | 990 | 1117 | 66 | 73 | 525 | | open marine - the prominence of chorate cysts between 990 and 1074 suggests and open marine environment of deposition | Echuca Shoals | 1370 | 1387 |
| Challis 1 | R.brotzeni | R.cushmani | 1321.1 | 1321.1 | 95 | 97.5 | 225 | middle Cenomanian | inner shelf | Echuca Shoals | 1370 | 1387 |
| Challis 1 | D.multispinum | | 1342.6 | 1342.6 | 92.5 | 98.5 | 425 | | open marine | Echuca Shoals | 1370 | 1387 |
| Challis 1 | P.ludbrookiae | | 1360 | 1360 | 100 | 101.5 | 325 | | open marine, possible shelfal | Echuca Shoals | 1370 | 1387 |
| Challis 1 | M.australis | M.testudinaria | 1375.2 | 1380.8 | 118 | 123 | 325 | | shelfal marine - associations usually confined to the greensand unit at the base of the Echuca Shoals | Echuca Shoals | 1370 | 1387 |
| Challis 1 | S.speciosus | | 1387.2 | 1657.5 | 214 | 226 | 200 | | deltaic | Echuca Shoals | 1370 | 1387 |
| Challis 1 | S.speciosus | | 1387.2 | 1657.5 | 217.5 | 232 | 200 | | deltaic | Echuca Shoals | 1370 | 1387 |
| Challis 1 | S.quadrifidus | | 1877 | 1927.9 | 226 | 238.5 | 100 | | marginal marine to deltaic | Echuca Shoals | 1370 | 1387 |
| Challis 1 | Indeterminate | | 952 | 968 | | | 425 | no younger than Early Paleocene | open marine - the prominence of chorate cysts suggests and open marine environment of deposition | Echuca Shoals | 1370 | 1387 |
| Challis 1 | | | 633 | 633 | | | 125 | | beach sand? | Echuca Shoals | 1370 | 1387 |
| Challis 1 | | | 678.9 | 678.9 | | | 225 | | inner shelf | Echuca Shoals | 1370 | 1387 |
| Challis 1 | | | 721.9 | 721.9 | | | 225 | | ?inner shelf | Echuca Shoals | 1370 | 1387 |
| Challis 1 | | | 765.9 | 765.9 | | | 225 | | inner shelf | Echuca Shoals | 1370 | 1387 |
| Challis 1 | | | 825 | 825 | | | 225 | | inner shelf | Echuca Shoals | 1370 | 1387 |
| Challis 1 | | | 928 | 928 | | | 225 | | inner shelf | Echuca Shoals | 1370 | 1387 |
| Challis 1 | | | 944 | 944 | | | 225 | | inner shelf (?dolomite) | Echuca Shoals | 1370 | 1387 |
| Challis 1 | | | 952 | 952 | | | 225 | | inner shelf | Echuca Shoals | 1370 | 1387 |
| Challis 1 | | | 958 | 958 | | | 225 | | inner shelf | Echuca Shoals | 1370 | 1387 |
| Challis 1 | | | 977 | 977 | | | 225 | | inner shelf | Echuca Shoals | 1370 | 1387 |
| Challis 1 | G.falsostuarti | G.elevata | 1074 | 1117 | | | 225 | Early Maastrichtian to Campanian | inner shelf | Echuca Shoals | 1370 | 1387 |
| Challis 1 | G.elevata | D.assymetrica | 1180 | 1180 | | | 225 | Earl Campanian to Late Santonian | inner shelf | Echuca Shoals | 1370 | 1387 |
| Challis 1 | D.assymetrica | | 1246.9 | 1246.9 | | | 325 | Late Santonian | mid shelf | Echuca Shoals | 1370 | 1387 |
| Challis 1 | D.concavata | | 1287.5 | 1287.5 | | | 225 | Late Coniacian-Santonian | inner shelf | Echuca Shoals | 1370 | 1387 |
| Challis 1 | | | 1383.6 | 1383.6 | | | 125 | This sample is below M.testudinaria (1380.8m) so it is at least as old as the base age of the M.tesudinaria interval (126.5) | ?estuarine | Echuca Shoals | 1370 | 1387 |
| Challis 1 | | | 874 | 874 | | | 225 | | inner shelf | Echuca Shoals | 1370 | 1387 |
| Challis 1 | | | 968 | 968 | | | 225 | | inner shelf | Echuca Shoals | 1370 | 1387 |
| Douglas 1 | CP8 | | 1816 | 1909 | 53.5 | 55.4 | 325 | | inner shelf | Echuca Shoals | 2346 | 2379 |
| Douglas 1 | CP8 | | 1850 | 1850 | 53.5 | 55.4 | 325 | | inner shelf | Echuca Shoals | 2346 | 2379 |
| Douglas 1 | T4 | | 1950 | 1990 | 57 | 59.2 | 325 | | middle shelf to shallow outer shelf | Echuca Shoals | 2346 | 2379 |
| Douglas 1 | CP4 | | 1990 | 1990 | 59.3 | 59.9 | 325 | | middle shelf to shallow outer shelf | Echuca Shoals | 2346 | 2379 |
| Douglas 1 | C11 | | 2111.5 | 2116 | 70 | 73 | 425 | | max outer shelf | Echuca Shoals | 2346 | 2379 |
| Douglas 1 | C6 | | 2129.5 | 2129.5 | 87 | 89.2 | 425 | | deep outer shelf | Echuca Shoals | 2346 | 2379 |
| Douglas 1 | C1 | | 2138.5 | 2332.5 | 100.5 | 108 | 425 | | outershelf or deeper - low diversity of abundant planktonic assemblages may be explained by relatively cool water. | Echuca Shoals | 2346 | 2379 |

## Appendix A - Biostrat zones and depositional environment information for Echuca Shoals Formation

| well_name | biozone name | biozone range | biostrat depth top (m) | biostrat depth base (m) | biozone age from (Ma) | biozone age to (Ma) | age_code | notes on biozone age | depositional enviroment | formation name | formation top (m) | formation base (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Douglas 1 | M.testudinaria | | 2347.5 | 2347.5 | 123 | 126.5 | 525 | | open marine | Echuca Shoals | 2346 | 2379 |
| Douglas 1 | P.burgeri | | 2357 | 2357 | 126.5 | 131 | 525 | | open marine | Echuca Shoals | 2346 | 2379 |
| Douglas 1 | S.tabulata | | 2362 | 2377.5 | 131 | 133 | 425 | | open to shelfal marine | Echuca Shoals | 2346 | 2379 |
| Douglas 1 | C.delicata | | 2380.5 | 2384 | 138 | 139 | 525 | | open marine | Echuca Shoals | 2346 | 2379 |
| Douglas 1 | K.wisemaniae | | 2390 | 2390 | 139 | 140 | 525 | | open marine | Echuca Shoals | 2346 | 2379 |
| Douglas 1 | P.iehiense | D.jurassicum | 2396.5 | 2450 | 140 | 142.5 | 525 | | open marine | Echuca Shoals | 2346 | 2379 |
| Douglas 1 | D.jurassicum | | 2454.5 | 2462.5 | 142.5 | 143.8 | 425 | | open to shelfal marine | Echuca Shoals | 2346 | 2379 |
| Douglas 1 | C.torosa | | 2487.3 | 2488.5 | 189.5 | 204.5 | 100 | | lower delta plain | Echuca Shoals | 2346 | 2379 |
| Douglas 1 | A.reducta | M.crenulatus | 2543 | 2556 | 204.5 | 206.5 | 100 | | non-marine | Echuca Shoals | 2346 | 2379 |
| Douglas 1 | M.crenulatus | | 2732 | 2748 | 206.5 | 214 | 100 | | lower delta plain | Echuca Shoals | 2346 | 2379 |
| Douglas 1 | CP7 | CP5 | 1970 | 1970 | | | 325 | | middle shelf to shallow outer shelf | Echuca Shoals | 2346 | 2379 |
| East Swan 2 | CP9 | | 1302.5 | 1338 | 52.4 | 53.5 | 400 | | middle neritic | Echuca Shoals | 2294 | 2317 |
| East Swan 2 | CP8 | | 1361 | 1361 | 53.5 | 55.4 | 400 | | middle neritic | Echuca Shoals | 2294 | 2317 |
| East Swan 2 | CP5 | | 1830.5 | 1830.5 | 57.8 | 59.3 | 450 | | outer neritic-upper bathyal | Echuca Shoals | 2294 | 2317 |
| East Swan 2 | CP4 | CP2 | 1836 | 1856 | 59.3 | 59.9 | 450 | | outer neritic (1836m) upper bathyal (1856m) | Echuca Shoals | 2294 | 2317 |
| East Swan 2 | CP1 | | 1880 | 1954 | 62.9 | 65 | 450 | | outer neritic-upper bathyal(1880m) / outer neritic (1944m & 1954m) | Echuca Shoals | 2294 | 2317 |
| East Swan 2 | KCN-2 | KCN-3 | 1984 | 1984 | 65.88 | 66.3 | 450 | | outer neritic-upper bathyal | Echuca Shoals | 2294 | 2317 |
| East Swan 2 | M.australis | | 2299 | 2303 | 118 | 123 | 325 | | at least shelfal - The prominence of plant debris in the organic residue suggest proximity of terrestial sources although high microplankton to spore-pollen ratio suggest that the environment of deposition is at least shelfal. | Echuca Shoals | 2294 | 2317 |
| East Swan 2 | P.burgeri | | 2315 | 2316 | 126.5 | 131 | 325 | | shelfal marine - The relative prominence of plant debrisand the microplankton to spore-pollen ratio suggest shelfal marine depositional environments. | Echuca Shoals | 2294 | 2317 |
| East Swan 2 | W.spectabilis | | 2319 | 2555 | 153.8 | 158.5 | 425 | | open marine, possibly shelfal - possibly shallowing downhole | Echuca Shoals | 2294 | 2317 |
| East Swan 2 | R.aemula | | 2607 | 2635.5 | 158.5 | 160.3 | 325 | | shelfal marine | Echuca Shoals | 2294 | 2317 |
| East Swan 2 | C.halosa | | 2642 | 2819 | 166.5 | 169 | 100 | | shallow marine to deltaic - The prominence and nature of the vascular plant debris and the spore-pollen to mircoplankton ratios suggest shallow marine to deltaic envronments fo deposition | Echuca Shoals | 2294 | 2317 |
| East Swan 2 | inderterminate | | 1350 | 1350 | | | 400 | | middle-outer neritic | Echuca Shoals | 2294 | 2317 |
| East Swan 2 | inderterminate | | 1808 | 1808 | | | 400 | | distal neritic | Echuca Shoals | 2294 | 2317 |
| East Swan 2 | inderterminate | | 2000 | 2000 | | | 425 | | undifferentiated marine | Echuca Shoals | 2294 | 2317 |
| Eclipse 1 | A.circumtabulata | | 1927.5 | 1938 | 65 | 66 | 525 | | open marine - dominance of chorate cysts and relatively low proportions of spores and pollen suggest open marine depositional environments | Echuca Shoals | 2295 | 2317 |
| Eclipse 1 | A.mayaroensis | | 1931.5 | 1945 | 65 | 67 | 325 | Late Maastrichtian | mid-outer shelf to outer shelf | Echuca Shoals | 2295 | 2317 |
| Eclipse 1 | C.diebelii | | 1997 | 2032 | 66 | 73 | 525 | | open marine - chroate cysts are very prominent suggesting open marine however, the increased vascular plant component together with prominent acritarchs may indicate a closer proximity to a land mass or more active sediment supply than in the samples abov | Echuca Shoals | 2295 | 2317 |
| Eclipse 1 | S.carnarvonensis | | 2068.5 | 2068.5 | 73 | 77 | 525 | | open marine - chorate cysts dominate suggesting an open marine environment | Echuca Shoals | 2295 | 2317 |
| Eclipse 1 | A.coronata | | 2105 | 2130 | 77 | 83 | 525 | | open marine - chorate cysts dominate suggesting an open marine environment | Echuca Shoals | 2295 | 2317 |

## Appendix A - Biostrat zones and depositional environment information for Echuca Shoals Formation

| well_name | biozone name | biozone range | biostrat depth top (m) | biostrat depth base (m) | biozone age from (Ma) | biozone age to (Ma) | age_code | notes on biozone age | depositional enviroment | formation name | formation top (m) | formation base (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Eclipse 1 | C.striatoconus | | 2179 | 2179 | 87 | 91 | 525 | | open marine | Echuca Shoals | 2295 | 2317 |
| Eclipse 1 | P.ludbrookiae | X.asperatus | 2249.9 | 2262.5 | 100 | 101.5 | 525 | | open marine | Echuca Shoals | 2295 | 2317 |
| Eclipse 1 | D.davidii | | 2288.5 | 2288.5 | 106.5 | 109 | 525 | | open marine | Echuca Shoals | 2295 | 2317 |
| Eclipse 1 | M.testudinaria | | 2307.6 | 2307.6 | 123 | 126.5 | 425 | | marine environment | Echuca Shoals | 2295 | 2317 |
| Eclipse 1 | P.iehiense | | 2328 | 2328 | 140 | 142.5 | 425 | | marine - in view of the extent of reworking the environment is uncertain, although a marine setting is preferred | Echuca Shoals | 2295 | 2317 |
| Eclipse 1 | W.spectabilis | W.spectabilis Mid | 2332 | 2489.9 | 153.8 | 158.5 | 225 | | marine/shallow marine? - The environment of deposition is clearly marine, although characterised by substantial vascular plant debris. This association has been interpreted previously as shallow marine | Echuca Shoals | 2295 | 2317 |
| Eclipse 1 | W.spectabilis | W.spectabilis Lw | 2555.1 | 2561.3 | 153.8 | 158.5 | 425 | | marine | Echuca Shoals | 2295 | 2317 |
| Eclipse 1 | R.aemula | | 2570.6 | 2570.6 | 158.5 | 160.3 | 425 | | marine | Echuca Shoals | 2295 | 2317 |
| Eclipse 1 | C.cooksoniae | D.complex | 2580 | 2647.5 | 163.5 | 167.5 | 425 | | marginal marine - The absence of dinoflagellates and the pattern of acritarch occurences suggests a marginal marine environment of deposition, possibly with increasing marine influence towards the lower part of the interval | Echuca Shoals | 2295 | 2317 |
| Eclipse 1 | D.caddaensis | | 2708.5 | 2742.5 | 174.5 | 179.5 | 125 | | marginal marine | Echuca Shoals | 2295 | 2317 |
| Eclipse 1 | C.turbatus | | 2799 | 2882.4 | 177 | 189.5 | 125 | | marginal marine (probably) - C.turbatus Lw | Echuca Shoals | 2295 | 2317 |
| Eclipse 1 | D.priscum Up | | 2945 | 1965 | | | 125 | | marginal marine (probably) | Echuca Shoals | 2295 | 2317 |
| Eclipse 1 | M.uncinata | S.pseudobulloides | 1826 | 1923 | | | 325 | Mid Paleocene to Early Paleocene | mid shelf | Echuca Shoals | 2295 | 2317 |
| Eclipse 1 | G.lapparenti | | 2026 | 2026 | | | 225 | Early Maastrichtian | inner shelf | Echuca Shoals | 2295 | 2317 |
| Eclipse 1 | G.elevata | | 2089 | 2121 | | | 225 | Early Campanian | inner shelf (2089m) to mid shelf (2121m) | Echuca Shoals | 2295 | 2317 |
| Eclipse 1 | G.elevata | G.carinata | 2138.3 | 2138.3 | | | 325 | Early Campanian to Early Coniacian | outer shelf | Echuca Shoals | 2295 | 2317 |
| Eclipse 1 | G.concavata | | 2168 | 2168 | | | 325 | Early Campanian to Early Coniacian | outer shelf | Echuca Shoals | 2295 | 2317 |
| Eclipse 1 | G.renzi | G.sigali | 2203.5 | 2203.5 | | | 325 | Early Campanian to Early Coniacian | outer shelf | Echuca Shoals | 2295 | 2317 |
| Fagin 1 | M.tetracantha | | 2646 | 2646 | 103.5 | 106.5 | 525 | | open marine | Echuca Shoals | 2672 | 2734 |
| Fagin 1 | D.davidii | | 2665.4 | 2665.4 | 106.5 | 109 | 525 | | open marine | Echuca Shoals | 2672 | 2734 |
| Fagin 1 | M.australis | | 2677.5 | 2697 | 118 | 123 | 425 | | shelfal to open marine | Echuca Shoals | 2672 | 2734 |
| Fagin 1 | P.burgeri | S.tabulata | 2721.4 | 2742 | 126.5 | 131 | 425 | | shelfal to open marine | Echuca Shoals | 2672 | 2734 |
| Fagin 1 | C.delicata | | 2759 | 2777.4 | 138 | 139 | 525 | | open marine | Echuca Shoals | 2672 | 2734 |
| Fagin 1 | P.iehiense | | 2869.4 | 2902 | 140 | 142.5 | 525 | | open marine | Echuca Shoals | 2672 | 2734 |
| Fagin 1 | P.iehiense | D.jurassicum | 2928 | 2949 | 140 | 142.5 | 525 | | open marine | Echuca Shoals | 2672 | 2734 |
| Fagin 1 | W.spectabilis | | 2970 | 3009 | 153.8 | 158.5 | 425 | | shelfal to open marine | Echuca Shoals | 2672 | 2734 |
| Fagin 1 | C.halosa | | 3020 | 3105 | 166.5 | 169 | 100 | | distal fluvial to marine delatic | Echuca Shoals | 2672 | 2734 |
| Fagin 1 | D.caddaensis | | 3105 | 3249 | 174.5 | 179.5 | 100 | | fringing marine to lower delta plain | Echuca Shoals | 2672 | 2734 |
| Halycon 1 | P.ludbrookiae | | 1010 | 1280 | 100 | 101.5 | 425 | | marine | Echuca Shoals | 1302 | 1327 |
| Halycon 1 | C.denticulata | | 1286 | 1299 | 101.5 | 103.5 | 4245 | | marine | Echuca Shoals | 1302 | 1327 |
| Halycon 1 | D.davidii | | 1311 | 1311 | 106.5 | 109 | 425 | | marine | Echuca Shoals | 1302 | 1327 |
| Halycon 1 | M.australis | | 1325 | 1325 | 118 | 123 | 425 | | marine | Echuca Shoals | 1302 | 1327 |
| Halycon 1 | S.areolata | | 1334 | 1337 | 133 | 135 | 425 | | marine | Echuca Shoals | 1302 | 1327 |
| Halycon 1 | D.lobospinosum | | 1341 | 1341 | 137 | 138 | 425 | | marine | Echuca Shoals | 1302 | 1327 |
| Halycon 1 | K.wisemaniae | | 1350 | 1353 | 139 | 140 | 425 | | marine | Echuca Shoals | 1302 | 1327 |
| Halycon 1 | S.quadrifidus | | 1739 | 1739 | 226 | 238.5 | 100 | | marginal marine - Marine acritarchs were common and the abundance of cuticle, spores and pollen indicates a marginal marine environment. Relatively common recycling is also consistent with this environment | Echuca Shoals | 1302 | 1327 |

## Appendix A - Biostrat zones and depositional environment information for Echuca Shoals Formation

| well_name | biozone name | biozone range | biostrat depth top (m) | biostrat depth base (m) | biozone age from (Ma) | biozone age to (Ma) | age_code | notes on biozone age | depositional enviroment | formation name | formation top (m) | formation base (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Halycon 1 | Indeterminate | | 615 | 677.3 | | | 425 | | undifferentiated marine | Echuca Shoals | 1302 | 1327 |
| Halycon 1 | KCCM-2 | KCCM-5 | 681.8 | 687.5 | | | 300 | lower Late - upper Middle Maastrichtian | inner neritic-middle neritic | Echuca Shoals | 1302 | 1327 |
| Halycon 1 | KCCM-12 | KCCM-13 | 705 | 745 | | | 300 | upper Late Campanian | undifferentiated marine (705m) / inner neritic-middle neritic (708-715m) / middle neritic (725-745m) | Echuca Shoals | 1302 | 1327 |
| Halycon 1 | KCCM-14 | KCCM-15 | 778.5 | 778.5 | | | 350 | upper-mid Late Campanian | middle neritic | Echuca Shoals | 1302 | 1327 |
| Halycon 1 | KCCM-20 | | 785 | 790 | | | 425 | upper Early Campanian | undifferentiated marine | Echuca Shoals | 1302 | 1327 |
| Halycon 1 | KCCM-24 | | 790 | 795 | | | 425 | upper Late Santonian | undifferentiated marine | Echuca Shoals | 1302 | 1327 |
| Halycon 1 | KCCM-26 | | 798 | 798 | | | 425 | upper Early Santonian | undifferentiated marine | Echuca Shoals | 1302 | 1327 |
| Halycon 1 | KCCM-28 | | 857 | 857 | | | 400 | Coniacian | middle neritic - outer neritic | Echuca Shoals | 1302 | 1327 |
| Halycon 1 | KCCM-29 | | 897.5 | 897.5 | | | 425 | upper Late Turonian | undifferentiated marine | Echuca Shoals | 1302 | 1327 |
| Halycon 1 | KCCM-37 | KCCM-42 | 920 | 1110 | | | 350 | Middle Cenomanian - mid Late Albian | middle neritic or deeper (920m) / undifferentiated marine (950m) | Echuca Shoals | 1302 | 1327 |
| Halycon 1 | KCCM-39 | KCCM-42 | 1160 | 1260 | | | 450 | upper-mid Late Albian | distal neritic - upper bathyal | Echuca Shoals | 1302 | 1327 |
| Halycon 1 | KCCM-44a | | 1280 | 1311 | | | 450 | Late Aptian to Middle Albian | outer neritic or deeper to upper bathyal | Echuca Shoals | 1302 | 1327 |
| Kalyptea 1 | CP8 | | 1800 | 2260 | 53.5 | 55.4 | 300 | | inner-middle neritic (1800-10m) undifferentiated marine (1840-2260m) | Echuca Shoals | 4079 | 4304 |
| Kalyptea 1 | KCN-4 | | 2634 | 2907 | 67.6 | 67.75 | 400 | | outer neritic | Echuca Shoals | 4079 | 4304 |
| Kalyptea 1 | KCN-7 | | 3021 | 3252 | 70.5 | 72.2 | 400 | | outer neritic (3021-3024) | Echuca Shoals | 4079 | 4304 |
| Kalyptea 1 | KCN-8 | KCN-9 | 3276 | 3375 | 72.2 | 73 | 450 | | outer neritic - upper bathyal (3201-3375) | Echuca Shoals | 4079 | 4304 |
| Kalyptea 1 | KCN-10 | KCN-11 | 3405 | 3408 | 73.3 | 75.5 | 400 | | distal neritic ? | Echuca Shoals | 4079 | 4304 |
| Kalyptea 1 | KCN-12 | | 3441 | 3468 | 78.4 | 81 | 500 | | upper bathyal (3441-3550) | Echuca Shoals | 4079 | 4304 |
| Kalyptea 1 | KCN-15 | | 3475 | 3475 | 82 | 83 | 500 | | upper bathyal | Echuca Shoals | 4079 | 4304 |
| Kalyptea 1 | KCN-16 | | 3500 | 3500 | 83 | 83.8 | 500 | | upper bathyal | Echuca Shoals | 4079 | 4304 |
| Kalyptea 1 | KCN-18 | | 3524 | 3524 | 85 | 85.5 | 500 | | upper bathyal | Echuca Shoals | 4079 | 4304 |
| Kalyptea 1 | KCN-19 | KCN-20 | 3540 | 3550 | 85.5 | 86 | 500 | | upper bathyal | Echuca Shoals | 4079 | 4304 |
| Kalyptea 1 | KCN-21 | | 3563 | 3563 | 88.1 | 89.5 | 425 | | undifferentiated marine | Echuca Shoals | 4079 | 4304 |
| Kalyptea 1 | KCN-25A | | 3592 | 3592 | 95.2 | 96.3 | 350 | | middle-upper bathyal | Echuca Shoals | 4079 | 4304 |
| Kalyptea 1 | KCN-25C | | 3682 | 3806 | 97.6 | 99.3 | 450 | | outer neritic-upper bathyal | Echuca Shoals | 4079 | 4304 |
| Kalyptea 1 | P.ludbrookiae | | 3682 | 3973 | 100 | 101.5 | 525 | | open marine | Echuca Shoals | 4079 | 4304 |
| Kalyptea 1 | KCN-27 | | 2933 | 2933 | 100.8 | 103.8 | 550 | | middle-upper bathyal (2933-2965m) | Echuca Shoals | 4079 | 4304 |
| Kalyptea 1 | KCN-28 | | 2965 | 2965 | 103.8 | 107.2 | 550 | | middle-upper bathyal (2933-2965m) | Echuca Shoals | 4079 | 4304 |
| Kalyptea 1 | D.davidii | | 3985 | 4022 | 106.5 | 109 | 525 | | open marine - The microplankton to spore-pollen ratio and the restricted vascular plant debris suggests open marine environments of deposition | Echuca Shoals | 4079 | 4304 |
| Kalyptea 1 | KCN-30 | | 4010 | 4040 | 108.9 | 110.6 | 400 | | outer neritic or deeper | Echuca Shoals | 4079 | 4304 |
| Kalyptea 1 | O.operculata | | 4040 | 4040 | 109 | 115 | 525 | | open marine | Echuca Shoals | 4079 | 4304 |
| Kalyptea 1 | A.cinctum | M.australis | 4060 | 4101 | 115 | 118 | 525 | | open marine | Echuca Shoals | 4079 | 4304 |
| Kalyptea 1 | M.australis | | 4110 | 4146 | 118 | 123 | 425 | | shelfal to open marine - The prominence of microplankton and the marginal increase in vascular plant debris into the bottom of the interval suggests shelfal to open marine environments of deposition. | Echuca Shoals | 4079 | 4304 |
| Kalyptea 1 | M.testudinaria | | 4158 | 4194 | 123 | 126.5 | 325 | | shelfal - The downhole increase in the amount of vascular plant debris suggests shelfal environments of deposition, although the relatively high microplankton to spore-pollen ratios are indicative of open marine environments. | Echuca Shoals | 4079 | 4304 |

## Appendix A - Biostrat zones and depositional environment information for Echuca Shoals Formation

| well_name | biozone name | biozone range | biostrat depth top (m) | biostrat depth base (m) | biozone age from (Ma) | biozone age to (Ma) | age_code | notes on biozone age | depositional enviroment | formation name | formation top (m) | formation base (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Kalyptea 1 | S.areolata | | 4209 | 4325 | 133 | 135 | 325 | | shelfal - The downhole increase in vascular plant debris and the ratio of microplankton to spore-pollen suggest shelfal environments of deposition | Echuca Shoals | 4079 | 4304 |
| Kalyptea 1 | E.torynum | C.delicata | 4350 | 4572 | 135 | 136 | 325 | | shelfal - tentatively regarded as shelfal | Echuca Shoals | 4079 | 4304 |
| Kalyptea 1 | | | 2388 | 2391 | | | 425 | | undiferentiated marine | Echuca Shoals | 4079 | 4304 |
| Kalyptea 1 | | | 2535 | 2604 | | | 250 | | inner neritic | Echuca Shoals | 4079 | 4304 |
| Kalyptea 1 | | | 2904 | 2988 | | | 350 | | distal neritic? | Echuca Shoals | 4079 | 4304 |
| Kalyptea 1 | Inderterminate | | 2973 | 2985 | | | 425 | | undifferentiated marine | Echuca Shoals | 4079 | 4304 |
| Kalyptea 1 | Inderterminate | | 4060 | 4060 | | | 400 | Sample lies between O.operculata (4040m) and A.cintum (4060m) and thus has been assigned an age of 118MA | mid-distal neritic | Echuca Shoals | 4079 | 4304 |
| Keeling 1 | D.davidii | | 2990 | 2990 | 106.5 | 109 | 525 | | open marine - The prominence of dinoflagellates and the nature of the other plant debris suggest an open marine environment of deposition | Echuca Shoals | 2998 | 3025 |
| Keeling 1 | M.australis | | 3000.5 | 3000.5 | 118 | 123 | 325 | | shelfal marine | Echuca Shoals | 2998 | 3025 |
| Keeling 1 | M.testudinaria | | 3017 | 3017 | 123 | 126.5 | 525 | | open marine | Echuca Shoals | 2998 | 3025 |
| Keeling 1 | M.crenulatus | | 3050.5 | 3116 | 206.5 | 214 | 100 | | lower delta plain - The abundance of Bartenia communis and the apparent absence of spinose acritarchs suggests lower delta plain environments of deposition | Echuca Shoals | 2998 | 3025 |
| Maple 1 | P1 | | 2524 | 2524 | 61.2 | 64.9 | 500 | | upper bathyal | Echuca Shoals | 2836 | 2846 |
| Maple 1 | A.circumtabulata | | 2552 | 2552 | 65 | 66 | 525 | | open marine | Echuca Shoals | 2836 | 2846 |
| Maple 1 | KCN-2 | KCN-3 | 2552 | 2552 | 65.88 | 66.3 | 500 | Late-upper Early Maastrichtian | upper bathyal | Echuca Shoals | 2836 | 2846 |
| Maple 1 | C.diebelii | | 2600 | 2600 | 66 | 73 | 525 | | open marine | Echuca Shoals | 2836 | 2846 |
| Maple 1 | P.ludbrookiae | | 2835 | 2835 | 100 | 101.5 | 525 | | open marine | Echuca Shoals | 2836 | 2846 |
| Maple 1 | M.testudinaria | | 2836 | 2836 | 123 | 126.5 | 525 | | open marine | Echuca Shoals | 2836 | 2846 |
| Maple 1 | P.burgeri | | 2839 | 2839 | 126.5 | 131 | 525 | | open marine | Echuca Shoals | 2836 | 2846 |
| Maple 1 | B.reticulatum | | 2846 | 2850 | 136 | 137 | 425 | | shelfal to open marine | Echuca Shoals | 2836 | 2846 |
| Maple 1 | D.lobospinosum | C.delicata | 2859 | 2938 | 137 | 138 | 425 | | shelfal to open marine | Echuca Shoals | 2836 | 2846 |
| Maple 1 | D.jurassicum | | 2975 | 3030 | 142.5 | 143.8 | 425 | | shelfal to open marine | Echuca Shoals | 2836 | 2846 |
| Maple 1 | O.montgomeryi | | 3069 | 3069 | 143.8 | 145.2 | 525 | | open marine | Echuca Shoals | 2836 | 2846 |
| Maple 1 | D.swanense | | 3087 | 3140 | 146 | 150.3 | 525 | | open marine | Echuca Shoals | 2836 | 2846 |
| Maple 1 | W.clathrata | | 3150 | 3150 | 150.3 | 153.8 | 525 | | open marine | Echuca Shoals | 2836 | 2846 |
| Maple 1 | W.spectabilis | | 3298.5 | 3600 | 153.8 | 158.5 | 425 | | shelfal to open marine | Echuca Shoals | 2836 | 2846 |
| Maple 1 | R.aemula | | 3680 | 3681.9 | 158.5 | 160.3 | 425 | | shelfal to open marine | Echuca Shoals | 2836 | 2846 |
| Maple 1 | M.crenulatus | | 3682.8 | 3689 | 206.5 | 214 | 100 | | marine deltaic to marginal marine | Echuca Shoals | 2836 | 2846 |
| Maple 1 | S.speciosus | | 3747 | 4087.58 | 214 | 226 | 100 | | ranging from fringing marine to deltaic | Echuca Shoals | 2836 | 2846 |
| Maple 1 | S.speciosus | | 3747 | 4087.58 | 217.5 | 232 | 100 | | ranging from fringing marine to deltaic | Echuca Shoals | 2836 | 2846 |
| Maret 1 | A.cinctum | | 3120 | 3130 | 115 | 118 | 525 | | | Echuca Shoals | 3118 | 3174 |
| Medusa 1 | KCN-7 | | 1479 | 1479 | 70.5 | 72.2 | 500 | | upper bathyal | Echuca Shoals | 1780 | 1792 |
| Medusa 1 | KCN-8 | | 1500 | 1500 | 72.2 | 73 | 500 | | upper bathyal | Echuca Shoals | 1780 | 1792 |
| Medusa 1 | S.carnarvonensis | | 1479 | 1500 | 73 | 77 | 525 | | open marine - environment interpreted as open marine on the basis of the microplankton to spore-pollen ratios and the nature of the plant debris (overwhelmingly fusainised) | Echuca Shoals | 1780 | 1792 |
| Medusa 1 | KCN-13 | KCN-14 | 1548 | 1548 | 81 | 81 | 500 | | upper bathyal | Echuca Shoals | 1780 | 1792 |
| Medusa 1 | KCN-16 | | 1609 | 1609 | 83 | 83.8 | 500 | | upper bathyal | Echuca Shoals | 1780 | 1792 |

## Appendix A - Biostrat zones and depositional environment information for Echuca Shoals Formation

| well_name | biozone name | biozone range | biostrat depth top (m) | biostrat depth base (m) | biozone age from (Ma) | biozone age to (Ma) | age_code | notes on biozone age | depositional enviroment | formation name | formation top (m) | formation base (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Medusa 1 | I.cretaceum | | 1609 | 1609 | 82 | 85 | 525 | | open marine - environment interpreted as open marine on the basis of microplankton to spore-pollen ratio and the fusainised nature of the plant debris | Echuca Shoals | 1780 | 1792 |
| Medusa 1 | KCN-18 | | 1653 | 1653 | 85 | 85.5 | 500 | | upper bathyal | Echuca Shoals | 1780 | 1792 |
| Medusa 1 | D.davidii | | 1776 | 1777 | 106.5 | 109 | 525 | | open marine - environment interpreted as open marine on the basis of microplankton to spore-pollen ratio | Echuca Shoals | 1780 | 1792 |
| Medusa 1 | S.tabulata | | 1785 | 1785 | 131 | 133 | 325 | | shelfal marine - The environment of deposition is interpreted as shelfal marine on the basis of the almost equal proporitons of microplankton and spore-pollen, although the relative paucity of cuticular and woody debris may indicate open marine conditions | Echuca Shoals | 1780 | 1792 |
| Medusa 1 | D.complex | | 1836 | 1836 | 167.5 | 177 | 100 | | lower deltaic plain - Environment of deposition is interpreted as lower deltaic plain, with extremely rare spinose acritarchs suggesting a possible estuarine to brackish influence | Echuca Shoals | 1780 | 1792 |
| Medusa 1 | C.turbatus | | 1902 | 1930 | 177 | 189.5 | 100 | | lower delta plain - Environment of deposition is interpreted as lower delta plain on the basis of the very high spore-pollen to microplankton ratios. However, the presence of very rare dinocysts and spinose acritarchs may indicate proximity to marine (est | Echuca Shoals | 1780 | 1792 |
| Medusa 1 | Indeterminate | | 1776 | 1777 | | | 350 | Sample is the same depth as D.davidii (1776m) and so has been assigned an age of at least 109MA | mid neritic or deeper - samples 1776 and 1777m contian abundant samples of spumellarian radiolaria which is consistent with deposition in a mid neritic or deeper setting. | Echuca Shoals | 1780 | 1792 |
| Medusa 1 | Indeterminate | | 1785 | 1785 | | | 425 | Sample lies between S.tabulata (1785m) and D.complex (1836m) and is most probably has an age of 109Ma as it was taken from the same depth as the S.tabulata (133MA) sample. | undifferentiated marine - The glauconitic SWC sampled is devoid of in-situ foraminifera and is barren of nannoplankton. The occurrence of abundant glauconite is consistent with deposition in a marine setting | Echuca Shoals | 1780 | 1792 |
| Octavius 1 | T8 | | 1280 | 1280 | 53.5 | 54.7 | 325 | | inner shelf to middle shelf | Echuca Shoals | 2420 | 2508 |
| Octavius 1 | T5 | T4 | 1422 | 1422 | 55.9 | 57 | 250 | | inner - middle shelf | Echuca Shoals | 2420 | 2508 |
| Octavius 1 | T4 | | 1608 | 1632 | 57 | 59.2 | 325 | | middle shelf (?deep) | Echuca Shoals | 2420 | 2508 |
| Octavius 1 | T1 | | 1705 | 1730 | 61.7 | 63 | 325 | | middle - outer shelf | Echuca Shoals | 2420 | 2508 |
| Octavius 1 | C13 | | 1865 | 1865 | 65 | 66 | 500 | | upper slope | Echuca Shoals | 2420 | 2508 |
| Octavius 1 | C9 | | 2005 | 2005 | 79 | 83 | 450 | | outer shelf or bathyal | Echuca Shoals | 2420 | 2508 |
| Octavius 1 | C7 | | 2090 | 2090 | 84.5 | 87 | 500 | | bathyal | Echuca Shoals | 2420 | 2508 |
| Octavius 1 | indeterminate | | 1755 | 1838 | | | 225 | | inner shelf | Echuca Shoals | 2420 | 2508 |
| Octavius 1 | indeterminate | | 1645 | 1645 | | | 225 | | inner to shallow middle shelf | Echuca Shoals | 2420 | 2508 |
| Octavius 1 | indeterminate | | 1465 | 1592 | | | 325 | | inner shelf | Echuca Shoals | 2420 | 2508 |
| Octavius 1 | indeterminate | | 1308 | 1390 | | | 225 | undifferentiated Eocene to Palaeocene | inner shelf to intertidal | Echuca Shoals | 2420 | 2508 |
| Octavius 1 | indeterminate | | 1260 | 1260 | | | 225 | Early Eocene | inner shelf | Echuca Shoals | 2420 | 2508 |
| Octavius 1 | indeterminate | | 1163 | 1242 | | | 225 | | intertidal and shallow inner shelf | Echuca Shoals | 2420 | 2508 |
| Octavius 1 | indeterminate | | 1025 | 1082 | | | 225 | Middle Eocene | shallow inner shelf | Echuca Shoals | 2420 | 2508 |
| Octavius 1 | indeterminate | | 943 | 968 | | | 225 | probably Middle Eocene | inner shelf | Echuca Shoals | 2420 | 2508 |
| Octavius 1 | indeterminate | | 885 | 908 | | | 225 | Late Eocene | inner shelf | Echuca Shoals | 2420 | 2508 |

## Appendix A - Biostrat zones and depositional environment information for Echuca Shoals Formation

| well_name | biozone name | biozone range | biostrat depth top (m) | biostrat depth base (m) | biozone age from (Ma) | biozone age to (Ma) | age_code | notes on biozone age | depositional enviroment | formation name | formation top (m) | formation base (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Octavius 1 | indeterminate | | 867 | 867 | | | 125 | undifferentiated E. Oligocene to Late Eocene | shallow lagoonal | Echuca Shoals | 2420 | 2508 |
| Octavius 1 | indeterminate | | 825 | 825 | | | 225 | Early Miocene | shallow inner shelf | Echuca Shoals | 2420 | 2508 |
| Octavius 1 | indeterminate | | 752 | 820 | | | 225 | basal M. to E. Miocene | inner shelf | Echuca Shoals | 2420 | 2508 |
| Octavius 1 | indeterminate | | 675 | 709 | | | 225 | | shallow inner shelf | Echuca Shoals | 2420 | 2508 |
| Octavius 1 | indeterminate | | 647 | 647 | | | 325 | late M. Miocene - Early Pliocene | inner-shallow middle shelf | Echuca Shoals | 2420 | 2508 |
| Oliver 1 | CN12 | | 666.5 | 733 | 1.9 | 3.6 | 350 | | middle neritic | Echuca Shoals | 2650 | 2700 |
| Oliver 1 | CN11 | CN8 | 816 | 930 | 3.6 | 4.5 | 300 | | low energy inner neritic - middle neritic | Echuca Shoals | 2650 | 2700 |
| Oliver 1 | CN5 | | 1488 | 1533 | 11.1 | 14.3 | 300 | | high to moderate energy inner neritic | Echuca Shoals | 2650 | 2700 |
| Oliver 1 | CN4 | CN3 | 1560 | 1560 | 14.3 | 15.9 | 300 | | moderate energy inner neritic | Echuca Shoals | 2650 | 2700 |
| Oliver 1 | CN2 | CN1 | 1567 | 1576 | 16.8 | 20.4 | 300 | | moderate energy inner neritic | Echuca Shoals | 2650 | 2700 |
| Oliver 1 | CP9 | | 2006.5 | 2006.5 | 52.4 | 53.5 | 350 | | low-moderate energy neritic | Echuca Shoals | 2650 | 2700 |
| Oliver 1 | P7 | P6 | 1993.5 | 1993.5 | 54 | 54.7 | 425 | | undifferentiated marine | Echuca Shoals | 2650 | 2700 |
| Oliver 1 | CP8 | CP6 | 2141.5 | 2141.5 | 53.5 | 55.4 | 425 | | undifferentiated marine | Echuca Shoals | 2650 | 2700 |
| Oliver 1 | KCN-16 | KCN-17 | 2406 | 2406 | 83 | 83.8 | 500 | | upper bathyal | Echuca Shoals | 2650 | 2700 |
| Oliver 1 | KCN-19 | KCN-21 | 2418.5 | 2418.5 | 85.5 | 86 | 500 | | upper bathyal ? | Echuca Shoals | 2650 | 2700 |
| Oliver 1 | KCN-21 | | 2441.5 | 2441.5 | 88.1 | 89.5 | 550 | | middle - upper bathyal | Echuca Shoals | 2650 | 2700 |
| Oliver 1 | KCN-22 | KCN-23 | 2446.5 | 2446.5 | 89.5 | 91.65 | 500 | | upper bathyal | Echuca Shoals | 2650 | 2700 |
| Oliver 1 | X.asperatus | | 2534 | 2540 | 98.5 | 100 | 425 | | open marine | Echuca Shoals | 2650 | 2700 |
| Oliver 1 | C.denticulata | | 2592 | 2604 | 101.5 | 103.5 | 525 | | open marine | Echuca Shoals | 2650 | 2700 |
| Oliver 1 | KCN-27 | | 2565 | 2581 | 100.8 | 103.8 | 550 | | middle - upper bathyal | Echuca Shoals | 2650 | 2700 |
| Oliver 1 | M.tetracantha | D.davidii | 2608 | 2609 | 103.5 | 106.5 | 525 | | open marine | Echuca Shoals | 2650 | 2700 |
| Oliver 1 | KCN-28 | | 2592 | 2606 | 103.8 | 107.2 | 550 | | middle - upper bathyal | Echuca Shoals | 2650 | 2700 |
| Oliver 1 | KCN-29 | | 2608 | 2608 | 107.2 | 108.9 | 400 | | outer neritic or deeper | Echuca Shoals | 2650 | 2700 |
| Oliver 1 | KCN-29 | KCN-30 | 2612 | 2612 | 107.2 | 108.9 | 400 | | distal neritic | Echuca Shoals | 2650 | 2700 |
| Oliver 1 | KCN-30 | | 2615 | 2615 | 108.9 | 110.6 | 400 | | outer neritic or deeper | Echuca Shoals | 2650 | 2700 |
| Oliver 1 | O.operculata | | 2612 | 2627 | 109 | 115 | 525 | | open marine | Echuca Shoals | 2650 | 2700 |
| Oliver 1 | A.cinctum | M.australis | 2645 | 2645 | 115 | 118 | 525 | | open marine | Echuca Shoals | 2650 | 2700 |
| Oliver 1 | M.australis | | 2654 | 2672 | 118 | 123 | 525 | | open marine | Echuca Shoals | 2650 | 2700 |
| Oliver 1 | M.testudinaria | | 2676 | 2681 | 123 | 126.5 | 525 | | open marine | Echuca Shoals | 2650 | 2700 |
| Oliver 1 | S.tabulata | | 2686 | 2691 | 131 | 133 | 325 | | shelfal - The downhole increase in the proportion of spores and pollen in the assemblage suggests possible downhole shallowing of shelfal environments of deposition | Echuca Shoals | 2650 | 2700 |
| Oliver 1 | S.areolata | | 2696 | 2696 | 133 | 135 | 325 | | shelfal marine | Echuca Shoals | 2650 | 2700 |
| Oliver 1 | C.delicata | | 2707 | 2758 | 138 | 139 | 325 | | shelfal marine | Echuca Shoals | 2650 | 2700 |
| Oliver 1 | P.iehiense | | 2789 | 2840 | 140 | 142.5 | 325 | | shelfal marine or deeper | Echuca Shoals | 2650 | 2700 |
| Oliver 1 | D.jurassicum | | 2874 | 2894 | 142.5 | 143.8 | 525 | | open marine | Echuca Shoals | 2650 | 2700 |
| Oliver 1 | W.spectabilis | | 2900 | 2943 | 153.8 | 158.5 | 525 | | open maine - The environment of deposition is interpreted as open marine, the increasing proportion of vascular plant debris suggests a shallowing with depth | Echuca Shoals | 2650 | 2700 |
| Oliver 1 | D.complex | | 2953 | 2956 | 167.5 | 177 | 100 | | deltaic - Spinose acritarchs did not exceed 1.5% and a single, tentatively identified, dinoflagellate was recorded. The environment of deposition is interpreted as deltaic | Echuca Shoals | 2650 | 2700 |
| Oliver 1 | D.caddaensis | | 2961 | 3044 | 174.5 | 179.5 | 100 | | shallow marine to marine/deltaic | Echuca Shoals | 2650 | 2700 |
| Oliver 1 | C.torosa | | 3094 | 3287 | 189.5 | 204.5 | 200 | | shallow marine to marine/deltaic - possibly shallowing downhole, although low recoveries below 3200m inhibit interpretation | Echuca Shoals | 2650 | 2700 |

## Appendix A - Biostrat zones and depositional environment information for Echuca Shoals Formation

| well_name | biozone name | biozone range | biostrat depth top (m) | biostrat depth base (m) | biozone age from (Ma) | biozone age to (Ma) | age_code | notes on biozone age | depositional enviroment | formation name | formation top (m) | formation base (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Oliver 1 | A.reducta | | 3417 | 3432 | 204.5 | 206.5 | 100 | | fluvio-deltaic - environment is possibly fluvio-deltaic | Echuca Shoals | 2650 | 2700 |
| Oliver 1 | | | 733 | 816 | | | 300 | | middle neritic | Echuca Shoals | 2650 | 2700 |
| Oliver 1 | indeterminate | | 990 | 1455 | | | 250 | | high energy inner neritic (1083m, 1142m & 1276 to 1455m) - undifferentiated marine (990m and 1188 to 1205.5m) | Echuca Shoals | 2650 | 2700 |
| Oliver 1 | indeterminate | | 1823 | 1853 | | | 300 | | low-middle energy inner neritic | Echuca Shoals | 2650 | 2700 |
| Oliver 1 | indeterminate | | 1871.5 | 1940.5 | | | 425 | | undifferentiated marine | Echuca Shoals | 2650 | 2700 |
| Oliver 1 | indeterminate | | 1983 | 1983 | | | 300 | | low energy inner neritic | Echuca Shoals | 2650 | 2700 |
| Oliver 1 | indeterminate | | 1993.5 | 1993.5 | | | 350 | | middle neritic | Echuca Shoals | 2650 | 2700 |
| Oliver 1 | indeterminate | | 2023.5 | 2056.5 | | | 300 | | low energy inner neritic? | Echuca Shoals | 2650 | 2700 |
| Oliver 1 | indeterminate | | 2080.5 | 2080.5 | | | 300 | | moderate-high energy inner neritic | Echuca Shoals | 2650 | 2700 |
| Oliver 1 | indeterminate | | 2110.5 | 2110.5 | | | 300 | | moderate-high energy inner neritic | Echuca Shoals | 2650 | 2700 |
| Oliver 1 | indeterminate | | 2119.5 | 2119.5 | | | 300 | | low energy inner neritic - middle neritic | Echuca Shoals | 2650 | 2700 |
| Oliver 1 | | | 2126.5 | 2264 | | | 425 | | undifferentiated marine | Echuca Shoals | 2650 | 2700 |
| Oliver 1 | | | 2349.5 | 2368.5 | | | 425 | | undifferentiated marine | Echuca Shoals | 2650 | 2700 |
| Oliver 1 | inderterminate | | 2627 | 2627 | | | 425 | Sample lies between KCN-30 (2615m) and A.cinctum (2645m) and thus has been assigned an age between 110.6MA and 115MA | undifferentiated marine | Echuca Shoals | 2650 | 2700 |
| Oliver 1 | CC2 | CC4 | 2645 | 2686 | | | 350 | Hauterivian-Valanginian | mid neritic to distal neritic at base | Echuca Shoals | 2650 | 2700 |
| Oliver 1 | inderterminate | | 2691 | 2840 | | | 425 | | undifferentiated marine | Echuca Shoals | 2650 | 2700 |
| Oliver 1 | E.communis | V.stradneri | 2900 | 2900 | | | 400 | lower late Kimmeridgian - Middle Oxfordian | distal neritic | Echuca Shoals | 2650 | 2700 |
| Oliver 1 | indeterminate | | 1643.5 | 1803.5 | | | 300 | | high energy inner neritic | Echuca Shoals | 2650 | 2700 |
| Oliver 1 | | | 2286.5 | 2286.5 | | | 300 | | low energy inner neritic - middle neritic | Echuca Shoals | 2650 | 2700 |
| Paqualin 1 | KCN-6 | | 2295 | 2295 | 68 | 70.5 | 450 | | outer neritic-upper bathyal | Echuca Shoals | 2492.5 | 2528 |
| Paqualin 1 | C.diebelii | | 2290 | 2300 | 66 | 73 | 525 | | open marine - prominence of microplankton and the nature of plant debris suggests open marine | Echuca Shoals | 2492.5 | 2528 |
| Paqualin 1 | KCN-21 | | 2286 | 2286 | 88.1 | 89.5 | 450 | | middle-upper bathyal | Echuca Shoals | 2492.5 | 2528 |
| Paqualin 1 | M.tetracantha | | 2469 | 2480 | 103.5 | 106.5 | 525 | | open marine | Echuca Shoals | 2492.5 | 2528 |
| Paqualin 1 | O.operculata | | 2489.5 | 2489.5 | 109 | 115 | 525 | | open marine | Echuca Shoals | 2492.5 | 2528 |
| Paqualin 1 | M.australis | | 2493 | 2511 | 118 | 123 | 425 | | open marine, possibly shelfal - There is a marginal downhole increase in in the proportion of woody and cuticular debris, although neither exceeds 3%, which with high microplankton to spore-pollen ratio, suggests open marin, possibly shelfal depositional | Echuca Shoals | 2492.5 | 2528 |
| Paqualin 1 | S.areolata | | 2525 | 2525 | 133 | 135 | 325 | | open marine, possibly shelfal - Although there is a definite increase in the spore-pollen to microplankton ratio, the prominence of microplankton and the relative low proportion of 'fresh' vascular plant debris suggests and open marine, possible shelfal, | Echuca Shoals | 2492.5 | 2528 |
| Paqualin 1 | C.delicata | | 2526 | 2583 | 138 | 139 | 525 | | open marine | Echuca Shoals | 2492.5 | 2528 |
| Paqualin 1 | K.wisemaniae | | 2619 | 2638 | 139 | 140 | 525 | | open marine | Echuca Shoals | 2492.5 | 2528 |
| Paqualin 1 | P.iehiense | | 2633 | 2685 | 140 | 142.5 | 525 | | open marine - prominence of microplankton and scarcity of vascular plant debris suggest open marine environments of deposition | Echuca Shoals | 2492.5 | 2528 |
| Paqualin 1 | D.jurassicum | | 2844 | 2907 | 142.5 | 143.8 | 525 | | open marine | Echuca Shoals | 2492.5 | 2528 |
| Paqualin 1 | D.swanense | | 2925 | 2952 | 146 | 150.3 | 525 | | open marine | Echuca Shoals | 2492.5 | 2528 |

## Appendix A - Biostrat zones and depositional environment information for Echuca Shoals Formation

| well_name | biozone name | biozone range | biostrat depth top (m) | biostrat depth base (m) | biozone age from (Ma) | biozone age to (Ma) | age_code | notes on biozone age | depositional enviroment | formation name | formation top (m) | formation base (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Paqualin 1 | W.clathrata | | 2961 | 3051 | 150.3 | 153.8 | 525 | | open marine | Echuca Shoals | 2492.5 | 2528 |
| Paqualin 1 | W.spectabilis | | 3060 | 3789 | 153.8 | 158.5 | 425 | | open marine to shelfal - The microplankton to spore-pollen ratio indicates open marine environments of deposition, although increased vascular plant debris indicate relatively high rates of deposition, some of which may derive from shelfal locations | Echuca Shoals | 2492.5 | 2528 |
| Paqualin 1 | indeterminate | | 1535 | 1650 | | | 425 | | undifferentiated marine | Echuca Shoals | 2492.5 | 2528 |
| Paqualin 1 | indeterminate | | 4077 | 4131 | | | 250 | Sample lies well below W.spectabilis (3789m) and is at least 158.5MA | proximal neritic | Echuca Shoals | 2492.5 | 2528 |
| Paqualin 1 | indeterminate | | 4169 | 4169 | | | 425 | | undifferentiated marine | Echuca Shoals | 2492.5 | 2528 |
| Paqualin 1 | indeterminate | | 4179 | 4179 | | | 425 | | undifferentiated marine | Echuca Shoals | 2492.5 | 2528 |
| Paqualin 1 | indeterminate | | 4215 | 4215 | | | 300 | | inner-middle neritic | Echuca Shoals | 2492.5 | 2528 |
| Paqualin 1 | indeterminate | | 4218 | 4218 | | | 425 | | undifferentiated marine | Echuca Shoals | 2492.5 | 2528 |
| Paqualin 1 | indeterminate | | 4212 | 4212 | | | 300 | | inner neritic | Echuca Shoals | 2492.5 | 2528 |
| Pascal 1 | KCN-1 | | 2200.5 | 2298 | 65 | 65.88 | 500 | | upper bathyal | Echuca Shoals | 2517 | 2525 |
| Pascal 1 | KCN-2 | KCN-3 | 2305 | 2333 | 65.88 | 66.3 | 500 | | upper bathyal | Echuca Shoals | 2517 | 2525 |
| Pascal 1 | KCN-4 | | 2345.5 | 2345.5 | 67.6 | 67.75 | 500 | | upper bathyal | Echuca Shoals | 2517 | 2525 |
| Pascal 1 | KCN-7 | | 2378 | 2413 | 70.5 | 72.2 | 500 | | upper bathyal | Echuca Shoals | 2517 | 2525 |
| Pascal 1 | KCN-9 | | 2428 | 2428 | 73 | 73.3 | 550 | | mid-upper bathyal | Echuca Shoals | 2517 | 2525 |
| Pascal 1 | KCN-10 | KCN-11 | 2443 | 2443 | 73.3 | 75.5 | 550 | | mid-upper bathyal | Echuca Shoals | 2517 | 2525 |
| Pascal 1 | KCN-13 | KCN-14 | 2453 | 2453 | 81 | 81 | 550 | | mid-upper bathyal | Echuca Shoals | 2517 | 2525 |
| Pascal 1 | KCN-17 | | 2460 | 2460 | 83.8 | 85 | 550 | | mid-upper bathyal | Echuca Shoals | 2517 | 2525 |
| Pascal 1 | KCN-19 | | 2473 | 2473 | 85.5 | 86 | 550 | | mid-upper bathyal | Echuca Shoals | 2517 | 2525 |
| Pascal 1 | KCN-25B | | 2498 | 2498 | 96.3 | 97.6 | 550 | | mid-upper bathyal | Echuca Shoals | 2517 | 2525 |
| Pascal 1 | KCN-27 | | 2503 | 2507 | 100.8 | 103.8 | 550 | | mid-upper bathyal | Echuca Shoals | 2517 | 2525 |
| Pascal 1 | KCN-29 | | 2511 | 2515 | 107.2 | 108.9 | 400 | | outer neritic or deeper | Echuca Shoals | 2517 | 2525 |
| Pascal 1 | KCN-30 | | 2517 | 2517 | 108.9 | 110.6 | 400 | | outer neritic or deeper | Echuca Shoals | 2517 | 2525 |
| Pascal 1 | S.wigginsii | | 2536 | 2557 | 214 | 220.5 | 100 | | fringing marine environment - due to abumdance of dinoflagellates | Echuca Shoals | 2517 | 2525 |
| Pascal 1 | S.speciosus | | 2692 | 2843 | 214 | 226 | 100 | | proximal delta plain environment of deposition | Echuca Shoals | 2517 | 2525 |
| Pascal 1 | S.speciosus | | 2692 | 2843 | 217.5 | 232 | 100 | | proximal delta plain environment of deposition | Echuca Shoals | 2517 | 2525 |
| Pascal 1 | indeterminate | | 2483 | 2493.5 | | | 550 | Sample has an age between 86MA and 87.5MA | mid-upper bathyal | Echuca Shoals | 2517 | 2525 |
| Pascal 1 | indeterminate | | 2520 | 2520 | | | 400 | Sample is below KCN-30 (2517m) and so is at least older than 110.6MA | middle neritic or deeper | Echuca Shoals | 2517 | 2525 |
| Pascal 1 | indeterminate | | 2522 | 2523.5 | | | 300 | | undifferentiated neritic | Echuca Shoals | 2517 | 2525 |
| Pascal 1 | indeterminate | | 2588 | 2588 | | | 425 | | undifferentiated marine | Echuca Shoals | 2517 | 2525 |
| Pascal 1 | indeterminate | | 2622 | 2622 | | | 300 | | inner?-middle neritic | Echuca Shoals | 2517 | 2525 |
| Pascal 1 | indeterminate | | 2699 | 2699 | | | 425 | | undifferentiated marine | Echuca Shoals | 2517 | 2525 |
| Pascal 1 | indeterminate | | 2715.5 | 2715.5 | | | 300 | | inner neritic | Echuca Shoals | 2517 | 2525 |
| Pascal 1 | indeterminate | | 2827 | 2827 | | | 425 | | undifferentiated marine | Echuca Shoals | 2517 | 2525 |
| Prion 1 | | | 213 | 908 | | | 200 | Miocene to more recent | inner neritic zone of continental shelf, littoral marine, under shallow-water with proably high energy | Echuca Shoals | 2626 | 2634 |
| Prion 1 | | | 911 | 1011 | | | 250 | Middle to Lower Miocene | inner neritic zone (marginal part) of the shelf under high energy conditions | Echuca Shoals | 2626 | 2634 |

## Appendix A - Biostrat zones and depositional environment information for Echuca Shoals Formation

| well_name | biozone name | biozone range | biostrat depth top (m) | biostrat depth base (m) | biozone age from (Ma) | biozone age to (Ma) | age_code | notes on biozone age | depositional enviroment | formation name | formation top (m) | formation base (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Prion 1 | | | 1097 | 1676 | | | 325 | Eocene | shelf - the interval seems to have been deposition on the shelf (behind a barrier? : lack of planktonic material) with the possibility of the installisation of a Nummulite constructed body from 1494 to 1585m | Echuca Shoals | 2626 | 2634 |
| Prion 1 | | | 1704 | 1859 | | | 525 | Lower Eocene (to Paleocene?) | connected with open sea but with fluctuating depths | Echuca Shoals | 2626 | 2634 |
| Prion 1 | | | 1880 | 2134 | | | 325 | Palaeocene | mid to outer shelf - The diversity and abundance of the association could indicate mid to outer shelf deposits; the occurrence of some forms indicative of deeper water depths in the lower part of the interval could indicate a shallowing of the water colum | Echuca Shoals | 2626 | 2634 |
| Prion 1 | | | 2161 | 2435 | | | 325 | Maastrichtian | proable outer shelf under normal marine conditions - the levels of agglutinated assemblages could be the result of a turbidite period | Echuca Shoals | 2626 | 2634 |
| Prion 1 | | | 2465 | 2499 | | | 325 | Lower Maastrichtian | shelf - normal marine conditions - could reflect restricted conditions at this level | Echuca Shoals | 2626 | 2634 |
| Prion 1 | | | 2513 | 2524 | | | 425 | Campanian | outer shelf - slope | Echuca Shoals | 2626 | 2634 |
| Prion 1 | | | 2626 | 2634 | | | 225 | Jurassic | shallow marine, probably near shore environment - according to palynoplanktology, glauconitic sandstones were deposited in a shallow marine, probably near shore environment | Echuca Shoals | 2626 | 2634 |
| Rainier 1 | C.denticulata | | 1647 | 1650.5 | 101.5 | 103.5 | 525 | | open marine | Echuca Shoals | 1652 | 1674 |
| Rainier 1 | M.tetracantha | | 1650 | 1653 | 103.5 | 106.5 | 525 | | open marine | Echuca Shoals | 1652 | 1674 |
| Rainier 1 | M.australis | | 1653 | 1659 | 118 | 123 | 525 | | open marine, possibley shelfal | Echuca Shoals | 1652 | 1674 |
| Rainier 1 | P.burgeri | | 1662.6 | 1665 | 126.5 | 131 | 525 | | open marine, possibley shelfal | Echuca Shoals | 1652 | 1674 |
| Rainier 1 | S.tabulata | | 1667.1 | 1667.4 | 131 | 133 | 325 | | shelfal marine | Echuca Shoals | 1652 | 1674 |
| Rainier 1 | C.delicata | | 1669.2 | 1671.9 | 138 | 139 | 525 | | open marine | Echuca Shoals | 1652 | 1674 |
| Rainier 1 | D.jurassicum | | 1672.2 | 1794 | 142.5 | 143.8 | 525 | | open marine | Echuca Shoals | 1652 | 1674 |
| Rainier 1 | W.spectabilis | | 1923 | 2115 | 153.8 | 158.5 | 525 | | open marine, possibley shelfal | Echuca Shoals | 1652 | 1674 |
| Rainier 1 | C.turbatus | | 2120 | 2120 | 177 | 189.5 | 100 | | deltaic | Echuca Shoals | 1652 | 1674 |
| Rainier 1 | M.crenulatus | S.speciosus | 2190 | 2244 | 206.5 | 214 | 100 | | lower delta plain | Echuca Shoals | 1652 | 1674 |
| Rainier 1 | S.wigginsii | S.speciosus | 2262 | 2361 | 214 | 220.5 | 100 | | marginal marine, shallowing with depth | Echuca Shoals | 1652 | 1674 |
| Rowan 1 | CP9 | | 1525 | 1522 | 52.4 | 53.5 | 350 | | middle neritic | Echuca Shoals | 2818 | 2865 |
| Rowan 1 | CP8 | | 1533.3 | 1587.5 | 53.5 | 55.4 | 350 | | middle neritic | Echuca Shoals | 2818 | 2865 |
| Rowan 1 | CP5 | CP7 | 1887 | 1926 | 57.8 | 59.3 | 400 | | outer neritic ? | Echuca Shoals | 2818 | 2865 |
| Rowan 1 | KCN-1 | | 1950 | 1969 | 65 | 65.88 | 425 | | undifferentiated marine | Echuca Shoals | 2818 | 2865 |
| Rowan 1 | KCN-7 | | 2360 | 2415 | 70.5 | 72.2 | 500 | | upper bathyal | Echuca Shoals | 2818 | 2865 |
| Rowan 1 | KCN-8 | | 2431 | 2475 | 72.2 | 73 | 500 | | upper bathyal | Echuca Shoals | 2818 | 2865 |
| Rowan 1 | KCN-9 | | 2512.5 | 2512.5 | 73 | 73.3 | 500 | | upper bathyal | Echuca Shoals | 2818 | 2865 |
| Rowan 1 | KCN-12 | | 2520 | 2520 | 78.4 | 81 | 550 | | middle-upper bathyal | Echuca Shoals | 2818 | 2865 |
| Rowan 1 | KCN-13 | KCN-14 | 2555 | 2555 | 81 | 81 | 550 | | middle-upper bathyal | Echuca Shoals | 2818 | 2865 |
| Rowan 1 | KCN-16 | | 2576 | 2576 | 83 | 83.8 | 550 | | middle-upper bathyal | Echuca Shoals | 2818 | 2865 |
| Rowan 1 | KCN-17 | | 2598 | 2598 | 83.8 | 85 | 550 | | middle-upper bathyal | Echuca Shoals | 2818 | 2865 |
| Rowan 1 | KCN-18 | | 2628 | 2628 | 85 | 85.5 | 450 | | middle-upper bathyal | Echuca Shoals | 2818 | 2865 |
| Rowan 1 | KCN-21 | | 2655 | 2655 | 88.1 | 89.5 | 550 | | middle-upper bathyal | Echuca Shoals | 2818 | 2865 |
| Rowan 1 | KCN-22 | KCN-23 | 2673 | 2674 | 89.5 | 91.65 | 550 | | middle-upper bathyal | Echuca Shoals | 2818 | 2865 |
| Rowan 1 | KCN-22 | | 2667.5 | 2667.5 | 89.5 | 91.65 | 425 | | undifferentiated marine | Echuca Shoals | 2818 | 2865 |

## Appendix A - Biostrat zones and depositional environment information for Echuca Shoals Formation

| well_name | biozone name | biozone range | biostrat depth top (m) | biostrat depth base (m) | biozone age from (Ma) | biozone age to (Ma) | age_code | notes on biozone age | depositional enviroment | formation name | formation top (m) | formation base (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rowan 1 | KCN-25B | | 2676 | 2676 | 96.3 | 97.6 | 550 | | middle-upper bathyal | Echuca Shoals | 2818 | 2865 |
| Rowan 1 | KCN-25C | | 2686 | 2715 | 97.6 | 99.3 | 550 | | middle-upper bathyal | Echuca Shoals | 2818 | 2865 |
| Rowan 1 | KCN-26 | | 2730 | 2730 | 99.3 | 100.8 | 550 | | middle-upper bathyal | Echuca Shoals | 2818 | 2865 |
| Rowan 1 | KCN-27 | | 2742 | 2817 | 100.8 | 103.8 | 500 | | upper bathyal = most / (2786 is outer neritic or deeper) | Echuca Shoals | 2818 | 2865 |
| Rowan 1 | S.tabulata | | 2808 | 2834 | 131 | 133 | 325 | | shelfal marine - the prominence of vascular plant debris and the spor-pollen to microplankton ratio suggests shelfal marine environments of deposition | Echuca Shoals | 2818 | 2865 |
| Rowan 1 | W.spectabilis | | 2865 | 3110 | 153.8 | 158.5 | 325 | | shelfal marine - the prominence of vascular plant debris and the dominance of the palynomorph suite by spores-pollen, suggests a shelfal marine environment of deposition, although, possible transport of this material to deeper environments cannot be disco | Echuca Shoals | 2818 | 2865 |
| Rowan 1 | R.aemula | | 3133 | 3183 | 158.5 | 160.3 | 325 | | shelfal marine environment - the high proportions of vascular plant debris and the dominance of the playnomorph suites by spores and pollen above 3150m suggests shelfal marine environments of depostion. The increasing prominence fo microplankton below 315 | Echuca Shoals | 2818 | 2865 |
| Rowan 1 | D.complex | | 3193 | 3305 | 167.5 | 177 | 100 | | lower delta plain (fringing marine to fluvio-deltaic) - The prominence of vascular plant debris, the prominence of acritarchs and the apparent absence of dinoflagellates suggest lower delta plain environments of deposition, ranging from fringing marine to | Echuca Shoals | 2818 | 2865 |
| Rowan 1 | D.caddaensis | | 3301 | 3302 | 174.5 | 179.5 | 100 | | fringing marine to marine-deltaic | Echuca Shoals | 2818 | 2865 |
| Rowan 1 | C.turbatus | | 3316 | 3316 | 177 | 189.5 | 100 | | lower delta plain to marine deltaic | Echuca Shoals | 2818 | 2865 |
| Rowan 1 | indeterminate | | 1515 | 1521 | | | 350 | | middle neritic | Echuca Shoals | 2818 | 2865 |
| Rowan 1 | indeterminate | | 1728 | 1728 | | | 350 | | middle-outer neritic | Echuca Shoals | 2818 | 2865 |
| Rowan 1 | indeterminate | | 1830 | 1830 | | | 425 | | undifferentiated marine | Echuca Shoals | 2818 | 2865 |
| Rowan 1 | indeterminate | | 2668 | 2668.5 | | | 550 | Sample lies in the KCN-22 zone and thus has been assigned an age of 91.65MA | middle-upper bathyal (anoxic) ? | Echuca Shoals | 2818 | 2865 |
| Rowan 1 | indeterminate | | 2819 | 2819 | | | 425 | | undifferentiated marine | Echuca Shoals | 2818 | 2865 |
| Skua 1 | | | 265 | 434 | | | 225 | Pleistocene to Miocene | inner shelf under warm and shallow water - more marine type of depostion | Echuca Shoals | 2405 | 2417 |
| Skua 1 | | | 458 | 777 | | | 225 | Middle to Lower Miocene | inner shelf - under warm shallow water and restricted conditions | Echuca Shoals | 2405 | 2417 |
| Skua 1 | | | 914 | 1350 | | | 225 | Eocene | inner shelf - restricted conditions and shallow water | Echuca Shoals | 2405 | 2417 |
| Skua 1 | | | 1366 | 1457 | | | 325 | Lower Eocene - probable | shelf - deposited over the shelf in an area submitted to an important continental influx (sandstones) which can obliterate the marine influx (planktonic forams) | Echuca Shoals | 2405 | 2417 |
| Skua 1 | | | 1474 | 1850 | | | 325 | Paleocene | shelf - normal marine conditions | Echuca Shoals | 2405 | 2417 |
| Snowmass 1 | KCN-4 | | 867.5 | 867.5 | 67.6 | 67.75 | 350 | | middle-outer neritic | Echuca Soals | 1258 | 1290 |
| Snowmass 1 | KCN-5 | | 893.5 | 893.5 | 67.75 | 68 | 350 | | middle-outer neritic | Echuca Soals | 1258 | 1290 |
| Snowmass 1 | KCN-8 | | 911 | 935 | 72.2 | 73 | 350 | | middle-outer neritic | Echuca Soals | 1258 | 1290 |
| Snowmass 1 | KCN-13 | | 962 | 962 | 81 | 81 | 400 | | outer neritic | Echuca Soals | 1258 | 1290 |
| Snowmass 1 | KCN-14 | KCN-15 | 974 | 974 | 81 | 82 | 400 | | outer neritic | Echuca Soals | 1258 | 1290 |

## Appendix A - Biostrat zones and depositional environment information for Echuca Shoals Formation

| well_name | biozone name | biozone range | biostrat depth top (m) | biostrat depth base (m) | biozone age from (Ma) | biozone age to (Ma) | age_code | notes on biozone age | depositional enviroment | formation name | formation top (m) | formation base (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Snowmass 1 | KCN-16 | | 988 | 988 | 83 | 83.8 | 400 | | outer neritic | Echuca Soals | 1258 | 1290 |
| Snowmass 1 | KCN-17 | | 1032 | 1032 | 83.8 | 85 | 450 | | outer neritic - upper bathyal | Echuca Soals | 1258 | 1290 |
| Snowmass 1 | KCN-18 | | 1046 | 1118 | 85 | 85.5 | 500 | | upper bathyal (1046) | Echuca Soals | 1258 | 1290 |
| Snowmass 1 | KCN-19 | KCN-20 | 1128 | 1128 | 85.5 | 86 | 450 | | outer neritic - upper bathyal | Echuca Soals | 1258 | 1290 |
| Snowmass 1 | KCN-21 | | 1148.5 | 1148.5 | 88.1 | 89.5 | 500 | | upper bathyal | Echuca Soals | 1258 | 1290 |
| Snowmass 1 | KCN-22 | KCN-23 | 1169.3 | 1169.3 | 89.5 | 91.65 | 425 | | undifferentiated marine | Echuca Soals | 1258 | 1290 |
| Snowmass 1 | KCN-25A | | 1182 | 1182 | 95.2 | 96.3 | 450 | | outer neritic - upper bathyal | Echuca Soals | 1258 | 1290 |
| Snowmass 1 | KCN-25B | | 1196 | 1196 | 96.3 | 97.6 | 500 | | upper bathyal | Echuca Soals | 1258 | 1290 |
| Snowmass 1 | KCN-25C | | 1209 | 1237.5 | 97.6 | 99.3 | 500 | | upper bathyal to mid-upper bathyal at base | Echuca Soals | 1258 | 1290 |
| Snowmass 1 | KCN-27 | | 1250 | 1250 | 100.8 | 103.8 | 550 | | mid-upper bathyal | Echuca Soals | 1258 | 1290 |
| Snowmass 1 | KCN-28 | | 1254.5 | 1254.5 | 103.8 | 107.2 | 550 | | mid-upper bathyal | Echuca Soals | 1258 | 1290 |
| Snowmass 1 | M.australis | | 1265 | 1268 | 118 | 123 | 325 | | shelfal marine | Echuca Soals | 1258 | 1290 |
| Snowmass 1 | M.testudinaria | P.burgeri | 1270 | 1270 | 123 | 126.5 | 325 | | shelfal marine | Echuca Soals | 1258 | 1290 |
| Snowmass 1 | S.tabulata | | 1275 | 1277 | 131 | 133 | 325 | | shelfal marine | Echuca Soals | 1258 | 1290 |
| Snowmass 1 | E.torynum | C.delicata | 1279.5 | 1291 | 135 | 136 | 425 | | undifferentiated marine | Echuca Soals | 1258 | 1290 |
| Snowmass 1 | S.speciosus | | 1296 | 1515 | 214 | 226 | 100 | | lower delta plain to marginal marine | Echuca Soals | 1258 | 1290 |
| Snowmass 1 | S.speciosus | | 1296 | 1515 | 217.5 | 232 | 100 | | lower delta plain to marginal marine | Echuca Soals | 1258 | 1290 |
| Snowmass 1 | S.quadrifidus | | 1586 | 1653 | 226 | 238.5 | 100 | | lower delta plain to marginal marine | Echuca Soals | 1258 | 1290 |
| Snowmass 1 | indeterminate | | 798.5 | 798.5 | | | 350 | | inner-middle neritic | Echuca Soals | 1258 | 1290 |
| Snowmass 1 | indeterminate | | 1260 | 1265 | | | 400 | Sample lies below KCN-28 (1254.5m) and above M.australis (1265M) and thus is older than 107.2MA and younger than 118MA | outer neritic ? (anoxic) | Echuca Soals | 1258 | 1290 |
| Snowmass 1 | indeterminate | | 1266.5 | 1270 | | | 300 | Sample lies between M.australis (1265m) and M.testudinaria (1270m) so has been given an estimated age of: 123MA | inner-middle neritic ? (anoxic) | Echuca Soals | 1258 | 1290 |
| Snowmass 1 | indeterminate | | 1273.8 | 1274 | | | 400 | Sample liest between M.testudinaria/P.burgeri (1270m) and S.tabulata (1275m) and thus has been assigned an age between 131MA and 133MA | middle-outer neritic ? (anoxic) | Echuca Soals | 1258 | 1290 |
| Snowmass 1 | indeterminate | | 1277 | 1277 | | | 300 | Sample lies between S.tabulata (1275m) and E.torynum/C.delicata (1279.5m), thus has been assigned an age of at least 133MA | inner-middle neritic ? (anoxic) | Echuca Soals | 1258 | 1290 |

## Appendix A - Biostrat zones and depositional environment information for Jamieson Formation

| well_name | biozone name | biozone range | biostrat depth top (m) | biostrat depth base (m) | biozone age from (Ma) | biozone age to (Ma) | age_code | notes on biozone age | depositional enviroment | formation name | formation top (m) | formation base (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Allaru 1 | D.davidii | | 2304 | 2307 | 106.5 | 109 | 525 | | open marine - The predominance of dinoflagellates and the relatively low proportion and composition of vascular plant debris (mainly opaque and semi-opaque fragments) suggest and open marine environment of deposition | Jamieson | 2227 | 2310 |
| Allaru 1 | A.cinctum | | 2310 | 2313 | 115 | 118 | 525 | | open marine - The abundance of dinoflagellates and the relatively low proportion of vascular plant debris suggest an open marine environment of deposition | Jamieson | 2227 | 2310 |
| Allaru 1 | M.australis | M.australis Lw | 2319 | 2322 | 118 | 123 | 525 | | open marine - The abundance of dinoflagellates and the relatively low proportion of vascular plant debris suggest an open marine environment of deposition | Jamieson | 2227 | 2310 |
| Allaru 1 | M.testudinaria | | 2328 | 2343 | 123 | 126.5 | 325 | | shelfal marine - The downhole increase in the vascular plant debris and increase in spore-pollen to microplankton ratio through this interval suggests some downhole shallowing to shelfal environments | Jamieson | 2227 | 2310 |
| Allaru 1 | P.iehiense | D.jurassicum | 2343 | 2403 | 140 | 142.5 | 525 | | open marine - The microplankton to spore-pollen ratio and the relatively low proportion of vascular plant debris in the residues suggest open marine environments | Jamieson | 2227 | 2310 |
| Allaru 1 | D.swanense | | 2406 | 2421 | 146 | 150.3 | 525 | | open marine - The microplankton to spore-pollen ratio suggests open marine environments of deposition | Jamieson | 2227 | 2310 |
| Allaru 1 | W.clathrata | | 2424 | 2448 | 150.3 | 153.8 | 525 | | open marine - shallowing downhole - The continued prominence of dinoflagellates suggests open marine conditions although there is a marked downhole increase in the spore-pollen to microplankton ratio suggesting shallowing relative to the overlying section | Jamieson | 2227 | 2310 |
| Allaru 1 | W.spectabilis | | 2451 | 2946 | 153.8 | 158.5 | 425 | | open marine - shelfal - The prominence of microplankton suggests open marine environments of deposition although the increase in the vascular plant debris suggests shelfal influence | Jamieson | 2227 | 2310 |
| Avocet 1a | KCN-3 | | 1224 | 1224 | 66.3 | 67.6 | 400 | Latest Early-Late Maastrichtian interpreted by Rexillius (WCR) | outer neritic | Jamieson | 1570 | 1725 |
| Avocet 1a | KCN-11 | | 1245 | 1245 | 75.5 | 78.4 | 450 | basal Middle Campanian | outer neritic-upper bathyal | Jamieson | 1570 | 1725 |
| Avocet 1a | KCN-16 | | 1310.5 | 1330 | 83 | 83.8 | 450 | upper Late Santonian | outer neritic-upper bathyal | Jamieson | 1570 | 1725 |
| Avocet 1a | KCN-17 | | 1350 | 1350 | 83.8 | 85 | 450 | lower Late Santonian | outer neritic-upper bathyal | Jamieson | 1570 | 1725 |
| Avocet 1a | KCN-18 | | 1369 | 1405 | 85 | 85.5 | 450 | upper Early Santonian | outer neritic-upper bathyal | Jamieson | 1570 | 1725 |
| Avocet 1a | KCN-20 | | 1434 | 1492 | 86.2 | 88.1 | 450 | Coniacian | outer neritic-upper bathyal | Jamieson | 1570 | 1725 |
| Avocet 1a | KCN-20 | KCN-21 | 1510 | 1510 | 86.2 | 88.1 | 500 | Turonian/Coniacian | upper bathyal | Jamieson | 1570 | 1725 |
| Avocet 1a | KCN-25A | | 1560 | 1600 | 95.2 | 96.3 | 500 | upper middle-early Late Cenomanian | upper bathyal | Jamieson | 1570 | 1725 |
| Avocet 1a | KCN-25B | KCN-25C | 1617.5 | 1638 | 96.3 | 97.6 | 500 | Late Albian-lower Middle Cenomanian | upper bathyal | Jamieson | 1570 | 1725 |
| Avocet 1a | C.denticulata | P.ludbrookiae | 1686 | 1686 | 101.5 | 103.5 | 425 | | open marine possibley shelfal. | Jamieson | 1570 | 1725 |
| Avocet 1a | M.tetracantha | | 1698 | 1714.5 | 103.5 | 106.5 | 525 | | open marine. | Jamieson | 1570 | 1725 |
| Avocet 1a | KCN-28 | | 1686 | 1698 | 103.8 | 107.2 | 550 | upper Early-lower Middle Albian | middle-upper bathyal | Jamieson | 1570 | 1725 |
| Avocet 1a | D.davidii | | 1718 | 1718 | 106.5 | 109 | 525 | | open marine | Jamieson | 1570 | 1725 |
| Avocet 1a | KCN-30 | | 1702 | 1703 | 108.9 | 110.6 | 425 | lower Late Aptian | undifferentiated marine | Jamieson | 1570 | 1725 |
| Avocet 1a | M.australis | | 1726 | 1734 | 118 | 123 | 325 | | shelfal marine | Jamieson | 1570 | 1725 |

## Appendix A - Biostrat zones and depositional environment information for Jamieson Formation

| well_name | biozone name | biozone range | biostrat depth top (m) | biostrat depth base (m) | biozone age from (Ma) | biozone age to (Ma) | age_code | notes on biozone age | depositional enviroment | formation name | formation top (m) | formation base (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Avocet 1a | M.testudinaria | P.burgeri | 1740 | 1742 | 123 | 126.5 | 325 | | shelfal marine | Jamieson | 1570 | 1725 |
| Avocet 1a | S.tabulata | P.burgeri | 1746.4 | 1746.5 | 131 | 133 | 325 | | shelfal marine | Jamieson | 1570 | 1725 |
| Avocet 1a | S.areolata | S.tabulata | 1749 | 1749 | 133 | 135 | 325 | | shelfal marine - The environment of deposition is interpreted as shelfal marine | Jamieson | 1570 | 1725 |
| Avocet 1a | C.delicata | | 1751.5 | 1769.5 | 138 | 139 | 425 | | open marine, possible shelfal | Jamieson | 1570 | 1725 |
| Avocet 1a | P.iehiense | | 1771.5 | 1771.5 | 140 | 142.5 | 525 | | open marine - The environment of deposition is interpreted as open marine, probably representing very slow rates of sedimentation. | Jamieson | 1570 | 1725 |
| Avocet 1a | D.jurassicum | P.iehiense | 1773 | 1780 | 142.5 | 143.8 | 325 | | shelfal marine. | Jamieson | 1570 | 1725 |
| Avocet 1a | C.torosa | C.turbatus | 1782 | 1908 | 189.5 | 204.5 | 100 | | distal fluvio-deltaic - The environment of deposition appears to be distal fluvio-deltaic. | Jamieson | 1570 | 1725 |
| Avocet 1a | KPF-13 | | 1539 | 1539 | | | 600 | Early Turonian or older | undifferentiated bathyal (anoxic) | Jamieson | 1570 | 1725 |
| Avocet 1a | | | 1704 | 1704 | | | 500 | This sample is younger than D.davidii (1718m) and has been assinged an age of 106MA | undifferentiated bathyal | Jamieson | 1570 | 1725 |
| Avocet 1a | | | 1712 | 1723 | | | 400 | This sample is younger than D.davidii (1718m) and has been assinged an age of 106MA | outer neritic or deeper | Jamieson | 1570 | 1725 |
| Avocet 1a | | | 1729 | 1746 | | | 350 | Sample is between M.australis(1726m) and M.testudinaria/P.burgeri(1740m) and thus has been assigned an age of 123MA | low energy middle - outer neritic (anoxic) | Jamieson | 1570 | 1725 |
| Avocet 1a | | | 1749 | 1751.5 | | | 425 | Sample lies between S.areolata/S.tabulata (1749m) and C.delicata (1751.5m) and thus has been assigned an age of 135MA to 138MA | undifferentiated marine | Jamieson | 1570 | 1725 |
| Brown Garnet 1 | Lycopodiumsporites sp. | | 1769.7 | 1769.7 | | | 435 | Maastrichtian | marine | Jamieson | 2128 | 2167 |
| Brown Garnet 1 | | | 1950 | 1950 | | | 425 | | marine | Jamieson | 2128 | 2167 |
| Brown Garnet 1 | | | 1981.2 | 1981.2 | | | 425 | | marine | Jamieson | 2128 | 2167 |
| Brown Garnet 1 | | | 2072.64 | 2072.64 | | | 425 | Sample lies between H.papula (2058m) and P.stephani (2104m) and thus has been assigned an age between 87.5MA and 89.5MA | marine | Jamieson | 2128 | 2167 |
| Brown Garnet 1 | | | 2133.6 | 2133.6 | | | 425 | Sample lies below a Turonian aged sample (2118.4m) and above P.buxtorfi (2150m) and thus has an age between 93.5Ma and 97.5MA | marine | Jamieson | 2128 | 2167 |
| Brown Garnet 1 | | | 2164.08 | 2164.1 | | | 425 | Sample lies below P.buxtorfi (2150m) and thus is older than 100Ma | marine | Jamieson | 2128 | 2167 |
| Brown Garnet 1 | | | 2179.9 | 2179.9 | | | 125 | | marine, probably near shore | Jamieson | 2128 | 2167 |
| Brown Garnet 1 | | | 2194.56 | 2194.6 | | | 125 | | marine, probably near shore | Jamieson | 2128 | 2167 |
| Brown Garnet 1 | | | 2240.3 | 2240.3 | | | 425 | | marine | Jamieson | 2128 | 2167 |
| Brown Garnet 1 | | | 2250.6 | 2250.6 | | | 425 | | marine | Jamieson | 2128 | 2167 |
| Brown Garnet 1 | | | 275.5 | 462.4 | | | 200 | Miocene - Pliocene? | internal neritic zone, littoral, in shallow water | Jamieson | 2128 | 2167 |
| Brown Garnet 1 | | | 533.4 | 587 | | | 200 | Probably middle Miocene | internal neritic zone, littoral, in shallow water | Jamieson | 2128 | 2167 |
| Brown Garnet 1 | | | 602.6 | 807.7 | | | 250 | Lower Miocene | internal neritic littoral zone, more oceanward than overlying zones | Jamieson | 2128 | 2167 |
| Brown Garnet 1 | | | 833.6 | 882.4 | | | 200 | Oligocene | internal neritic zone, littoral | Jamieson | 2128 | 2167 |

# Appendix A - Biostrat zones and depositional environment information for Jamieson Formation

| well_name | biozone name | biozone range | biostrat depth top (m) | biostrat depth base (m) | biozone age from (Ma) | biozone age to (Ma) | age_code | notes on biozone age | depositional enviroment | formation name | formation top (m) | formation base (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Brown Garnet 1 | | | 886.4 | 1040.3 | | | 250 | Eocene (probably Upper) | internal neritic zone with relatively calm intervals: proliferation of small bethonic Foraminifera | Jamieson | 2128 | 2167 |
| Brown Garnet 1 | | | 1061.3 | 1670.3 | | | 300 | Middle Eocene (to Lower) | internal to middle neritic zone (contributions from open sea) | Jamieson | 2128 | 2167 |
| Brown Garnet 1 | | | 1722 | 1764.2 | | | 400 | Lower Eocene | external neritic zone to deeper (slope?) | Jamieson | 2128 | 2167 |
| Brown Garnet 1 | | | 2042.16 | 2042.16 | | | 425 | | marine | Jamieson | 2128 | 2167 |
| Brown Garnet 1 | | | 2209.8 | 2209.8 | | | 225 | | marine, probably near shore | Jamieson | 2128 | 2167 |
| Brown Garnet 1 | | | 1783.1 | 1935.5 | | | 400 | Paleocene | external neritic zone to deeper (slope) | Jamieson | 2128 | 2167 |
| Brown Garnet 1 | | | 1966 | 2027 | | | 400 | Upper Senonian | external neritic zone to deeper (slope?) | Jamieson | 2128 | 2167 |
| Challis 1 | A.mayaroensis | G.gansseri | 990 | 1037 | 65 | 67 | 325 | mid - late Maastrichtian | mid shelf (990) to inner shelf (1037) | Jamieson | 1324 | 1370 |
| Challis 1 | C.diebelii | | 990 | 1117 | 66 | 73 | 525 | | open marine - the prominence of chorate cysts between 990 and 1074 suggests and open marine environment of deposition | Jamieson | 1324 | 1370 |
| Challis 1 | R.brotzeni | R.cushmani | 1321.1 | 1321.1 | 95 | 97.5 | 225 | middle Cenomanian | inner shelf | Jamieson | 1324 | 1370 |
| Challis 1 | D.multispinum | | 1342.6 | 1342.6 | 92.5 | 98.5 | 425 | | open marine | Jamieson | 1324 | 1370 |
| Challis 1 | P.ludbrookiae | | 1360 | 1360 | 100 | 101.5 | 325 | | open marine, possible shelfal | Jamieson | 1324 | 1370 |
| Challis 1 | M.australis | M.testudinaria | 1375.2 | 1380.8 | 118 | 123 | 325 | | shelfal marine - associations usually confined to the greensand unit at the base of the Echuca Shoals | Jamieson | 1324 | 1370 |
| Challis 1 | S.speciosus | | 1387.2 | 1657.5 | 214 | 226 | 200 | | deltaic | Jamieson | 1324 | 1370 |
| Challis 1 | S.speciosus | | 1387.2 | 1657.5 | 217.5 | 232 | 200 | | deltaic | Jamieson | 1324 | 1370 |
| Challis 1 | S.quadrifidus | | 1877 | 1927.9 | 226 | 238.5 | 100 | | marginal marine to deltaic | Jamieson | 1324 | 1370 |
| Challis 1 | Indeterminate | | 952 | 968 | | | 425 | no younger than Early Paleocene | open marine - the prominence of chorate cysts suggests and open marine environment of deposition | Jamieson | 1324 | 1370 |
| Challis 1 | | | 633 | 633 | | | 125 | | beach sand? | Jamieson | 1324 | 1370 |
| Challis 1 | | | 678.9 | 678.9 | | | 225 | | inner shelf | Jamieson | 1324 | 1370 |
| Challis 1 | | | 721.9 | 721.9 | | | 225 | | ?inner shelf | Jamieson | 1324 | 1370 |
| Challis 1 | | | 765.9 | 765.9 | | | 225 | | inner shelf | Jamieson | 1324 | 1370 |
| Challis 1 | | | 825 | 825 | | | 225 | | inner shelf | Jamieson | 1324 | 1370 |
| Challis 1 | | | 928 | 928 | | | 225 | | inner shelf | Jamieson | 1324 | 1370 |
| Challis 1 | | | 944 | 944 | | | 225 | | inner shelf (?dolomite) | Jamieson | 1324 | 1370 |
| Challis 1 | | | 952 | 952 | | | 225 | | inner shelf | Jamieson | 1324 | 1370 |
| Challis 1 | | | 958 | 958 | | | 225 | | inner shelf | Jamieson | 1324 | 1370 |
| Challis 1 | | | 977 | 977 | | | 225 | | inner shelf | Jamieson | 1324 | 1370 |
| Challis 1 | G.falsostuarti | G.elevata | 1074 | 1117 | | | 225 | Early Maastrichtian to Campanian | inner shelf | Jamieson | 1324 | 1370 |
| Challis 1 | G.elevata | D.assymetrica | 1180 | 1180 | | | 225 | Earl Campanian to Late Santonian | inner shelf | Jamieson | 1324 | 1370 |
| Challis 1 | D.assymetrica | | 1246.9 | 1246.9 | | | 325 | Late Santonian | mid shelf | Jamieson | 1324 | 1370 |
| Challis 1 | D.concavata | | 1287.5 | 1287.5 | | | 225 | Late Coniacian-Santonian | inner shelf | Jamieson | 1324 | 1370 |
| Challis 1 | | | 1383.6 | 1383.6 | | | 125 | This sample is below M.testudinaria (1380.8m) so it is at least as old as the base age of the M.tesudinaria interval (126.5) | ?estuarine | Jamieson | 1324 | 1370 |
| Challis 1 | | | 874 | 874 | | | 225 | | inner shelf | Jamieson | 1324 | 1370 |
| Challis 1 | | | 968 | 968 | | | 225 | | inner shelf | Jamieson | 1324 | 1370 |
| Douglas 1 | CP8 | | 1816 | 1909 | 53.5 | 55.4 | 325 | | inner shelf | Jamieson | 2137 | 2346 |
| Douglas 1 | CP8 | | 1850 | 1850 | 53.5 | 55.4 | 325 | | inner shelf | Jamieson | 2137 | 2346 |
| Douglas 1 | T4 | | 1950 | 1990 | 57 | 59.2 | 325 | | middle shelf to shallow outer shelf | Jamieson | 2137 | 2346 |
| Douglas 1 | CP4 | | 1990 | 1990 | 59.3 | 59.9 | 325 | | middle shelf to shallow outer shelf | Jamieson | 2137 | 2346 |

## Appendix A - Biostrat zones and depositional environment information for Jamieson Formation

| well_name | biozone name | biozone range | biostrat depth top (m) | biostrat depth base (m) | biozone age from (Ma) | biozone age to (Ma) | age_code | notes on biozone age | depositional enviroment | formation name | formation top (m) | formation base (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Douglas 1 | C11 | | 2111.5 | 2116 | 70 | 73 | 425 | | max outer shelf | Jamieson | 2137 | 2346 |
| Douglas 1 | C6 | | 2129.5 | 2129.5 | 87 | 89.2 | 425 | | deep outer shelf | Jamieson | 2137 | 2346 |
| Douglas 1 | C1 | | 2138.5 | 2332.5 | 100.5 | 108 | 425 | | outershelf or deeper - low diversity of abundant planktonic assemblages may be explained by relatively cool water. | Jamieson | 2137 | 2346 |
| Douglas 1 | M.testudinaria | | 2347.5 | 2347.5 | 123 | 126.5 | 525 | | open marine | Jamieson | 2137 | 2346 |
| Douglas 1 | P.burgeri | | 2357 | 2357 | 126.5 | 131 | 525 | | open marine | Jamieson | 2137 | 2346 |
| Douglas 1 | S.tabulata | | 2362 | 2377.5 | 131 | 133 | 425 | | open to shelfal marine | Jamieson | 2137 | 2346 |
| Douglas 1 | C.delicata | | 2380.5 | 2384 | 138 | 139 | 525 | | open marine | Jamieson | 2137 | 2346 |
| Douglas 1 | K.wisemaniae | | 2390 | 2390 | 139 | 140 | 525 | | open marine | Jamieson | 2137 | 2346 |
| Douglas 1 | P.iehiense | D.jurassicum | 2396.5 | 2450 | 140 | 142.5 | 525 | | open marine | Jamieson | 2137 | 2346 |
| Douglas 1 | D.jurassicum | | 2454.5 | 2462.5 | 142.5 | 143.8 | 425 | | open to shelfal marine | Jamieson | 2137 | 2346 |
| Douglas 1 | C.torosa | | 2487.3 | 2488.5 | 189.5 | 204.5 | 100 | | lower delta plain | Jamieson | 2137 | 2346 |
| Douglas 1 | A.reducta | M.crenulatus | 2543 | 2556 | 204.5 | 206.5 | 100 | | non-marine | Jamieson | 2137 | 2346 |
| Douglas 1 | M.crenulatus | | 2732 | 2748 | 206.5 | 214 | 100 | | lower delta plain | Jamieson | 2137 | 2346 |
| Douglas 1 | CP7 | CP5 | 1970 | 1970 | | | 325 | | middle shelf to shallow outer shelf | Jamieson | 2137 | 2346 |
| East Swan 2 | CP9 | | 1302.5 | 1338 | 52.4 | 53.5 | 400 | | middle neritic | Jamieson | 2256 | 2294 |
| East Swan 2 | CP8 | | 1361 | 1361 | 53.5 | 55.4 | 400 | | middle neritic | Jamieson | 2256 | 2294 |
| East Swan 2 | CP5 | | 1830.5 | 1830.5 | 57.8 | 59.3 | 450 | | outer neritic-upper bathyal | Jamieson | 2256 | 2294 |
| East Swan 2 | CP4 | CP2 | 1836 | 1856 | 59.3 | 59.9 | 450 | | outer neritic (1836m) upper bathyal (1856m) | Jamieson | 2256 | 2294 |
| East Swan 2 | CP1 | | 1880 | 1954 | 62.9 | 65 | 450 | | outer neritic-upper bathyal(1880m) / outer neritic (1944m & 1954m) | Jamieson | 2256 | 2294 |
| East Swan 2 | KCN-2 | KCN-3 | 1984 | 1984 | 65.88 | 66.3 | 450 | | outer neritic-upper bathyal | Jamieson | 2256 | 2294 |
| East Swan 2 | M.australis | | 2299 | 2303 | 118 | 123 | 325 | | at least shelfal - The prominence of plant debris in the organic residue suggest proximity of terrestial sources although high microplankton to spore-pollen ratio suggest that the environment of deposition is at least shelfal. | Jamieson | 2256 | 2294 |
| East Swan 2 | P.burgeri | | 2315 | 2316 | 126.5 | 131 | 325 | | shelfal marine - The relative prominence of plant debrisand the microplankton to spore-pollen ratio suggest shelfal marine depositional environments. | Jamieson | 2256 | 2294 |
| East Swan 2 | W.spectabilis | | 2319 | 2555 | 153.8 | 158.5 | 425 | | open marine, possibly shelfal - possibly shallowing downhole | Jamieson | 2256 | 2294 |
| East Swan 2 | R.aemula | | 2607 | 2635.5 | 158.5 | 160.3 | 325 | | shelfal marine | Jamieson | 2256 | 2294 |
| East Swan 2 | C.halosa | | 2642 | 2819 | 166.5 | 169 | 100 | | shallow marine to deltaic - The prominence and nature of the vascular plant debris and the spore-pollen to mircoplankton ratios suggest shallow marine to deltaic envronments fo deposition | Jamieson | 2256 | 2294 |
| East Swan 2 | inderterminate | | 1350 | 1350 | | | 400 | | middle-outer neritic | Jamieson | 2256 | 2294 |
| East Swan 2 | inderterminate | | 1808 | 1808 | | | 400 | | distal neritic | Jamieson | 2256 | 2294 |
| East Swan 2 | inderterminate | | 2000 | 2000 | | | 425 | | undifferentiated marine | Jamieson | 2256 | 2294 |
| Eclipse 1 | A.circumtabulata | | 1927.5 | 1938 | 65 | 66 | 525 | | open marine - dominance of chorate cysts and relatively low proportions of spores and pollen suggest open marine depositional environments | Jamieson | 2250 | 2295 |
| Eclipse 1 | A.mayaroensis | | 1931.5 | 1945 | 65 | 67 | 325 | Late Maastrichtian | mid-outer shelf to outer shelf | Jamieson | 2250 | 2295 |

## Appendix A - Biostrat zones and depositional environment information for Jamieson Formation

| well_name | biozone name | biozone range | biostrat depth top (m) | biostrat depth base (m) | biozone age from (Ma) | biozone age to (Ma) | age_code | notes on biozone age | depositional enviroment | formation name | formation top (m) | formation base (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Eclipse 1 | C.diebelii | | 1997 | 2032 | 66 | 73 | 525 | | open marine - chroate cysts are very prominent suggesting open marine however, the increased vascular plant component together with prominent acritarchs may indicate a closer proximity to a land mass or more active sediment supply than in the samples abov | Jamieson | 2250 | 2295 |
| Eclipse 1 | S.carnarvonensis | | 2068.5 | 2068.5 | 73 | 77 | 525 | | open marine - chorate cysts dominate suggesting an open marine environment | Jamieson | 2250 | 2295 |
| Eclipse 1 | A.coronata | | 2105 | 2130 | 77 | 83 | 525 | | open marine - chorate cysts dominate suggesting an open marine environment | Jamieson | 2250 | 2295 |
| Eclipse 1 | C.striatoconus | | 2179 | 2179 | 87 | 91 | 525 | | open marine | Jamieson | 2250 | 2295 |
| Eclipse 1 | P.ludbrookiae | X.asperatus | 2249.9 | 2262.5 | 100 | 101.5 | 525 | | open marine | Jamieson | 2250 | 2295 |
| Eclipse 1 | D.davidii | | 2288.5 | 2288.5 | 106.5 | 109 | 525 | | open marine | Jamieson | 2250 | 2295 |
| Eclipse 1 | M.testudinaria | | 2307.6 | 2307.6 | 123 | 126.5 | 425 | | marine environment | Jamieson | 2250 | 2295 |
| Eclipse 1 | P.iehiense | | 2328 | 2328 | 140 | 142.5 | 425 | | marine - in view of the extent of reworking the environment is uncertain, although a marine setting is preferred | Jamieson | 2250 | 2295 |
| Eclipse 1 | W.spectabilis | W.spectabilis Mid | 2332 | 2489.9 | 153.8 | 158.5 | 225 | | marine/shallow marine? - The environment of deposition is clearly marine, although characterised by substantial vascular plant debris. This association has been interpreted previously as shallow marine | Jamieson | 2250 | 2295 |
| Eclipse 1 | W.spectabilis | W.spectabilis Lw | 2555.1 | 2561.3 | 153.8 | 158.5 | 425 | | marine | Jamieson | 2250 | 2295 |
| Eclipse 1 | R.aemula | | 2570.6 | 2570.6 | 158.5 | 160.3 | 425 | | marine | Jamieson | 2250 | 2295 |
| Eclipse 1 | C.cooksoniae | D.complex | 2580 | 2647.5 | 163.5 | 167.5 | 425 | | marginal marine - The absence of dinoflagellates and the pattern of acritarch occurences suggests a marginal marine environment of deposition, possibly with increasing marine influence towards the lower part of the interval | Jamieson | 2250 | 2295 |
| Eclipse 1 | D.caddaensis | | 2708.5 | 2742.5 | 174.5 | 179.5 | 125 | | marginal marine | Jamieson | 2250 | 2295 |
| Eclipse 1 | C.turbatus | | 2799 | 2882.4 | 177 | 189.5 | 125 | | marginal marine (probably) - C.turbatus Lw | Jamieson | 2250 | 2295 |
| Eclipse 1 | D.priscum Up | | 2945 | 1965 | | | 125 | | marginal marine (probably) | Jamieson | 2250 | 2295 |
| Eclipse 1 | M.uncinata | S.pseudobulloides | 1826 | 1923 | | | 325 | Mid Paleocene to Early Paleocene | mid shelf | Jamieson | 2250 | 2295 |
| Eclipse 1 | G.lapparenti | | 2026 | 2026 | | | 225 | Early Maastrichtian | inner shelf | Jamieson | 2250 | 2295 |
| Eclipse 1 | G.elevata | | 2089 | 2121 | | | 225 | Early Campanian | inner shelf (2089m) to mid shelf (2121m) | Jamieson | 2250 | 2295 |
| Eclipse 1 | G.elevata | G.carinata | 2138.3 | 2138.3 | | | 325 | Early Campanian to Early Coniacian | outer shelf | Jamieson | 2250 | 2295 |
| Eclipse 1 | G.concavata | | 2168 | 2168 | | | 325 | Early Campanian to Early Coniacian | outer shelf | Jamieson | 2250 | 2295 |
| Eclipse 1 | G.renzi | G.sigali | 2203.5 | 2203.5 | | | 325 | Early Campanian to Early Coniacian | outer shelf | Jamieson | 2250 | 2295 |
| Fagin 1 | M.tetracantha | | 2646 | 2646 | 103.5 | 106.5 | 525 | | open marine | Jamieson | 2506 | 2672 |
| Fagin 1 | D.davidii | | 2665.4 | 2665.4 | 106.5 | 109 | 525 | | open marine | Jamieson | 2506 | 2672 |
| Fagin 1 | M.australis | | 2677.5 | 2697 | 118 | 123 | 425 | | shelfal to open marine | Jamieson | 2506 | 2672 |
| Fagin 1 | P.burgeri | S.tabulata | 2721.4 | 2742 | 126.5 | 131 | 425 | | shelfal to open marine | Jamieson | 2506 | 2672 |
| Fagin 1 | C.delicata | | 2759 | 2777.4 | 138 | 139 | 525 | | open marine | Jamieson | 2506 | 2672 |
| Fagin 1 | P.iehiense | | 2869.4 | 2902 | 140 | 142.5 | 525 | | open marine | Jamieson | 2506 | 2672 |
| Fagin 1 | P.iehiense | D.jurassicum | 2928 | 2949 | 140 | 142.5 | 525 | | open marine | Jamieson | 2506 | 2672 |
| Fagin 1 | W.spectabilis | | 2970 | 3009 | 153.8 | 158.5 | 425 | | shelfal to open marine | Jamieson | 2506 | 2672 |
| Fagin 1 | C.halosa | | 3020 | 3105 | 166.5 | 169 | 100 | | distal fluvial to marine delatic | Jamieson | 2506 | 2672 |
| Fagin 1 | D.caddaensis | | 3105 | 3249 | 174.5 | 179.5 | 100 | | fringing marine to lower delta plain | Jamieson | 2506 | 2672 |
| Halycon 1 | P.ludbrookiae | | 1010 | 1280 | 100 | 101.5 | 425 | | marine | Jamieson | 908 | 1302 |
| Halycon 1 | C.denticulata | | 1286 | 1299 | 101.5 | 103.5 | 4245 | | marine | Jamieson | 908 | 1302 |
| Halycon 1 | D.davidii | | 1311 | 1311 | 106.5 | 109 | 425 | | marine | Jamieson | 908 | 1302 |

## Appendix A - Biostrat zones and depositional environment information for Jamieson Formation

| well_name | biozone name | biozone range | biostrat depth top (m) | biostrat depth base (m) | biozone age from (Ma) | biozone age to (Ma) | age_code | notes on biozone age | depositional enviroment | formation name | formation top (m) | formation base (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Halycon 1 | M.australis | | 1325 | 1325 | 118 | 123 | 425 | | marine | Jamieson | 908 | 1302 |
| Halycon 1 | S.areolata | | 1334 | 1337 | 133 | 135 | 425 | | marine | Jamieson | 908 | 1302 |
| Halycon 1 | D.lobospinosum | | 1341 | 1341 | 137 | 138 | 425 | | marine | Jamieson | 908 | 1302 |
| Halycon 1 | K.wisemaniae | | 1350 | 1353 | 139 | 140 | 425 | | marine | Jamieson | 908 | 1302 |
| Halycon 1 | S.quadrifidus | | 1739 | 1739 | 226 | 238.5 | 100 | | marginal marine - Marine acritarchs were common and the abundance of cuticle, spores and pollen indicates a marginal marine environment. Relatively common recycling is also consistent with this environment | Jamieson | 908 | 1302 |
| Halycon 1 | Indeterminate | | 615 | 677.3 | | | 425 | | undifferentiated marine | Jamieson | 908 | 1302 |
| Halycon 1 | KCCM-2 | KCCM-5 | 681.8 | 687.5 | | | 300 | lower Late - upper Middle Maastrichtian | inner neritic-middle neritic | Jamieson | 908 | 1302 |
| Halycon 1 | KCCM-12 | KCCM-13 | 705 | 745 | | | 300 | upper Late Campanian | undifferentiated marine (705m) / inner neritic-middle neritic (708-715m) / middle neritic (725-745m) | Jamieson | 908 | 1302 |
| Halycon 1 | KCCM-14 | KCCM-15 | 778.5 | 778.5 | | | 350 | upper-mid Late Campanian | middle neritic | Jamieson | 908 | 1302 |
| Halycon 1 | KCCM-20 | | 785 | 790 | | | 425 | upper Early Campanian | undifferentiated marine | Jamieson | 908 | 1302 |
| Halycon 1 | KCCM-24 | | 790 | 795 | | | 425 | upper Late Santonian | undifferentiated marine | Jamieson | 908 | 1302 |
| Halycon 1 | KCCM-26 | | 798 | 798 | | | 425 | upper Early Santonian | undifferentiated marine | Jamieson | 908 | 1302 |
| Halycon 1 | KCCM-28 | | 857 | 857 | | | 400 | Coniacian | middle neritic - outer neritic | Jamieson | 908 | 1302 |
| Halycon 1 | KCCM-29 | | 897.5 | 897.5 | | | 425 | upper Late Turonian | undifferentiated marine | Jamieson | 908 | 1302 |
| Halycon 1 | KCCM-37 | KCCM-42 | 920 | 1110 | | | 350 | Middle Cenomanian - mid Late Albian | middle neritic or deeper (920m) / undifferentiated marine (950m) | Jamieson | 908 | 1302 |
| Halycon 1 | KCCM-39 | KCCM-42 | 1160 | 1260 | | | 450 | upper-mid Late Albian | distal neritic - upper bathyal | Jamieson | 908 | 1302 |
| Halycon 1 | KCCM-44a | | 1280 | 1311 | | | 450 | Late Aptian to Middle Albian | outer neritic or deeper to upper bathyal | Jamieson | 908 | 1302 |
| Jabiru 2 | T.rugulatum | | 1246 | 1246 | 64.5 | 66.5 | 525 | | open marine - prominence of chorate microplankton and very low proportion of vascular plant microfossils | Jamieson | 1565 | 1623 |
| Jabiru 2 | A.coronata | | 1326 | 1326 | 77 | 83 | 525 | | open marine - an increase in vascular plant material is noted | Jamieson | 1565 | 1623 |
| Jabiru 2 | A.suggestium | | 1535.5 | 1535.5 | 83 | 84.3 | 525 | | open marine | Jamieson | 1565 | 1623 |
| Jabiru 2 | P.ludbrookiae | | 1575 | 1599.5 | 100 | 101.5 | 525 | | open marine - although acritarchs may represent a relatively shallow environment of deposition | Jamieson | 1565 | 1623 |
| Jabiru 2 | M.tetracantha | | 1615 | 1615 | 103.5 | 106.5 | 425 | | marine environemnt - although prominence of acritarchs may represent a relatively shallow or restricted environment | Jamieson | 1565 | 1623 |
| Jabiru 2 | W.spectabilis | | 1625 | 1642.5 | 153.8 | 158.5 | 325 | | shelfal marine - environment of deposition is shelfal marine with substantial vascualr plant debris | Jamieson | 1565 | 1623 |
| Jabiru 2 | S.listeri | | 2075.5 | 2075.5 | 209 | 214 | 225 | | marine - possibly marginal | Jamieson | 1565 | 1623 |
| Jabiru 2 | S.wigginsii | | 2342 | 2342 | 214 | 220.5 | 100 | | marine-deltaic? | Jamieson | 1565 | 1623 |
| Jabiru 2 | S.speciosus | | 2169.6 | 2271 | 214 | 226 | 100 | | fluvio-deltaic - Dinoflagellates were not present and spinose acritarchs were not prominent, suggesting a fluvio-deltaic environment of deposition | Jamieson | 1565 | 1623 |
| Jabiru 2 | S.speciosus | | 2169.6 | 2271 | 217.5 | 232 | 100 | | fluvio-deltaic - Dinoflagellates were not present and spinose acritarchs were not prominent, suggesting a fluvio-deltaic environment of deposition | Jamieson | 1565 | 1623 |
| Kalyptea 1 | CP8 | | 1800 | 2260 | 53.5 | 55.4 | 300 | | inner-middle neritic (1800-10m) undifferentiated marine (1840-2260m) | Jamieson | 3577.5 | 4079 |
| Kalyptea 1 | KCN-4 | | 2634 | 2907 | 67.6 | 67.75 | 400 | | outer neritic | Jamieson | 3577.5 | 4079 |

## Appendix A - Biostrat zones and depositional environment information for Jamieson Formation

| well_name | biozone name | biozone range | biostrat depth top (m) | biostrat depth base (m) | biozone age from (Ma) | biozone age to (Ma) | age_code | notes on biozone age | depositional enviroment | formation name | formation top (m) | formation base (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Kalyptea 1 | KCN-7 | | 3021 | 3252 | 70.5 | 72.2 | 400 | | outer neritic (3021-3024) | Jamieson | 3577.5 | 4079 |
| Kalyptea 1 | KCN-8 | KCN-9 | 3276 | 3375 | 72.2 | 73 | 450 | | outer neritic - upper bathyal (3201-3375) | Jamieson | 3577.5 | 4079 |
| Kalyptea 1 | KCN-10 | KCN-11 | 3405 | 3408 | 73.3 | 75.5 | 400 | | distal neritic ? | Jamieson | 3577.5 | 4079 |
| Kalyptea 1 | KCN-12 | | 3441 | 3468 | 78.4 | 81 | 500 | | upper bathyal (3441-3550) | Jamieson | 3577.5 | 4079 |
| Kalyptea 1 | KCN-15 | | 3475 | 3475 | 82 | 83 | 500 | | upper bathyal | Jamieson | 3577.5 | 4079 |
| Kalyptea 1 | KCN-16 | | 3500 | 3500 | 83 | 83.8 | 500 | | upper bathyal | Jamieson | 3577.5 | 4079 |
| Kalyptea 1 | KCN-18 | | 3524 | 3524 | 85 | 85.5 | 500 | | upper bathyal | Jamieson | 3577.5 | 4079 |
| Kalyptea 1 | KCN-19 | KCN-20 | 3540 | 3550 | 85.5 | 86 | 500 | | upper bathyal | Jamieson | 3577.5 | 4079 |
| Kalyptea 1 | KCN-21 | | 3563 | 3563 | 88.1 | 89.5 | 425 | | undifferentiated marine | Jamieson | 3577.5 | 4079 |
| Kalyptea 1 | KCN-25A | | 3592 | 3592 | 95.2 | 96.3 | 350 | | middle-upper bathyal | Jamieson | 3577.5 | 4079 |
| Kalyptea 1 | KCN-25C | | 3682 | 3806 | 97.6 | 99.3 | 450 | | outer neritic-upper bathyal | Jamieson | 3577.5 | 4079 |
| Kalyptea 1 | P.ludbrookiae | | 3682 | 3973 | 100 | 101.5 | 525 | | open marine | Jamieson | 3577.5 | 4079 |
| Kalyptea 1 | KCN-27 | | 2933 | 2933 | 100.8 | 103.8 | 550 | | middle-upper bathyal (2933-2965m) | Jamieson | 3577.5 | 4079 |
| Kalyptea 1 | KCN-28 | | 2965 | 2965 | 103.8 | 107.2 | 550 | | middle-upper bathyal (2933-2965m) | Jamieson | 3577.5 | 4079 |
| Kalyptea 1 | D.davidii | | 3985 | 4022 | 106.5 | 109 | 525 | | open marine - The microplankton to spore-pollen ratio and the restricted vascular plant debris suggests open marine environments of deposition | Jamieson | 3577.5 | 4079 |
| Kalyptea 1 | KCN-30 | | 4010 | 4040 | 108.9 | 110.6 | 400 | | outer neritic or deeper | Jamieson | 3577.5 | 4079 |
| Kalyptea 1 | O.operculata | | 4040 | 4040 | 109 | 115 | 525 | | open marine | Jamieson | 3577.5 | 4079 |
| Kalyptea 1 | A.cinctum | M.australis | 4060 | 4101 | 115 | 118 | 525 | | open marine | Jamieson | 3577.5 | 4079 |
| Kalyptea 1 | M.australis | | 4110 | 4146 | 118 | 123 | 425 | | shelfal to open marine - The prominence of microplankton and the marginal increase in vascular plant debris into the bottom of the interval suggests shelfal to open marine environments of deposition. | Jamieson | 3577.5 | 4079 |
| Kalyptea 1 | M.testudinaria | | 4158 | 4194 | 123 | 126.5 | 325 | | shelfal - The downhole increase in the amount of vascular plant debris suggests shelfal environments of deposition, although the relatively high microplankton to spore-pollen ratios are indicative of open marine environments. | Jamieson | 3577.5 | 4079 |
| Kalyptea 1 | S.areolata | | 4209 | 4325 | 133 | 135 | 325 | | shelfal - The downhole increase in vascular plant debris and the ratio of microplankton to spore-pollen suggest shelfal environments of deposition | Jamieson | 3577.5 | 4079 |
| Kalyptea 1 | E.torynum | C.delicata | 4350 | 4572 | 135 | 136 | 325 | | shelfal - tentatively regarded as shelfal | Jamieson | 3577.5 | 4079 |
| Kalyptea 1 | | | 2388 | 2391 | | | 425 | | undiferentiated marine | Jamieson | 3577.5 | 4079 |
| Kalyptea 1 | | | 2535 | 2604 | | | 250 | | inner neritic | Jamieson | 3577.5 | 4079 |
| Kalyptea 1 | | | 2904 | 2988 | | | 350 | | distal neritic? | Jamieson | 3577.5 | 4079 |
| Kalyptea 1 | Inderterminate | | 2973 | 2985 | | | 425 | | undifferentiated marine | Jamieson | 3577.5 | 4079 |
| Kalyptea 1 | Inderterminate | | 4060 | 4060 | | | 400 | Sample lies between O.operculata (4040m) and A.cintum (4060m) and thus has been assigned an age of 118MA | mid-distal neritic | Jamieson | 3577.5 | 4079 |
| Keeling 1 | D.davidii | | 2990 | 2990 | 106.5 | 109 | 525 | | open marine - The prominence of dinoflagellates and the nature of the other plant debris suggest an open marine environment of deposition | Jamieson | 2889 | 2998 |
| Keeling 1 | M.australis | | 3000.5 | 3000.5 | 118 | 123 | 325 | | shelfal marine | Jamieson | 2889 | 2998 |
| Keeling 1 | M.testudinaria | | 3017 | 3017 | 123 | 126.5 | 525 | | open marine | Jamieson | 2889 | 2998 |

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| well_name | biozone name | biozone range | biostrat depth top (m) | biostrat depth base (m) | biozone age from (Ma) | biozone age to (Ma) | age_code | notes on biozone age | depositional enviroment | formation name | formation top (m) | formation base (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Keeling 1 | M.crenulatus | | 3050.5 | 3116 | 206.5 | 214 | 100 | | lower delta plain - The abundance of Bartenia communis and the apparent absence of spinose acritarchs suggests lower delta plain environments of deposition | Jamieson | 2889 | 2998 |
| Maple 1 | P1 | | 2524 | 2524 | 61.2 | 64.9 | 500 | | upper bathyal | Jamieson | 2827 | 2836 |
| Maple 1 | A.circumtabulata | | 2552 | 2552 | 65 | 66 | 525 | | open marine | Jamieson | 2827 | 2836 |
| Maple 1 | KCN-2 | KCN-3 | 2552 | 2552 | 65.88 | 66.3 | 500 | Late-upper Early Maastrichtian | upper bathyal | Jamieson | 2827 | 2836 |
| Maple 1 | C.diebelii | | 2600 | 2600 | 66 | 73 | 525 | | open marine | Jamieson | 2827 | 2836 |
| Maple 1 | P.ludbrookiae | | 2835 | 2835 | 100 | 101.5 | 525 | | open marine | Jamieson | 2827 | 2836 |
| Maple 1 | M.testudinaria | | 2836 | 2836 | 123 | 126.5 | 525 | | open marine | Jamieson | 2827 | 2836 |
| Maple 1 | P.burgeri | | 2839 | 2839 | 126.5 | 131 | 525 | | open marine | Jamieson | 2827 | 2836 |
| Maple 1 | B.reticulatum | | 2846 | 2850 | 136 | 137 | 425 | | shelfal to open marine | Jamieson | 2827 | 2836 |
| Maple 1 | D.lobospinosum | C.delicata | 2859 | 2938 | 137 | 138 | 425 | | shelfal to open marine | Jamieson | 2827 | 2836 |
| Maple 1 | D.jurassicum | | 2975 | 3030 | 142.5 | 143.8 | 425 | | shelfal to open marine | Jamieson | 2827 | 2836 |
| Maple 1 | O.montgomeryi | | 3069 | 3069 | 143.8 | 145.2 | 525 | | open marine | Jamieson | 2827 | 2836 |
| Maple 1 | D.swanense | | 3087 | 3140 | 146 | 150.3 | 525 | | open marine | Jamieson | 2827 | 2836 |
| Maple 1 | W.clathrata | | 3150 | 3150 | 150.3 | 153.8 | 525 | | open marine | Jamieson | 2827 | 2836 |
| Maple 1 | W.spectabilis | | 3298.5 | 3600 | 153.8 | 158.5 | 425 | | shelfal to open marine | Jamieson | 2827 | 2836 |
| Maple 1 | R.aemula | | 3680 | 3681.9 | 158.5 | 160.3 | 425 | | shelfal to open marine | Jamieson | 2827 | 2836 |
| Maple 1 | M.crenulatus | | 3682.8 | 3689 | 206.5 | 214 | 100 | | marine deltaic to marginal marine | Jamieson | 2827 | 2836 |
| Maple 1 | S.speciosus | | 3747 | 4087.58 | 214 | 226 | 100 | | ranging from fringing marine to deltaic | Jamieson | 2827 | 2836 |
| Maple 1 | S.speciosus | | 3747 | 4087.58 | 217.5 | 232 | 100 | | ranging from fringing marine to deltaic | Jamieson | 2827 | 2836 |
| Maret 1 | A.cinctum | | 3120 | 3130 | 115 | 118 | 525 | | | Jamieson | 2835 | 3118 |
| Medusa 1 | KCN-7 | | 1479 | 1479 | 70.5 | 72.2 | 500 | | upper bathyal | Jamieson | 1689 | 1780 |
| Medusa 1 | KCN-8 | | 1500 | 1500 | 72.2 | 73 | 500 | | upper bathyal | Jamieson | 1689 | 1780 |
| Medusa 1 | S.carnarvonensis | | 1479 | 1500 | 73 | 77 | 525 | | open marine - environment interpreted as open marine on the basis of the microplankton to spore-pollen ratios and the nature of the plant debris (overwhelmingly fusainised) | Jamieson | 1689 | 1780 |
| Medusa 1 | KCN-13 | KCN-14 | 1548 | 1548 | 81 | 81 | 500 | | upper bathyal | Jamieson | 1689 | 1780 |
| Medusa 1 | KCN-16 | | 1609 | 1609 | 83 | 83.8 | 500 | | upper bathyal | Jamieson | 1689 | 1780 |
| Medusa 1 | I.cretaceum | | 1609 | 1609 | 82 | 85 | 525 | | open marine - environment interpreted as open marine on the basis of microplankton to spore-pollen ratio and the fusainised nature of the plant debris | Jamieson | 1689 | 1780 |
| Medusa 1 | KCN-18 | | 1653 | 1653 | 85 | 85.5 | 500 | | upper bathyal | Jamieson | 1689 | 1780 |
| Medusa 1 | D.davidii | | 1776 | 1777 | 106.5 | 109 | 525 | | open marine - environment interpreted as open marine on the basis of microplankton to spore-pollen ratio | Jamieson | 1689 | 1780 |
| Medusa 1 | S.tabulata | | 1785 | 1785 | 131 | 133 | 325 | | shelfal marine - The environment of deposition is interpreted as shelfal marine on the basis of the almost equal proporitons of microplankton and spore-pollen, although the relative paucity of cuticular and woody debris may indicate open marine conditions | Jamieson | 1689 | 1780 |
| Medusa 1 | D.complex | | 1836 | 1836 | 167.5 | 177 | 100 | | lower deltaic plain - Environment of deposition is interpreted as lower deltaic plain, with extremely rare spinose acritarchs suggesting a possible estuarine to brackish influence | Jamieson | 1689 | 1780 |

## Appendix A - Biostrat zones and depositional environment information for Jamieson Formation

| well_name | biozone name | biozone range | biostrat depth top (m) | biostrat depth base (m) | biozone age from (Ma) | biozone age to (Ma) | age_code | notes on biozone age | depositional enviroment | formation name | formation top (m) | formation base (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Medusa 1 | C.turbatus | | 1902 | 1930 | 177 | 189.5 | 100 | | lower delta plain - Environment of deposition is interpreted as lower delta plain on the basis of the very high spore-pollen to microplankton ratios. However, the presence of very rare dinocysts and spinose acritarchs may indicate proximity to marine (est | Jamieson | 1689 | 1780 |
| Medusa 1 | Indeterminate | | 1776 | 1777 | | | 350 | Sample is the same depth as D.davidii (1776m) and so has been assigned an age of at least 109MA | mid neritic or deeper - samples 1776 and 1777m contian abundant samples of spumellarian radiolaria which is consistent with deposition in a mid neritic or deeper setting. | Jamieson | 1689 | 1780 |
| Medusa 1 | Indeterminate | | 1785 | 1785 | | | 425 | Sample lies between S.tabulata (1785m) and D.complex (1836m) and is most probably has an age of 109Ma as it was taken from the same depth as the S.tabulata (133MA) sample. | undifferentiated marine - The glauconitic SWC sampled is devoid of in-situ foraminifera and is barren of nannoplankton. The occurrence of abundant glauconite is consistent with deposition in a marine setting | Jamieson | 1689 | 1780 |
| Montara 1 | C13 | | 1683 | 1719 | 65 | 66 | 325 | | probably turbidite | Jamieson | 2330 | 2389 |
| Montara 1 | C12 | | 1929 | 1932 | 66 | 67 | 525 | | outer shelf or deeper; probably turbidite | Jamieson | 2330 | 2389 |
| Montara 1 | C11 | C10 | 2019 | 2022 | 70 | 73 | 500 | | bathyal | Jamieson | 2330 | 2389 |
| Montara 1 | C11 | | 1959 | 1992 | 70 | 73 | 450 | | outer shelf, becoming bathyal at 1992m | Jamieson | 2330 | 2389 |
| Montara 1 | C10 | | 2049 | 2112 | 73 | 79 | 500 | | bathyal | Jamieson | 2330 | 2389 |
| Montara 1 | C8 | C7 | 2120 | 2200 | 83 | 84.5 | 325 | | outer shelf | Jamieson | 2330 | 2389 |
| Montara 1 | C7 | | 2213 | 2228 | 84.5 | 87 | 325 | | outer shelf | Jamieson | 2330 | 2389 |
| Montara 1 | C6 | | 2232 | 2285 | 87 | 89.2 | 500 | | upper bathyal | Jamieson | 2330 | 2389 |
| Montara 1 | C5 | | 2289 | 2292 | 89.2 | 90 | 500 | | upper bathyal | Jamieson | 2330 | 2389 |
| Montara 1 | C4 | | 2320 | 2322 | 90 | 91 | 500 | | upper bathyal | Jamieson | 2330 | 2389 |
| Montara 1 | P.infusorioides | | 2326 | 2326 | 91 | 92.5 | 525 | | open marine | Jamieson | 2330 | 2389 |
| Montara 1 | C3 | | 2349 | 2350 | 91 | 97 | 425 | | outer shelf or deeper | Jamieson | 2330 | 2389 |
| Montara 1 | D.multispinum | | 2338 | 2347 | 92.5 | 98.5 | 525 | | open marine - The environment of deposition is considered open marine, although spore-pollen to micropalnkton ratios in the upper part of the interval (down to 2343m) suggest a shelfal environment, with the marked change in the ratio below this level sugg | Jamieson | 2330 | 2389 |
| Montara 1 | X.asperatus | | 2350 | 2360 | 98.5 | 100 | 525 | | open marine - (possibly shelfal at 2360m) - Environment of deposition is open marine, although the spore-pollen ratio suggests shallowing to possible shelfal environments at 2360m | Jamieson | 2330 | 2389 |
| Montara 1 | C2 | | 2352 | 2375 | 97 | 100.5 | 500 | | upper bathyal | Jamieson | 2330 | 2389 |
| Montara 1 | P.ludbrookiae | | 2363 | 2387 | 100 | 101.5 | 525 | | open marine (possibly shelfal) | Jamieson | 2330 | 2389 |
| Montara 1 | C1 | | 2379 | 2382 | 100.5 | 108 | 450 | | outer shelf to upper bathyal | Jamieson | 2330 | 2389 |
| Montara 1 | W.spectabilis | | 2390 | 2978 | 153.8 | 158.5 | 425 | | shelfal to open marine - The spore-pollen to microplankton ratio, together with the nature and proportion of vascular plant debris suggests shelfal, open-marine environments of deposition | Jamieson | 2330 | 2389 |
| Montara 1 | R.aemula | | 3135 | 3135 | 158.5 | 160.3 | 425 | | shelfal to open marine - The spore-pollen to microplankton ratio, together with the nature and proportion of vascular plant debris suggests shelfal, open-marine environments of deposition | Jamieson | 2330 | 2389 |
| Montara 1 | D.caddaensis | | 3199 | 3199 | 174.5 | 179.5 | 100 | | marginal marine | Jamieson | 2330 | 2389 |

## Appendix A - Biostrat zones and depositional environment information for Jamieson Formation

| well_name | biozone name | biozone range | biostrat depth top (m) | biostrat depth base (m) | biozone age from (Ma) | biozone age to (Ma) | age_code | notes on biozone age | depositional enviroment | formation name | formation top (m) | formation base (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Montara 1 | C.turbatus | | 3270 | 3396 | 177 | 189.5 | 100 | | deltaic - The apparent absence of microplankton in most samples suggests deltaic environments of deposition | Jamieson | 2330 | 2389 |
| Montara 1 | indeterminate | | 2340 | 2340 | | | 325 | Cenomanian | at least middle shelf; oxygen poor sea floor | Jamieson | 2330 | 2389 |
| Montara 1 | indeterminate | | 2333 | 2333 | | | 325 | Sample lies below the Turonian/Cenomanian clay marker (2327m) and so is at lease 93.5MA | ?turbidite - barren sand | Jamieson | 2330 | 2389 |
| Montara 1 | indeterminate | | 2327 | 2327 | | | 325 | Turonian/Cenomanian boundary clay marker | oxygen minimum event? | Jamieson | 2330 | 2389 |
| Montara 1 | indeterminate | | 2304 | 2304 | | | 325 | Sample lies between C5 (2289m) and C4 (2330m) and thus has been assigned an age of 90MA | ?turbidite - barren sand | Jamieson | 2330 | 2389 |
| Montara 1 | indeterminate | | 1539 | 1620 | | | 225 | Palaeocene | inner shelf | Jamieson | 2330 | 2389 |
| Montara 1 | indeterminate | | 1270 | 1300 | | | 225 | Palaeocene | shallow inner shelf | Jamieson | 2330 | 2389 |
| Montara 1 | indeterminate | | 1060 | 1240 | | | 225 | | nearshore and shallow inner shelf | Jamieson | 2330 | 2389 |
| Montara 1 | indeterminate | | 950 | 1030 | | | 225 | Early Eocene | inner shelf | Jamieson | 2330 | 2389 |
| Montara 1 | indeterminate | | 820 | 880 | | | 225 | Middle to Early Eocene | lagoonal; and shallow inner shelf | Jamieson | 2330 | 2389 |
| Montara 1 | indeterminate | | 760 | 760 | | | 225 | undiff. Early Oilgocene to Late Eocene | lagoonal; and shallow inner shelf | Jamieson | 2330 | 2389 |
| Montara 1 | indeterminate | | 520 | 580 | | | 125 | Middle Miocene | lagoonal; and shallow inner shelf | Jamieson | 2330 | 2389 |
| Montara 1 | indeterminate | | 460 | 460 | | | 225 | probably Miocene | shallow inner shelf, high energy | Jamieson | 2330 | 2389 |
| Oliver 1 | CN12 | | 666.5 | 733 | 1.9 | 3.6 | 350 | | middle neritic | Jamieson | 2450 | 2650 |
| Oliver 1 | CN11 | CN8 | 816 | 930 | 3.6 | 4.5 | 300 | | low energy inner neritic - middle neritic | Jamieson | 2450 | 2650 |
| Oliver 1 | CN5 | | 1488 | 1533 | 11.1 | 14.3 | 300 | | high to moderate energy inner neritic | Jamieson | 2450 | 2650 |
| Oliver 1 | CN4 | CN3 | 1560 | 1560 | 14.3 | 15.9 | 300 | | moderate energy inner neritic | Jamieson | 2450 | 2650 |
| Oliver 1 | CN2 | CN1 | 1567 | 1576 | 16.8 | 20.4 | 300 | | moderate energy inner neritic | Jamieson | 2450 | 2650 |
| Oliver 1 | CP9 | | 2006.5 | 2006.5 | 52.4 | 53.5 | 350 | | low-moderate energy neritic | Jamieson | 2450 | 2650 |
| Oliver 1 | P7 | P6 | 1993.5 | 1993.5 | 54 | 54.7 | 425 | | undifferentiated marine | Jamieson | 2450 | 2650 |
| Oliver 1 | CP8 | CP6 | 2141.5 | 2141.5 | 53.5 | 55.4 | 425 | | undifferentiated marine | Jamieson | 2450 | 2650 |
| Oliver 1 | KCN-16 | KCN-17 | 2406 | 2406 | 83 | 83.8 | 500 | | upper bathyal | Jamieson | 2450 | 2650 |
| Oliver 1 | KCN-19 | KCN-21 | 2418.5 | 2418.5 | 85.5 | 86 | 500 | | upper bathyal ? | Jamieson | 2450 | 2650 |
| Oliver 1 | KCN-21 | | 2441.5 | 2441.5 | 88.1 | 89.5 | 550 | | middle - upper bathyal | Jamieson | 2450 | 2650 |
| Oliver 1 | KCN-22 | KCN-23 | 2446.5 | 2446.5 | 89.5 | 91.65 | 500 | | upper bathyal | Jamieson | 2450 | 2650 |
| Oliver 1 | X.asperatus | | 2534 | 2540 | 98.5 | 100 | 425 | | open marine | Jamieson | 2450 | 2650 |
| Oliver 1 | C.denticulata | | 2592 | 2604 | 101.5 | 103.5 | 525 | | open marine | Jamieson | 2450 | 2650 |
| Oliver 1 | KCN-27 | | 2565 | 2581 | 100.8 | 103.8 | 550 | | middle - upper bathyal | Jamieson | 2450 | 2650 |
| Oliver 1 | M.tetracantha | D.davidii | 2608 | 2609 | 103.5 | 106.5 | 525 | | open marine | Jamieson | 2450 | 2650 |
| Oliver 1 | KCN-28 | | 2592 | 2606 | 103.8 | 107.2 | 550 | | middle - upper bathyal | Jamieson | 2450 | 2650 |
| Oliver 1 | KCN-29 | | 2608 | 2608 | 107.2 | 108.9 | 400 | | outer neritic or deeper | Jamieson | 2450 | 2650 |
| Oliver 1 | KCN-29 | KCN-30 | 2612 | 2612 | 107.2 | 108.9 | 400 | | distal neritic | Jamieson | 2450 | 2650 |
| Oliver 1 | KCN-30 | | 2615 | 2615 | 108.9 | 110.6 | 400 | | outer neritic or deeper | Jamieson | 2450 | 2650 |
| Oliver 1 | O.operculata | | 2612 | 2627 | 109 | 115 | 525 | | open marine | Jamieson | 2450 | 2650 |
| Oliver 1 | A.cinctum | M.australis | 2645 | 2645 | 115 | 118 | 525 | | open marine | Jamieson | 2450 | 2650 |
| Oliver 1 | M.australis | | 2654 | 2672 | 118 | 123 | 525 | | open marine | Jamieson | 2450 | 2650 |
| Oliver 1 | M.testudinaria | | 2676 | 2681 | 123 | 126.5 | 525 | | open marine | Jamieson | 2450 | 2650 |
| Oliver 1 | S.tabulata | | 2686 | 2691 | 131 | 133 | 325 | | shelfal - The downhole increase in the proportion of spores and pollen in the assemblage suggests possible downhole shallowing of shelfal environments of deposition | Jamieson | 2450 | 2650 |
| Oliver 1 | S.areolata | | 2696 | 2696 | 133 | 135 | 325 | | shelfal marine | Jamieson | 2450 | 2650 |

## Appendix A - Biostrat zones and depositional environment information for Jamieson Formation

| well_name | biozone name | biozone range | biostrat depth top (m) | biostrat depth base (m) | biozone age from (Ma) | biozone age to (Ma) | age_code | notes on biozone age | depositional enviroment | formation name | formation top (m) | formation base (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Oliver 1 | C.delicata | | 2707 | 2758 | 138 | 139 | 325 | | shelfal marine | Jamieson | 2450 | 2650 |
| Oliver 1 | P.iehiense | | 2789 | 2840 | 140 | 142.5 | 325 | | shelfal marine or deeper | Jamieson | 2450 | 2650 |
| Oliver 1 | D.jurassicum | | 2874 | 2894 | 142.5 | 143.8 | 525 | | open marine | Jamieson | 2450 | 2650 |
| Oliver 1 | W.spectabilis | | 2900 | 2943 | 153.8 | 158.5 | 525 | | open maine - The environment of deposition is interpreted as open marine, the increasing proportion of vascular plant debris suggests a shallowing with depth | Jamieson | 2450 | 2650 |
| Oliver 1 | D.complex | | 2953 | 2956 | 167.5 | 177 | 100 | | deltaic - Spinose acritarchs did not exceed 1.5% and a single, tentatively identified, dinoflagellate was recorded. The environment of deposition is interpreted as deltaic | Jamieson | 2450 | 2650 |
| Oliver 1 | D.caddaensis | | 2961 | 3044 | 174.5 | 179.5 | 100 | | shallow marine to marine/deltaic | Jamieson | 2450 | 2650 |
| Oliver 1 | C.torosa | | 3094 | 3287 | 189.5 | 204.5 | 200 | | shallow marine to marine/deltaic - possibly shallowing downhole, although low recoveries below 3200m inhibit interpretation | Jamieson | 2450 | 2650 |
| Oliver 1 | A.reducta | | 3417 | 3432 | 204.5 | 206.5 | 100 | | fluvio-deltaic - environment is possibly fluvio-deltaic | Jamieson | 2450 | 2650 |
| Oliver 1 | | | 733 | 816 | | | 300 | | middle neritic | Jamieson | 2450 | 2650 |
| Oliver 1 | indeterminate | | 990 | 1455 | | | 250 | | high energy inner neritic (1083m, 1142m & 1276 to 1455m) - undifferentiated marine (990m and 1188 to 1205.5m) | Jamieson | 2450 | 2650 |
| Oliver 1 | indeterminate | | 1823 | 1853 | | | 300 | | low-middle energy inner neritic | Jamieson | 2450 | 2650 |
| Oliver 1 | indeterminate | | 1871.5 | 1940.5 | | | 425 | | undifferentiated marine | Jamieson | 2450 | 2650 |
| Oliver 1 | indeterminate | | 1983 | 1983 | | | 300 | | low energy inner neritic | Jamieson | 2450 | 2650 |
| Oliver 1 | indeterminate | | 1993.5 | 1993.5 | | | 350 | | middle neritic | Jamieson | 2450 | 2650 |
| Oliver 1 | indeterminate | | 2023.5 | 2056.5 | | | 300 | | low energy inner neritic? | Jamieson | 2450 | 2650 |
| Oliver 1 | indeterminate | | 2080.5 | 2080.5 | | | 300 | | moderate-high energy inner neritic | Jamieson | 2450 | 2650 |
| Oliver 1 | indeterminate | | 2110.5 | 2110.5 | | | 300 | | moderate-high energy inner neritic | Jamieson | 2450 | 2650 |
| Oliver 1 | indeterminate | | 2119.5 | 2119.5 | | | 300 | | low energy inner neritic - middle neritic | Jamieson | 2450 | 2650 |
| Oliver 1 | | | 2126.5 | 2264 | | | 425 | | undifferentiated marine | Jamieson | 2450 | 2650 |
| Oliver 1 | | | 2349.5 | 2368.5 | | | 425 | | undifferentiated marine | Jamieson | 2450 | 2650 |
| Oliver 1 | inderterminate | | 2627 | 2627 | | | 425 | Sample lies between KCN-30 (2615m) and A.cinctum (2645m) and thus has been assigned an age between 110.6MA and 115MA | undifferentiated marine | Jamieson | 2450 | 2650 |
| Oliver 1 | CC2 | CC4 | 2645 | 2686 | | | 350 | Hauterivian-Valanginian | mid neritic to distal neritic at base | Jamieson | 2450 | 2650 |
| Oliver 1 | inderterminate | | 2691 | 2840 | | | 425 | | undifferentiated marine | Jamieson | 2450 | 2650 |
| Oliver 1 | E.communis | V.stradneri | 2900 | 2900 | | | 400 | lower late Kimmeridgian - Middle Oxfordian | distal neritic | Jamieson | 2450 | 2650 |
| Oliver 1 | indeterminate | | 1643.5 | 1803.5 | | | 300 | | high energy inner neritic | Jamieson | 2450 | 2650 |
| Oliver 1 | | | 2286.5 | 2286.5 | | | 300 | | low energy inner neritic - middle neritic | Jamieson | 2450 | 2650 |
| Osprey 1 | | | 283 | 419.1 | | | 200 | Miocene | internal littoral neritic zone in shallow water depth | Jamieson | 1074 | 1256 |
| Osprey 1 | | | 469 | 487 | | | 200 | possibly Eocene | internal littoral neritic zone in shallow water depth | Jamieson | 1074 | 1256 |
| Osprey 1 | | | 501 | 621 | | | 200 | Eocene | internal littoral neritic zone in shallow water depth | Jamieson | 1074 | 1256 |
| Osprey 1 | | | 640 | 722 | | | 300 | Upper Cretaceous | neritic zone (regression of Upper Cretaceous) | Jamieson | 1074 | 1256 |
| Osprey 1 | | | 734 | 809 | | | 200 | Lower Maastrichtian and Campanian | unstable neritic zone; alterations of clearly marine levels with good connections to open sea and poor, limonitic, pyritic levels showing and unfavourable, confined environment | Jamieson | 1074 | 1256 |

## Appendix A - Biostrat zones and depositional environment information for Jamieson Formation

| well_name | biozone name | biozone range | biostrat depth top (m) | biostrat depth base (m) | biozone age from (Ma) | biozone age to (Ma) | age_code | notes on biozone age | depositional enviroment | formation name | formation top (m) | formation base (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Osprey 1 | | | 822 | 851 | | | 350 | Campanian | external to middle neritic zone | Jamieson | 1074 | 1256 |
| Osprey 1 | | | 859 | 926 | | | 350 | Santonian to Coniacian | external to middle neritic zone (859 to 890m); below (890-926m) a more confined environment (internal neritic zone?), restricted (abundance of agglutinates), poorly suited for development of both benthonic and planktonic calcareous forms (possible presenc | Jamieson | 1074 | 1256 |
| Osprey 1 | | | 932 | 945 | | | 250 | Lower Senonian? Turonian? | internal neritic zone with a confined environment (see 859 to 926m) | Jamieson | 1074 | 1256 |
| Osprey 1 | | | 959 | 1079 | | | 350 | Turonian | external to middle neritic zone | Jamieson | 1074 | 1256 |
| Osprey 1 | | | 1082 | 1130 | | | 350 | Cenomanian | middle to external neritic zone; a more confined environment at the top | Jamieson | 1074 | 1256 |
| Osprey 1 | | | 1161 | 1226 | | | 400 | Lower Cenomanian to Upper Albian | external neritic zone (deeper part) | Jamieson | 1074 | 1256 |
| Osprey 1 | | | 1310 | 2365 | | | 425 | | marine character of deposits | Jamieson | 1074 | 1256 |
| Paqualin 1 | KCN-6 | | 2295 | 2295 | 68 | 70.5 | 450 | | outer neritic-upper bathyal | Jamieson | 2462 | 2492.5 |
| Paqualin 1 | C.diebelii | | 2290 | 2300 | 66 | 73 | 525 | | open marine - prominence of microplankton and the nature of plant debris suggests open marine | Jamieson | 2462 | 2492.5 |
| Paqualin 1 | KCN-21 | | 2286 | 2286 | 88.1 | 89.5 | 450 | | middle-upper bathyal | Jamieson | 2462 | 2492.5 |
| Paqualin 1 | M.tetracantha | | 2469 | 2480 | 103.5 | 106.5 | 525 | | open marine | Jamieson | 2462 | 2492.5 |
| Paqualin 1 | O.operculata | | 2489.5 | 2489.5 | 109 | 115 | 525 | | open marine | Jamieson | 2462 | 2492.5 |
| Paqualin 1 | M.australis | | 2493 | 2511 | 118 | 123 | 425 | | open marine, possibly shelfal - There is a marginal downhole increase in in the proportion of woody and cuticular debris, although neither exceeds 3%, which with high microplankton to spore-pollen ratio, suggests open marin, possibly shelfal depositional | Jamieson | 2462 | 2492.5 |
| Paqualin 1 | S.areolata | | 2525 | 2525 | 133 | 135 | 325 | | open marine, possibly shelfal - Although there is a definite increase in the spore-pollen to microplankton ratio, the prominence of microplankton and the relative low proportion of 'fresh' vascular plant debris suggests and open marine, possible shelfal, | Jamieson | 2462 | 2492.5 |
| Paqualin 1 | C.delicata | | 2526 | 2583 | 138 | 139 | 525 | | open marine | Jamieson | 2462 | 2492.5 |
| Paqualin 1 | K.wisemaniae | | 2619 | 2638 | 139 | 140 | 525 | | open marine | Jamieson | 2462 | 2492.5 |
| Paqualin 1 | P.iehiense | | 2633 | 2685 | 140 | 142.5 | 525 | | open marine - prominence of microplankton and scarcity of vascular plant debris suggest open marine environments of deposition | Jamieson | 2462 | 2492.5 |
| Paqualin 1 | D.jurassicum | | 2844 | 2907 | 142.5 | 143.8 | 525 | | open marine | Jamieson | 2462 | 2492.5 |
| Paqualin 1 | D.swanense | | 2925 | 2952 | 146 | 150.3 | 525 | | open marine | Jamieson | 2462 | 2492.5 |
| Paqualin 1 | W.clathrata | | 2961 | 3051 | 150.3 | 153.8 | 525 | | open marine | Jamieson | 2462 | 2492.5 |
| Paqualin 1 | W.spectabilis | | 3060 | 3789 | 153.8 | 158.5 | 425 | | open marine to shelfal - The microplankton to spore-pollen ratio indicates open marine environments of deposition, although increased vascular plant debris indicate relatively high rates of deposition, some of which may derive from shelfal locations | Jamieson | 2462 | 2492.5 |
| Paqualin 1 | indeterminate | | 1535 | 1650 | | | 425 | | undifferentiated marine | Jamieson | 2462 | 2492.5 |
| Paqualin 1 | indeterminate | | 4077 | 4131 | | | 250 | Sample lies well below W.spectabilis (3789m) and is at least 158.5MA | proximal neritic | Jamieson | 2462 | 2492.5 |
| Paqualin 1 | indeterminate | | 4169 | 4169 | | | 425 | | undifferentiated marine | Jamieson | 2462 | 2492.5 |
| Paqualin 1 | indeterminate | | 4179 | 4179 | | | 425 | | undifferentiated marine | Jamieson | 2462 | 2492.5 |
| Paqualin 1 | indeterminate | | 4215 | 4215 | | | 300 | | inner-middle neritic | Jamieson | 2462 | 2492.5 |

## Appendix A - Biostrat zones and depositional environment information for Jamieson Formation

| well_name | biozone name | biozone range | biostrat depth top (m) | biostrat depth base (m) | biozone age from (Ma) | biozone age to (Ma) | age_code | notes on biozone age | depositional enviroment | formation name | formation top (m) | formation base (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Paqualin 1 | indeterminate | | 4218 | 4218 | | | 425 | | undifferentiated marine | Jamieson | 2462 | 2492.5 |
| Paqualin 1 | indeterminate | | 4212 | 4212 | | | 300 | | inner neritic | Jamieson | 2462 | 2492.5 |
| Pascal 1 | KCN-1 | | 2200.5 | 2298 | 65 | 65.88 | 500 | | upper bathyal | Jamieson | 2497 | 2517 |
| Pascal 1 | KCN-2 | KCN-3 | 2305 | 2333 | 65.88 | 66.3 | 500 | | upper bathyal | Jamieson | 2497 | 2517 |
| Pascal 1 | KCN-4 | | 2345.5 | 2345.5 | 67.6 | 67.75 | 500 | | upper bathyal | Jamieson | 2497 | 2517 |
| Pascal 1 | KCN-7 | | 2378 | 2413 | 70.5 | 72.2 | 500 | | upper bathyal | Jamieson | 2497 | 2517 |
| Pascal 1 | KCN-9 | | 2428 | 2428 | 73 | 73.3 | 550 | | mid-upper bathyal | Jamieson | 2497 | 2517 |
| Pascal 1 | KCN-10 | KCN-11 | 2443 | 2443 | 73.3 | 75.5 | 550 | | mid-upper bathyal | Jamieson | 2497 | 2517 |
| Pascal 1 | KCN-13 | KCN-14 | 2453 | 2453 | 81 | 81 | 550 | | mid-upper bathyal | Jamieson | 2497 | 2517 |
| Pascal 1 | KCN-17 | | 2460 | 2460 | 83.8 | 85 | 550 | | mid-upper bathyal | Jamieson | 2497 | 2517 |
| Pascal 1 | KCN-19 | | 2473 | 2473 | 85.5 | 86 | 550 | | mid-upper bathyal | Jamieson | 2497 | 2517 |
| Pascal 1 | KCN-25B | | 2498 | 2498 | 96.3 | 97.6 | 550 | | mid-upper bathyal | Jamieson | 2497 | 2517 |
| Pascal 1 | KCN-27 | | 2503 | 2507 | 100.8 | 103.8 | 550 | | mid-upper bathyal | Jamieson | 2497 | 2517 |
| Pascal 1 | KCN-29 | | 2511 | 2515 | 107.2 | 108.9 | 400 | | outer neritic or deeper | Jamieson | 2497 | 2517 |
| Pascal 1 | KCN-30 | | 2517 | 2517 | 108.9 | 110.6 | 400 | | outer neritic or deeper | Jamieson | 2497 | 2517 |
| Pascal 1 | S.wigginsii | | 2536 | 2557 | 214 | 220.5 | 100 | | fringing marine environment - due to abumdance of dinoflagellates | Jamieson | 2497 | 2517 |
| Pascal 1 | S.speciosus | | 2692 | 2843 | 214 | 226 | 100 | | proximal delta plain environment of deposition | Jamieson | 2497 | 2517 |
| Pascal 1 | S.speciosus | | 2692 | 2843 | 217.5 | 232 | 100 | | proximal delta plain environment of deposition | Jamieson | 2497 | 2517 |
| Pascal 1 | indeterminate | | 2483 | 2493.5 | | | 550 | Sample has an age between 86MA and 87.5MA | mid-upper bathyal | Jamieson | 2497 | 2517 |
| Pascal 1 | indeterminate | | 2520 | 2520 | | | 400 | Sample is below KCN-30 (2517m) and so is at least older than 110.6MA | middle neritic or deeper | Jamieson | 2497 | 2517 |
| Pascal 1 | indeterminate | | 2522 | 2523.5 | | | 300 | | undifferentiated neritic | Jamieson | 2497 | 2517 |
| Pascal 1 | indeterminate | | 2588 | 2588 | | | 425 | | undifferentiated marine | Jamieson | 2497 | 2517 |
| Pascal 1 | indeterminate | | 2622 | 2622 | | | 300 | | inner?-middle neritic | Jamieson | 2497 | 2517 |
| Pascal 1 | indeterminate | | 2699 | 2699 | | | 425 | | undifferentiated marine | Jamieson | 2497 | 2517 |
| Pascal 1 | indeterminate | | 2715.5 | 2715.5 | | | 300 | | inner neritic | Jamieson | 2497 | 2517 |
| Pascal 1 | indeterminate | | 2827 | 2827 | | | 425 | | undifferentiated marine | Jamieson | 2497 | 2517 |
| Prion 1 | | | 213 | 908 | | | 200 | Miocene to more recent | inner neritic zone of continental shelf, littoral marine, under shallow-water with proably high energy | Jamieson | 2588 | 2626 |
| Prion 1 | | | 911 | 1011 | | | 250 | Middle to Lower Miocene | inner neritic zone (marginal part) of the shelf under high energy conditions | Jamieson | 2588 | 2626 |
| Prion 1 | | | 1097 | 1676 | | | 325 | Eocene | shelf - the interval seems to have been deposition on the shelf (behind a barrier? : lack of planktonic material) with the possibility of the installisation of a Nummulite constructed body from 1494 to 1585m | Jamieson | 2588 | 2626 |
| Prion 1 | | | 1704 | 1859 | | | 525 | Lower Eocene (to Paleocene?) | connected with open sea but with fluctuating depths | Jamieson | 2588 | 2626 |
| Prion 1 | | | 1880 | 2134 | | | 325 | Palaeocene | mid to outer shelf - The diversity and abundance of the association could indicate mid to outer shelf deposits; the occurrence of some forms indicative of deeper water depths in the lower part of the interval could indicate a shallowing of the water colum | Jamieson | 2588 | 2626 |
| Prion 1 | | | 2161 | 2435 | | | 325 | Maastrichtian | proable outer shelf under normal marine conditions - the levels of agglutinated assemblages could be the result of a turbidite period | Jamieson | 2588 | 2626 |

## Appendix A - Biostrat zones and depositional environment information for Jamieson Formation

| well_name | biozone name | biozone range | biostrat depth top (m) | biostrat depth base (m) | biozone age from (Ma) | biozone age to (Ma) | age_code | notes on biozone age | depositional enviroment | formation name | formation top (m) | formation base (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Prion 1 | | | 2465 | 2499 | | | 325 | Lower Maastrichtian | shelf - normal marine conditions - could reflect restricted conditions at this level | Jamieson | 2588 | 2626 |
| Prion 1 | | | 2513 | 2524 | | | 425 | Campanian | outer shelf - slope | Jamieson | 2588 | 2626 |
| Prion 1 | | | 2626 | 2634 | | | 225 | Jurassic | shallow marine, probably near shore environment - according to palynoplanktology, glauconitic sandstones were deposited in a shallow marine, probably near shore environment | Jamieson | 2588 | 2626 |
| Puffin 2 | P6 | | 1660 | 1729 | 54.7 | 55.9 | 325 | | continental influence equal to marine influence (old study) | Jamieson | 2425 | 2436 |
| Puffin 2 | A.mayaroensis | | 1987 | 2069 | 65 | 67 | 325 | | organic matter has continental origin but marine microplankton is frequence (marine and continental matter equal) (old study) | Jamieson | 2425 | 2436 |
| Puffin 2 | | | 803 | 899 | | | 200 | Miocene to more recent | inner neritic zone of shelf, littoral marine, under shallow water with probable high energy | Jamieson | 2425 | 2436 |
| Puffin 2 | | | 902 | 1027 | | | 200 | Middle to Lower Miocene | inner neritic zone of shelf, littoral marine, under shallow water conditions - occurrence of scarce planktonic forms is the result of transport by currents | Jamieson | 2425 | 2436 |
| Puffin 2 | | | 1045 | 1637 | | | 250 | Eocene | inner neritic part of the shelf - with the possibility of a Nummulites constructed body | Jamieson | 2425 | 2436 |
| Puffin 2 | | | 1661 | 1728 | | | 325 | Lower Eocene | middle shelf, largely connected with open sea | Jamieson | 2425 | 2436 |
| Puffin 2 | | | 1756 | 2003 | | | 325 | Palaeocene | mid to outer shelf deposits - the benthonic assemblage and the relative abundance of planktonic forms are representative of mid to outer shelf deposits, the lower part of the Palaeocene sequence could be deper than the upper part as the benthonic associat | Jamieson | 2425 | 2436 |
| Puffin 2 | | | 2030 | 2185 | | | 325 | Upper Maastrichtian | mid to outer shelf - (large amount of planktonic species and abundance and diversity of the bethonic assemblage) | Jamieson | 2425 | 2436 |
| Rainier 1 | C.denticulata | | 1647 | 1650.5 | 101.5 | 103.5 | 525 | | open marine | Jamieson | 1595 | 1652 |
| Rainier 1 | M.tetracantha | | 1650 | 1653 | 103.5 | 106.5 | 525 | | open marine | Jamieson | 1595 | 1652 |
| Rainier 1 | M.australis | | 1653 | 1659 | 118 | 123 | 525 | | open marine, possibley shelfal | Jamieson | 1595 | 1652 |
| Rainier 1 | P.burgeri | | 1662.6 | 1665 | 126.5 | 131 | 525 | | open marine, possibley shelfal | Jamieson | 1595 | 1652 |
| Rainier 1 | S.tabulata | | 1667.1 | 1667.4 | 131 | 133 | 325 | | shelfal marine | Jamieson | 1595 | 1652 |
| Rainier 1 | C.delicata | | 1669.2 | 1671.9 | 138 | 139 | 525 | | open marine | Jamieson | 1595 | 1652 |
| Rainier 1 | D.jurassicum | | 1672.2 | 1794 | 142.5 | 143.8 | 525 | | open marine | Jamieson | 1595 | 1652 |
| Rainier 1 | W.spectabilis | | 1923 | 2115 | 153.8 | 158.5 | 525 | | open marine, possibley shelfal | Jamieson | 1595 | 1652 |
| Rainier 1 | C.turbatus | | 2120 | 2120 | 177 | 189.5 | 100 | | deltaic | Jamieson | 1595 | 1652 |
| Rainier 1 | M.crenulatus | S.speciosus | 2190 | 2244 | 206.5 | 214 | 100 | | lower delta plain | Jamieson | 1595 | 1652 |
| Rainier 1 | S.wigginsii | S.speciosus | 2262 | 2361 | 214 | 220.5 | 100 | | marginal marine, shallowing with depth | Jamieson | 1595 | 1652 |
| Rowan 1 | CP9 | | 1525 | 1522 | 52.4 | 53.5 | 350 | | middle neritic | Jamieson | 2675 | 2818 |
| Rowan 1 | CP8 | | 1533.3 | 1587.5 | 53.5 | 55.4 | 350 | | middle neritic | Jamieson | 2675 | 2818 |
| Rowan 1 | CP5 | CP7 | 1887 | 1926 | 57.8 | 59.3 | 400 | | outer neritic ? | Jamieson | 2675 | 2818 |
| Rowan 1 | KCN-1 | | 1950 | 1969 | 65 | 65.88 | 425 | | undifferentiated marine | Jamieson | 2675 | 2818 |
| Rowan 1 | KCN-7 | | 2360 | 2415 | 70.5 | 72.2 | 500 | | upper bathyal | Jamieson | 2675 | 2818 |
| Rowan 1 | KCN-8 | | 2431 | 2475 | 72.2 | 73 | 500 | | upper bathyal | Jamieson | 2675 | 2818 |
| Rowan 1 | KCN-9 | | 2512.5 | 2512.5 | 73 | 73.3 | 500 | | upper bathyal | Jamieson | 2675 | 2818 |
| Rowan 1 | KCN-12 | | 2520 | 2520 | 78.4 | 81 | 550 | | middle-upper bathyal | Jamieson | 2675 | 2818 |
| Rowan 1 | KCN-13 | KCN-14 | 2555 | 2555 | 81 | 81 | 550 | | middle-upper bathyal | Jamieson | 2675 | 2818 |

## Appendix A - Biostrat zones and depositional environment information for Jamieson Formation

| well_name | biozone name | biozone range | biostrat depth top (m) | biostrat depth base (m) | biozone age from (Ma) | biozone age to (Ma) | age_code | notes on biozone age | depositional enviroment | formation name | formation top (m) | formation base (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rowan 1 | KCN-16 | | 2576 | 2576 | 83 | 83.8 | 550 | | middle-upper bathyal | Jamieson | 2675 | 2818 |
| Rowan 1 | KCN-17 | | 2598 | 2598 | 83.8 | 85 | 550 | | middle-upper bathyal | Jamieson | 2675 | 2818 |
| Rowan 1 | KCN-18 | | 2628 | 2628 | 85 | 85.5 | 450 | | middle-upper bathyal | Jamieson | 2675 | 2818 |
| Rowan 1 | KCN-21 | | 2655 | 2655 | 88.1 | 89.5 | 550 | | middle-upper bathyal | Jamieson | 2675 | 2818 |
| Rowan 1 | KCN-22 | KCN-23 | 2673 | 2674 | 89.5 | 91.65 | 550 | | middle-upper bathyal | Jamieson | 2675 | 2818 |
| Rowan 1 | KCN-22 | | 2667.5 | 2667.5 | 89.5 | 91.65 | 425 | | undifferentiated marine | Jamieson | 2675 | 2818 |
| Rowan 1 | KCN-25B | | 2676 | 2676 | 96.3 | 97.6 | 550 | | middle-upper bathyal | Jamieson | 2675 | 2818 |
| Rowan 1 | KCN-25C | | 2686 | 2715 | 97.6 | 99.3 | 550 | | middle-upper bathyal | Jamieson | 2675 | 2818 |
| Rowan 1 | KCN-26 | | 2730 | 2730 | 99.3 | 100.8 | 550 | | middle-upper bathyal | Jamieson | 2675 | 2818 |
| Rowan 1 | KCN-27 | | 2742 | 2817 | 100.8 | 103.8 | 500 | | upper bathyal = most / (2786 is outer neritic or deeper) | Jamieson | 2675 | 2818 |
| Rowan 1 | S.tabulata | | 2808 | 2834 | 131 | 133 | 325 | | shelfal marine - the prominence of vascular plant debris and the spor-pollen to microplankton ratio suggests shelfal marine environments of deposition | Jamieson | 2675 | 2818 |
| Rowan 1 | W.spectabilis | | 2865 | 3110 | 153.8 | 158.5 | 325 | | shelfal marine - the prominence of vascular plant debris and the dominance of the palynomorph suite by spores-pollen, suggests a shelfal marine environment of deposition, although, possible transport of this material to deeper environments cannot be disco | Jamieson | 2675 | 2818 |
| Rowan 1 | R.aemula | | 3133 | 3183 | 158.5 | 160.3 | 325 | | shelfal marine environment - the high proportions of vascular plant debris and the dominance of the playnomorph suites by spores and pollen above 3150m suggests shelfal marine environments of depostion. The increasing prominence fo microplankton below 315 | Jamieson | 2675 | 2818 |
| Rowan 1 | D.complex | | 3193 | 3305 | 167.5 | 177 | 100 | | lower delta plain (fringing marine to fluvio-deltaic) - The prominence of vascular plant debris, the prominence of acritarchs and the apparent absence of dinoflagellates suggest lower delta plain environments of deposition, ranging from fringing marine to | Jamieson | 2675 | 2818 |
| Rowan 1 | D.caddaensis | | 3301 | 3302 | 174.5 | 179.5 | 100 | | fringing marine to marine-deltaic | Jamieson | 2675 | 2818 |
| Rowan 1 | C.turbatus | | 3316 | 3316 | 177 | 189.5 | 100 | | lower delta plain to marine deltaic | Jamieson | 2675 | 2818 |
| Rowan 1 | indeterminate | | 1515 | 1521 | | | 350 | | middle neritic | Jamieson | 2675 | 2818 |
| Rowan 1 | indeterminate | | 1728 | 1728 | | | 350 | | middle-outer neritic | Jamieson | 2675 | 2818 |
| Rowan 1 | indeterminate | | 1830 | 1830 | | | 425 | | undifferentiated marine | Jamieson | 2675 | 2818 |
| Rowan 1 | indeterminate | | 2668 | 2668.5 | | | 550 | Sample lies in the KCN-22 zone and thus has been assigned an age of 91.65MA | middle-upper bathyal (anoxic) ? | Jamieson | 2675 | 2818 |
| Rowan 1 | indeterminate | | 2819 | 2819 | | | 425 | | undifferentiated marine | Jamieson | 2675 | 2818 |
| Skua 1 | | | 265 | 434 | | | 225 | Pleistocene to Miocene | inner shelf under warm and shallow water - more marine type of depostion | Jamieson | 2389 | 2405 |
| Skua 1 | | | 458 | 777 | | | 225 | Middle to Lower Miocene | inner shelf - under warm shallow water and restricted conditions | Jamieson | 2389 | 2405 |
| Skua 1 | | | 914 | 1350 | | | 225 | Eocene | inner shelf - restricted conditions and shallow water | Jamieson | 2389 | 2405 |
| Skua 1 | | | 1366 | 1457 | | | 325 | Lower Eocene - probable | shelf - deposited over the shelf in an area submitted to an important continental influx (sandstones) which can obliterate the marine influx (planktonic forams) | Jamieson | 2389 | 2405 |

## Appendix A - Biostrat zones and depositional environment information for Jamieson Formation

| well_name | biozone name | biozone range | biostrat depth top (m) | biostrat depth base (m) | biozone age from (Ma) | biozone age to (Ma) | age_code | notes on biozone age | depositional enviroment | formation name | formation top (m) | formation base (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Skua 1 | | | 1474 | 1850 | | | 325 | Paleocene | shelf - normal marine conditions | Jamieson | 2389 | 2405 |
| Skua 3 | CN11 | | 310 | 310 | 3.6 | 4.5 | 250 | | high energy inner neritic | Jamieson | 2359 | 2371 |
| Skua 3 | CN10 | | 430 | 730 | 4.5 | 5.9 | 250 | | high energy inner neritic | Jamieson | 2359 | 2371 |
| Skua 3 | CN5 | | 790 | 820 | 11.1 | 14.3 | 350 | | high-low energy inner/middle neritic | Jamieson | 2359 | 2371 |
| Skua 3 | Tf1 | Tf2 | 760 | 760 | 15 | 18 | 250 | | mod-high energy inner neritic | Jamieson | 2359 | 2371 |
| Skua 3 | Tb | | 880 | 910 | 33.7 | 37 | 300 | | mod-low energy inner neritic | Jamieson | 2359 | 2371 |
| Skua 3 | Tb | | 940 | 1090 | 33.7 | 37 | 250 | | high energy inner neritic | Jamieson | 2359 | 2371 |
| Skua 3 | Ta3 | | 1180 | 1210 | 37 | 49 | 250 | | high energy inner neritic | Jamieson | 2359 | 2371 |
| Skua 3 | CP9 | | 1360 | 1390 | 52.4 | 53.5 | 300 | | low energy inner neritic | Jamieson | 2359 | 2371 |
| Skua 3 | CP8 | | 1450 | 1465 | 53.5 | 55.4 | 350 | | low energy inner to middle neritic | Jamieson | 2359 | 2371 |
| Skua 3 | P4 | | 1474 | 1789 | 56.5 | 59.2 | 450 | | middle neritic (1474-1537m) outer neritic to upper bathyal (1546-1789m) | Jamieson | 2359 | 2371 |
| Skua 3 | CP4 | | 1828 | 1831 | 59.3 | 59.9 | 450 | | outer neritic - upper bathyal | Jamieson | 2359 | 2371 |
| Skua 3 | P3 | | 1795 | 1795 | 59.2 | 61 | 400 | | outer neritic | Jamieson | 2359 | 2371 |
| Skua 3 | P3 | | 1834 | 1834 | 59.2 | 61 | 400 | | outer neritic | Jamieson | 2359 | 2371 |
| Skua 3 | KCN-1 | KCN-2 | 1840 | 2047 | 65 | 65.88 | 400 | | outer neritic | Jamieson | 2359 | 2371 |
| Skua 3 | KCN-3 | | 2056 | 2131 | 66.3 | 67.6 | 400 | | outer neritic | Jamieson | 2359 | 2371 |
| Skua 3 | KCN-4 | | 2134 | 2167 | 67.6 | 67.75 | 450 | | outer neritic-upper bathyal | Jamieson | 2359 | 2371 |
| Skua 3 | KCN-5 | | 2170 | 2194 | 67.75 | 68 | 500 | | upper bathyal | Jamieson | 2359 | 2371 |
| Skua 3 | KCN-6 | | 2197 | 2248 | 68 | 70.5 | 500 | | upper bathyal | Jamieson | 2359 | 2371 |
| Skua 3 | KCN-7 | | 2251 | 2272 | 70.5 | 72.2 | 500 | | upper bathyal | Jamieson | 2359 | 2371 |
| Skua 3 | KCN-7 | KCN-8 | 2275 | 2308 | 70.5 | 72.2 | 500 | | upper bathyal | Jamieson | 2359 | 2371 |
| Skua 3 | C.diebelii | | 2148 | 2159 | 66 | 73 | 525 | | open marine | Jamieson | 2359 | 2371 |
| Skua 3 | KCN-8 | KCN-9 | 2311 | 2320 | 72.2 | 73 | 500 | | upper bathyal | Jamieson | 2359 | 2371 |
| Skua 3 | KCN-10 | KCN-11 | 2320 | 2347 | 73.3 | 75.5 | 500 | | upper bathyal | Jamieson | 2359 | 2371 |
| Skua 3 | S.carnarvonensis | | 2314 | 2353 | 73 | 77 | 525 | | open marine | Jamieson | 2359 | 2371 |
| Skua 3 | KCN-12 | KCN-13 | 2350 | 2359 | 78.4 | 81 | 500 | | upper bathyal | Jamieson | 2359 | 2371 |
| Skua 3 | KCN-14 | | 2362 | 2368 | 81 | 82 | 500 | | upper bathyal | Jamieson | 2359 | 2371 |
| Skua 3 | A.coronata | | 2353 | 2374 | 77 | 83 | 525 | | open marine | Jamieson | 2359 | 2371 |
| Skua 3 | KCN-15 | KCN-17 | 2371 | 2371 | 82 | 83 | 500 | | upper bathyal | Jamieson | 2359 | 2371 |
| Skua 3 | C.torosa | | 2405.2 | 2500 | 189.5 | 204.5 | 100 | | deltaic to marginal marine - spinose acritarchs occurred consistently as minor components suggesting deltaic to marginal marine environments of deposition | Jamieson | 2359 | 2371 |
| Skua 3 | Susadinium sp. | | 2394 | 2402.5 | | | 100 | Toarcian | marginal marine to marine/deltaic | Jamieson | 2359 | 2371 |
| Skua 3 | indeterminate | | 340 | 400 | | | 250 | | high energy inner neritic | Jamieson | 2359 | 2371 |
| Skua 3 | indeterminate | | 850 | 850 | | | 300 | | mod-low energy inner neritic | Jamieson | 2359 | 2371 |
| Snowmass 1 | KCN-4 | | 867.5 | 867.5 | 67.6 | 67.75 | 350 | | middle-outer neritic | Jamieson | 1176 | 1258 |
| Snowmass 1 | KCN-5 | | 893.5 | 893.5 | 67.75 | 68 | 350 | | middle-outer neritic | Jamieson | 1176 | 1258 |
| Snowmass 1 | KCN-8 | | 911 | 935 | 72.2 | 73 | 350 | | middle-outer neritic | Jamieson | 1176 | 1258 |
| Snowmass 1 | KCN-13 | | 962 | 962 | 81 | 81 | 400 | | outer neritic | Jamieson | 1176 | 1258 |
| Snowmass 1 | KCN-14 | KCN-15 | 974 | 974 | 81 | 82 | 400 | | outer neritic | Jamieson | 1176 | 1258 |
| Snowmass 1 | KCN-16 | | 988 | 988 | 83 | 83.8 | 400 | | outer neritic | Jamieson | 1176 | 1258 |
| Snowmass 1 | KCN-17 | | 1032 | 1032 | 83.8 | 85 | 450 | | outer neritic - upper bathyal | Jamieson | 1176 | 1258 |
| Snowmass 1 | KCN-18 | | 1046 | 1118 | 85 | 85.5 | 500 | | upper bathyal (1046) | Jamieson | 1176 | 1258 |
| Snowmass 1 | KCN-19 | KCN-20 | 1128 | 1128 | 85.5 | 86 | 450 | | outer neritic - upper bathyal | Jamieson | 1176 | 1258 |
| Snowmass 1 | KCN-21 | | 1148.5 | 1148.5 | 88.1 | 89.5 | 500 | | upper bathyal | Jamieson | 1176 | 1258 |
| Snowmass 1 | KCN-22 | KCN-23 | 1169.3 | 1169.3 | 89.5 | 91.65 | 425 | | undifferentiated marine | Jamieson | 1176 | 1258 |
| Snowmass 1 | KCN-25A | | 1182 | 1182 | 95.2 | 96.3 | 450 | | outer neritic - upper bathyal | Jamieson | 1176 | 1258 |

## Appendix A - Biostrat zones and depositional environment information for Jamieson Formation

| well_name | biozone name | biozone range | biostrat depth top (m) | biostrat depth base (m) | biozone age from (Ma) | biozone age to (Ma) | age_code | notes on biozone age | depositional enviroment | formation name | formation top (m) | formation base (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Snowmass 1 | KCN-25B | | 1196 | 1196 | 96.3 | 97.6 | 500 | | upper bathyal | Jamieson | 1176 | 1258 |
| Snowmass 1 | KCN-25C | | 1209 | 1237.5 | 97.6 | 99.3 | 500 | | upper bathyal to mid-upper bathyal at base | Jamieson | 1176 | 1258 |
| Snowmass 1 | KCN-27 | | 1250 | 1250 | 100.8 | 103.8 | 550 | | mid-upper bathyal | Jamieson | 1176 | 1258 |
| Snowmass 1 | KCN-28 | | 1254.5 | 1254.5 | 103.8 | 107.2 | 550 | | mid-upper bathyal | Jamieson | 1176 | 1258 |
| Snowmass 1 | M.australis | | 1265 | 1268 | 118 | 123 | 325 | | shelfal marine | Jamieson | 1176 | 1258 |
| Snowmass 1 | M.testudinaria | P.burgeri | 1270 | 1270 | 123 | 126.5 | 325 | | shelfal marine | Jamieson | 1176 | 1258 |
| Snowmass 1 | S.tabulata | | 1275 | 1277 | 131 | 133 | 325 | | shelfal marine | Jamieson | 1176 | 1258 |
| Snowmass 1 | E.torynum | C.delicata | 1279.5 | 1291 | 135 | 136 | 425 | | undifferentiated marine | Jamieson | 1176 | 1258 |
| Snowmass 1 | S.speciosus | | 1296 | 1515 | 214 | 226 | 100 | | lower delta plain to marginal marine | Jamieson | 1176 | 1258 |
| Snowmass 1 | S.speciosus | | 1296 | 1515 | 217.5 | 232 | 100 | | lower delta plain to marginal marine | Jamieson | 1176 | 1258 |
| Snowmass 1 | S.quadrifidus | | 1586 | 1653 | 226 | 238.5 | 100 | | lower delta plain to marginal marine | Jamieson | 1176 | 1258 |
| Snowmass 1 | indeterminate | | 798.5 | 798.5 | | | 350 | | inner-middle neritic | Jamieson | 1176 | 1258 |
| Snowmass 1 | indeterminate | | 1260 | 1265 | | | 400 | Sample lies below KCN-28 (1254.5m) and above M.australis (1265M) and thus is older than 107.2MA and younger than 118MA | outer neritic ? (anoxic) | Jamieson | 1176 | 1258 |
| Snowmass 1 | indeterminate | | 1266.5 | 1270 | | | 300 | Sample lies between M.australis (1265m) and M.testudinaria (1270m) so has been given an estimated age of: 123MA | inner-middle neritic ? (anoxic) | Jamieson | 1176 | 1258 |
| Snowmass 1 | indeterminate | | 1273.8 | 1274 | | | 400 | Sample liest between M.testudinaria/P.burgeri (1270m) and S.tabulata (1275m) and thus has been assigned an age between 131MA and 133MA | middle-outer neritic ? (anoxic) | Jamieson | 1176 | 1258 |
| Snowmass 1 | indeterminate | | 1277 | 1277 | | | 300 | Sample lies between S.tabulata (1275m) and E.torynum/C.delicata (1279.5m), thus has been assigned an age of at least 133MA | inner-middle neritic ? (anoxic) | Jamieson | 1176 | 1258 |
| Swan 1 | X.asperatus | | 2590 | 2590 | 98.5 | 100 | 425 | | marine environment of deposition relatively close to an active source of fluvial sediment - The diversity of the microplankton suite and the diminished prominence of Hystrichosphaera together with relatively common pieces of cuticle suggest a marine envir | Jamieson | 2590 | 2635 |
| Swan 1 | P.ludbrookiae | | 2607 | 2628 | 100 | 101.5 | 525 | | open marine | Jamieson | 2590 | 2635 |
| Swan 1 | B.reticulatum | | 2638 | 2638 | 136 | 137 | 325 | | marine environment of deposition relatively close to an active fluvial sediment source | Jamieson | 2590 | 2635 |
| Swan 1 | K.wisemaniae | | 2729 | 2729 | 139 | 140 | 225 | | marine environment of deposition relatively close to an active fluvial sediment source | Jamieson | 2590 | 2635 |
| Swan 1 | D.jurassicum | | 2812 | 2837 | 142.5 | 143.8 | 425 | | distinct marine environment of deposition | Jamieson | 2590 | 2635 |
| Swan 1 | D.swanense | | 2865 | 2865 | 146 | 150.3 | 425 | | marine environment of deposition relatively close to an active source of fluvial sediment - amount of wood and cuticle suggests this. | Jamieson | 2590 | 2635 |
| Swan 1 | W.clathrata | | 2988 | 3137 | 150.3 | 153.8 | 425 | | top - marine environment of deposition relatively close to an active source of fluvial sediment - bottom - marine environment of depisition some distance removed from an active source of fluvial sedimentation | Jamieson | 2590 | 2635 |
| Swan 1 | W.spectabilis | | 3200 | 3259 | 153.8 | 158.5 | 325 | | 10500 - marine environment of deposition some distance removed from an active fluvial sediment source | Jamieson | 2590 | 2635 |

## Appendix A - Biostrat zones and depositional environment information for Jamieson Formation

| well_name | biozone name | biozone range | biostrat depth top (m) | biostrat depth base (m) | biozone age from (Ma) | biozone age to (Ma) | age_code | notes on biozone age | depositional enviroment | formation name | formation top (m) | formation base (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Swift 1 | A.coronata | | 2265 | 2265 | 77 | 83 | 525 | | open marine | Jamieson | 2365 | 2394 |
| Swift 1 | A.suggestium | | 2290 | 2290 | 83 | 84.3 | 525 | | open marine | Jamieson | 2365 | 2394 |
| Swift 1 | C.striatoconus | | 2325 | 2325 | 87 | 91 | 525 | | open marine | Jamieson | 2365 | 2394 |
| Swift 1 | X.asperatus | | 2353.5 | 2369 | 98.5 | 100 | 525 | | open marine | Jamieson | 2365 | 2394 |
| Swift 1 | P.ludbrookiae | | 2375 | 2387 | 100 | 101.5 | 525 | | open marine | Jamieson | 2365 | 2394 |
| Swift 1 | W.spectabilis | | 2394.9 | 2437.6 | 153.8 | 158.5 | 325 | | shelfal marine - with considerable terrestrial plant input | Jamieson | 2365 | 2394 |
| Swift 1 | D.complex | | 2471 | 2485 | 167.5 | 177 | 100 | Mid Bajocian to Bathonian | marginal marine to fluvio-deltaic | Jamieson | 2365 | 2394 |
| Swift 1 | D.complex | | 2545 | 2581 | 167.5 | 177 | 100 | Mid to Late Bajocian | marginal marine | Jamieson | 2365 | 2394 |
| Swift 1 | C.turbatus | | 2647.5 | 2704 | 177 | 189.5 | 100 | | marginal marine | Jamieson | 2365 | 2394 |

## Appendix A - Biostrat zones and depositional environment information for Woolaston, Gibson and Fenelon Formations (WGF)

| well_name | biozone name | biozone range | biostrat depth top (m) | biostrat depth base (m) | biozone age from (Ma) | biozone age to (Ma) | age_code | notes on biozone age | depositional enviroment | formation name | formation top (m) | formation base (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Allaru 1 | D.davidii | | 2304 | 2307 | 106.5 | 109 | 525 | | open marine - The predominance of dinoflagellates and the relatively low proportion and composition of vascular plant debris (mainly opaque and semi-opaque fragments) suggest and open marine environment of deposition | WGF | 1970 | 2227 |
| Allaru 1 | A.cinctum | | 2310 | 2313 | 115 | 118 | 525 | | open marine - The abundance of dinoflagellates and the relatively low proportion of vascular plant debris suggest an open marine environment of deposition | WGF | 1970 | 2227 |
| Allaru 1 | M.australis | M.australis Lw | 2319 | 2322 | 118 | 123 | 525 | | open marine - The abundance of dinoflagellates and the relatively low proportion of vascular plant debris suggest an open marine environment of deposition | WGF | 1970 | 2227 |
| Allaru 1 | M.testudinaria | | 2328 | 2343 | 123 | 126.5 | 325 | | shelfal marine - The downhole increase in the vascular plant debris and increase in spore-pollen to microplankton ratio through this interval suggests some downhole shallowing to shelfal environments | WGF | 1970 | 2227 |
| Allaru 1 | P.iehiense | D.jurassicum | 2343 | 2403 | 140 | 142.5 | 525 | | open marine - The microplankton to spore-pollen ratio and the relatively low proportion of vascular plant debris in the residues suggest open marine environments | WGF | 1970 | 2227 |
| Allaru 1 | D.swanense | | 2406 | 2421 | 146 | 150.3 | 525 | | open marine - The microplankton to spore-pollen ratio suggests open marine environments of deposition | WGF | 1970 | 2227 |
| Allaru 1 | W.clathrata | | 2424 | 2448 | 150.3 | 153.8 | 525 | | open marine - shallowing downhole - The continued prominence of dinoflagellates suggests open marine conditions although there is a marked downhole increase in the spore-pollen to microplankton ratio suggesting shallowing relative to the overlying section | WGF | 1970 | 2227 |
| Allaru 1 | W.spectabilis | | 2451 | 2946 | 153.8 | 158.5 | 425 | | open marine - shelfal - The prominence of microplankton suggests open marine environments of deposition although the increase in the vascular plant debris suggests shelfal influence | WGF | 1970 | 2227 |
| Anderdon 1 | P.helvetica | | 1410 | 1427 | 89 | 90.1 | 425 | Mid to Early Turonian interpreted by I.Deighton (WCR) | outer shelf - slope | WGF | 1250 | 1438 |
| Anderdon 1 | P.infusorioides | A.suggestium | 1320 | 1410 | 91 | 92.5 | 525 | | Environment of deposition is interpreted as open marine on the basis of the prominence of chorate dinoflagellates and the relative absence of vascular plant debris and microfossils | WGF | 1250 | 1438 |
| Anderdon 1 | T.playfordii | | 1458 | 1630 | 238.5 | 245 | 100 | | Environment of deposition is interpreted as deltiac to non-marine, with increasing marine influence towards the base of the sequence indicated by a marked increase in acritarchs. | WGF | 1250 | 1438 |
| Anderdon 1 | P.samoilovichii | L.pellucidus? | 1740 | 2410 | 245 | 251 | 425 | | The prominence of acritarchs throughout the interval indicates a marine environment of deposition. | WGF | 1250 | 1438 |
| Anderdon 1 | D.parvithola | D.playfordii | 2445 | 2752.8 | 257 | 268.5 | 425 | | The consistent and often prominent occurrence of acanthomorph acritarchs indicates marine environments of deposition | WGF | 1250 | 1438 |
| Anderdon 1 | G.gansseri | G.falsostuarti | 1080 | 1135 | | | 225 | Age=Mid Maastrichtian - Foraminifera interpreted by I.Deighton (WCR) | inner shelf | WGF | 1250 | 1438 |

## Appendix A - Biostrat zones and depositional environment information for Woolaston, Gibson and Fenelon Formations (WGF)

| well_name | biozone name | biozone range | biostrat depth top (m) | biostrat depth base (m) | biozone age from (Ma) | biozone age to (Ma) | age_code | notes on biozone age | depositional enviroment | formation name | formation top (m) | formation base (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Anderdon 1 | G.calcarata | G.ventricosa | 1150 | 1190 | | | 225 | Late - Mid Campanian interprteted by I.Deighton (WCR) | inner shelf | WGF | 1250 | 1438 |
| Anderdon 1 | G.elevata | | 1200 | 1310 | | | 325 | Early Campanian interpreted by I.Deighton (WCR) | inner shelf (1200-1270) to mid shelf (1270-1310) | WGF | 1250 | 1438 |
| Anderdon 1 | D.assymetrica | | 1310 | 1320 | | | 325 | Late Santonian interpreted by I.Deighton (WCR) | outer shelf | WGF | 1250 | 1438 |
| Anderdon 1 | G.gansseri | | 1000 | 1039.9 | | | 325 | | mid shelf | WGF | 1250 | 1438 |
| Anderdon 1 | D.concavata | M.schneegansi | 1340 | 1400 | | | 325 | Early Santonian to Late Turonian interpreted by I.Deighton (WCR) | outer shelf | WGF | 1250 | 1438 |
| Avocet 1a | KCN-3 | | 1224 | 1224 | 66.3 | 67.6 | 400 | Latest Early-Late Maastrichtian interpreted by Rexillius (WCR) | outer neritic | WGF | 1237 | 1570 |
| Avocet 1a | KCN-11 | | 1245 | 1245 | 75.5 | 78.4 | 450 | basal Middle Campanian | outer neritic-upper bathyal | WGF | 1237 | 1570 |
| Avocet 1a | KCN-16 | | 1310.5 | 1330 | 83 | 83.8 | 450 | upper Late Santonian | outer neritic-upper bathyal | WGF | 1237 | 1570 |
| Avocet 1a | KCN-17 | | 1350 | 1350 | 83.8 | 85 | 450 | lower Late Santonian | outer neritic-upper bathyal | WGF | 1237 | 1570 |
| Avocet 1a | KCN-18 | | 1369 | 1405 | 85 | 85.5 | 450 | upper Early Santonian | outer neritic-upper bathyal | WGF | 1237 | 1570 |
| Avocet 1a | KCN-20 | | 1434 | 1492 | 86.2 | 88.1 | 450 | Coniacian | outer neritic-upper bathyal | WGF | 1237 | 1570 |
| Avocet 1a | KCN-20 | KCN-21 | 1510 | 1510 | 86.2 | 88.1 | 500 | Turonian/Coniacian | upper bathyal | WGF | 1237 | 1570 |
| Avocet 1a | KCN-25A | | 1560 | 1600 | 95.2 | 96.3 | 500 | upper middle-early Late Cenomanian | upper bathyal | WGF | 1237 | 1570 |
| Avocet 1a | KCN-25B | KCN-25C | 1617.5 | 1638 | 96.3 | 97.6 | 500 | Late Albian-lower Middle Cenomanian | upper bathyal | WGF | 1237 | 1570 |
| Avocet 1a | C.denticulata | P.ludbrookiae | 1686 | 1686 | 101.5 | 103.5 | 425 | | open marine possibley shelfal. | WGF | 1237 | 1570 |
| Avocet 1a | M.tetracantha | | 1698 | 1714.5 | 103.5 | 106.5 | 525 | | open marine. | WGF | 1237 | 1570 |
| Avocet 1a | KCN-28 | | 1686 | 1698 | 103.8 | 107.2 | 550 | upper Early-lower Middle Albian | middle-upper bathyal | WGF | 1237 | 1570 |
| Avocet 1a | D.davidii | | 1718 | 1718 | 106.5 | 109 | 525 | | open marine | WGF | 1237 | 1570 |
| Avocet 1a | KCN-30 | | 1702 | 1703 | 108.9 | 110.6 | 425 | lower Late Aptian | undifferentiated marine | WGF | 1237 | 1570 |
| Avocet 1a | M.australis | | 1726 | 1734 | 118 | 123 | 325 | | shelfal marine | WGF | 1237 | 1570 |
| Avocet 1a | M.testudinaria | P.burgeri | 1740 | 1742 | 123 | 126.5 | 325 | | shelfal marine | WGF | 1237 | 1570 |
| Avocet 1a | S.tabulata | P.burgeri | 1746.4 | 1746.5 | 131 | 133 | 325 | | shelfal marine | WGF | 1237 | 1570 |
| Avocet 1a | S.areolata | S.tabulata | 1749 | 1749 | 133 | 135 | 325 | | shelfal marine - The environment of deposition is interpreted as shelfal marine | WGF | 1237 | 1570 |
| Avocet 1a | C.delicata | | 1751.5 | 1769.5 | 138 | 139 | 425 | | open marine, possible shelfal | WGF | 1237 | 1570 |
| Avocet 1a | P.iehiense | | 1771.5 | 1771.5 | 140 | 142.5 | 525 | | open marine - The environment of deposition is interpreted as open marine, probably representing very slow rates of sedimentation. | WGF | 1237 | 1570 |
| Avocet 1a | D.jurassicum | P.iehiense | 1773 | 1780 | 142.5 | 143.8 | 325 | | shelfal marine. | WGF | 1237 | 1570 |
| Avocet 1a | C.torosa | C.turbatus | 1782 | 1908 | 189.5 | 204.5 | 100 | | distal fluvio-deltaic - The environment of deposition appears to be distal fluvio-deltaic. | WGF | 1237 | 1570 |
| Avocet 1a | KPF-13 | | 1539 | 1539 | | | 600 | Early Turonian or older | undifferentiated bathyal (anoxic) | WGF | 1237 | 1570 |
| Avocet 1a | | | 1704 | 1704 | | | 500 | This sample is younger than D.davidii (1718m) and has been assinged an age of 106MA | undifferentiated bathyal | WGF | 1237 | 1570 |
| Avocet 1a | | | 1712 | 1723 | | | 400 | This sample is younger than D.davidii (1718m) and has been assinged an age of 106MA | outer neritic or deeper | WGF | 1237 | 1570 |
| Avocet 1a | | | 1729 | 1746 | | | 350 | Sample is between M.australis(1726m) and M.testudinaria/P.burgeri(1740m) and thus has been assigned an age of 123MA | low energy middle - outer neritic (anoxic) | WGF | 1237 | 1570 |

## Appendix A - Biostrat zones and depositional environment information for Woolaston, Gibson and Fenelon Formations (WGF)

| well_name | biozone name | biozone range | biostrat depth top (m) | biostrat depth base (m) | biozone age from (Ma) | biozone age to (Ma) | age_code | notes on biozone age | depositional enviroment | formation name | formation top (m) | formation base (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Avocet 1a | | | 1749 | 1751.5 | | | 425 | Sample lies between S.areolata/S.tabulata (1749m) and C.delicata (1751.5m) and thus has been assigned an age of 135MA to 138MA | undifferentiated marine | WGF | 1237 | 1570 |
| Brown Garnet 1 | Lycopodiumsporites sp. | | 1769.7 | 1769.7 | | | 435 | Maastrichtian | marine | WGF | 2050 | 2128 |
| Brown Garnet 1 | | | 1950 | 1950 | | | 425 | | marine | WGF | 2050 | 2128 |
| Brown Garnet 1 | | | 1981.2 | 1981.2 | | | 425 | | marine | WGF | 2050 | 2128 |
| Brown Garnet 1 | | | 2072.64 | 2072.64 | | | 425 | Sample lies between H.papula (2058m) and P.stephani (2104m) and thus has been assigned an age between 87.5MA and 89.5MA | marine | WGF | 2050 | 2128 |
| Brown Garnet 1 | | | 2133.6 | 2133.6 | | | 425 | Sample lies below a Turonian aged sample (2118.4m) and above P.buxtorfi (2150m) and thus has an age between 93.5Ma and 97.5MA | marine | WGF | 2050 | 2128 |
| Brown Garnet 1 | | | 2164.08 | 2164.1 | | | 425 | Sample lies below P.buxtorfi (2150m) and thus is older than 100Ma | marine | WGF | 2050 | 2128 |
| Brown Garnet 1 | | | 2179.9 | 2179.9 | | | 125 | | marine, probably near shore | WGF | 2050 | 2128 |
| Brown Garnet 1 | | | 2194.56 | 2194.6 | | | 125 | | marine, probably near shore | WGF | 2050 | 2128 |
| Brown Garnet 1 | | | 2240.3 | 2240.3 | | | 425 | | marine | WGF | 2050 | 2128 |
| Brown Garnet 1 | | | 2250.6 | 2250.6 | | | 425 | | marine | WGF | 2050 | 2128 |
| Brown Garnet 1 | | | 275.5 | 462.4 | | | 200 | Miocene - Pliocene? | internal neritic zone, littoral, in shallow water | WGF | 2050 | 2128 |
| Brown Garnet 1 | | | 533.4 | 587 | | | 200 | Probably middle Miocene | internal neritic zone, littoral, in shallow water | WGF | 2050 | 2128 |
| Brown Garnet 1 | | | 602.6 | 807.7 | | | 250 | Lower Miocene | internal neritic littoral zone, more oceanward than overlying zones | WGF | 2050 | 2128 |
| Brown Garnet 1 | | | 833.6 | 882.4 | | | 200 | Oligocene | internal neritic zone, littoral | WGF | 2050 | 2128 |
| Brown Garnet 1 | | | 886.4 | 1040.3 | | | 250 | Eocene (probably Upper) | internal neritic zone with relatively calm intervals: proliferation of small bethonic Foraminifera | WGF | 2050 | 2128 |
| Brown Garnet 1 | | | 1061.3 | 1670.3 | | | 300 | Middle Eocene (to Lower) | internal to middle neritic zone (contributions from open sea) | WGF | 2050 | 2128 |
| Brown Garnet 1 | | | 1722 | 1764.2 | | | 400 | Lower Eocene | external neritic zone to deeper (slope?) | WGF | 2050 | 2128 |
| Brown Garnet 1 | | | 2042.16 | 2042.16 | | | 425 | | marine | WGF | 2050 | 2128 |
| Brown Garnet 1 | | | 2209.8 | 2209.8 | | | 225 | | marine, probably near shore | WGF | 2050 | 2128 |
| Brown Garnet 1 | | | 1783.1 | 1935.5 | | | 400 | Paleocene | external neritic zone to deeper (slope) | WGF | 2050 | 2128 |
| Brown Garnet 1 | | | 1966 | 2027 | | | 400 | Upper Senonian | external neritic zone to deeper (slope?) | WGF | 2050 | 2128 |
| Challis 1 | A.mayaroensis | G.gansseri | 990 | 1037 | 65 | 67 | 325 | mid - late Maastrichtian | mid shelf (990) to inner shelf (1037) | WGF | 1140 | 1324 |
| Challis 1 | C.diebelii | | 990 | 1117 | 66 | 73 | 525 | | open marine - the prominence of chorate cysts between 990 and 1074 suggests and open marine environment of deposition | WGF | 1140 | 1324 |
| Challis 1 | R.brotzeni | R.cushmani | 1321.1 | 1321.1 | 95 | 97.5 | 225 | middle Cenomanian | inner shelf | WGF | 1140 | 1324 |
| Challis 1 | D.multispinum | | 1342.6 | 1342.6 | 92.5 | 98.5 | 425 | | open marine | WGF | 1140 | 1324 |
| Challis 1 | P.ludbrookiae | | 1360 | 1360 | 100 | 101.5 | 325 | | open marine, possible shelfal | WGF | 1140 | 1324 |
| Challis 1 | M.australis | M.testudinaria | 1375.2 | 1380.8 | 118 | 123 | 325 | | shelfal marine - associations usually confined to the greensand unit at the base of the Echuca Shoals | WGF | 1140 | 1324 |
| Challis 1 | S.speciosus | | 1387.2 | 1657.5 | 214 | 226 | 200 | | deltaic | WGF | 1140 | 1324 |
| Challis 1 | S.speciosus | | 1387.2 | 1657.5 | 217.5 | 232 | 200 | | deltaic | WGF | 1140 | 1324 |
| Challis 1 | S.quadrifidus | | 1877 | 1927.9 | 226 | 238.5 | 100 | | marginal marine to deltaic | WGF | 1140 | 1324 |

## Appendix A - Biostrat zones and depositional environment information for Woolaston, Gibson and Fenelon Formations (WGF)

| well_name | biozone name | biozone range | biostrat depth top (m) | biostrat depth base (m) | biozone age from (Ma) | biozone age to (Ma) | age_code | notes on biozone age | depositional enviroment | formation name | formation top (m) | formation base (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Challis 1 | Indeterminate | | 952 | 968 | | | 425 | no younger than Early Paleocene | open marine - the prominence of chorate cysts suggests and open marine environment of deposition | WGF | 1140 | 1324 |
| Challis 1 | | | 633 | 633 | | | 125 | | beach sand? | WGF | 1140 | 1324 |
| Challis 1 | | | 678.9 | 678.9 | | | 225 | | inner shelf | WGF | 1140 | 1324 |
| Challis 1 | | | 721.9 | 721.9 | | | 225 | | ?inner shelf | WGF | 1140 | 1324 |
| Challis 1 | | | 765.9 | 765.9 | | | 225 | | inner shelf | WGF | 1140 | 1324 |
| Challis 1 | | | 825 | 825 | | | 225 | | inner shelf | WGF | 1140 | 1324 |
| Challis 1 | | | 928 | 928 | | | 225 | | inner shelf | WGF | 1140 | 1324 |
| Challis 1 | | | 944 | 944 | | | 225 | | inner shelf (?dolomite) | WGF | 1140 | 1324 |
| Challis 1 | | | 952 | 952 | | | 225 | | inner shelf | WGF | 1140 | 1324 |
| Challis 1 | | | 958 | 958 | | | 225 | | inner shelf | WGF | 1140 | 1324 |
| Challis 1 | | | 977 | 977 | | | 225 | | inner shelf | WGF | 1140 | 1324 |
| Challis 1 | G.falsostuarti | G.elevata | 1074 | 1117 | | | 225 | Early Maastrichtian to Campanian | inner shelf | WGF | 1140 | 1324 |
| Challis 1 | G.elevata | D.assymetrica | 1180 | 1180 | | | 225 | Earl Campanian to Late Santonian | inner shelf | WGF | 1140 | 1324 |
| Challis 1 | D.assymetrica | | 1246.9 | 1246.9 | | | 325 | Late Santonian | mid shelf | WGF | 1140 | 1324 |
| Challis 1 | D.concavata | | 1287.5 | 1287.5 | | | 225 | Late Coniacian-Santonian | inner shelf | WGF | 1140 | 1324 |
| Challis 1 | | | 1383.6 | 1383.6 | | | 125 | This sample is below M.testudinaria (1380.8m) so it is at least as old as the base age of the M.tesudinaria interval (126.5) | ?estuarine | WGF | 1140 | 1324 |
| Challis 1 | | | 874 | 874 | | | 225 | | inner shelf | WGF | 1140 | 1324 |
| Challis 1 | | | 968 | 968 | | | 225 | | inner shelf | WGF | 1140 | 1324 |
| Douglas 1 | CP8 | | 1816 | 1909 | 53.5 | 55.4 | 325 | | inner shelf | WGF | 2119 | 2137 |
| Douglas 1 | CP8 | | 1850 | 1850 | 53.5 | 55.4 | 325 | | inner shelf | WGF | 2119 | 2137 |
| Douglas 1 | T4 | | 1950 | 1990 | 57 | 59.2 | 325 | | middle shelf to shallow outer shelf | WGF | 2119 | 2137 |
| Douglas 1 | CP4 | | 1990 | 1990 | 59.3 | 59.9 | 325 | | middle shelf to shallow outer shelf | WGF | 2119 | 2137 |
| Douglas 1 | C11 | | 2111.5 | 2116 | 70 | 73 | 425 | | max outer shelf | WGF | 2119 | 2137 |
| Douglas 1 | C6 | | 2129.5 | 2129.5 | 87 | 89.2 | 425 | | deep outer shelf | WGF | 2119 | 2137 |
| Douglas 1 | C1 | | 2138.5 | 2332.5 | 100.5 | 108 | 425 | | outershelf or deeper - low diversity of abundant planktonic assemblages may be explained by relatively cool water. | WGF | 2119 | 2137 |
| Douglas 1 | M.testudinaria | | 2347.5 | 2347.5 | 123 | 126.5 | 525 | | open marine | WGF | 2119 | 2137 |
| Douglas 1 | P.burgeri | | 2357 | 2357 | 126.5 | 131 | 525 | | open marine | WGF | 2119 | 2137 |
| Douglas 1 | S.tabulata | | 2362 | 2377.5 | 131 | 133 | 425 | | open to shelfal marine | WGF | 2119 | 2137 |
| Douglas 1 | C.delicata | | 2380.5 | 2384 | 138 | 139 | 525 | | open marine | WGF | 2119 | 2137 |
| Douglas 1 | K.wisemaniae | | 2390 | 2390 | 139 | 140 | 525 | | open marine | WGF | 2119 | 2137 |
| Douglas 1 | P.iehiense | D.jurassicum | 2396.5 | 2450 | 140 | 142.5 | 525 | | open marine | WGF | 2119 | 2137 |
| Douglas 1 | D.jurassicum | | 2454.5 | 2462.5 | 142.5 | 143.8 | 425 | | open to shelfal marine | WGF | 2119 | 2137 |
| Douglas 1 | C.torosa | | 2487.3 | 2488.5 | 189.5 | 204.5 | 100 | | lower delta plain | WGF | 2119 | 2137 |
| Douglas 1 | A.reducta | M.crenulatus | 2543 | 2556 | 204.5 | 206.5 | 100 | | non-marine | WGF | 2119 | 2137 |
| Douglas 1 | M.crenulatus | | 2732 | 2748 | 206.5 | 214 | 100 | | lower delta plain | WGF | 2119 | 2137 |
| Douglas 1 | CP7 | CP5 | 1970 | 1970 | | | 325 | | middle shelf to shallow outer shelf | WGF | 2119 | 2137 |
| East Swan 2 | CP9 | | 1302.5 | 1338 | 52.4 | 53.5 | 400 | | middle neritic | WGF | 2095 | 2256 |
| East Swan 2 | CP8 | | 1361 | 1361 | 53.5 | 55.4 | 400 | | middle neritic | WGF | 2095 | 2256 |
| East Swan 2 | CP5 | | 1830.5 | 1830.5 | 57.8 | 59.3 | 450 | | outer neritic-upper bathyal | WGF | 2095 | 2256 |
| East Swan 2 | CP4 | CP2 | 1836 | 1856 | 59.3 | 59.9 | 450 | | outer neritic (1836m) upper bathyal (1856m) | WGF | 2095 | 2256 |
| East Swan 2 | CP1 | | 1880 | 1954 | 62.9 | 65 | 450 | | outer neritic-upper bathyal(1880m) / outer neritic (1944m & 1954m) | WGF | 2095 | 2256 |

## Appendix A - Biostrat zones and depositional environment information for Woolaston, Gibson and Fenelon Formations (WGF)

| well_name | biozone name | biozone range | biostrat depth top (m) | biostrat depth base (m) | biozone age from (Ma) | biozone age to (Ma) | age_code | notes on biozone age | depositional enviroment | formation name | formation top (m) | formation base (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| East Swan 2 | KCN-2 | KCN-3 | 1984 | 1984 | 65.88 | 66.3 | 450 | | outer neritic-upper bathyal | WGF | 2095 | 2256 |
| East Swan 2 | M.australis | | 2299 | 2303 | 118 | 123 | 325 | | at least shelfal - The prominence of plant debris in the organic residue suggest proximity of terrestial sources although high microplankton to spore-pollen ratio suggest that the environment of deposition is at least shelfal. | WGF | 2095 | 2256 |
| East Swan 2 | P.burgeri | | 2315 | 2316 | 126.5 | 131 | 325 | | shelfal marine - The relative prominence of plant debrisand the microplankton to spore-pollen ratio suggest shelfal marine depositional environments. | WGF | 2095 | 2256 |
| East Swan 2 | W.spectabilis | | 2319 | 2555 | 153.8 | 158.5 | 425 | | open marine, possibly shelfal - possibly shallowing downhole | WGF | 2095 | 2256 |
| East Swan 2 | R.aemula | | 2607 | 2635.5 | 158.5 | 160.3 | 325 | | shelfal marine | WGF | 2095 | 2256 |
| East Swan 2 | C.halosa | | 2642 | 2819 | 166.5 | 169 | 100 | | shallow marine to deltaic - The prominence and nature of the vascular plant debris and the spore-pollen to mircoplankton ratios suggest shallow marine to deltaic envronments fo deposition | WGF | 2095 | 2256 |
| East Swan 2 | inderterminate | | 1350 | 1350 | | | 400 | | middle-outer neritic | WGF | 2095 | 2256 |
| East Swan 2 | inderterminate | | 1808 | 1808 | | | 400 | | distal neritic | WGF | 2095 | 2256 |
| East Swan 2 | inderterminate | | 2000 | 2000 | | | 425 | | undifferentiated marine | WGF | 2095 | 2256 |
| Eclipse 1 | A.circumtabulata | | 1927.5 | 1938 | 65 | 66 | 525 | | open marine - dominance of chorate cysts and relatively low proportions of spores and pollen suggest open marine depositional environments | WGF | 2060 | 2250 |
| Eclipse 1 | A.mayaroensis | | 1931.5 | 1945 | 65 | 67 | 325 | Late Maastrichtian | mid-outer shelf to outer shelf | WGF | 2060 | 2250 |
| Eclipse 1 | C.diebelii | | 1997 | 2032 | 66 | 73 | 525 | | open marine - chroate cysts are very prominent suggesting open marine however, the increased vascular plant component together with prominent acritarchs may indicate a closer proximity to a land mass or more active sediment supply than in the samples abov | WGF | 2060 | 2250 |
| Eclipse 1 | S.carnarvonensis | | 2068.5 | 2068.5 | 73 | 77 | 525 | | open marine - chorate cysts dominate suggesting an open marine environment | WGF | 2060 | 2250 |
| Eclipse 1 | A.coronata | | 2105 | 2130 | 77 | 83 | 525 | | open marine - chorate cysts dominate suggesting an open marine environment | WGF | 2060 | 2250 |
| Eclipse 1 | C.striatoconus | | 2179 | 2179 | 87 | 91 | 525 | | open marine | WGF | 2060 | 2250 |
| Eclipse 1 | P.ludbrookiae | X.asperatus | 2249.9 | 2262.5 | 100 | 101.5 | 525 | | open marine | WGF | 2060 | 2250 |
| Eclipse 1 | D.davidii | | 2288.5 | 2288.5 | 106.5 | 109 | 525 | | open marine | WGF | 2060 | 2250 |
| Eclipse 1 | M.testudinaria | | 2307.6 | 2307.6 | 123 | 126.5 | 425 | | marine environment | WGF | 2060 | 2250 |
| Eclipse 1 | P.iehiense | | 2328 | 2328 | 140 | 142.5 | 425 | | marine - in view of the extent of reworking the environment is uncertain, although a marine setting is preferred | WGF | 2060 | 2250 |
| Eclipse 1 | W.spectabilis | W.spectabilis Mid | 2332 | 2489.9 | 153.8 | 158.5 | 225 | | marine/shallow marine? - The environment of deposition is clearly marine, although characterised by substantial vascular plant debris. This association has been interpreted previously as shallow marine | WGF | 2060 | 2250 |
| Eclipse 1 | W.spectabilis | W.spectabilis Lw | 2555.1 | 2561.3 | 153.8 | 158.5 | 425 | | marine | WGF | 2060 | 2250 |
| Eclipse 1 | R.aemula | | 2570.6 | 2570.6 | 158.5 | 160.3 | 425 | | marine | WGF | 2060 | 2250 |

## Appendix A - Biostrat zones and depositional environment information for Woolaston, Gibson and Fenelon Formations (WGF)

| well_name | biozone name | biozone range | biostrat depth top (m) | biostrat depth base (m) | biozone age from (Ma) | biozone age to (Ma) | age_code | notes on biozone age | depositional enviroment | formation name | formation top (m) | formation base (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Eclipse 1 | C.cooksoniae | D.complex | 2580 | 2647.5 | 163.5 | 167.5 | 425 | | marginal marine - The absence of dinoflagellates and the pattern of acritarch occurences suggests a marginal marine environment of deposition, possibly with increasing marine influence towards the lower part of the interval | WGF | 2060 | 2250 |
| Eclipse 1 | D.caddaensis | | 2708.5 | 2742.5 | 174.5 | 179.5 | 125 | | marginal marine | WGF | 2060 | 2250 |
| Eclipse 1 | C.turbatus | | 2799 | 2882.4 | 177 | 189.5 | 125 | | marginal marine (probably) - C.turbatus Lw | WGF | 2060 | 2250 |
| Eclipse 1 | D.priscum Up | | 2945 | 1965 | | | 125 | | marginal marine (probably) | WGF | 2060 | 2250 |
| Eclipse 1 | M.uncinata | S.pseudobulloides | 1826 | 1923 | | | 325 | Mid Paleocene to Early Paleocene | mid shelf | WGF | 2060 | 2250 |
| Eclipse 1 | G.lapparenti | | 2026 | 2026 | | | 225 | Early Maastrichtian | inner shelf | WGF | 2060 | 2250 |
| Eclipse 1 | G.elevata | | 2089 | 2121 | | | 225 | Early Campanian | inner shelf (2089m) to mid shelf (2121m) | WGF | 2060 | 2250 |
| Eclipse 1 | G.elevata | G.carinata | 2138.3 | 2138.3 | | | 325 | Early Campanian to Early Coniacian | outer shelf | WGF | 2060 | 2250 |
| Eclipse 1 | G.concavata | | 2168 | 2168 | | | 325 | Early Campanian to Early Coniacian | outer shelf | WGF | 2060 | 2250 |
| Eclipse 1 | G.renzi | G.sigali | 2203.5 | 2203.5 | | | 325 | Early Campanian to Early Coniacian | outer shelf | WGF | 2060 | 2250 |
| Fagin 1 | M.tetracantha | | 2646 | 2646 | 103.5 | 106.5 | 525 | | open marine | WGF | 2365 | 2506 |
| Fagin 1 | D.davidii | | 2665.4 | 2665.4 | 106.5 | 109 | 525 | | open marine | WGF | 2365 | 2506 |
| Fagin 1 | M.australis | | 2677.5 | 2697 | 118 | 123 | 425 | | shelfal to open marine | WGF | 2365 | 2506 |
| Fagin 1 | P.burgeri | S.tabulata | 2721.4 | 2742 | 126.5 | 131 | 425 | | shelfal to open marine | WGF | 2365 | 2506 |
| Fagin 1 | C.delicata | | 2759 | 2777.4 | 138 | 139 | 525 | | open marine | WGF | 2365 | 2506 |
| Fagin 1 | P.iehiense | | 2869.4 | 2902 | 140 | 142.5 | 525 | | open marine | WGF | 2365 | 2506 |
| Fagin 1 | P.iehiense | D.jurassicum | 2928 | 2949 | 140 | 142.5 | 525 | | open marine | WGF | 2365 | 2506 |
| Fagin 1 | W.spectabilis | | 2970 | 3009 | 153.8 | 158.5 | 425 | | shelfal to open marine | WGF | 2365 | 2506 |
| Fagin 1 | C.halosa | | 3020 | 3105 | 166.5 | 169 | 100 | | distal fluvial to marine delatic | WGF | 2365 | 2506 |
| Fagin 1 | D.caddaensis | | 3105 | 3249 | 174.5 | 179.5 | 100 | | fringing marine to lower delta plain | WGF | 2365 | 2506 |
| Halycon 1 | P.ludbrookiae | | 1010 | 1280 | 100 | 101.5 | 425 | | marine | WGF | 780 | 908 |
| Halycon 1 | C.denticulata | | 1286 | 1299 | 101.5 | 103.5 | 4245 | | marine | WGF | 780 | 908 |
| Halycon 1 | D.davidii | | 1311 | 1311 | 106.5 | 109 | 425 | | marine | WGF | 780 | 908 |
| Halycon 1 | M.australis | | 1325 | 1325 | 118 | 123 | 425 | | marine | WGF | 780 | 908 |
| Halycon 1 | S.areolata | | 1334 | 1337 | 133 | 135 | 425 | | marine | WGF | 780 | 908 |
| Halycon 1 | D.lobospinosum | | 1341 | 1341 | 137 | 138 | 425 | | marine | WGF | 780 | 908 |
| Halycon 1 | K.wisemaniae | | 1350 | 1353 | 139 | 140 | 425 | | marine | WGF | 780 | 908 |
| Halycon 1 | S.quadrifidus | | 1739 | 1739 | 226 | 238.5 | 100 | | marginal marine - Marine acritarchs were common and the abundance of cuticle, spores and pollen indicates a marginal marine environment. Relatively common recycling is also consistent with this environment | WGF | 780 | 908 |
| Halycon 1 | Indeterminate | | 615 | 677.3 | | | 425 | | undifferentiated marine | WGF | 780 | 908 |
| Halycon 1 | KCCM-2 | KCCM-5 | 681.8 | 687.5 | | | 300 | lower Late - upper Middle Maastrichtian | inner neritic-middle neritic | WGF | 780 | 908 |
| Halycon 1 | KCCM-12 | KCCM-13 | 705 | 745 | | | 300 | upper Late Campanian | undifferentiated marine (705m) / inner neritic-middle neritic (708-715m) / middle neritic (725-745m) | WGF | 780 | 908 |
| Halycon 1 | KCCM-14 | KCCM-15 | 778.5 | 778.5 | | | 350 | upper-mid Late Campanian | middle neritic | WGF | 780 | 908 |
| Halycon 1 | KCCM-20 | | 785 | 790 | | | 425 | upper Early Campanian | undifferentiated marine | WGF | 780 | 908 |
| Halycon 1 | KCCM-24 | | 790 | 795 | | | 425 | upper Late Santonian | undifferentiated marine | WGF | 780 | 908 |
| Halycon 1 | KCCM-26 | | 798 | 798 | | | 425 | upper Early Santonian | undifferentiated marine | WGF | 780 | 908 |
| Halycon 1 | KCCM-28 | | 857 | 857 | | | 400 | Coniacian | middle neritic - outer neritic | WGF | 780 | 908 |
| Halycon 1 | KCCM-29 | | 897.5 | 897.5 | | | 425 | upper Late Turonian | undifferentiated marine | WGF | 780 | 908 |
| Halycon 1 | KCCM-37 | KCCM-42 | 920 | 1110 | | | 350 | Middle Cenomanian - mid Late Albian | middle neritic or deeper (920m) / undifferentiated marine (950m) | WGF | 780 | 908 |

## Appendix A - Biostrat zones and depositional environment information for Woolaston, Gibson and Fenelon Formations (WGF)

| well_name | biozone name | biozone range | biostrat depth top (m) | biostrat depth base (m) | biozone age from (Ma) | biozone age to (Ma) | age_code | notes on biozone age | depositional enviroment | formation name | formation top (m) | formation base (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Halycon 1 | KCCM-39 | KCCM-42 | 1160 | 1260 | | | 450 | upper-mid Late Albian | distal neritic - upper bathyal | WGF | 780 | 908 |
| Halycon 1 | KCCM-44a | | 1280 | 1311 | | | 450 | Late Aptian to Middle Albian | outer neritic or deeper to upper bathyal | WGF | 780 | 908 |
| Jabiru 2 | T.rugulatum | | 1246 | 1246 | 64.5 | 66.5 | 525 | | open marine - prominence of chorate microplankton and very low proportion of vascular plant microfossils | WGF | 1283 | 1565 |
| Jabiru 2 | A.coronata | | 1326 | 1326 | 77 | 83 | 525 | | open marine - an increase in vascular plant material is noted | WGF | 1283 | 1565 |
| Jabiru 2 | A.suggestium | | 1535.5 | 1535.5 | 83 | 84.3 | 525 | | open marine | WGF | 1283 | 1565 |
| Jabiru 2 | P.ludbrookiae | | 1575 | 1599.5 | 100 | 101.5 | 525 | | open marine - although acritarchs may represent a relatively shallow environment of deposition | WGF | 1283 | 1565 |
| Jabiru 2 | M.tetracantha | | 1615 | 1615 | 103.5 | 106.5 | 425 | | marine environemnt - although prominence of acritarchs may represent a relatively shallow or restricted environment | WGF | 1283 | 1565 |
| Jabiru 2 | W.spectabilis | | 1625 | 1642.5 | 153.8 | 158.5 | 325 | | shelfal marine - environment of deposition is shelfal marine with substantial vascualr plant debris | WGF | 1283 | 1565 |
| Jabiru 2 | S.listeri | | 2075.5 | 2075.5 | 209 | 214 | 225 | | marine - possibly marginal | WGF | 1283 | 1565 |
| Jabiru 2 | S.wigginsii | | 2342 | 2342 | 214 | 220.5 | 100 | | marine-deltaic? | WGF | 1283 | 1565 |
| Jabiru 2 | S.speciosus | | 2169.6 | 2271 | 214 | 226 | 100 | | fluvio-deltaic - Dinoflagellates were not present and spinose acritarchs were not prominent, suggesting a fluvio-deltaic environment of deposition | WGF | 1283 | 1565 |
| Jabiru 2 | S.speciosus | | 2169.6 | 2271 | 217.5 | 232 | 100 | | fluvio-deltaic - Dinoflagellates were not present and spinose acritarchs were not prominent, suggesting a fluvio-deltaic environment of deposition | WGF | 1283 | 1565 |
| Kalyptea 1 | CP8 | | 1800 | 2260 | 53.5 | 55.4 | 300 | | inner-middle neritic (1800-10m) undifferentiated marine (1840-2260m) | WGF | 3434.5 | 3577.5 |
| Kalyptea 1 | KCN-4 | | 2634 | 2907 | 67.6 | 67.75 | 400 | | outer neritic | WGF | 3434.5 | 3577.5 |
| Kalyptea 1 | KCN-7 | | 3021 | 3252 | 70.5 | 72.2 | 400 | | outer neritic (3021-3024) | WGF | 3434.5 | 3577.5 |
| Kalyptea 1 | KCN-8 | KCN-9 | 3276 | 3375 | 72.2 | 73 | 450 | | outer neritic - upper bathyal (3201-3375) | WGF | 3434.5 | 3577.5 |
| Kalyptea 1 | KCN-10 | KCN-11 | 3405 | 3408 | 73.3 | 75.5 | 400 | | distal neritic ? | WGF | 3434.5 | 3577.5 |
| Kalyptea 1 | KCN-12 | | 3441 | 3468 | 78.4 | 81 | 500 | | upper bathyal (3441-3550) | WGF | 3434.5 | 3577.5 |
| Kalyptea 1 | KCN-15 | | 3475 | 3475 | 82 | 83 | 500 | | upper bathyal | WGF | 3434.5 | 3577.5 |
| Kalyptea 1 | KCN-16 | | 3500 | 3500 | 83 | 83.8 | 500 | | upper bathyal | WGF | 3434.5 | 3577.5 |
| Kalyptea 1 | KCN-18 | | 3524 | 3524 | 85 | 85.5 | 500 | | upper bathyal | WGF | 3434.5 | 3577.5 |
| Kalyptea 1 | KCN-19 | KCN-20 | 3540 | 3550 | 85.5 | 86 | 500 | | upper bathyal | WGF | 3434.5 | 3577.5 |
| Kalyptea 1 | KCN-21 | | 3563 | 3563 | 88.1 | 89.5 | 425 | | undifferentiated marine | WGF | 3434.5 | 3577.5 |
| Kalyptea 1 | KCN-25A | | 3592 | 3592 | 95.2 | 96.3 | 350 | | middle-upper bathyal | WGF | 3434.5 | 3577.5 |
| Kalyptea 1 | KCN-25C | | 3682 | 3806 | 97.6 | 99.3 | 450 | | outer neritic-upper bathyal | WGF | 3434.5 | 3577.5 |
| Kalyptea 1 | P.ludbrookiae | | 3682 | 3973 | 100 | 101.5 | 525 | | open marine | WGF | 3434.5 | 3577.5 |
| Kalyptea 1 | KCN-27 | | 2933 | 2933 | 100.8 | 103.8 | 550 | | middle-upper bathyal (2933-2965m) | WGF | 3434.5 | 3577.5 |
| Kalyptea 1 | KCN-28 | | 2965 | 2965 | 103.8 | 107.2 | 550 | | middle-upper bathyal (2933-2965m) | WGF | 3434.5 | 3577.5 |
| Kalyptea 1 | D.davidii | | 3985 | 4022 | 106.5 | 109 | 525 | | open marine - The microplankton to spore-pollen ratio and the restricted vascular plant debris suggests open marine environments of deposition | WGF | 3434.5 | 3577.5 |
| Kalyptea 1 | KCN-30 | | 4010 | 4040 | 108.9 | 110.6 | 400 | | outer neritic or deeper | WGF | 3434.5 | 3577.5 |
| Kalyptea 1 | O.operculata | | 4040 | 4040 | 109 | 115 | 525 | | open marine | WGF | 3434.5 | 3577.5 |
| Kalyptea 1 | A.cinctum | M.australis | 4060 | 4101 | 115 | 118 | 525 | | open marine | WGF | 3434.5 | 3577.5 |

## Appendix A - Biostrat zones and depositional environment information for Woolaston, Gibson and Fenelon Formations (WGF)

| well_name | biozone name | biozone range | biostrat depth top (m) | biostrat depth base (m) | biozone age from (Ma) | biozone age to (Ma) | age_code | notes on biozone age | depositional enviroment | formation name | formation top (m) | formation base (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Kalyptea 1 | M.australis | | 4110 | 4146 | 118 | 123 | 425 | | shelfal to open marine - The prominence of microplankton and the marginal increase in vascular plant debris into the bottom of the interval suggests shelfal to open marine environments of deposition. | WGF | 3434.5 | 3577.5 |
| Kalyptea 1 | M.testudinaria | | 4158 | 4194 | 123 | 126.5 | 325 | | shelfal - The downhole increase in the amount of vascular plant debris suggests shelfal environments of deposition, although the relatively high microplankton to spore-pollen ratios are indicative of open marine environments. | WGF | 3434.5 | 3577.5 |
| Kalyptea 1 | S.areolata | | 4209 | 4325 | 133 | 135 | 325 | | shelfal - The downhole increase in vascular plant debris and the ratio of microplankton to spore-pollen suggest shelfal environments of deposition | WGF | 3434.5 | 3577.5 |
| Kalyptea 1 | E.torynum | C.delicata | 4350 | 4572 | 135 | 136 | 325 | | shelfal - tentatively regarded as shelfal | WGF | 3434.5 | 3577.5 |
| Kalyptea 1 | | | 2388 | 2391 | | | 425 | | undiferentiated marine | WGF | 3434.5 | 3577.5 |
| Kalyptea 1 | | | 2535 | 2604 | | | 250 | | inner neritic | WGF | 3434.5 | 3577.5 |
| Kalyptea 1 | | | 2904 | 2988 | | | 350 | | distal neritic? | WGF | 3434.5 | 3577.5 |
| Kalyptea 1 | Inderterminate | | 2973 | 2985 | | | 425 | | undifferentiated marine | WGF | 3434.5 | 3577.5 |
| Kalyptea 1 | Inderterminate | | 4060 | 4060 | | | 400 | Sample lies between O.operculata (4040m) and A.cintum (4060m) and thus has been assigned an age of 118MA | mid-distal neritic | WGF | 3434.5 | 3577.5 |
| Keeling 1 | D.davidii | | 2990 | 2990 | 106.5 | 109 | 525 | | open marine - The prominence of dinoflagellates and the nature of the other plant debris suggest an open marine environment of deposition | WGF | 2760 | 2889 |
| Keeling 1 | M.australis | | 3000.5 | 3000.5 | 118 | 123 | 325 | | shelfal marine | WGF | 2760 | 2889 |
| Keeling 1 | M.testudinaria | | 3017 | 3017 | 123 | 126.5 | 525 | | open marine | WGF | 2760 | 2889 |
| Keeling 1 | M.crenulatus | | 3050.5 | 3116 | 206.5 | 214 | 100 | | lower delta plain - The abundance of Bartenia communis and the apparent absence of spinose acritarchs suggests lower delta plain environments of deposition | WGF | 2760 | 2889 |
| Maple 1 | P1 | | 2524 | 2524 | 61.2 | 64.9 | 500 | | upper bathyal | WGF | 2660 | 2827 |
| Maple 1 | A.circumtabulata | | 2552 | 2552 | 65 | 66 | 525 | | open marine | WGF | 2660 | 2827 |
| Maple 1 | KCN-2 | KCN-3 | 2552 | 2552 | 65.88 | 66.3 | 500 | Late-upper Early Maastrichtian | upper bathyal | WGF | 2660 | 2827 |
| Maple 1 | C.diebelii | | 2600 | 2600 | 66 | 73 | 525 | | open marine | WGF | 2660 | 2827 |
| Maple 1 | P.ludbrookiae | | 2835 | 2835 | 100 | 101.5 | 525 | | open marine | WGF | 2660 | 2827 |
| Maple 1 | M.testudinaria | | 2836 | 2836 | 123 | 126.5 | 525 | | open marine | WGF | 2660 | 2827 |
| Maple 1 | P.burgeri | | 2839 | 2839 | 126.5 | 131 | 525 | | open marine | WGF | 2660 | 2827 |
| Maple 1 | B.reticulatum | | 2846 | 2850 | 136 | 137 | 425 | | shelfal to open marine | WGF | 2660 | 2827 |
| Maple 1 | D.lobospinosum | C.delicata | 2859 | 2938 | 137 | 138 | 425 | | shelfal to open marine | WGF | 2660 | 2827 |
| Maple 1 | D.jurassicum | | 2975 | 3030 | 142.5 | 143.8 | 425 | | shelfal to open marine | WGF | 2660 | 2827 |
| Maple 1 | O.montgomeryi | | 3069 | 3069 | 143.8 | 145.2 | 525 | | open marine | WGF | 2660 | 2827 |
| Maple 1 | D.swanense | | 3087 | 3140 | 146 | 150.3 | 525 | | open marine | WGF | 2660 | 2827 |
| Maple 1 | W.clathrata | | 3150 | 3150 | 150.3 | 153.8 | 525 | | open marine | WGF | 2660 | 2827 |
| Maple 1 | W.spectabilis | | 3298.5 | 3600 | 153.8 | 158.5 | 425 | | shelfal to open marine | WGF | 2660 | 2827 |
| Maple 1 | R.aemula | | 3680 | 3681.9 | 158.5 | 160.3 | 425 | | shelfal to open marine | WGF | 2660 | 2827 |
| Maple 1 | M.crenulatus | | 3682.8 | 3689 | 206.5 | 214 | 100 | | marine deltaic to marginal marine | WGF | 2660 | 2827 |
| Maple 1 | S.speciosus | | 3747 | 4087.58 | 214 | 226 | 100 | | ranging from fringing marine to deltaic | WGF | 2660 | 2827 |
| Maple 1 | S.speciosus | | 3747 | 4087.58 | 217.5 | 232 | 100 | | ranging from fringing marine to deltaic | WGF | 2660 | 2827 |

## Appendix A - Biostrat zones and depositional environment information for Woolaston, Gibson and Fenelon Formations (WGF)

| well_name | biozone name | biozone range | biostrat depth top (m) | biostrat depth base (m) | biozone age from (Ma) | biozone age to (Ma) | age_code | notes on biozone age | depositional enviroment | formation name | formation top (m) | formation base (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Maret 1 | A.cinctum | | 3120 | 3130 | 115 | 118 | 525 | | | WGF | 2505 | 2835 |
| Medusa 1 | KCN-7 | | 1479 | 1479 | 70.5 | 72.2 | 500 | | upper bathyal | WGF | 1590 | 1689 |
| Medusa 1 | KCN-8 | | 1500 | 1500 | 72.2 | 73 | 500 | | upper bathyal | WGF | 1590 | 1689 |
| Medusa 1 | S.camarvonensis | | 1479 | 1500 | 73 | 77 | 525 | | open marine - environment interpreted as open marine on the basis of the microplankton to spore-pollen ratios and the nature of the plant debris (overwhelmingly fusainised) | WGF | 1590 | 1689 |
| Medusa 1 | KCN-13 | KCN-14 | 1548 | 1548 | 81 | 81 | 500 | | upper bathyal | WGF | 1590 | 1689 |
| Medusa 1 | KCN-16 | | 1609 | 1609 | 83 | 83.8 | 500 | | upper bathyal | WGF | 1590 | 1689 |
| Medusa 1 | I.cretaceum | | 1609 | 1609 | 82 | 85 | 525 | | open marine - environment interpreted as open marine on the basis of microplankton to spore-pollen ratio and the fusainised nature of the plant debris | WGF | 1590 | 1689 |
| Medusa 1 | KCN-18 | | 1653 | 1653 | 85 | 85.5 | 500 | | upper bathyal | WGF | 1590 | 1689 |
| Medusa 1 | D.davidii | | 1776 | 1777 | 106.5 | 109 | 525 | | open marine - environment interpreted as open marine on the basis of microplankton to spore-pollen ratio | WGF | 1590 | 1689 |
| Medusa 1 | S.tabulata | | 1785 | 1785 | 131 | 133 | 325 | | shelfal marine - The environment of deposition is interpreted as shelfal marine on the basis of the almost equal proporitons of microplankton and spore-pollen, although the relative paucity of cuticular and woody debris may indicate open marine conditions | WGF | 1590 | 1689 |
| Medusa 1 | D.complex | | 1836 | 1836 | 167.5 | 177 | 100 | | lower deltaic plain - Environment of deposition is interpreted as lower deltaic plain, with extremely rare spinose acritarchs suggesting a possible estuarine to brackish influence | WGF | 1590 | 1689 |
| Medusa 1 | C.turbatus | | 1902 | 1930 | 177 | 189.5 | 100 | | lower delta plain - Environment of deposition is interpreted as lower delta plain on the basis of the very high spore-pollen to microplankton ratios. However, the presence of very rare dinocysts and spinose acritarchs may indicate proximity to marine (est | WGF | 1590 | 1689 |
| Medusa 1 | Indeterminate | | 1776 | 1777 | | | 350 | Sample is the same depth as D.davidii (1776m) and so has been assigned an age of at least 109MA | mid neritic or deeper - samples 1776 and 1777m contian abundant samples of spumellarian radiolaria which is consistent with deposition in a mid neritic or deeper setting. | WGF | 1590 | 1689 |
| Medusa 1 | Indeterminate | | 1785 | 1785 | | | 425 | Sample lies between S.tabulata (1785m) and D.complex (1836m) and is most probably has an age of 109Ma as it was taken from the same depth as the S.tabulata (133MA) sample. | undifferentiated marine - The glauconitic SWC sampled is devoid of in-situ foraminifera and is barren of nannoplankton. The occurrence of abundant glauconite is consistent with deposition in a marine setting | WGF | 1590 | 1689 |
| Montara 1 | C13 | | 1683 | 1719 | 65 | 66 | 325 | | probably turbidite | WGF | 2119 | 2330 |
| Montara 1 | C12 | | 1929 | 1932 | 66 | 67 | 525 | | outer shelf or deeper; probably turbidite | WGF | 2119 | 2330 |
| Montara 1 | C11 | C10 | 2019 | 2022 | 70 | 73 | 500 | | bathyal | WGF | 2119 | 2330 |
| Montara 1 | C11 | | 1959 | 1992 | 70 | 73 | 450 | | outer shelf, becoming bathyal at 1992m | WGF | 2119 | 2330 |
| Montara 1 | C10 | | 2049 | 2112 | 73 | 79 | 500 | | bathyal | WGF | 2119 | 2330 |
| Montara 1 | C8 | C7 | 2120 | 2200 | 83 | 84.5 | 325 | | outer shelf | WGF | 2119 | 2330 |
| Montara 1 | C7 | | 2213 | 2228 | 84.5 | 87 | 325 | | outer shelf | WGF | 2119 | 2330 |
| Montara 1 | C6 | | 2232 | 2285 | 87 | 89.2 | 500 | | upper bathyal | WGF | 2119 | 2330 |
| Montara 1 | C5 | | 2289 | 2292 | 89.2 | 90 | 500 | | upper bathyal | WGF | 2119 | 2330 |

## Appendix A - Biostrat zones and depositional environment information for Woolaston, Gibson and Fenelon Formations (WGF)

| well_name | biozone name | biozone range | biostrat depth top (m) | biostrat depth base (m) | biozone age from (Ma) | biozone age to (Ma) | age_code | notes on biozone age | depositional enviroment | formation name | formation top (m) | formation base (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Montara 1 | C4 | | 2320 | 2322 | 90 | 91 | 500 | | upper bathyal | WGF | 2119 | 2330 |
| Montara 1 | P.infusorioides | | 2326 | 2326 | 91 | 92.5 | 525 | | open marine | WGF | 2119 | 2330 |
| Montara 1 | C3 | | 2349 | 2350 | 91 | 97 | 425 | | outer shelf or deeper | WGF | 2119 | 2330 |
| Montara 1 | D.multispinum | | 2338 | 2347 | 92.5 | 98.5 | 525 | | open marine - The environment of deposition is considered open marine, although spore-pollen to micropalnkton ratios in the upper part of the interval (down to 2343m) suggest a shelfal environment, with the marked change in the ratio below this level sugg | WGF | 2119 | 2330 |
| Montara 1 | X.asperatus | | 2350 | 2360 | 98.5 | 100 | 525 | | open marine - (possibly shelfal at 2360m) - Environment of deposition is open marine, although the spore-pollen ratio suggests shallowing to possible shelfal environments at 2360m | WGF | 2119 | 2330 |
| Montara 1 | C2 | | 2352 | 2375 | 97 | 100.5 | 500 | | upper bathyal | WGF | 2119 | 2330 |
| Montara 1 | P.ludbrookiae | | 2363 | 2387 | 100 | 101.5 | 525 | | open marine (possibly shelfal) | WGF | 2119 | 2330 |
| Montara 1 | C1 | | 2379 | 2382 | 100.5 | 108 | 450 | | outer shelf to upper bathyal | WGF | 2119 | 2330 |
| Montara 1 | W.spectabilis | | 2390 | 2978 | 153.8 | 158.5 | 425 | | shelfal to open marine - The spore-pollen to microplankton ratio, together with the nature and proportion of vascular plant debris suggests shelfal, open-marine environments of deposition | WGF | 2119 | 2330 |
| Montara 1 | R.aemula | | 3135 | 3135 | 158.5 | 160.3 | 425 | | shelfal to open marine - The spore-pollen to microplankton ratio, together with the nature and proportion of vascular plant debris suggests shelfal, open-marine environments of deposition | WGF | 2119 | 2330 |
| Montara 1 | D.caddaensis | | 3199 | 3199 | 174.5 | 179.5 | 100 | | marginal marine | WGF | 2119 | 2330 |
| Montara 1 | C.turbatus | | 3270 | 3396 | 177 | 189.5 | 100 | | deltaic - The apparent absence of microplankton in most samples suggests deltaic environments of deposition | WGF | 2119 | 2330 |
| Montara 1 | indeterminate | | 2340 | 2340 | | | 325 | Cenomanian | at least middle shelf; oxygen poor sea floor | WGF | 2119 | 2330 |
| Montara 1 | indeterminate | | 2333 | 2333 | | | 325 | Sample lies below the Turonian/Cenomanian clay marker (2327m) and so is at lease 93.5MA | ?turbidite - barren sand | WGF | 2119 | 2330 |
| Montara 1 | indeterminate | | 2327 | 2327 | | | 325 | Turonian/Cenomanian boundary clay marker | oxygen minimum event? | WGF | 2119 | 2330 |
| Montara 1 | indeterminate | | 2304 | 2304 | | | 325 | Sample lies between C5 (2289m) and C4 (2330m) and thus has been assigned an age of 90MA | ?turbidite - barren sand | WGF | 2119 | 2330 |
| Montara 1 | indeterminate | | 1539 | 1620 | | | 225 | Palaeocene | inner shelf | WGF | 2119 | 2330 |
| Montara 1 | indeterminate | | 1270 | 1300 | | | 225 | Palaeocene | shallow inner shelf | WGF | 2119 | 2330 |
| Montara 1 | indeterminate | | 1060 | 1240 | | | 225 | | nearshore and shallow inner shelf | WGF | 2119 | 2330 |
| Montara 1 | indeterminate | | 950 | 1030 | | | 225 | Early Eocene | inner shelf | WGF | 2119 | 2330 |
| Montara 1 | indeterminate | | 820 | 880 | | | 225 | Middle to Early Eocene | lagoonal; and shallow inner shelf | WGF | 2119 | 2330 |
| Montara 1 | indeterminate | | 760 | 760 | | | 225 | undiff. Early Oilgocene to Late Eocene | lagoonal; and shallow inner shelf | WGF | 2119 | 2330 |
| Montara 1 | indeterminate | | 520 | 580 | | | 125 | Middle Miocene | lagoonal; and shallow inner shelf | WGF | 2119 | 2330 |
| Montara 1 | indeterminate | | 460 | 460 | | | 225 | probably Miocene | shallow inner shelf, high energy | WGF | 2119 | 2330 |
| Octavius 1 | T8 | | 1280 | 1280 | 53.5 | 54.7 | 325 | | inner shelf to middle shelf | WGF | 2000 | 2150 |
| Octavius 1 | T5 | T4 | 1422 | 1422 | 55.9 | 57 | 250 | | inner - middle shelf | WGF | 2000 | 2150 |
| Octavius 1 | T4 | | 1608 | 1632 | 57 | 59.2 | 325 | | middle shelf (?deep) | WGF | 2000 | 2150 |
| Octavius 1 | T1 | | 1705 | 1730 | 61.7 | 63 | 325 | | middle - outer shelf | WGF | 2000 | 2150 |
| Octavius 1 | C13 | | 1865 | 1865 | 65 | 66 | 500 | | upper slope | WGF | 2000 | 2150 |

## Appendix A - Biostrat zones and depositional environment information for Woolaston, Gibson and Fenelon Formations (WGF)

| well_name | biozone name | biozone range | biostrat depth top (m) | biostrat depth base (m) | biozone age from (Ma) | biozone age to (Ma) | age_code | notes on biozone age | depositional enviroment | formation name | formation top (m) | formation base (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Octavius 1 | C9 | | 2005 | 2005 | 79 | 83 | 450 | | outer shelf or bathyal | WGF | 2000 | 2150 |
| Octavius 1 | C7 | | 2090 | 2090 | 84.5 | 87 | 500 | | bathyal | WGF | 2000 | 2150 |
| Octavius 1 | indeterminate | | 1755 | 1838 | | | 225 | | inner shelf | WGF | 2000 | 2150 |
| Octavius 1 | indeterminate | | 1645 | 1645 | | | 225 | | inner to shallow middle shelf | WGF | 2000 | 2150 |
| Octavius 1 | indeterminate | | 1465 | 1592 | | | 325 | | inner shelf | WGF | 2000 | 2150 |
| Octavius 1 | indeterminate | | 1308 | 1390 | | | 225 | undifferentiated Eocene to Palaeocene | inner shelf to intertidal | WGF | 2000 | 2150 |
| Octavius 1 | indeterminate | | 1260 | 1260 | | | 225 | Early Eocene | inner shelf | WGF | 2000 | 2150 |
| Octavius 1 | indeterminate | | 1163 | 1242 | | | 225 | | intertidal and shallow inner shelf | WGF | 2000 | 2150 |
| Octavius 1 | indeterminate | | 1025 | 1082 | | | 225 | Middle Eocene | shallow inner shelf | WGF | 2000 | 2150 |
| Octavius 1 | indeterminate | | 943 | 968 | | | 225 | probably Middle Eocene | inner shelf | WGF | 2000 | 2150 |
| Octavius 1 | indeterminate | | 885 | 908 | | | 225 | Late Eocene | inner shelf | WGF | 2000 | 2150 |
| Octavius 1 | indeterminate | | 867 | 867 | | | 125 | undifferentiated E. Oligocene to Late Eocene | shallow lagoonal | WGF | 2000 | 2150 |
| Octavius 1 | indeterminate | | 825 | 825 | | | 225 | Early Miocene | shallow inner shelf | WGF | 2000 | 2150 |
| Octavius 1 | indeterminate | | 752 | 820 | | | 225 | basal M. to E. Miocene | inner shelf | WGF | 2000 | 2150 |
| Octavius 1 | indeterminate | | 675 | 709 | | | 225 | | shallow inner shelf | WGF | 2000 | 2150 |
| Octavius 1 | indeterminate | | 647 | 647 | | | 325 | late M. Miocene - Early Pliocene | inner-shallow middle shelf | WGF | 2000 | 2150 |
| Oliver 1 | CN12 | | 666.5 | 733 | 1.9 | 3.6 | 350 | | middle neritic | WGF | 2392 | 2450 |
| Oliver 1 | CN11 | CN8 | 816 | 930 | 3.6 | 4.5 | 300 | | low energy inner neritic - middle neritic | WGF | 2392 | 2450 |
| Oliver 1 | CN5 | | 1488 | 1533 | 11.1 | 14.3 | 300 | | high to moderate energy inner neritic | WGF | 2392 | 2450 |
| Oliver 1 | CN4 | CN3 | 1560 | 1560 | 14.3 | 15.9 | 300 | | moderate energy inner neritic | WGF | 2392 | 2450 |
| Oliver 1 | CN2 | CN1 | 1567 | 1576 | 16.8 | 20.4 | 300 | | moderate energy inner neritic | WGF | 2392 | 2450 |
| Oliver 1 | CP9 | | 2006.5 | 2006.5 | 52.4 | 53.5 | 350 | | low-moderate energy neritic | WGF | 2392 | 2450 |
| Oliver 1 | P7 | P6 | 1993.5 | 1993.5 | 54 | 54.7 | 425 | | undifferentiated marine | WGF | 2392 | 2450 |
| Oliver 1 | CP8 | CP6 | 2141.5 | 2141.5 | 53.5 | 55.4 | 425 | | undifferentiated marine | WGF | 2392 | 2450 |
| Oliver 1 | KCN-16 | KCN-17 | 2406 | 2406 | 83 | 83.8 | 500 | | upper bathyal | WGF | 2392 | 2450 |
| Oliver 1 | KCN-19 | KCN-21 | 2418.5 | 2418.5 | 85.5 | 86 | 500 | | upper bathyal ? | WGF | 2392 | 2450 |
| Oliver 1 | KCN-21 | | 2441.5 | 2441.5 | 88.1 | 89.5 | 550 | | middle - upper bathyal | WGF | 2392 | 2450 |
| Oliver 1 | KCN-22 | KCN-23 | 2446.5 | 2446.5 | 89.5 | 91.65 | 500 | | upper bathyal | WGF | 2392 | 2450 |
| Oliver 1 | X.asperatus | | 2534 | 2540 | 98.5 | 100 | 425 | | open marine | WGF | 2392 | 2450 |
| Oliver 1 | C.denticulata | | 2592 | 2604 | 101.5 | 103.5 | 525 | | open marine | WGF | 2392 | 2450 |
| Oliver 1 | KCN-27 | | 2565 | 2581 | 100.8 | 103.8 | 550 | | middle - upper bathyal | WGF | 2392 | 2450 |
| Oliver 1 | M.tetracantha | D.davidii | 2608 | 2609 | 103.5 | 106.5 | 525 | | open marine | WGF | 2392 | 2450 |
| Oliver 1 | KCN-28 | | 2592 | 2606 | 103.8 | 107.2 | 550 | | middle - upper bathyal | WGF | 2392 | 2450 |
| Oliver 1 | KCN-29 | | 2608 | 2608 | 107.2 | 108.9 | 400 | | outer neritic or deeper | WGF | 2392 | 2450 |
| Oliver 1 | KCN-29 | KCN-30 | 2612 | 2612 | 107.2 | 108.9 | 400 | | distal neritic | WGF | 2392 | 2450 |
| Oliver 1 | KCN-30 | | 2615 | 2615 | 108.9 | 110.6 | 400 | | outer neritic or deeper | WGF | 2392 | 2450 |
| Oliver 1 | O.operculata | | 2612 | 2627 | 109 | 115 | 525 | | open marine | WGF | 2392 | 2450 |
| Oliver 1 | A.cinctum | M.australis | 2645 | 2645 | 115 | 118 | 525 | | open marine | WGF | 2392 | 2450 |
| Oliver 1 | M.australis | | 2654 | 2672 | 118 | 123 | 525 | | open marine | WGF | 2392 | 2450 |
| Oliver 1 | M.testudinaria | | 2676 | 2681 | 123 | 126.5 | 525 | | open marine | WGF | 2392 | 2450 |
| Oliver 1 | S.tabulata | | 2686 | 2691 | 131 | 133 | 325 | | shelfal - The downhole increase in the proportion of spores and pollen in the assemblage suggests possible downhole shallowing of shelfal environments of deposition | WGF | 2392 | 2450 |
| Oliver 1 | S.areolata | | 2696 | 2696 | 133 | 135 | 325 | | shelfal marine | WGF | 2392 | 2450 |
| Oliver 1 | C.delicata | | 2707 | 2758 | 138 | 139 | 325 | | shelfal marine | WGF | 2392 | 2450 |
| Oliver 1 | P.iehiense | | 2789 | 2840 | 140 | 142.5 | 325 | | shelfal marine or deeper | WGF | 2392 | 2450 |

## Appendix A - Biostrat zones and depositional environment information for Woolaston, Gibson and Fenelon Formations (WGF)

| well_name | biozone name | biozone range | biostrat depth top (m) | biostrat depth base (m) | biozone age from (Ma) | biozone age to (Ma) | age_code | notes on biozone age | depositional enviroment | formation name | formation top (m) | formation base (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Oliver 1 | D.jurassicum | | 2874 | 2894 | 142.5 | 143.8 | 525 | | open marine | WGF | 2392 | 2450 |
| Oliver 1 | W.spectabilis | | 2900 | 2943 | 153.8 | 158.5 | 525 | | open maine - The environment of deposition is interpreted as open marine, the increasing proportion of vascular plant debris suggests a shallowing with depth | WGF | 2392 | 2450 |
| Oliver 1 | D.complex | | 2953 | 2956 | 167.5 | 177 | 100 | | deltaic - Spinose acritarchs did not exceed 1.5% and a single, tentatively identified, dinoflagellate was recorded. The environment of deposition is interpreted as deltaic | WGF | 2392 | 2450 |
| Oliver 1 | D.caddaensis | | 2961 | 3044 | 174.5 | 179.5 | 100 | | shallow marine to marine/deltaic | WGF | 2392 | 2450 |
| Oliver 1 | C.torosa | | 3094 | 3287 | 189.5 | 204.5 | 200 | | shallow marine to marine/deltaic - possibly shallowing downhole, although low recoveries below 3200m inhibit interpretation | WGF | 2392 | 2450 |
| Oliver 1 | A.reducta | | 3417 | 3432 | 204.5 | 206.5 | 100 | | fluvio-deltaic - environment is possibly fluvio-deltaic | WGF | 2392 | 2450 |
| Oliver 1 | | | 733 | 816 | | | 300 | | middle neritic | WGF | 2392 | 2450 |
| Oliver 1 | indeterminate | | 990 | 1455 | | | 250 | | high energy inner neritic (1083m, 1142m & 1276 to 1455m) - undifferentiated marine (990m and 1188 to 1205.5m) | WGF | 2392 | 2450 |
| Oliver 1 | indeterminate | | 1823 | 1853 | | | 300 | | low-middle energy inner neritic | WGF | 2392 | 2450 |
| Oliver 1 | indeterminate | | 1871.5 | 1940.5 | | | 425 | | undifferentiated marine | WGF | 2392 | 2450 |
| Oliver 1 | indeterminate | | 1983 | 1983 | | | 300 | | low energy inner neritic | WGF | 2392 | 2450 |
| Oliver 1 | indeterminate | | 1993.5 | 1993.5 | | | 350 | | middle neritic | WGF | 2392 | 2450 |
| Oliver 1 | indeterminate | | 2023.5 | 2056.5 | | | 300 | | low energy inner neritic? | WGF | 2392 | 2450 |
| Oliver 1 | indeterminate | | 2080.5 | 2080.5 | | | 300 | | moderate-high energy inner neritic | WGF | 2392 | 2450 |
| Oliver 1 | indeterminate | | 2110.5 | 2110.5 | | | 300 | | moderate-high energy inner neritic | WGF | 2392 | 2450 |
| Oliver 1 | indeterminate | | 2119.5 | 2119.5 | | | 300 | | low energy inner neritic - middle neritic | WGF | 2392 | 2450 |
| Oliver 1 | | | 2126.5 | 2264 | | | 425 | | undifferentiated marine | WGF | 2392 | 2450 |
| Oliver 1 | | | 2349.5 | 2368.5 | | | 425 | | undifferentiated marine | WGF | 2392 | 2450 |
| Oliver 1 | inderterminate | | 2627 | 2627 | | | 425 | Sample lies between KCN-30 (2615m) and A.cinctum (2645m) and thus has been assigned an age between 110.6MA and 115MA | undifferentiated marine | WGF | 2392 | 2450 |
| Oliver 1 | CC2 | CC4 | 2645 | 2686 | | | 350 | Hauterivian-Valanginian | mid neritic to distal neritic at base | WGF | 2392 | 2450 |
| Oliver 1 | inderterminate | | 2691 | 2840 | | | 425 | | undifferentiated marine | WGF | 2392 | 2450 |
| Oliver 1 | E.communis | V.stradneri | 2900 | 2900 | | | 400 | lower late Kimmeridgian - Middle Oxfordian | distal neritic | WGF | 2392 | 2450 |
| Oliver 1 | indeterminate | | 1643.5 | 1803.5 | | | 300 | | high energy inner neritic | WGF | 2392 | 2450 |
| Oliver 1 | | | 2286.5 | 2286.5 | | | 300 | | low energy inner neritic - middle neritic | WGF | 2392 | 2450 |
| Osprey 1 | | | 283 | 419.1 | | | 200 | Miocene | internal littoral neritic zone in shallow water depth | WGF | 810 | 1074 |
| Osprey 1 | | | 469 | 487 | | | 200 | possibly Eocene | internal littoral neritic zone in shallow water depth | WGF | 810 | 1074 |
| Osprey 1 | | | 501 | 621 | | | 200 | Eocene | internal littoral neritic zone in shallow water depth | WGF | 810 | 1074 |
| Osprey 1 | | | 640 | 722 | | | 300 | Upper Cretaceous | neritic zone (regression of Upper Cretaceous) | WGF | 810 | 1074 |
| Osprey 1 | | | 734 | 809 | | | 200 | Lower Maastrichtian and Campanian | unstable neritic zone; alterations of clearly marine levels with good connections to open sea and poor, limonitic, pyritic levels showing and unfavourable, confined environment | WGF | 810 | 1074 |
| Osprey 1 | | | 822 | 851 | | | 350 | Campanian | external to middle neritic zone | WGF | 810 | 1074 |

## Appendix A - Biostrat zones and depositional environment information for Woolaston, Gibson and Fenelon Formations (WGF)

| well_name | biozone name | biozone range | biostrat depth top (m) | biostrat depth base (m) | biozone age from (Ma) | biozone age to (Ma) | age_code | notes on biozone age | depositional enviroment | formation name | formation top (m) | formation base (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Osprey 1 | | | 859 | 926 | | | 350 | Santonian to Coniacian | external to middle neritic zone (859 to 890m); below (890-926m) a more confined environment (internal neritic zone?), restricted (abundance of agglutinates), poorly suited for development of both benthonic and planktonic calcareous forms (possible presenc | WGF | 810 | 1074 |
| Osprey 1 | | | 932 | 945 | | | 250 | Lower Senonian? Turonian? | internal neritic zone with a confined environment (see 859 to 926m) | WGF | 810 | 1074 |
| Osprey 1 | | | 959 | 1079 | | | 350 | Turonian | external to middle neritic zone | WGF | 810 | 1074 |
| Osprey 1 | | | 1082 | 1130 | | | 350 | Cenomanian | middle to external neritic zone; a more confined environment at the top | WGF | 810 | 1074 |
| Osprey 1 | | | 1161 | 1226 | | | 400 | Lower Cenomanian to Upper Albian | external neritic zone (deeper part) | WGF | 810 | 1074 |
| Osprey 1 | | | 1310 | 2365 | | | 425 | | marine character of deposits | WGF | 810 | 1074 |
| Paqualin 1 | KCN-6 | | 2295 | 2295 | 68 | 70.5 | 450 | | outer neritic-upper bathyal | WGF | 2358 | 2462 |
| Paqualin 1 | C.diebelii | | 2290 | 2300 | 66 | 73 | 525 | | open marine - prominence of microplankton and the nature of plant debris suggests open marine | WGF | 2358 | 2462 |
| Paqualin 1 | KCN-21 | | 2286 | 2286 | 88.1 | 89.5 | 450 | | middle-upper bathyal | WGF | 2358 | 2462 |
| Paqualin 1 | M.tetracantha | | 2469 | 2480 | 103.5 | 106.5 | 525 | | open marine | WGF | 2358 | 2462 |
| Paqualin 1 | O.operculata | | 2489.5 | 2489.5 | 109 | 115 | 525 | | open marine | WGF | 2358 | 2462 |
| Paqualin 1 | M.australis | | 2493 | 2511 | 118 | 123 | 425 | | open marine, possibly shelfal - There is a marginal downhole increase in in the proportion of woody and cuticular debris, although neither exceeds 3%, which with high microplankton to spore-pollen ratio, suggests open marin, possibly shelfal depositional | WGF | 2358 | 2462 |
| Paqualin 1 | S.areolata | | 2525 | 2525 | 133 | 135 | 325 | | open marine, possibly shelfal - Although there is a definite increase in the spore-pollen to microplankton ratio, the prominence of microplankton and the relative low proportion of 'fresh' vascular plant debris suggests and open marine, possible shelfal, | WGF | 2358 | 2462 |
| Paqualin 1 | C.delicata | | 2526 | 2583 | 138 | 139 | 525 | | open marine | WGF | 2358 | 2462 |
| Paqualin 1 | K.wisemaniae | | 2619 | 2638 | 139 | 140 | 525 | | open marine | WGF | 2358 | 2462 |
| Paqualin 1 | P.iehiense | | 2633 | 2685 | 140 | 142.5 | 525 | | open marine - prominence of microplankton and scarcity of vascular plant debris suggest open marine environments of deposition | WGF | 2358 | 2462 |
| Paqualin 1 | D.jurassicum | | 2844 | 2907 | 142.5 | 143.8 | 525 | | open marine | WGF | 2358 | 2462 |
| Paqualin 1 | D.swanense | | 2925 | 2952 | 146 | 150.3 | 525 | | open marine | WGF | 2358 | 2462 |
| Paqualin 1 | W.clathrata | | 2961 | 3051 | 150.3 | 153.8 | 525 | | open marine | WGF | 2358 | 2462 |
| Paqualin 1 | W.spectabilis | | 3060 | 3789 | 153.8 | 158.5 | 425 | | open marine to shelfal - The microplankton to spore-pollen ratio indicates open marine environments of deposition, although increased vascular plant debris indicate relatively high rates of deposition, some of which may derive from shelfal locations | WGF | 2358 | 2462 |
| Paqualin 1 | indeterminate | | 1535 | 1650 | | | 425 | | undifferentiated marine | WGF | 2358 | 2462 |
| Paqualin 1 | indeterminate | | 4077 | 4131 | | | 250 | Sample lies well below W.spectabilis (3789m) and is at least 158.5MA | proximal neritic | WGF | 2358 | 2462 |
| Paqualin 1 | indeterminate | | 4169 | 4169 | | | 425 | | undifferentiated marine | WGF | 2358 | 2462 |
| Paqualin 1 | indeterminate | | 4179 | 4179 | | | 425 | | undifferentiated marine | WGF | 2358 | 2462 |
| Paqualin 1 | indeterminate | | 4215 | 4215 | | | 300 | | inner-middle neritic | WGF | 2358 | 2462 |
| Paqualin 1 | indeterminate | | 4218 | 4218 | | | 425 | | undifferentiated marine | WGF | 2358 | 2462 |

## Appendix A - Biostrat zones and depositional environment information for Woolaston, Gibson and Fenelon Formations (WGF)

| well_name | biozone name | biozone range | biostrat depth top (m) | biostrat depth base (m) | biozone age from (Ma) | biozone age to (Ma) | age_code | notes on biozone age | depositional enviroment | formation name | formation top (m) | formation base (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Paqualin 1 | indeterminate | | 4212 | 4212 | | | 300 | | inner neritic | WGF | 2358 | 2462 |
| Pascal 1 | KCN-1 | | 2200.5 | 2298 | 65 | 65.88 | 500 | | upper bathyal | WGF | 2420 | 2497 |
| Pascal 1 | KCN-2 | KCN-3 | 2305 | 2333 | 65.88 | 66.3 | 500 | | upper bathyal | WGF | 2420 | 2497 |
| Pascal 1 | KCN-4 | | 2345.5 | 2345.5 | 67.6 | 67.75 | 500 | | upper bathyal | WGF | 2420 | 2497 |
| Pascal 1 | KCN-7 | | 2378 | 2413 | 70.5 | 72.2 | 500 | | upper bathyal | WGF | 2420 | 2497 |
| Pascal 1 | KCN-9 | | 2428 | 2428 | 73 | 73.3 | 550 | | mid-upper bathyal | WGF | 2420 | 2497 |
| Pascal 1 | KCN-10 | KCN-11 | 2443 | 2443 | 73.3 | 75.5 | 550 | | mid-upper bathyal | WGF | 2420 | 2497 |
| Pascal 1 | KCN-13 | KCN-14 | 2453 | 2453 | 81 | 81 | 550 | | mid-upper bathyal | WGF | 2420 | 2497 |
| Pascal 1 | KCN-17 | | 2460 | 2460 | 83.8 | 85 | 550 | | mid-upper bathyal | WGF | 2420 | 2497 |
| Pascal 1 | KCN-19 | | 2473 | 2473 | 85.5 | 86 | 550 | | mid-upper bathyal | WGF | 2420 | 2497 |
| Pascal 1 | KCN-25B | | 2498 | 2498 | 96.3 | 97.6 | 550 | | mid-upper bathyal | WGF | 2420 | 2497 |
| Pascal 1 | KCN-27 | | 2503 | 2507 | 100.8 | 103.8 | 550 | | mid-upper bathyal | WGF | 2420 | 2497 |
| Pascal 1 | KCN-29 | | 2511 | 2515 | 107.2 | 108.9 | 400 | | outer neritic or deeper | WGF | 2420 | 2497 |
| Pascal 1 | KCN-30 | | 2517 | 2517 | 108.9 | 110.6 | 400 | | outer neritic or deeper | WGF | 2420 | 2497 |
| Pascal 1 | S.wigginsii | | 2536 | 2557 | 214 | 220.5 | 100 | | fringing marine environment - due to abumdance of dinoflagellates | WGF | 2420 | 2497 |
| Pascal 1 | S.speciosus | | 2692 | 2843 | 214 | 226 | 100 | | proximal delta plain environment of deposition | WGF | 2420 | 2497 |
| Pascal 1 | S.speciosus | | 2692 | 2843 | 217.5 | 232 | 100 | | proximal delta plain environment of deposition | WGF | 2420 | 2497 |
| Pascal 1 | indeterminate | | 2483 | 2493.5 | | | 550 | Sample has an age between 86MA and 87.5MA | mid-upper bathyal | WGF | 2420 | 2497 |
| Pascal 1 | indeterminate | | 2520 | 2520 | | | 400 | Sample is below KCN-30 (2517m) and so is at least older than 110.6MA | middle neritic or deeper | WGF | 2420 | 2497 |
| Pascal 1 | indeterminate | | 2522 | 2523.5 | | | 300 | | undifferentiated neritic | WGF | 2420 | 2497 |
| Pascal 1 | indeterminate | | 2588 | 2588 | | | 425 | | undifferentiated marine | WGF | 2420 | 2497 |
| Pascal 1 | indeterminate | | 2622 | 2622 | | | 300 | | inner?-middle neritic | WGF | 2420 | 2497 |
| Pascal 1 | indeterminate | | 2699 | 2699 | | | 425 | | undifferentiated marine | WGF | 2420 | 2497 |
| Pascal 1 | indeterminate | | 2715.5 | 2715.5 | | | 300 | | inner neritic | WGF | 2420 | 2497 |
| Pascal 1 | indeterminate | | 2827 | 2827 | | | 425 | | undifferentiated marine | WGF | 2420 | 2497 |
| Pollard 1 | E.crassitabulata | | 1853 | 1900.9 | 57 | 58 | 525 | | open marine | WGF | 2020 | 2043 |
| Pollard 1 | T.rugulatum | | 1925 | 1965.9 | 64.5 | 66.5 | 525 | | open marine | WGF | 2020 | 2043 |
| Pollard 1 | A.mayaroensis | | 1965.9 | 1985.8 | 65 | 67 | 325 | | outer shelf | WGF | 2020 | 2043 |
| Pollard 1 | C.diebelii | | 1977 | 2017.9 | 66 | 73 | 525 | | open marine | WGF | 2020 | 2043 |
| Pollard 1 | S.carnarvonensis | | 2031 | 2031 | 73 | 77 | 525 | | open marine | WGF | 2020 | 2043 |
| Pollard 1 | S.speciosus | | 2159 | 2513.9 | 214 | 226 | 100 | | fluvio-delatic depositional environment - occurrence of rare spinose acritarchs through the interval suggests fluvio-deltaic environments of deposition | WGF | 2020 | 2043 |
| Pollard 1 | S.speciosus | | 2159 | 2513.9 | 217.5 | 232 | 100 | | fluvio-delatic depositional environment - occurrence of rare spinose acritarchs through the interval suggests fluvio-deltaic environments of deposition | WGF | 2020 | 2043 |
| Pollard 1 | S.quadrifidus | | 2532.4 | 2684 | 226 | 238.5 | 100 | | fluvio-deltaic depositional environment | WGF | 2020 | 2043 |
| Pollard 1 | M.subbotinae | | 1537.5 | 1635.1 | | | 325 | Early Eocene | mid shelf | WGF | 2020 | 2043 |
| Pollard 1 | M.velascoensis | | 1661 | 1726 | | | 325 | Late Paleocene | mid-outer shelf | WGF | 2020 | 2043 |
| Pollard 1 | P.pseudomenardii | | 1734.9 | 1819 | | | 325 | Late Paleocene | mid shelf | WGF | 2020 | 2043 |
| Pollard 1 | A.pusilla | | 1847.4 | 1847.4 | | | 325 | Mid Paleocene | outer shelf | WGF | 2020 | 2043 |
| Pollard 1 | M.angulata | | 1857 | 1891 | | | 325 | Mid Paleocene | outer shelf | WGF | 2020 | 2043 |
| Pollard 1 | A.uncinata | | 1900.9 | 1932.9 | | | 325 | Mid Paleocene | outer shelf | WGF | 2020 | 2043 |
| Pollard 1 | S.trinidadensis | | 1944.8 | 1944.8 | | | 325 | Mid Paleocene | outer shelf | WGF | 2020 | 2043 |
| Pollard 1 | G.calcarata | | 2017.9 | 2017.9 | | | 325 | Late Campanian | mid-outer shelf | WGF | 2020 | 2043 |

## Appendix A - Biostrat zones and depositional environment information for Woolaston, Gibson and Fenelon Formations (WGF)

| well_name | biozone name | biozone range | biostrat depth top (m) | biostrat depth base (m) | biozone age from (Ma) | biozone age to (Ma) | age_code | notes on biozone age | depositional enviroment | formation name | formation top (m) | formation base (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pollard 1 | G.elevata | | 2021 | 2021 | | | 325 | Early Campanian | inner-mid shelf | WGF | 2020 | 2043 |
| Pollard 1 | S.pseudobulloides | | 1954.9 | 1954.9 | | | 325 | Early Paleocene | outer shelf | WGF | 2020 | 2043 |
| Pollard 1 | D.assymetrica | | 2035 | 2035 | | | 325 | Late Santonian | outer shelf | WGF | 2020 | 2043 |
| Pollard 1 | M.schneegansi | | 2042 | 2042 | | | 325 | Late Turonian | outer shelf | WGF | 2020 | 2043 |
| Prion 1 | | | 213 | 908 | | | 200 | Miocene to more recent | inner neritic zone of continental shelf, littoral marine, under shallow-water with probaly high energy | WGF | 2470 | 2588 |
| Prion 1 | | | 911 | 1011 | | | 250 | Middle to Lower Miocene | inner neritic zone (marginal part) of the shelf under high energy conditions | WGF | 2470 | 2588 |
| Prion 1 | | | 1097 | 1676 | | | 325 | Eocene | shelf - the interval seems to have been deposition on the shelf (behind a barrier? : lack of planktonic material) with the possibility of the installisation of a Nummulite constructed body from 1494 to 1585m | WGF | 2470 | 2588 |
| Prion 1 | | | 1704 | 1859 | | | 525 | Lower Eocene (to Paleocene?) | connected with open sea but with fluctuating depths | WGF | 2470 | 2588 |
| Prion 1 | | | 1880 | 2134 | | | 325 | Palaeocene | mid to outer shelf - The diversity and abundance of the association could indicate mid to outer shelf deposits; the occurrence of some forms indicative of deeper water depths in the lower part of the interval could indicate a shallowing of the water colum | WGF | 2470 | 2588 |
| Prion 1 | | | 2161 | 2435 | | | 325 | Maastrichtian | proable outer shelf under normal marine conditions - the levels of agglutinated assemblages could be the result of a turbidite period | WGF | 2470 | 2588 |
| Prion 1 | | | 2465 | 2499 | | | 325 | Lower Maastrichtian | shelf - normal marine conditions - could reflect restricted conditions at this level | WGF | 2470 | 2588 |
| Prion 1 | | | 2513 | 2524 | | | 425 | Campanian | outer shelf - slope | WGF | 2470 | 2588 |
| Prion 1 | | | 2626 | 2634 | | | 225 | Jurassic | shallow marine, probably near shore environment - according to palynoplanktology, glauconitic sandstones were deposited in a shallow marine, probably near shore environment | WGF | 2470 | 2588 |
| Puffin 2 | P6 | | 1660 | 1729 | 54.7 | 55.9 | 325 | | continental influence equal to marine influence (old study) | WGF | 2390 | 2425 |
| Puffin 2 | A.mayaroensis | | 1987 | 2069 | 65 | 67 | 325 | | organic matter has continental origin but marine microplankton is frequence (marine and continental matter equal) (old study) | WGF | 2390 | 2425 |
| Puffin 2 | | | 803 | 899 | | | 200 | Miocene to more recent | inner neritic zone of shelf, littoral marine, under shallow water with probable high energy | WGF | 2390 | 2425 |
| Puffin 2 | | | 902 | 1027 | | | 200 | Middle to Lower Miocene | inner neritic zone of shelf, littoral marine, under shallow water conditions - occurrence of scarce planktonic forms is the result of transport by currents | WGF | 2390 | 2425 |
| Puffin 2 | | | 1045 | 1637 | | | 250 | Eocene | inner neritic part of the shelf - with the possibility of a Nummulites constructed body | WGF | 2390 | 2425 |
| Puffin 2 | | | 1661 | 1728 | | | 325 | Lower Eocene | middle shelf, largely connected with open sea | WGF | 2390 | 2425 |
| Puffin 2 | | | 1756 | 2003 | | | 325 | Palaeocene | mid to outer shelf deposits - the benthonic assemblage and the relative abundance of planktonic forms are representative of mid to outer shelf deposits, the lower part of the Palaeocene sequence could be deper than the upper part as the benthonic associat | WGF | 2390 | 2425 |

## Appendix A - Biostrat zones and depositional environment information for Woolaston, Gibson and Fenelon Formations (WGF)

| well_name | biozone name | biozone range | biostrat depth top (m) | biostrat depth base (m) | biozone age from (Ma) | biozone age to (Ma) | age_code | notes on biozone age | depositional enviroment | formation name | formation top (m) | formation base (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Puffin 2 | | | 2030 | 2185 | | | 325 | Upper Maastrichtian | mid to outer shelf - (large amount of planktonic species and abundance and diversity of the bethonic assemblage) | WGF | 2390 | 2425 |
| Rainier 1 | C.denticulata | | 1647 | 1650.5 | 101.5 | 103.5 | 525 | | open marine | WGF | 1400 | 1595 |
| Rainier 1 | M.tetracantha | | 1650 | 1653 | 103.5 | 106.5 | 525 | | open marine | WGF | 1400 | 1595 |
| Rainier 1 | M.australis | | 1653 | 1659 | 118 | 123 | 525 | | open marine, possibley shelfal | WGF | 1400 | 1595 |
| Rainier 1 | P.burgeri | | 1662.6 | 1665 | 126.5 | 131 | 525 | | open marine, possibley shelfal | WGF | 1400 | 1595 |
| Rainier 1 | S.tabulata | | 1667.1 | 1667.4 | 131 | 133 | 325 | | shelfal marine | WGF | 1400 | 1595 |
| Rainier 1 | C.delicata | | 1669.2 | 1671.9 | 138 | 139 | 525 | | open marine | WGF | 1400 | 1595 |
| Rainier 1 | D.jurassicum | | 1672.2 | 1794 | 142.5 | 143.8 | 525 | | open marine | WGF | 1400 | 1595 |
| Rainier 1 | W.spectabilis | | 1923 | 2115 | 153.8 | 158.5 | 525 | | open marine, possibley shelfal | WGF | 1400 | 1595 |
| Rainier 1 | C.turbatus | | 2120 | 2120 | 177 | 189.5 | 100 | | deltaic | WGF | 1400 | 1595 |
| Rainier 1 | M.crenulatus | S.speciosus | 2190 | 2244 | 206.5 | 214 | 100 | | lower delta plain | WGF | 1400 | 1595 |
| Rainier 1 | S.wigginsii | S.speciosus | 2262 | 2361 | 214 | 220.5 | 100 | | marginal marine, shallowing with depth | WGF | 1400 | 1595 |
| Rowan 1 | CP9 | | 1525 | 1522 | 52.4 | 53.5 | 350 | | middle neritic | WGF | 2470 | 2675 |
| Rowan 1 | CP8 | | 1533.3 | 1587.5 | 53.5 | 55.4 | 350 | | middle neritic | WGF | 2470 | 2675 |
| Rowan 1 | CP5 | CP7 | 1887 | 1926 | 57.8 | 59.3 | 400 | | outer neritic ? | WGF | 2470 | 2675 |
| Rowan 1 | KCN-1 | | 1950 | 1969 | 65 | 65.88 | 425 | | undifferentiated marine | WGF | 2470 | 2675 |
| Rowan 1 | KCN-7 | | 2360 | 2415 | 70.5 | 72.2 | 500 | | upper bathyal | WGF | 2470 | 2675 |
| Rowan 1 | KCN-8 | | 2431 | 2475 | 72.2 | 73 | 500 | | upper bathyal | WGF | 2470 | 2675 |
| Rowan 1 | KCN-9 | | 2512.5 | 2512.5 | 73 | 73.3 | 500 | | upper bathyal | WGF | 2470 | 2675 |
| Rowan 1 | KCN-12 | | 2520 | 2520 | 78.4 | 81 | 550 | | middle-upper bathyal | WGF | 2470 | 2675 |
| Rowan 1 | KCN-13 | KCN-14 | 2555 | 2555 | 81 | 81 | 550 | | middle-upper bathyal | WGF | 2470 | 2675 |
| Rowan 1 | KCN-16 | | 2576 | 2576 | 83 | 83.8 | 550 | | middle-upper bathyal | WGF | 2470 | 2675 |
| Rowan 1 | KCN-17 | | 2598 | 2598 | 83.8 | 85 | 550 | | middle-upper bathyal | WGF | 2470 | 2675 |
| Rowan 1 | KCN-18 | | 2628 | 2628 | 85 | 85.5 | 450 | | middle-upper bathyal | WGF | 2470 | 2675 |
| Rowan 1 | KCN-21 | | 2655 | 2655 | 88.1 | 89.5 | 550 | | middle-upper bathyal | WGF | 2470 | 2675 |
| Rowan 1 | KCN-22 | KCN-23 | 2673 | 2674 | 89.5 | 91.65 | 550 | | middle-upper bathyal | WGF | 2470 | 2675 |
| Rowan 1 | KCN-22 | | 2667.5 | 2667.5 | 89.5 | 91.65 | 425 | | undifferentiated marine | WGF | 2470 | 2675 |
| Rowan 1 | KCN-25B | | 2676 | 2676 | 96.3 | 97.6 | 550 | | middle-upper bathyal | WGF | 2470 | 2675 |
| Rowan 1 | KCN-25C | | 2686 | 2715 | 97.6 | 99.3 | 550 | | middle-upper bathyal | WGF | 2470 | 2675 |
| Rowan 1 | KCN-26 | | 2730 | 2730 | 99.3 | 100.8 | 550 | | middle-upper bathyal | WGF | 2470 | 2675 |
| Rowan 1 | KCN-27 | | 2742 | 2817 | 100.8 | 103.8 | 500 | | upper bathyal = most / (2786 is outer neritic or deeper) | WGF | 2470 | 2675 |
| Rowan 1 | S.tabulata | | 2808 | 2834 | 131 | 133 | 325 | | shelfal marine - the prominence of vascular plant debris and the spor-pollen to microplankton ratio suggests shelfal marine environments of deposition | WGF | 2470 | 2675 |
| Rowan 1 | W.spectabilis | | 2865 | 3110 | 153.8 | 158.5 | 325 | | shelfal marine - the prominence of vascular plant debris and the dominance of the palynomorph suite by spores-pollen, suggests a shelfal marine environment of deposition, although, possible transport of this material to deeper environments cannot be disco | WGF | 2470 | 2675 |
| Rowan 1 | R.aemula | | 3133 | 3183 | 158.5 | 160.3 | 325 | | shelfal marine environment - the high proportions of vascular plant debris and the dominance of the playnomorph suites by spores and pollen above 3150m suggests shelfal marine environments of depostion. The increasing prominence fo microplankton below 315 | WGF | 2470 | 2675 |

## Appendix A - Biostrat zones and depositional environment information for Woolaston, Gibson and Fenelon Formations (WGF)

| well_name | biozone name | biozone range | biostrat depth top (m) | biostrat depth base (m) | biozone age from (Ma) | biozone age to (Ma) | age_code | notes on biozone age | depositional enviroment | formation name | formation top (m) | formation base (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rowan 1 | D.complex | | 3193 | 3305 | 167.5 | 177 | 100 | | lower delta plain (fringing marine to fluvio-deltaic) - The prominence of vascular plant debris, the prominence of acritarchs and the apparent absence of dinoflagellates suggest lower delta plain environments of deposition, ranging from fringing marine to | WGF | 2470 | 2675 |
| Rowan 1 | D.caddaensis | | 3301 | 3302 | 174.5 | 179.5 | 100 | | fringing marine to marine-deltaic | WGF | 2470 | 2675 |
| Rowan 1 | C.turbatus | | 3316 | 3316 | 177 | 189.5 | 100 | | lower delta plain to marine deltaic | WGF | 2470 | 2675 |
| Rowan 1 | indeterminate | | 1515 | 1521 | | | 350 | | middle neritic | WGF | 2470 | 2675 |
| Rowan 1 | indeterminate | | 1728 | 1728 | | | 350 | | middle-outer neritic | WGF | 2470 | 2675 |
| Rowan 1 | indeterminate | | 1830 | 1830 | | | 425 | | undifferentiated marine | WGF | 2470 | 2675 |
| Rowan 1 | indeterminate | | 2668 | 2668.5 | | | 550 | Sample lies in the KCN-22 zone and thus has been assigned an age of 91.65MA | middle-upper bathyal (anoxic) ? | WGF | 2470 | 2675 |
| Rowan 1 | indeterminate | | 2819 | 2819 | | | 425 | | undifferentiated marine | WGF | 2470 | 2675 |
| Skua 1 | | | 265 | 434 | | | 225 | Pleistocene to Miocene | inner shelf under warm and shallow water - more marine type of depostion | WGF | 2244 | 2389 |
| Skua 1 | | | 458 | 777 | | | 225 | Middle to Lower Miocene | inner shelf - under warm shallow water and restricted conditions | WGF | 2244 | 2389 |
| Skua 1 | | | 914 | 1350 | | | 225 | Eocene | inner shelf - restricted conditions and shallow water | WGF | 2244 | 2389 |
| Skua 1 | | | 1366 | 1457 | | | 325 | Lower Eocene - probable | shelf - deposited over the shelf in an area submitted to an important continental influx (sandstones) which can obliterate the marine influx (planktonic forams) | WGF | 2244 | 2389 |
| Skua 1 | | | 1474 | 1850 | | | 325 | Paleocene | shelf - normal marine conditions | WGF | 2244 | 2389 |
| Skua 2 | Te5 | Tf2 | 803.4 | 803.4 | 18 | 23.8 | 300 | Early-Middle Miocene | moderate energy inner neritic | WGF | 2225 | 2340 |
| Skua 2 | NP10 | NP9 | 1346.1 | 1346.1 | 53.3 | 54.8 | 425 | latest Late Paleocene - Earliest Eocene | undiff. marine | WGF | 2225 | 2340 |
| Skua 2 | NP9 | | 1392 | 1411 | 54.8 | 55.4 | 300 | upper Late Paleocene | low energy inner-middle neritic | WGF | 2225 | 2340 |
| Skua 2 | P5 | | 1440 | 1475 | 55.9 | 56.5 | 350 | upper Late Paleocene | low energy middle neritic | WGF | 2225 | 2340 |
| Skua 2 | P4 | | 1505.1 | 1505.1 | 56.5 | 59.2 | 300 | mid Late Paleocene | low energy middle neritic | WGF | 2225 | 2340 |
| Skua 2 | P3 | | 1844.3 | 1845 | 59.2 | 61 | 500 | | upper bathyal | WGF | 2225 | 2340 |
| Skua 2 | A.circumtabulata | | 1856.1 | 2082.5 | 65 | 66 | 525 | | open marine | WGF | 2225 | 2340 |
| Skua 2 | C.diebelii | | 2127 | 2159 | 66 | 73 | 525 | | open marine | WGF | 2225 | 2340 |
| Skua 2 | I.cretaceum | | 2333 | 2338.5 | 82 | 85 | 525 | | open marine | WGF | 2225 | 2340 |
| Skua 2 | C.torosa | | 2342 | 2596 | 189.5 | 204.5 | 100 | | deltaic to marginal marine - microplankton, particularily spinose acritarchs, are prominent, suggesting deltaic to marginal marine environments of deposition. | WGF | 2225 | 2340 |
| Skua 2 | P.catilliformis | | 444 | 444.9 | | | 250 | latest Late Miocene or younger | high energy inner neritic | WGF | 2225 | 2340 |
| Skua 2 | indeterminate | | 574.9 | 650.1 | | | 250 | Indeterminate | high energy inner neritic | WGF | 2225 | 2340 |
| Skua 2 | indeterminate | | 860 | 860 | | | 250 | | high energy inner neritic | WGF | 2225 | 2340 |
| Skua 2 | indeterminate | | 866 | 866 | | | 250 | undiff. Eocene | high energy inner neritic | WGF | 2225 | 2340 |
| Skua 2 | indeterminate | | 950.1 | 1058 | | | 250 | | high energy inner neritic | WGF | 2225 | 2340 |
| Skua 2 | indeterminate | | 1230 | 1230 | | | 250 | undiff. Eocene | high energy inner neritic | WGF | 2225 | 2340 |
| Skua 2 | indeterminate | | 1372 | 1372 | | | 250 | undiff. Eocene | high energy inner neritic | WGF | 2225 | 2340 |
| Skua 2 | indeterminate | | 1685.1 | 1823 | | | 425 | | ? marine | WGF | 2225 | 2340 |
| Skua 2 | KCCM-35 | | 1847.2 | 1941 | | | 450 | upper Late Maastrichtian | outer neritic - upper bathyal | WGF | 2225 | 2340 |
| Skua 2 | indeterminate | | 1983 | 1983 | | | 425 | | undiff. marine | WGF | 2225 | 2340 |
| Skua 2 | indeterminate | | 2060 | 2060 | | | 400 | | outer neritic or deeper | WGF | 2225 | 2340 |

## Appendix A - Biostrat zones and depositional environment information for Woolaston, Gibson and Fenelon Formations (WGF)

| well_name | biozone name | biozone range | biostrat depth top (m) | biostrat depth base (m) | biozone age from (Ma) | biozone age to (Ma) | age_code | notes on biozone age | depositional enviroment | formation name | formation top (m) | formation base (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Skua 2 | KCCM-28 | KCCM-29 | 2127 | 2159 | | | 450 | latest Early Maastrichtian | outer neritic - upper bathyal | WGF | 2225 | 2340 |
| Skua 2 | KCCM-27 | | 2227 | 2227 | | | 450 | Maastrichtian or younger | outer neritic - upper bathyal | WGF | 2225 | 2340 |
| Skua 2 | KCCM-23 | | 2258 | 2258 | | | 500 | mid-Late Campanian | upper bathyal | WGF | 2225 | 2340 |
| Skua 2 | KCCM-23 | KCCM-22 | 2273 | 2273 | | | 500 | Late Campanian | upper bathyal | WGF | 2225 | 2340 |
| Skua 2 | KCCM-20 | | 2286 | 2320 | | | 500 | Middle Campanian or younger | upper bathyal | WGF | 2225 | 2340 |
| Skua 2 | KCCM-19 | | 2323 | 2323 | | | 500 | upper Early Campanian | upper bathyal | WGF | 2225 | 2340 |
| Skua 2 | KCCM-17 | KCCM-18 | 2330 | 2330 | | | 500 | lower Early Campanian | upper bathyal | WGF | 2225 | 2340 |
| Skua 2 | KCCM-16 | | 2332.5 | 2332.5 | | | 550 | basal Late Santonian | middle-upper bathyal | WGF | 2225 | 2340 |
| Skua 2 | KCCM-13 | KCCM-16 | 2334.5 | 2334.5 | | | 500 | Santonian | bathyal or deeper | WGF | 2225 | 2340 |
| Skua 3 | CN11 | | 310 | 310 | 3.6 | 4.5 | 250 | | high energy inner neritic | WGF | 2235 | 2359 |
| Skua 3 | CN10 | | 430 | 730 | 4.5 | 5.9 | 250 | | high energy inner neritic | WGF | 2235 | 2359 |
| Skua 3 | CN5 | | 790 | 820 | 11.1 | 14.3 | 350 | | high-low energy inner/middle neritic | WGF | 2235 | 2359 |
| Skua 3 | Tf1 | Tf2 | 760 | 760 | 15 | 18 | 250 | | mod-high energy inner neritic | WGF | 2235 | 2359 |
| Skua 3 | Tb | | 880 | 910 | 33.7 | 37 | 300 | | mod-low energy inner neritic | WGF | 2235 | 2359 |
| Skua 3 | Tb | | 940 | 1090 | 33.7 | 37 | 250 | | high energy inner neritic | WGF | 2235 | 2359 |
| Skua 3 | Ta3 | | 1180 | 1210 | 37 | 49 | 250 | | high energy inner neritic | WGF | 2235 | 2359 |
| Skua 3 | CP9 | | 1360 | 1390 | 52.4 | 53.5 | 300 | | low energy inner neritic | WGF | 2235 | 2359 |
| Skua 3 | CP8 | | 1450 | 1465 | 53.5 | 55.4 | 350 | | low energy inner to middle neritic | WGF | 2235 | 2359 |
| Skua 3 | P4 | | 1474 | 1789 | 56.5 | 59.2 | 450 | | middle neritic (1474-1537m) outer neritic to upper bathyal (1546-1789m) | WGF | 2235 | 2359 |
| Skua 3 | CP4 | | 1828 | 1831 | 59.3 | 59.9 | 450 | | outer neritic - upper bathyal | WGF | 2235 | 2359 |
| Skua 3 | P3 | | 1795 | 1795 | 59.2 | 61 | 400 | | outer neritic | WGF | 2235 | 2359 |
| Skua 3 | P3 | | 1834 | 1834 | 59.2 | 61 | 400 | | outer neritic | WGF | 2235 | 2359 |
| Skua 3 | KCN-1 | KCN-2 | 1840 | 2047 | 65 | 65.88 | 400 | | outer neritic | WGF | 2235 | 2359 |
| Skua 3 | KCN-3 | | 2056 | 2131 | 66.3 | 67.6 | 400 | | outer neritic | WGF | 2235 | 2359 |
| Skua 3 | KCN-4 | | 2134 | 2167 | 67.6 | 67.75 | 450 | | outer neritic-upper bathyal | WGF | 2235 | 2359 |
| Skua 3 | KCN-5 | | 2170 | 2194 | 67.75 | 68 | 500 | | upper bathyal | WGF | 2235 | 2359 |
| Skua 3 | KCN-6 | | 2197 | 2248 | 68 | 70.5 | 500 | | upper bathyal | WGF | 2235 | 2359 |
| Skua 3 | KCN-7 | | 2251 | 2272 | 70.5 | 72.2 | 500 | | upper bathyal | WGF | 2235 | 2359 |
| Skua 3 | KCN-7 | KCN-8 | 2275 | 2308 | 70.5 | 72.2 | 500 | | upper bathyal | WGF | 2235 | 2359 |
| Skua 3 | C.diebelii | | 2148 | 2159 | 66 | 73 | 525 | | open marine | WGF | 2235 | 2359 |
| Skua 3 | KCN-8 | KCN-9 | 2311 | 2320 | 72.2 | 73 | 500 | | upper bathyal | WGF | 2235 | 2359 |
| Skua 3 | KCN-10 | KCN-11 | 2320 | 2347 | 73.3 | 75.5 | 500 | | upper bathyal | WGF | 2235 | 2359 |
| Skua 3 | S.camarvonensis | | 2314 | 2353 | 73 | 77 | 525 | | open marine | WGF | 2235 | 2359 |
| Skua 3 | KCN-12 | KCN-13 | 2350 | 2359 | 78.4 | 81 | 500 | | upper bathyal | WGF | 2235 | 2359 |
| Skua 3 | KCN-14 | | 2362 | 2368 | 81 | 82 | 500 | | upper bathyal | WGF | 2235 | 2359 |
| Skua 3 | A.coronata | | 2353 | 2374 | 77 | 83 | 525 | | open marine | WGF | 2235 | 2359 |
| Skua 3 | KCN-15 | KCN-17 | 2371 | 2371 | 82 | 83 | 500 | | upper bathyal | WGF | 2235 | 2359 |
| Skua 3 | C.torosa | | 2405.2 | 2500 | 189.5 | 204.5 | 100 | | deltaic to marginal marine - spinose acritarchs occurred consistently as minor components suggesting deltaic to marginal marine environments of deposition | WGF | 2235 | 2359 |
| Skua 3 | Susadinium sp. | | 2394 | 2402.5 | | | 100 | Toarcian | marginal marine to marine/deltaic | WGF | 2235 | 2359 |
| Skua 3 | indeterminate | | 340 | 400 | | | 250 | | high energy inner neritic | WGF | 2235 | 2359 |
| Skua 3 | indeterminate | | 850 | 850 | | | 300 | | mod-low energy inner neritic | WGF | 2235 | 2359 |
| Skua 5 | CP8 | | 1885 | 1885 | 53.5 | 55.4 | 400 | | outer neritic | WGF | 2255 | 2355 |
| Skua 5 | CP5 | CP4 | 1894.5 | 1896 | 57.8 | 59.3 | 400 | | outer neritic | WGF | 2255 | 2355 |
| Skua 5 | CP1 | | 1907.5 | 1907.5 | 62.9 | 65 | 400 | | mid-distal neritic | WGF | 2255 | 2355 |
| Skua 5 | KCN-2 | | 1912 | 1979 | 65.88 | 66.3 | 450 | | outer neritic - upper bathyal | WGF | 2255 | 2355 |

## Appendix A - Biostrat zones and depositional environment information for Woolaston, Gibson and Fenelon Formations (WGF)

| well_name | biozone name | biozone range | biostrat depth top (m) | biostrat depth base (m) | biozone age from (Ma) | biozone age to (Ma) | age_code | notes on biozone age | depositional enviroment | formation name | formation top (m) | formation base (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Skua 5 | KCN-3 | | 1985 | 2035 | 66.3 | 67.6 | 450 | | outer neritic - upper bathyal | WGF | 2255 | 2355 |
| Skua 5 | KCN-3 | KCN-4 | 2061.5 | 2061.5 | 66.3 | 67.6 | 500 | | upper bathyal | WGF | 2255 | 2355 |
| Skua 5 | KCN-4 | | 2076 | 2076 | 67.6 | 67.75 | 500 | | upper bathyal | WGF | 2255 | 2355 |
| Skua 5 | KCN-6 | | 2115 | 2115 | 68 | 70.5 | 500 | | upper bathyal | WGF | 2255 | 2355 |
| Skua 5 | KCN-7 | | 2190 | 2190 | 70.5 | 72.2 | 500 | | upper bathyal | WGF | 2255 | 2355 |
| Skua 5 | KCN-8 | | 2213 | 2237.5 | 72.2 | 73 | 500 | | upper bathyal | WGF | 2255 | 2355 |
| Skua 5 | KCN-10 | | 2250 | 2250 | 73.3 | 75.5 | 500 | | upper bathyal | WGF | 2255 | 2355 |
| Skua 5 | S.carnarvonensis | | 2215 | 2250 | 73 | 77 | 525 | | open marine | WGF | 2255 | 2355 |
| Skua 5 | KCN-11 | | 2260 | 2260 | 75.5 | 78.4 | 500 | | upper bathyal | WGF | 2255 | 2355 |
| Skua 5 | KCN-13 | KCN-14 | 2280 | 2295 | 81 | 81 | 550 | | middle-upper bathyal | WGF | 2255 | 2355 |
| Skua 5 | A.coronata | | 2260 | 2295 | 77 | 83 | 525 | | open marine | WGF | 2255 | 2355 |
| Skua 5 | KCN-15 | | 2302 | 2302 | 82 | 83 | 550 | | middle-upper bathyal | WGF | 2255 | 2355 |
| Skua 5 | KCN-16 | | 2312 | 2328 | 83 | 83.8 | 550 | | middle-upper bathyal | WGF | 2255 | 2355 |
| Skua 5 | I.cretaceum | | 2302 | 2321.5 | 82 | 85 | 525 | | open marine | WGF | 2255 | 2355 |
| Skua 5 | KCN-17 | | 2337 | 2339.5 | 83.8 | 85 | 550 | | middle-upper bathyal | WGF | 2255 | 2355 |
| Skua 5 | KCN-18 | | 2343 | 2350 | 85 | 85.5 | 550 | | middle-upper bathyal | WGF | 2255 | 2355 |
| Skua 5 | KCN-19 | KCN-20 | 2352 | 2352 | 85.5 | 86 | 550 | | middle-upper bathyal | WGF | 2255 | 2355 |
| Skua 5 | D.complex | | 2355 | 2468.5 | 167.5 | 177 | 225 | | ranges from shelfal marine to delta plain | WGF | 2255 | 2355 |
| Skua 5 | C.turbatus | | 2484 | 2680 | 177 | 189.5 | 100 | | ranges from lower delta plain to marginal marine | WGF | 2255 | 2355 |
| Skua 5 | indeterminate | | 2328 | 2350 | | | 525 | Coniacian to Santonian | open marine | WGF | 2255 | 2355 |
| Skua 5 | indeterminate | | 1730 | 1730 | | | 400 | | mid-distal neritic? | WGF | 2255 | 2355 |
| Skua 5 | indeterminate | | 1735 | 1879 | | | 425 | | indifferentiated marine | WGF | 2255 | 2355 |
| Skua 8 | CP4 | | 1853 | 1867 | 59.3 | 59.9 | 400 | | outer neritic or deeper | WGF | 2220 | 2310 |
| Skua 8 | CP3 | | 1874 | 1876 | 59.9 | 61.2 | 500 | | upper bathyal | WGF | 2220 | 2310 |
| Skua 8 | KCN-1 | | 1878 | 2052 | 65 | 65.88 | 450 | | outer neritic-upper bathyal | WGF | 2220 | 2310 |
| Skua 8 | KCN-7 | | 2185 | 2185 | 70.5 | 72.2 | 500 | | upper bathyal | WGF | 2220 | 2310 |
| Skua 8 | KCN-8 | | 2210 | 2250 | 72.2 | 73 | 500 | | upper bathyal | WGF | 2220 | 2310 |
| Skua 8 | KCN-9 | | 2275 | 2308.5 | 73 | 73.3 | 500 | | upper bathyal | WGF | 2220 | 2310 |
| Skua 8 | I.cretaceum | | 2309.5 | 2309.5 | 82 | 85 | 525 | | open marine | WGF | 2220 | 2310 |
| Skua 8 | C.turbatus | | 2315.8 | 2349.1 | 177 | 189.5 | 100 | | marginal marine to distal delta plain environment - The occurrence of substantial amounts of vascular plant debris (particularly cuticular and woody fragments) together with megaspores and consistent dinoflagellates suggests marginal marine to distal delt | WGF | 2220 | 2310 |
| Skua 9 | C.turbatus | | 2355.8 | 2425.6 | 177 | 189.5 | 100 | | marginal marine to distal delta plain environments | WGF | 2207 | 2315 |
| Skua 9 | C.torosa | | 2403 | 2508 | 189.5 | 204.5 | 100 | | estuarine to lower delta plain environments possible shallowing below 2430 | WGF | 2207 | 2315 |
| Snowmass 1 | KCN-4 | | 867.5 | 867.5 | 67.6 | 67.75 | 350 | | middle-outer neritic | WGF | 953 | 1176 |
| Snowmass 1 | KCN-5 | | 893.5 | 893.5 | 67.75 | 68 | 350 | | middle-outer neritic | WGF | 953 | 1176 |
| Snowmass 1 | KCN-8 | | 911 | 935 | 72.2 | 73 | 350 | | middle-outer neritic | WGF | 953 | 1176 |
| Snowmass 1 | KCN-13 | | 962 | 962 | 81 | 81 | 400 | | outer neritic | WGF | 953 | 1176 |
| Snowmass 1 | KCN-14 | KCN-15 | 974 | 974 | 81 | 82 | 400 | | outer neritic | WGF | 953 | 1176 |
| Snowmass 1 | KCN-16 | | 988 | 988 | 83 | 83.8 | 400 | | outer neritic | WGF | 953 | 1176 |
| Snowmass 1 | KCN-17 | | 1032 | 1032 | 83.8 | 85 | 450 | | outer neritic - upper bathyal | WGF | 953 | 1176 |
| Snowmass 1 | KCN-18 | | 1046 | 1118 | 85 | 85.5 | 500 | | upper bathyal (1046) | WGF | 953 | 1176 |
| Snowmass 1 | KCN-19 | KCN-20 | 1128 | 1128 | 85.5 | 86 | 450 | | outer neritic - upper bathyal | WGF | 953 | 1176 |
| Snowmass 1 | KCN-21 | | 1148.5 | 1148.5 | 88.1 | 89.5 | 500 | | upper bathyal | WGF | 953 | 1176 |
| Snowmass 1 | KCN-22 | KCN-23 | 1169.3 | 1169.3 | 89.5 | 91.65 | 425 | | undifferentiated marine | WGF | 953 | 1176 |

# Appendix A - Biostrat zones and depositional environment information for Woolaston, Gibson and Fenelon Formations (WGF)

| well_name | biozone name | biozone range | biostrat depth top (m) | biostrat depth base (m) | biozone age from (Ma) | biozone age to (Ma) | age_code | notes on biozone age | depositional enviroment | formation name | formation top (m) | formation base (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Snowmass 1 | KCN-25A | | 1182 | 1182 | 95.2 | 96.3 | 450 | | outer neritic - upper bathyal | WGF | 953 | 1176 |
| Snowmass 1 | KCN-25B | | 1196 | 1196 | 96.3 | 97.6 | 500 | | upper bathyal | WGF | 953 | 1176 |
| Snowmass 1 | KCN-25C | | 1209 | 1237.5 | 97.6 | 99.3 | 500 | | upper bathyal to mid-upper bathyal at base | WGF | 953 | 1176 |
| Snowmass 1 | KCN-27 | | 1250 | 1250 | 100.8 | 103.8 | 550 | | mid-upper bathyal | WGF | 953 | 1176 |
| Snowmass 1 | KCN-28 | | 1254.5 | 1254.5 | 103.8 | 107.2 | 550 | | mid-upper bathyal | WGF | 953 | 1176 |
| Snowmass 1 | M.australis | | 1265 | 1268 | 118 | 123 | 325 | | shelfal marine | WGF | 953 | 1176 |
| Snowmass 1 | M.testudinaria | P.burgeri | 1270 | 1270 | 123 | 126.5 | 325 | | shelfal marine | WGF | 953 | 1176 |
| Snowmass 1 | S.tabulata | | 1275 | 1277 | 131 | 133 | 325 | | shelfal marine | WGF | 953 | 1176 |
| Snowmass 1 | E.torynum | C.delicata | 1279.5 | 1291 | 135 | 136 | 425 | | undifferentiated marine | WGF | 953 | 1176 |
| Snowmass 1 | S.speciosus | | 1296 | 1515 | 214 | 226 | 100 | | lower delta plain to marginal marine | WGF | 953 | 1176 |
| Snowmass 1 | S.speciosus | | 1296 | 1515 | 217.5 | 232 | 100 | | lower delta plain to marginal marine | WGF | 953 | 1176 |
| Snowmass 1 | S.quadrifidus | | 1586 | 1653 | 226 | 238.5 | 100 | | lower delta plain to marginal marine | WGF | 953 | 1176 |
| Snowmass 1 | indeterminate | | 798.5 | 798.5 | | | 350 | | inner-middle neritic | WGF | 953 | 1176 |
| Snowmass 1 | indeterminate | | 1260 | 1265 | | | 400 | Sample lies below KCN-28 (1254.5m) and above M.australis (1265M) and thus is older than 107.2MA and younger than 118MA | outer neritic ? (anoxic) | WGF | 953 | 1176 |
| Snowmass 1 | indeterminate | | 1266.5 | 1270 | | | 300 | Sample lies between M.australis (1265m) and M.testudinaria (1270m) so has been given an estimated age of: 123MA | inner-middle neritic ? (anoxic) | WGF | 953 | 1176 |
| Snowmass 1 | indeterminate | | 1273.8 | 1274 | | | 400 | Sample liest between M.testudinaria/P.burgeri (1270m) and S.tabulata (1275m) and thus has been assigned an age between 131MA and 133MA | middle-outer neritic ? (anoxic) | WGF | 953 | 1176 |
| Snowmass 1 | indeterminate | | 1277 | 1277 | | | 300 | Sample lies between S.tabulata (1275m) and E.torynum/C.delicata (1279.5m), thus has been assigned an age of at least 133MA | inner-middle neritic ? (anoxic) | WGF | 953 | 1176 |
| Swan 1 | X.asperatus | | 2590 | 2590 | 98.5 | 100 | 425 | | marine environment of deposition relatively close to an active source of fluvial sediment - The diversity of the microplankton suite and the diminished prominence of Hystrichosphaera together with relatively common pieces of cuticle suggest a marine envir | WGF | 2450 | 2590 |
| Swan 1 | P.ludbrookiae | | 2607 | 2628 | 100 | 101.5 | 525 | | open marine | WGF | 2450 | 2590 |
| Swan 1 | B.reticulatum | | 2638 | 2638 | 136 | 137 | 325 | | marine environment of deposition relatively close to an active fluvial sediment source | WGF | 2450 | 2590 |
| Swan 1 | K.wisemaniae | | 2729 | 2729 | 139 | 140 | 225 | | marine environment of deposition relatively close to an active fluvial sediment source | WGF | 2450 | 2590 |
| Swan 1 | D.jurassicum | | 2812 | 2837 | 142.5 | 143.8 | 425 | | distinct marine environment of deposition | WGF | 2450 | 2590 |
| Swan 1 | D.swanense | | 2865 | 2865 | 146 | 150.3 | 425 | | marine environment of deposition relatively close to an active source of fluvial sediment - amount of wood and cuticle suggests this. | WGF | 2450 | 2590 |
| Swan 1 | W.clathrata | | 2988 | 3137 | 150.3 | 153.8 | 425 | | top - marine environment of deposition relatively close to an active source of fluvial sediment - bottom - marine environment of depisition some distance removed from an active source of fluvial sedimentation | WGF | 2450 | 2590 |

## Appendix A - Biostrat zones and depositional environment information for Woolaston, Gibson and Fenelon Formations (WGF)

| well_name | biozone name | biozone range | biostrat depth top (m) | biostrat depth base (m) | biozone age from (Ma) | biozone age to (Ma) | age_code | notes on biozone age | depositional enviroment | formation name | formation top (m) | formation base (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Swan 1 | W.spectabilis | | 3200 | 3259 | 153.8 | 158.5 | 325 | | 10500 - marine environment of deposition some distance removed from an active fluvial sediment source | WGF | 2450 | 2590 |
| Swift 1 | A.coronata | | 2265 | 2265 | 77 | 83 | 525 | | open marine | WGF | 2145 | 2365 |
| Swift 1 | A.suggestium | | 2290 | 2290 | 83 | 84.3 | 525 | | open marine | WGF | 2145 | 2365 |
| Swift 1 | C.striatoconus | | 2325 | 2325 | 87 | 91 | 525 | | open marine | WGF | 2145 | 2365 |
| Swift 1 | X.asperatus | | 2353.5 | 2369 | 98.5 | 100 | 525 | | open marine | WGF | 2145 | 2365 |
| Swift 1 | P.ludbrookiae | | 2375 | 2387 | 100 | 101.5 | 525 | | open marine | WGF | 2145 | 2365 |
| Swift 1 | W.spectabilis | | 2394.9 | 2437.6 | 153.8 | 158.5 | 325 | | shelfal marine - with considerable terrestrial plant input | WGF | 2145 | 2365 |
| Swift 1 | D.complex | | 2471 | 2485 | 167.5 | 177 | 100 | Mid Bajocian to Bathonian | marginal marine to fluvio-deltaic | WGF | 2145 | 2365 |
| Swift 1 | D.complex | | 2545 | 2581 | 167.5 | 177 | 100 | Mid to Late Bajocian | marginal marine | WGF | 2145 | 2365 |
| Swift 1 | C.turbatus | | 2647.5 | 2704 | 177 | 189.5 | 100 | | marginal marine | WGF | 2145 | 2365 |

## Appendix 2: Seal Potential - Lower Vulcan Formation

| | | Seal Capacity | | | | | | Seal Thickness | | | | | Areal Extent | | | | Seal Potential | Seal Integrity | | | | | | | | | Seal Potential | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Well Name | Lithology Comments | Seal Capacity | Strucutral Closure | structure / seal capabilty | Geological Factory | Data Quality and Quantity | Risk Matrix Value | Seal Thickness (m) | fault throws in cap rock | Geological Factory | Data Quality and Quantity | Risk Matrix Value | Seal Areal Extent | Geological Fatfory | Data Quality and Quantity | Risk Matrix Value | Seal Cap *Thickness *Areal extent | Brittle Index Range | BRI-mean | BRI-StDev | depth from | depth to | BRI Count | Geological Factory | Data Quality and Quantity | Risk Matrix Value | Seal Cap *Thickness *Areal extent *BRI index | Comments |
| Allaru 1 | dominated by claystones that become increasingly silty with depth and occasionally grade to argillaceous siltstone | | 111 | 0.5 | good | moderate | 0.625 | 102 | 25 | very good | enough | 0.875 | 1 | very good | plentiful | 1 | 0.55 | no logs over this interval | | | | | | good | poor | 0.563 | 0.31 | interbeded clystne and sltstne |
| Birch 1 | siltstones , appear to have deltaic influence (based on underlying sandstone log character) - poor seals | | 111 | 0.25 | bad | moderate | 0.375 | 100 | no apparent faults offset the seal in vlt - main bounding fault on line vlt-06 is the only fault visible | very good | enough | 0.875 | due to deltaic nature of sediments horizontal variation expected | good | moderate | 0.625 | 0.21 | lower section which contains more interbedded siltstones has a BRI ~ 3 to 4, as the clay content increases the BRI drops to ~2 | 2.6 | 0.79 | 2380 | 2495 | | good | moderate | 0.625 | 0.13 | siltstones , appear to have deltaic influence (based on underlying sandstone log character) - poor seals - sandstones in bottom half of lower vulcan have a distinct delta sand log character |
| Champagny 1 | argl siltstone & grey-brwn arenaceous clayst | | 53 | 0.25 | good | moderate | 0.625 | 50 | none apparent on vlt | good | enough | 0.688 | 1 | very good | enough | 0.875 | 0.38 | no logs over this interval | | | | | | good | poor | 0.563 | 0.21 | no logs at this depth |
| Conway 1 | sandstones | | 160 | 0 | very bad | enough | 0.125 | 0 | 0 | | | | 0 | | | | 0.00 | | | | | | | | | | 0.00 | sandstone |
| East Swan 1 | interbd thin sandstones, siltstone and clystones | | 50 | 0.26 | good | moderate | 0.625 | inbds<10m | overall interval is thick however individual lithlogies are thin - this well is near a major fault or diapir(hard to say) | good | enough | 0.688 | correlates to Eswan1 and Eclipse 1 | very good | plentifl | 1 | 0.43 | ~4 | 2.64 | 0.91 | 2338 | 2690 | 2310 | good | moderate | 0.625 | 0.27 | restricted marine low energy claystones underlain by 31m thick shallow marine sandstone |
| East Swan 2 | The Lower Vulcan Formation comprises 289m a restricted marine low energy, dark brown to black claystones underlain by a 31m thick shallow marine argillaceous sandstone which is a Montara Formation lateral equivalent | | 111 | | good | moderate | 0.625 | 284 | | good | enough | 0.688 | correlates to Eswan1 and Eclipse 1 | very good | plentifl | 1 | 0.43 | | 2.82 | 0.65 | 2300 | 2600 | 1772 | good | moderate | 0.625 | 0.27 | |
| Eclipse 1 | | 76 | 110 | 0.69090909 | good | moderate | 0.625 | 215 | very thick seal & no resolvable faults in top seal | very good | enough | 0.875 | correlates to Eswan1 and Eclipse 1 | very good | plentifl | 1 | 0.55 | 2 to 4 | 2.92 | 0.65 | 2330 | 2540 | 1378 | good | moderate | 0.625 | 0.34 | dary grey shales with fine to very fine quartz sanstones over the basal 35m. |
| Eclipse 2 | dary grey shales with fine to very fine quartz sanstones over the basal interval. | | | | good | moderate | 0.625 | 240 | | very good | enough | 0.875 | correlates to Eswan1 and Eclipse 1 | very good | plentifl | 1 | 0.55 | | 3.23 | 0.6 | 2540 | 2780 | | good | moderate | 0.625 | 0.34 | |
| Fagin 1 | silty claystones and siltstones | | 111 | 0.75 | good | moderate | 0.625 | 53 | major fault dependant closure with main fault having ~60m throw | very good | enough | 0.875 | 1 | very good | plentiful | 1 | 0.55 | | 3.18 | 0.69 | 2964 | 3017 | 384 | good | moderate | 0.625 | 0.34 | thin intbded clystne/sltstne |
| Jabiru 2 | Kimmeridgian claystone/ marl? | >400 | >250 | 1 | very good | plentiful | 1 | 11 | no major top seal faults - if Challis is used as and analagous field top seal fault throws are in the order of 10 to 15m | bad | moderate | 0.375 | no present on top of structure | bad | plentiful | 0.25 | 0.09 | | 4.06 | 0.64 | 1623 | 1635 | 79 | bad | moderate | 0.375 | 0.04 | this 11m claystone overlies the lower vulcan sandstone and is most probably not the top seal to the accumulation - it si not laterally extensive as it is not present in Jabiru 1a which is on structure - jabiru 2 is just off structure |
| Longleat 1 | sandy section, interdded sandstone with siltsone and claystones - predominantly sands - oil show at the top of the Lw Vulcan | | 70 | 0.25 | very bad | enough | 0.125 | inbds<10m | | bad | moderate | 0.375 | Most probably a deltaic depositional environment | bad | moderate | 0.375 | 0.03 | no logs at ncpgg | | | | | | even | poor | 0.5 | 0.01 | |
| Maple 1 | 600m of restricted marine low energy, dark brown to black claystones. | | 500 | 1 | very good | enough | 0.875 | 600 | no apparent faults in cap rock although siesmic at this level is not great | very good | enough | 0.875 | This thick section of claystones in the Lw Vulcan are taken to be laterally extensive within the basin depocenters based on the restricted marine depsoitional environment | very good | plentiful | 1 | 0.77 | 2 to 3 | 2.22 | 1.9 | 3060 | 3660 | 3937 | good | moderate | 0.625 | 0.48 | main bouding fault has significant offset at callovian level - the Lw Vulcan claystones are most probably the juxtaposition seal for this accumulation as well as the top seal - the sample run in MICP was in the challis Fmtn and did not test the Lw Vulcan |
| Marel 1 | good | | 60 | good | good | moderate | 0.625 | 70 | 30 | good | plentiful | 0.75 | seismic est | good | enough | 0.688 | 0.32 | 2 to 4 | 2.52 | 0.363 | 3276 | 3340 | 420 | good | moderate | 0.625 | 0.20 | the reservoir is deltaic and this similar seal in a more proximal montara 1 is a siltstone with poor seal capacity - the seal covers the structure in dip and strike lines (vlt survey) so based on seismic seal estimated to be areally extensive - however li |
| Montara 1 | siltstones with some clystne = 0.25 | 14 | 50 | 0.28 | bad | plentiful | 0.25 | 210 | 30 | very good | plentiful | 1 | vlt-04 seal extends over struct | good | enough | 0.688 | 0.17 | 3 to 4 | 3.81 | 0.74 | 2390 | 2600 | 1221 | good | moderate | 0.625 | 0.11 | siltstones intbded clystnes |
| Octavius 1 | calcareous claystone intbeded with non-calc claystone - in Octavius 2 a substantial residual column was observed in the plover sealed by the lw Vulcan - conclusion was that Lw Vulcan seal breached during Lt Miocene-Pliocene tectonic event | a very good seal capacity was measured in Jabiru 2 for a thin interval which correlates to the Lw Vulcan in Octavius 1 | 270m fault throw measured on the cross section enclosed in the WCR | 0.75 | good | moderate | 0.635 | >100m | except for bounding faults there do not appear to be any resolvable top seal faults on vlt | very good | plentiful | 1 | present in Octavius 2 as a thick section as well - extensive over sturcture | good | plentiful | 0.75 | 0.48 | no logs over this interval | | | | | | bad | poor | 0.438 | 0.21 | |
| Octavius 2 | basal sandstone - thin basal transgressive sand unit which rapidly lines into siltstones and claystones deposited in an open marine environment | | 260 | | good | moderate | 0.635 | 200 | | very good | moderate | 1 | | good | plentiful | 0.75 | 0.48 | due a ratty caliper only the lower part of the LV was tested for BRI - this would have been the seal to the plover formation | 4.26 | 0.87 | 3100 | 3190 | 590 | bad | moderate | 0.375 | 0.18 | |
| Oliver 1 | interval dominated by claystones | 250 | 280 | 0.69285714 | very good | plentiful | 1 | 54 | major fault bound structure | very good | enough | 0.875 | 1 | very good | plentiful | 1 | 0.68 | no DT over this interval | | | | | | good | poor | 0.563 | 0.49 | thin intbded clystne/sltstne |
| Paqualin 1 | ~1200m of mainly clystne with minor siltstone and sandstone intbds | | | | very good | enough | 0.875 | >1200 | no resolvable faults seismic deteriorated due to adjacent diapir | very good | enough | 0.875 | a much ticker section than in the adjacent Maple1 well - lateally extensive and thickens in the grabens | very good | plentiful | 1 | 0.77 | thick LV - interval chosen for good hole conditions | 1.98 | 0.29 | 3800 | 4100 | 1968 | very good | moderate | 0.75 | 0.57 | |
| Rainer 1 | massive medium to coarse grained sandstone section | | | | bad | plentiful | 0.25 | | | bad | plentiful | 0.25 | 0 | bad | plentiful | 0.25 | 0.02 | | | | | | | even | poor | 0.5 | 0.01 | sandstone |

## Appendix 2: Seal Potential - Lower Vulcan Formation

| | | Seal Capacity | | | | | | Seal Thickness | | | | | Areal Extent | | | | Seal Potential | Seal Integrity | | | | | | | | | Seal Potential | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Well Name | Lithology Comments | Seal Capacity | Structural Closure | structure / seal capacity | Geological Factory | Data Quality and Quantity | Risk Matrix Value | Seal Thickness (m) | fault throws in cap rock | Geological Factory | Data Quality and Quantity | Risk Matrix Value | Seal Areal Extent | Geological Factory | Data Quality and Quantity | Risk Matrix Value | Seal Cap *Thickness *Areal extent | Brittle Index Range | BRI-mean | BRI-StDev | depth from | depth to | BRI Count | Geological Factory | Data Quality and Quantity | Risk Matrix Value | Seal Cap *Thickness *Areal extent *BRI Index | Comments |
| Rowan 1 | claystones - seem good seal | 54 | 111 | 0.54 | good | plentiful | 0.75 | 125 | no apparent in Skua3D - seal onlap onto structure | very good | enough | 0.875 | tilted fault block | good | moderate | 0.625 | 0.41 | ~3 | 2.82 | 0.47 | 2870 | 2990 | 787 | good | moderate | 0.625 | 0.26 | a high risk that this seal contains siltstone and sandstone stringers - like many Lw Vulcan sediments a mid neritic environment has been established for some of these sediments |
| Swan 1 | seal capacity is estimated to not seal entire sturctural closure | 100 (allaru 1) | 274 | 0.5 | good | moderate | 0.625 | 270 | strata lift up around diapir intrusion - mo major faults apparent | very good | plentiful | 1 | only a thick uppermost Lw Vulcan was penetrated, taken to be laterally extensive - correlates out to maple 1 | very good | plentifl | 1 | 0.63 | 2 to 4 | 2.66 | 1.01 | 2990 | 3250 | 1706 | good | moderate | 0.625 | 0.39 | predominantly clystne - some sand and slt intbds - no reservoir penetrated in this interval |
| Swift 1 | moderaly porous and perm hydrocarbon bearin sands | | | 0 | bad | plentiful | 0.25 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | moderatly porous and perm hydrocarbon bearin sands |
| Tahbilk 1 | siltstones with some clystne = 0.25 | | 111 | 0.25 | bad | enough | 0.313 | 160 | 18 | very good | plentiful | 1 | vkt-04 seal extends over struct | good | enough | 0.688 | 0.22 | ~4 | 3.98 | 0.669 | 2460 | 2620 | 1050 | good | moderate | 0.625 | 0.13 | seal cap takend from Montara 1 same play and structural setting - more distal restricted marine - logs have not been imported yet into Geolog |
| Taltarni 1 | intbded siltstone, minor sands and clystone | | 100 | 0.13 | bad | moderate | 0.375 | 525 | | very good | enough | 0.875 | 1 | very good | moderate | 0.75 | 0.25 | ~4 | 3.89 | 0.56 | 2326 | 2850 | 3438 | good | moderate | 0.625 | 0.15 | intbd sltstne/clystne - Montara 1 similar - regional high gives clystne sltstne interbeds - Deltaic sand bodies obvious on logs |
| Vulcan 1b | claystones - seem good seal | | 111 | | very good | moderate | 0.75 | 1052 | area is quite faulted however the seal is very thick | very good | plentiful | 1 | correlates to Swan 1 | very good | plentifl | 1 | 0.75 | three sandstone intervals in this interval have a BRI of over 4 - rest is claystone with BRI of 2 | 2.15 | 0.92 | 3300 | 3480 | 1181 | good | moderate | 0.625 | 0.47 | clystne |
| Anderdon 1 | missing section | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Brown Gannet 1 | missing section | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Cassini 1 | missing section | | 15 | | | | | | | | | | | | | | | | | | | | | | | | | |
| Cassini 2 | missing section | | 15 | | | | | | | | | | | | | | | | | | | | | | | | | |
| Challis 1 | missing section | | 65 | | | | | | | | | | | | | | | | | | | | | | | | | |
| Douglas 1 | missing section | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Halycon 1 | missing section | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Jabiru 1a | missing section | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Keeling 1 | missing section | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Medusa 1 | missing section | | 100 | | | | | | | | | | | | | | | | | | | | | | | | | |
| Pascal 1 | missing section | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Pollard 1 | missing section | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Prion 1 | missing section | | 100 | | | | | | | | | | | | | | | | | | | | | | | | | |
| Puffin 1 | missing section | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Puffin 2 | missing section | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Rainbow 1 | missing section | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Sahul Shoals 1 | missing section | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Skua | missing section | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Snowmass 1 | missing section | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Talbot 1 | missing section | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Turnstone 1 | missing section | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Warb 1a | missing section | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Woodbine 1 | missing section | | | | | | | | | | | | | | | | | | | | | | | | | | | |

## Appendix 2: Seal Potential - Upper Vulcan Formation

| | | Seal Capacity | | | | | | Seal Thickness | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Well Name | Lithology Comments | Seal Capacity | Strucutral Closure | structure / seal capacity | Geological Factory | Data Quality and Quanlity | Risk Matrix Value | Seal Thickness (m) | fault throws in cap rock | Geological Factory | Data Quality and Quantity | Risk Matrix Value |
| Allaru 1 | basal transgressive SS overlain by restricted marine claystones | | 40 | 0.25 | good | moderate | 0.625 | 70 | 25 | very good | enough | 0.875 |
| Champagny 1 | very arenaceous clystne - silty-intbd fine grained SS | | 50 | | good | moderate | 0.625 | 110 | 23m | very good | plentiful | 1 |
| Conway 1 | sands - some interbedded siltstones at top | | 160 | sand-siltstone | bad | enough | 0.313 | | | very bad | moderate | 0.25 |
| Douglas 1 | interbedded claystones and siltstones overly tithonian sandstone - the claystones have 'excellent sealing potential' | | 111 - fault bound closure on both sides of the horst - the well intersects faults - main reason the bathurst island grp is largly missing | 0.5 | very good | moderate | 0.75 | 70 | major fault bound closure offset in top seal assumed | good | enough | 0.688 |
| East Swan 2 | | | | | even | moderate | 0.5 | 73 | | good | moderate | 0.625 |
| Eclipse 1 | very thin interbded sandstone, claystone and siltstone - thicker section in Eclipse 2 has more thin sands | | 122 | | even | moderate | 0.5 | 12 | below seismic resolution | good | moderate | 0.625 |
| Eclipse 2 | turbidite deposition - thin sands (<2m) interbedded with siltstones and claystone | | | | even | moderate | 0.5 | 102 | | good | moderate | 0.625 |
| Fagin 1 | interbedded claystone and siltstone | | 280 | 0.75 | good | enough | 0.688 | 230 | | very good | enough | 0.875 |
| Halycon 1 | 32m section of sandstone | | | | bad | plentiful | 0.25 | | | very good | enough | 0.875 |
| Maple 1 | approx 240m of restricted marine slightly silty claystoens | | >500 | | good | moderate | 0.625 | 266 | no apparent faults in cap rock although siesmic at this level is not great | very good | enough | 0.875 |
| Maret 1 | interbeded sandstones, siltstones and claystones | | 50 | sand-siltstone | bad | moderate | 0.375 | 100 | 30 | very good | enough | 0.875 |
| Octavius 1 | interbedded claystones and siltstones with minor sandstones overlying the Tithonian SS member | 560 | 260 | 0.75 | good | moderate | 0.625 | 360m | a small reverse fault with ~9m throw and a bigger normal fault were interpreted from the dipmeter data | very good | enough | 0.875 |
| Octavius 2 | open marine claystones and siltstone with lots of minor faults and fractures on fms | | | | good | moderate | 0.625 | 270m | | very good | enough | 0.875 |
| Oliver 1 | interval dominated by claystones | 115 | 280 | 0.4107143 | good | plentiful | 0.75 | 194 | | very good | enough | 0.875 |

| | Areal Extent | | | | Seal Potential | Seal Integrity | | | | | | | | | Seal Potential | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Well Name | Seal Areal Extent | Geological Factory | Data Quality and Quantity | Risk Matrix Value | Seal Cap *Thickness *Areal extent | Brittle Index Range | BRI-mean | BRI-StDev | depth from | depth to | BRI Count | Geological Factory | Data Quality and Quanlity | Risk Matrix Value | Seal Cap *Thickness *Areal extent *BRI Index | Comments |
| Allaru 1 | very thin interbeds, lithologies are likely to be hererogeneous laterally | very good | enough | 0.875 | 0.48 | no logs run over this interval | | | | | | good | poor | 0.563 | 0.27 | turbiditic facies - ss very argillaceous - thin inbeds of sand, silt and claystone |
| Champagny 1 | from vtt looks like extends over structre | good | plentiful | 0.75 | 0.47 | no logs run over this interval | | | | | | good | poor | 0.563 | 0.26 | base 50m SS - 110m arenaceous clystne - interbd siltstone and thin fine grained SS - becomes more silty and sandy with depth |
| Conway 1 | | good | enough | 0.688 | 0.05 | ~4 | 3.76 | 1.14 | 2127 | 2306 | 1175 | good | moderate | 0.625 | 0.03 | predominantly sandstones top some interbedded siltstones in top 15m however these are not considered to be valid seals |
| Douglas 1 | laterteral variation in facies my by high - this section is thought to be turbidites in origion | good | moderate | 0.625 | 0.32 | 4 to 6 in the lower half and 2 to 4 in the upper half | 4.28 | 0.89 | 2380 | 2450 | 460 | bad | moderate | 0.375 | 0.12 | turbiditic facies - ss very argillaceous - thin inbeds of sand, silt and claystone |
| East Swan 2 | missing in East Swan 1 | good | moderate | 0.625 | 0.20 | | 2.54 | 1.31 | 2317 | 2390 | 479 | good | moderate | 0.625 | 0.12 | significant sandstone beds (~5m thickness) have high BRI while majority of interval is claystone and has a low BRI |
| Eclipse 1 | correlates to Eclipse 2 | good | moderate | 0.625 | 0.20 | seal BRI 1to2 | 2.36 | 1.23 | 2315 | 2330 | 98 | good | moderate | 0.625 | 0.12 | interbedded sandstone, siltstone and shales - based on log motifs - BRI for 2320-2330 is 1to2 and for 2313-2320 is 2 to 6 - 6 sands - 2 claystones |
| Eclipse 2 | correlates to Eclipse 1 | good | moderate | 0.625 | 0.20 | | 2.55 | 0.84 | 2440 | 2540 | 656 | good | moderate | 0.625 | 0.12 | |
| Fagin 1 | | very good | enough | 0.875 | 0.53 | | 3.01 | 0.36 | 2770 | 2860 | 177 | good | moderate | 0.625 | 0.33 | clystne |
| Halycon 1 | | bad | plentiful | 0.25 | 0.05 | | | | | | | even | poor | 0.5 | 0.03 | sandstone |
| Maple 1 | interped as areally extensive over closure based on thickness and seismic | very good | plentiful | 1 | 0.55 | 2 to 3 | 2.49 | 0.57 | 2843 | 3060 | 1424 | good | moderate | 0.625 | 0.34 | silty claystone |
| Maret 1 | | good | plentiful | 0.75 | 0.25 | 2 to 4 | 2.86 | 0.557 | 3174 | 3276 | 670 | good | moderate | 0.625 | 0.15 | sandstones and siltstone very thin not seal lithologies - no logs in interval so no Bri - cuttings and SWC descriptions used to determine lithologies |
| Octavius 1 | laterteral variation in facies may by high - this section is thought to be turbidites in origion - correlates to Octavius 2 | good | moderate | 0.625 | 0.34 | 4 to 6 in the lower half and 2 to 4 in the upper half - BRI taken for lower section which is the seal for the Tithonian sands | 4.64 | 0.68 | 2650 | 2780 | 1903 | bad | moderate | 0.375 | 0.13 | siltstone/clystone turbiditic deposition, mixed phase - hard to get a good reading using cuttings and MCIP |
| Octavius 2 | correlates to Octavius 1 | good | moderate | 0.625 | 0.34 | 4 to 6 in the lower half and 2 to 4 in the upper half - BRI taken for lower section which is the seal for the Tithonian sands | 4.66 | 0.83 | 2600 | 2800 | 1312 | bad | moderate | 0.375 | 0.13 | |
| Oliver 1 | 1 | very good | enough | 0.875 | 0.57 | no logs over this interval | | | | | | good | poor | 0.563 | 0.32 | clystne with interbeded siltstones |

## Appendix 2: Seal Potential - Upper Vulcan Formation

| | | Seal Capacity | | | | | | Seal Thickness | | | | | Areal Extent | | | | Seal Potential | Seal Integrity | | | | | | | | | Seal Potential | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Well Name | Lithology Comments | Seal Capacity | Strucutral Closure | structure / seal capacity | Geological Factory | Data Quality and Quantity | Risk Matrix Value | Seal Thickness (m) | fault throws in cap rock | Geological Factory | Data Quality and Quantity | Risk Matrix Value | Seal Areal Extent | Geological Factory | Data Quality and Quantity | Risk Matrix Value | Seal Cap *Thickness *Areal extent | Brittle Index Range | BRI-mean | BRI-StDev | depth from | depth to | BRI Count | Geological Factory | Data Quality and Quantity | Risk Matrix Value | Seal Cap *Thickness *Areal extent *BRI Index | Comments |
| Paquain 1 | approx 400m of restricted marine slightly silty claystones | | | | good | moderate | 0.625 | 400 | no resolvable faults seismic deteriorated due to adjacent diapir | very good | enough | 0.875 | a much ticker section than in the adjacent Maple1 well - laterally extensive and thickens in the grabens | very good | plentiful | 1 | 0.55 | | 2.15 | 0.26 | 2700 | 2832 | 866 | good | moderate | 0.625 | **0.34** | |
| Rainer 1 | massive medium to coarse grained sandstone section | | | | bad | plentiful | 0.25 | | | bad | plentiful | 0.25 | 0 | bad | plentiful | 0.25 | 0.02 | | | | | | | even | poor | 0.5 | **0.01** | sandstone |
| Swan 1 | | | 270 | 0.5 | very good | enough | 0.875 | 220 | strata lift up around diapir intrusion - mo major faults apparent | very good | plentiful | 1 | only a thick uppermost Lw Vulcan was penetrated, taken to be laterally extensive - correlates out to maple 1 | very good | plentiful | 1 | 0.68 | 2 to 4 | 3.04 | 0.79 | 2635 | 2980 | 2263 | good | moderate | 0.625 | **0.58** | base clystne inbd sltstne grades to clystne |
| Vulcan 1b | interbd shales (silty) with rare thin finegrained SS - SS more prevalent in Up Vulcan than in Lw Vulcan | | | 1 | very good | enough | 0.875 | 402 | very thick seal fault throws in the order of 60 to 100m | very good | plentiful | 1 | | very good | plentiful | 1 | 0.88 | | 2.31 | 0.54 | 2300 | 2850 | 3609 | good | moderate | 0.625 | **0.55** | clystone |
| Anderdon 1 | missing section | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Birch 1 | missing section | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Brown Gannet 1 | missing section | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Cassini 1 | missing section | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Cassini 2 | missing section | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Challis 1 | missing section | | 65 | | | | | | | | | | | | | | | | | | | | | | | | | |
| East Swan 1 | missing section | | 75 | | | | | | | | | | | | | | | | | | | | | | | | | |
| Jabiru 1a | missing section | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Jabiru 2 | missing section | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Longleat 1 | missing section | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Medusa 1 | missing section | | 100 | | | | | | | | | | | | | | | | | | | | | | | | | |
| Pascal 1 | missing section | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Pollard 1 | missing section | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Prion 1 | missing section | | 100 | | | | | | | | | | | | | | | | | | | | | | | | | |
| Puffin 1 | missing section | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Puffin 2 | missing section | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Rainbow 1 | missing section | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Rowan 1 | missing section | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Sahul Shoals 1 | missing section | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Skua | missing section | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Snowmass 1 | missing section | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Swift 1 | missing section | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Talbot 1 | missing section | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Taltarni 1 | missing section | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Turnstone 1 | missing section | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Waeb 1a | missing section | | | | | | | | | | | | | | | | | | | | | | | | | | | |

## Appendix 2: Seal Potential - Echuca Shoals Formation

| | | Seal Capacity | | | | | | Seal Thickness | | | | | Areal Extent | | | | Seal Potential | Seal Integrity | | | | | | | | | Seal Potential | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Well Name | Lithology Comments | Seal Capacity | Structural Closure | structure / seal capacity | Geological Factory | Data Quality and Quantity | Risk Matrix Value | Seal Thickness (m) | fault throws in cap rock | Geological Factory | Data Quality and Quantity | Risk Matrix Value | Seal Areal Extent | Geological Factory | Data Quality and Quantity | Risk Matrix Value | Seal Cap *Thickness *Areal extent | Brittle Index Range | BRI-mean | BRI-StDev | depth from | depth to | BRI Count | Geological Factory | Data Quality and Quantity | Risk Matrix Value | Seal Cap *Thickness *Areal extent *BRI Index | Comments |
| Allaru 1 | basal transgressive argillaceous SS grades rapidly to siltstone and then to a restricted marine glauconitic claystone | 305 | 40 | 1 | very good | plentiful | 1 | 15(15) | 25 | bad | plentiful | 0.25 | areal extensive in basin depocenter | very good | poor | 0.625 | 0.16 | no logs taken over interval | | | | | | very good | poor | 0.625 | 0.10 | base ss/sltstne fines up to glauc clystne |
| Brown Gannet | missing or possible 2m high gamma spike at ~2167m may be very thin echuca | | | | very good | moderate | 0.75 | 2 | | bad | moderate | 0.375 | | good | moderate | 0.625 | 0.18 | 1to2 | 1.31 | 0.3 | 2165 | 2166 | 6 | very good | moderate | 0.75 | 0.13 | echuca shoals may be present at a 2m shale - not sure if it is actually there |
| Cassini 1 | glauconitic claystone | | | 1 | very good | enough | 0.875 | 10 | major fault bound closure - bounding fault has a 65+m throw - minor associated faulting likely in top seal - same structure as challis and cap rock faults in challis had throws in the 10 to 15m range | bad | enough | 0.313 | areally extensive over Cassini wells | very good | plentiful | 1 | 0.27 | | 1.55 | 0.84 | 1421 | 1431 | 65 | very good | moderate | 0.75 | 0.21 | |
| Cassini 2 | assumed similar to Cassini 1 | | | 1 | very good | enough | 0.875 | 11 | major fault bound closure - bounding fault has a 65+m throw - minor associated faulting likely in top seal - same structure as challis and cap rock faults in challis had throws in the 10 to 15m range | bad | enough | 0.313 | areally extensive over Cassini wells | very good | plentiful | 1 | 0.27 | 1 to 2 | 1.44 | 0.31 | 1451 | 1462 | 73 | very good | moderate | 0.75 | 0.21 | |
| Challis 1 | glauconitic siltstones and claystones | 433 | 65 | 1 | very good | plentiful | 1 | 14 | 10 to 15m throws on faults at top of structure | bad | plentiful | 0.25 | areally extensive over Challis structure | very good | plentiful | 1 | 0.25 | 1to2 | 1.55 | 0.79 | 1371 | 1389 | 118 | very good | moderate | 0.75 | 0.19 | glauc clystne |
| Champagny 1 | clystne glauc - trace silty | | 53 | | very good | enough | 0.875 | 71(25) | 0 | very good | plentiful | 1 | thick echuca over struct | very good | plentiful | 1 | 0.88 | no logs taken over interval | | | | | | good | poor | 0.563 | 0.49 | glauc clystne |
| Conway 1 | grey weak calc claystone | | 160 | grey weak calc claystone | very good | enough | 0.875 | 25 | 0 | very good | enough | 0.875 | relatively thick some horizontal heterogenaity possible | good | enough | 0.688 | 0.53 | 1 to 2 | 1.59 | 0.56 | 2104 | 2127 | 151 | very good | moderate | 0.75 | 0.40 | 25m clystne - not 100% sure clystne covers structure as this is a downthrown fault side tilted graben play |
| Douglas 1 | dark olive grey, slightly calcareous carbonaceous claystone with traces of glauconite and pyrite | 281 | 111 - fault bound closure on both sides of the horst - the well intersects faults - main reason the bathurst island grp is largly missing | 0.75 | very good | plentiful | 1 | 33 | echuca and jamieson contact is a major fault and at least 50m of echuca is missing/based on correlation with Octavius 1) - dip meter suggest that whole echuca may be imbricated with minor faults | bad | poor | 0.438 | areally extensive | very good | plentiful | 1 | 0.44 | 1 to 2 | 1.17 | 0.46 | 2348 | 2380 | 210 | very good | moderate | 0.75 | 0.33 | |
| East Swan 1 | condensed dary grey/black glauconitic claystone | 511 | 50 | 1 | very good | plentiful | 1 | 25 | no apparent faults in top seal - vtt | very good | enough | 0.875 | echuca shoals is extensive in this region | very good | enough | 0.875 | 0.77 | 1to2 | 1.08 | 0.59 | 2316 | 2338 | 144 | very good | moderate | 0.75 | 0.57 | |
| East Swan 2 | | | | | very good | enough | 0.875 | 23 | | very good | moderate | 0.75 | | very good | plentiful | 1 | 0.66 | | 1.62 | 0.43 | 2294 | 2317 | | very good | moderate | 0.75 | 0.49 | |
| Eclipse 1 | echuca claystone | 678 | 110 | 1 | very good | plentiful | 1 | 26 | | very good | enough | 0.875 | 1 | very good | plentiful | 1 | 0.88 | 1to2 | 1.53 | 1 | 2295 | 2315 | 131 | very good | moderate | 0.75 | 0.66 | |
| Eclipse 2 | | | | | very good | enough | 0.875 | 38 | | very good | enough | 0.875 | | very good | plentiful | 1 | 0.77 | | 1.49 | 0.58 | 2400 | 2438 | | very good | moderate | 0.75 | 0.57 | |
| Fagin 1 | claystone | | 200 | 1 | very good | enough | 0.875 | 62 | | very good | enough | 0.875 | 1 | very good | plentiful | 1 | 0.77 | | 1.25 | 0.54 | 2672 | 2734 | 407 | very good | moderate | 0.75 | 0.57 | |
| Halycon 1 | transgressive argillaceous siltstone overlies Kval and grades into a dark shale with high gamma | | 43 | 0.5 | good | enough | 0.688 | 25 | | very good | moderate | 0.75 | 1 | very good | moderate | 0.75 | 0.39 | | 1.08 | 0.66 | 1313 | 1339 | 151 | very good | moderate | 0.75 | 0.29 | glauconitic siltstone/some blocky claystoen |
| Keeling 1 | carbonaceous claystones - no glauc | | 150 | 1 | very good | enough | 0.875 | 27 | 25 | good | plentiful | 0.75 | 7 | very good | plentiful | 1 | 0.66 | ~1 | 1.2 | 0.27 | 3000 | 3025 | 164 | very good | moderate | 0.75 | 0.49 | 32m sand - gas filled - glauc clystne = seal - fault throws on top of sturcture partially offset the seal which is the highest risk for this cap rock |
| Maple 1 | condensed dark grey to black glauc claystone | | 500 | 1 | very good | enough | 0.875 | 9 | none apparent on vtt | good | poor | 0.563 | areal extensive in basin depocenter | very good | poor | 0.625 | 0.31 | 1to2 | 1.49 | 0.48 | 2635 | 2645 | 65 | very good | moderate | 0.75 | 0.23 | |
| Maret 1 | | | 50 | 1 | very good | enough | 0.875 | 60(77) | 30 | good | plentiful | 0.75 | seismic est | very good | plentiful | 1 | 0.66 | ~1 | 1.35 | 0.515 | 3118 | 3174 | 367 | very good | moderate | 0.75 | 0.49 | 77m silts and sands - then 65m glauc clystne - no logs in interval so no BRI |
| Medusa 1 | glauconitic claystone | | 100 | 1 | very good | enough | 0.875 | 12 | sub seismic resolution thickness | good | poor | 0.563 | areally extensive in terrace areas | good | poor | 0.563 | 0.28 | 1 to 2 | 2.37 | 0.99 | 1780 | 1792 | 79 | good | moderate | 0.625 | 0.17 | glauc clystone - base SS |
| Octavius 1 | medium dark grey micaceous claystones with traces of glauconite and pyrite | 617 | 260 | 1 | very good | plentiful | 1 | 87 | | very good | enough | 0.875 | areally extensive over Octavius structure - well correlation | very good | plentiful | 1 | 0.88 | 1 to 2 | 1.29 | 0.15 | 2420 | 2500 | 525 | very good | moderate | 0.75 | 0.66 | |
| Octavius 2 | mostly claystone with occasional thin silt stringers. It is more argillaceus than the overlying formations | | 260 | | very good | enough | 0.875 | 104 | | very good | enough | 0.875 | | very good | plentiful | 1 | 0.77 | | 1.47 | 0.4 | 2418 | 2516 | 603 | very good | moderate | 0.75 | 0.57 | |
| Oliver 1 | green-grey glauconitic claystone | | 260 | 1 | very good | enough | 0.875 | 53 | relatively thick echuca | very good | enough | 0.875 | extensive in basin depocenter | very good | plentiful | 1 | 0.77 | no logs over this interval | | | | | | very good | poor | 0.625 | 0.48 | |
| Paqualin 1 | approx 40m of claystone | | ~100 | 1 | very good | enough | 0.875 | 38 | none apparent on vtt | good | enough | 0.75 | areal extensive in basin depocenter | very good | enough | 0.875 | 0.57 | 1 to 2 | 1.59 | 0.85 | 2490 | 2528 | 249 | very good | moderate | 0.75 | 0.43 | |

## Appendix 2: Seal Potential - Echuca Shoals Formation

| | | Seal Capacity | | | | | | Seal Thickness | | | | | Areal Extent | | | | Seal Potential | Seal Integrity | | | | | | | | | Seal Potential | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Well Name | Lithology Comments | Seal Capacity | Structural Closure | structure / seal capacity | Geological Factory | Data Quality and Quantity | Risk Matrix Value | Seal Thickness (m) | fault throws in cap rock | Geological Factory | Data Quality and Quantity | Risk Matrix Value | Seal Areal Extent | Geological Factory | Data Quality and Quantity | Risk Matrix Value | Seal Cap *Thickness *Areal extent | Brittle Index Range | BRI-mean | BRI-StDev | depth from | depth to | BRI Count | Geological Factory | Data Quality and Quantity | Risk Matrix Value | Seal Cap *Thickness *Areal extent *BRI Index | Comments |
| Pascal 1 | condensed dark brown to green glauconitic claystone | 278 | 70 | 1 | very good | plentiful | 1 | 8 | very tentative fault interpretation of 13m throw at kval horizon - fault does not extend past kval on seismic - because echuca is very thin and some faults could be interped as offsetting the top seal on the vtt - a moderatge data quality has been assigne | good | poor | 0.563 | the echuca shoals is extensively present in wells however it is very thin and not mappable on seismic (there for a moderate data qual and quant is assigned | good | poor | 0.563 | 0.32 | 1to2 | 2.11 | 1.29 | 2517 | 2525 | 53 | good | moderate | 0.625 | 0.20 | condensed dark brown to green glauconitic claystone |
| Pollard 1 | 0.75 | | 111 | 0.75 | very good | enough | 0.875 | 10 | very thin echuca | good | moderate | 0.625 | 0.75 | good | poor | 0.563 | 0.31 | | | | | | | good | poor | 0.563 | 0.17 | |
| Prion 1 | tentative interpretation mainly on wireline log motif of Echuca Shoals | | 100 | 1 | very good | moderate | 0.75 | 9 | none apparent on vtt | good | poor | 0.563 | the echuca shoals is extensively present in wells however it is very thin and not mappable on seismic (there for a moderate data qual and quant is assigned | good | poor | 0.563 | 0.24 | 1to2 | 2.49 | 2 | 2626 | 2634 | 53 | good | moderate | 0.625 | 0.15 | |
| Rainbow 1 | picked on biostrat and log motif | | 30 | 1 | very good | enough | 0.875 | 8 | | good | poor | 0.563 | 0.75 | good | poor | 0.563 | 0.28 | 1to2 | 1.77 | 0.38 | 2384 | 2391 | 45 | very good | moderate | 0.75 | 0.21 | |
| Rainer 1 | dk green to black glauconitic claystone | 617 | 90 | 1 | very good | plentiful | 1 | 19 | the trap is a roll over anticline - no apparent top seal faulting is visible on vtt seismic(there good geological expression) however the echuca shoals thickness is below seismic resolution (therefore moderate data qual) | good | poor | 0.563 | areally extensive over Challis structure | good | poor | 0.563 | 0.32 | 1to2 | 1.54 | 0.68 | 1656 | 1665 | 66 | very good | moderate | 0.75 | 0.24 | |
| Rowan 1 | Echuca is sandy in Rowan 1 - .5m intbd sand,silt & clystne | | 111 | sandy | bad | plentiful | 0.25 | 52 | non apparent in Skua3D seal onlap onto structure | very good | enough | 0.875 | tilted fault block- echuca is becoming sandy | bad | moderate | 0.375 | 0.08 | clystne~3 sands~4 - mainly clystones with 6x2m sand int | 3.1 | 0.83 | 2820 | 2870 | 329 | good | moderate | 0.625 | 0.05 | glauc fine sands off skua horst or sandy silts/sandy clystone |
| Skua 1 | non calc shale 2 thin SS beds ~2m | 679 | 111 | | good | plentiful | 0.75 | 18 | thin echuca - faults minor faults hard to see on vtt | very good | moderate | 0.75 | does not cover structure | bad | plentiful | 0.25 | 0.14 | shales ~2 & minor SS~5to6 | 2.62 | 1.04 | 2407 | 2418 | 73 | good | moderate | 0.625 | 0.09 | |
| Snowmass 1 | 15m thick non-cal glauc claystone which grades down into a 13m thick medium grained glauconitic Qtz arenite - sequence overlies the Triassic | | | 1 | very good | enough | 0.875 | 19(13) | | good | poor | 0.563 | correlates to Rainer1 - same graben | good | poor | 0.563 | 0.28 | | 1.38 | 0.62 | 1258 | 1276 | 131 | very good | moderate | 0.75 | 0.21 | |
| Talbot 1 | thin echuca claystone | | 70 | 0.9 | very good | enough | 0.875 | 8 | fault bound closre on 2 sides and seal is sub seismic resolution | bad | moderate | 0.375 | very hard to estimate areal extent as seal is very thin and sub seismic resolution | good | moderate | 0.625 | 0.21 | | 1.7 | 0.78 | 1499 | 1597 | 53 | very good | moderate | 0.75 | 0.15 | |
| Turnstone 1 | claystone | | 80 | 1 | very good | enough | 0.875 | 14 | | good | poor | 0.563 | 0.75 | good | poor | 0.563 | 0.29 | | 1.72 | 0.49 | 1411 | 1425 | 92 | very good | moderate | 0.75 | 0.21 | |
| Vulcan 1b | condensed dary grey/black glauconitic claystone | | | 1 | very good | plentiful | 1 | 10 | | good | poor | 0.563 | correlates to nearby wells | good | poor | 0.563 | 0.32 | 2 with 2 sand units of 1m thickness over 4 | 2.77 | 0.88 | 2281 | 2291 | 65 | good | moderate | 0.625 | 0.20 | |
| Warb 1a | | 500 | 111 - post drill structure is thought not to be sealed at bounding fault where Triassic sands are juxtaposed against Triassic sands | 1 | very good | plentiful | 1 | 16 | echuca thickness is at a sub-seismic resolution so a moderate data quality is assigned - good geological factor | good | poor | 0.563 | echuca is thin and extensive | good | poor | 0.563 | 0.32 | ~2 | 2.17 | 0.38 | 2350 | 2365 | 99 | good | moderate | 0.625 | 0.20 | |
| Woodbine 1 | claystone - similar to Keeling 1 | | 111 | | very good | enough | 0.875 | 24 | 8 | very good | moderate | 0.75 | | very good | plentiful | 1 | 0.66 | ~1 | 1.51 | 0.5 | 3053 | 3076 | 151 | very good | moderate | 0.75 | 0.40 | slightly less risk of seal thickness being breached by faults - lithologies extend from Keeling-1 thus high confidence that structure is covered and lithologies are consistent. |
| Anderdon 1 | missing section | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Birch 1 | missing section | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Jabiru 1a | missing section | | 200 | | | | | | | | | | | | | | | | | | | | | | | | | |
| Jabiru 2 | missing section | | 200 | | | | | | | | | | | | | | | | | | | | | | | | | |
| Longleat 1 | missing section | | 70 | | | | | | | | | | | | | | | | | | | | | | | | | |
| Montara 1 | missing section | | 50 | | | | | | | | | | | | | | | | | | | | | | | | | |
| Puffin 1 | missing section | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Puffin 2 | missing section | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Sahul Shoals 1 | missing section | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Skua rest of | missing section | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Swan 1 | missing section | | 200 | | | | | | | | | | | | | | | | | | | | | | | | | |
| Swift 1 | missing section | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Tahbilk 1 | missing section | | 100 | | | | | | | | | | | | | | | | | | | | | | | | | |
| Taltarni 1 | missing section | | 100 | | | | | | | | | | | | | | | | | | | | | | | | | |

## Appendix 2: Seal Potential - Jamieson Formation

| | | Seal Capacity | | | | | | Seal Thickness | | | | | Areal Extent | | | | Seal Potential | Seal Integrity | | | | | | | | | Seal Potential | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Well Name | Lithology Comments | Seal Capacity | Strucutral Closure | structure / seal capacity | Geological Factory | Data Quality and Quantity | Risk Matrix Value | Seal Thickness (m) | fault throws in cap lock | Geological Factory | Data Quality and Quantity | Risk Matrix Value | Seal Areal Extent | Geological Factory | Data Quality and Quantity | Risk Matrix Value | Seal Cap *Thickness *Areal extent | Brittle Index Range | BRI-mean | BRI-StDev | depth from | depth to | BRI Count | Geological Factory | Data Quality and Quantity | Risk Matrix Value | Seal Cap *Thickness *Areal extent *BRI index | Comments |
| Alaru 1 | medium dark grey claystones | | 111 | 1 | very good | enough | 0.875 | 82 | 25 | good | plentiful | 0.75 | Jamieson is regionally extensive in VSB depocenter | very good | plentiful | 1 | 0.66 | no logs taken for this interval | | | | | | very good | poor | 0.625 | 0.41 | 12m base radiolarite - clystne |
| Brown Ganne | marl, limestone and calcareous shale | 180&219 | 100 | 1 | very good | plentiful | 1 | 39 | no seismic out there | very good | moderate | 0.75 | Jamieson is thin and extensive on the Ashmore platform, correlates to other wells in the region | very good | plentiful | 1 | 0.75 | 4to6 | 4.49 | 1.03 | 2128 | 2153 | 164 | bad | moderate | 0.375 | 0.28 | |
| Cassini 1 | calcareous claystone and shale | | 15 | 1 | very good | enough | 0.875 | 38 | ~20m fault offset on antithetic fault to bounding fault | good | plentiful | 0.75 | correlates over Cassini sturcuture | very good | plentiful | 1 | 0.66 | | 1.27 | 0.38 | 1385 | 1421 | 237 | very good | moderate | 0.75 | 0.49 | |
| Cassini 2 | calcareous claystone and shale | | | 1 | very good | enough | 0.875 | 31 | no apparent top seal faulting in vtt | very good | enough | 0.875 | correlates over Cassini sturcuture | very good | plentiful | 1 | 0.77 | 1 to 2 | 1.39 | 0.43 | 1420 | 1451 | 203 | very good | moderate | 0.75 | 0.57 | |
| Challis 1 | dark grey claystones | 122 | 90 | 1 | very good | plentiful | 1 | 48 | 10 to 15m - WCR | very good | plentiful | 1 | correlates over Challis structure | very good | plentiful | 1 | 1.00 | 1 to 2 | 1.28 | 0.25 | 1324 | 1371 | 309 | very good | moderate | 0.75 | 0.75 | |
| Champagny 1 | calc claystones | | 53 | 0.75 | very good | enough | 0.875 | 115 | - | very good | plentiful | 1 | 1 | very good | plentiful | 1 | 0.88 | DT log needs to be in us/m not us/ft - main problem | | | | | | very good | poor | 0.625 | 0.55 | base 8m radiolarite - clystne - DT log is in feet so not possible to calc BRI at this time |
| Conway 1 | low energy marine claystone | | 160 | 1 | very good | enough | 0.875 | 95 | 0 | very good | plentiful | 1 | 1 | very good | plentiful | 1 | 0.88 | ~1 to 2 | 1.81 | 0.6 | 2010 | 2104 | 617 | very good | moderate | 0.75 | 0.66 | |
| Douglas 1 | calcareous claystones | 359 | 111 - fault bo | 0.75 | very good | plentiful | 1 | 208 | major faulting - top and bottom of jamieson is fault bound | very good | moderate | 0.75 | extensive over this area - correlates to Octavius | very good | plentiful | 1 | 0.75 | 1 to 2 | 1.4 | 0.6 | 2140 | 2346 | 1352 | very good | moderate | 0.75 | 0.56 | |
| East Swan 1 | deepwater dark grey to black claystones | | 50 | 1 | very good | enough | 0.875 | 33 | | very good | enough | 0.875 | Jamieson is regionally extensive in the Basin center | very good | plentiful | 1 | 0.77 | ~1 | 1.71 | 0.55 | 2255 | 2310 | 197 | very good | moderate | 0.75 | 0.57 | 5m base radiolarite/clystne |
| East Swan 2 | upper interval of deepwater, dark grey to black claystones, with a basal radiolarite claystone unit (7m) | | | | very good | enough | 0.875 | 42 | | very good | enough | 0.875 | Jamieson is regionally extensive in the Basin center | very good | plentiful | 1 | 0.77 | | 1.76 | 0.19 | 2256 | 2286 | 197 | very good | moderate | 0.75 | 0.57 | 7m base radiolarite |
| Eclipse 1 | 40m claystones with basal 5m probably radiolarite | | 110 | 1 | very good | enough | 0.875 | 52 | eclipse 1 is not on vtt survey however there is a line nearby and there do not appear to be resolvabel faults in the top seal | very good | enough | 0.875 | Jamieson is regionally extensive in the Basin center | very good | plentiful | 1 | 0.77 | ~1 | 1.45 | 0.17 | 2250 | 2290 | 263 | very good | moderate | 0.75 | 0.57 | top jamieson is faulted out |
| Eclipse 2 | claystones with basal 18m radiolarite | | 111 | | very good | enough | 0.875 | 42 | | very good | enough | 0.875 | | very good | plentiful | 1 | 0.77 | | 1.35 | 0.15 | 3338 | 2380 | 275 | very good | moderate | 0.75 | 0.57 | 18m base radiolarite |
| Fagin 1 | claystone | | 200 | 0.75 | very good | enough | 0.875 | 166 | thick jamieson section | very good | plentiful | 1 | extensive over this area - correlates to Octavius | very good | plentiful | 1 | 0.88 | | 1.59 | 0.41 | 2506 | 2658 | 997 | very good | moderate | 0.75 | 0.66 | |
| Halycon 1 | claystone | | 43 | 1 | very good | enough | 0.875 | 390 | thick jamieson section | very good | plentiful | 1 | extensive over this area - correlates to Octavius | very good | plentiful | 1 | 0.88 | poor hole conditions | | | | | | very good | poor | 0.625 | 0.55 | |
| Jabiru 1a | shale prominent | 616 | 200 | 1 | very good | plentiful | 1 | 49 | no major top seal faults - if Challis is used as and analagous field top seal fault throws are in the order of 10 to 15m | very good | plentiful | 1 | extensive over the Jabiru structure | very good | plentiful | 1 | 1.00 | 1 to 2 with some section as high as 3 but predominantly in the 1 to 2 range | 2.14 | 0.81 | 1540 | 1592 | 342 | good | moderate | 0.625 | 0.63 | clystne |
| Jabiru 2 | shale prominent | 616 | 200 | 1 | very good | plentiful | 1 | 63 | no major top seal faults - if Challis is used as and analagous field top seal fault throws are in the order of 10 to 15m | very good | plentiful | 1 | extensive over the Jabiru structure | very good | plentiful | 1 | 1.00 | ~2 | 2.33 | 1.29 | 1570 | 1623 | 348 | good | moderate | 0.625 | 0.63 | clystne |
| Keeling 1 | 1 | | 150 | 1 | very good | enough | 0.875 | 97 | 30 | very good | plentiful | 1 | seismic est | very good | plentiful | 1 | 0.88 | 1 to 2 | 1.56 | 0.31 | 2900 | 2987 | 571 | very good | moderate | 0.75 | 0.66 | WCR - variably calcareous claystones |
| Longleat 1 | 1 | | 70 | 1 | very good | enough | 0.875 | 11 | fault dependant closure - very thin jamieson is a worry - main bouding fault offsets jamieson significantly | good | moderate | 0.625 | good areal extent - Longleat1 drilled at top of sturcture thus jamieson will only get thicker off sturcture | good | moderate | 0.625 | 0.34 | no logs at the ntpgg | | | | | | good | poor | 0.563 | 0.19 | |
| Maple 1 | bathyal dark grey to black claystones | 180 | 500 | | very good | enough | 0.875 | 18 | | very good | moderate | 0.75 | correlates to paqualin 1 | very good | plentiful | 1 | 0.66 | 2to4 | 3.16 | 0.39 | 2828 | 2835 | 46 | good | moderate | 0.625 | 0.41 | |
| Maret 1 | 1 | | 50 | 1 | very good | enough | 0.875 | 286 | 30 | very good | plentiful | 1 | seismic est | very good | plentiful | 1 | 0.88 | | 1.73 | 0.513 | 3000 | 3118 | 774 | very good | moderate | 0.75 | 0.66 | clystne - thick and regionally extensive - bad hole condition in top 70m of jamieson so BRI only estimated under this zone |
| Medusa 1 | claystone | | 100 | 1 | very good | enough | 0.875 | 91 | thick jamieson section | very good | plentiful | 1 | extensive over this area - correlates to Octavius | very good | plentiful | 1 | 0.88 | 1 to 2 | 1.61 | 0.31 | 1690 | 1774 | 551 | very good | moderate | 0.75 | 0.66 | |
| Montara 1 | grey, silty calc claystones | | 50 | 1 | very good | enough | 0.875 | 46 | 15 | very good | enough | 0.875 | 1 | very good | plentiful | 1 | 0.77 | no sonic log over this interval | | | | | | very good | poor | 0.625 | 0.48 | no sonic inthis interval |

## Appendix 2: Seal Potential - Jamieson Formation

| | | Seal Capacity | | | | | | Seal Thickness | | | | | Areal Extent | | | | Seal Potential | Seal Integrity | | | | | | | | | Seal Potential | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Well Name | Lithology Comments | Seal Capacity | Strucutral Closure | structure / seal capacity | Geological Factory | Data Quality and Quantity | Risk Matrix Value | Seal Thickness (m) | fault throws in cap rock | Geological Factory | Data Quality and Quantity | Risk Matrix Value | Seal Areal Extent | Geological Factory | Data Quality and Quantity | Risk Matrix Value | Seal Cap *Thickness *Areal extent | Brittle Index Range | BRI-mean | BRI-StDev | depth from | depth to | BRI Count | Geological Factory | Data Quality and Quantity | Risk Matrix Value | Seal Cap *Thickness *Areal extent *BRI Index | Comments |
| Octavius 1 | marine claystone which becomes increasingly calcareous upwards and eventually grades into marl | | 260 | 1 | very good | enough | 0.875 | 266 | ~25m fault intersected in Octavius 2 | very good | plentiful | 1 | extensive over Octavius wells | very good | plentiful | 1 | 0.88 | 1 to 2 with some section as high as 3 but predominantly in the 1 to 2 range | 1.48 | 0.49 | 2150 | 2404 | 1667 | very good | moderate | 0.75 | 0.66 | clystne |
| Octavius 2 | marine claystone which becomes increasingly calcareous upwards and eventually grades into marl | | | | very good | enough | 0.875 | 240 | | very good | plentiful | 1 | extensive over Octavius wells | very good | plentiful | 1 | 0.88 | | 1.53 | 0.39 | 2170 | 2400 | 1510 | very good | moderate | 0.75 | 0.66 | |
| Oliver 1 | calcareous claystones and marls | | 280 | 0.75 | very good | enough | 0.875 | 200 | thick jamieson section | very good | plentiful | 1 | extensive over this area - correlates to Octavius | very good | plentiful | 1 | 0.88 | no logs over this interval | | | | | | very good | poor | 0.625 | 0.55 | |
| Osprey 1 | shales | 172 | 60 | 1 | very good | plentiful | 1 | 107 | thick jamieson section | very good | enough | 0.875 | extensive over this area - correlates to Octavius | very good | plentiful | 1 | 0.88 | 1 to 2 - two 10m SS and Sltstone intervals in the base 25m are transgressive expression with BRI ~4 | 1.04 | 0.48 | 1100 | 1230 | 853 | very good | moderate | 0.75 | 0.66 | |
| Paquallin 1 | calc claystones | 165 | ~100 | 1 | very good | enough | 0.875 | 28 | poor seismic quality near diapr | very good | moderate | 0.75 | correlatesl to maple 1 | very good | plentiful | 1 | 0.66 | lower half of this int has high bri over 4, upper half has BRIs 2 to 4 | 3.44 | 1 | 2462 | 2490 | 184 | good | moderate | 0.625 | 0.41 | |
| Pascal 1 | calcareous claystone and marl - clystone is dolomitic in part and has occasional siliceous cement | 165 | 70 | 1 | very good | plentiful | 1 | 20 | ~8m - measured on vtt survey on one of the main faults visible offsetting the topseal | good | plentiful | 0.75 | Jamieson is thin and extensive on the Ashmore platform | very good | enough | 0.875 | 0.66 | 2to4 | 2.94 | 0.89 | 2497 | 2513 | 118 | good | moderate | 0.625 | 0.41 | |
| Prion 1 | red brown and green grey calc shale | | 100 | 1 | very good | enough | 0.875 | 38 | no apparent top seal faulting in vtt | very good | plentiful | 1 | Jamieson is thin and extensive on the Ashmore platform | very good | enough | 0.875 | 0.77 | 2to4 | 3.24 | 1 | 2588 | 2626 | 249 | good | moderate | 0.625 | 0.48 | |
| Puffin 1 | may be sandy | | 170 | 0.5 | good | moderate | 0.625 | 8 | major fault bound high - sub seismic thickness - not able to confidently estimate on current data | good | moderate | 0.625 | Jamieson is regionally extensive in the Basin center - this is a local high and Jamieson is present on top of it - however this is very thin for the jamieson and it may be heterogeneous laterally | good | moderate | 0.625 | 0.24 | no logs for this well - need to import | | | | | | good | poor | 0.563 | 0.14 | based largely on puffin 2 results |
| Puffin 2 | very calcareous marl and minor SS | | 140 | 0.5 | very good | enough | 0.875 | 11 | ~17 - measured on vtt survey on one of the main faults visible offsetting the topseal | bad | moderate | 0.375 | Jamieson is regionally extensive in the Basin center - this is a local high and Jamieson is present on top of it - however this is very thin for the jamieson and it may be heterogeneous laterally | good | moderate | 0.625 | 0.21 | 2to4 | 3.81 | 0.94 | 2425 | 2432 | 98 | good | moderate | 0.625 | 0.13 | |
| Rainbow 1 | marl, limestone and calcareous shale | 165 | 111 | 1 | very good | enough | 0.875 | 45 | ~30m - this is most probably not a bounding fault and the whole horst structure was tested for hydrocarbons. | good | plentiful | 0.75 | Jamieson is thin and extensive on the Ashmore platform, correlates to other wells in the region | very good | plentiful | 1 | 0.66 | 2to4 | 3.09 | 0.77 | 2335 | 2370 | 322 | good | moderate | 0.625 | 0.41 | marl |
| Rainer 1 | medium dark grey claystones which become increasingly argillaceous and glauconitic with depth | 561 | 90 | 1 | very good | plentiful | 1 | 60 | | very good | plentiful | 1 | 1 | very good | plentiful | 1 | 1.00 | 1 to 2 | 1.38 | 0.26 | 1599 | 1655 | 394 | very good | moderate | 0.75 | 0.75 | |
| Rowan 1 | outer neritic to mid-up bathyal marls and calc claystones | 249 | 111 | 1 | very good | plentiful | 1 | 132 | | very good | enough | 0.875 | covers Rowan fault block not Skua horst | very good | enough | 0.875 | 0.77 | ~2 | 1.89 | 0.54 | 2675 | 2820 | 951 | very good | moderate | 0.75 | 0.57 | outer neritic to mid-up bathyal marls and calc claystones |
| Sahul Shoals | calcareous shale and marl | 120 | 40 | 1 | very good | plentiful | 1 | 23 | | good | moderate | 0.625 | extensive over this area - correlates to Octavius | very good | plentiful | 1 | 0.63 | 2 to 3 (~2) | 2.31 | 0.97 | 1770 | 1792 | 144 | good | moderate | 0.625 | 0.39 | base 3m trans glauc ss - clystne marl |
| Skua 1 | calc shale | >1000m | 111 | | very good | plentiful | 1 | 15 | thin seal | very good | moderate | 0.75 | does not cover structure | bad | plentiful | 0.25 | 0.19 | 2 to 4 | 2.87 | 0.8 | 2389 | 2407 | 118 | good | moderate | 0.625 | 0.12 | thin jamieson interpreted based on biostrat - no base radiolarite interpreted |
| Skua 6 | shale | | 111 | | very good | plentiful | 1 | 10 | thin seal | very good | moderate | 0.75 | does not cover structure | bad | plentiful | 0.25 | 0.19 | 2 to 4 | 3.04 | 0.75 | 2350 | 2363 | 86 | good | moderate | 0.625 | 0.12 | |

## Appendix 2: Seal Potential - Jamieson Formation

| | | Seal Capacity | | | | | | Seal Thickness | | | | | Areal Extent | | | | Seal Potential | Seal Integrity | | | | | | | | | Seal Potential | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Well Name | Lithology Comments | Seal Capacity | Strucutral Closure | structure / seal capacity | Geological Factory | Data Quality and Quantity | Risk Matrix Value | Seal Thickness (m) | fault throws in cap rock | Geological Factory | Data Quality and Quantity | Risk Matrix Value | Seal Areal Extent | Geological Factory | Data Quality and Quantity | Risk Matrix Value | Seal Cap *Thickness *Areal extent | Brittle Index Range | BRI-mean | BRI-StDev | depth from | depth to | BRI Count | Geological Factory | Data Quality and Quantity | Risk Matrix Value | **Seal Cap *Thickness *Areal extent *BRI Index** | Comments |
| Snowmass 1 | calcareous claystones that become more argillaceous with depth - depositional environements reflect a gradual shoaling upwards cycle from upper bathyal grey black slightly calcareous claystones to more carbonate rich outer neritic light grey claystones. | | | | very good | enough | 0.875 | 80 | no major top seal faults - if Challis is used as and analagous field top seal fault throws are in the order of 10 to 15m | very good | plentiful | 1 | 1 | very good | plentiful | 1 | 0.88 | | 1.21 | 0.39 | 1176 | 1258 | 538 | very good | moderate | 0.75 | **0.66** | |
| Swan 1 | No description of Jam in WCR however log motif suggest a typical claystone (slightly calcareos) with basal radiolarite | | 200 | 1 | very good | enough | 0.875 | 40 | strata lift up around diapir intrusion - mo major faults apparent | very good | plentiful | 1 | Jamieson is regionally extensive in the Basin center | very good | enough | 0.875 | 0.77 | 1 to 2 | 1.72 | 1.08 | 2590 | 2619 | 164 | very good | moderate | 0.75 | **0.57** | |
| Swift 1 | dark grey to reddish brown shale | | 111 | 1 | very good | plentiful | 1 | 28 | no apparent top seal faulting in vtt | good | enough | 0.75 | correlates to skua 1 | very good | plentiful | 1 | 0.75 | -2 | 2.29 | 0.5 | 2365 | 2394 | 190 | good | moderate | 0.625 | **0.47** | dark grey to reddish brown shale |
| Tahbilk 1 | claystone & minor siltstone | | 100 | 0.75 | very good | enough | 0.875 | 122 | 17 | very good | plentiful | 1 | correlates to montara | very good | plentiful | 1 | 0.88 | 1 to 2 | 1.36 | 0.391 | 2370 | 2460 | 590 | very good | moderate | 0.75 | **0.66** | |
| Talbot 1 | calc claystones | | 70 | 1 | very good | enough | 0.875 | 34 | bounding faults do offset the jameison fmtn by about half it's thickness - therefore and faults through seal that are not resolvable are smaller than this | good | moderate | 0.625 | Jamieson is regionally extensive in the Basin center | very good | plentiful | 1 | 0.55 | - | 1.59 | 0.43 | 1460 | 1499 | 255 | very good | moderate | 0.75 | **0.41** | logs need to be imported for this well |
| Taltarni 1 | dark gray claystone | | 100 | 1 | very good | enough | 0.875 | 21 | no apparent top seal faulting in vtt | very good | moderate | 0.75 | 1 | very good | plentiful | 1 | 0.66 | -2 | 2.03 | 0.54 | 2306 | 2325 | 124 | good | moderate | 0.625 | **0.41** | fault may have cut some lithologies out of this well. |
| Turnstone 1 | claystone, marl and calcilutite | | 80 | 0.75 | very good | enough | 0.875 | 91 | thick jamieson section | very good | plentiful | 1 | extensive over this area - correlates to Octavius | very good | plentiful | 1 | 0.88 | | 1.68 | 0.62 | 1325 | 1411 | 564 | very good | moderate | 0.75 | **0.66** | |
| Vulcan 1b | deepwater dark grey to black claystones | | | 1 | very good | enough | 0.875 | 76 | | very good | enough | 0.875 | Jamieson is regionally extensive in the Basin center | very good | plentiful | 1 | 0.77 | 1 to 2 | 1.2 | 0.41 | 2206 | 2281 | 492 | very good | moderate | 0.75 | **0.57** | clystne |
| Woodbine 1 | shale-olive black | | 111 | | very good | enough | 0.875 | 127 | 0 | very good | plentiful | 1 | corelate to keeling1 | very good | plentiful | 1 | 0.88 | 1 to 2 | 1.69 | 0.93 | 2930 | 3046 | 761 | very good | moderate | 0.75 | **0.66** | WCR - shales |
| Skua rest | missing section | | 111 | | | | | | | | | | | | | | | | | | | | | | | | | |
| Birch 1 | missing section | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Anderdon 1 | missing section | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Warb 1a | missing section | | 300 | | | | | | | | | | | | | | | | | | | | | | | | | |
| Pollard 1 | missing section | | | | | | | | | | | | | | | | | | | | | | | | | | | |

## Appendix 2: Seal Potential - WGF Formations

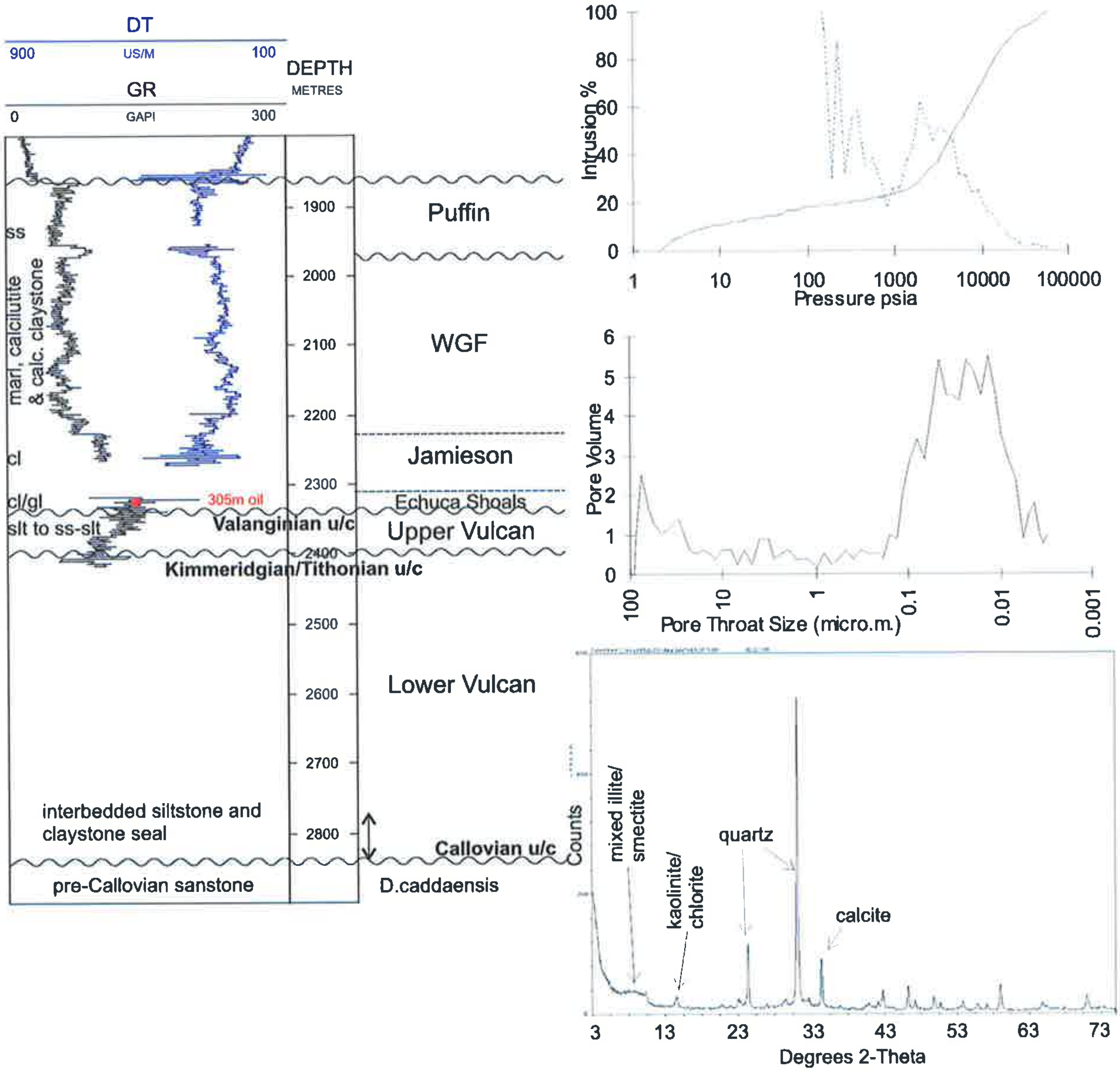
| | | Seal Capacity | | | | | | Seal Thickness | | | | | Areal Extent | | | | Seal Potential | Seal Integrity | | | | | | | | | Seal Potential | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Well Name | Lithology Comments | Seal Capacity | Structural Closure | structure / seal capacity | Geological Factory | Data Quality and Quantity | Risk Matrix Value | Seal Thickness (m) | fault throws in cap rock | Geological Factory | Data Quality and Quantity | Risk Matrix Value | Seal Areal Extent | Geological Factory | Data Quality and Quantity | Risk Matrix Value | Seal Cap *Thickness *Areal extent | Brittle Index Range | BRI-mean | BRI-StDev | depth from | depth to | BRI Count | Geological Factory | Data Quality and Quantity | Risk Matrix Value | Seal Cap *Thickness *Areal extent *BRI Index | Comments |
| Maru 1 | calcareous claystones, argillaceous calcilutites, outer neritic marls | | 111 | 1 | very good | enough | 0.875 | 187 | 27 | very good | plentiful | 1 | WGF is laterally extensive over entire Vulcan Sub Basin | very good | plentiful | 1 | 0.88 | logs were not run over this interval | | | | | | good | poor | 0.563 | 0.49 | |
| Anderdon 1 | marls calc-claystones and calcilutites | 512 | | 1 | very good | plentiful | 1 | 185 | thick extensive | very good | plentiful | 1 | thick extensive | very good | plentiful | 1 | 1.00 | poor hole conditions - where hole is good in lower section (1380-1420m) BRI~2 to 4 and higher up (1340-1360m) BRI~4 to 6 | | | | | | good | poor | 0.563 | 0.56 | |
| Birch 1 | calcilutite intbd w/ marl | | 111 | 1 | very good | enough | 0.875 | 125 | | very good | plentiful | 1 | 1 | very good | plentiful | 1 | 0.88 | | 4.31 | 0.85 | 2257 | 2380 | 787 | bad | moderate | 0.375 | 0.33 | |
| Brown Gannet 1 | | 100 - from pascal | 100 | 1 | very good | plentiful | 1 | 79 | no seismic out there | very good | moderate | 0.75 | WGF is laterally extensive over entire Vulcan Sub Basin | very good | plentiful | 1 | 0.75 | 4to6below 2110 and above 6 above 2110 | 8.00 | 1.21 | 2050 | 2115 | 512 | very bad | moderate | 0.25 | 0.19 | |
| Cassini 1 | carbonate rich - marl, argillaceous calcilutite | | 15 | 1 | very good | enough | 0.875 | 170 | -20 | very good | plentiful | 1 | WGF is laterally extensive over entire Vulcan Sub-Basin | very good | plentiful | 1 | 0.84 | 2 to 4 | 3.21 | 1.27 | 1250 | 1385 | 583 | good | moderate | 0.625 | 0.55 | |
| Cassini 2 | carbonate rich - marl, argillaceous calcilutite | | | 1 | very good | enough | 0.875 | 160 | | very good | plentiful | 1 | WGF is laterally extensive over entire Vulcan Sub-Basin | very good | plentiful | 1 | 0.88 | base 35m has bri ~6 next 30m has BRI 2to4 | 3.56 | 1.56 | 1260 | 1423 | 1050 | good | moderate | 0.625 | 0.55 | |
| Challis 1 | marl argillaceous calcilutites and calc claystones | 361 | 90 | 1 | very good | plentiful | 1 | 185 | 10 to 15m | very good | plentiful | 1 | WGF is laterally extensive over entire Vulcan Sub-Basin | very good | plentiful | 1 | 1.00 | 2 to 4 | 3.19 | 1.36 | 1140 | 1324 | 1207 | good | moderate | 0.625 | 0.63 | |
| Champagny 1 | argillaceous calcilutites | | 53 | 1 | very good | enough | 0.875 | 175 | - | very good | plentiful | 1 | areal extensive on vtl | very good | plentiful | 1 | 0.88 | | 5.60 | 1.2 | 2730 | 2890 | 1017 | bad | moderate | 0.375 | 0.33 | |
| Conway 1 | marls-calc claystones | | 111 | 1 | very good | enough | 0.875 | 381 | | very good | plentiful | 1 | 1 | very good | plentiful | 1 | 0.88 | 2 to 4 | 3.17 | 1.24 | 1630 | 2009 | 2480 | good | moderate | 0.625 | 0.56 | marls, calcilutites and calcareous claystones |
| Douglas 1 | marls - only Gibson is present rest are faulted out | | 111 - fault bound closure on both sides of the horst - the well intersects faults - main reason the bathurst island grp is largly missing | 1 | very good | enough | 0.875 | ~30 | major bounding fault has faulted out a large part of the WGF - this however is the bounding fault and the WGF is still interpreted to be significantly thick based on vtl | very good | enough | 0.875 | WGF is laterally extensive over entire Vulcan Sub Basin | very good | plentiful | 1 | 0.77 | wgf virtually faulted out | | | | | | good | poor | 0.563 | 0.43 | poor data quality |
| East Swan 1 | open marine shell-slope argillaceous calcilutites, marls and calcareous claystones | | 50 | 1 | very good | enough | 0.875 | 114 | thick extensive | very good | plentiful | 1 | covers struct on vtl | very good | plentiful | 1 | 0.88 | woolaston ~2to4; gibson ~2to6; fenelon ~2 and ~4 | 4.37 | 1.01 | 2130 | 2255 | 748 | bad | moderate | 0.375 | 0.33 | there is more of a distinction bt claystones and marls in WGF with much higher clay contents in calc claystones |
| East Swan 2 | | | | | very good | enough | 0.875 | 161 | | very good | plentiful | 1 | covers struct on vtl | very good | plentiful | 1 | 0.88 | base 30m has a BRI~3 rest has high BRI | 4.49 | 1.08 | 2093 | 2256 | 1057 | bad | moderate | 0.375 | 0.33 | |
| Eclipse 1 | calcareous claystones and marls | | 110 | 1 | very good | enough | 0.875 | 170 | thick extensive | very good | plentiful | 1 | covers struct on vtl | very good | plentiful | 1 | 0.88 | poor hole conditions | 5.44 | 1.17 | 2060 | 2250 | 1240 | bad | poor | 0.438 | 0.38 | fault contact at base with underlying jamieson |
| Eclipse 2 | | | | | very good | enough | 0.875 | 283 | | very good | plentiful | 1 | | very good | plentiful | 1 | 0.88 | base 35m BRI~2 rest ranges from ~4to6 | 4.03 | 1.43 | 2053 | 2308 | 1857 | bad | moderate | 0.375 | 0.33 | |
| Fagin 1 | interbedded marl and calcilutite | | 200 | 0.9 | very good | enough | 0.875 | 176 | | very good | enough | 0.875 | WGF is laterally extensive over entire Vulcan Sub-Basin | very good | plentiful | 1 | 0.77 | | 3.88 | 1.11 | 2370 | 2506 | 882 | good | moderate | 0.625 | 0.44 | |
| Halycon 1 | claystone | | 43 | 1 | very good | enough | 0.875 | 132 | | very good | enough | 0.875 | WGF is laterally extensive over entire Vulcan Sub-Basin | very good | plentiful | 1 | 0.77 | 2 to 4 | 2.71 | 0.68 | 790 | 908 | | good | moderate | 0.625 | 0.44 | |
| Jabiru 1a | marl argillaceous calcilutites and calc claystones | | 200 | | very good | plentiful | 1 | 170 | | very good | plentiful | 1 | WGF is laterally extensive over entire Vulcan Sub-Basin | very good | plentiful | 1 | 1.00 | 2 to 4 | 2.88 | 1 | 1366 | 1540 | 1141 | good | moderate | 0.625 | 0.63 | 2 = calc claystones and 4 = calcilutites |
| Jabiru 2 | marl argillaceous calcilutites and calc claystones | 436 | 200 | 2.18 | very good | plentiful | 1 | 170 | | very good | plentiful | 1 | WGF is laterally extensive over entire Vulcan Sub-Basin | very good | plentiful | 1 | 1.00 | 2 to 4 | 3.15 | 1.34 | 1285 | 1570 | 1870 | good | moderate | 0.625 | 0.63 | |
| Kooking 1 | 1 | | 150 | | very good | enough | 0.875 | 129 | 30 | very good | plentiful | 1 | seismic est | very good | plentiful | 1 | 0.88 | 4 to 6 | 5.68 | 1.03 | 2760 | 2893 | 833 | bad | moderate | 0.375 | 0.30 | high BRI over the interval brings SP into high risk - there is a velocity pull up over this structure, the propensity of the rocks to fracture may have an influence |
| Longline 1 | marls calc-claystones and calcilutites | | 70 | 1 | very good | enough | 0.875 | 235 | thick extensive | very good | plentiful | 1 | thick extensive | very good | plentiful | 1 | 0.88 | no logs for this well at the [illegible] | | | | | | good | poor | 0.563 | 0.49 | logs need to be imported for this well |
| Maple 1 | deep water outer shelf slope setting, argillaceous calcilutites, marls and calc claystones - increasingly argillaceous with depth | | 500 | 0.7 | very good | enough | 0.875 | 182 | | very good | enough | 0.875 | WGF is laterally extensive over entire Vulcan Sub Basin | very good | plentiful | 1 | 0.77 | ~6 or greater | 5.75 | 1.37 | 2660 | 2825 | 1234 | bad | moderate | 0.375 | 0.29 | .5 due to large structure, seal caps in 'Z' are generally of the 100-200m order |
| Marel 1 | 1 | | 30 | 1 | very good | enough | 0.875 | 300 | 30 | very good | plentiful | 1 | seismic est | very good | plentiful | 1 | 0.88 | 4 to 6 in the lower half and 2 to 4 in the upper half | 3.57 | 1.18 | 2505 | 2835 | 2105 | good | moderate | 0.625 | 0.56 | base 30m interbedded SS in Woolaston, 300m interbedded marl and calc claystones |
| Medusa 1 | interbedded marl and calcilutite | | 100 | 1 | very good | enough | 0.875 | 100 | | very good | enough | 0.875 | WGF is laterally extensive over entire Vulcan Sub-Basin | very good | plentiful | 1 | 0.77 | 2 to 6 - I assume that the high Bri are more carbonate rich and lower BRI are more shale rich | 2.89 | 1.09 | 1593 | 1663 | 656 | good | moderate | 0.625 | 0.44 | |
| Montara 1 | marls-calc claystones | | 50 | 1 | very good | enough | 0.875 | 224 | 0 | very good | plentiful | 1 | 1 | very good | plentiful | 1 | 0.88 | no sonic log over this interval | | | | | | bad | poor | 0.438 | 0.38 | no sonic in interval |
| Octavius 1 | marl argillaceous calcilutites and calc claystones | | 280 | | very good | enough | 0.875 | 157 | | very good | plentiful | 1 | WGF is laterally extensive over entire Vulcan Sub-Basin | very good | plentiful | 1 | 0.88 | 2 to 4 for the calcareous claystone parts and 4to6 for the more calcilutite parts | 3.29 | 1.02 | 2000 | 2150 | | good | moderate | 0.625 | 0.55 | |
| Octavius 2 | marl argillaceous calcilutites and calc claystones | | | | very good | enough | 0.875 | 240 | | very good | plentiful | 1 | | very good | plentiful | 1 | 0.88 | | 3.72 | 1.11 | 1970 | 2165 | 1298 | good | moderate | 0.625 | 0.55 | |
| Oliver 1 | calcareous claystones and marls | 217-from rainer 1 | 280 | 0.78 | very good | enough | 0.875 | 57-top faulted | missing section at top of WGF due to fault | very good | enough | 0.875 | WGF is laterally extensive over entire Vulcan Sub-Basin | very good | plentiful | 1 | 0.77 | no log data for this interval | | | | | | good | poor | 0.563 | 0.43 | |

## Appendix 2: Seal Potential - WGF Formations

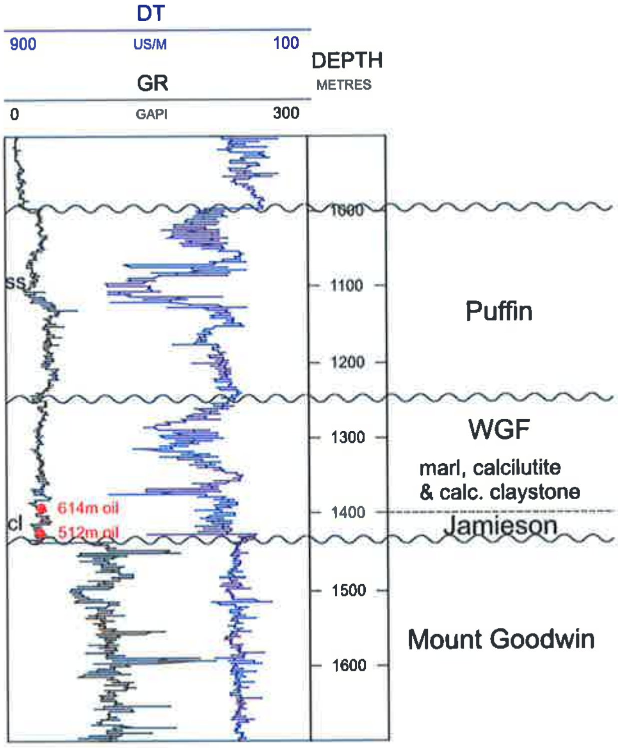
| | | Seal Capacity | | | | | | Seal Thickness | | | | | Areal Extent | | | | Seal Potential | Seal Integrity | | | | | | | | | Seal Potential | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Well Name | Lithology Comments | Seal Capacity | Structural Closure | structure / seal capacity | Geological Factory | Data Quality and Quantity | Risk Matrix Value | Seal Thickness (m) | fault throws in cap rock | Geological Factory | Data Quality and Quantity | Risk Matrix Value | Seal Areal Extent | Geological Factory | Data Quality and Quantity | Risk Matrix Value | Seal Cap *Thickness *Areal extent | Brittle Index Range | BRI-mean | BRI-StDev | depth from | depth to | BRI Count | Geological Factory | Data Quality and Quantity | Risk Matrix Value | Seal Cap *Thickness *Areal extent *BRI Index | Comments |
| Osprey 1 | shale and limestone - minor SS | | | | very good | enough | 0.875 | >200m | | very good | enough | 0.875 | WGF is laterally extensive over entire Vulcan Sub-Basin | very good | plentiful | 1 | 0.77 | poor hole conditions | 2.37 | 0.79 | 965 | 1060 | 884 | good | moderate | 0.625 | 0.48 | |
| Paqualin 1 | marl and calcilutite | | ~100 | 1 | very good | enough | 0.875 | 102 | poor seismic quality near diapr | very good | enough | 0.875 | WGF is laterally extensive over entire Vulcan Sub-Basin | very good | plentiful | 1 | 0.77 | all over 4 except for turonian spike which is 1 | 5.38 | 0.8 | 2370 | 2462 | 603 | bad | moderate | 0.375 | 0.29 | |
| Pascal 1 | WGF consist of argillaceous calcilutite, calcilutite and marl | 103 | 70 | 1 | very good | plentiful | 1 | 77 | no faults through cap | very good | enough | 0.875 | WGF is laterally extensive over entire Vulcan Sub Basin | very good | plentiful | 1 | 0.88 | 6 to 8 | 6.53 | 0.94 | 2420 | 2497 | 505 | very bad | moderate | 0.25 | 0.22 | large low relief structural closure |
| Pollard 1 | interbedded marl and micritic limestone | 514 | 111 | | very good | plentiful | 1 | 23 | | very good | moderate | 0.75 | WGF is laterally extensive over entire Vulcan Sub Basin | very good | plentiful | 1 | 0.75 | ~4 to 6 | 5.18 | 1.7 | 2020 | 2041 | 138 | bad | moderate | 0.375 | 0.28 | |
| Prion 1 | grey firm to hard marl | | 100 | | very good | enough | 0.875 | 118 | no faults through cap | very good | plentiful | 1 | WGF is laterally extensive over entire Vulcan Sub Basin | very good | plentiful | 1 | 0.88 | 6 to 8 | 6.53 | 1.00 | 2470 | 2588 | 774 | very bad | moderate | 0.25 | 0.22 | |
| Puffin 1 | 1 | | 111 | 1 | very good | enough | 0.875 | 55 | | good | plentiful | 0.75 | WGF is laterally extensive over entire Vulcan Sub-Basin | very good | plentiful | 1 | 0.66 | | | | | | | very bad | poor | 0.375 | 0.25 | based largely on puffin 2 results |
| Puffin 2 | marls and shales are brick red and minor green in the lowest part of the upper cretaceous section | | 140 | 1 | very good | enough | 0.875 | 42 | ~17 fault throw in cap rock | good | plentiful | 0.75 | WGF is laterally extensive over entire Vulcan Sub-Basin | very good | plentiful | 1 | 0.66 | 6 to 8 | 7.47 | 1.61 | 2390 | 2425 | 230 | very bad | moderate | 0.25 | 0.16 | |
| Rainbow 1 | calcilutite w/ thin intbd shale | | 111 | 1 | very good | enough | 0.875 | ~80 | ~30m - this is most probably not a bounding fault and the whole horst structure was tested for hydrocarbons. | good | plentiful | 0.75 | WGF is laterally extensive over entire Vulcan Sub-Basin | very good | plentiful | 1 | 0.66 | ~6 or greater | 6.18 | 1.09 | 2245 | 2335 | 591 | very bad | moderate | 0.25 | 0.16 | |
| Rainer 1 | calcareous claystones, argillaceous calcilutites and marls | 217 | 90 | 1 | very good | plentiful | 1 | 195 | | very good | plentiful | 1 | WGF is laterally extensive over entire Vulcan Sub-Basin | very good | plentiful | 1 | 1.00 | Woolaston and Gibson are predominantly in the 2 to 4 range, while the Fenelon is in the 4 to 6 range | 3.48 | 1.47 | 1400 | 1593 | 1279 | good | moderate | 0.625 | 0.63 | |
| Rowan 1 | WGF consist of argillaceous calcilutite, calcilutite and marl | | 111 | 1 | very good | enough | 0.875 | 211 | no faults through cap | very good | plentiful | 1 | 1 | very good | plentiful | 1 | 0.88 | 4 to 6 = WGF - up part Fenelon 2 to 4 | 5.04 | 0.82 | 2520 | 2675 | 1017 | bad | moderate | 0.375 | 0.33 | calc claystone/marl |
| Sahul Shoals | calcilutite, shale, marl and calcareous shale | 88 | 40 | 1 | very good | plentiful | 1 | 68 | | very good | enough | 0.875 | WGF is laterally extensive over entire Vulcan Sub Basin | very good | plentiful | 1 | 0.88 | ~6 | 6.21 | 1.00 | 1705 | 1770 | 427 | very bad | moderate | 0.25 | 0.22 | |
| Skua 1 | | 139 | 111 | 1.2522523 | very good | plentiful | 1 | 160 | major bouding fault has throw of ~100m at top Paleocene horizon | good | plentiful | 0.75 | seal extends onto structure - well control | very good | plentiful | 1 | 0.75 | bottom 30m of @WGF has BRI over 6 - upper part has BRI~4to6 | 5.57 | 1.54 | 2250 | 2390 | 919 | bad | moderate | 0.375 | 0.28 | calcareous shales and argillaceous limestones |
| Skua 3 | | 116 | 111 | 1.045045 | very good | plentiful | 1 | 100 | major bouding fault has throw of ~100m at top Paleocene horizon | good | plentiful | 0.75 | seal extends onto structure - well control | very good | plentiful | 1 | 0.75 | very poor hole conditions | | | | | | bad | poor | 0.438 | 0.33 | calcareous shales and argillaceous limestones |
| Skua 5 | | 83 | 50 | 1 | very good | plentiful | 1 | 100 | no major faults of signif through top seal | very good | plentiful | 1 | seal extends onto structure - well control | very good | plentiful | 1 | 1.00 | ~4to6 | 5.63 | 1.04 | 2255 | 2355 | 820 | bad | moderate | 0.375 | 0.38 | intbd marl, argillaceous calcilutite and cal claystones |
| Skua 6 | | 120 | 111 | 1.0810811 | very good | plentiful | 1 | 85 | major bouding fault has throw of ~100m at top Paleocene horizon | good | plentiful | 0.75 | seal extends onto structure - well control | very good | plentiful | 1 | 0.75 | ~6 | 6.19 | 0.89 | 2265 | 2350 | 523 | very bad | moderate | 0.25 | 0.19 | marl/calcilutite |
| Skua 8 | calcilutite inbd w/ marl | 120(149) | 111 | 1.0810811 | very good | plentiful | 1 | 85 | major bouding fault has throw of ~100m at top Paleocene horizon | good | plentiful | 0.75 | seal extends onto structure - well control | very good | plentiful | 1 | 0.75 | ~6 | 6.83 | 1.15 | 2229 | 2310 | 391 | very bad | moderate | 0.25 | 0.19 | calcilutite inbd w/ marl |
| Skua 9 | intbd marl, argillaceous calcilutite and cal claystones | 120 | 111 | 1.0810811 | very good | plentiful | 1 | 105 | major bouding fault has throw of ~100m at top Paleocene horizon | good | plentiful | 0.75 | seal extends onto structure - well control | very good | plentiful | 1 | 0.75 | bottom half of WGF has a bri of over 6 and top half has BRI of ~4 | 5.64 | 1.57 | 2210 | 2310 | | bad | moderate | 0.375 | 0.28 | intbd marl, argillaceous calcilutite and cal claystones No logs for BRI |
| Snowmass 1 | calcareous shales, calcilutites and marls | | | | very good | enough | 0.875 | ~170 | | very good | plentiful | 1 | WGF is laterally extensive over entire Vulcan Sub Basin | very good | plentiful | 1 | 0.88 | poor hole conditions but BRI appears to be low | 2.52 | 1.43 | 950 | 1176 | 1483 | good | moderate | 0.625 | 0.55 | |
| Swan 1 | intbd marl, argillaceous calcilutite and cal claystones | | 200 | 0.7 | very good | enough | 0.875 | 150 | strata lift up around diapir intrusion - no major faults apparent | very good | plentiful | 1 | WGF is laterally extensive over entire Vulcan Sub Basin | very good | plentiful | 1 | 0.88 | ~4to9 ranges | 5.73 | 1.61 | 2450 | 2580 | 918 | bad | moderate | 0.375 | 0.33 | marl |
| Swift 1 | marl with minor calcilutite | | 111 | | very good | enough | 0.875 | 139 | | very good | plentiful | 1 | 1 | very good | plentiful | 1 | 0.88 | ~4to6 | 4.08 | 1.3 | 2145 | 2365 | 1444 | bad | moderate | 0.375 | 0.33 | marl with minor calcilutite |
| Tahbilk 1 | marl and limestone - some SS inGibson | | 111 | 1 | good | moderate | 0.625 | 345 | | very good | plentiful | 1 | seal corl to montara 1 | very good | plentiful | 1 | 0.63 | poor hole conditions and turbiditic sands show oil in the WGF | | | | | | even | poor | 0.5 | 0.31 | marl and limestone - some SS in Gibson - interpreted as distal turbidite facies has oil shows |
| Talbot 1 | marls calc-claystones and calcilutites | | 70 | 1 | very good | plentiful | 1 | 159 | thick extensive | very good | plentiful | 1 | covers struct on vil | very good | plentiful | 1 | 1.00 | | 2.6 | 0.94 | 1310 | 1460 | 985 | good | moderate | 0.625 | 0.63 | logs need to be imported for this well |
| Taltami 1 | calcareous claystones | | 100 | 1 | very good | enough | 0.875 | 345 | | very good | plentiful | 1 | 1 | very good | plentiful | 1 | 0.88 | bottom 80m has BRI of 4 to 6, next 140m has BRI of ~2 and upper 100m has BRI of 4 to 6 | 3.23 | 1.25 | 1850 | 2300 | 2296 | good | moderate | 0.625 | 0.55 | |
| Turnstone 1 | interbedded marl and calcilutite | | 80 | 1 | very good | enough | 0.875 | 200 | | very good | enough | 0.875 | WGF is laterally extensive over entire Vulcan Sub-Basin | very good | plentiful | 1 | 0.77 | | 2.6 | 1.23 | 1150 | 1325 | 1149 | good | moderate | 0.625 | 0.48 | |
| Vulcan 1b | marl and calcareous claystones | | | 1 | very good | enough | 0.875 | 73 | some offset in WGF - area is highly faulted | good | plentiful | 0.75 | covers struct on vil | very good | plentiful | 1 | 0.66 | mainly 4 with for bottom half - then ranges from 6 to 2 | 3.65 | 1.06 | 2130 | 2204 | 499 | good | moderate | 0.625 | 0.41 | |
| Warb 1a | glauconitic claystone | 300 | 300 | 1 | very good | plentiful | 1 | ~25 | FMS fault shows approx throw of 10m | very good | moderate | 0.75 | very thin WGF in this well, WGF is laterally continuous on the Ashmore platform however it is a distal facies | very good | plentiful | 1 | 0.75 | ~4 to 6 | 5.72 | 1.09 | 2330 | 2350 | 99 | bad | moderate | 0.375 | 0.28 | |
| Woodbine 1 | marls-calc claystones | | 111 | | very good | enough | 0.875 | 148 | | very good | plentiful | 1 | corelate to keeling1 | very good | plentiful | 1 | 0.88 | 4 to 8 | 5.89 | 1.29 | 2900 | 2925 | 820 | bad | moderate | 0.375 | 0.33 | marls, calcilutites and calcareous claystones |

# Appendix 3 – Mercury Capillary Pressure, Scanning Electron Microscopy and X-Ray Diffraction Results for All Samples Tested

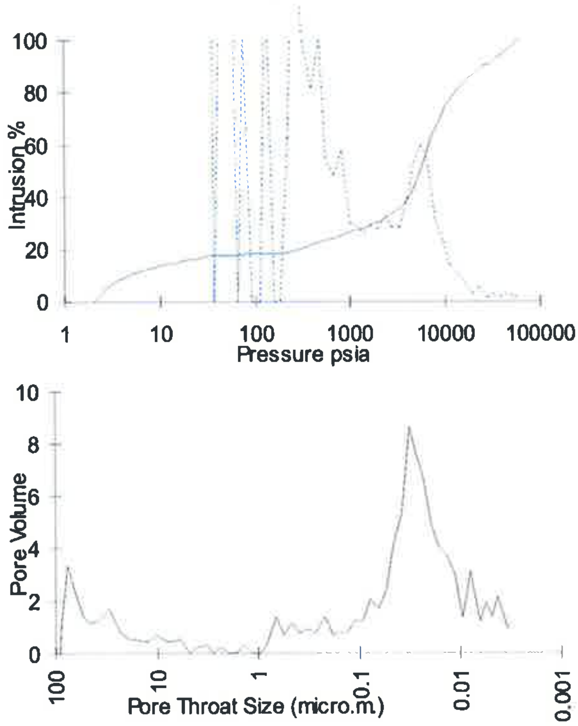
Allaru 1


DT
900
US/M
100
GR
0
GAPI
300
DEPTH
METRES
ss
marl, calcilutite & calc. claystone
cl
cl/gl
305m oil
slt to ss-slt
1900
2000
2100
2200
2300
2400
2500
2600
2700
2800
Puffin
WGF
Jamieson
Echuca Shoals
Valanginian u/c
Upper Vulcan
Kimmeridgian/Tithonian u/c
Lower Vulcan
interbedded siltstone and claystone seal
Callovian u/c
pre-Callovian sanstone
D.caddaensis
Depth: 2313-2319m Pth: 1765psi SC: 305m oil
Intrusion %
Pressure psia
Pore Volume
Pore Throat Size (micro.m.)
Counts
mixed illite/ smectite
kaolinite/ chlorite
quartz
calcite
Degrees 2-Theta

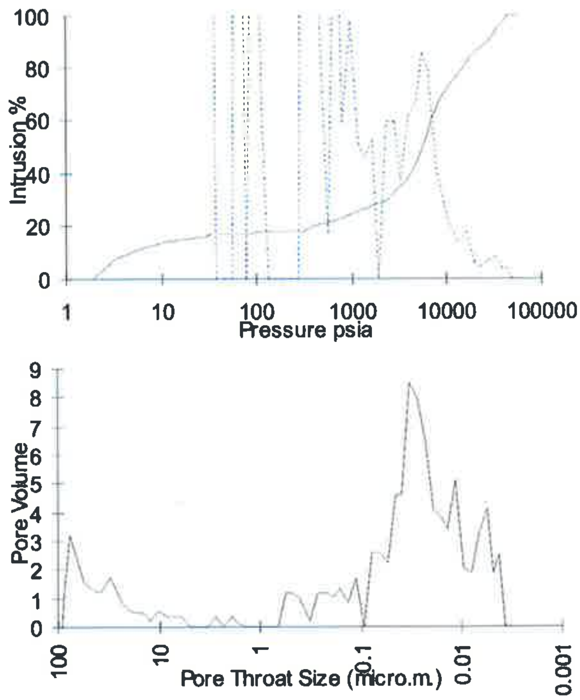
## Anderdon 1

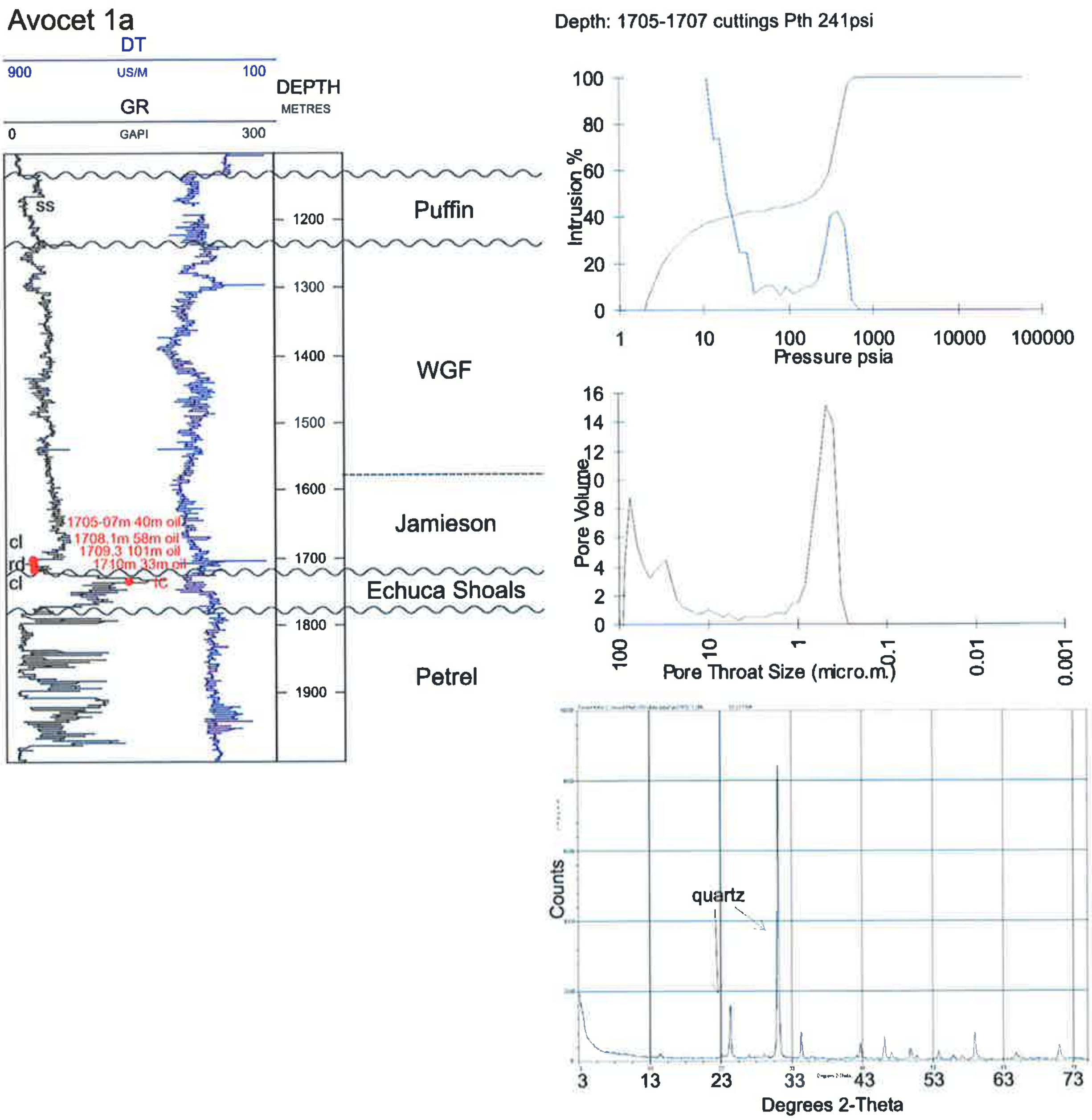



Depth: 1390-1400m Pth: 3540psi SC: 614m oil




Depth: 1410-1420m Pth: 2953psi SC: 512m oil



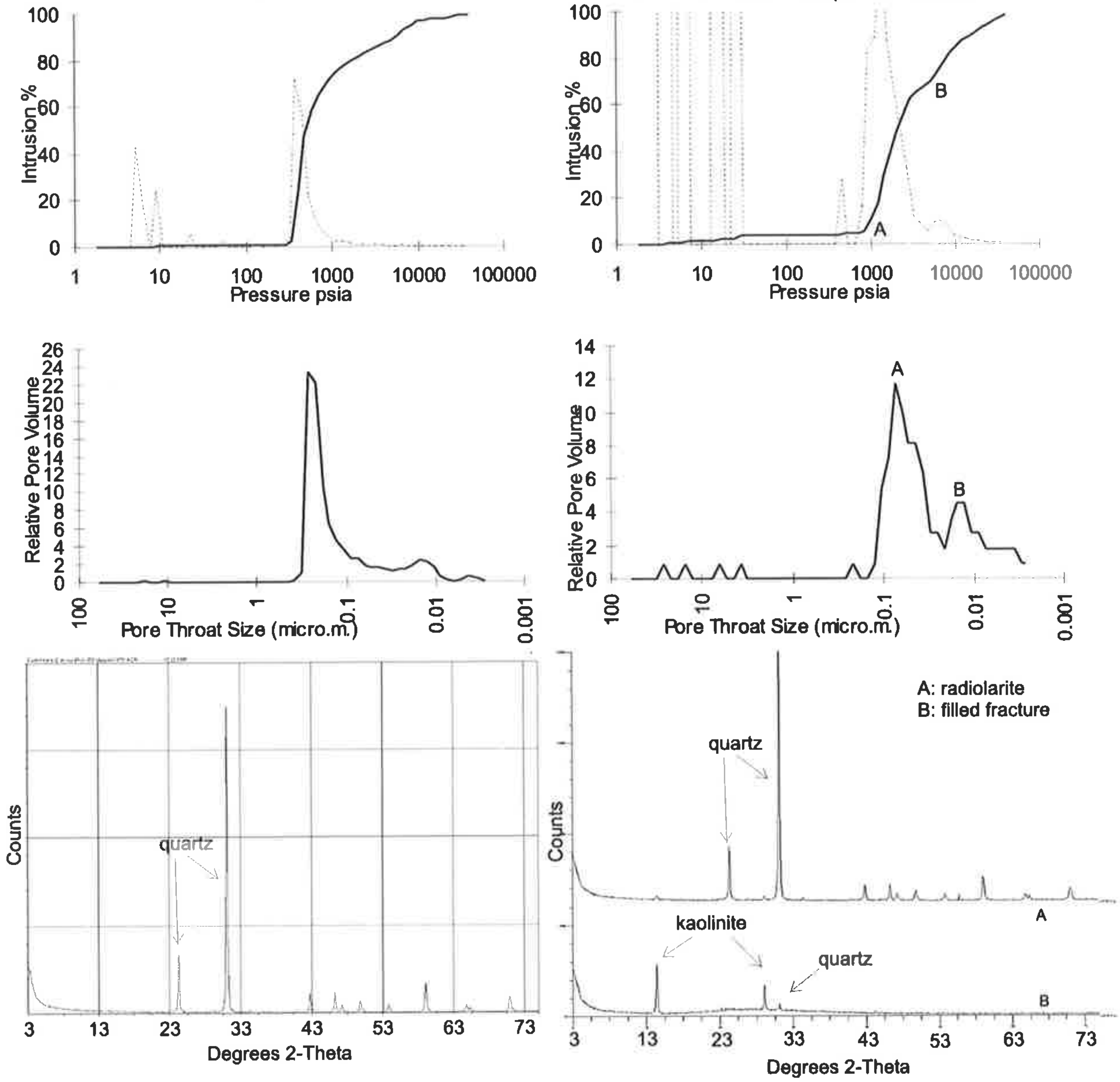



Gamma ray log, stratigraphy and seal lithologies for the Avocet 1A. Seal capacities, measured are listed in red.

## Avocet 1a

Depth: 1708.1m core Pth 345 psi SC:58m oil

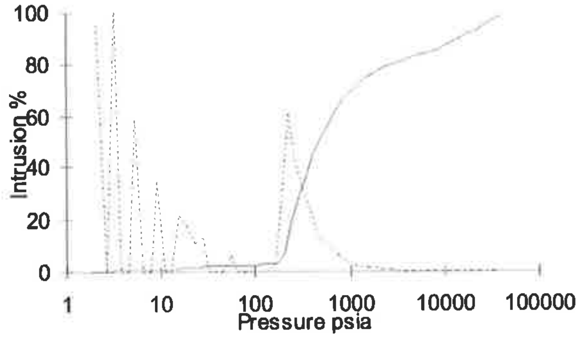
Depth: A: 1709.3m core Pth 588psi SC 101m oil
B: filled fracture Pth 4990psi SC 1480m oil

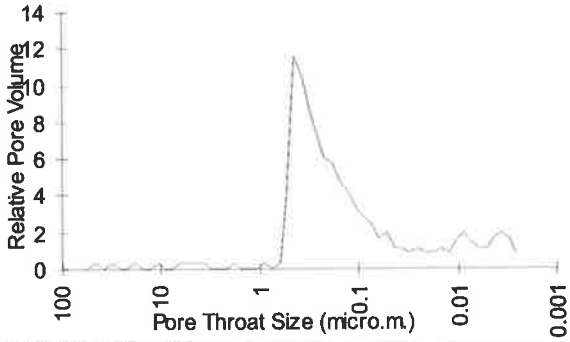


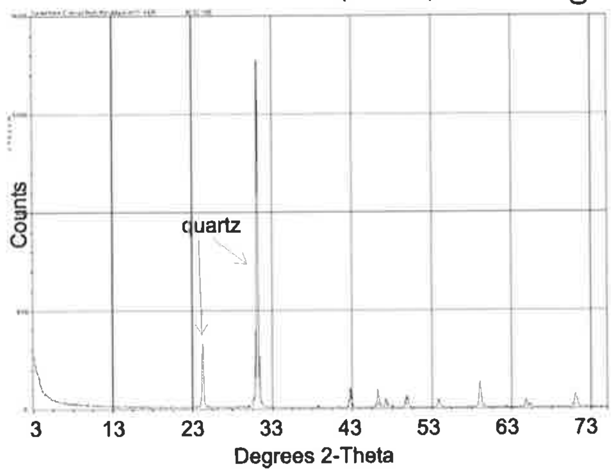

Radiolarite siltstone, MICP intrusion curve(top) pore size distribution curve (middle) and XRD analysis (bottom). This sample contained a filled fracture, which had a higher threshold pressure than the radiolarite siltstone.

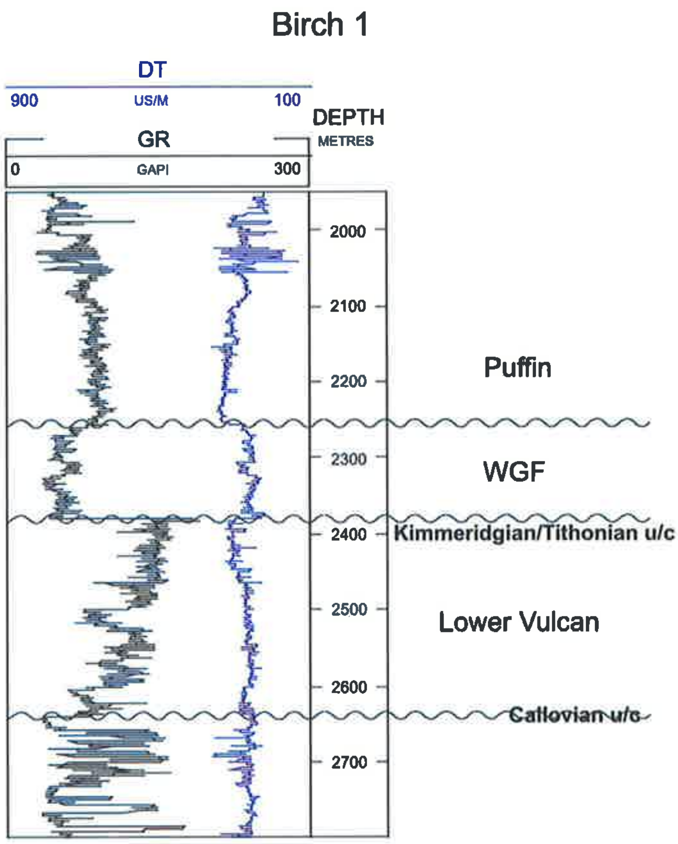
# Avocet 1a

Depth: 1710m core Pth 202 psi SC:33m oil



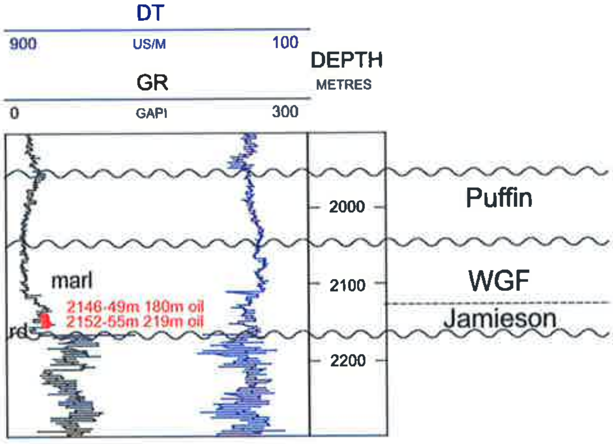



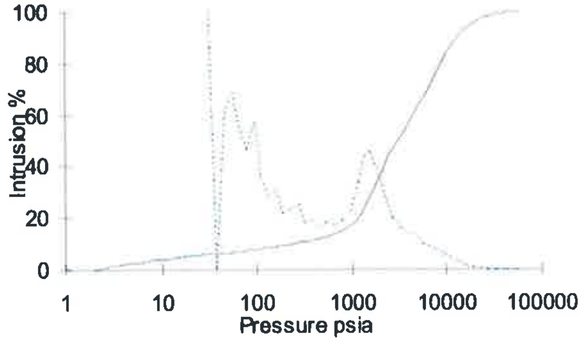


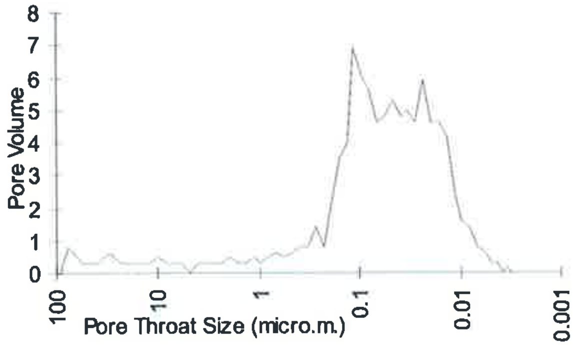
Birch 1
DT
900
US/M
100
DEPTH
METRES
GR
0
GAPI
300
2000
2100
2200
2300
2400
2500
2600
2700
Puffin
WGF
Kimmeridgian/Tithonian u/c
Lower Vulcan
Callovian u/c

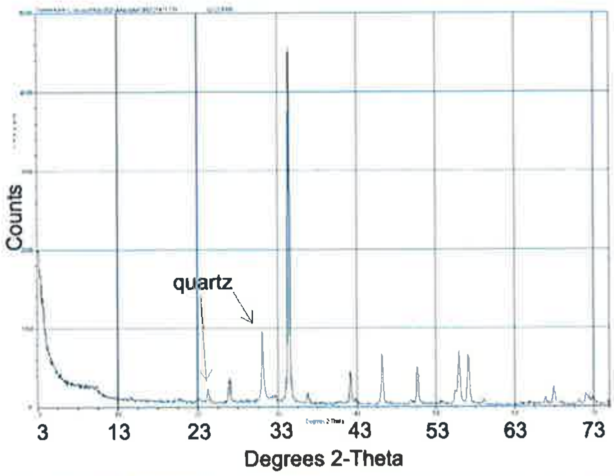
## Brown Gannet 1




Depth: 2149-2149m cuttings Pth 1043psi SC: 180m oil



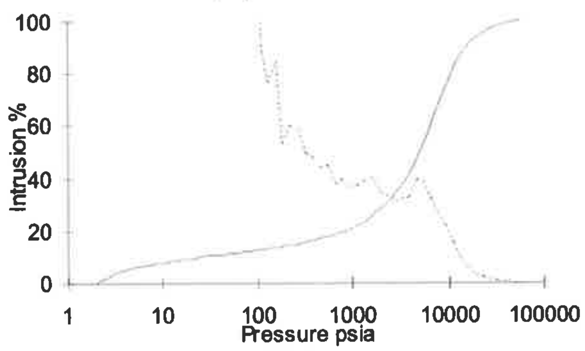



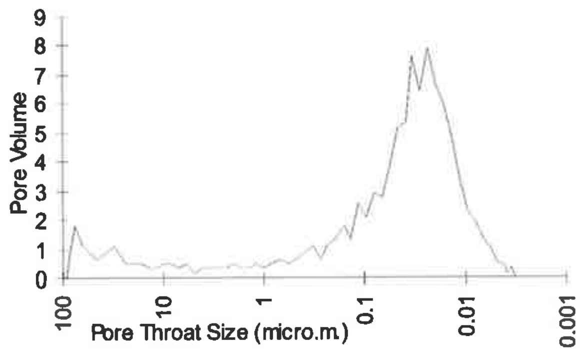



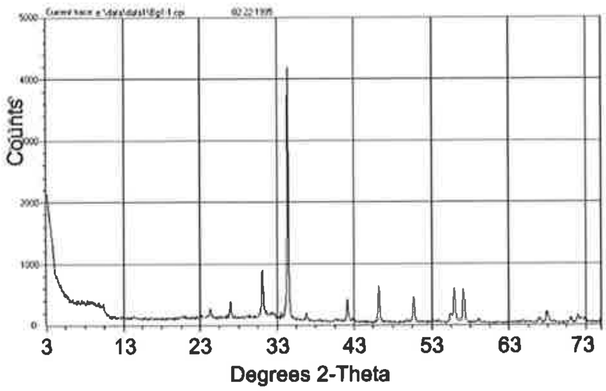


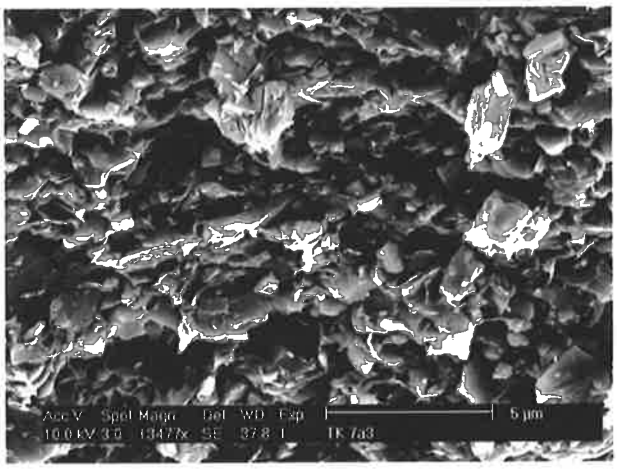
## Brown Gannet 1

**Depth: 2152-2155m Pth 1270 psi SC:219m oil**

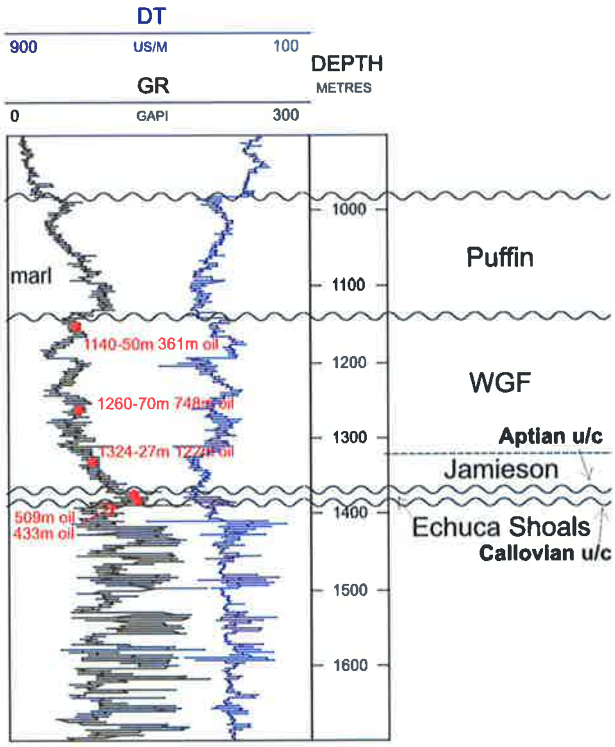


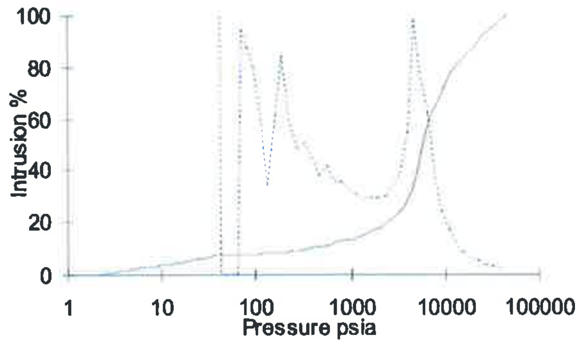



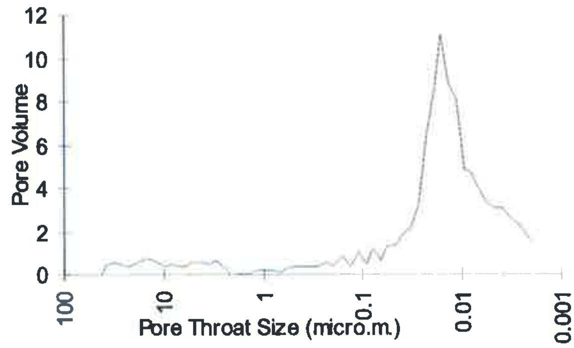



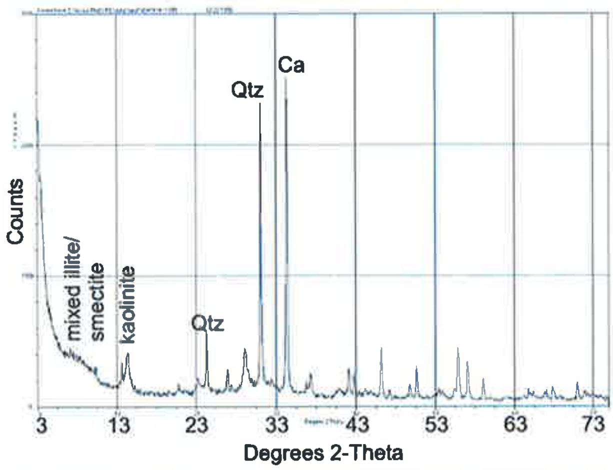
## Challis 1

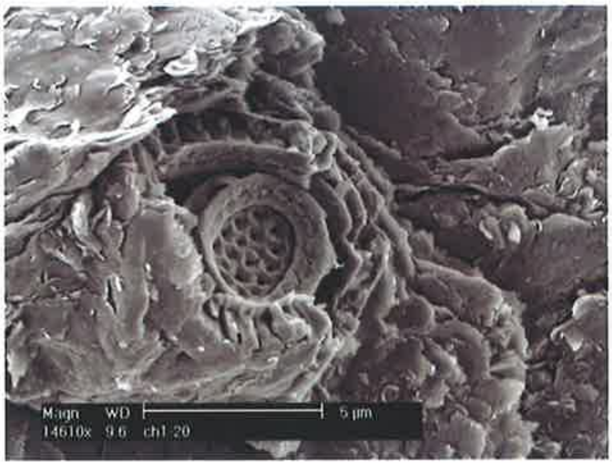



Depth: 1140-1150m cuttings Pth 2083psi SC: 361m oil



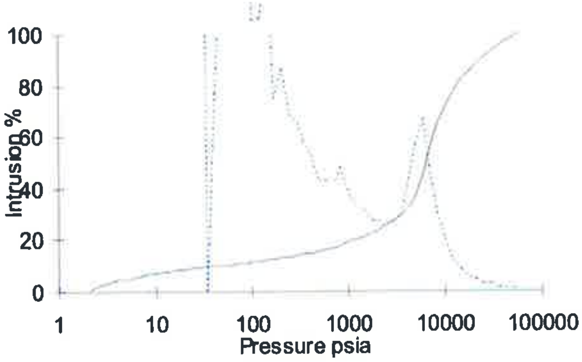



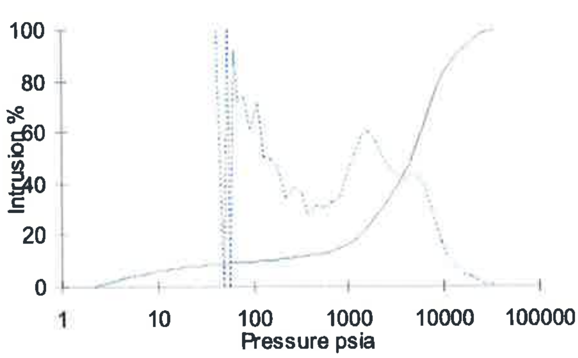



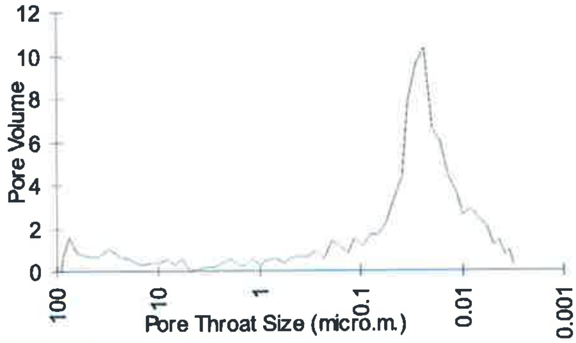
# Challis 1

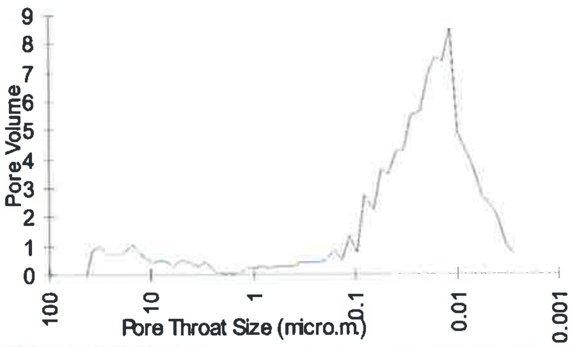
Depth: 1260-1270m Pth 4309 psi SC:748m oil

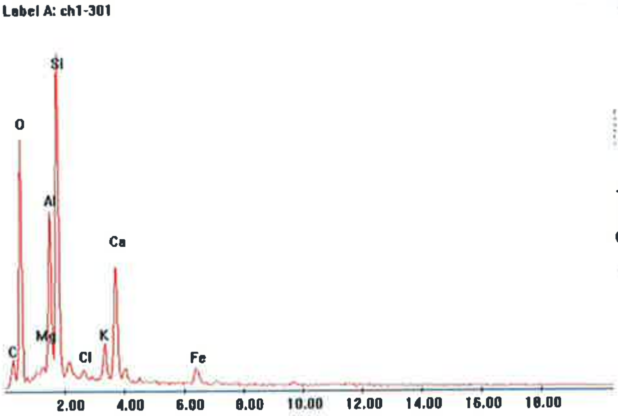


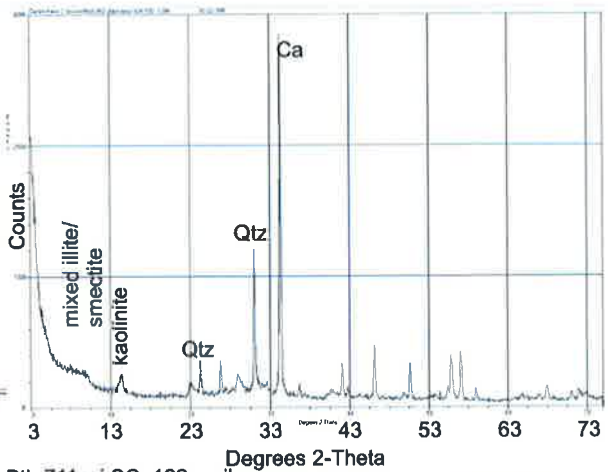

Depth: 1324-1327m Pth 711psi SC: 122m oil



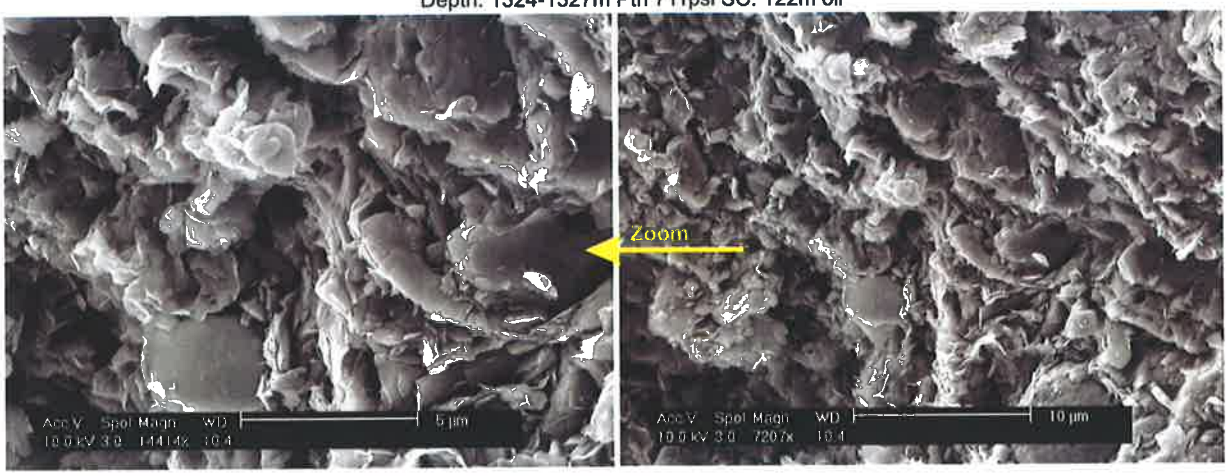



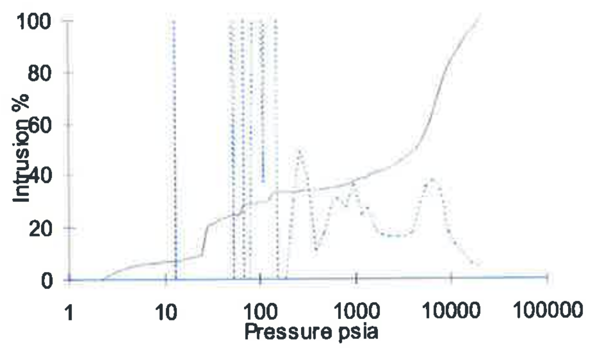



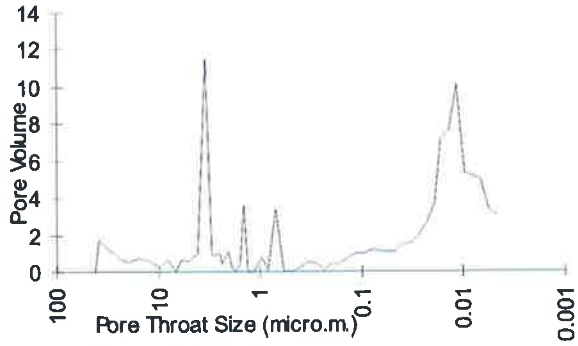

Depth: 1324-1327m Pth 711psi SC: 122m oil

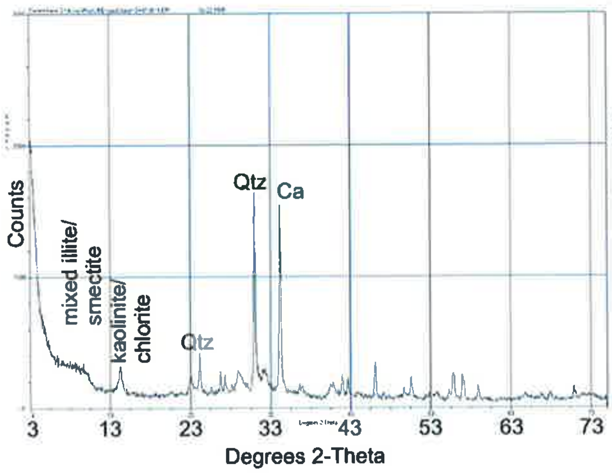


# Challis 1

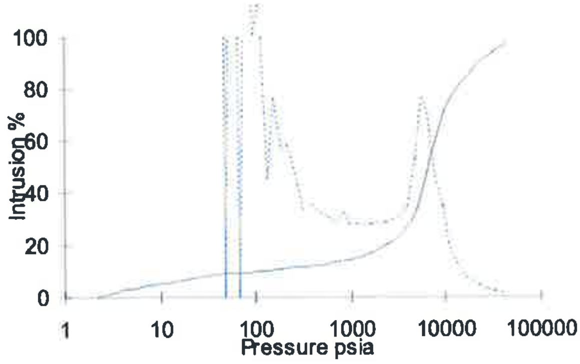
**Depth: 1363-1366m Pth 4282psi SC: 743m oil**

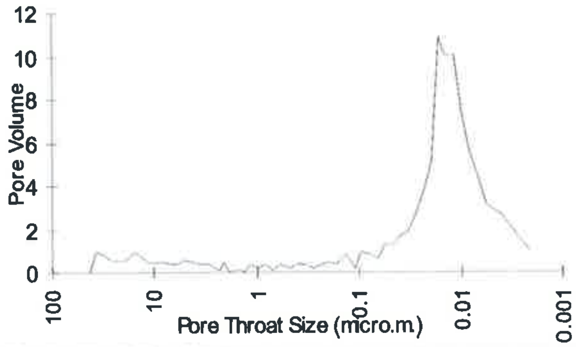


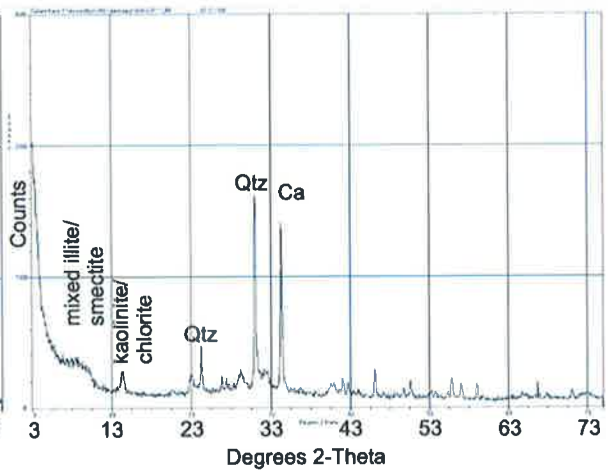




**Depth: 1378-1381m Pth 2936psi SC: 509m oil**

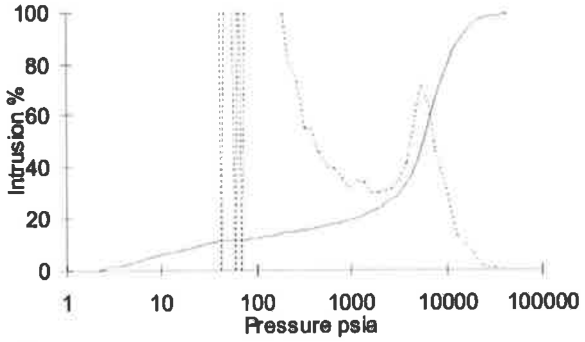


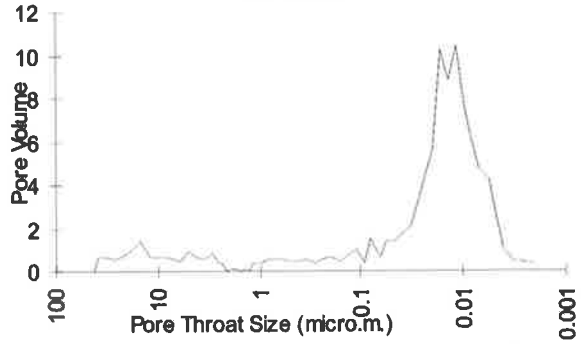



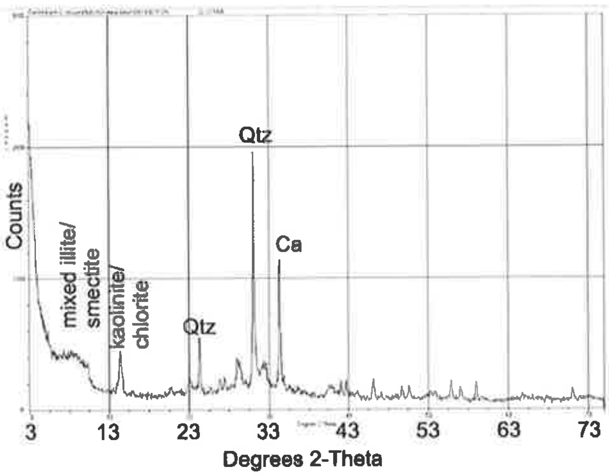



## Challis 1

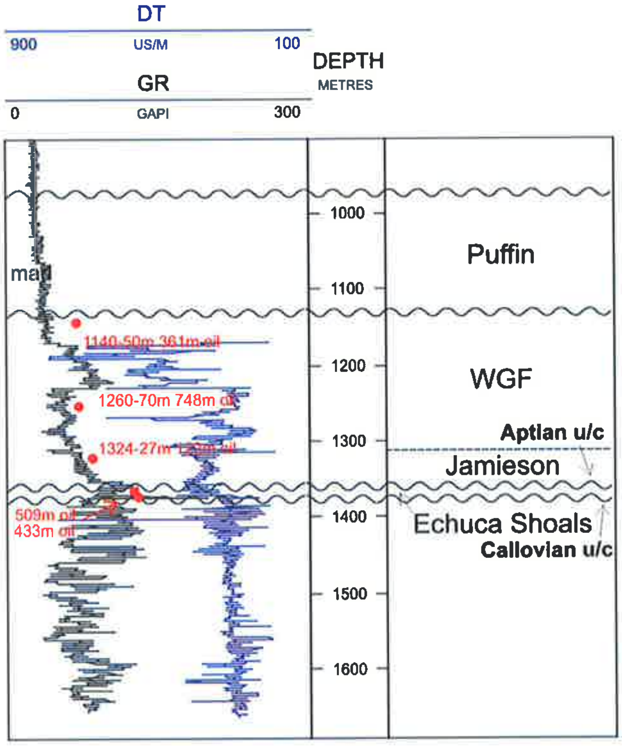
**Depth: 1384-1387m Pth 2954psi SC: 433m oil**



## Challis 7



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Puffin
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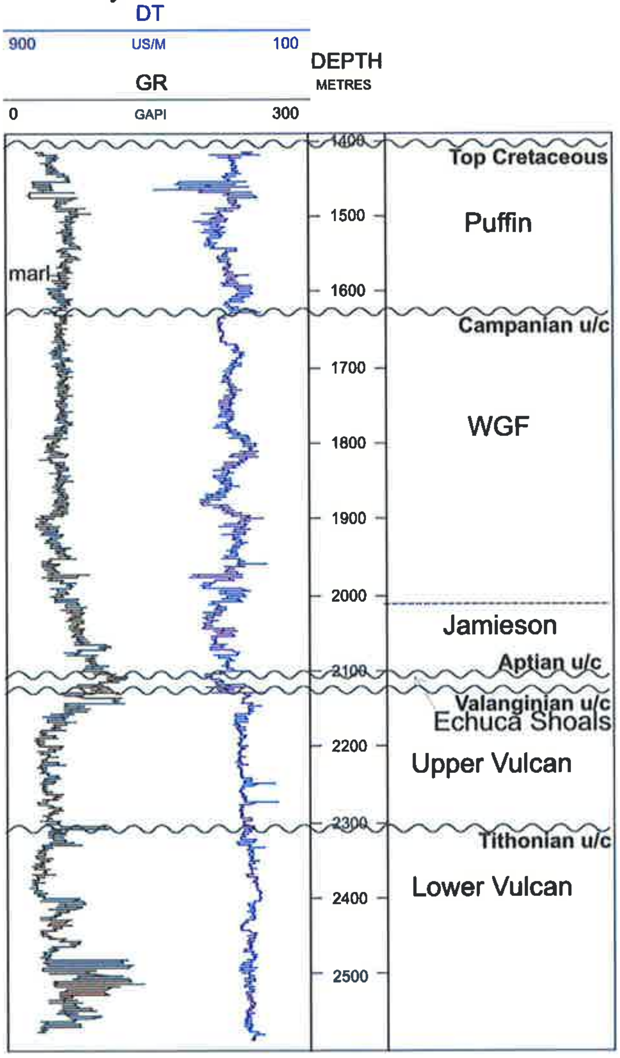
WGF
Aptian u/c
Jamieson
Echuca Shoals
Callovian u/c
1140-50m 361m oil
1260-70m 748m oil
1324-27m
509m oil
433m oil

Conway 1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Top Cretaceous
Puffin
Campanian u/c
WGF
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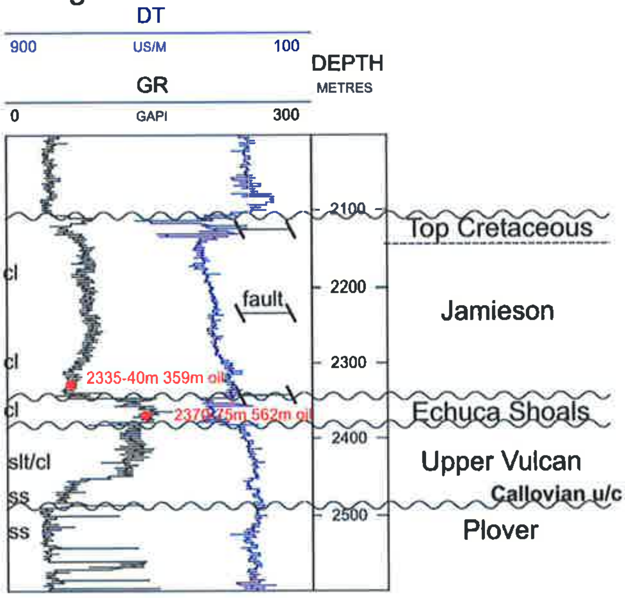
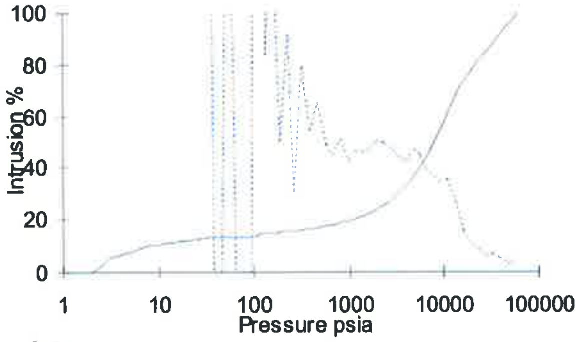
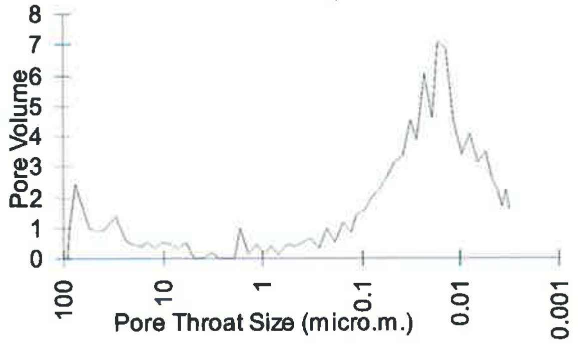
Valanginian u/c
Echuca Shoals
Upper Vulcan
Tithonian u/c
Lower Vulcan

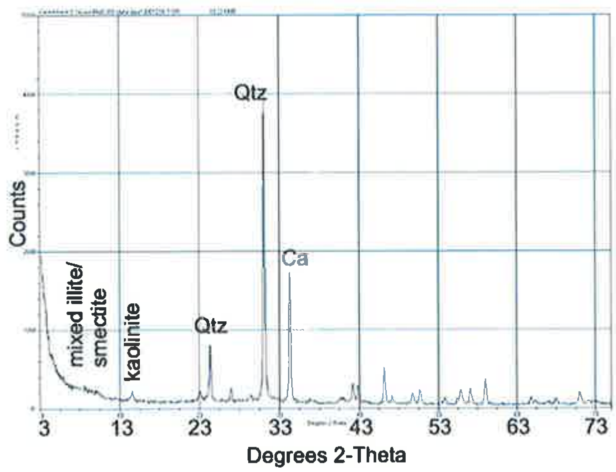
## Douglas 1

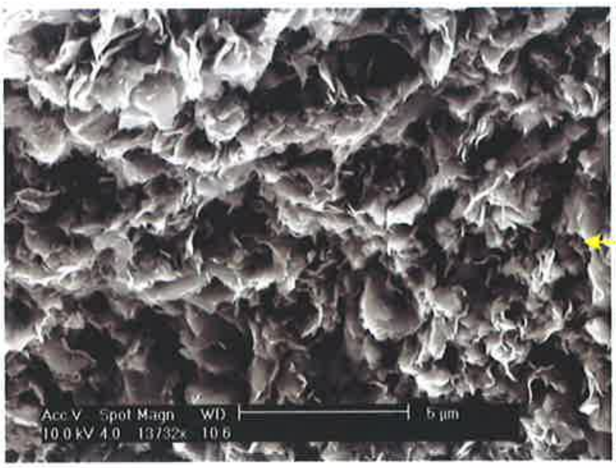


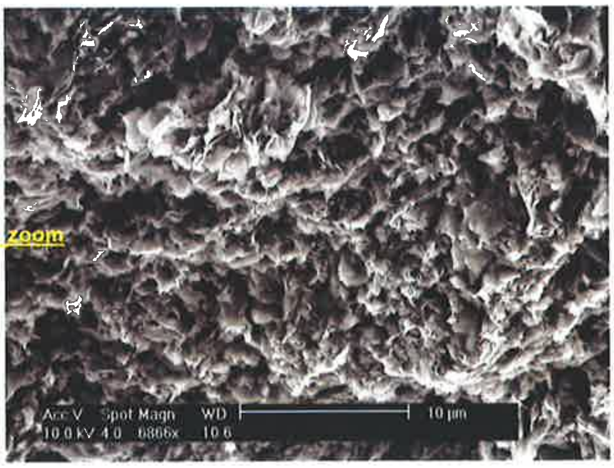

Depth: 2335-2340m cuttings Pth 2075psi SC: 359m oil



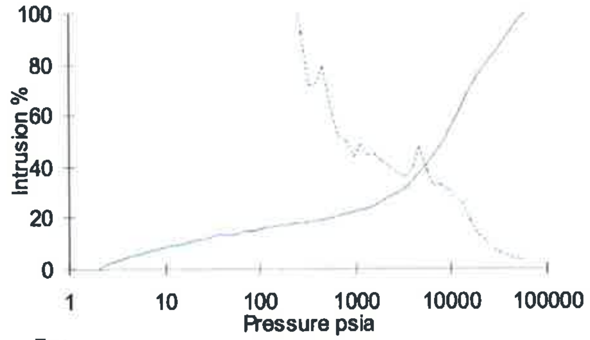



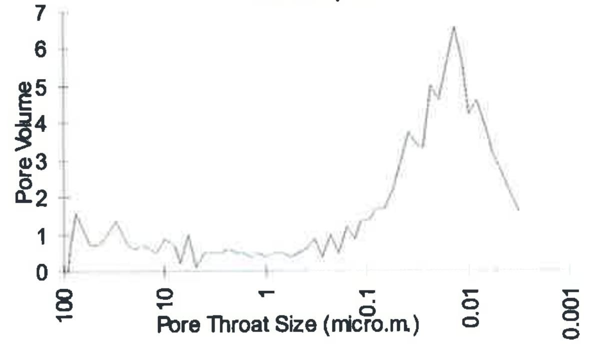



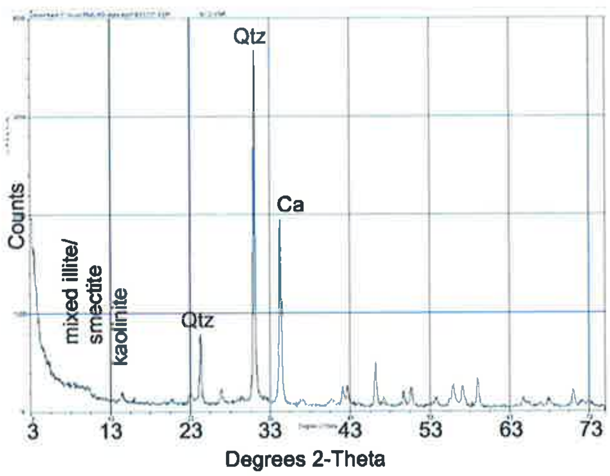



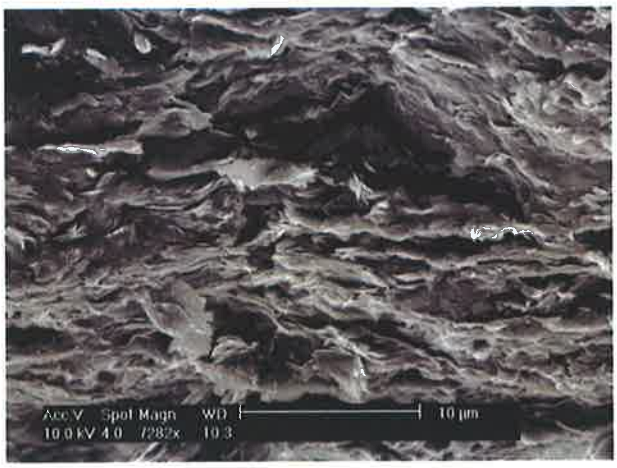
# Douglas 1

**Depth: 2370-2375m Pth 3244 psi SC: 562m oil**

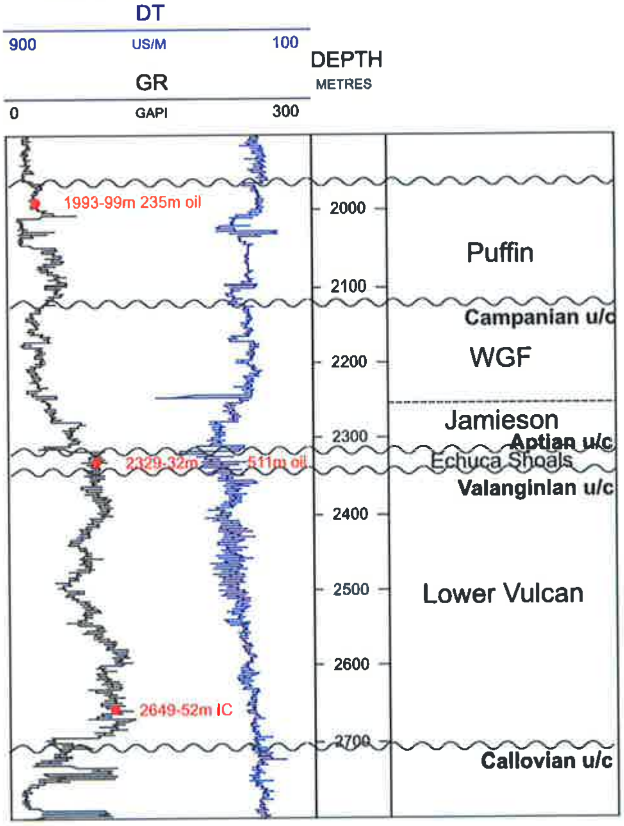


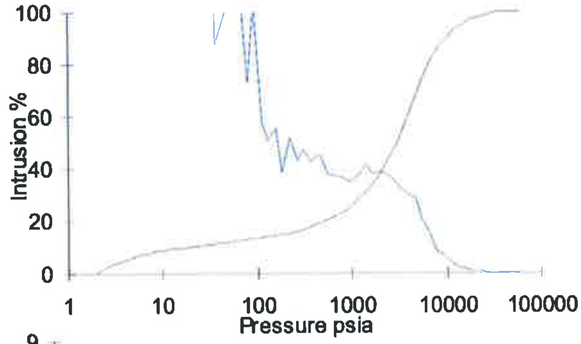



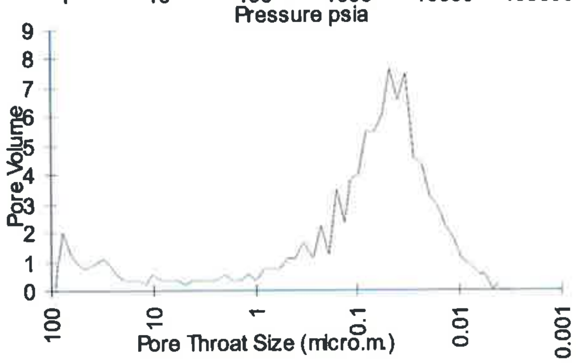



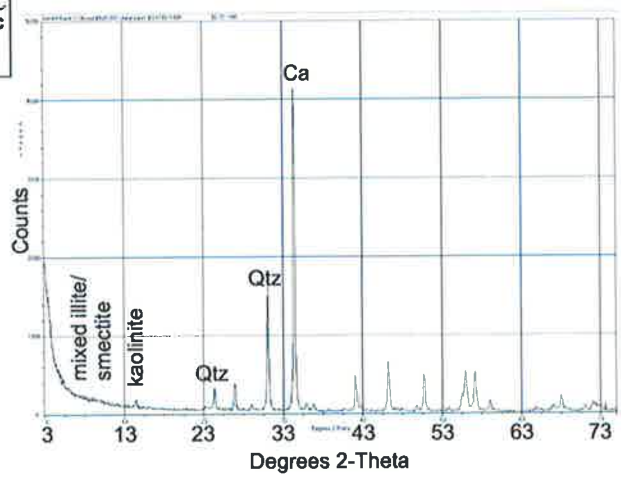
## East Swan 1



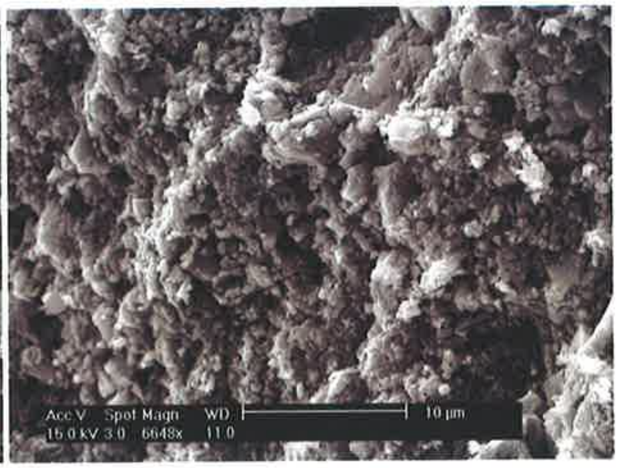

Depth: 1993-1999m cuttings Pth 1361psi SC: 235m oil



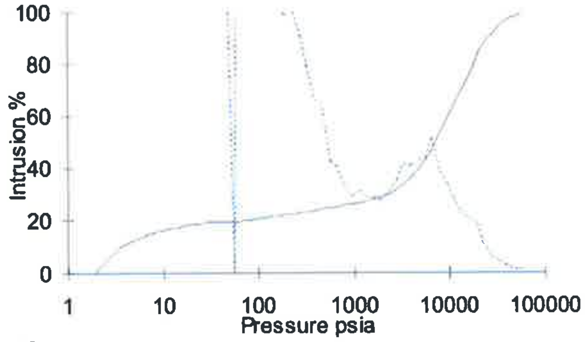



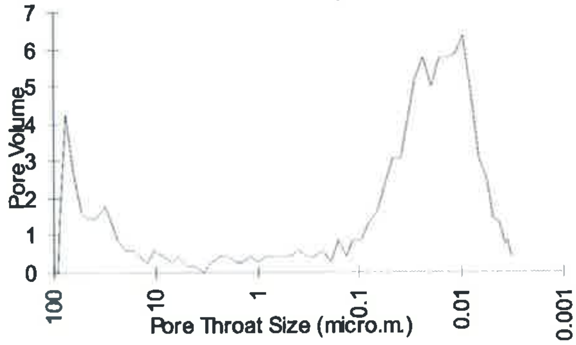




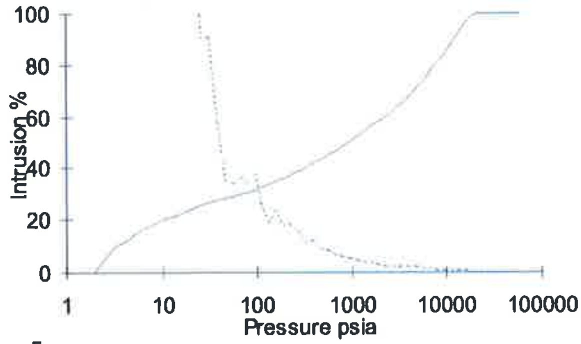
## East Swan1

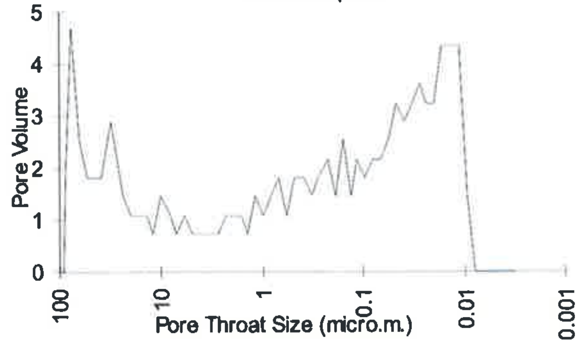
Depth: 2329-2332m Pth 2949psi SC: 511m oil

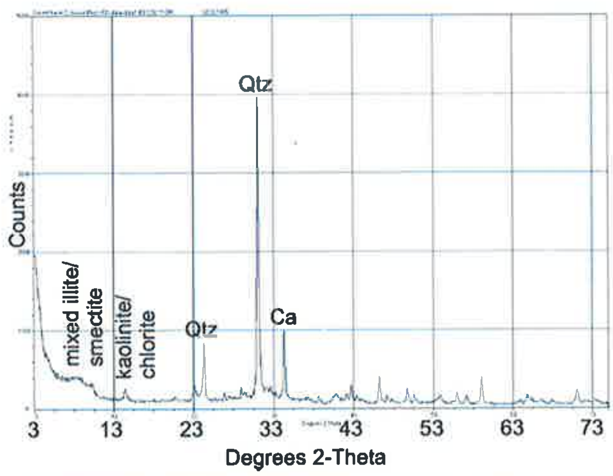


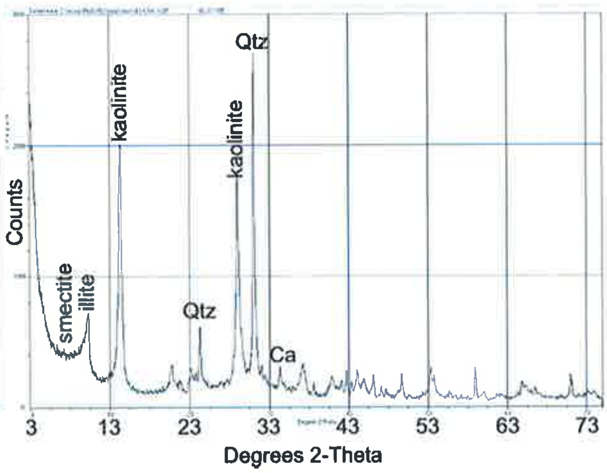



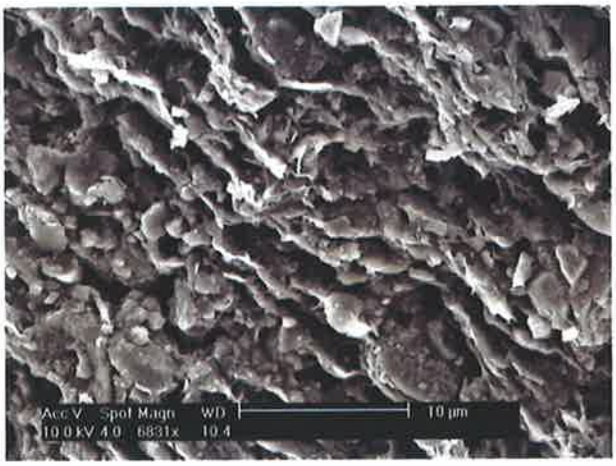

Depth: 2649-2652m Pth inconclusive (IC)l

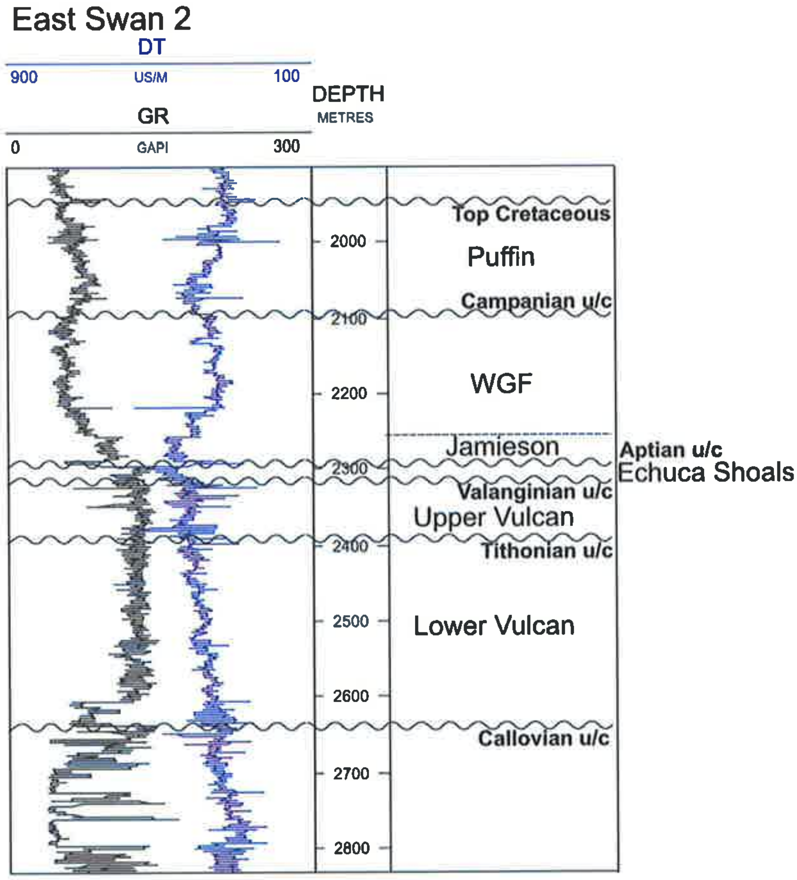
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Puffin
Campanian u/c
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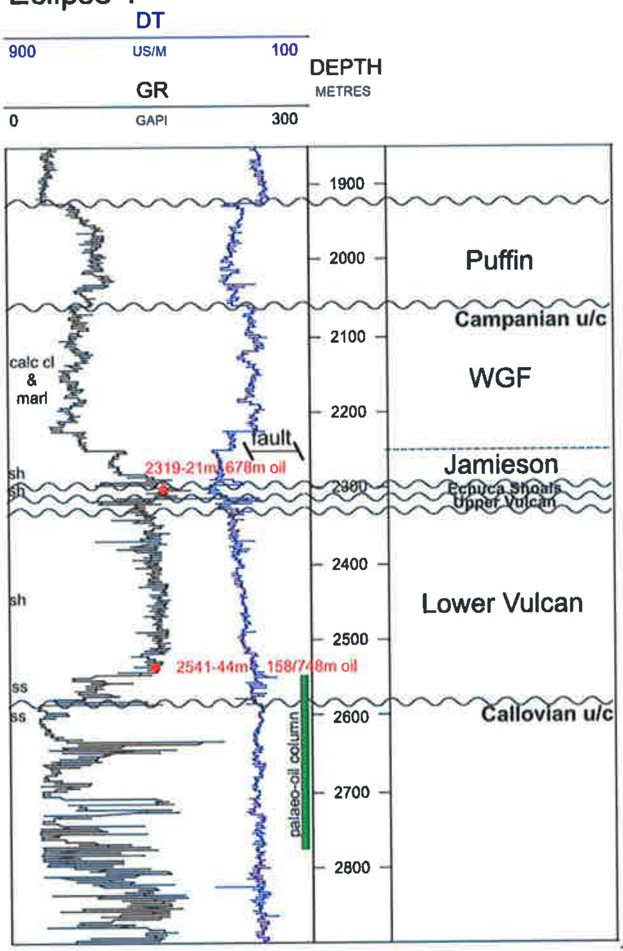
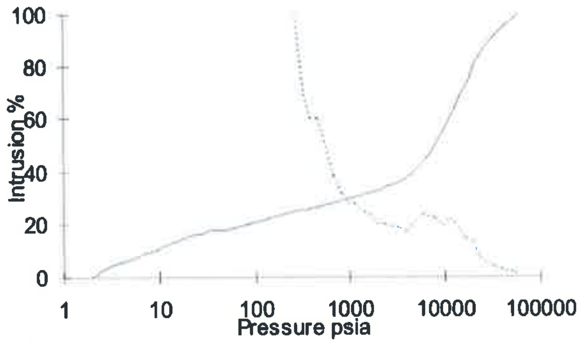
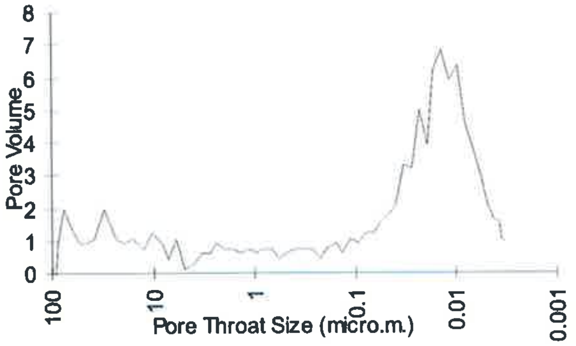
Echuca Shoals
Valanginian u/c
Upper Vulcan
Tithonian u/c
Lower Vulcan
Callovian u/c

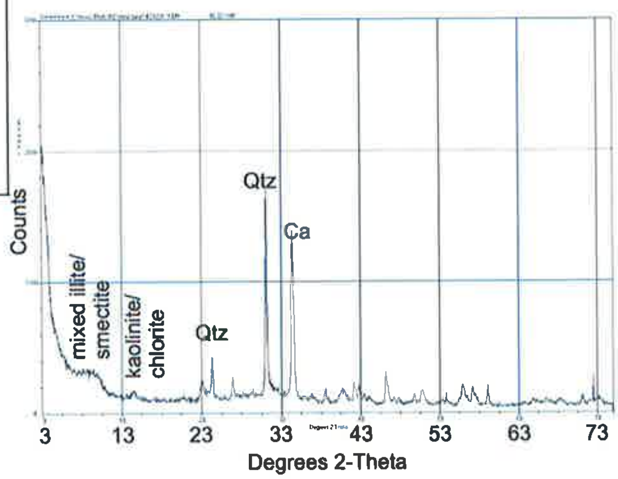
Eclipse 1

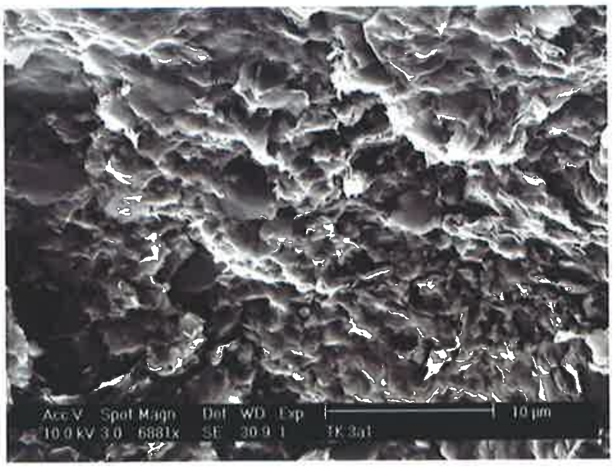



Depth: 2319-2321m cuttings Pth 3906psi SC: 678m oil



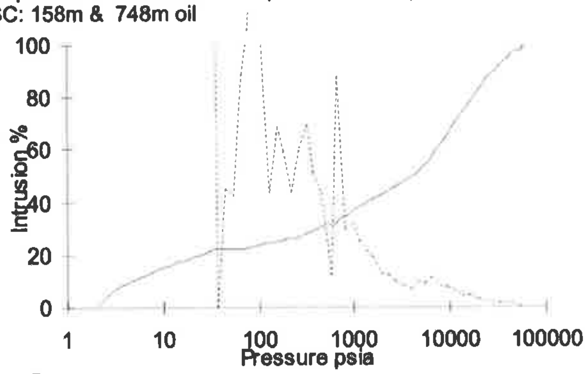



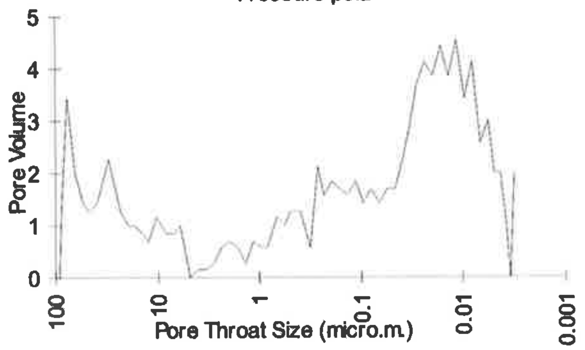



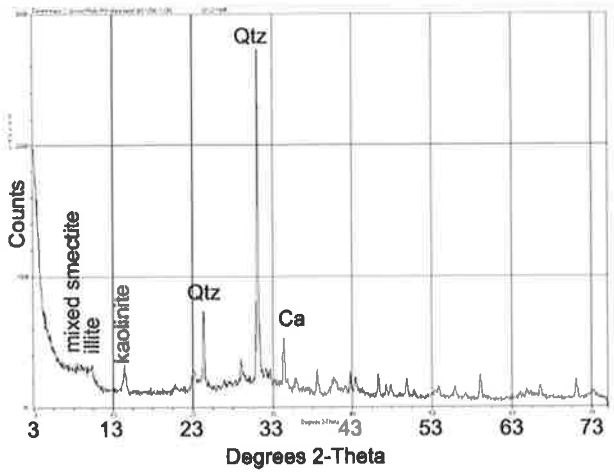



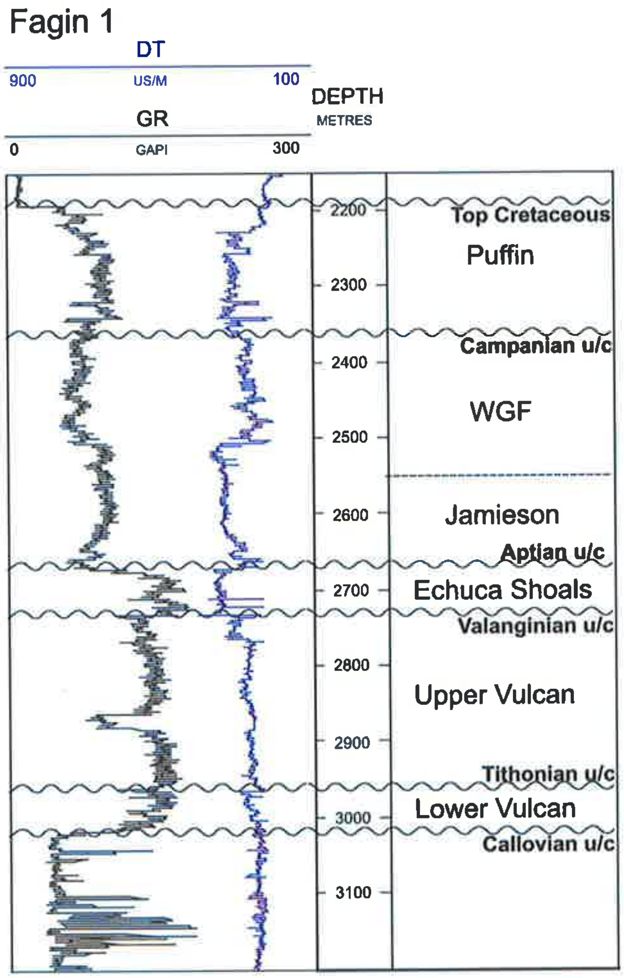
# Eclipse 1

**Depth: 2541-2544m Pth multiple 640 & 4311psi**
**SC: 158m & 748m oil**





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Campanian u/c
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Lower Vulcan
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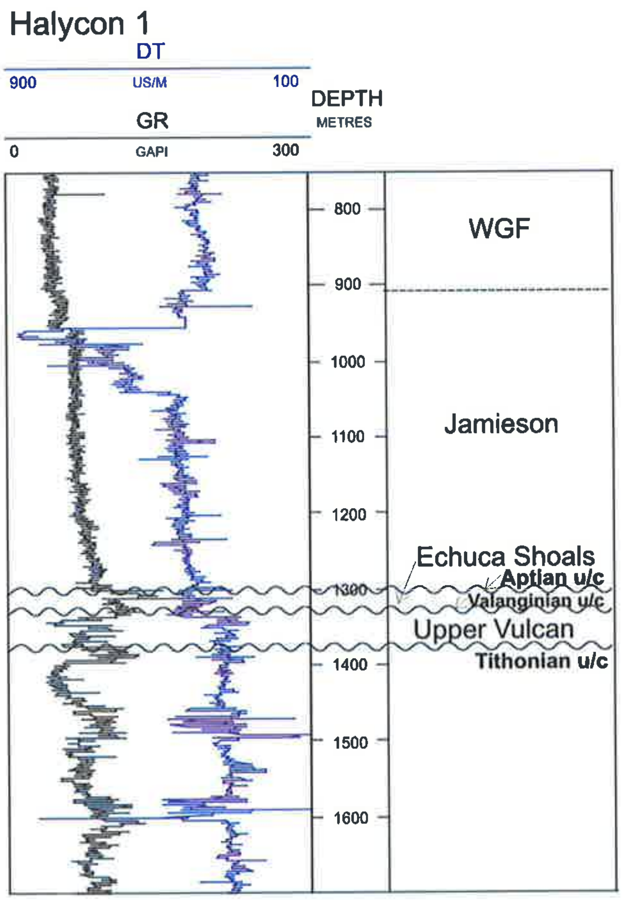

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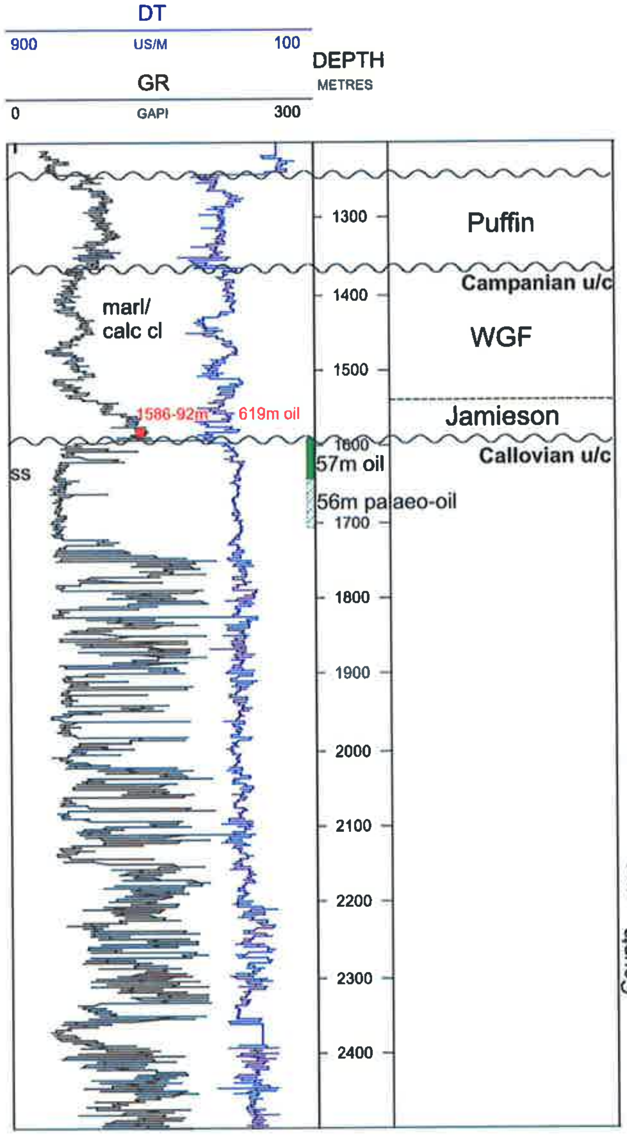
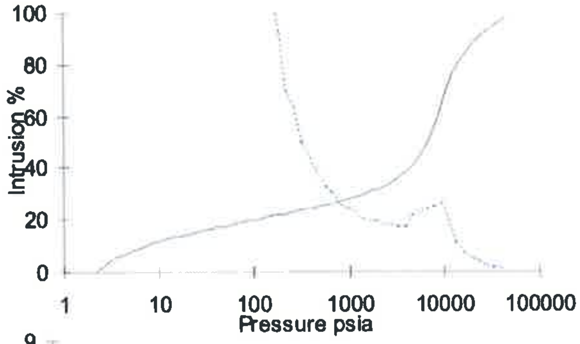
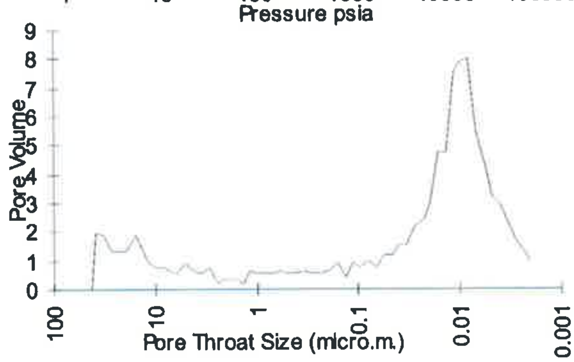
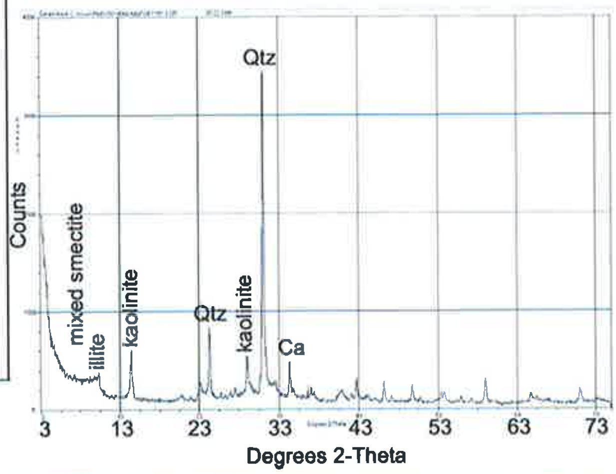
## Jabiru 1a

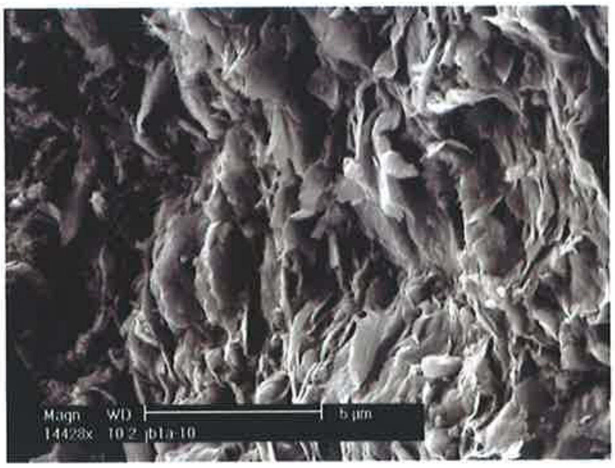



Depth: 1586-1592m cuttings Pth 3569psi SC: 619m oil



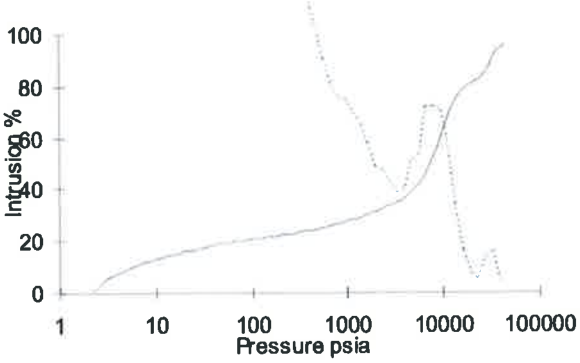



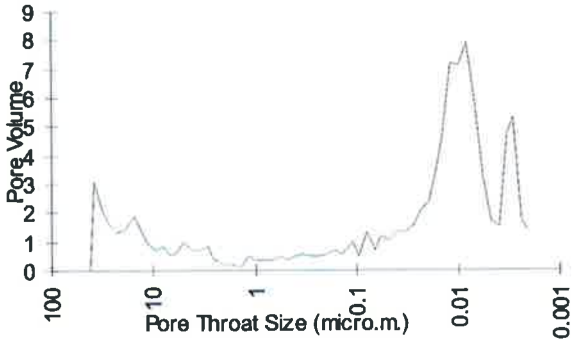



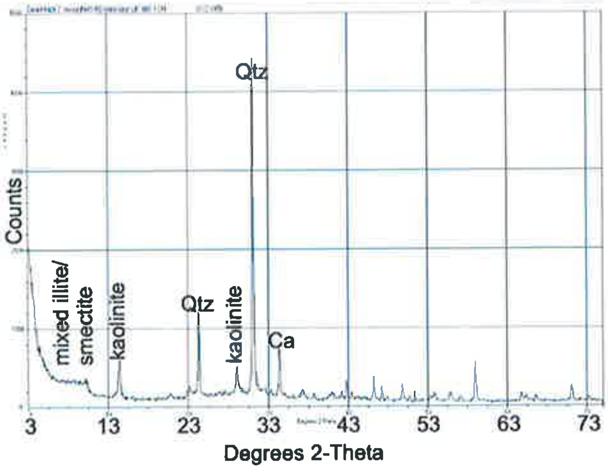



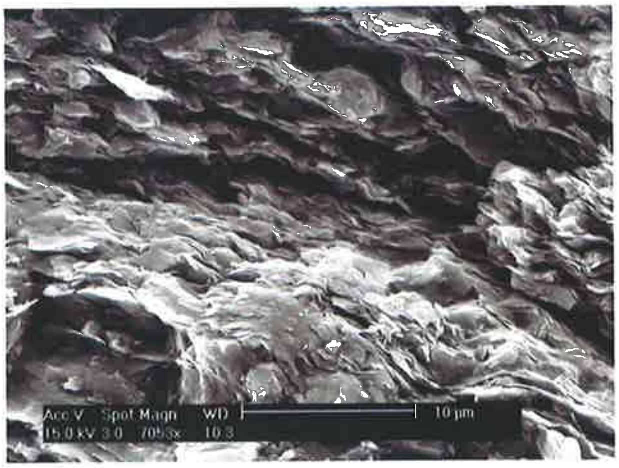
## Jabiru 1a

Depth: 1601-1603m Pth 3538 psi SC: 614m oil

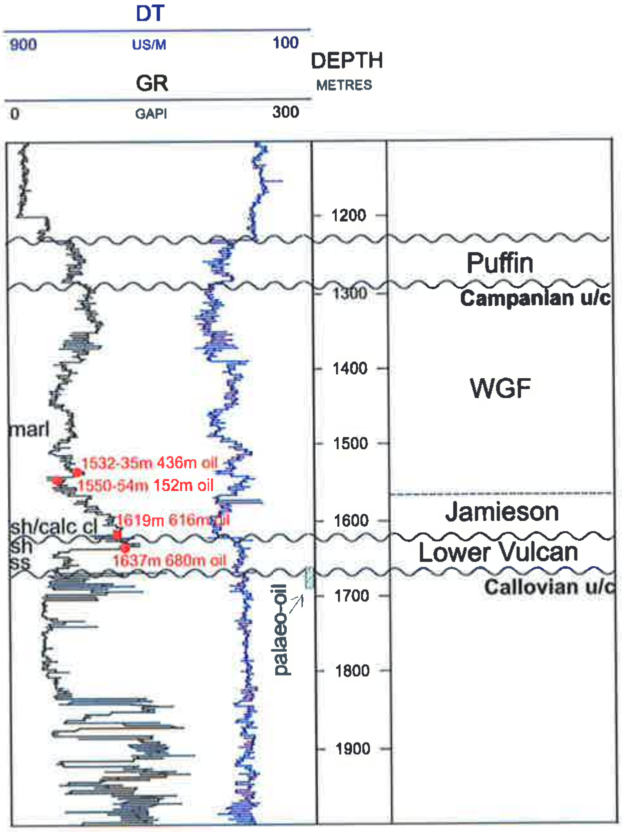


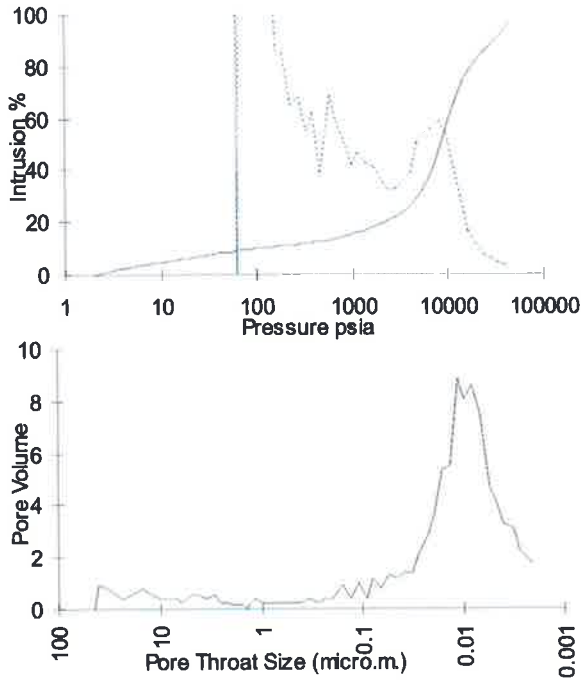



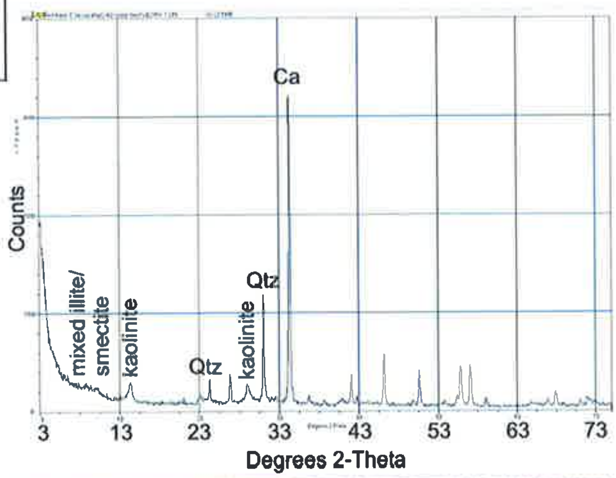



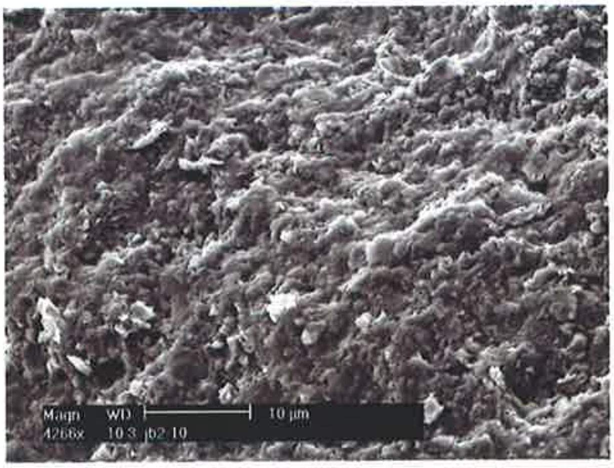
## Jabiru 2




Depth: 1532-1535m cuttings Pth 2515psi SC: 436m oil

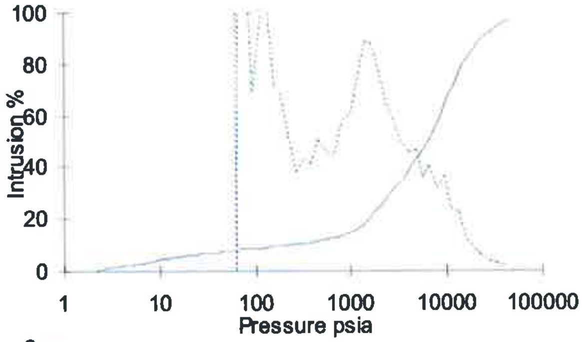


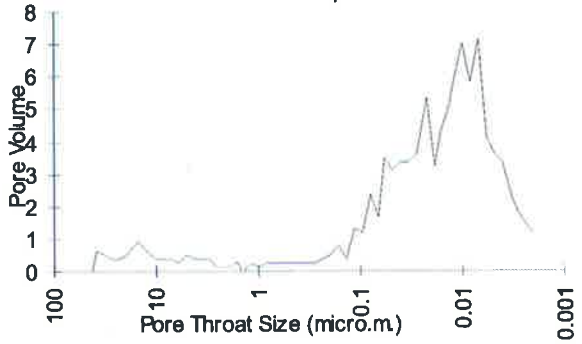



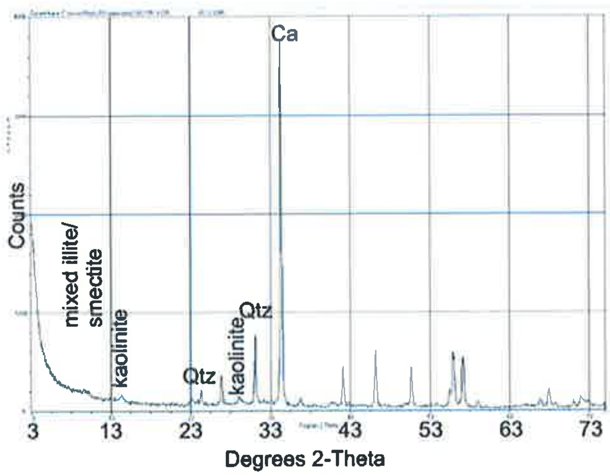



# Jabiru 2

**Depth: 1550-1554m Pth 885psi SC: 152m oil**

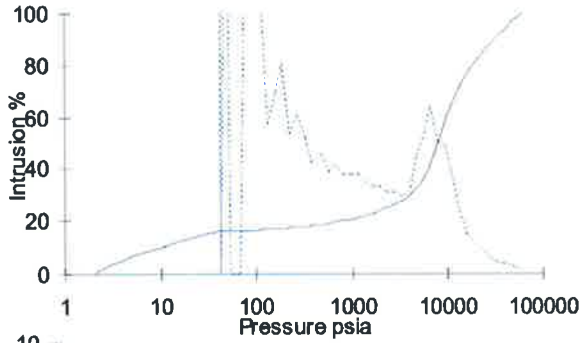


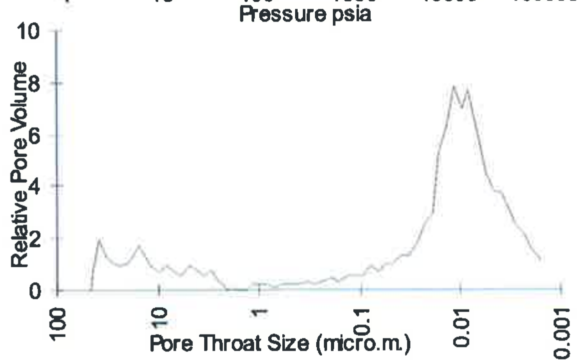



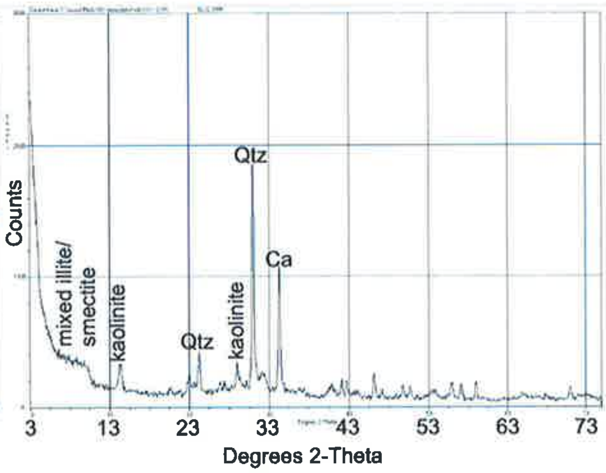



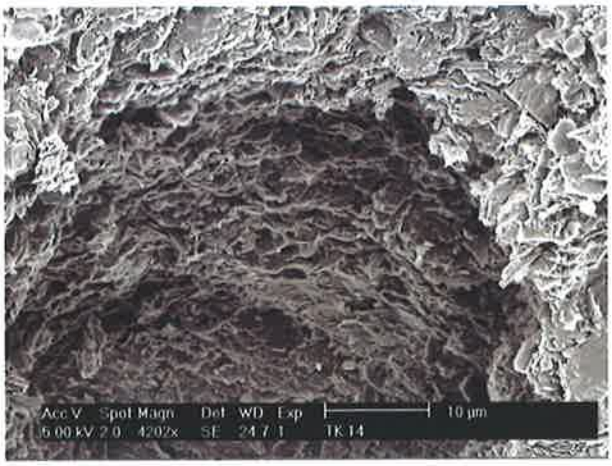


**Depth: 1619m Pth 3552psi SC: 616m oil**



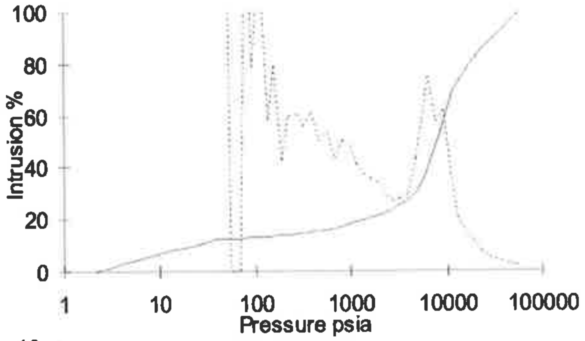



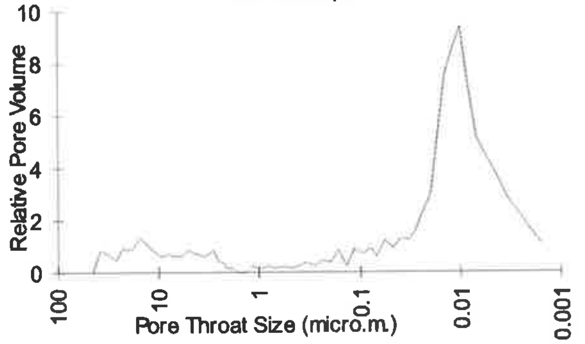



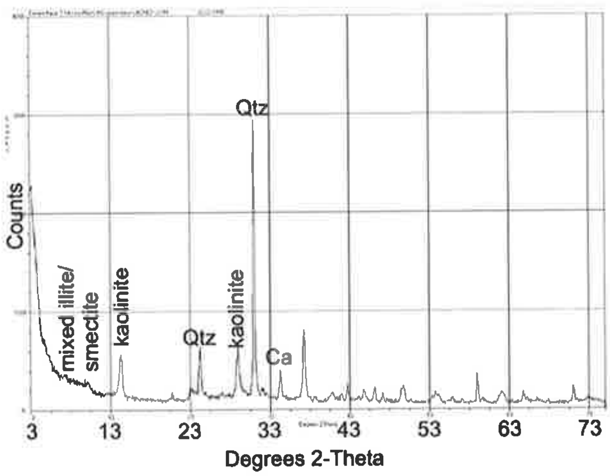



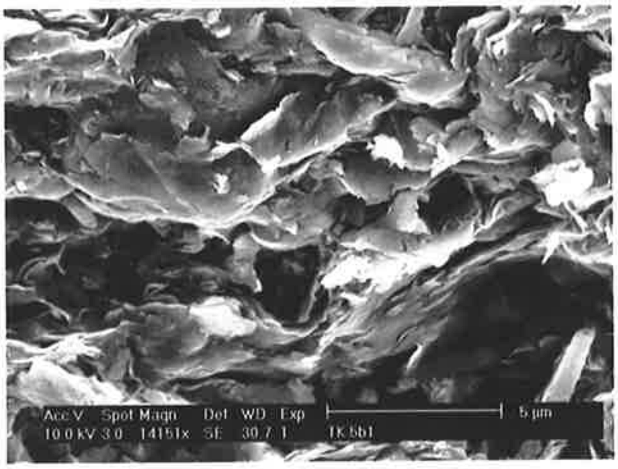
# Jabiru 2

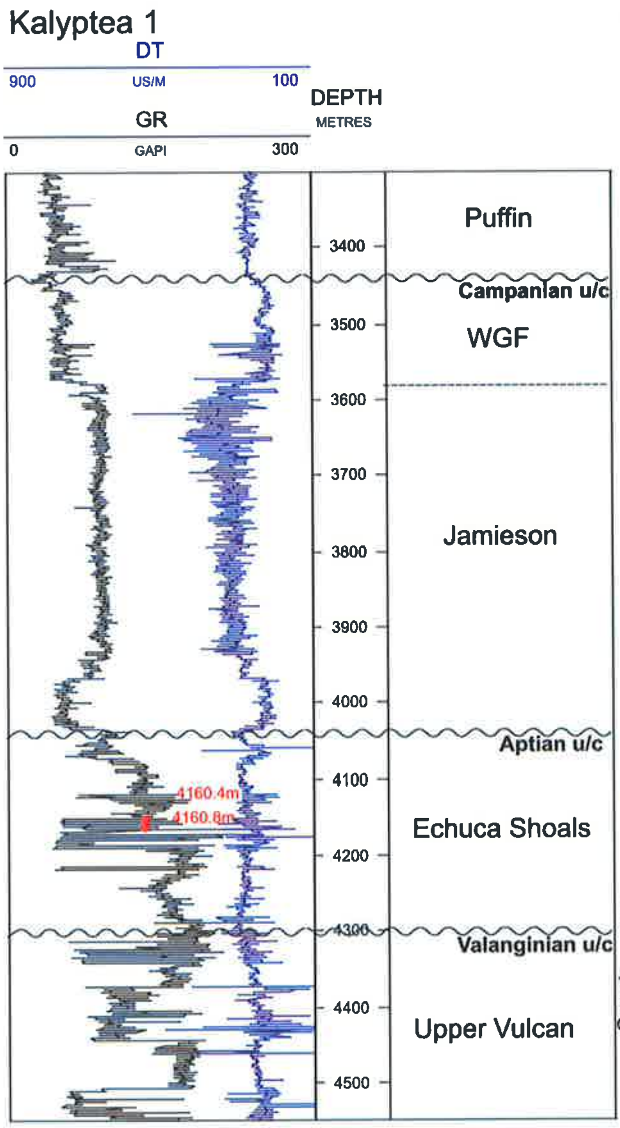
Depth: 1637m Pth 3917psi SC: 340m oil

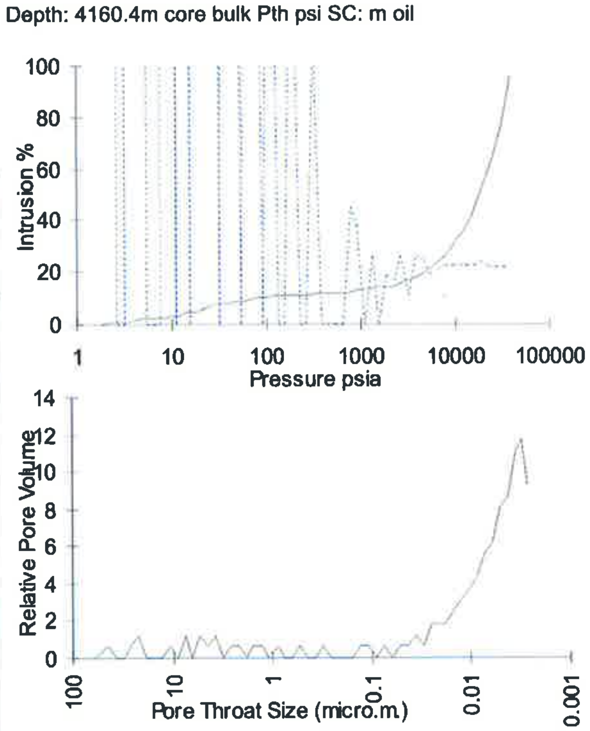


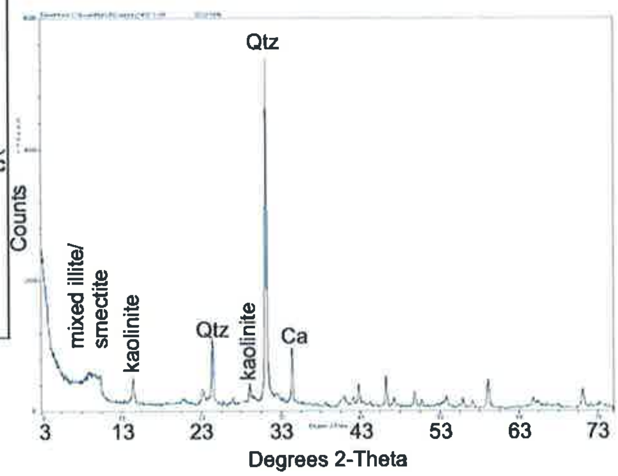



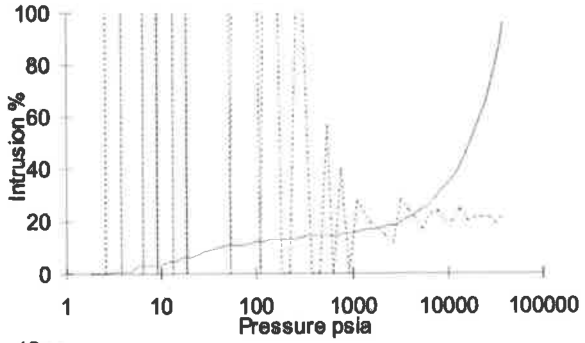

Kalyptea 1
DT
900
US/M
100
GR
0
GAPI
300
DEPTH
METRES
3400
3500
3600
3700
3800
3900
4000
4100
4200
4300
4400
4500
4160.4m
4160.8m
Puffin
Campanian u/c
WGF
Jamieson
Aptian u/c
Echuca Shoals
Valanginian u/c
Upper Vulcan

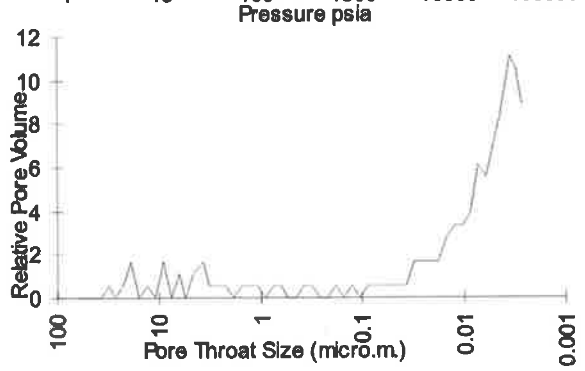

Depth: 4160.4m core bulk Pth psi SC: m oil
Intrusion %
100
80
60
40
20
0
1
10
100
1000
10000
100000
Pressure psia
Relative Pore Volume
14
12
10
8
6
4
2
0
100
10
1
0.1
0.01
0.001
Pore Throat Size (micro.m.)

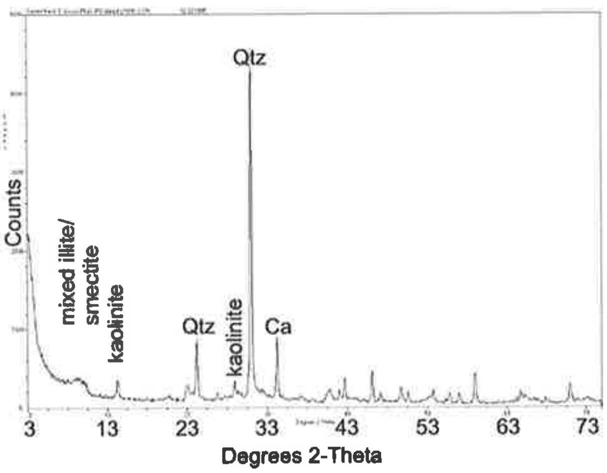

Qtz
Counts
mixed illite/
smectite
kaolinite
Qtz
kaolinite
Ca
3
13
23
33
43
53
63
73
Degrees 2-Theta

## Kalyptea 1

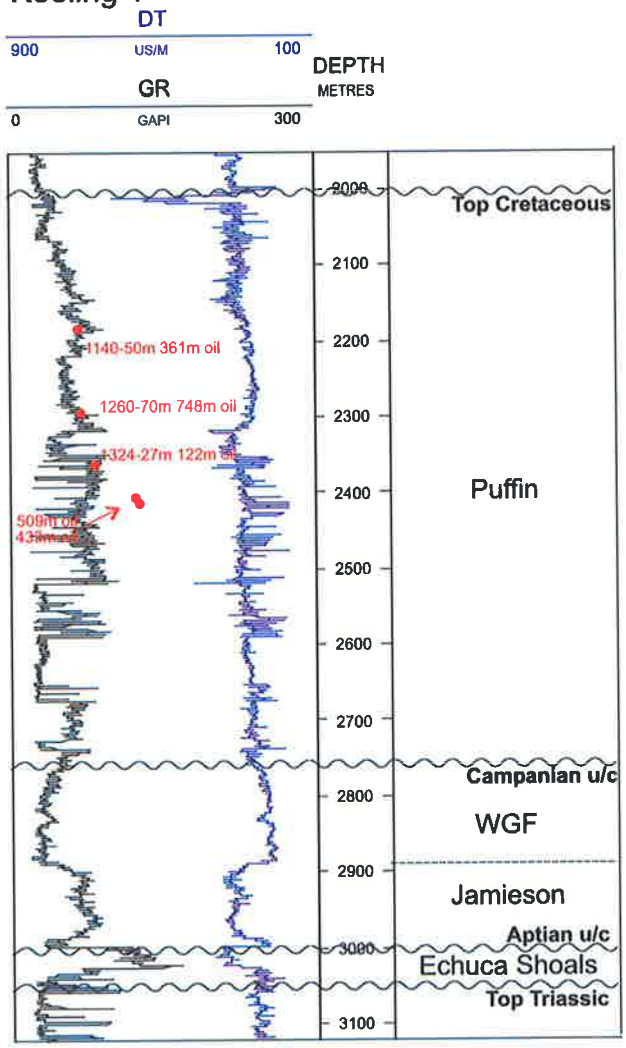
**Depth: 4160.8m Pth 5933psi SC: m oil**



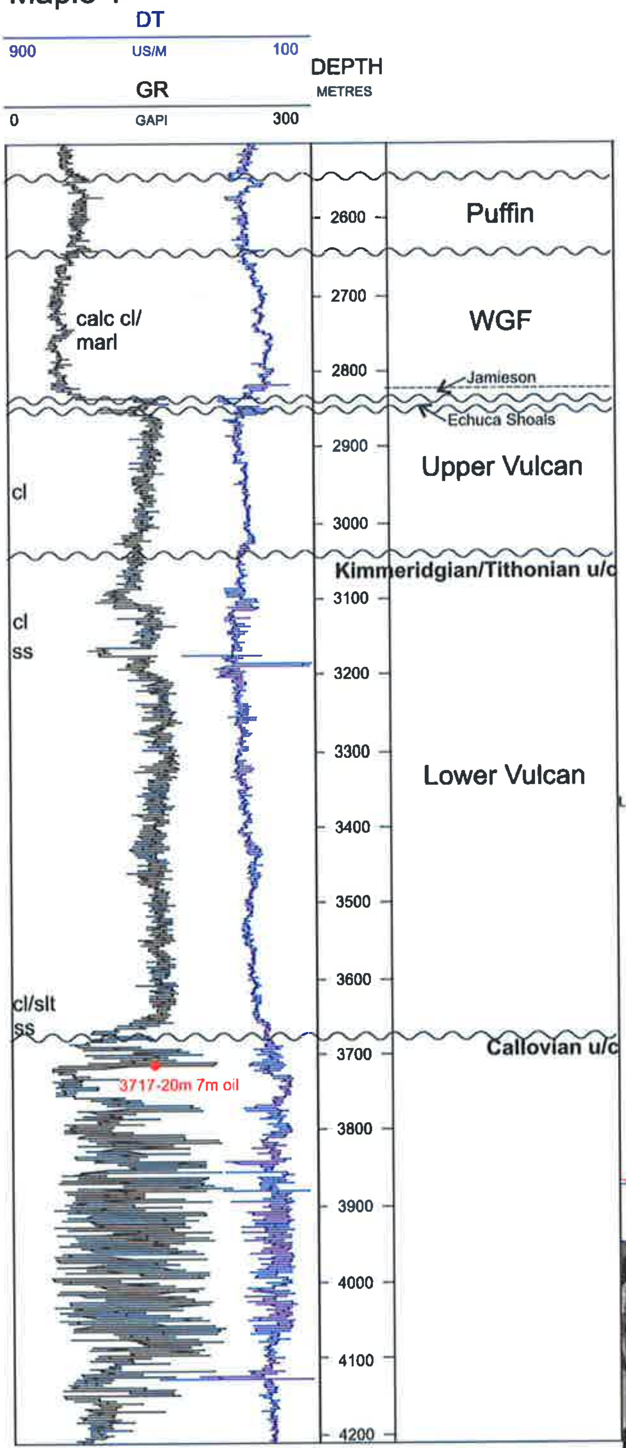



## Keeling 1

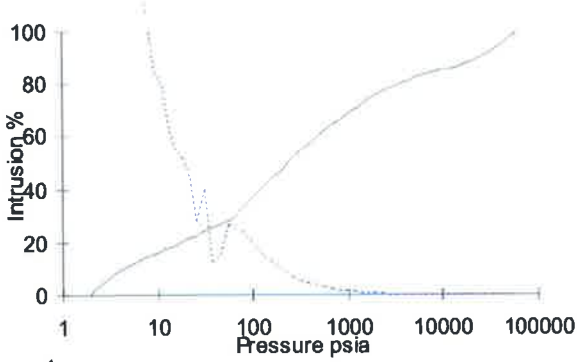


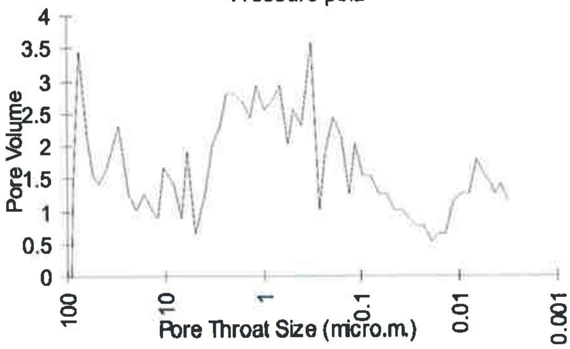
DT
900
US/M
100
GR
0
GAPI
300
DEPTH
METRES
2000
2100
2200
2300
2400
2500
2600
2700
2800
2900
3000
3100
1140-50m 361m oil
1260-70m 748m oil
1324-27m 122m oil
509m oil
Top Cretaceous
Puffin
Campanian u/c
WGF
Jamieson
Aptian u/c
Echuca Shoals
Top Triassic

## Maple 1



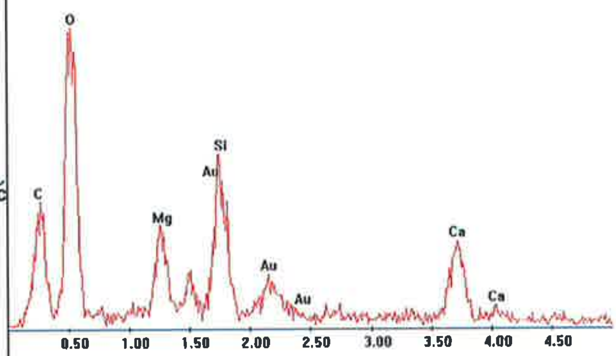

Depth: 3717-3720m Pth 50psi SC: 7m oil

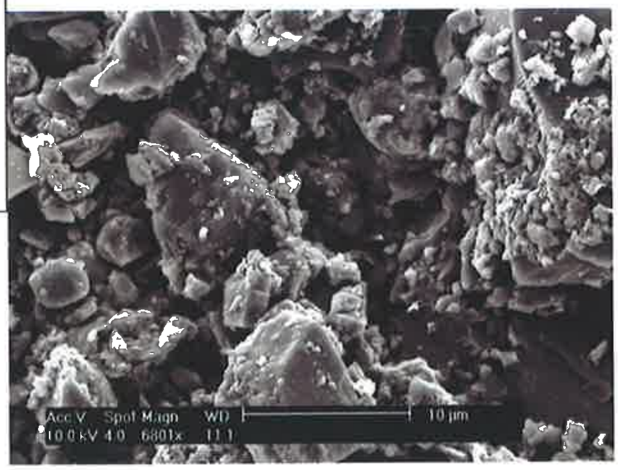


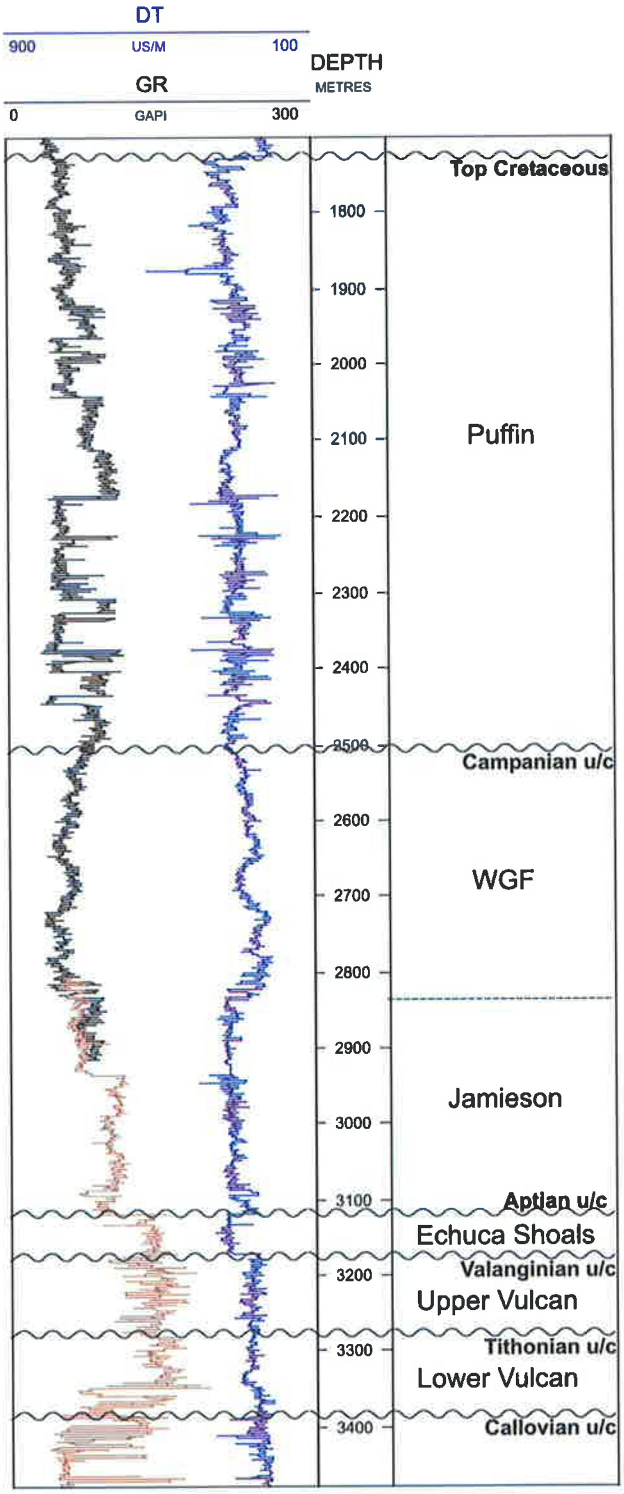

O:\TKIVIOR\MP1-1702.spc

Label A: OB-11-1

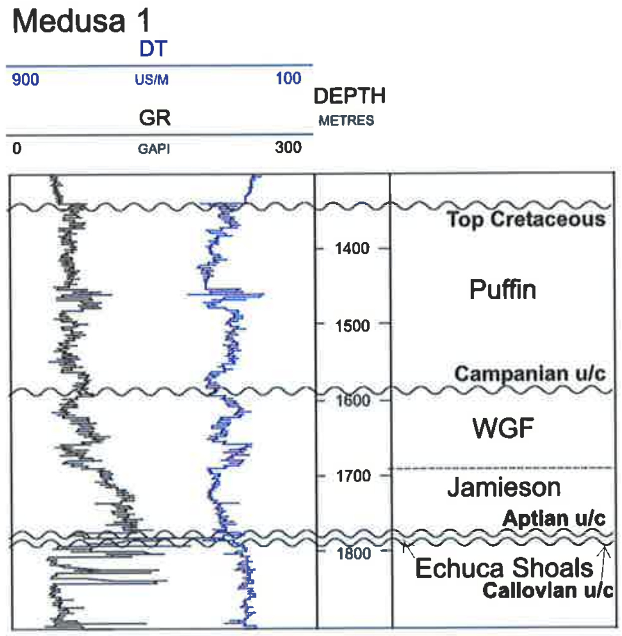


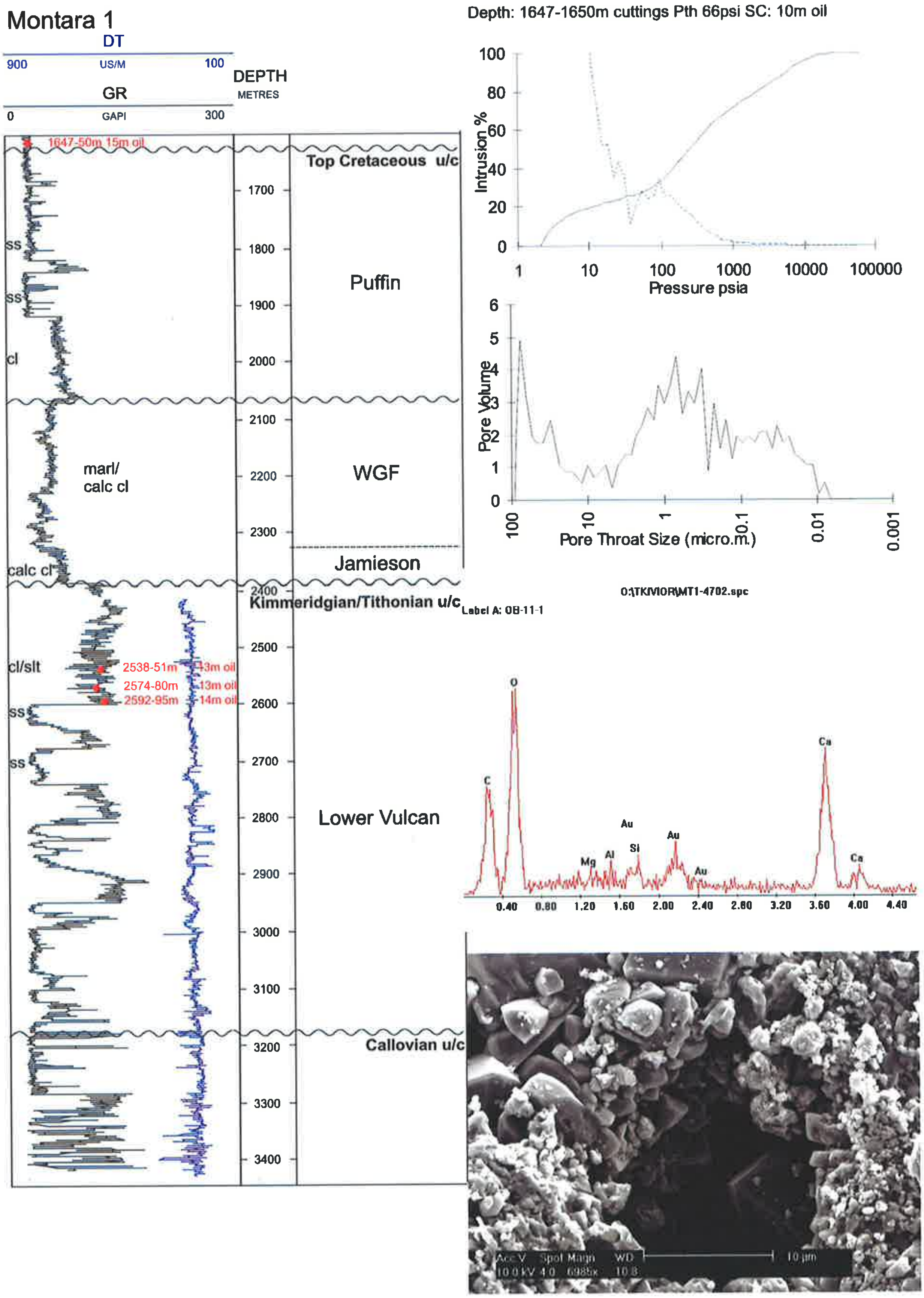
## Maret 1



DT
900
US/M
100
DEPTH
METRES
GR
0
GAPI
300
Top Cretaceous
1800
1900
2000
2100
Puffin
2200
2300
2400
2500
Campanian u/c
2600
WGF
2700
2800
2900
Jamieson
3000
3100
Aptian u/c
Echuca Shoals
3200
Valanginian u/c
Upper Vulcan
3300
Tithonian u/c
Lower Vulcan
3400
Callovian u/c



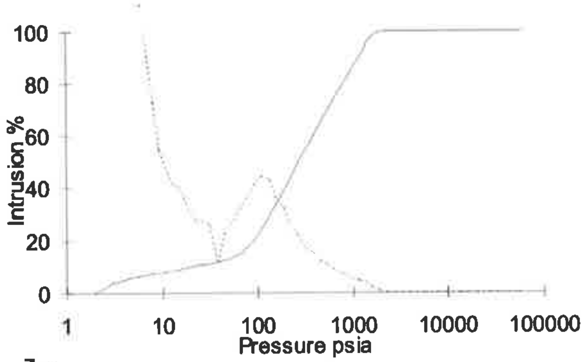
Medusa 1
DT
900
US/M
100
DEPTH
METRES
GR
0
GAPI
300
Top Cretaceous
1400
Puffin
1500
Campanian u/c
1600
WGF
1700
Jamieson
Aptian u/c
1800
Echuca Shoals
Callovian u/c

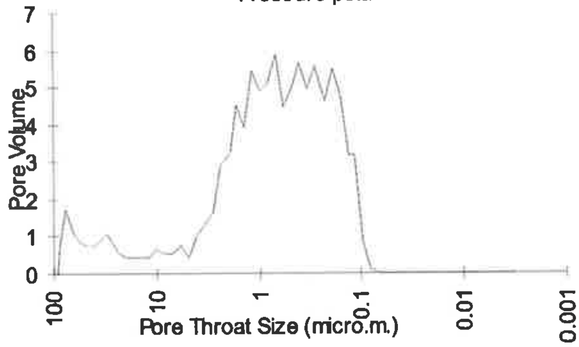


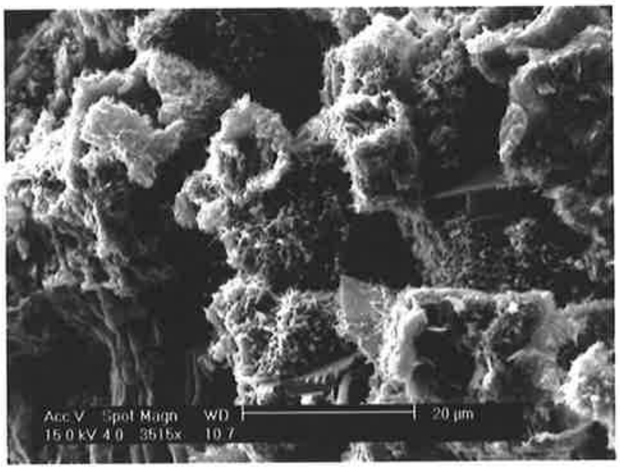
Montara 1
DT
900
US/M
100
GR
0
GAPI
300
DEPTH
METRES
1647-50m 15m oil
Top Cretaceous u/c
1700
1800
1900
2000
ss
ss
cl
Puffin
2100
2200
2300
marl/
calc cl
WGF
Jamieson
calc cl
2400
Kimmeridgian/Tithonian u/c
2500
2600
2700
2800
2900
3000
3100
cl/slt
2538-51m
13m oil
2574-80m
13m oil
2592-95m
14m oil
ss
ss
Lower Vulcan
Callovian u/c
3200
3300
3400
Depth: 1647-1650m cuttings Pth 66psi SC: 10m oil
Intrusion %
Pressure psia
Pore Volume
Pore Throat Size (micro.m.)
O:\TKMOR\MT1-4702.spc
Label A: 08-11-1
O
C
Mg
Al
Si
Au
Ca
Acc.V Spot Magn WD
10.0 kV 4.0 6985x 10.8
10 µm

# Montara 1

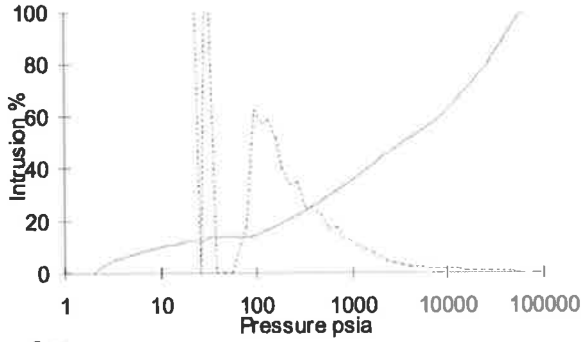
**Depth: 2538-2541m Pth 85psi SC: 13m oil**

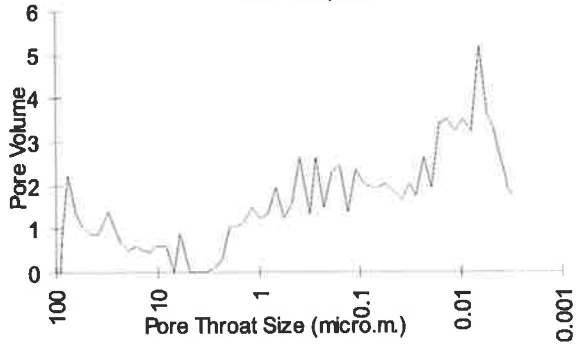


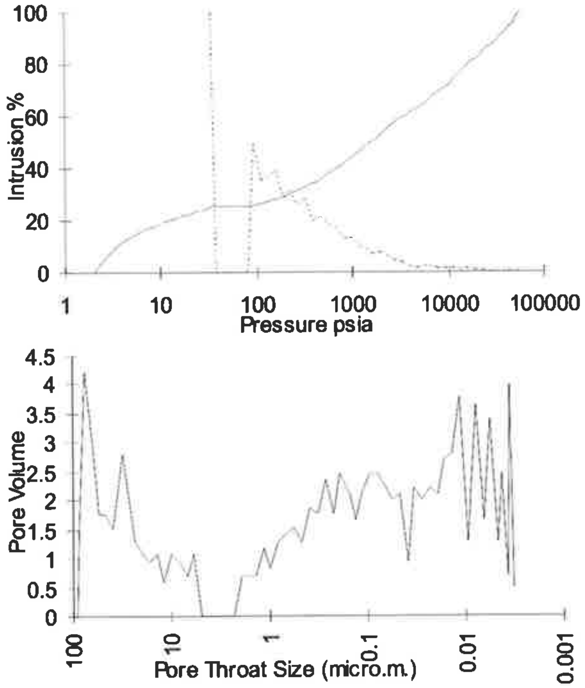

**Depth: 2574-2580m Pth 85psi SC: 13m oil**

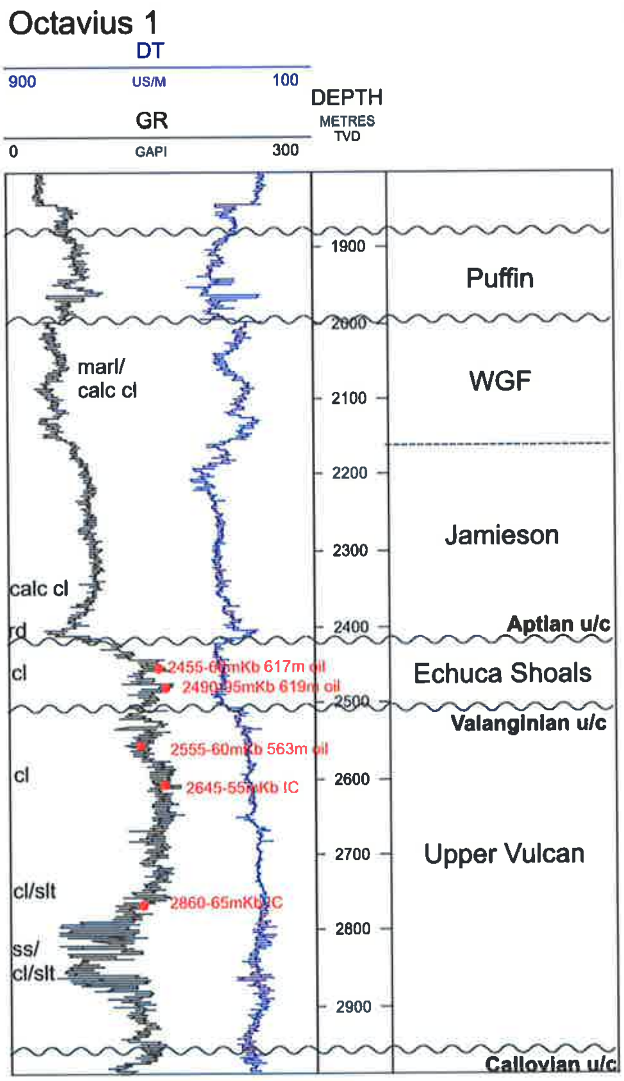


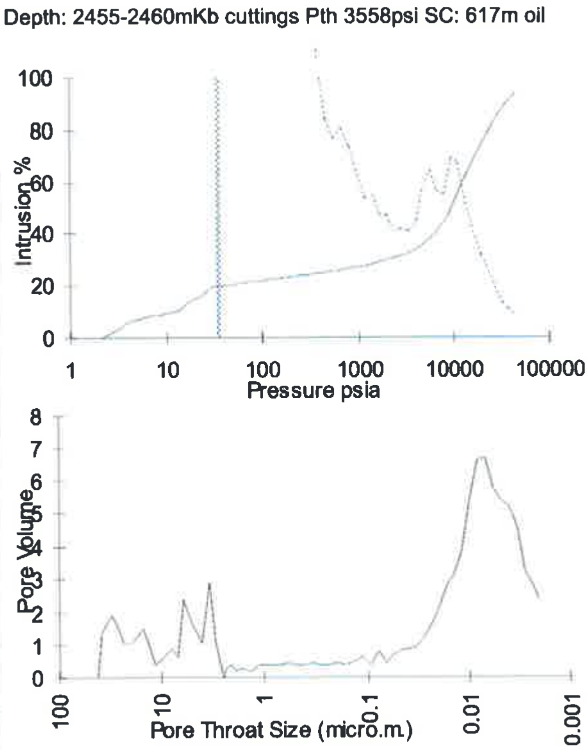
# Montara 1

**Depth: 2592-2595m Pth 93psi SC: 14m oil**





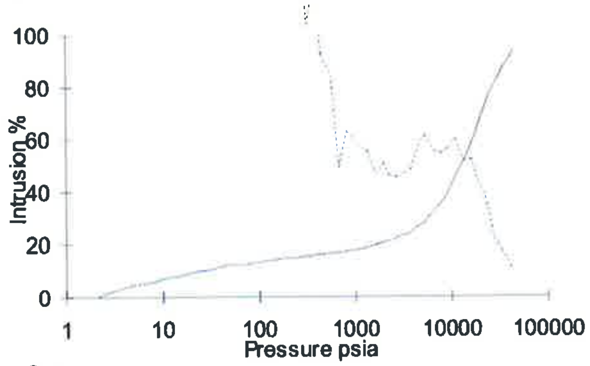
Octavius 1
DT
900
US/M
100
GR
0
GAPI
300
DEPTH
METRES
TVD
1900
2000
2100
2200
2300
2400
2500
2600
2700
2800
2900
Puffin
WGF
Jamieson
Aptian u/c
Echuca Shoals
Valanginian u/c
Upper Vulcan
Callovian u/c
marl/
calc cl
calc cl
rd
cl
cl
cl/slt
ss/
cl/slt
2455-60mKb 617m oil
2490-95mKb 619m oil
2555-60mKb 563m oil
2645-55mKb IC
2860-65mKb IC

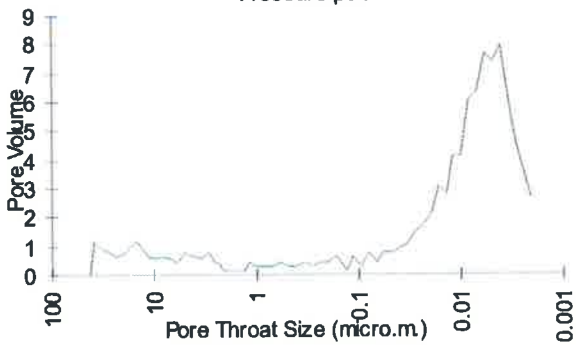



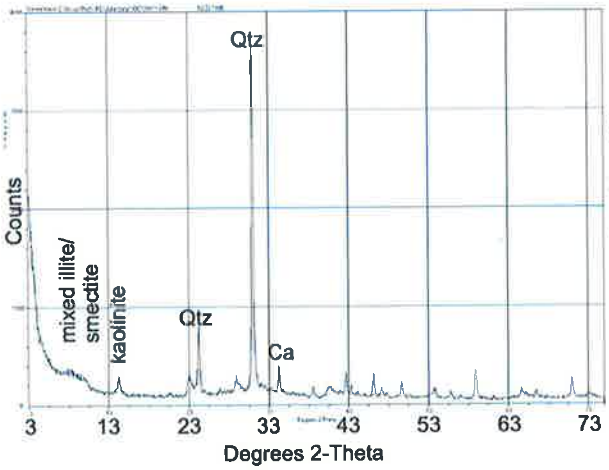
Depth: 2455-2460mKb cuttings Pth 3558psi SC: 617m oil
Intrusion %
Pressure psia
Pore Volume
Pore Throat Size (micro.m)

# Octavius 1

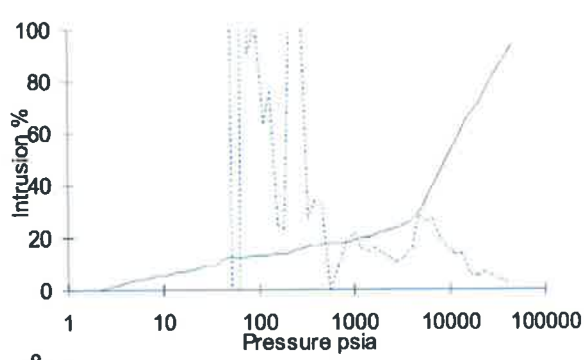
**Depth: 2490-2495mKb Pth 3568psi SC: 619m oil**

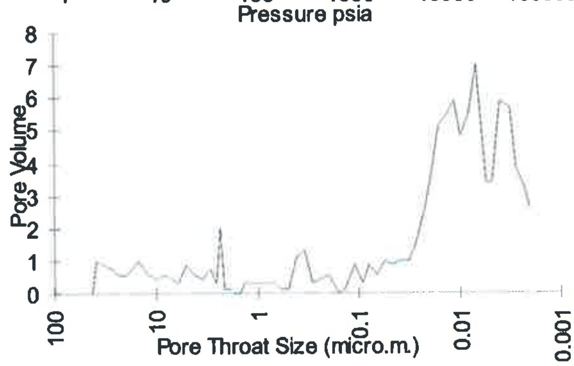


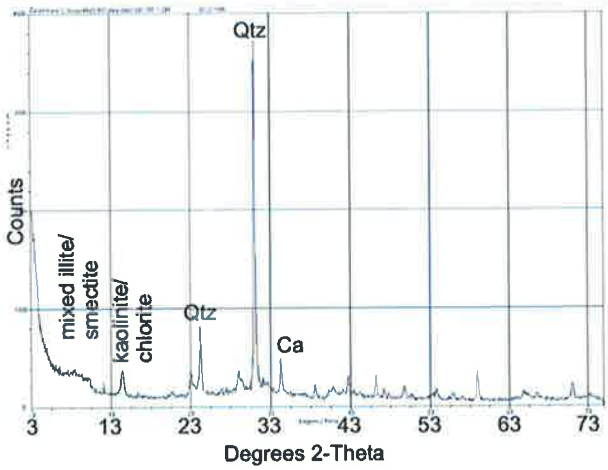




**Depth: 2555-2560mKb Pth 3245psi SC: 563m oil**

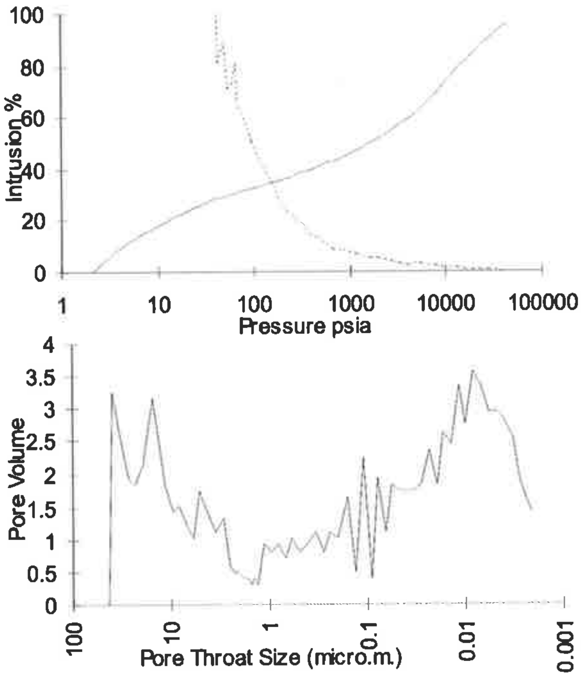


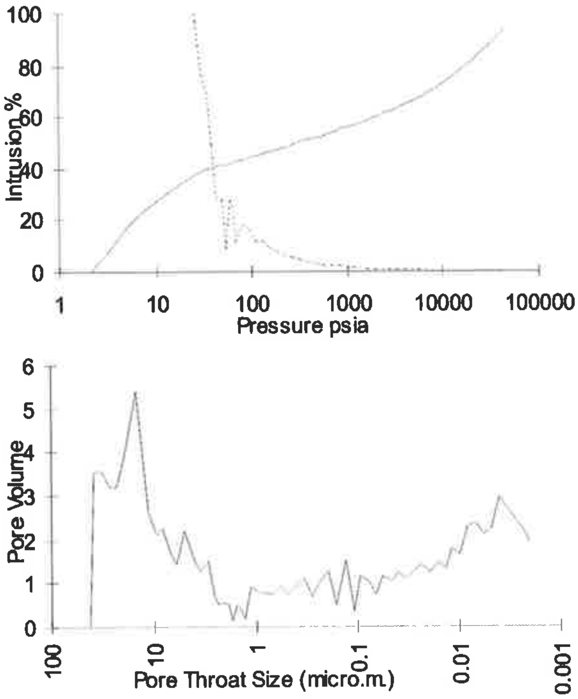



## Octavius 1

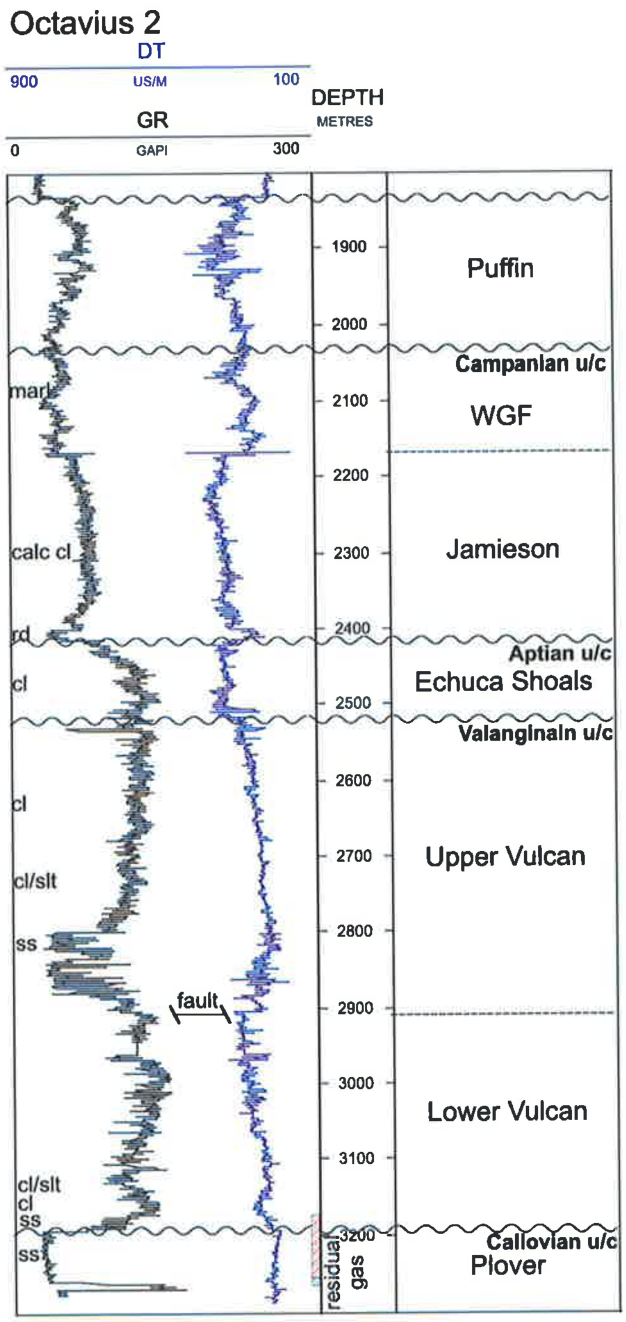
Depth: 2645-2655mKb Pth Inconclusive

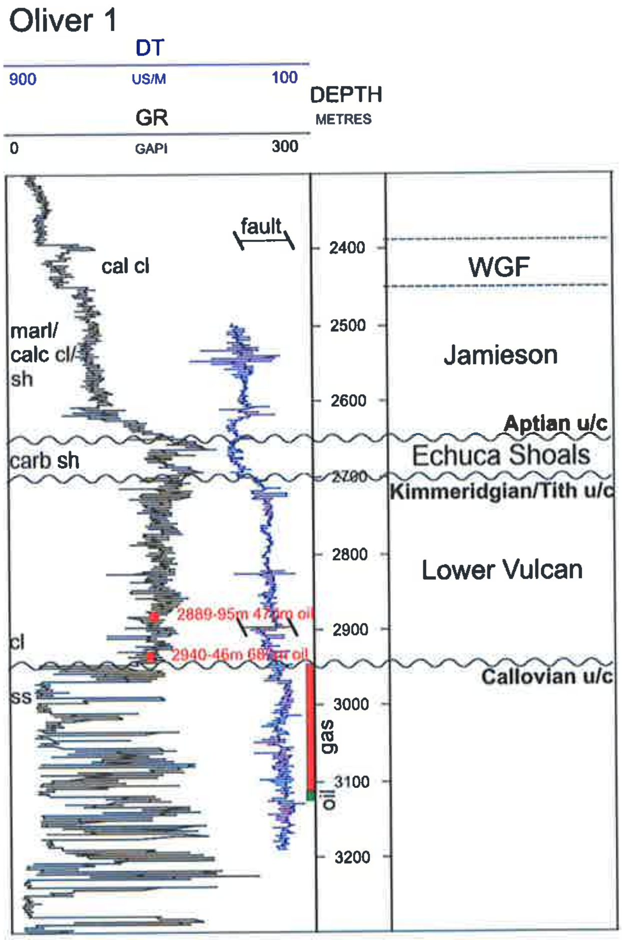



Depth: 2860-2865mKb Pth Inconclusive

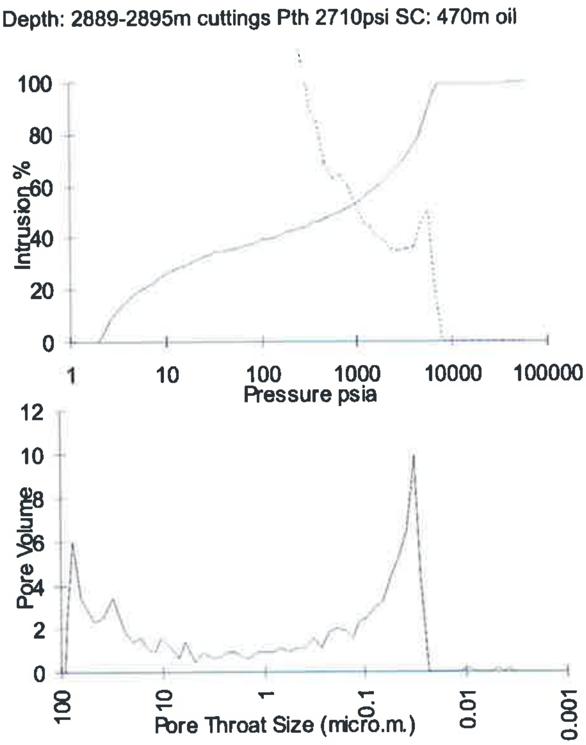



Inconclusive MICP tests run on cuttings from the Octavius 1 well. It is not possible to confidently pick a threshold pressure from these curves. Inconclusive tests were not used to estimate seal capacities in this study.


Octavius 2
DT
900
US/M
100
GR
0
GAPI
300
DEPTH
METRES
1900
2000
2100
2200
2300
2400
2500
2600
2700
2800
2900
3000
3100
3200
Puffin
Campanian u/c
WGF
Jamieson
Aptian u/c
Echuca Shoals
Valanginain u/c
Upper Vulcan
Lower Vulcan
Callovian u/c
Plover
marl
calc cl
rd
cl
cl
cl/slt
ss
fault
cl/slt
cl
ss
ss
residual gas



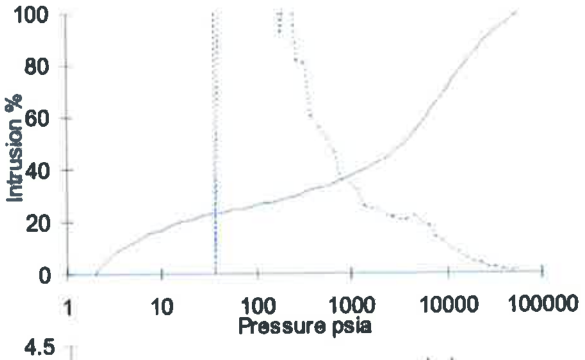
Oliver 1
DT
900
US/M
100
GR
0
GAPI
300
DEPTH
METRES
fault
cal cl
marl/
calc cl/
sh
carb sh
cl
ss
2889-95m 470m oil
2940-46m 680m oil
gas
oil
2400
2500
2600
2700
2800
2900
3000
3100
3200
WGF
Jamieson
Aptian u/c
Echuca Shoals
Kimmeridgian/Tith u/c
Lower Vulcan
Callovian u/c

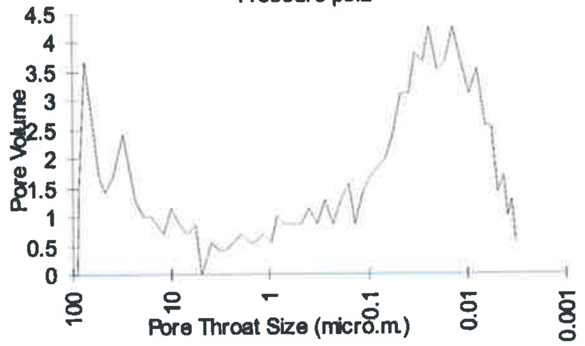



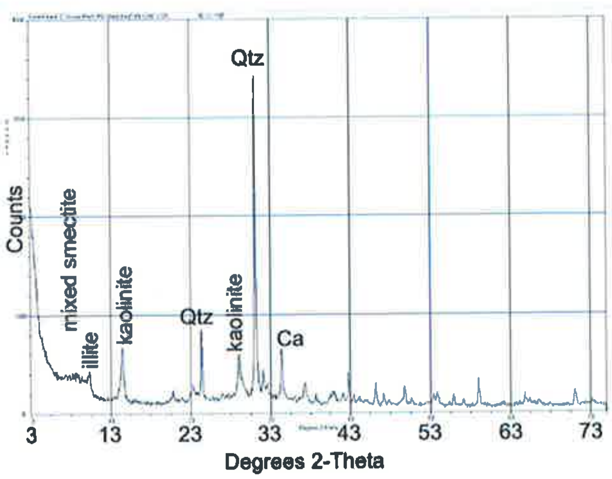
Depth: 2889-2895m cuttings Pth 2710psi SC: 470m oil
Intrusion %
Pressure psia
Pore Volume
Pore Throat Size (micro.m.)

# Oliver 1

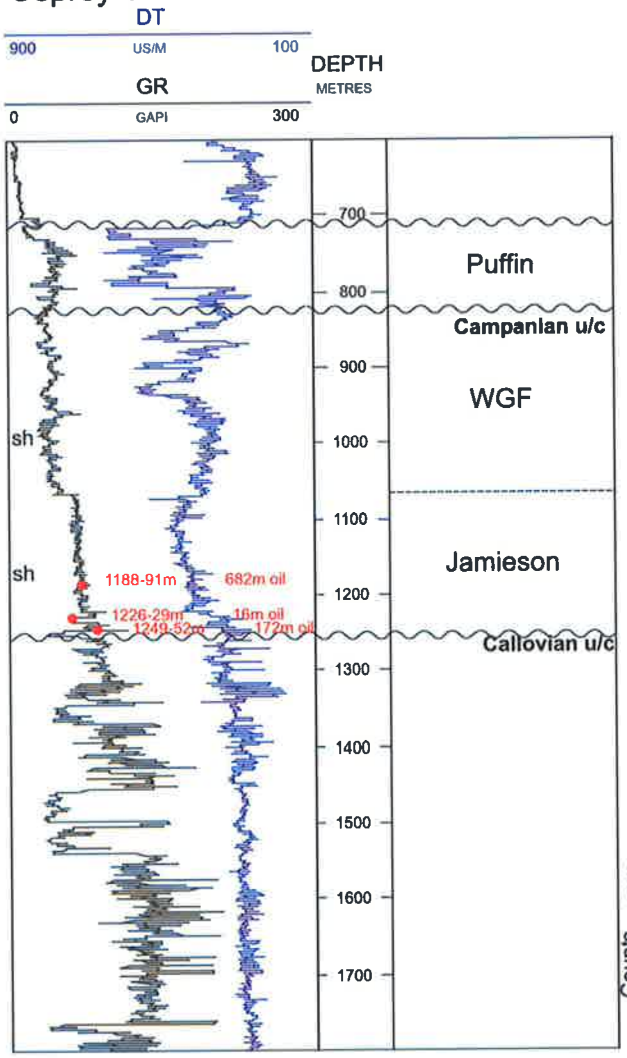
**Depth: 2940-2946m Pth 3920psi SC: 680m oil**



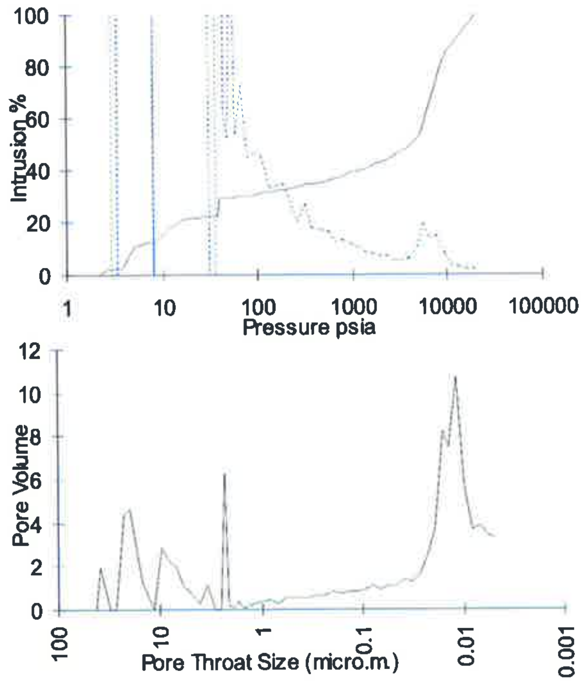



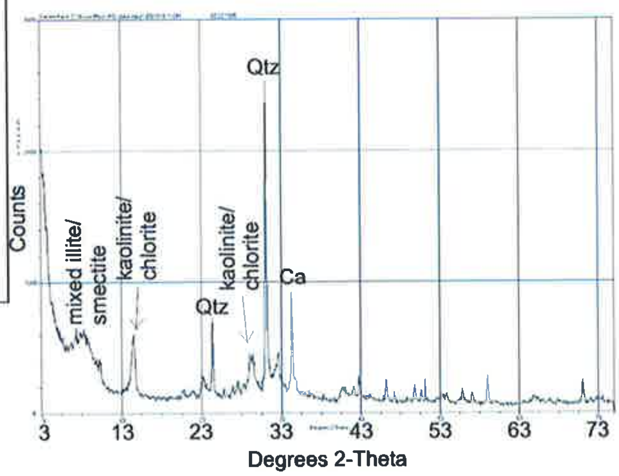



## Osprey 1



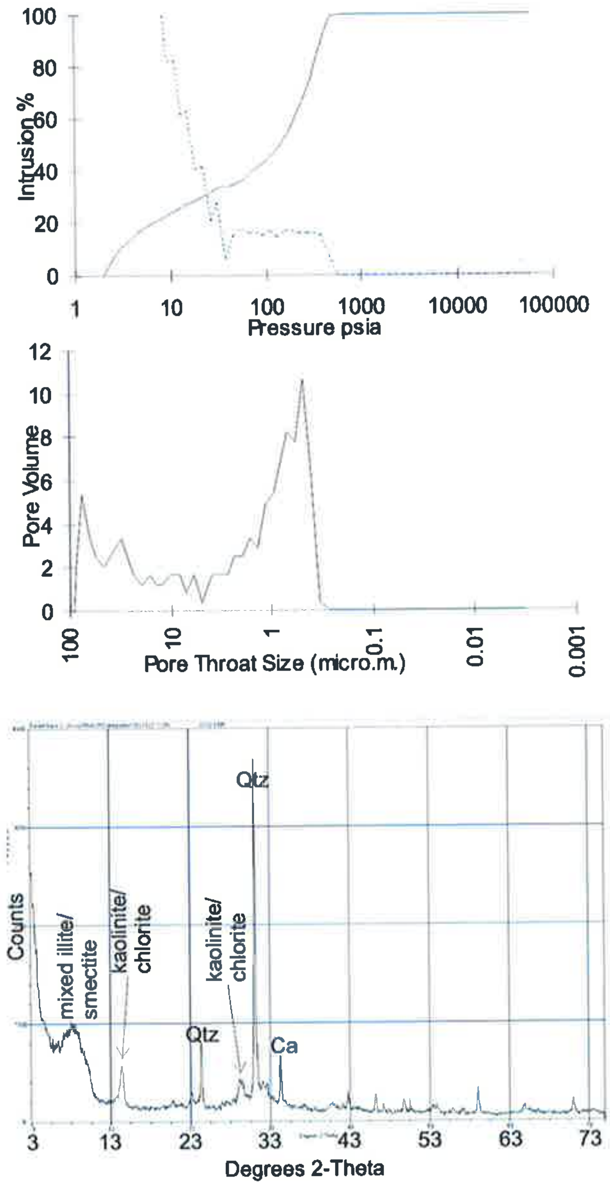

Depth: 1188-1191m cuttings Pth 3522psi SC: 682m oil



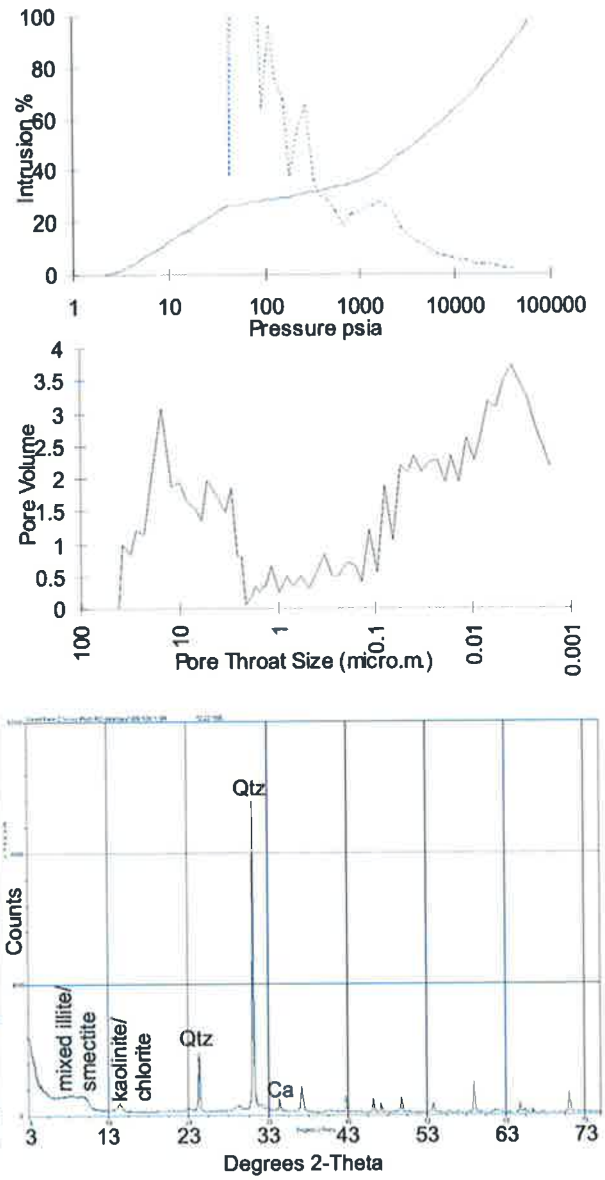



# Osprey 1

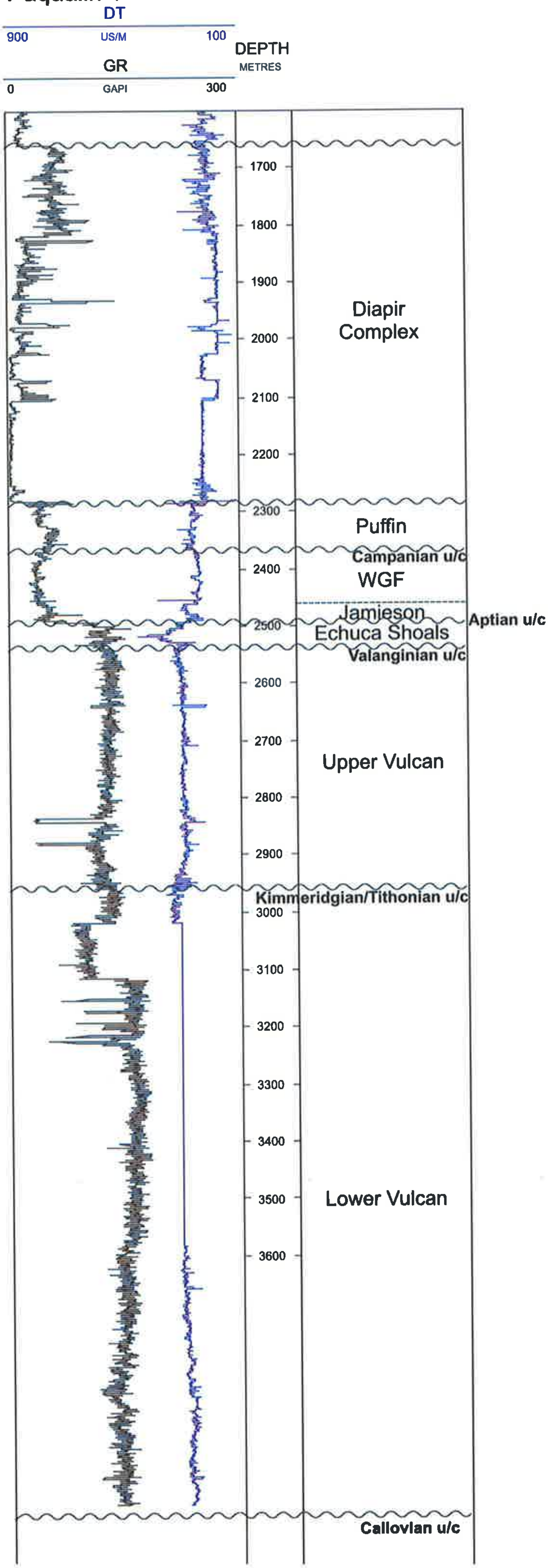
Depth: 1226-1229m Pth 120psi SC: 16m oil



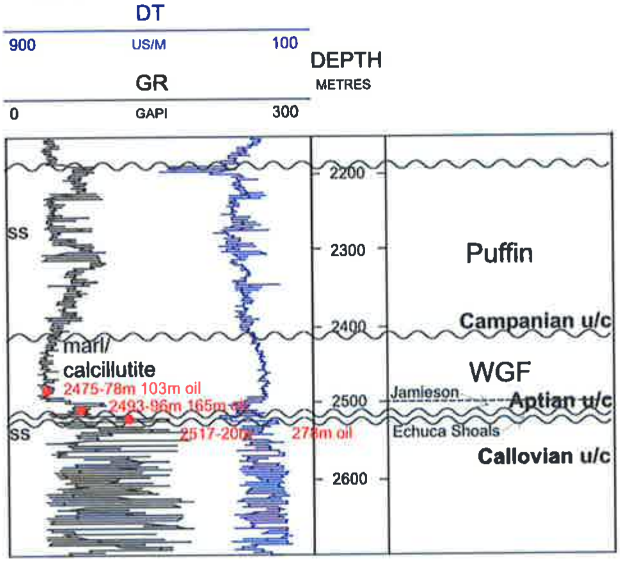

Depth: 1249-1252m Pth 1290psi SC: 172m oil



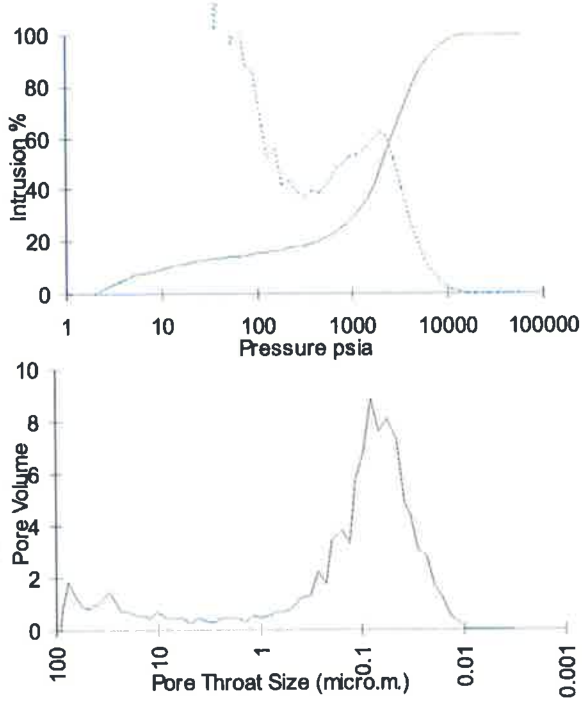
# Paqualin 1

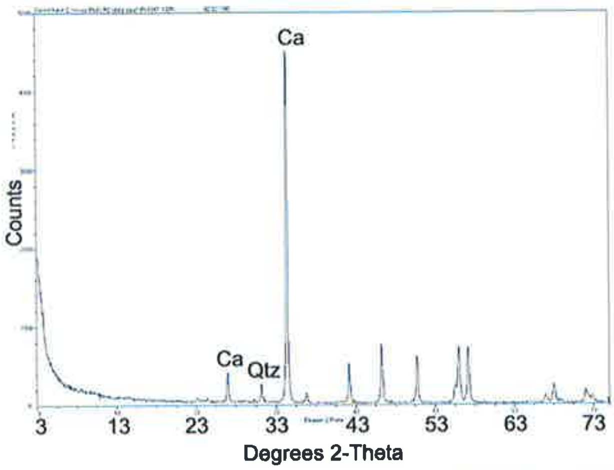

DT
900
US/M
100
DEPTH
METRES
GR
0
GAPI
300
1700
1800
1900
2000
2100
2200
2300
2400
2500
2600
2700
2800
2900
3000
3100
3200
3300
3400
3500
3600
Diapir Complex
Puffin
Campanian u/c
WGF
Jamieson
Aptian u/c
Echuca Shoals
Valanginian u/c
Upper Vulcan
Kimmeridgian/Tithonian u/c
Lower Vulcan
Callovian u/c

Pascal 1



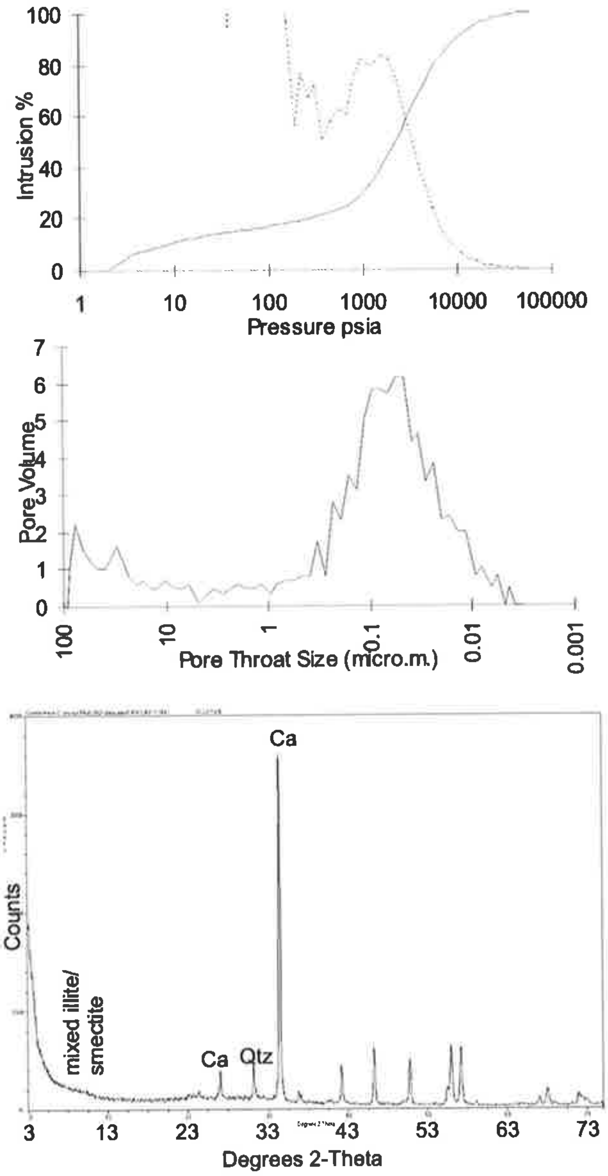

Depth: 2475-2478m cuttings Pth 600psi SC: 103m oil



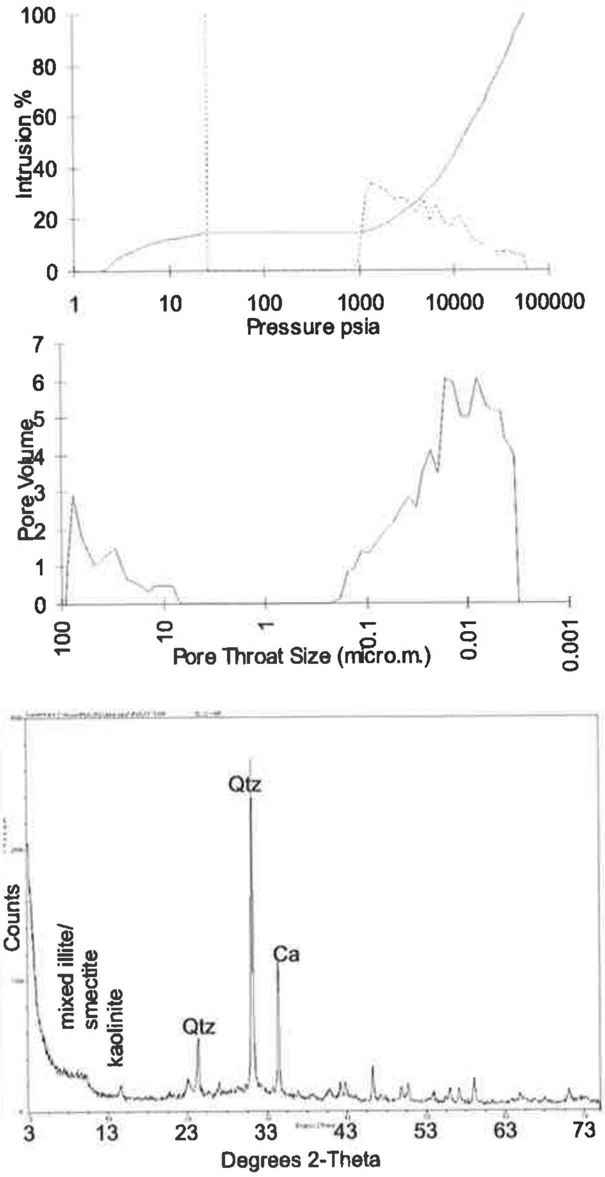




# Pascal 1

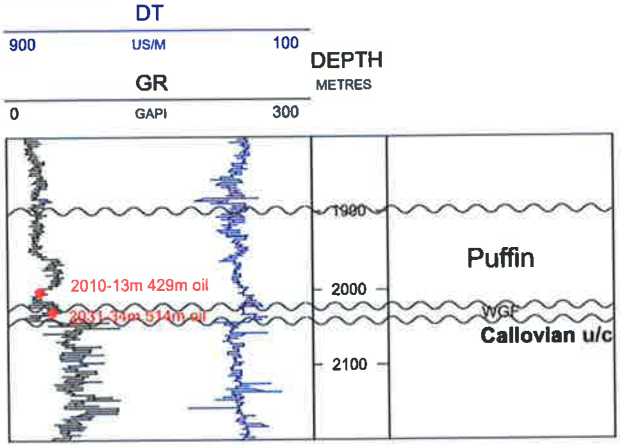
**Depth: 2493-2496m Pth 958psi SC: 165m oil**



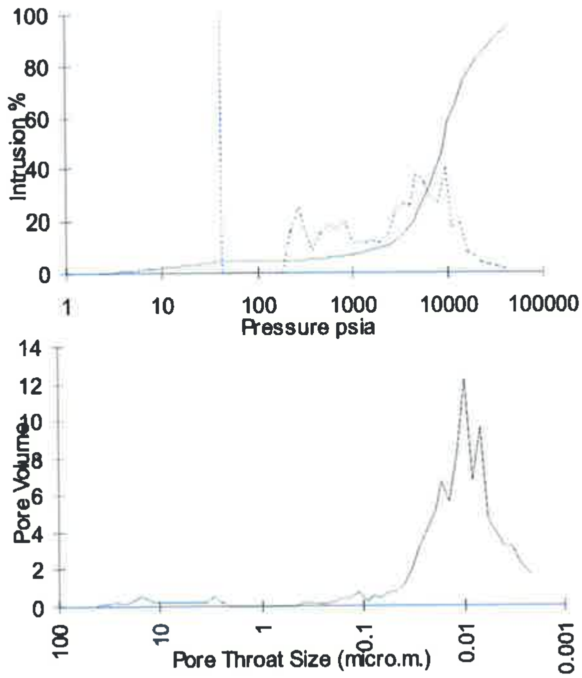

**Depth: 2517-2520m Pth 1610psi SC: 278m oil**



## Pollard 1

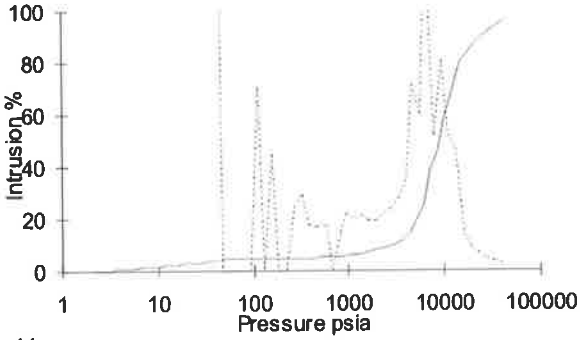


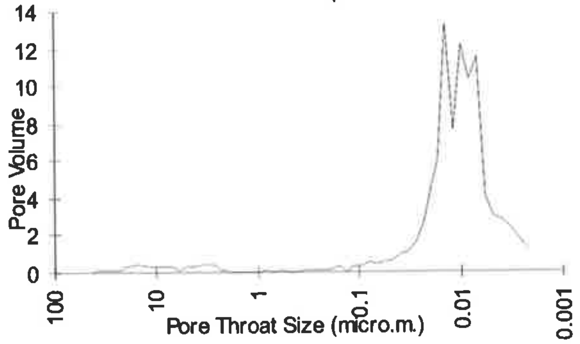

Depth: 2010-2013m cuttings Pth 2477psi SC: 429m oil

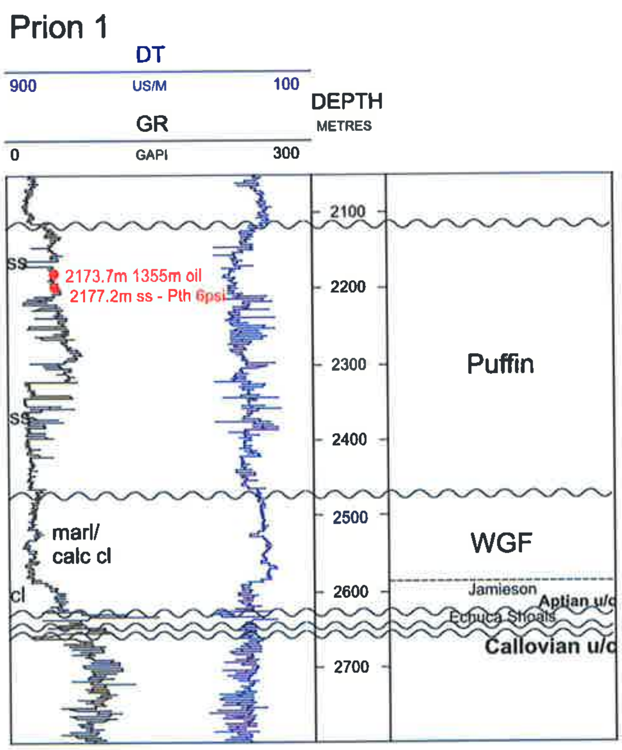


# Pollard 1

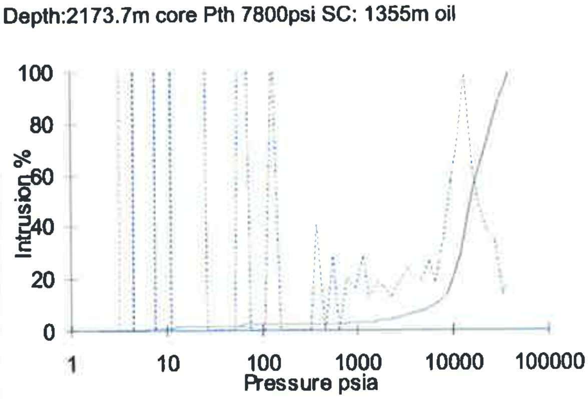
Depth: 2031-2034m Pth 2962psi SC: 514m oil



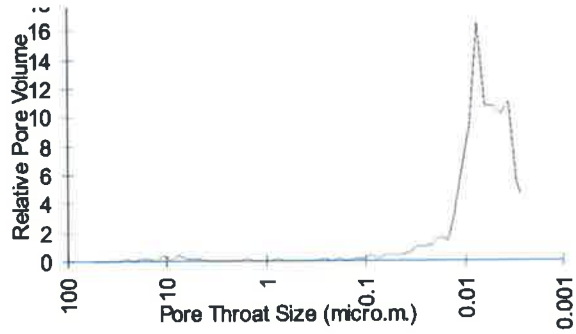





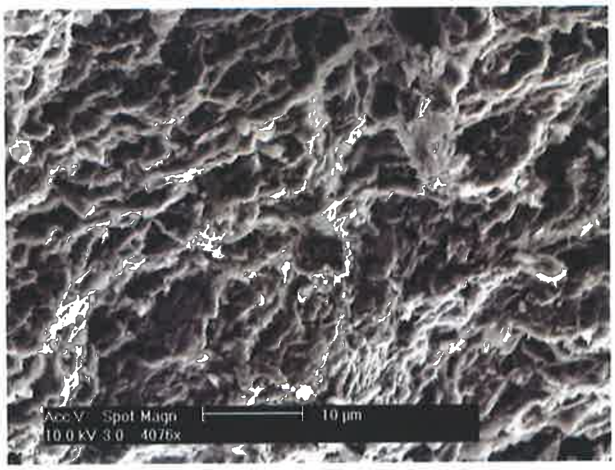
Prion 1
DT
900
US/M
100
DEPTH
METRES
GR
0
GAPI
300
ss
2173.7m 1355m oil
2177.2m ss - Pth 6psi
ss
marl/
calc cl
cl
2100
2200
2300
2400
2500
2600
2700
Puffin
WGF
Jamieson
Aptian u/c
Echuca Shoals
Callovian u/c

Depth:2173.7m core Pth 7800psi SC: 1355m oil
Intrusion %
100
80
60
40
20
0
1
10
100
1000
10000
100000
Pressure psia

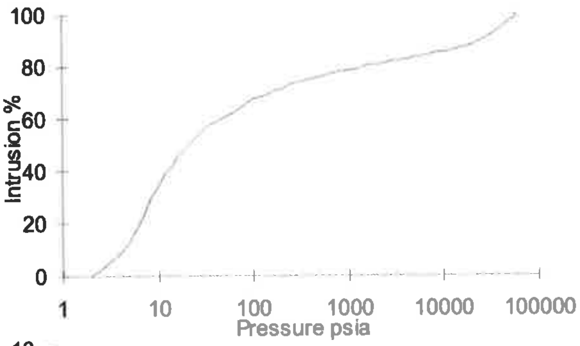
Relative Pore Volume
16
14
12
10
8
6
4
2
0
100
10
1
0.1
0.01
0.001
Pore Throat Size (micro.m.)

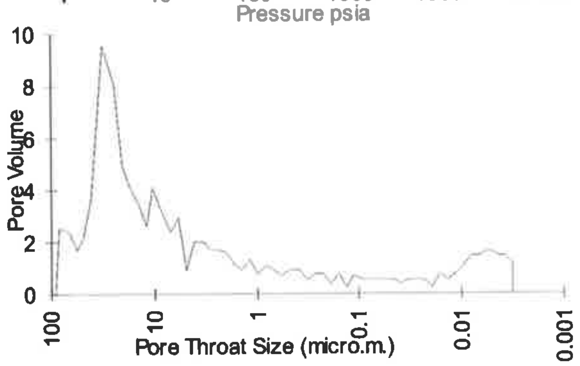



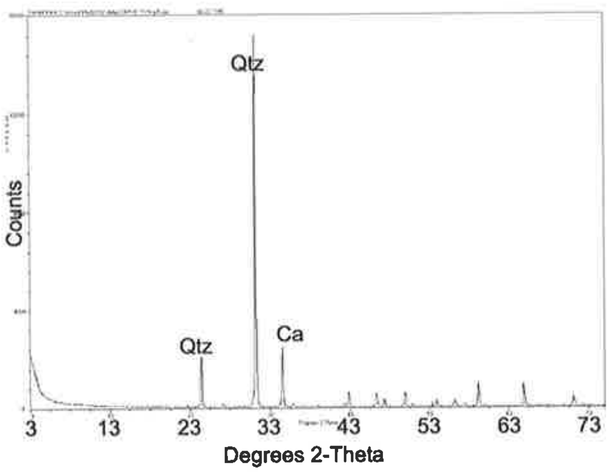
Acc.V Spot Magn
10.0 kV 3.0 4076x
10 µm

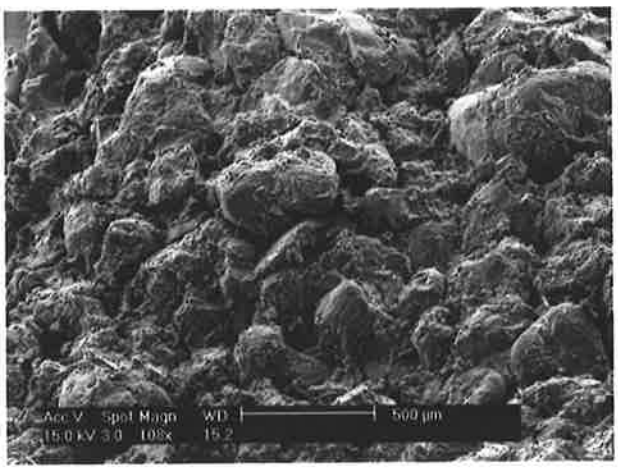
# Prion 1

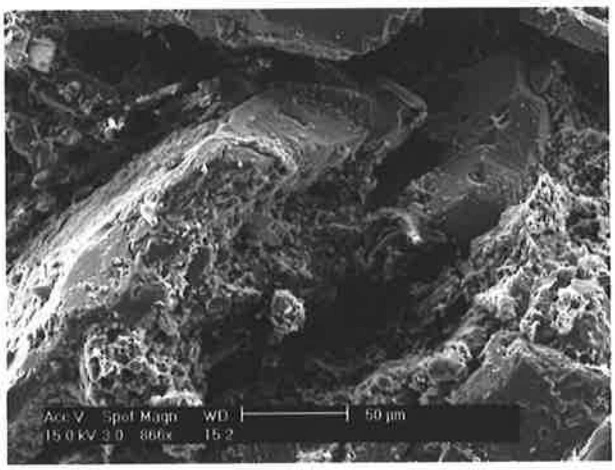
Depth: 2177.2-2177.4m core Pth 6psi SC:-oil



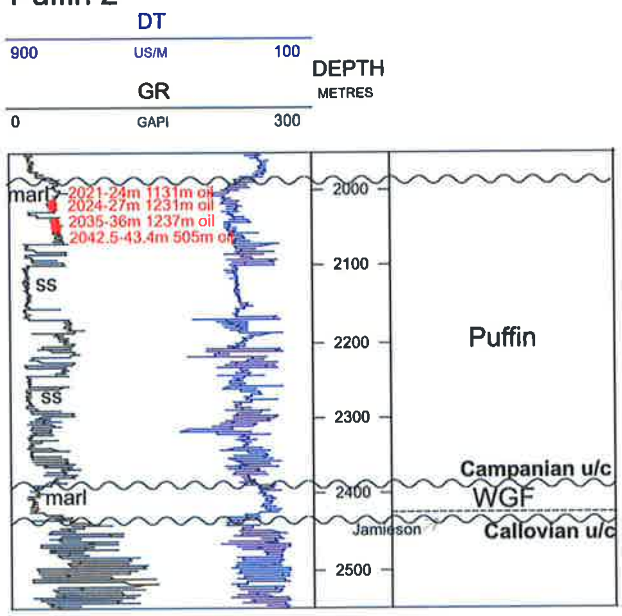



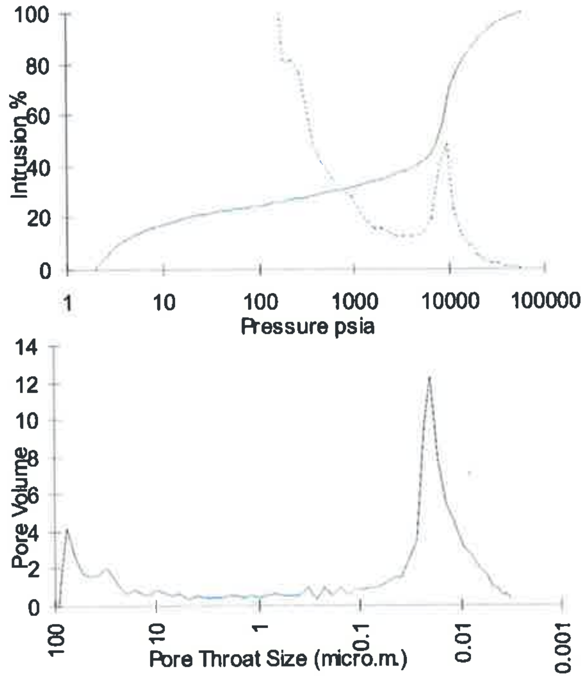



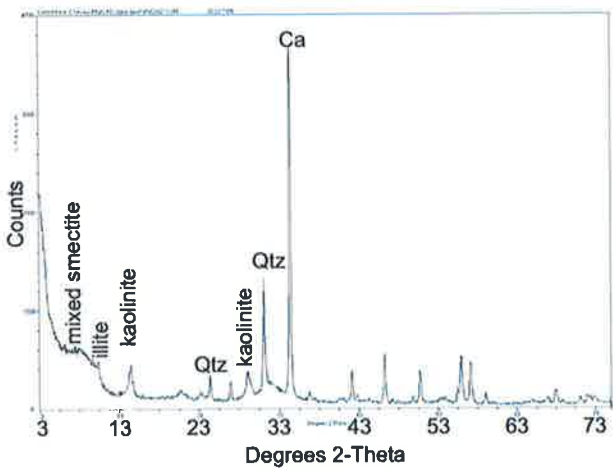



# Puffin 2



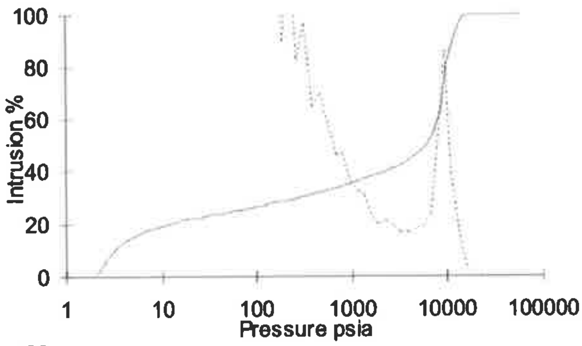

Depth: 2021-2024m cuttings Pth 6511psi SC: 1131m oil

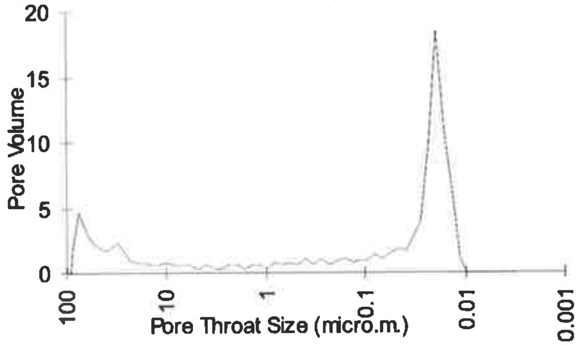


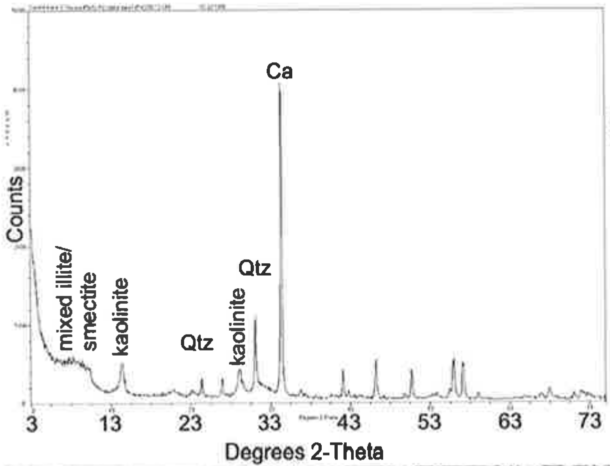



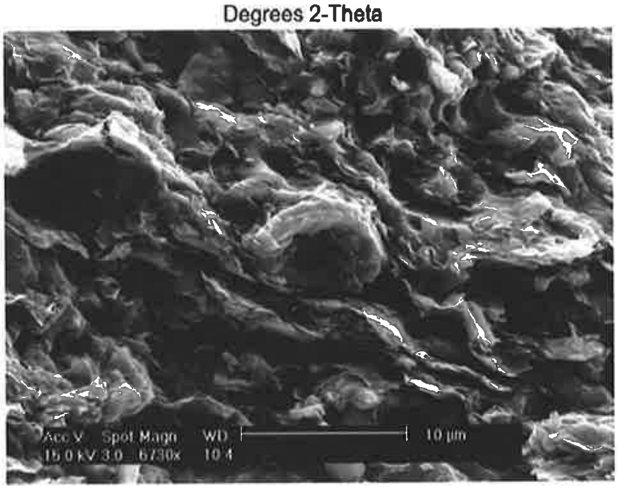
## Puffin 2

**Depth: 2024-2027m Pth 7085psi SC: 1231m oil**

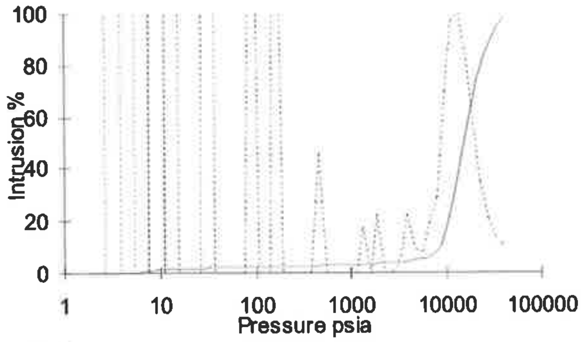


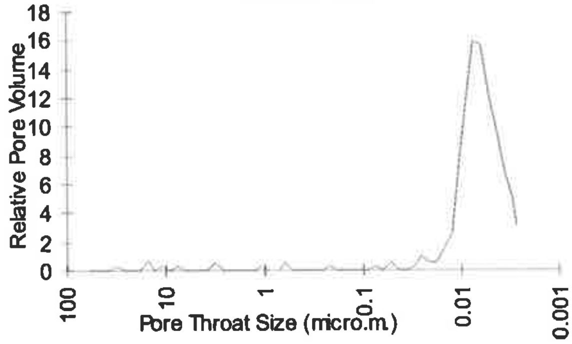



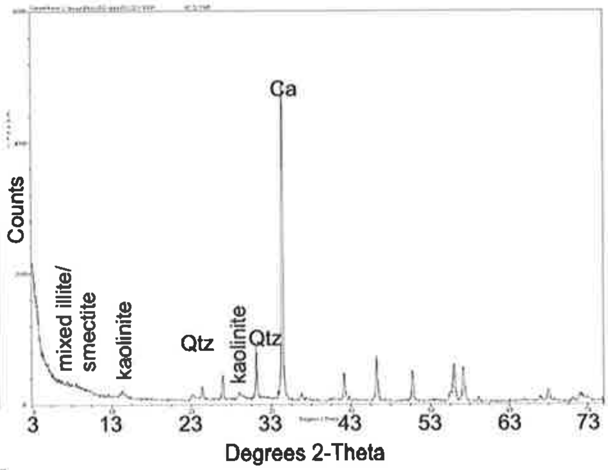




**Depth: 2035-2036m Pth 7118psi SC: 618m oil**

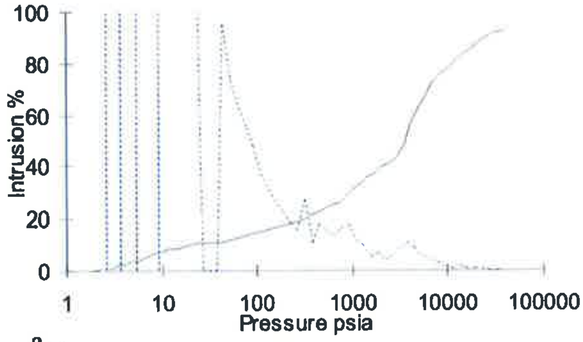


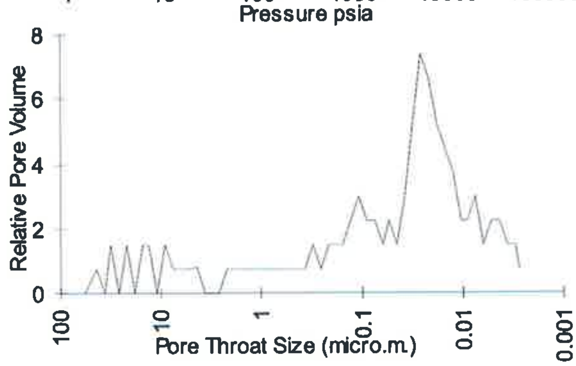



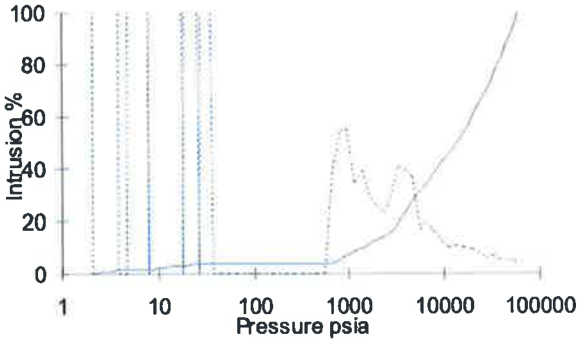
## Puffin 2

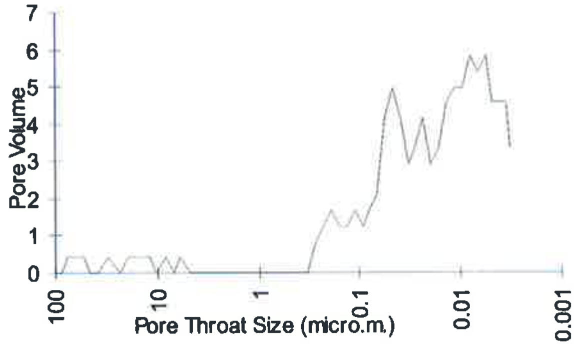
Depth: 2042.5-2043.4m core bulk1
Pth 704 & 2433psi SC: 121m & 422m oil

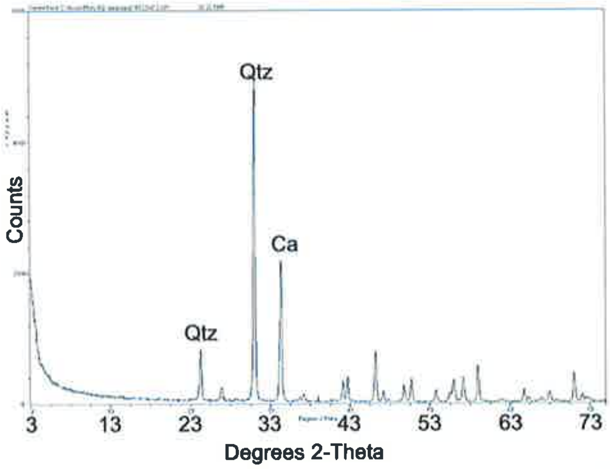


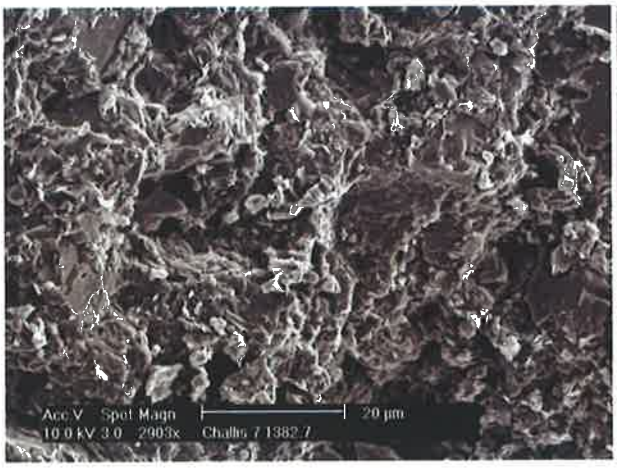




Depth: 2042.5-2043.4m core bulk2
Pth 721 & 2498psi SC: 124m & 433m oil



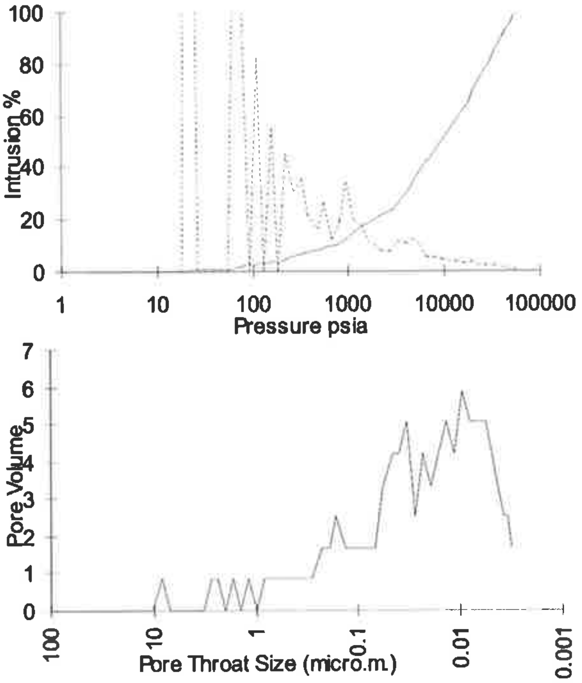



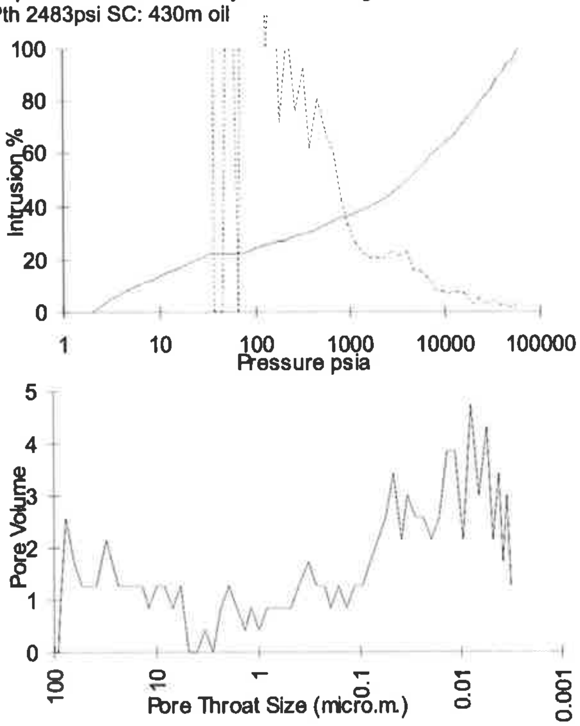



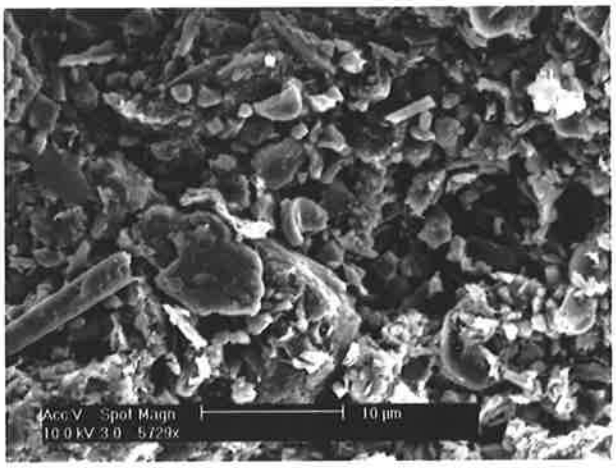

## Puffin 2

Depth: 2042.5-2043.4m core araldite
Pth 729 & 2935psi SC: 125m & 509m oil

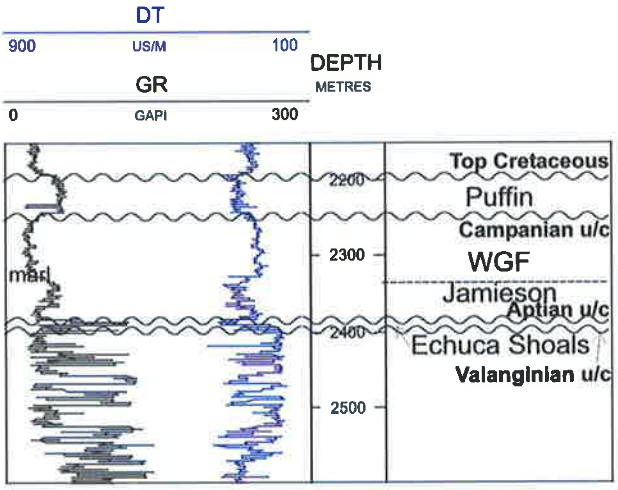



Depth: 2042.5-2043.4m synthetic cuttings
Pth 2483psi SC: 430m oil



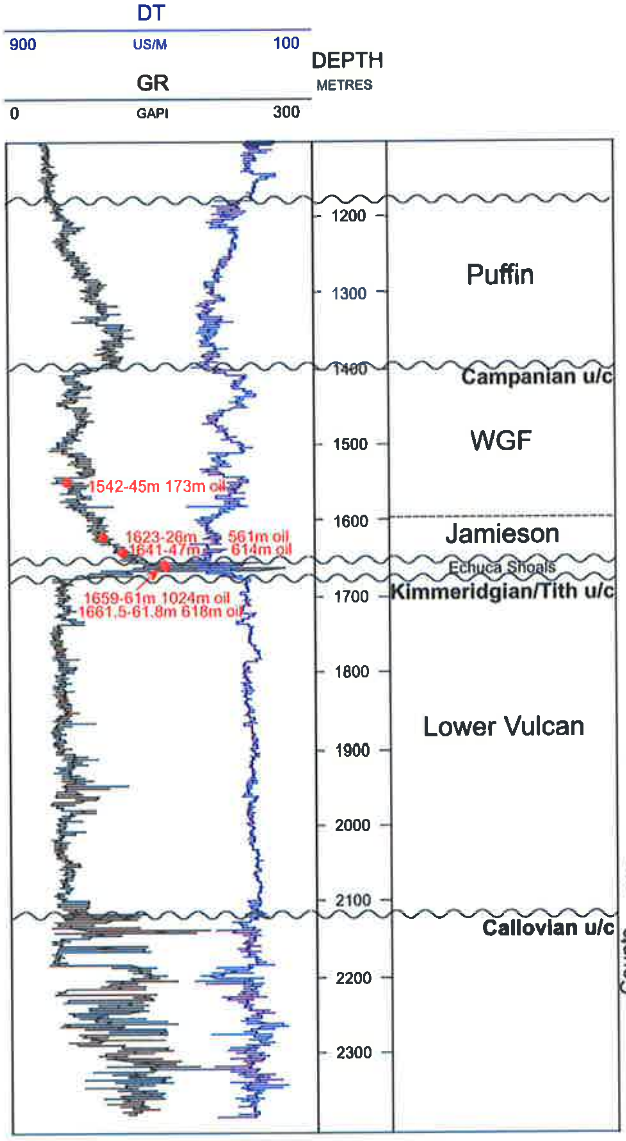



Rainbow 1

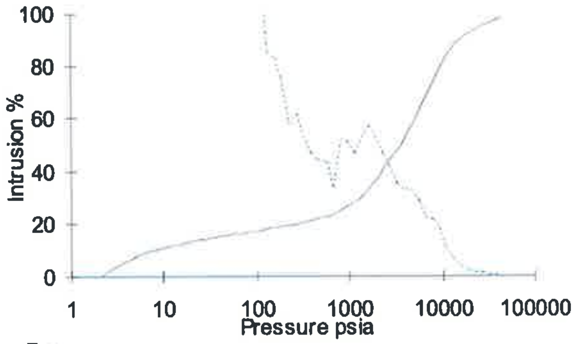


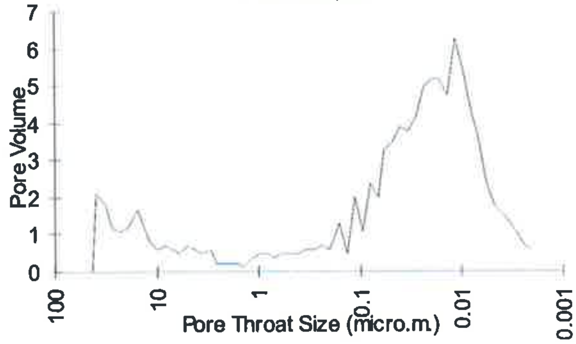
DT
900
US/M
100
GR
0
GAPI
300
DEPTH
METRES
2200
2300
2400
2500
marl
Top Cretaceous
Puffin
Campanian u/c
WGF
Jamieson
Aptian u/c
Echuca Shoals
Valanginian u/c

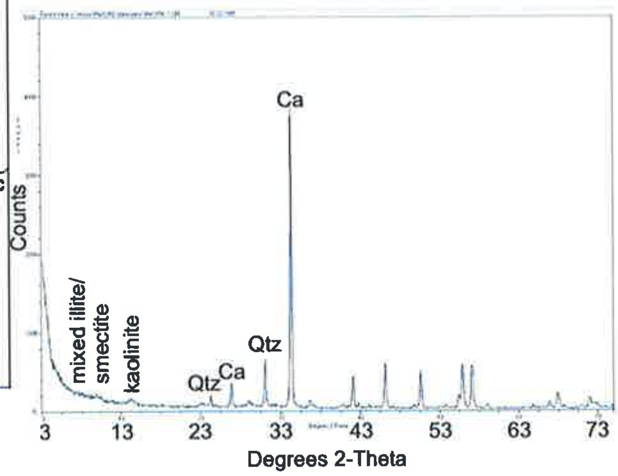
## Rainier 1




Depth: 1542-1545m cuttings Pth 1024psi SC: 173m oil

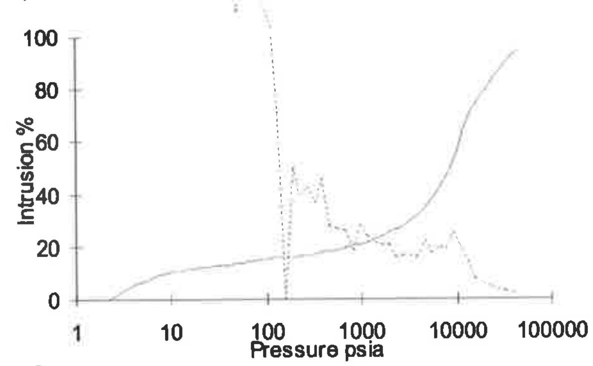


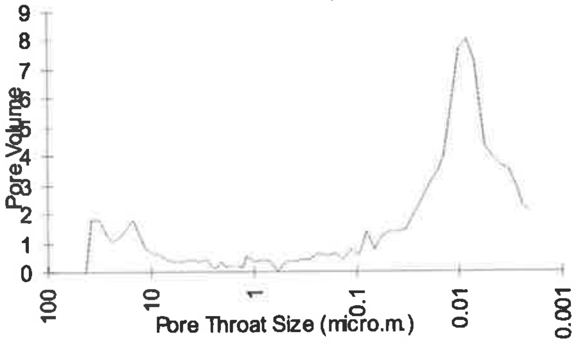



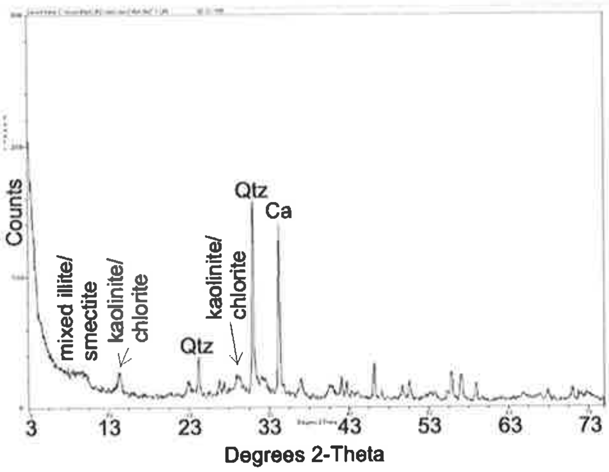



## Rainier 1

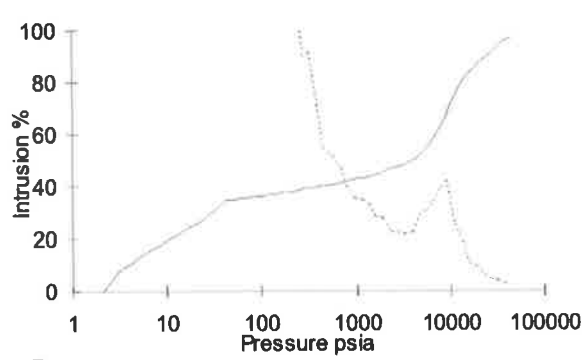
**Depth: 1623-1626m Pth 3237psi SC: 561m oil**

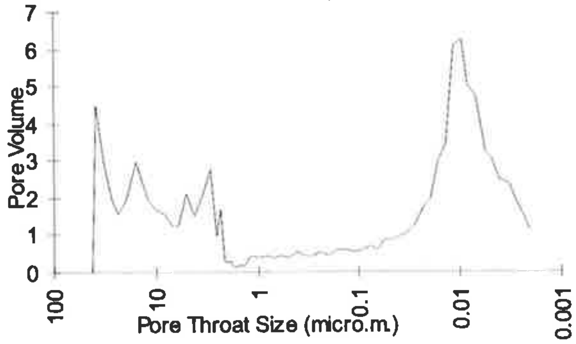


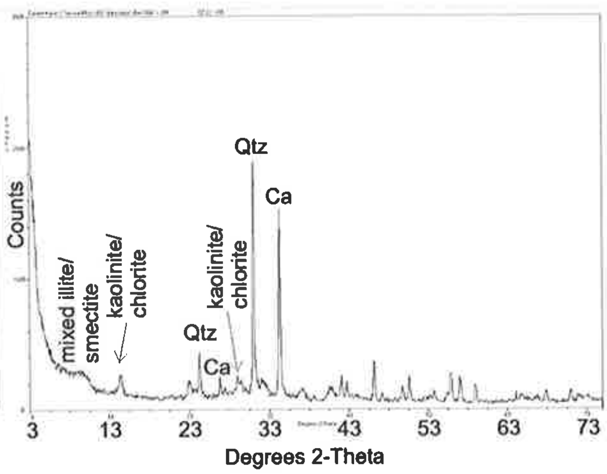




**Depth: 1641-1647m Pth 3538psi SC: 614m oil**

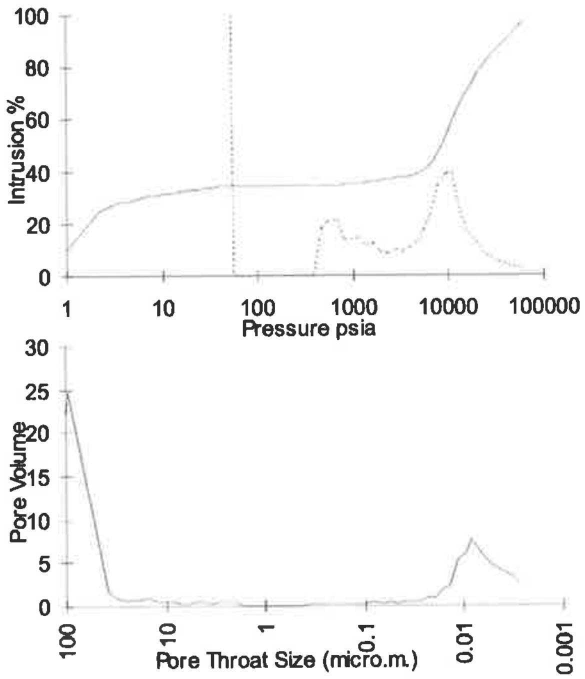


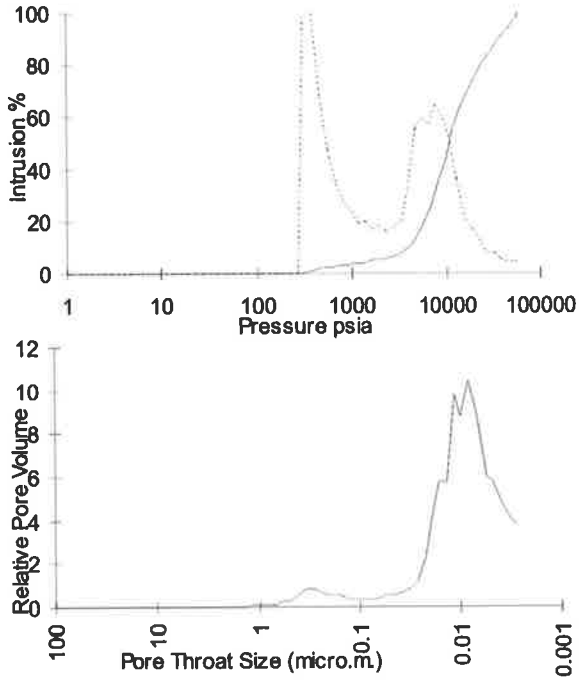



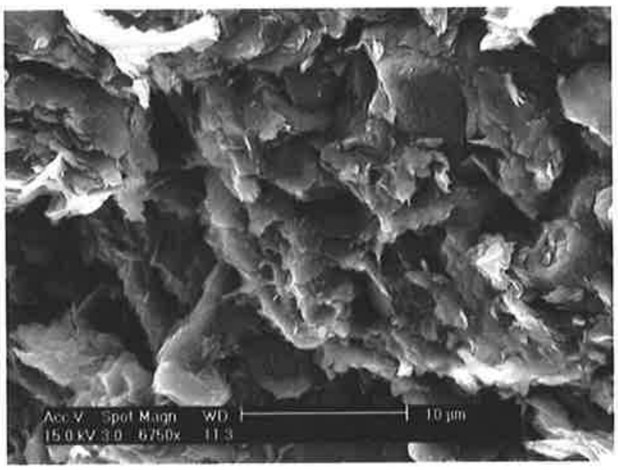
# Rainier 1

Depth: 1659-1661m Pth 4330psi SC:1024m oil



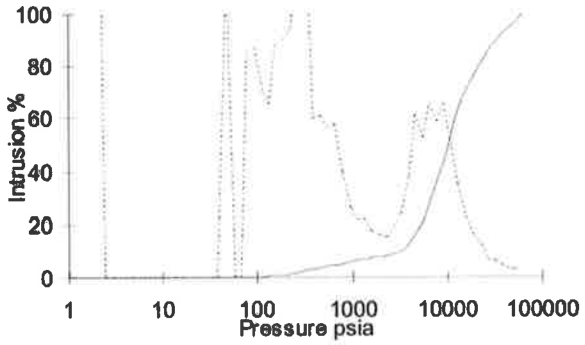

Depth: 1661.5m core vertical intrustion
Pth 3564psi SC: 618m oil

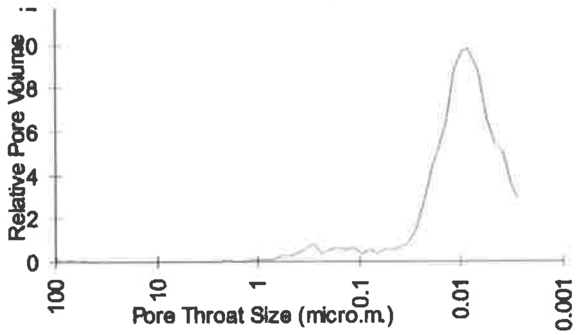


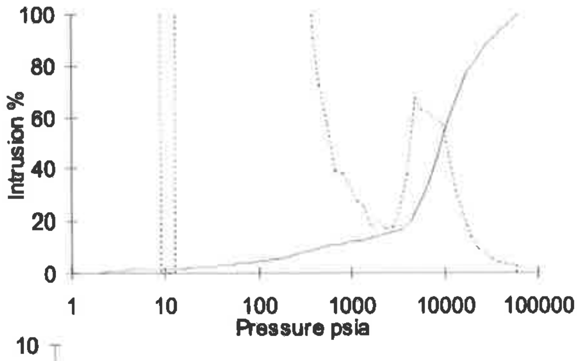
# Rainier 1

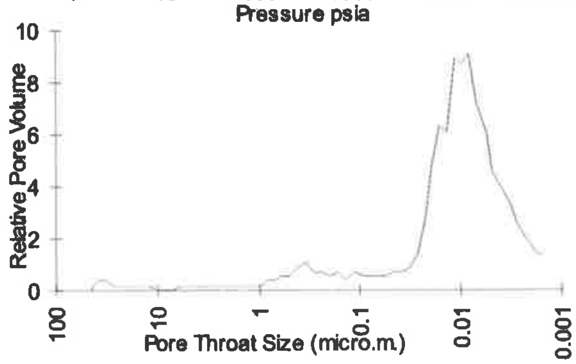
Depth: 1661.5m core horizontal intrusion
Pth 3556psi SC: 617m oil



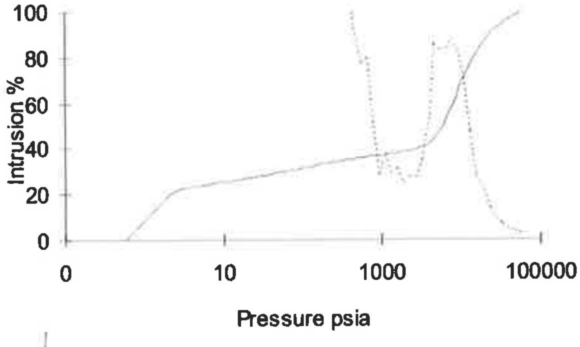

Depth: 1661.5m core bulk
Pth 3555 psi SC: 617m oil

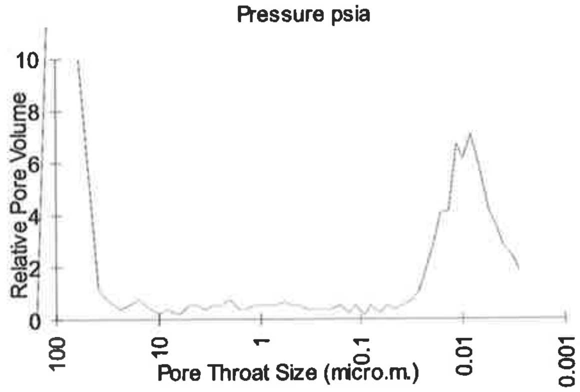


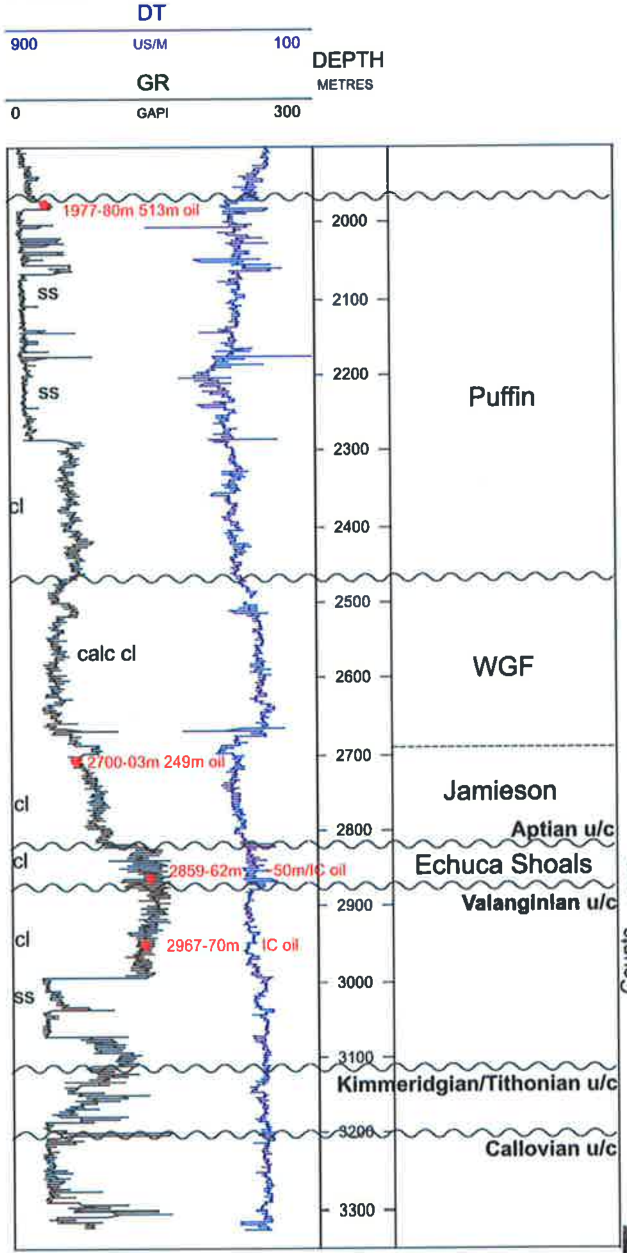
# Rainier 1

Depth: 1661.5m core synthetic cuttings
Pth 3560psi SC:618m oil

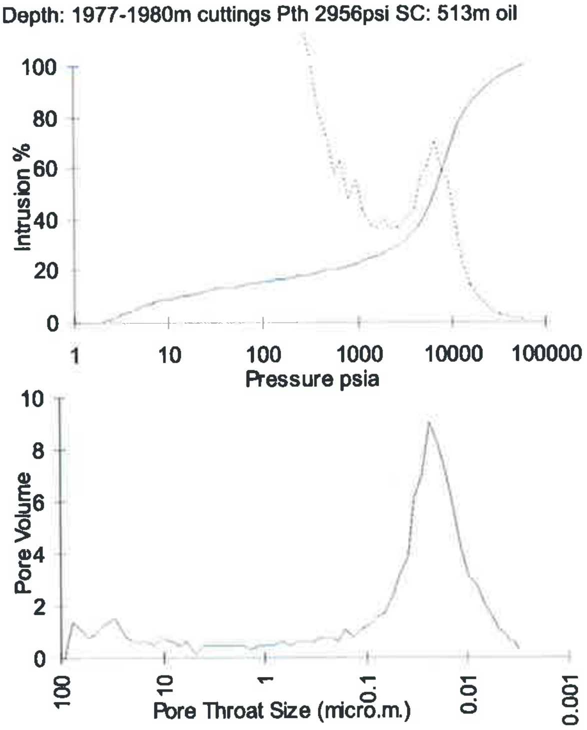


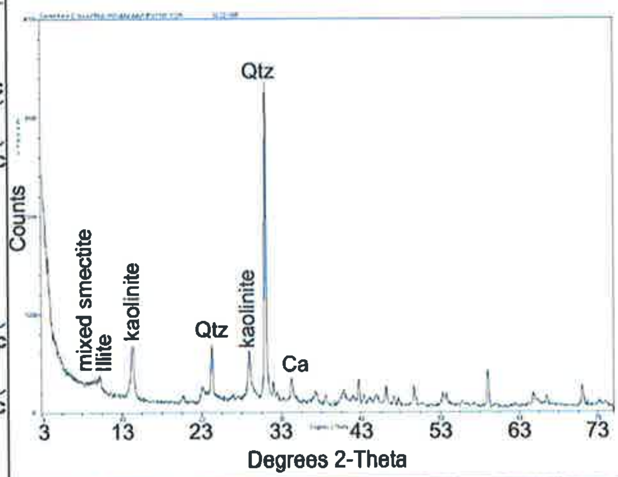



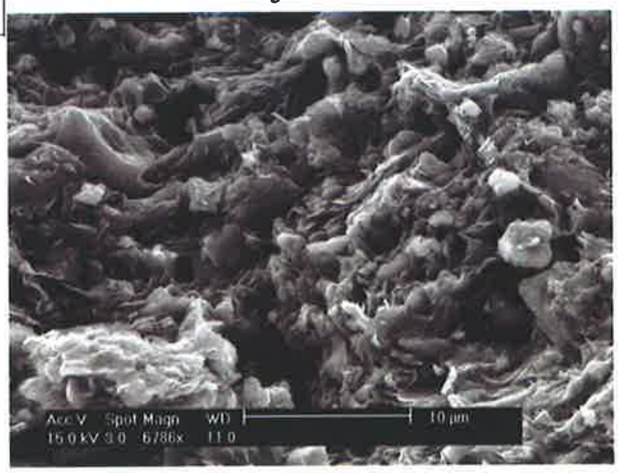
## Rowan 1




Depth: 1977-1980m cuttings Pth 2956psi SC: 513m oil

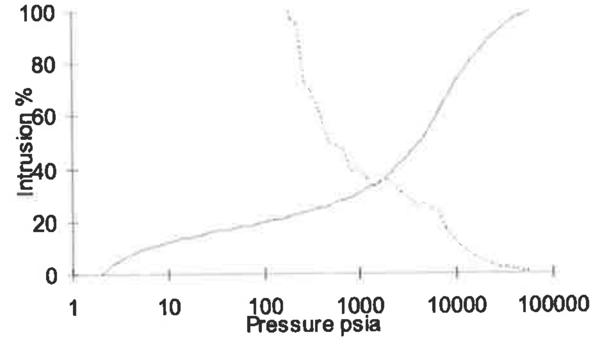


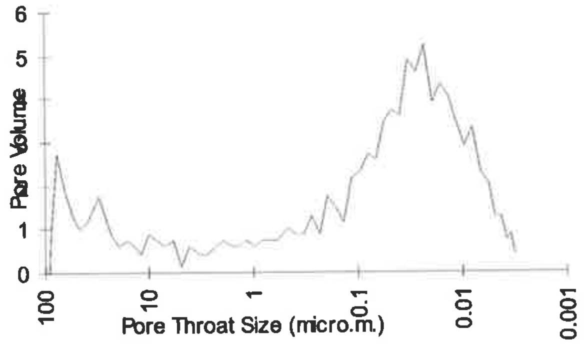



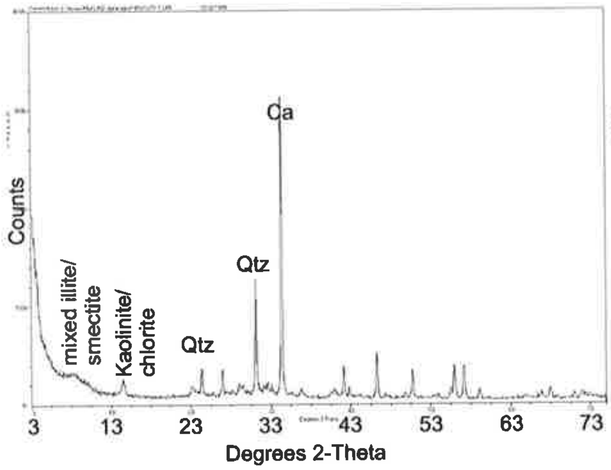



# Rowan 1

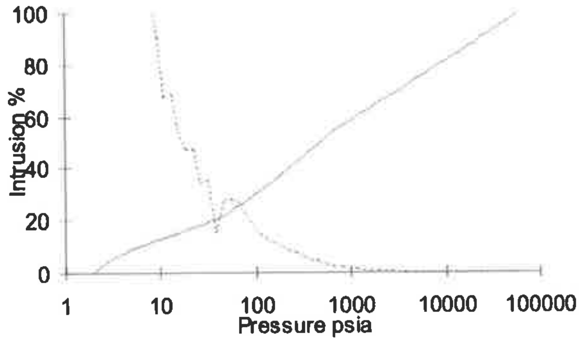
Depth: 2700-2703m Pth 1443psi SC: 249m oil

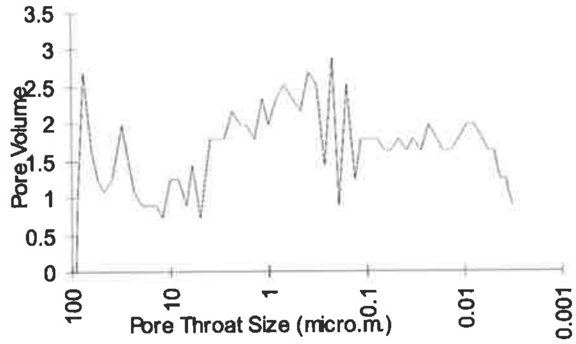


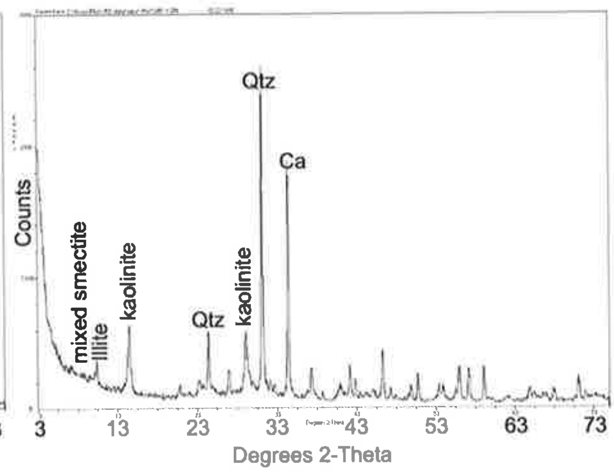




Depth: 2859-2862m Pth psi SC: 50m?/ICm oil

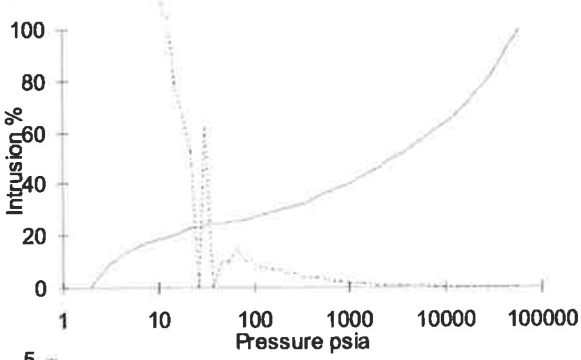


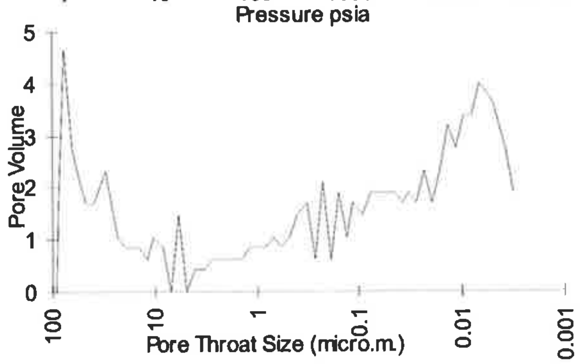



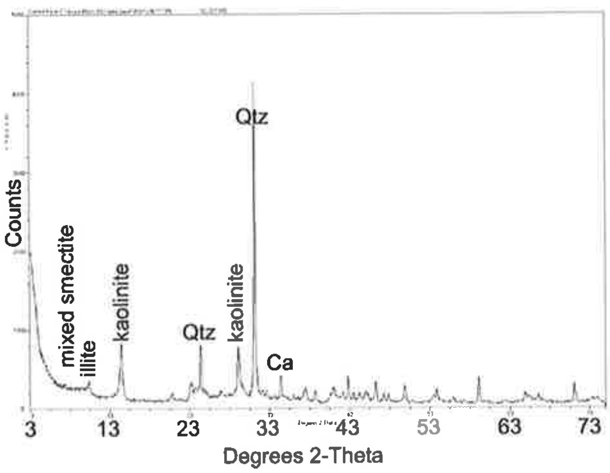



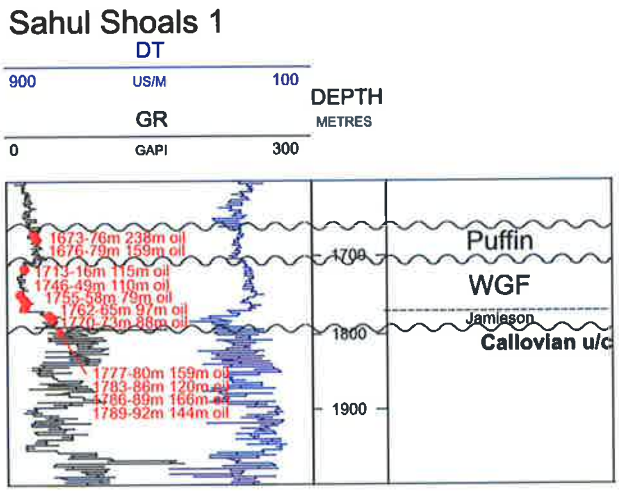
Rowan 1

Depth: 2967-2970m Pth Inconclusive

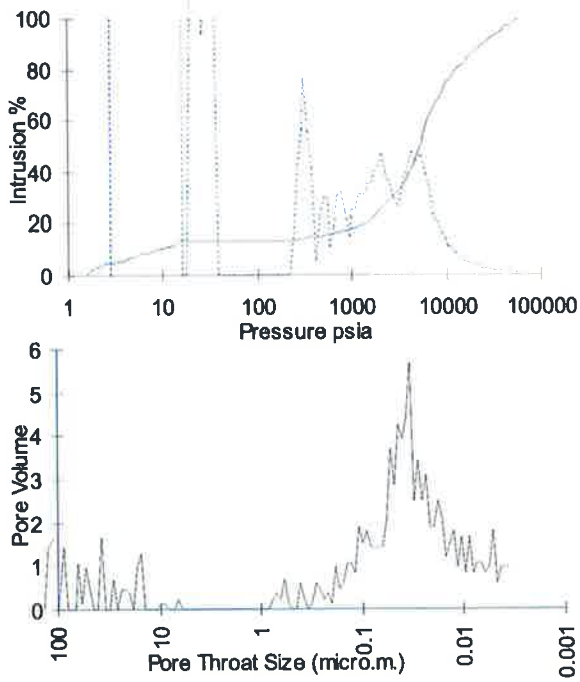


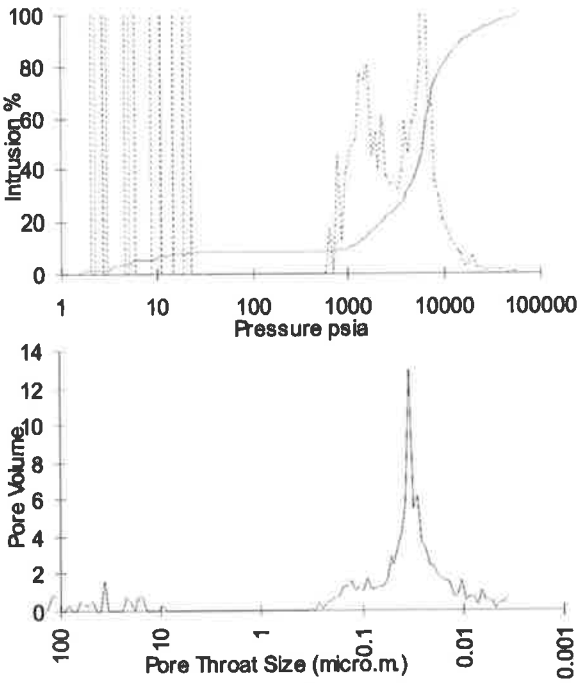



Depth: 1673-1676m cuttings Pth 1378psi SC: 238m oil

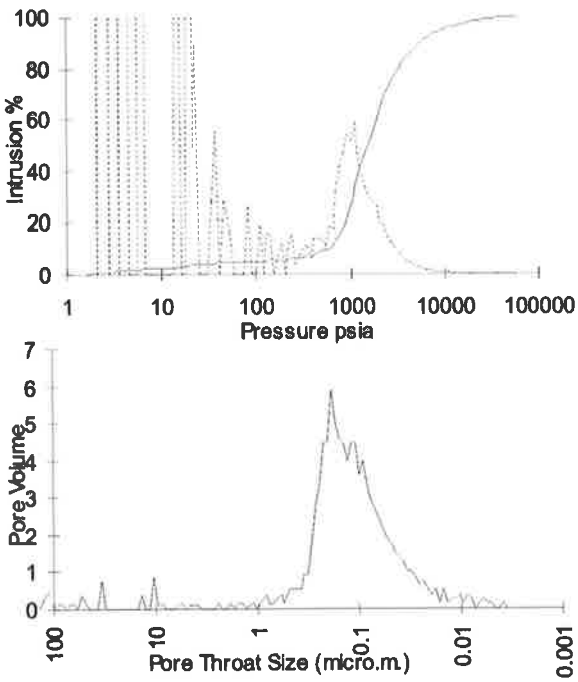


# Sahul Shoals 1

Depth: 1676-1679m Pth 922psi SC:159m oil

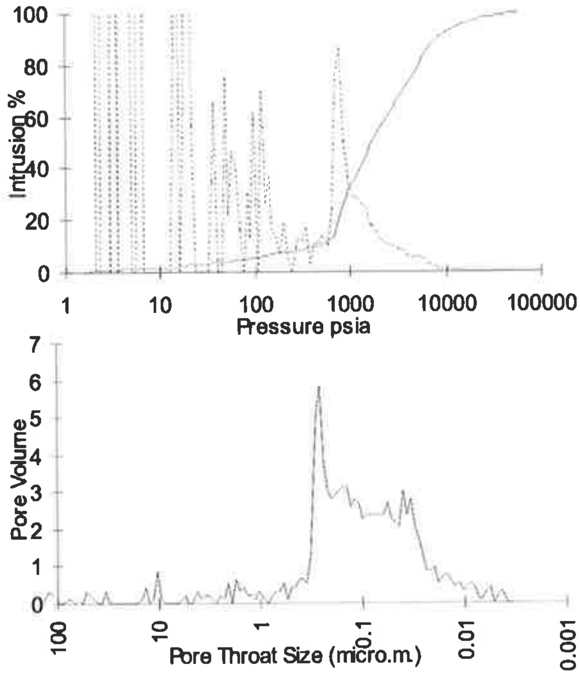



Depth: 1713-1716m Pth 670psi SC: 115m oil

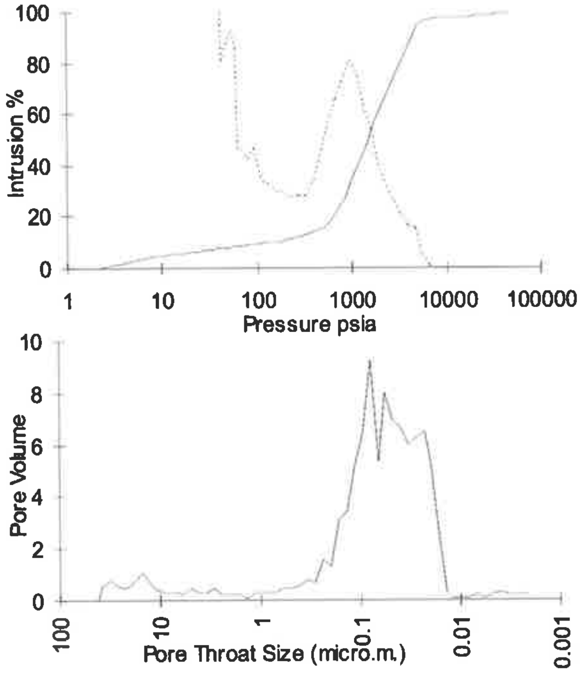


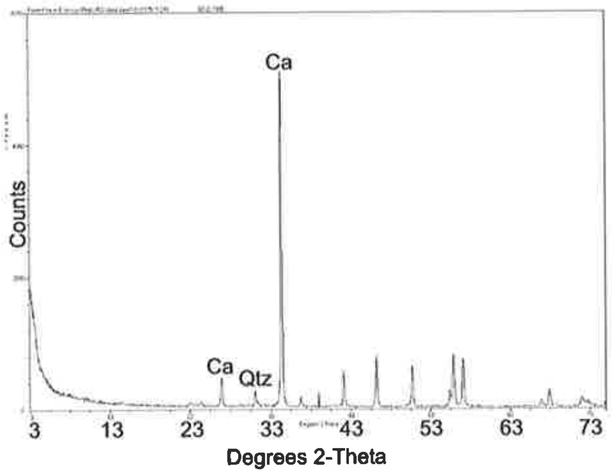
## Sahul Shoals 1

**Depth: 1746-1749.5m Pth 643psi SC:110m oil**



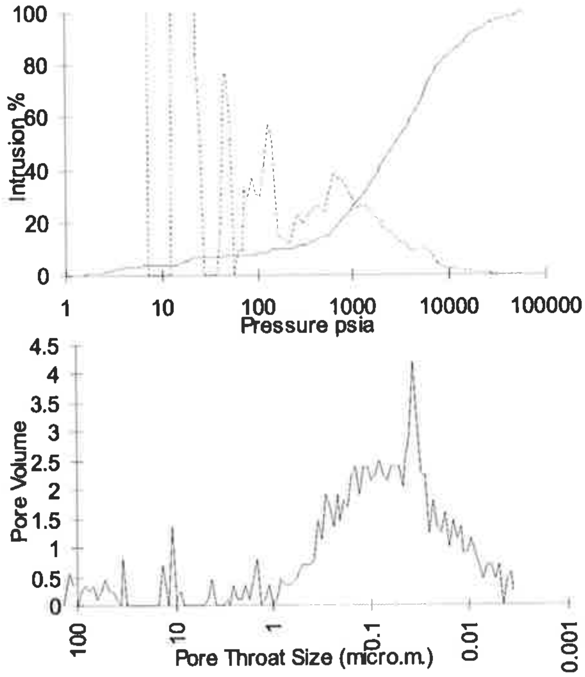

**Depth: 1755-1758m Pth 464psi SC: 79m oil**



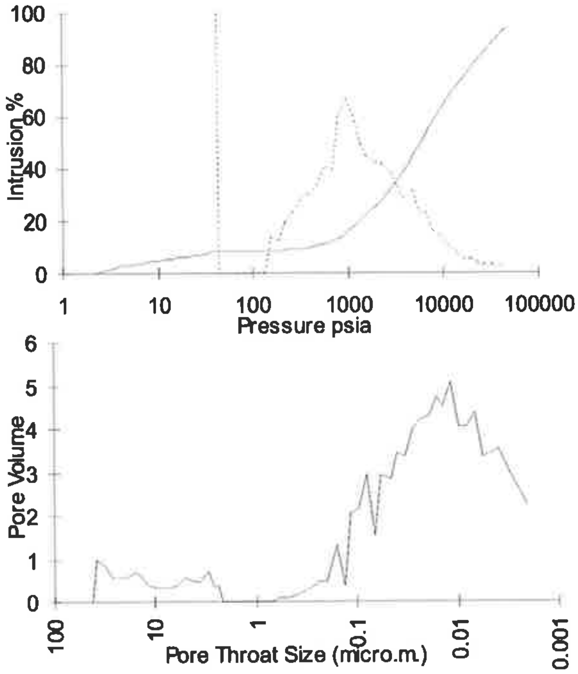



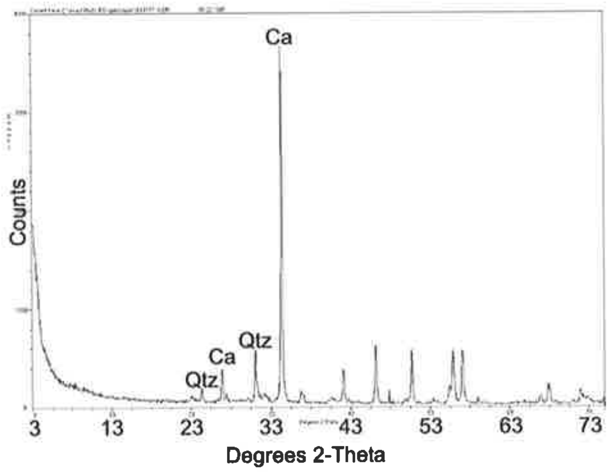
# Sahul Shoals 1

**Depth: 1762-1765m Pth 566psi SC: 97m oil**



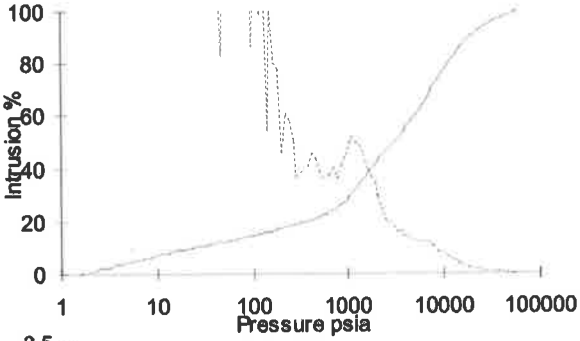

**Depth: 1770-1773m Pth 513psi SC: 88m oil**

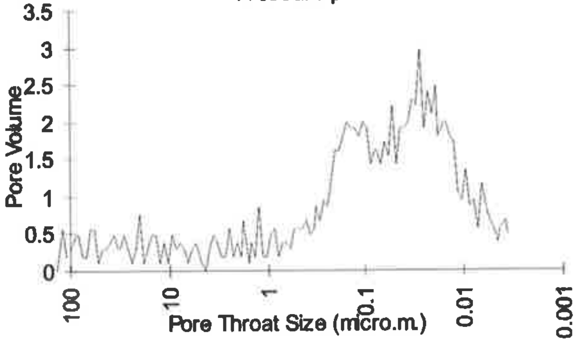


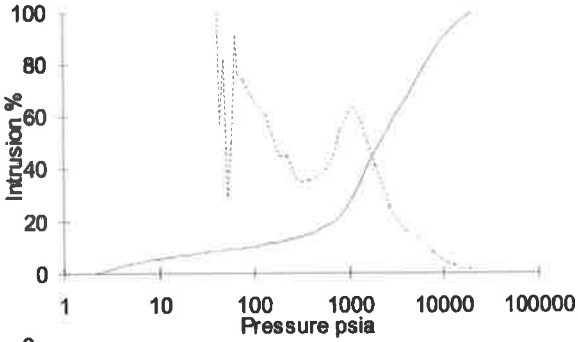
# Sahul Shoals 1

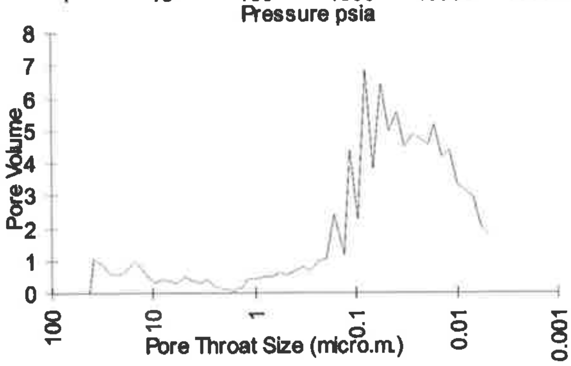
**Depth: 1777-1780m Pth 922psi SC: 159m oil**

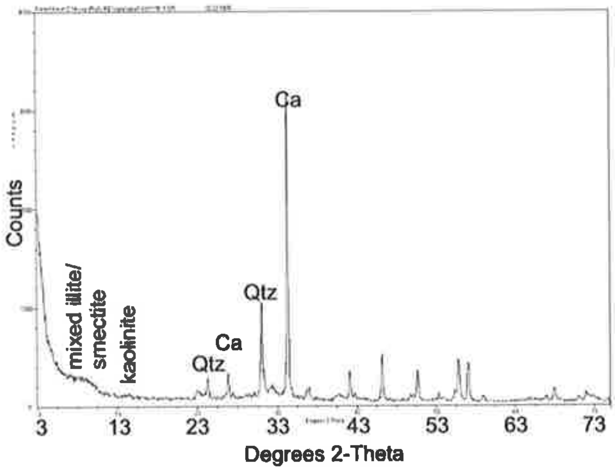



**Depth: 1783-1786m Pth 700psi SC: 120m oil**

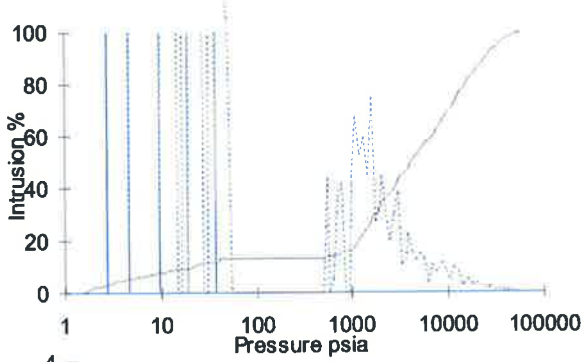


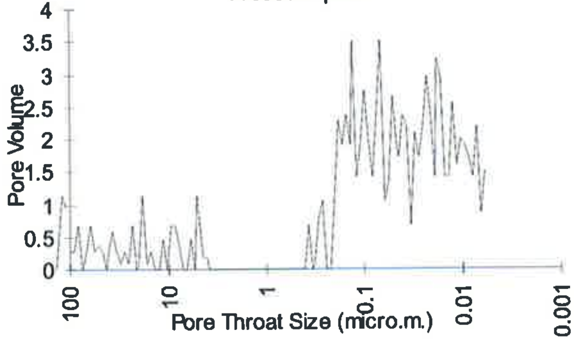



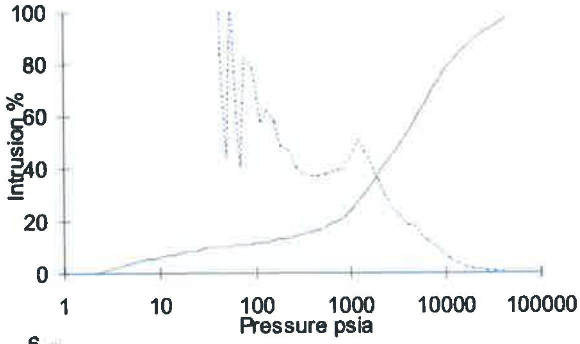
# Sahul Shoals 1

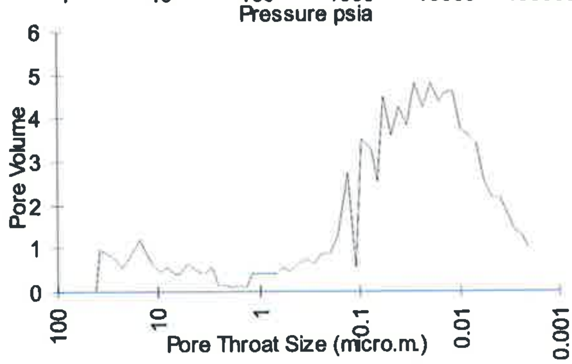
Depth: 1786-1789m Pth 962psi SC: 166m oil

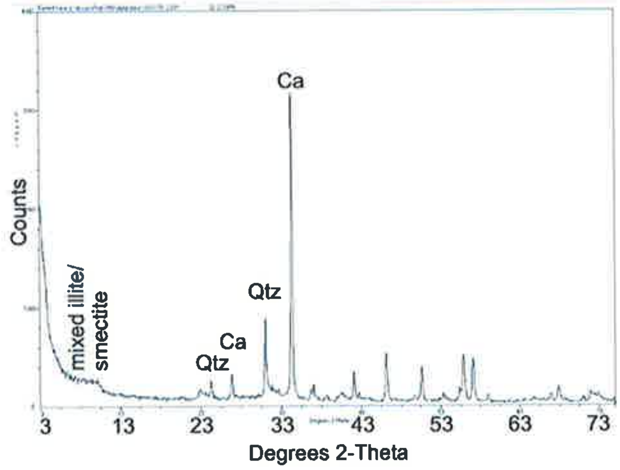


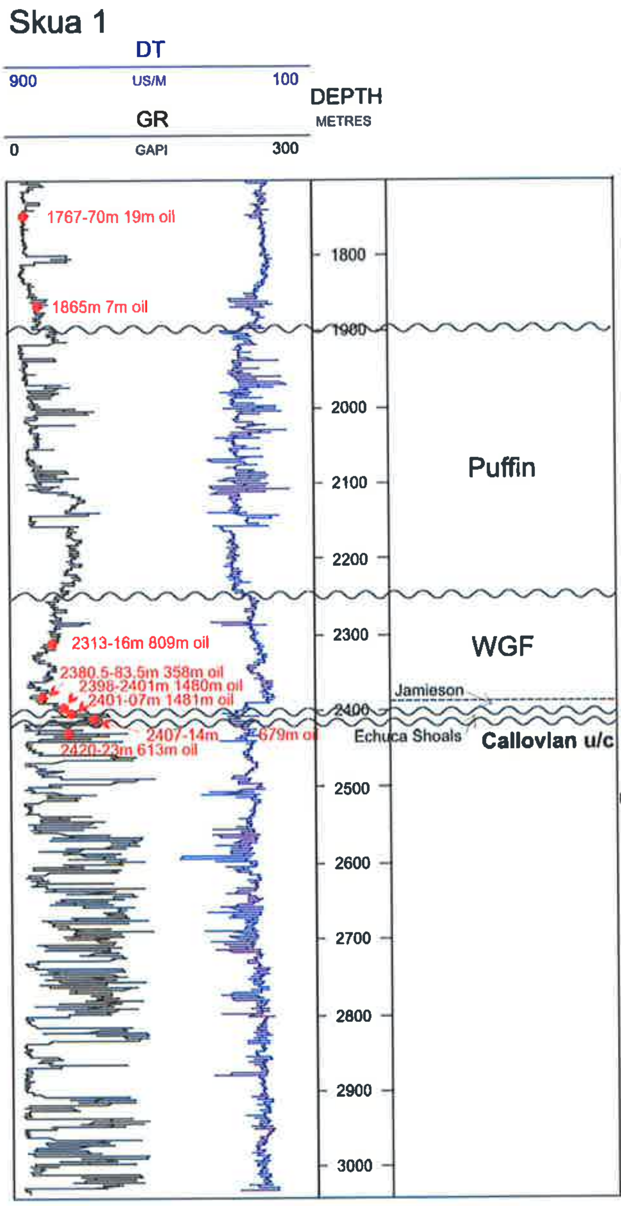




Depth: 1789-1792m Pth 839psi SC: 144m oil

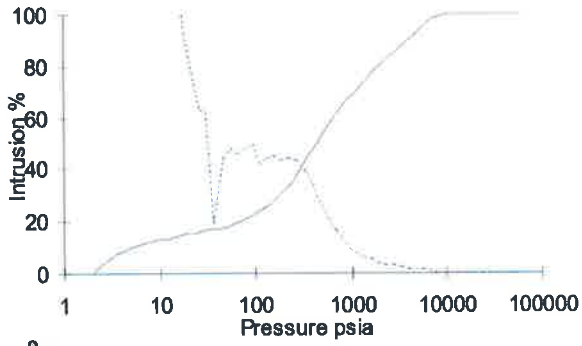


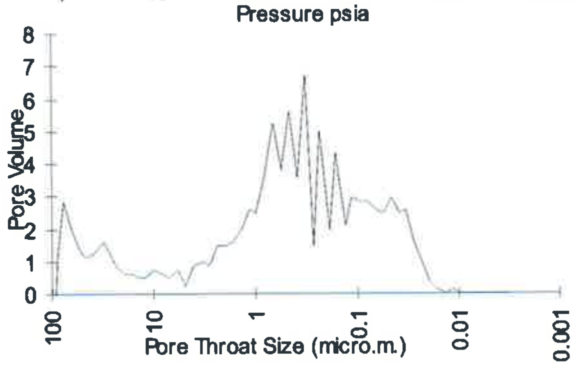



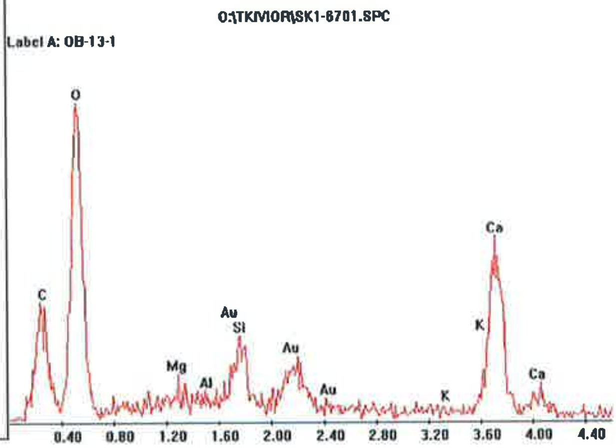



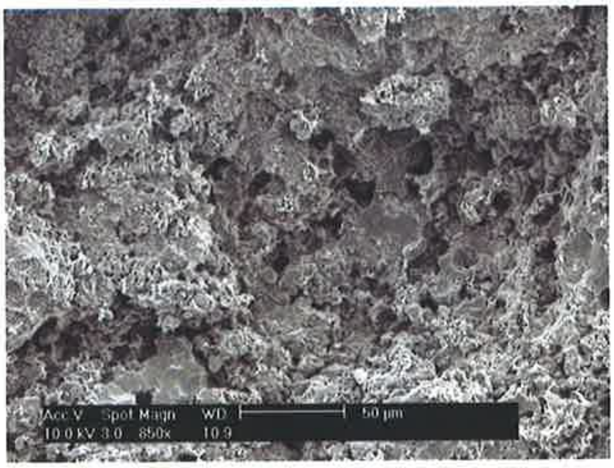



Depth: 1767-1770m cuttings Pth 120psi SC: 19m oil



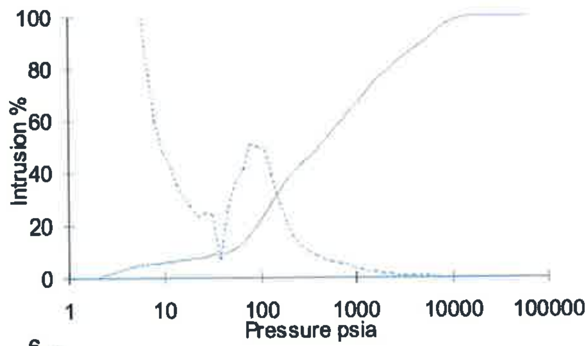



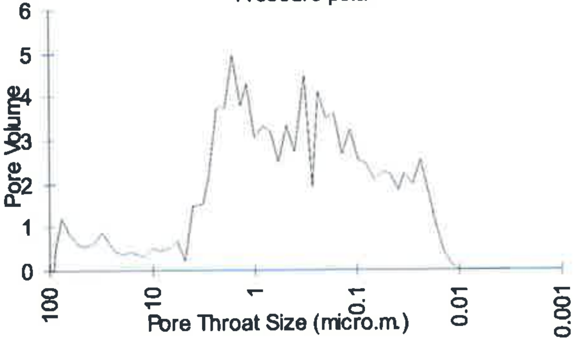



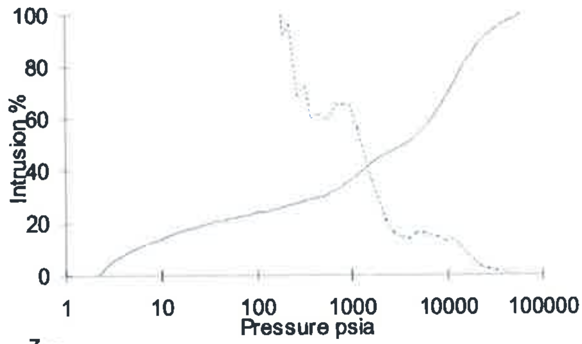
## Skua 1

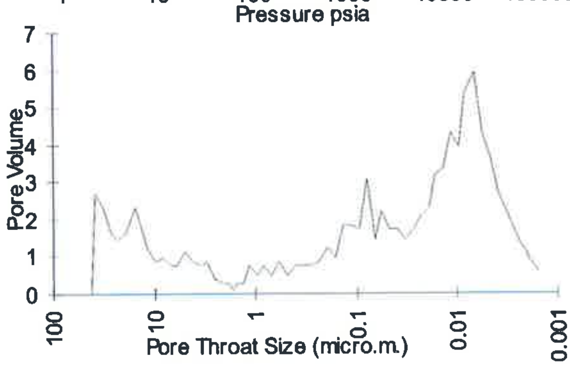
**Depth: 1865m Pth 51psi SC: 7m oil**

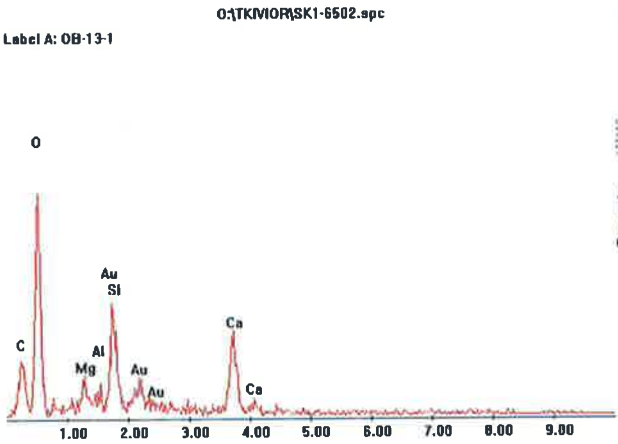


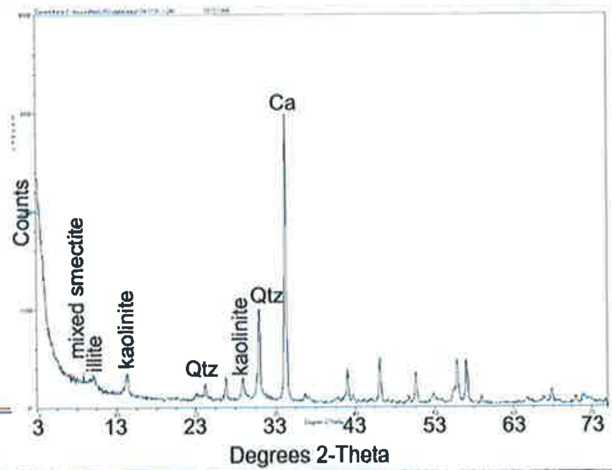




**Depth: 2313-2316m Pth 809psi SC: 139m oil**

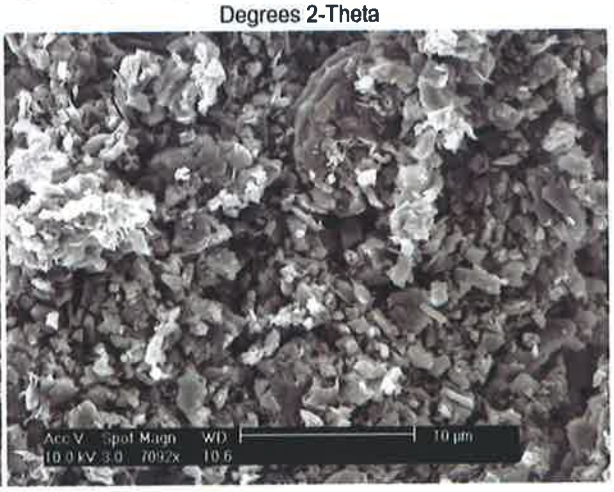


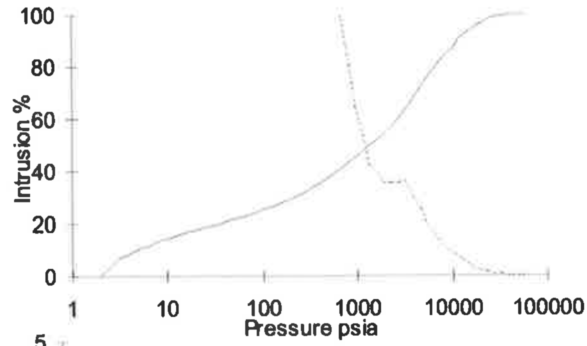



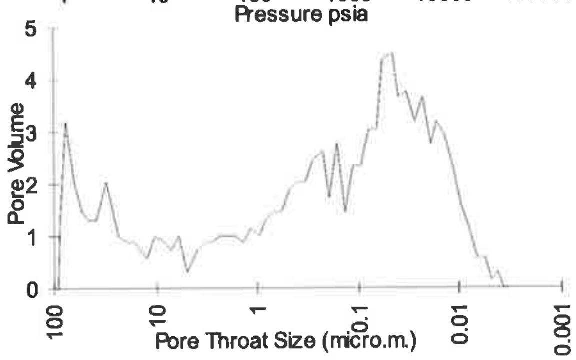


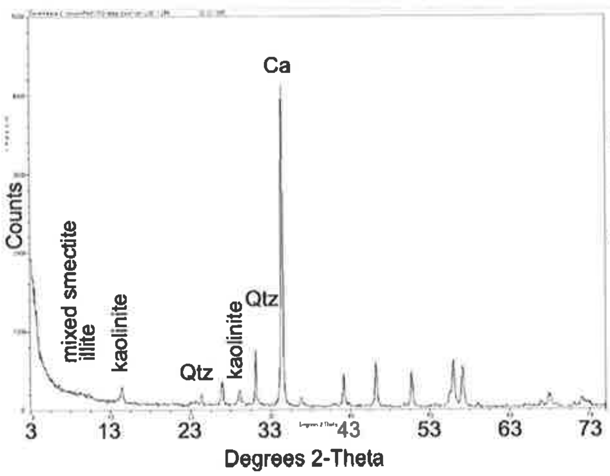


# Skua 1

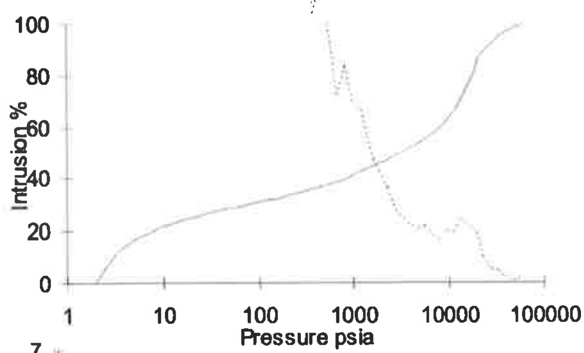
Depth: 2380.5-2383.5m Pth 2068psi SC: 358m oil

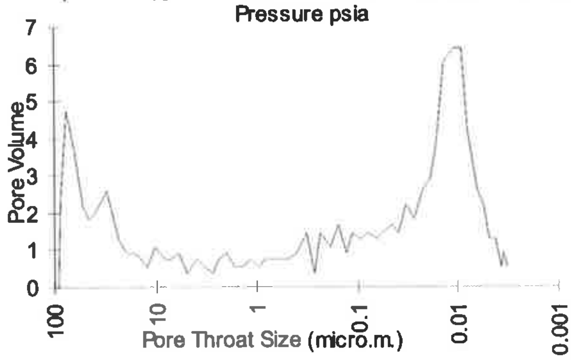


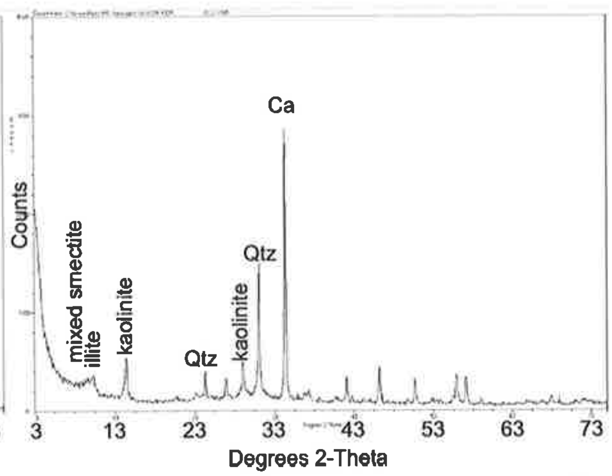



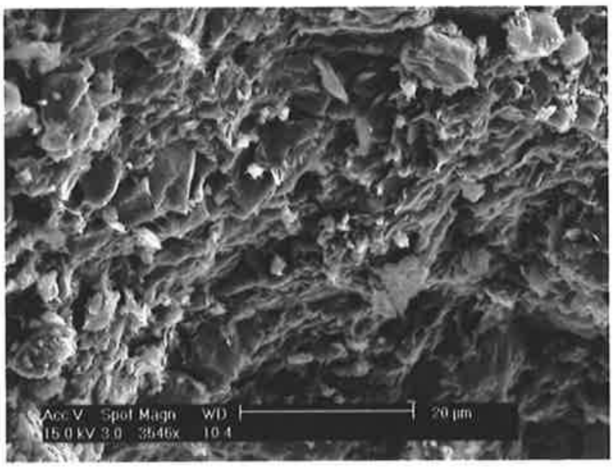




Depth: 2398-2401m Pth 8515psi SC: 1480m oil



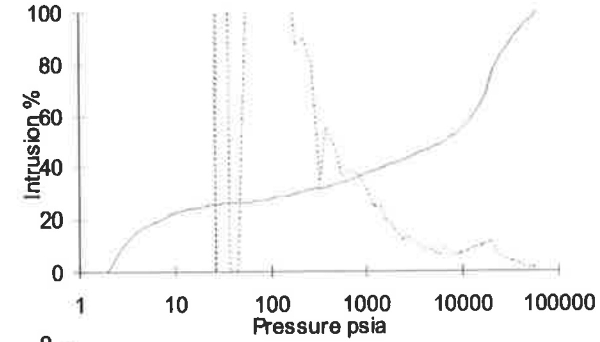



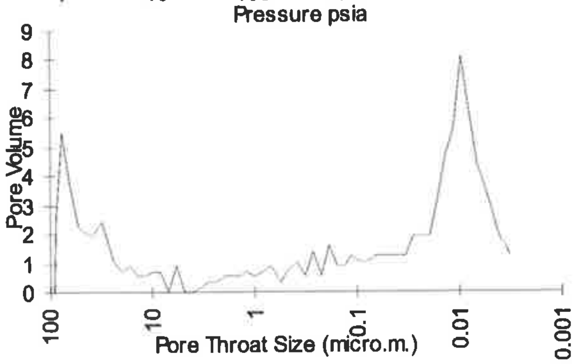



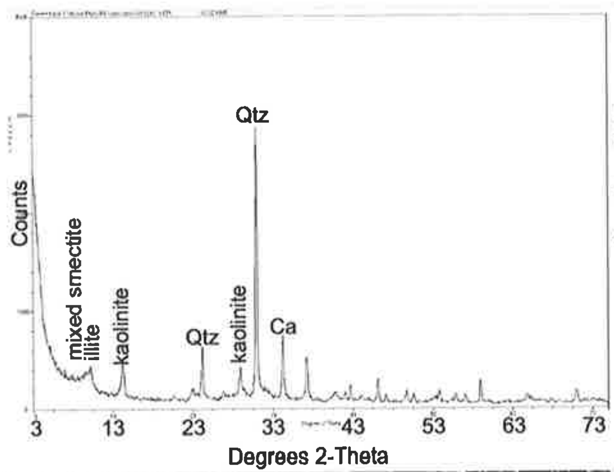



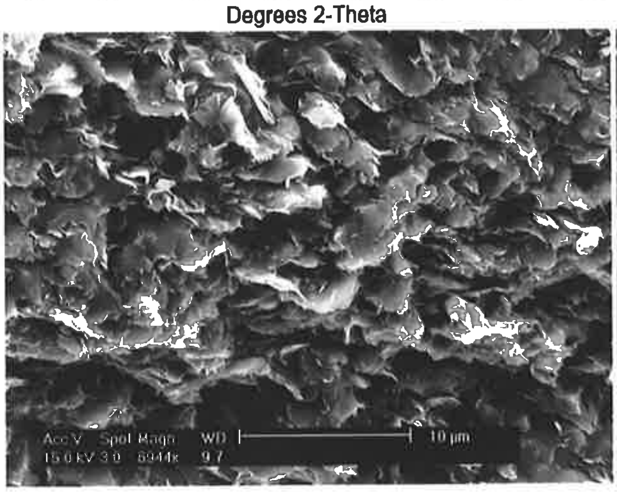
## Skua 1

**Depth: 2404-2407m Pth 8525psi SC: 1481m oil**

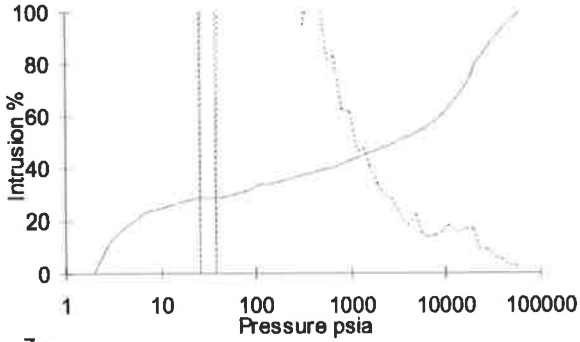


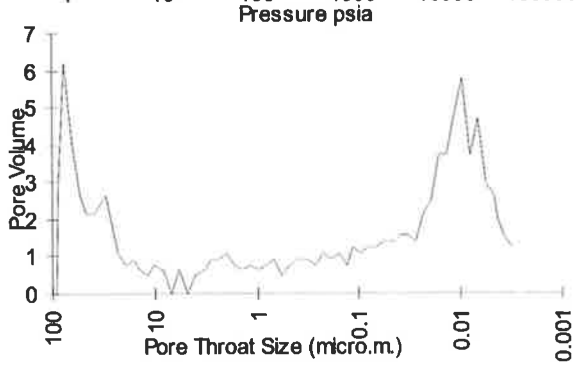



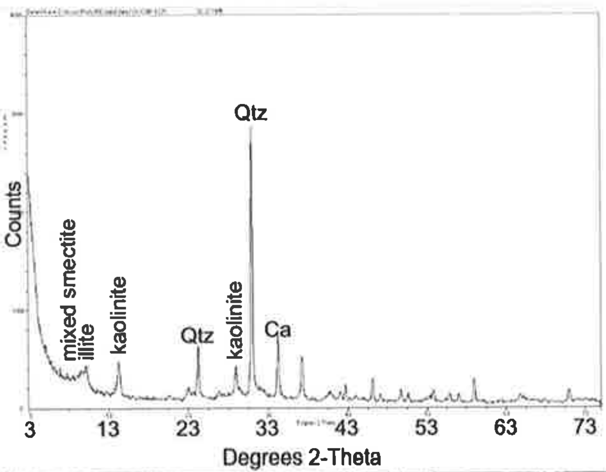



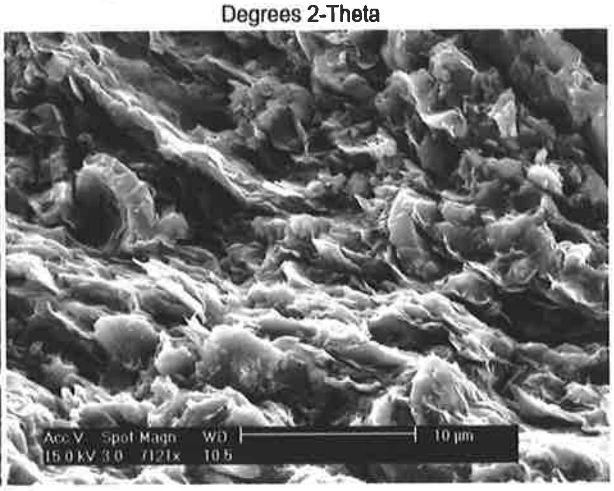




**Depth: 2407-2414m Pth 8465psi SC: 1481m oil**



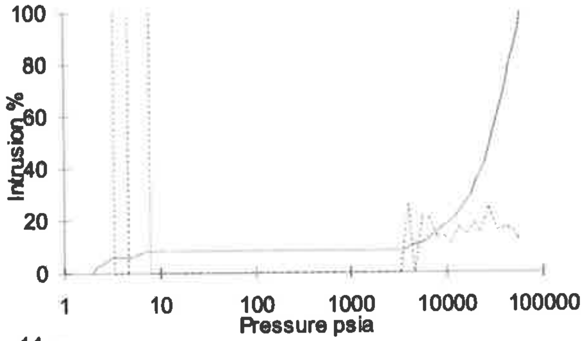



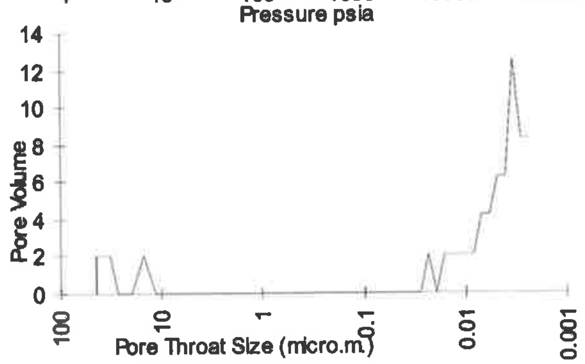



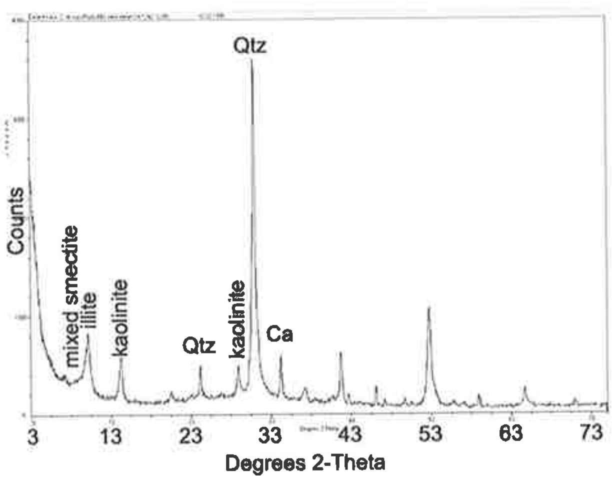



# Skua 1

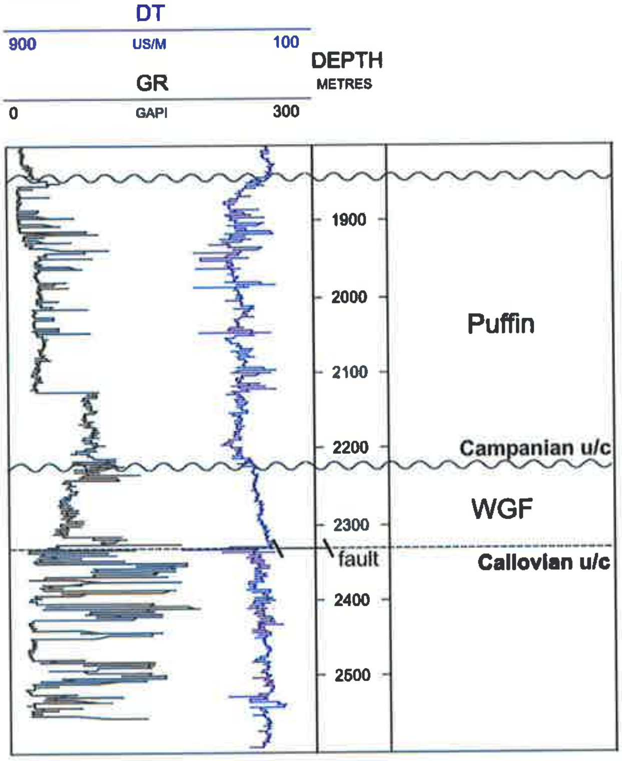
Depth: 2420-2423m Pth 3535psi SC: 613m oil



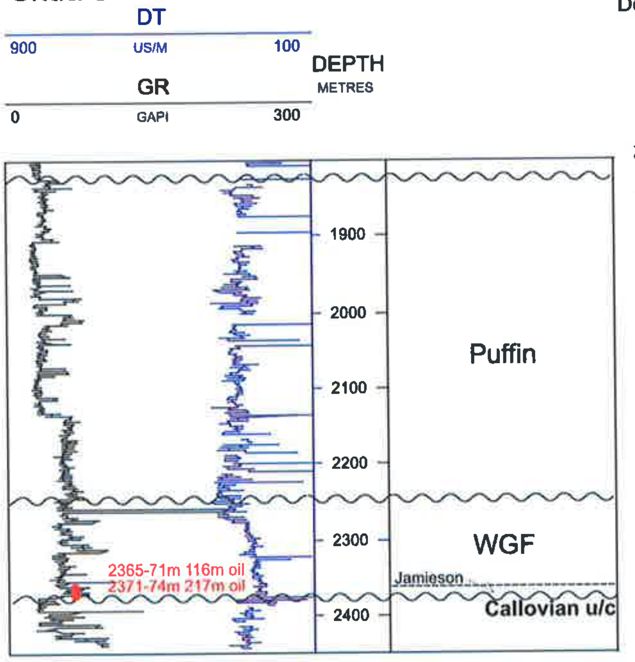



## Skua 2

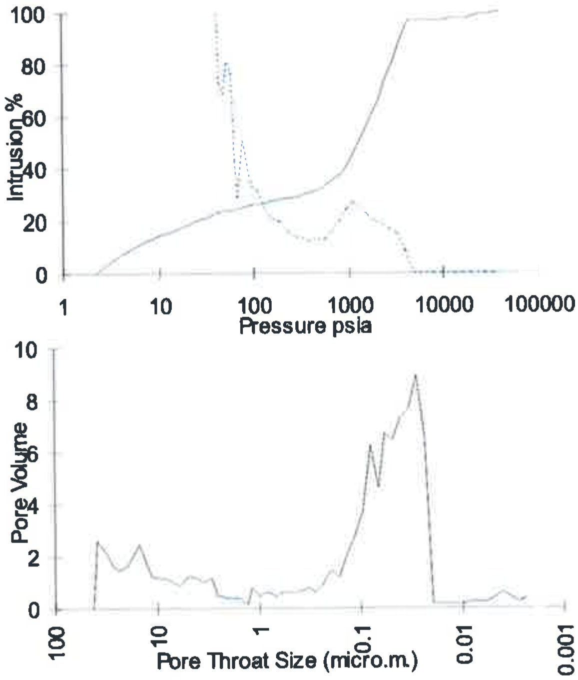


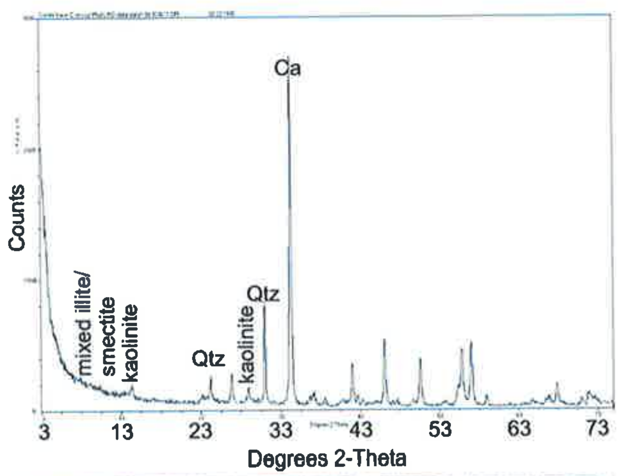
DT
900
US/M
100
DEPTH
METRES
GR
0
GAPI
300
1900
2000
2100
2200
2300
2400
2500
Puffin
Campanian u/c
WGF
fault
Callovian u/c

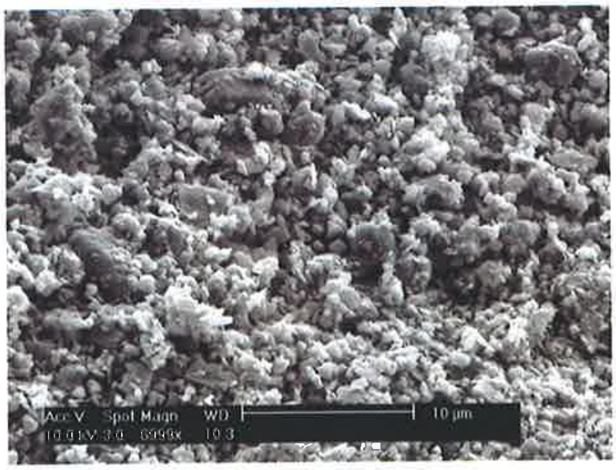
## Skua 3




Depth: 1324-1327m Pth 711psi SC: 122m oil

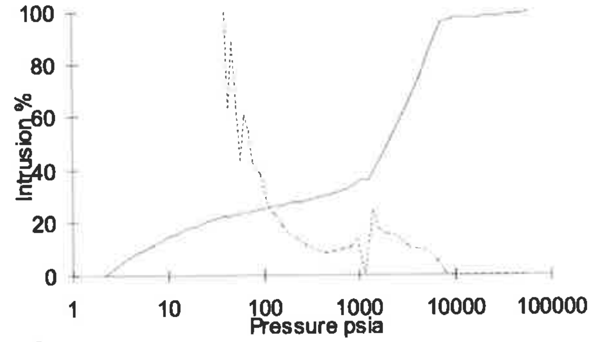


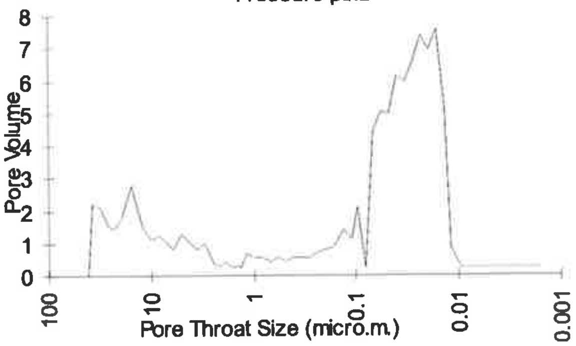



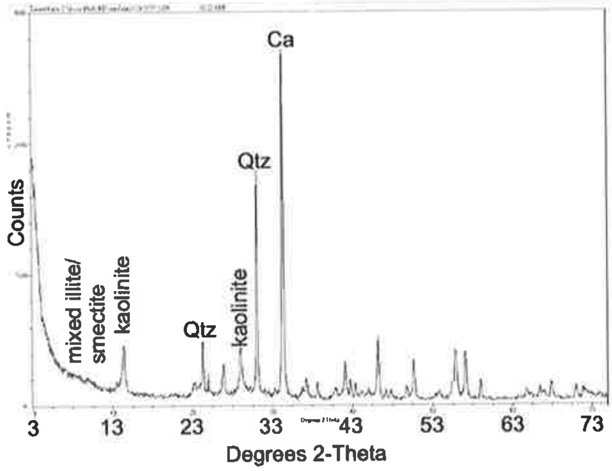



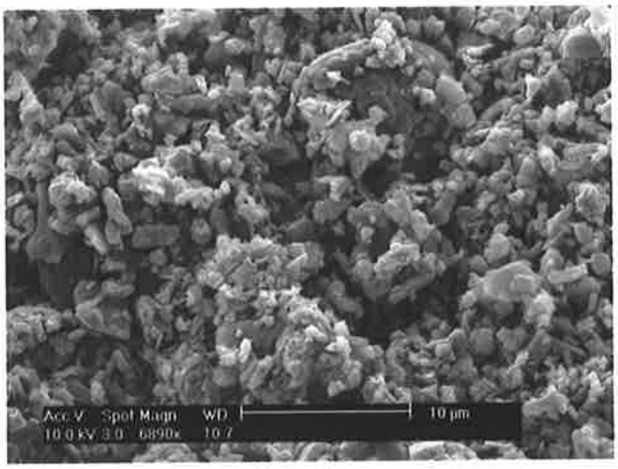
## Skua 3

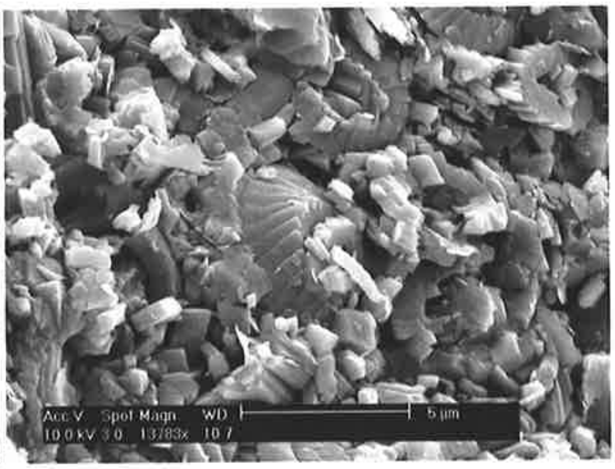
Depth: 2371-2374m Pth 1256psi SC: 217m oil



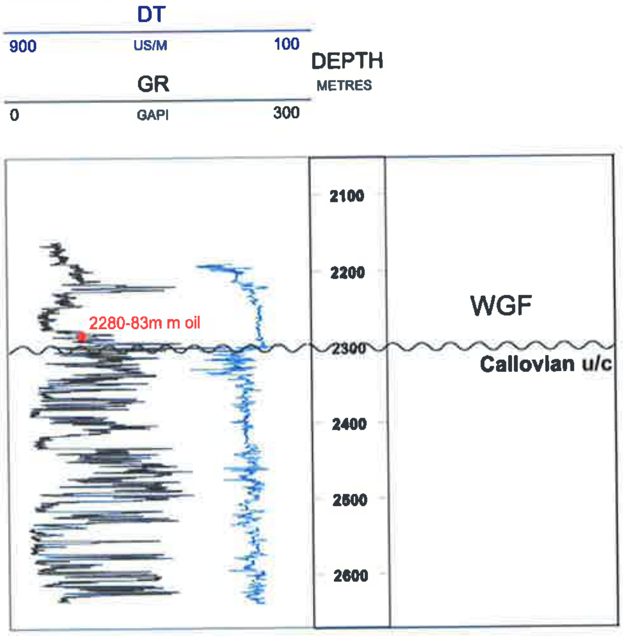



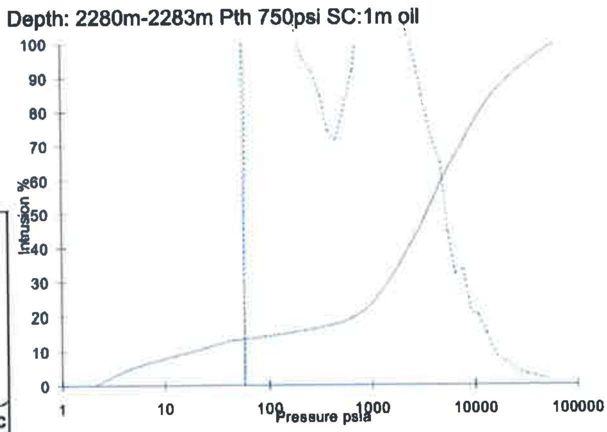



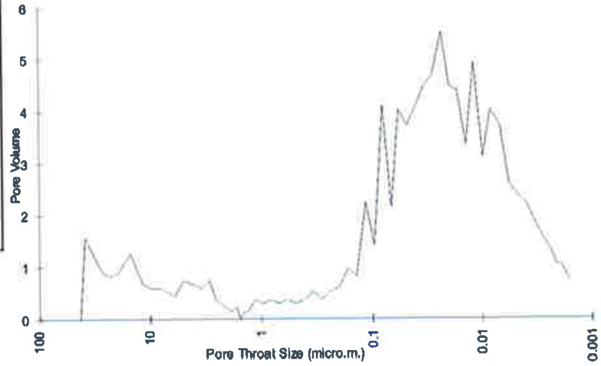



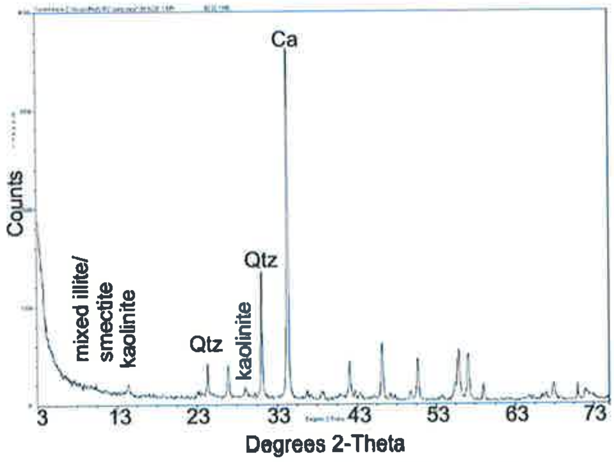



## Skua 4


DT
900 US/M 100
GR
0 GAPI 300
DEPTH
METRES
2100
2200
2300
2400
2500
2600
2280-83m m oil
WGF
Callovian u/c

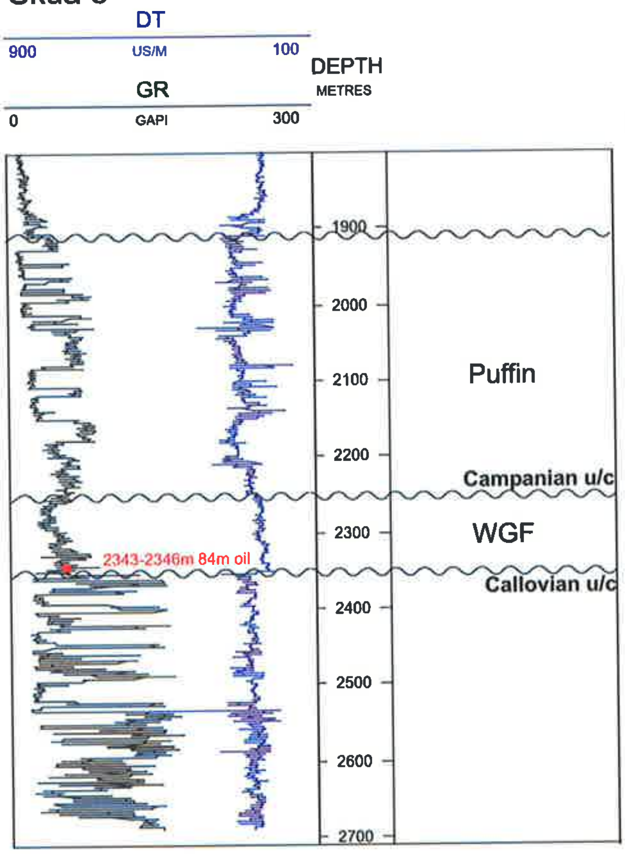

Depth: 2280m-2283m Pth 750psi SC:1m oil
Intrusion %
Pressure psia
0
10
20
30
40
50
60
70
80
90
100
1
10
100
1000
10000
100000


Pore Volume
Pore Throat Size (micro.m.)
100
10
1
0.1
0.01
0.001

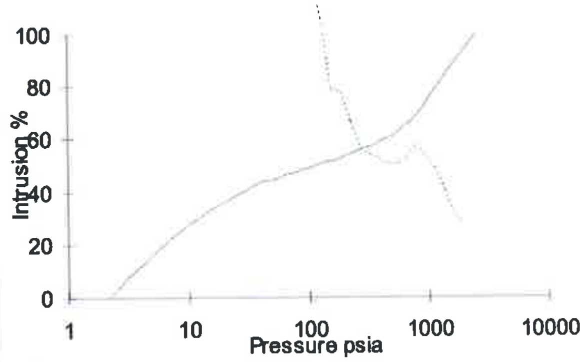

Counts
Ca
Qtz
Qtz
mixed illite/
smectite
kaolinite
kaolinite
3
13
23
33
43
53
63
73
Degrees 2-Theta

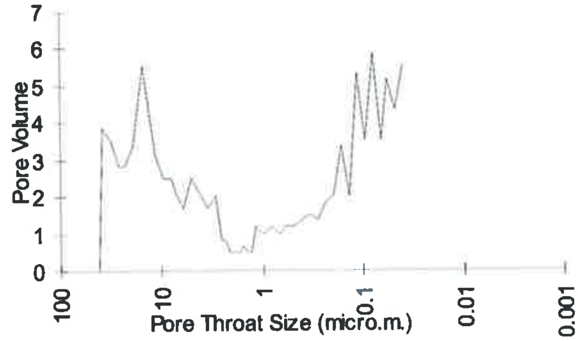

Acc.V Spot Magn WD 5 µm
10.0 kV 3.0 13805x 10.9

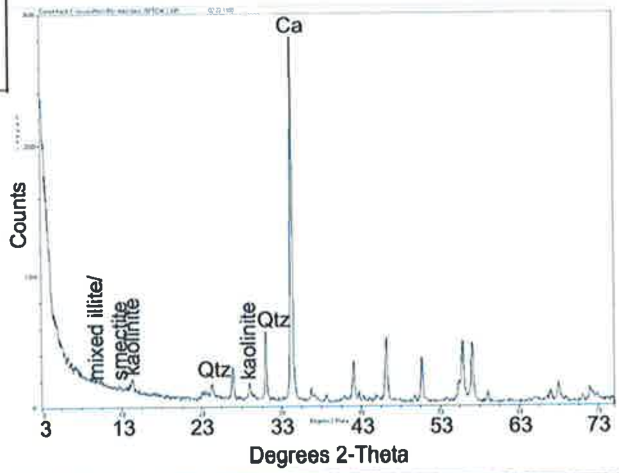
## Skua 5



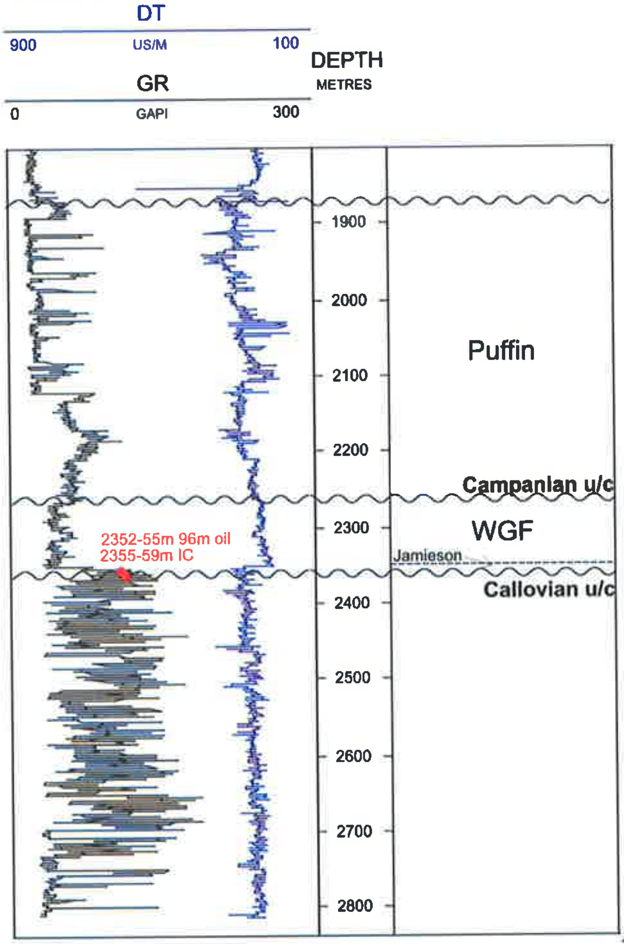

Depth: 2343-2346m cuttings Pth 491psi SC: 84m oil



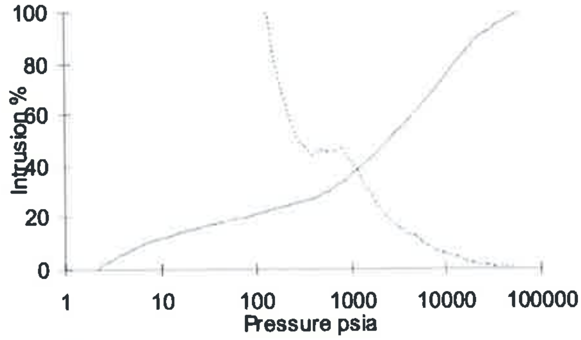



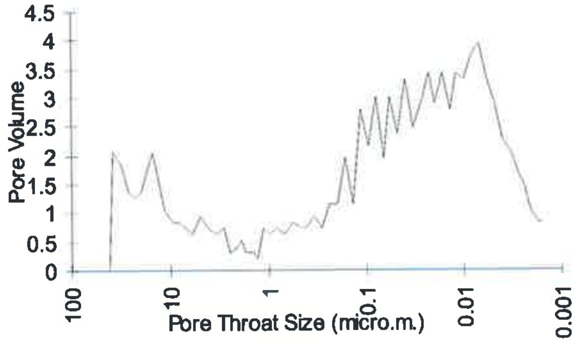



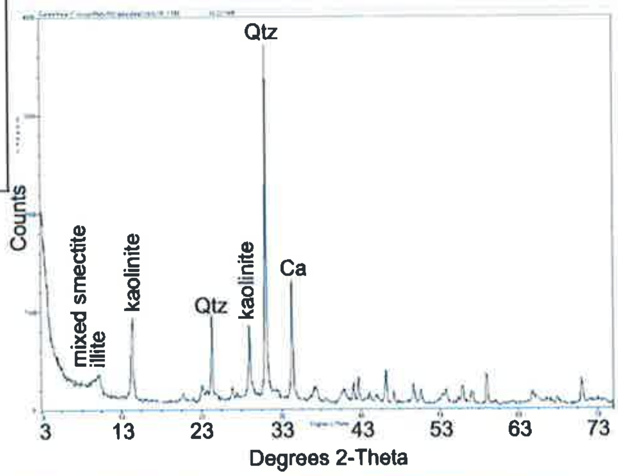

## Skua 6

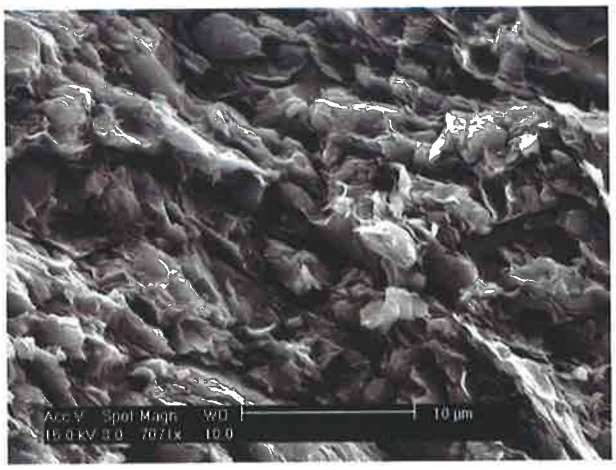



Depth: 2352-2355m cuttings Pth 9psi SC: 361m oil



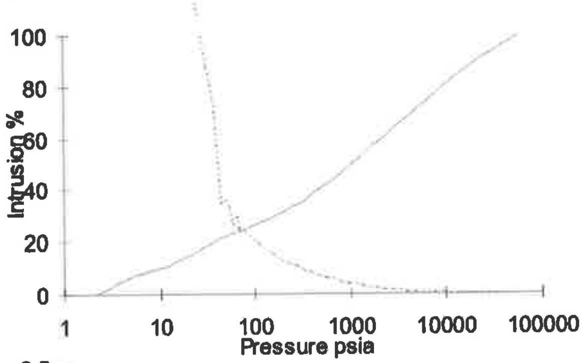



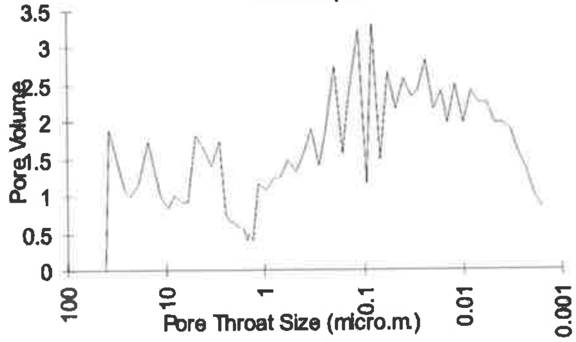



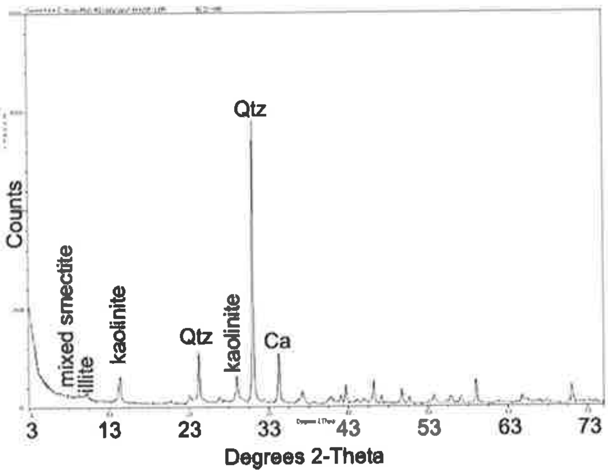



# Skua 6

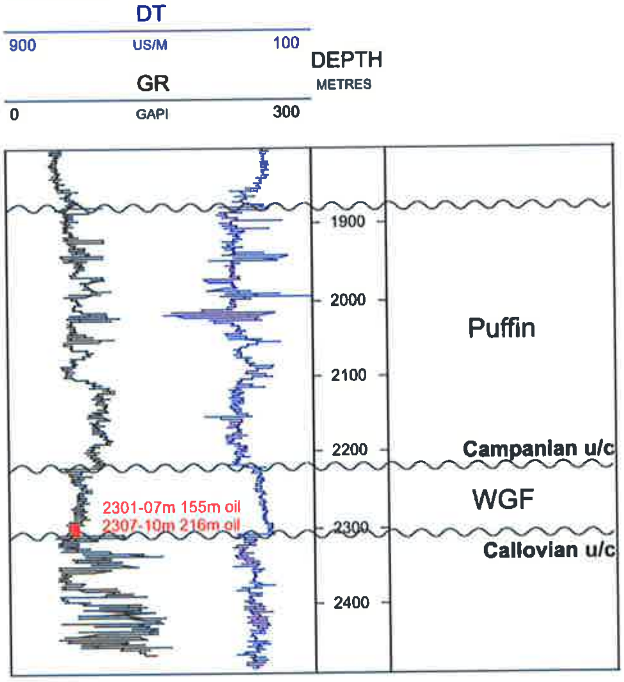
**Depth: 2355-2358m Pth Inconclusive**



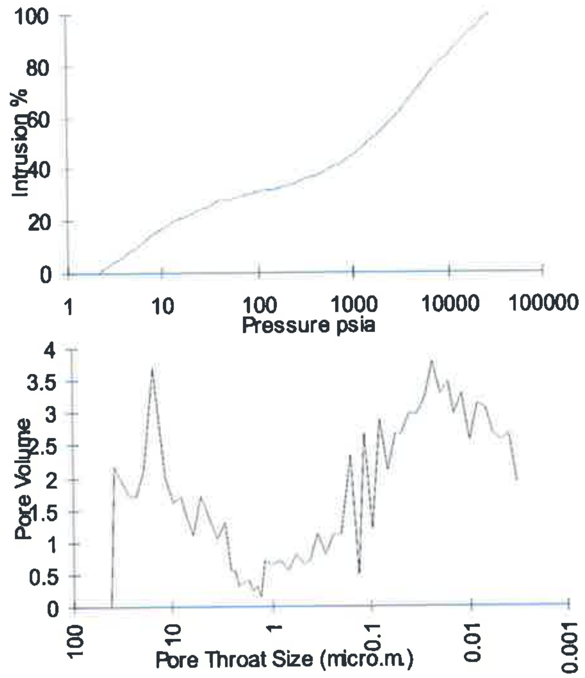



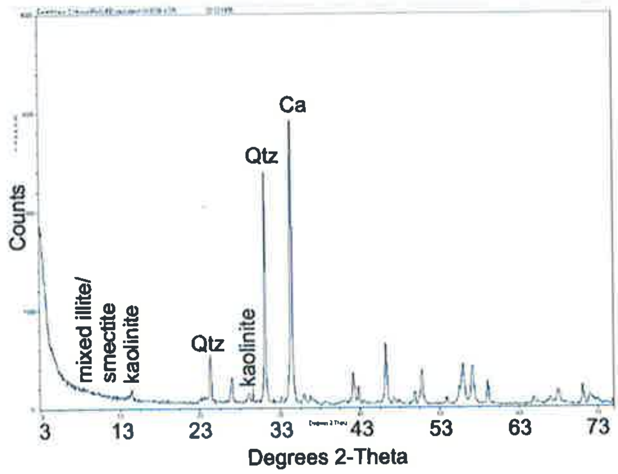



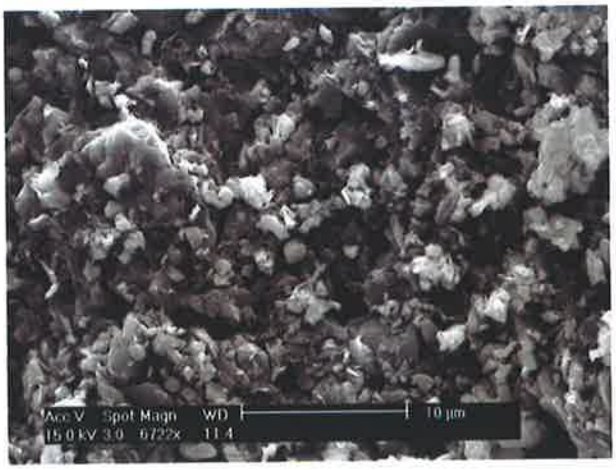
Skua 8




Depth: 2301-2307m cuttings Pth 900psi SC: 155m oil

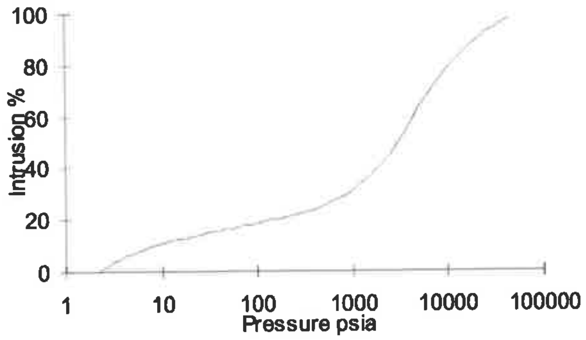


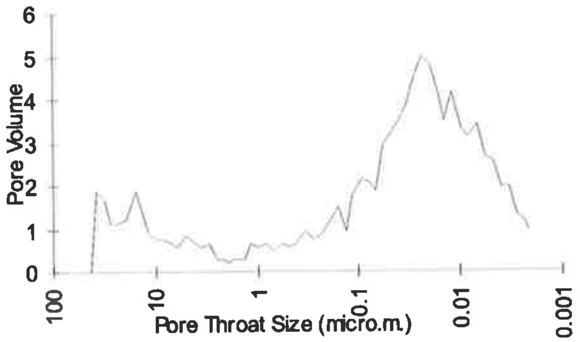



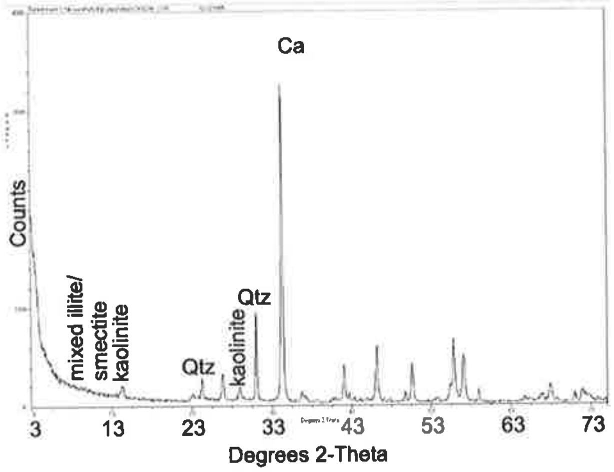



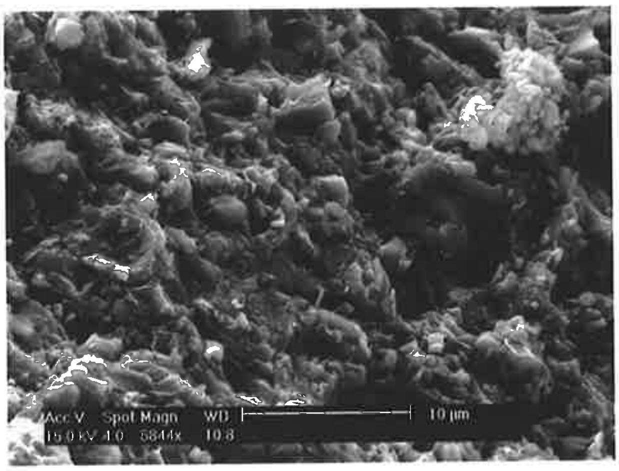
# Skua 8

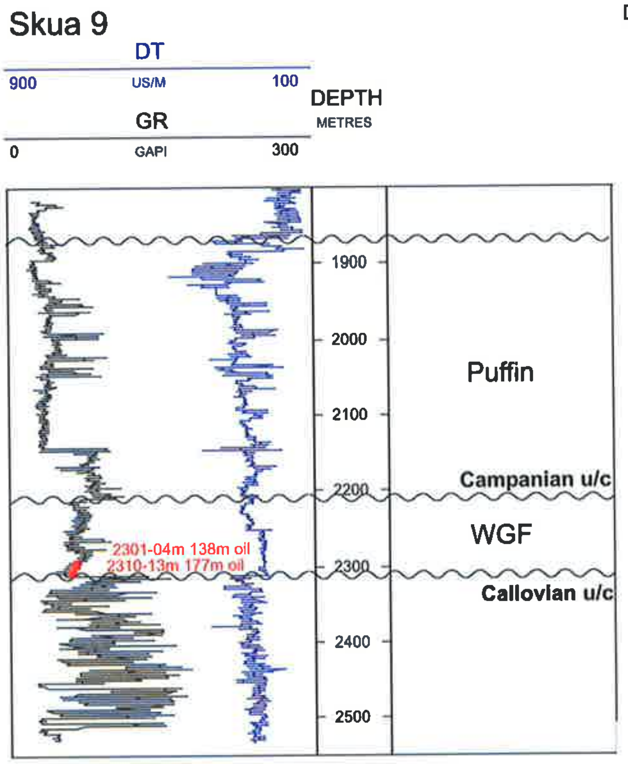
Depth: 2307-2310m Pth 1251psi SC: 216m oil

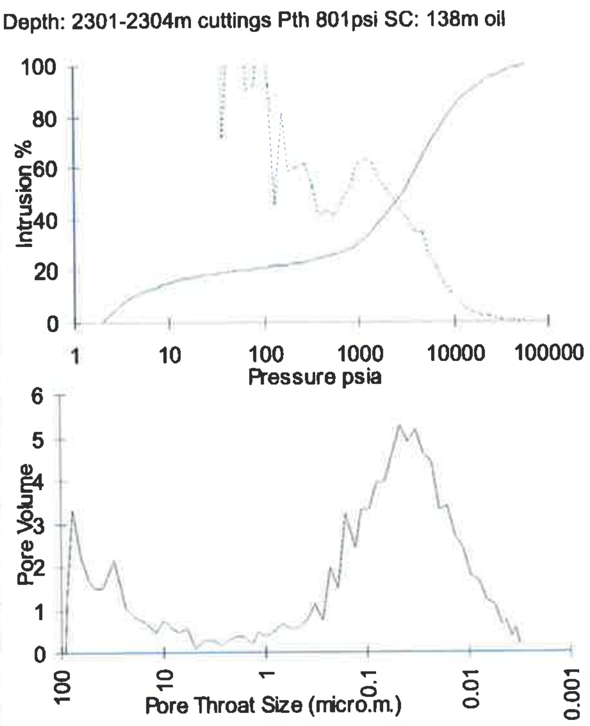


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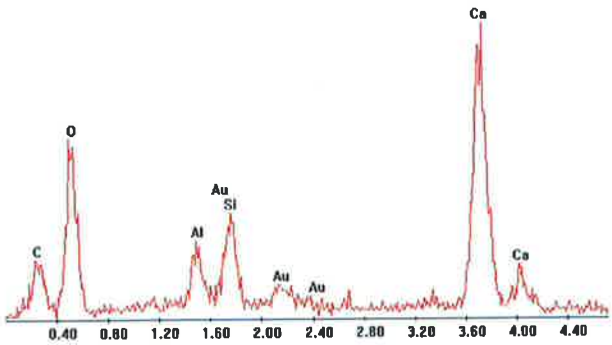
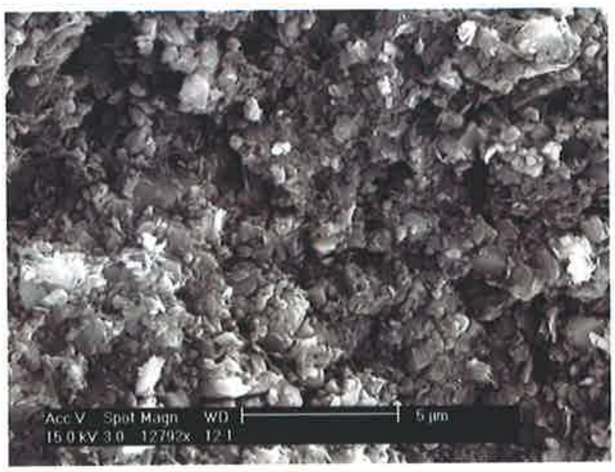
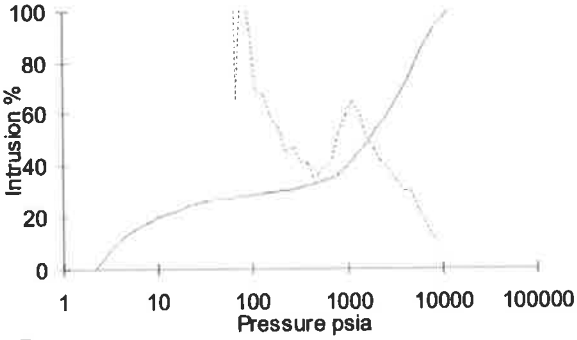
Label A:

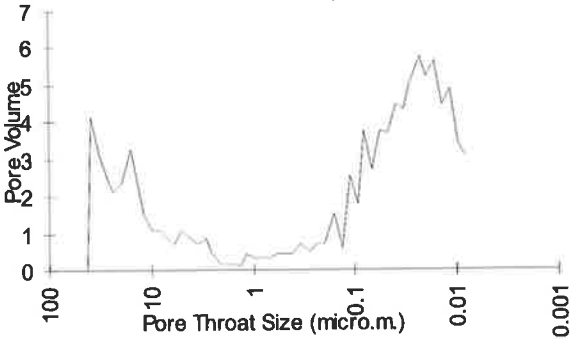


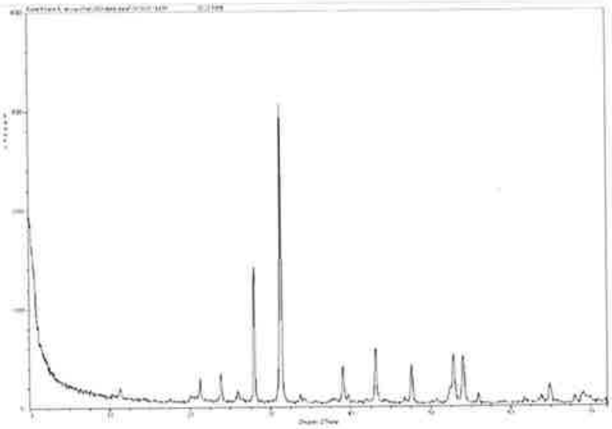



# Skua 9

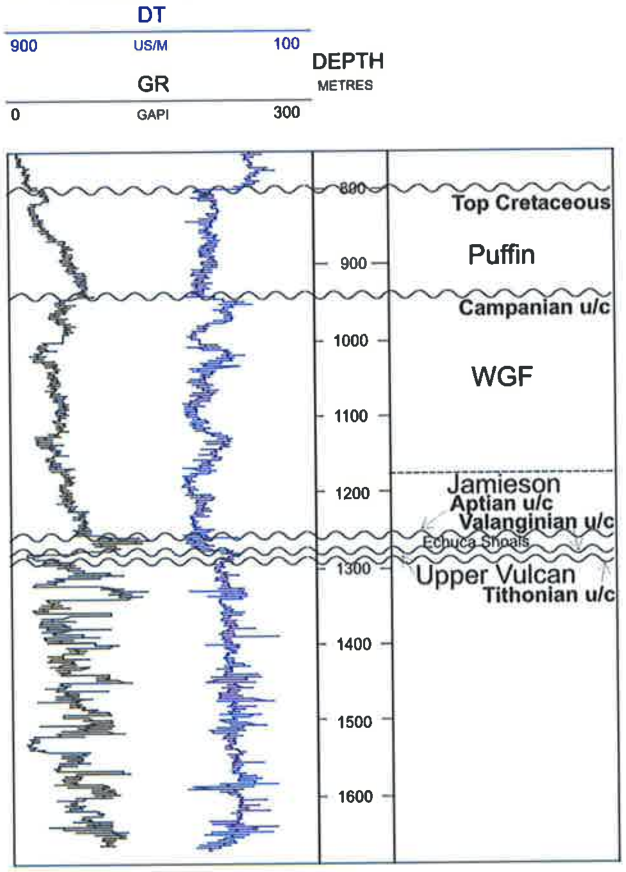
**Depth: 2310-2313m Pth 1026psi SC: 177m oil**



Snowmass 1



DT
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US/M
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DEPTH
METRES
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GAPI
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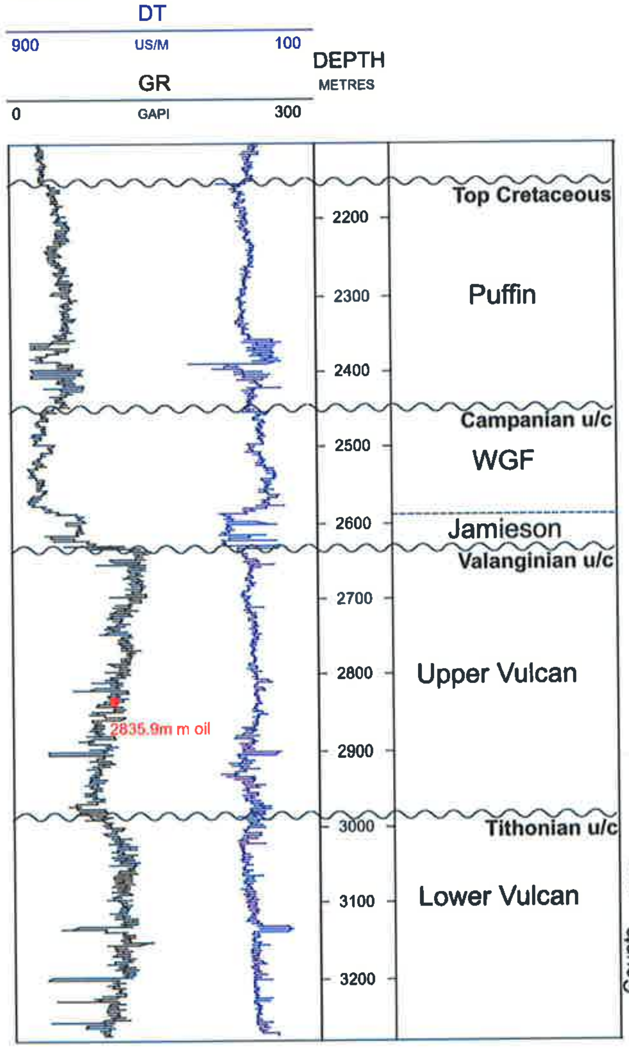
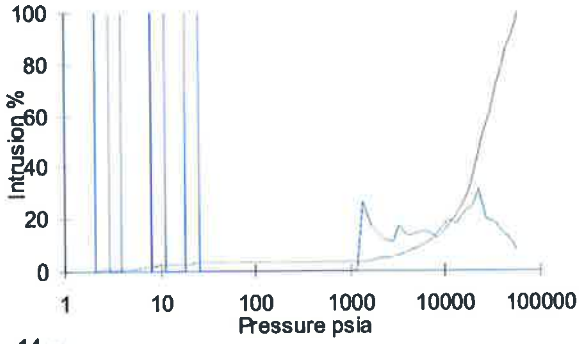
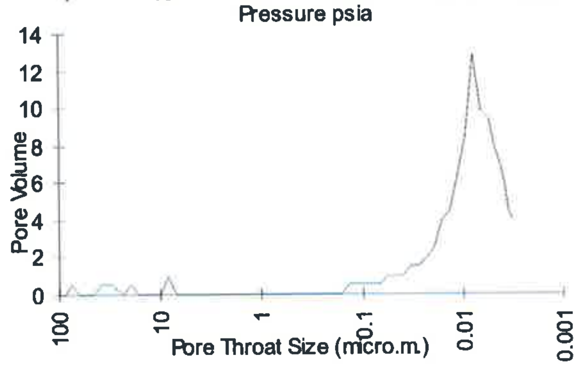
800
900
1000
1100
1200
1300
1400
1500
1600
Top Cretaceous
Puffin
Campanian u/c
WGF
Jamieson
Aptian u/c
Valanginian u/c
Echuca Shoals
Upper Vulcan
Tithonian u/c

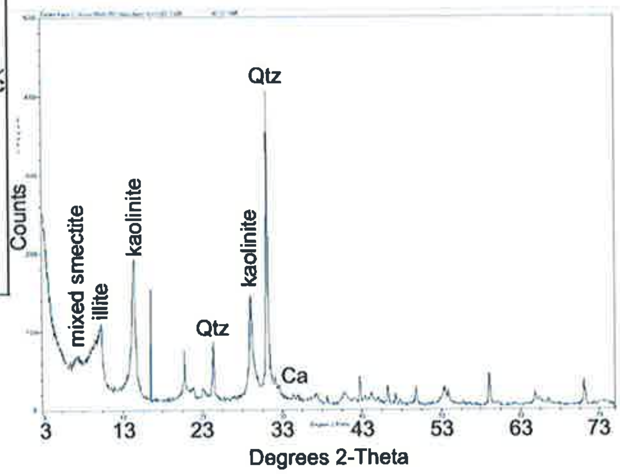
## Swan 1

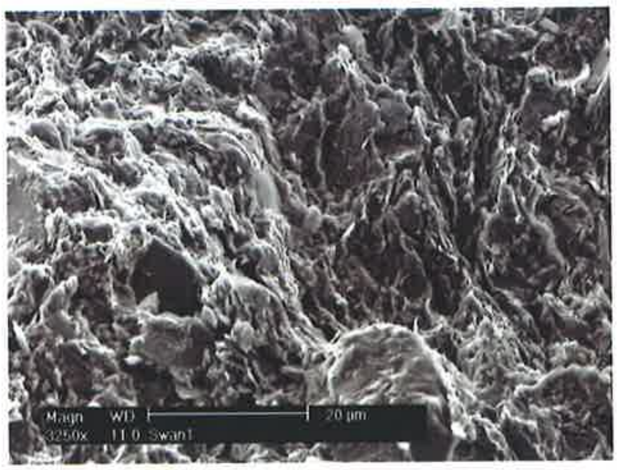



Depth: 2835.9m core bulk sample Pth 8500psi SC: m oil



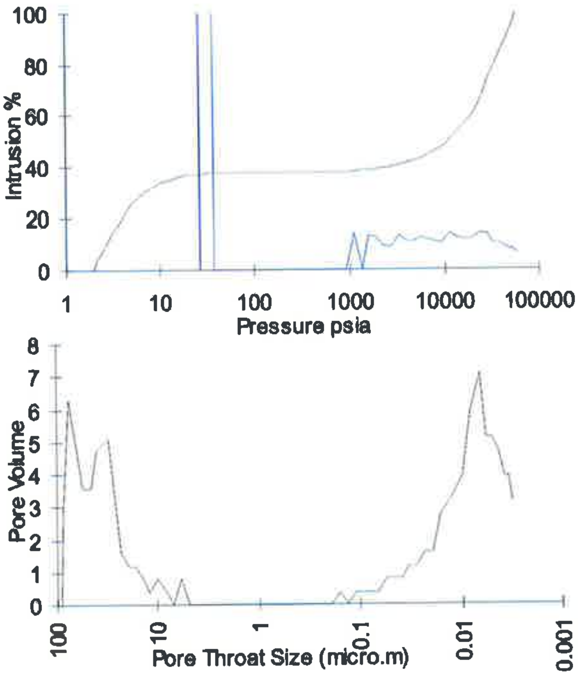



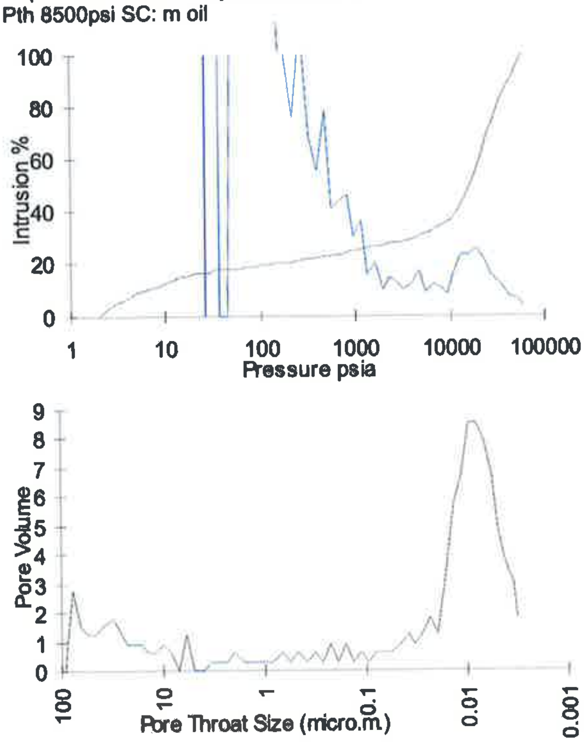



# Swan 1

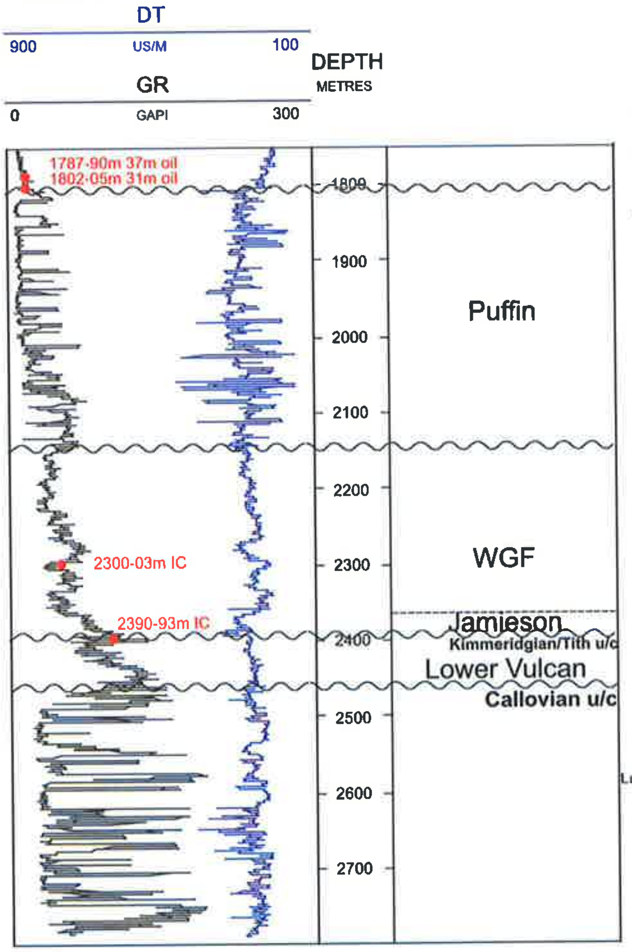
**Depth: 2835.9m core - vertical intrusion**
**Pth 8500 psi SC: m oil**



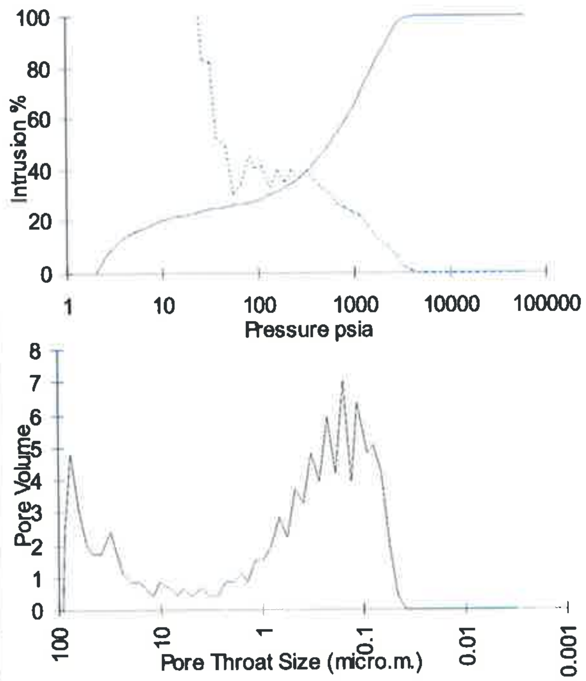

**Depth: 2835.9m core synthetic cuttings**
**Pth 8500psi SC: m oil**



## Swift 1




Depth: 1178-1790m cuttings Pth 221psi SC: 37m oil

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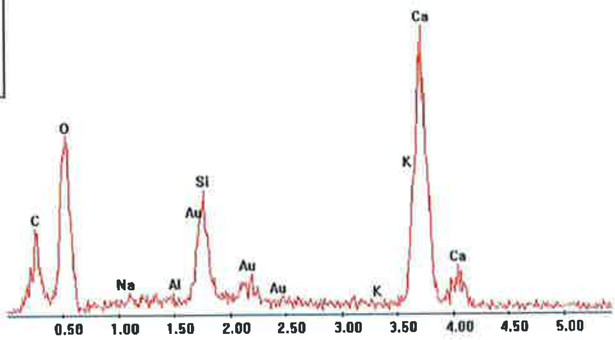
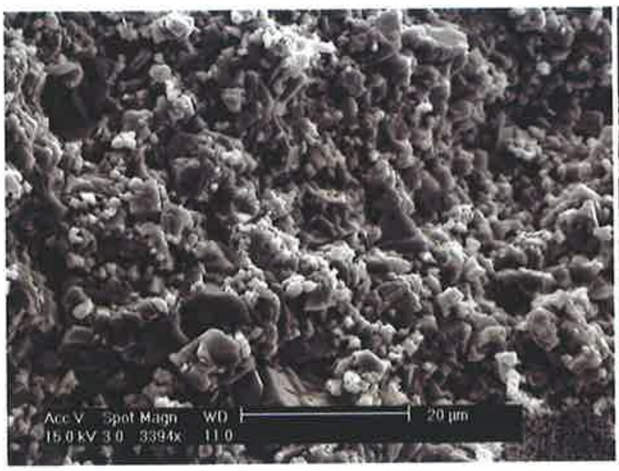
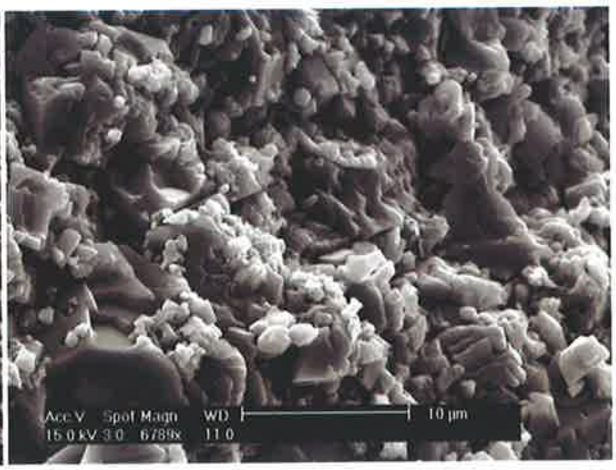
Label A: K22767c

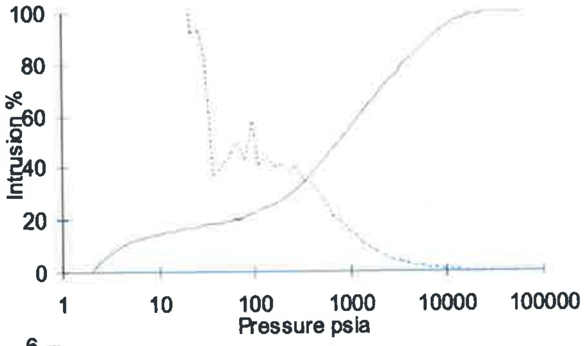


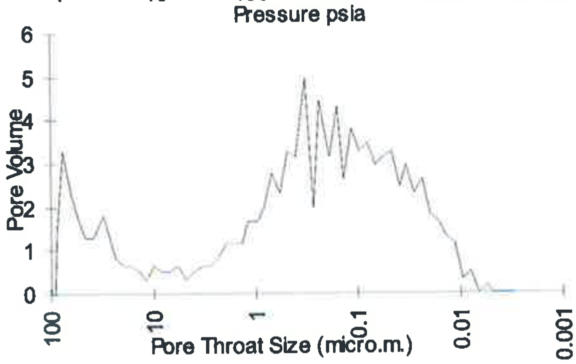



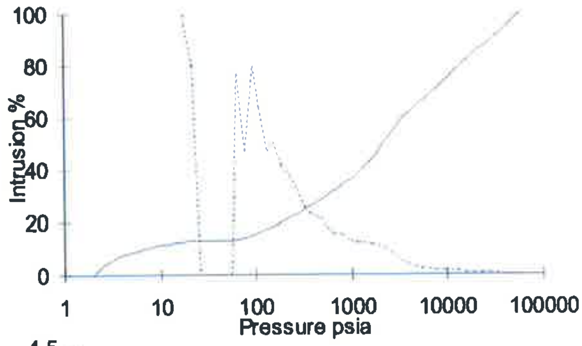
# Swift 1

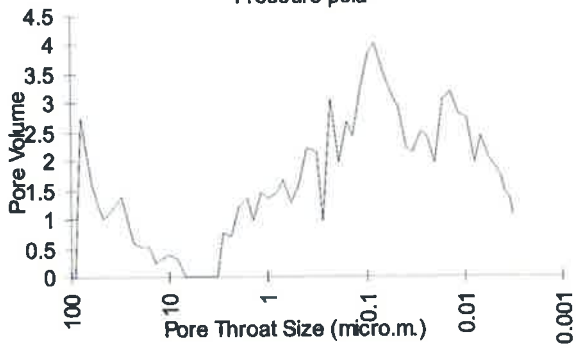
Depth: 1802-1805m Pth186psi SC: 31m oil




Depth: 2300-2303m Pth Inconclusive

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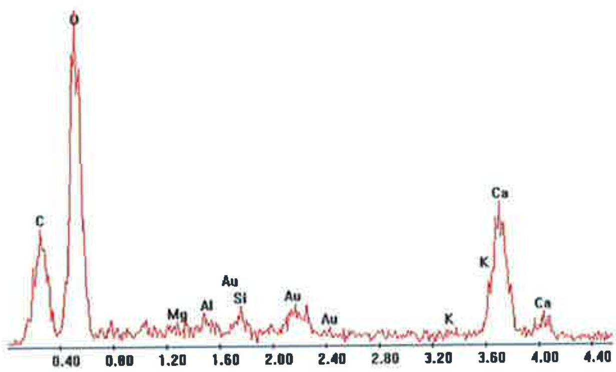
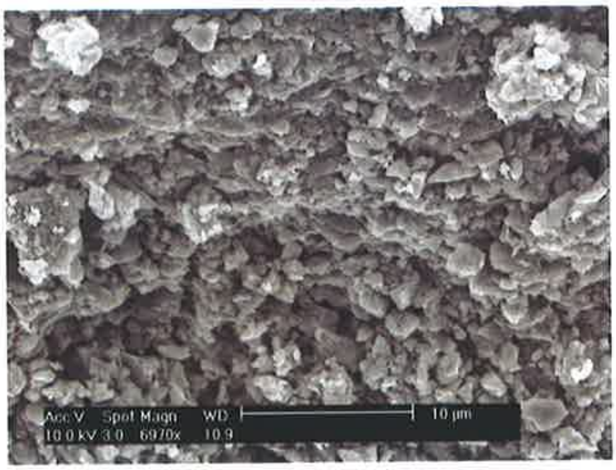
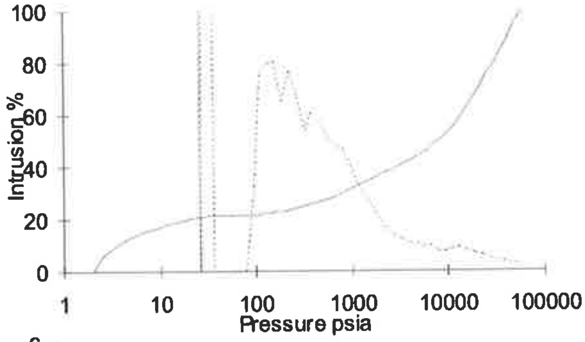
Label A: OB-13-1

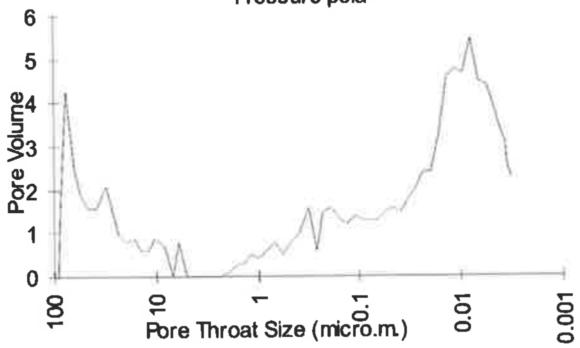


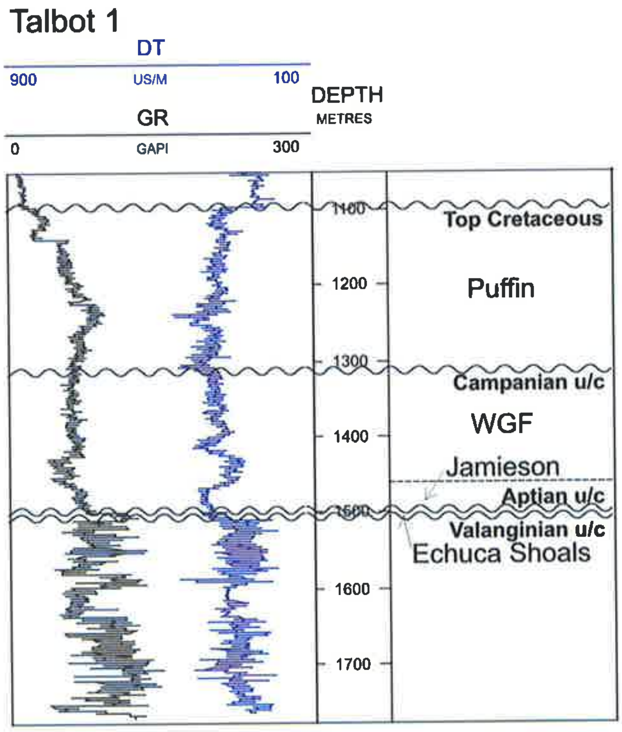



Swift 1

Depth: 2390-2393m Pth Inconclusive

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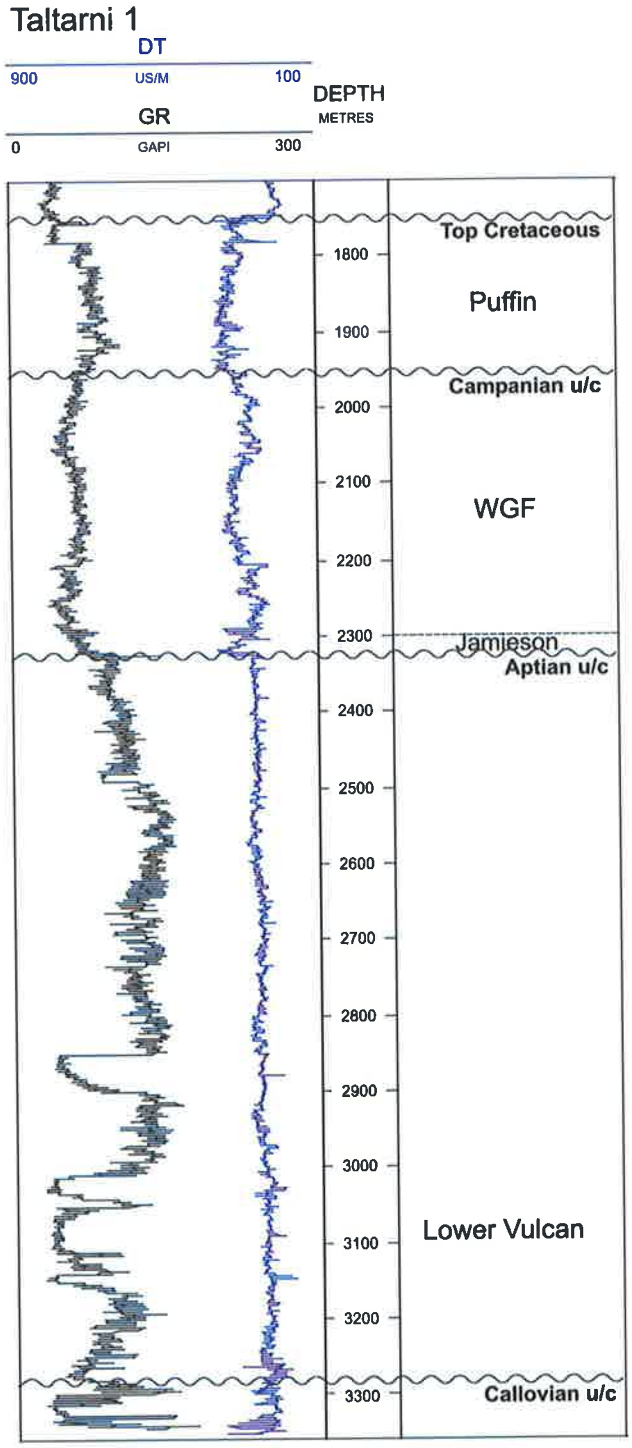
1600
1700
Top Cretaceous
Puffin
Campanian u/c
WGF
Jamieson
Aptian u/c
Valanginian u/c
Echuca Shoals



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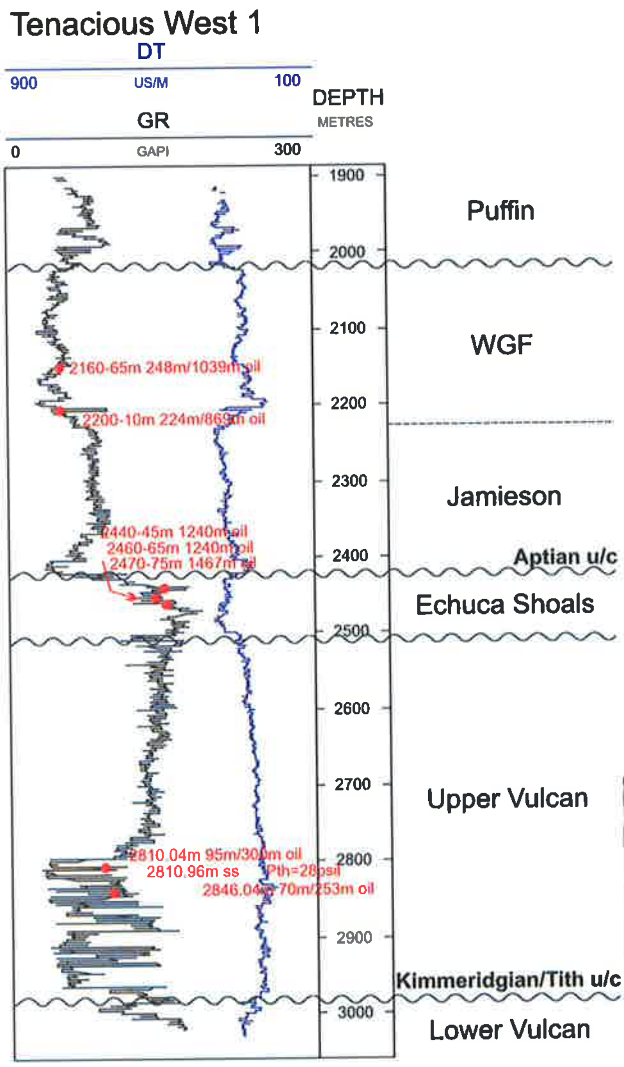
Puffin
Campanian u/c
WGF
Jamieson
Aptian u/c
Lower Vulcan
Callovian u/c


Tenacious West 1
DT
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2200
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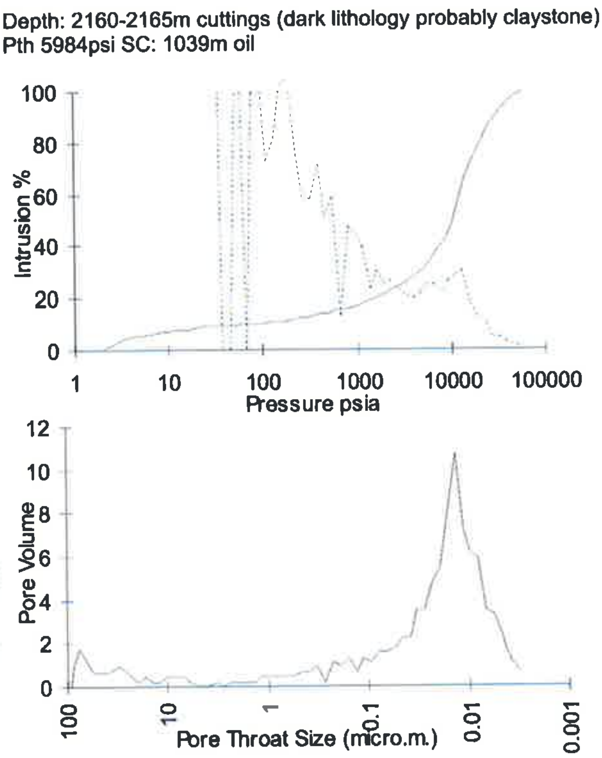
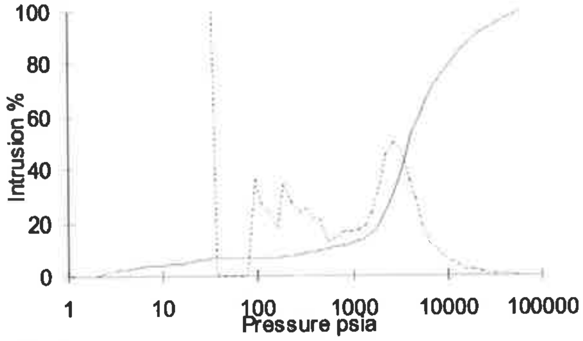
2400
2500
2600
2700
2800
2900
3000
Puffin
WGF
Jamieson
Aptian u/c
Echuca Shoals
Upper Vulcan
Kimmeridgian/Tith u/c
Lower Vulcan
2160-65m 248m/1039m oil
2200-10m 224m/869m oil
2440-45m 1240m oil
2460-65m 1240m oil
2470-75m 1467m oil
2810.04m 95m/300m oil
2810.96m ss
Pth=28psi
2846.04m 70m/253m oil

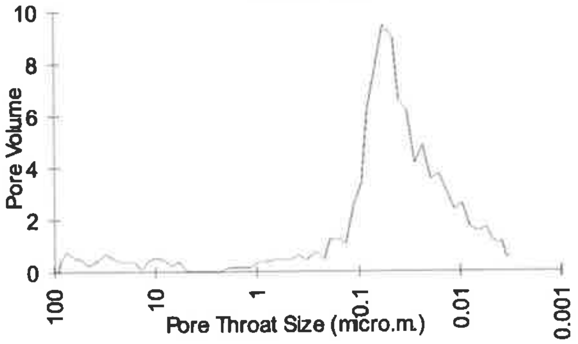

Depth: 2160-2165m cuttings (dark lithology probably claystone)
Pth 5984psi SC: 1039m oil
Intrusion %
100
80
60
40
20
0
1
10
100
1000
10000
100000
Pressure psia
Pore Volume
12
10
8
6
4
2
0
100
10
1
0.1
0.01
0.001
Pore Throat Size (micro.m.)


Acc.V Spot Magn
15.0 kV 4.0 7165x
10 µm

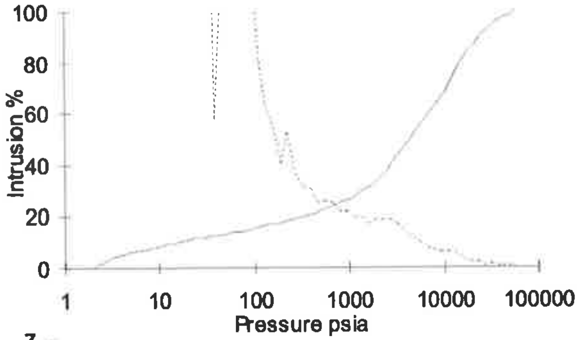
# Tenacious West 1

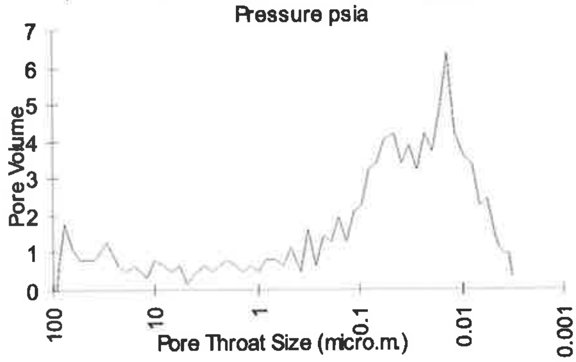
**Depth: 2160-2165m cuttings light lithology probably carbonate**
**Pth 1438psi SC: 248m oil**

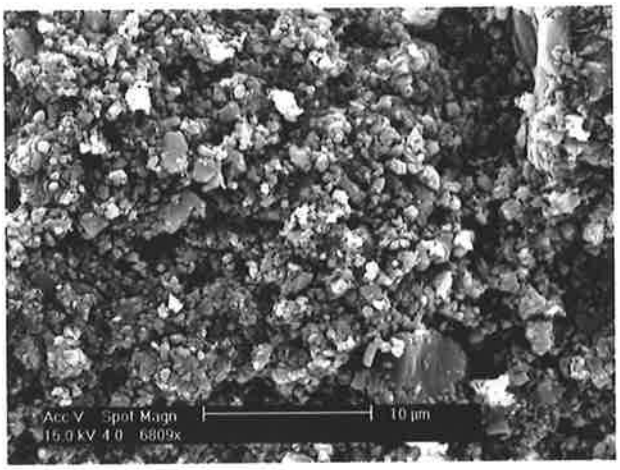



**Depth: 2200-2210m cuttings marl**
**Pth 1598psi SC: 276m oil**

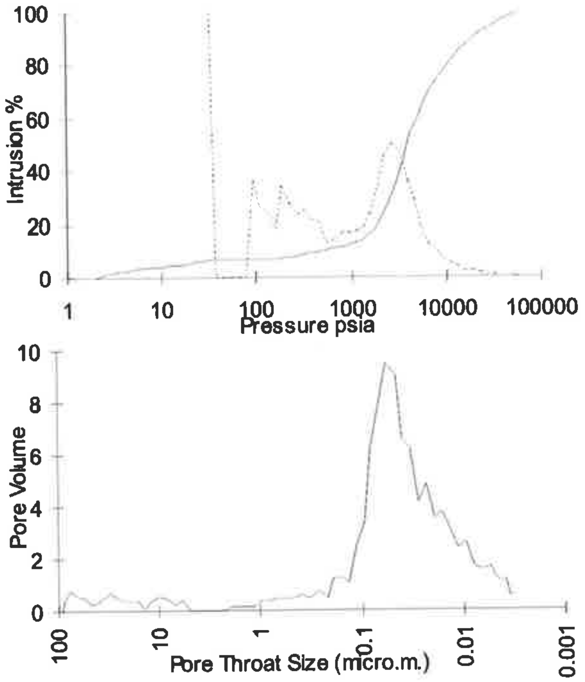


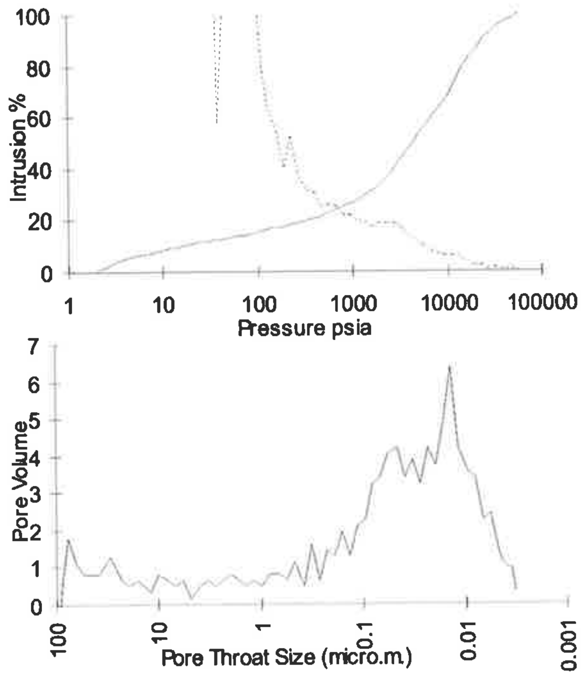



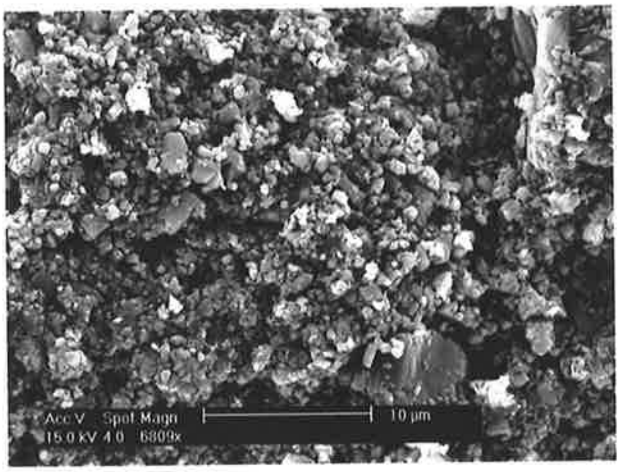
# Tenacious West 1

Depth: 2160-2165m cuttings light lithology probably carbonate
Pth 1438psi SC: 248m oil



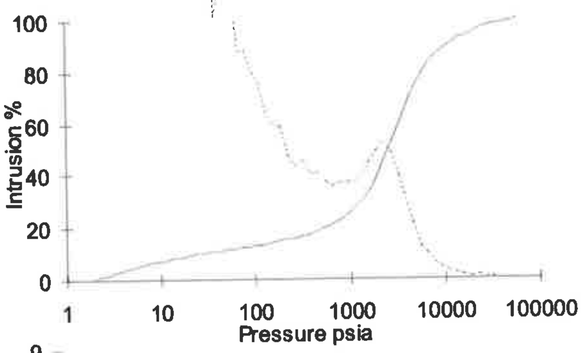

Depth: 2200-2210m cuttings marl
Pth 1598psi SC: 276m oil

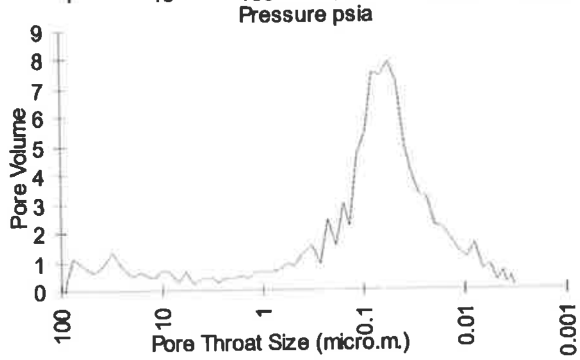


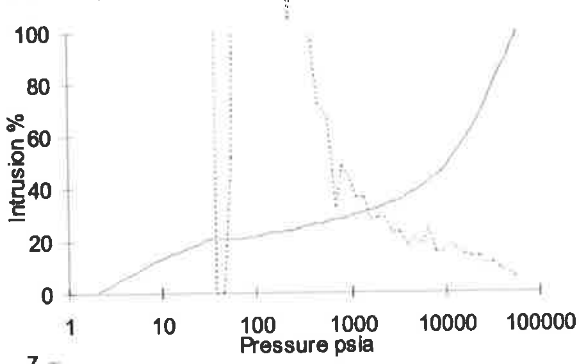
# Tenacious West 1

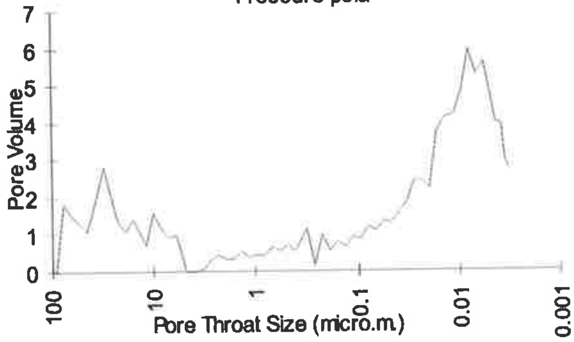
Depth: 2200-2210m cuttings carbonate
Pth 1300psi SC: 224m oil

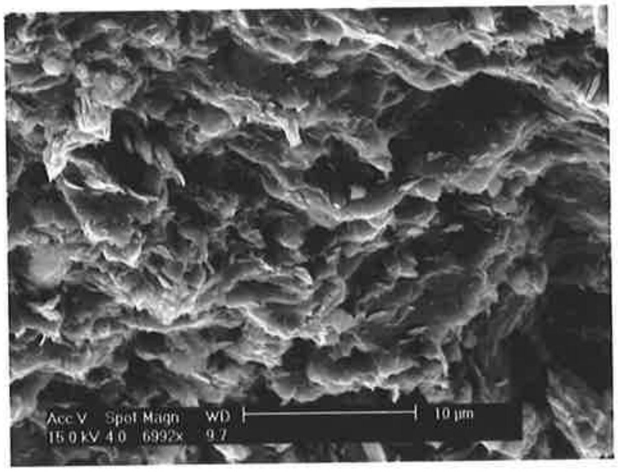



Depth: 2200-2210m cuttings shale
Pth 5005psi SC: 869m oil

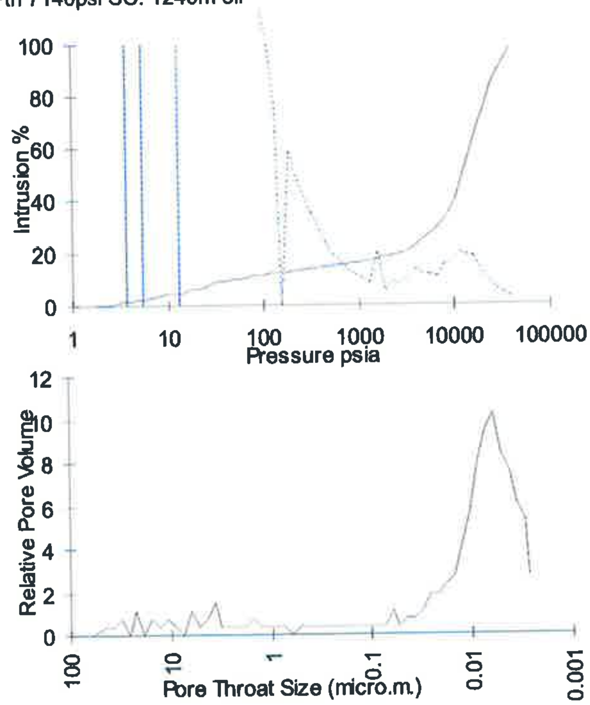


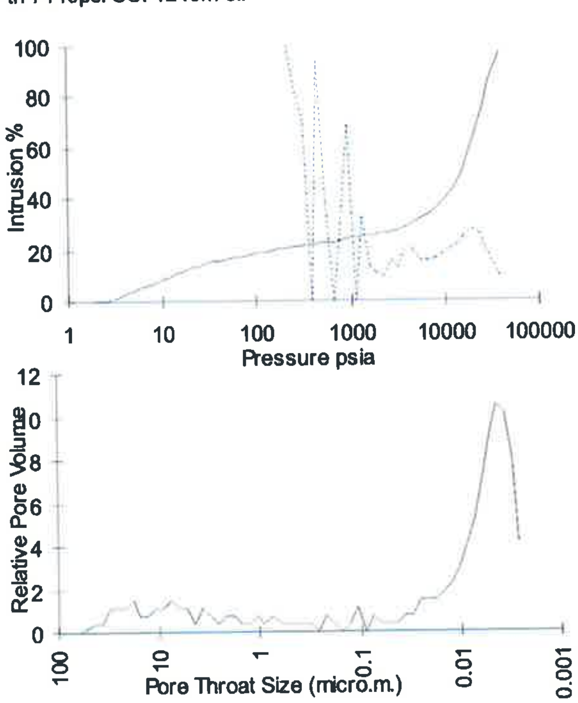



# Tenacious West 1

Depth: 2440-2445m cuttings Echuca Shoals
Pth 7140psi SC: 1240m oil

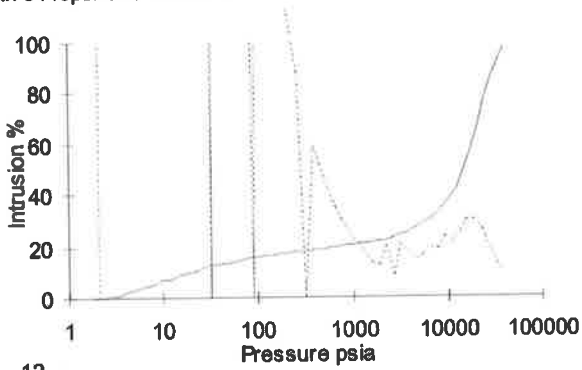


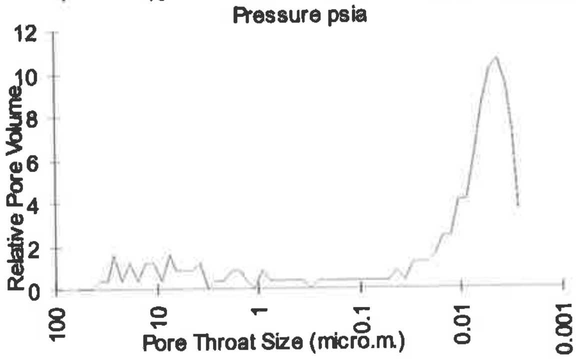

Depth: 2460-2465m cuttings Echuca Shoals
Pth 7140psi SC: 1240m oil



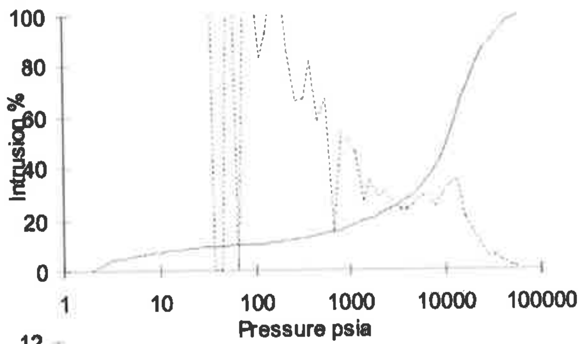
# Tenacious West 1

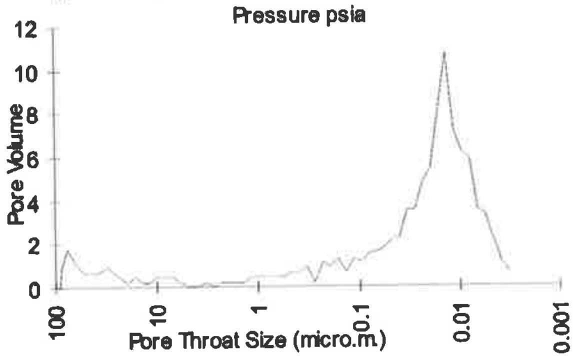
Depth: 2470-2475m cuttings Echuca Shoals
Pth 8445psi SC: 1467m oil



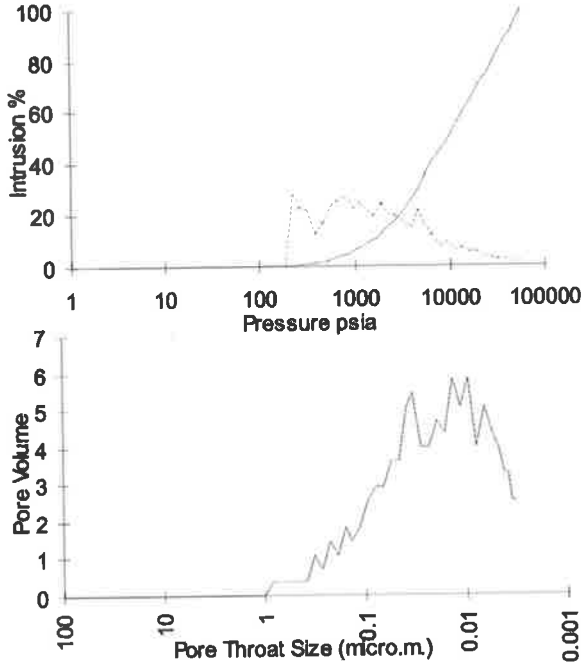

Depth: 2810.04m core araldite run1
Pth 4282psi SC: 743m oil



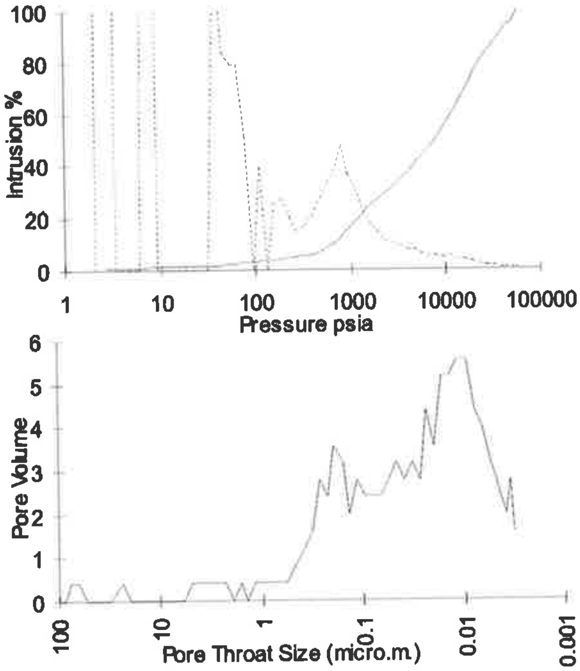



# Tenacious West 1

**Depth: 22810.04m core araldite run2**
**Pth 1735psi SC: 300m oil**

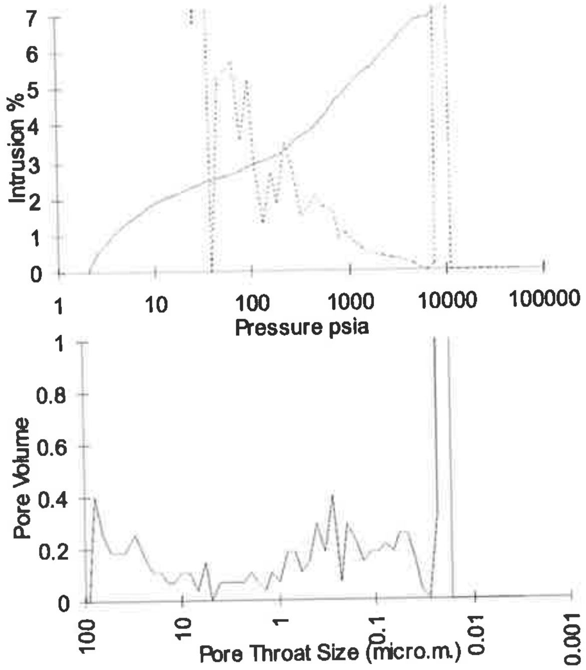



**Depth: 2810.04m core bulk sample**
**Pth 554psi SC: 95m oil**

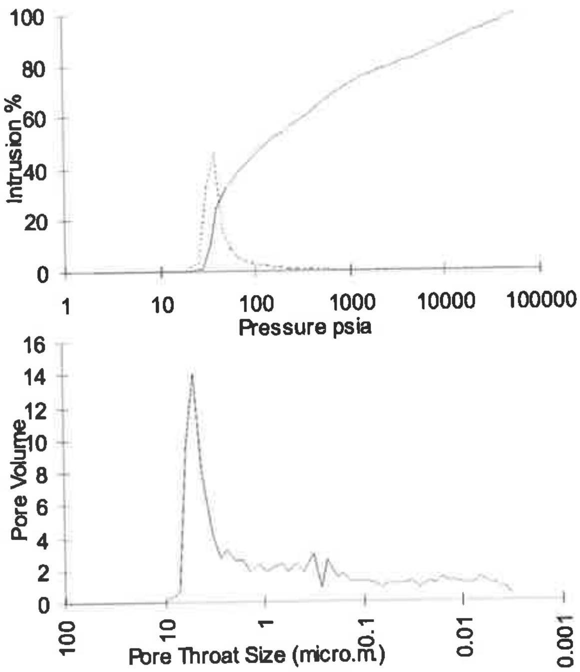


# Tenacious West 1

Depth: 2810.04m core synthetic cuttings
Pth 408psi SC: 69m oil




Depth: 2810.96m core-araldite sandstone reservoir
Pth 28psi - reservoir

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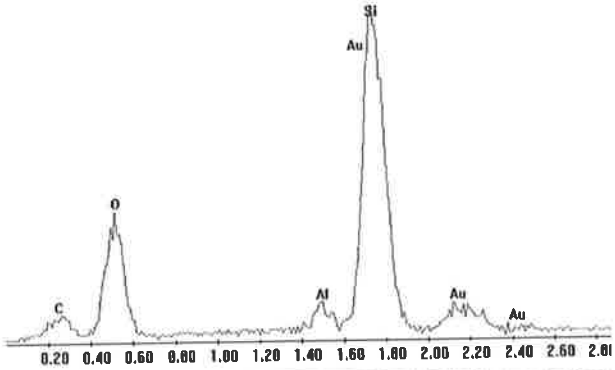
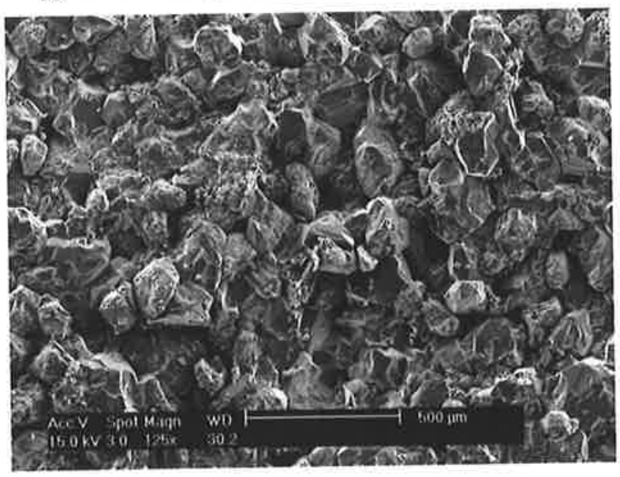
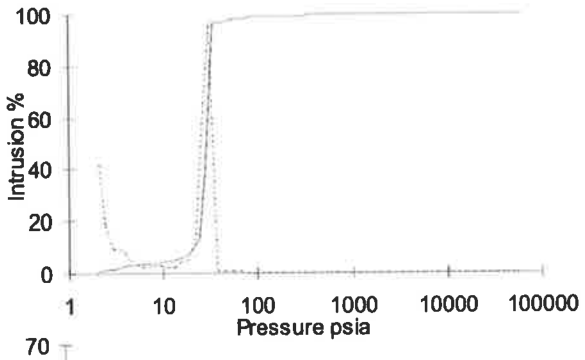
Label A:

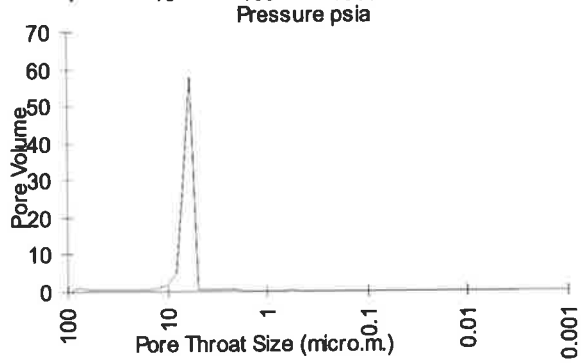


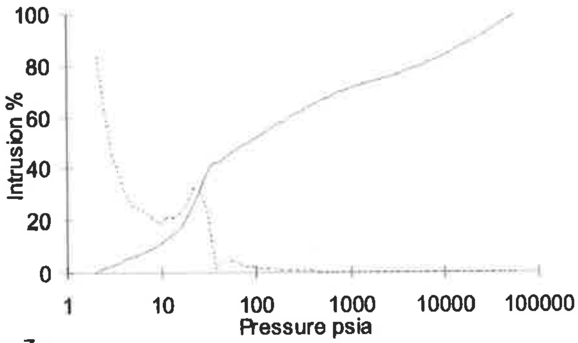
# Tenacious West 1

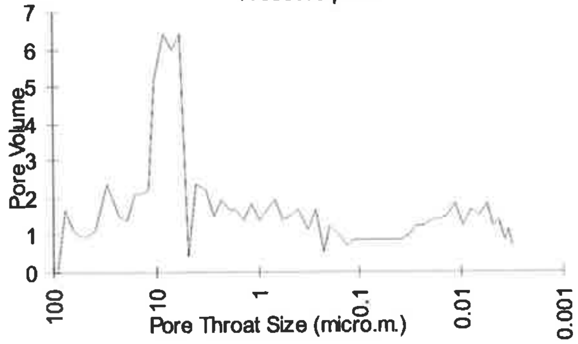
Depth: 2810.96m core-bulk sandstone reservoir
Pth 20psi

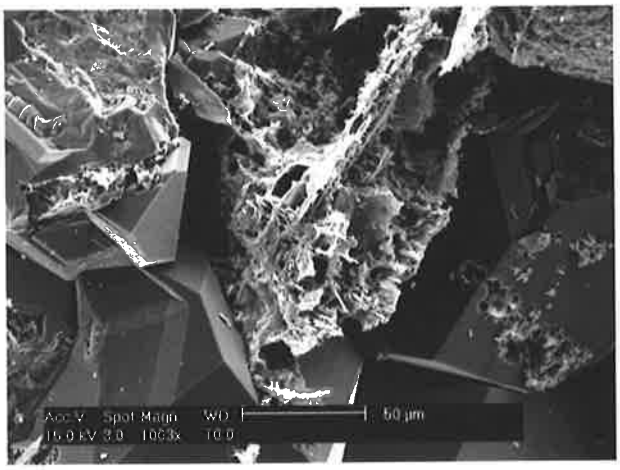


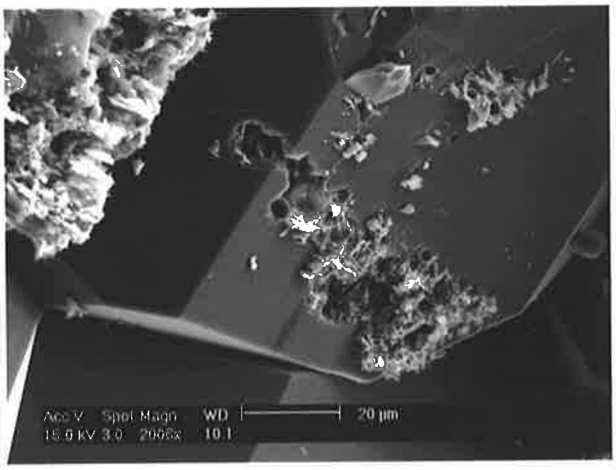




Depth: 2810.96m core-synthetic cuttings sandstone reservoir
Pth 15psi



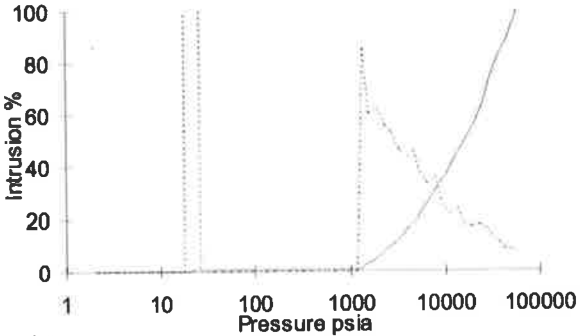



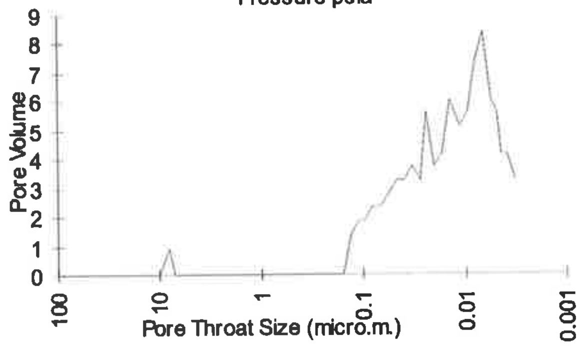



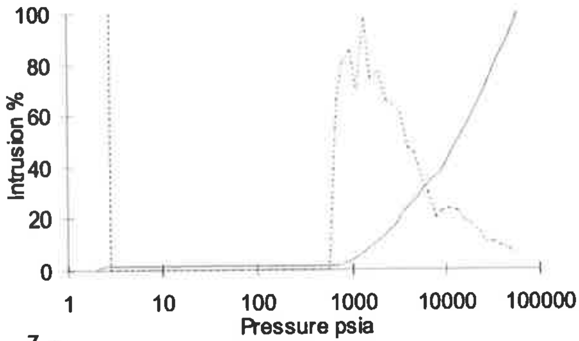
# Tenacious West 1

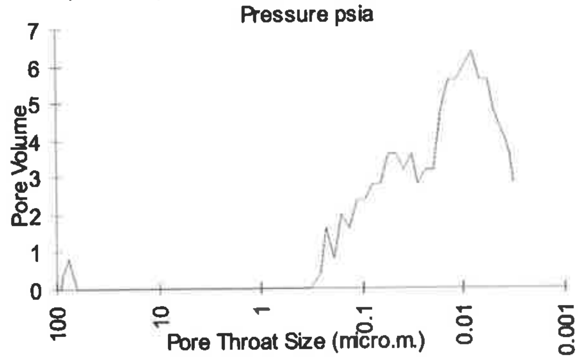
Depth: 2846.04m core-araldite run1
Pth 1462psi SC: 253m oil

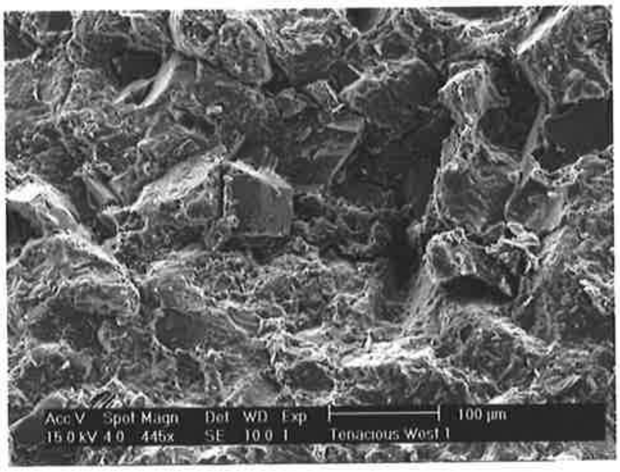



Depth: 2846.04 core-araldite run2
Pth 710psi SC: 122m oil

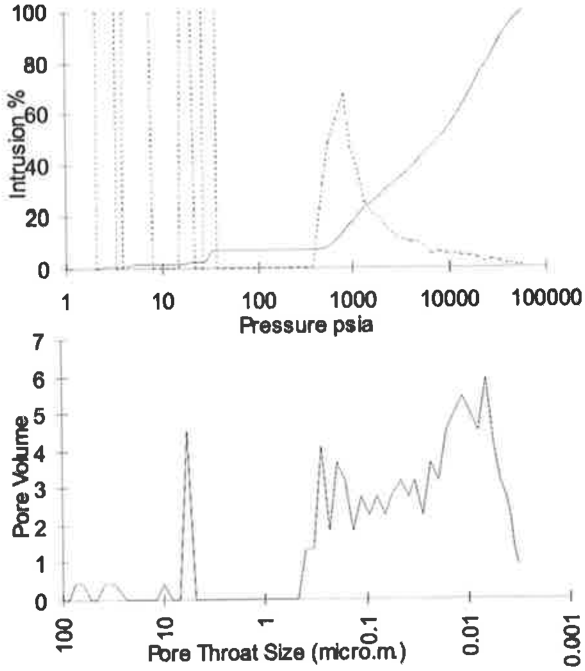


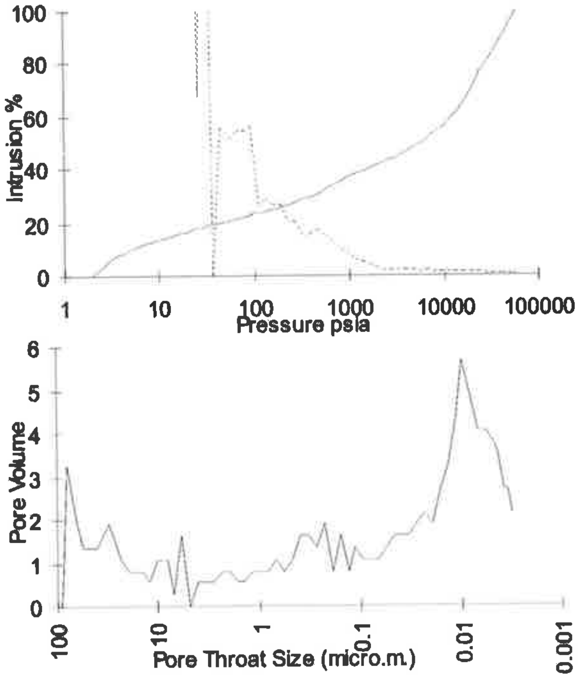



# Tenacious West 1

Depth: 2846.04m core-bulk
Pth 415psi SC: 70m oil

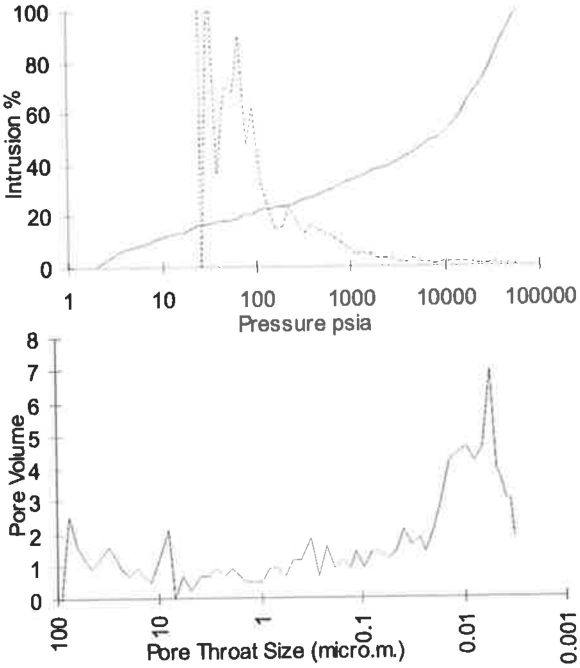


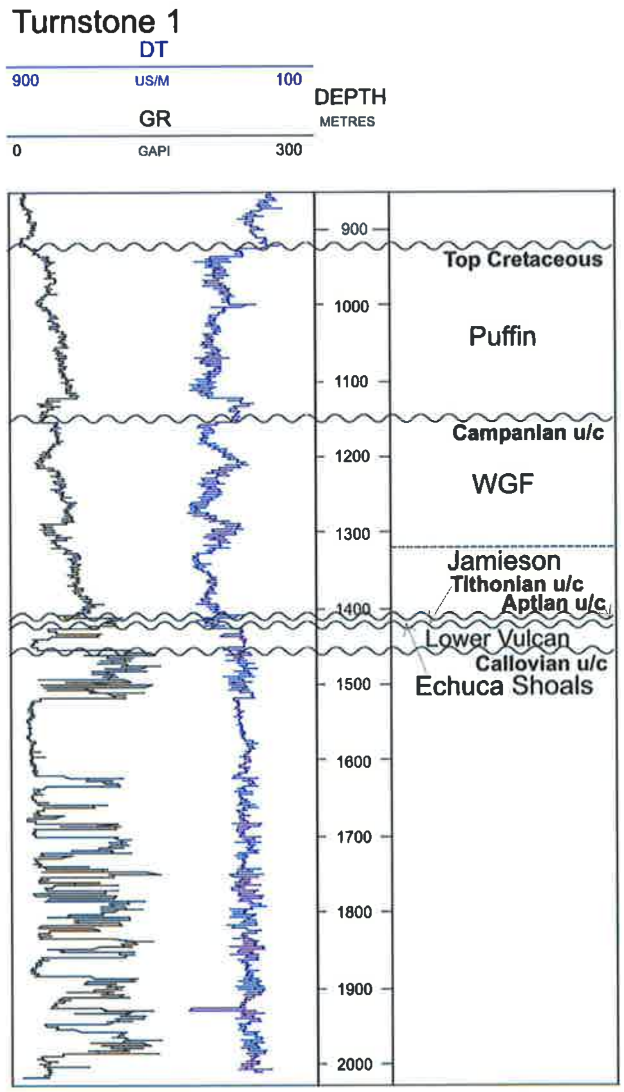

Depth: 2846.04m core-synthetic cuttings run1
Inconclusive MICP curve - no Pth pick



# Tenacious West 1

Depth: 2846.04m core-synthetic cuttings run2
Inconclusive MICP curve - no Pth pick





Turnstone 1
DT
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100
DEPTH
METRES
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GAPI
300
900
1000
1100
1200
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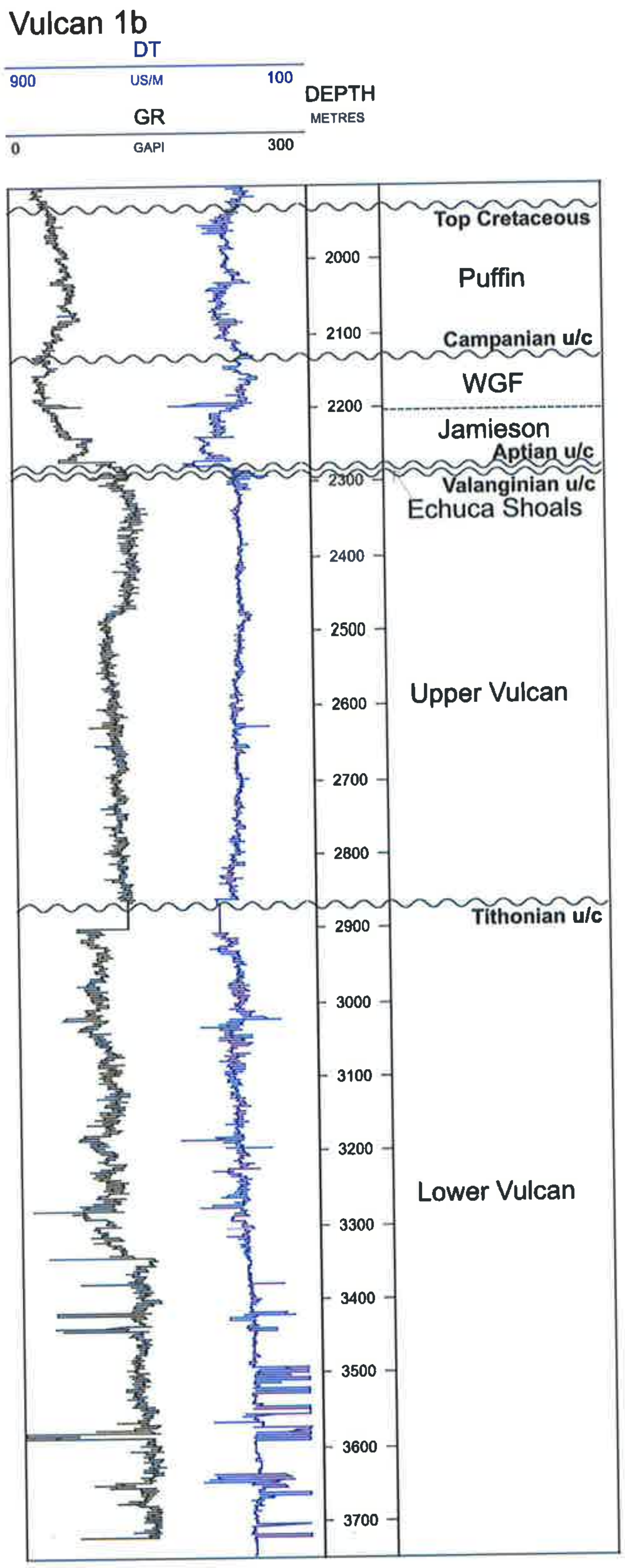
1400
1500
1600
1700
1800
1900
2000
Top Cretaceous
Puffin
Campanian u/c
WGF
Jamieson
Tithonian u/c
Aptian u/c
Lower Vulcan
Callovian u/c
Echuca Shoals



Vulcan 1b
DT
900
US/M
100
GR
0
GAPI
300
DEPTH
METRES
Top Cretaceous
Puffin
Campanian u/c
WGF
Jamieson
Aptian u/c
Valanginian u/c
Echuca Shoals
Upper Vulcan
Tithonian u/c
Lower Vulcan
2000
2100
2200
2300
2400
2500
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2700
2800
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3200
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3400
3500
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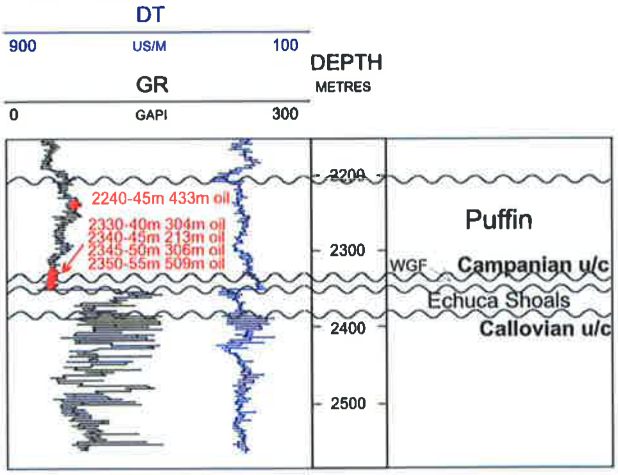
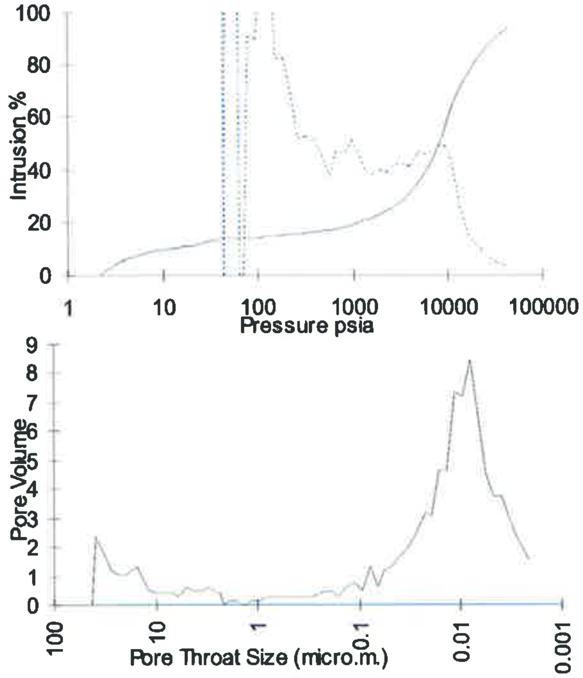
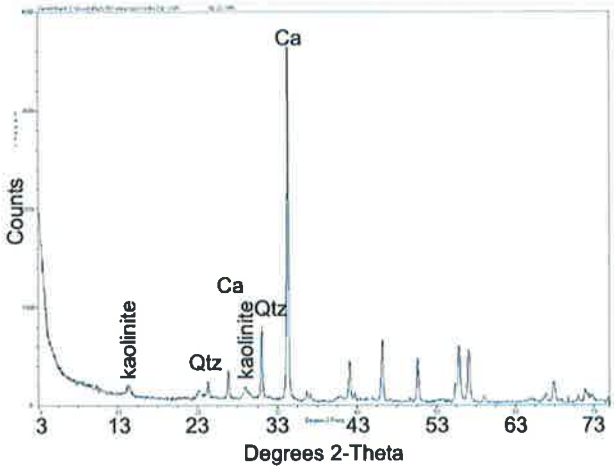
3700

Warb 1a



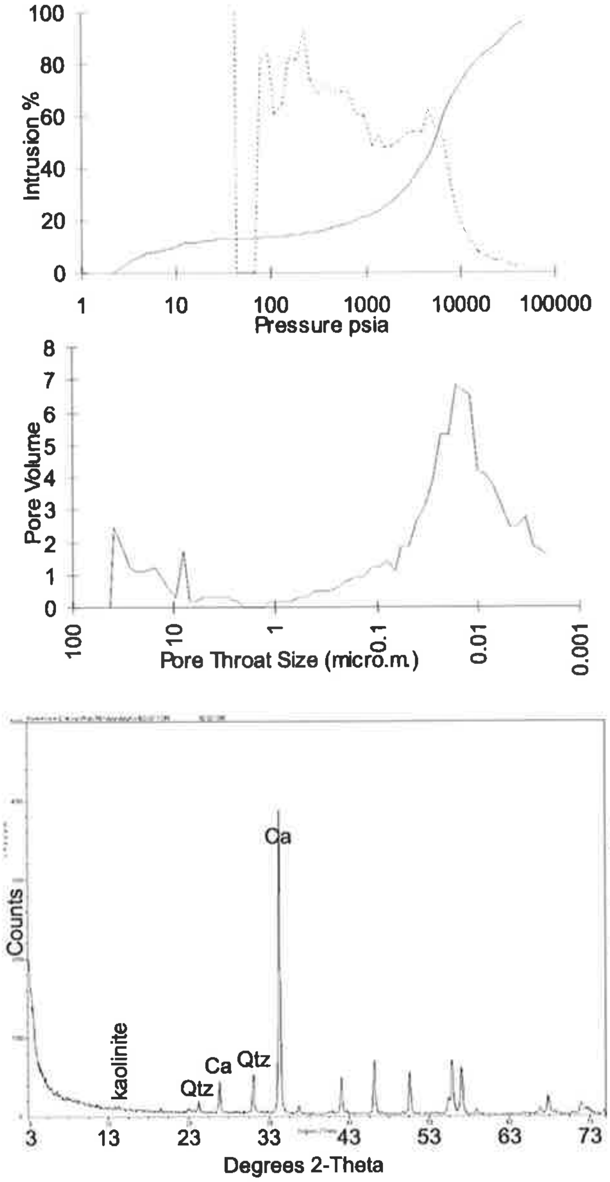

Depth: 2240-2245m cuttings Pth 2500psi SC: 433m oil



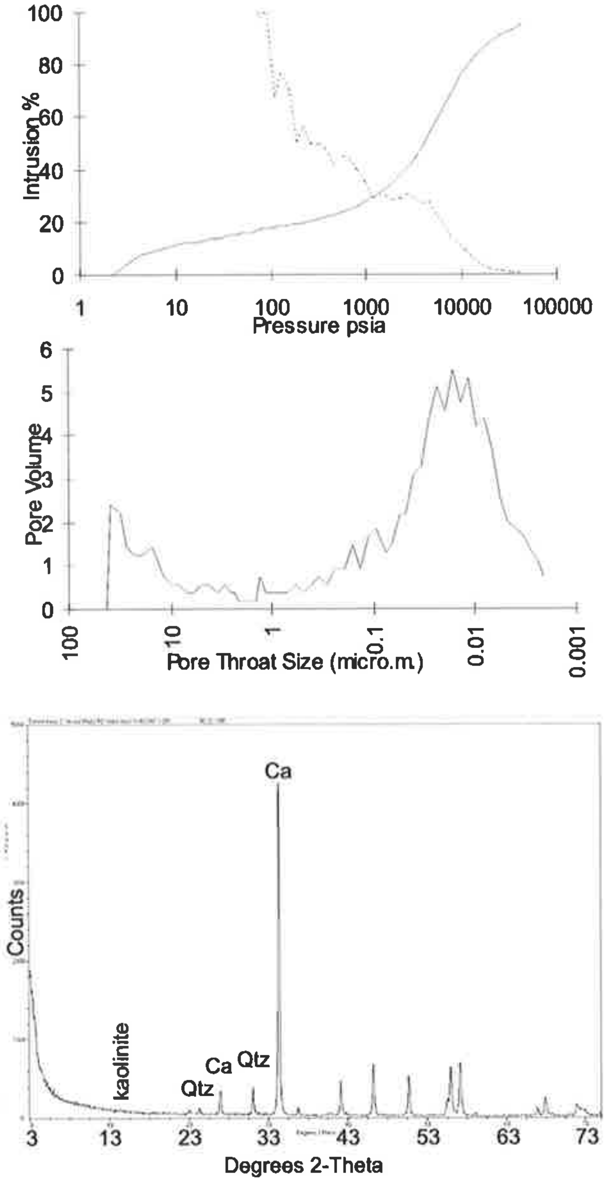



# Warb 1a

Depth: 2330-2340m Pth 1758psi SC: 304m oil

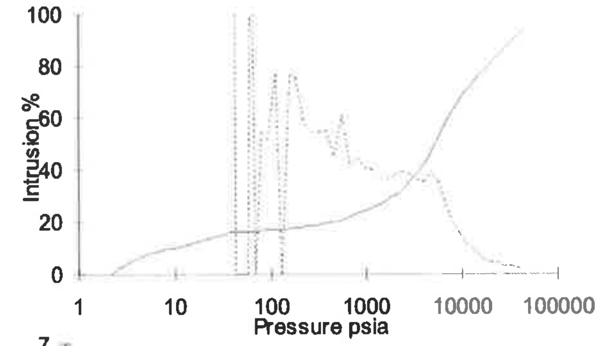


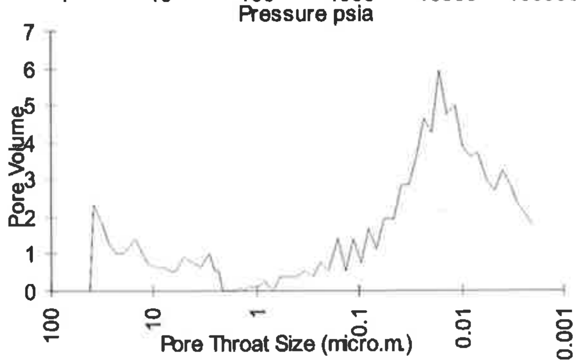

Depth: 2340-2345m cuttings Pth 1236psi SC: 213m oil

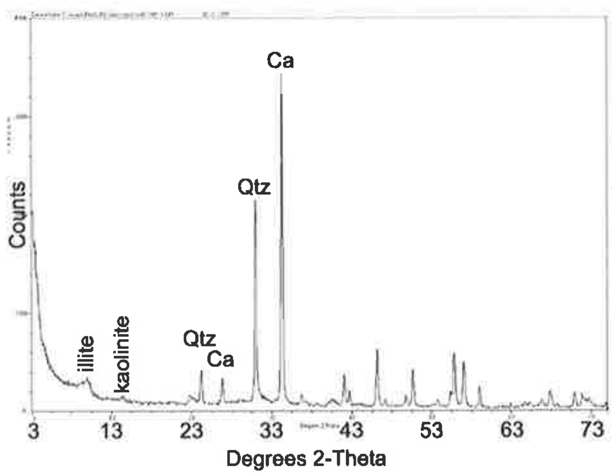


# Warb 1a

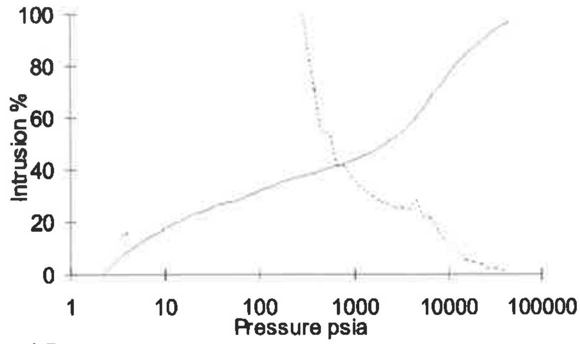
Depth: 2345-2350m Pth 1771psi SC: 306m oil

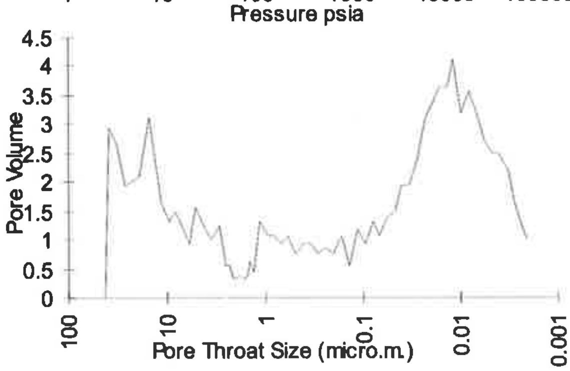


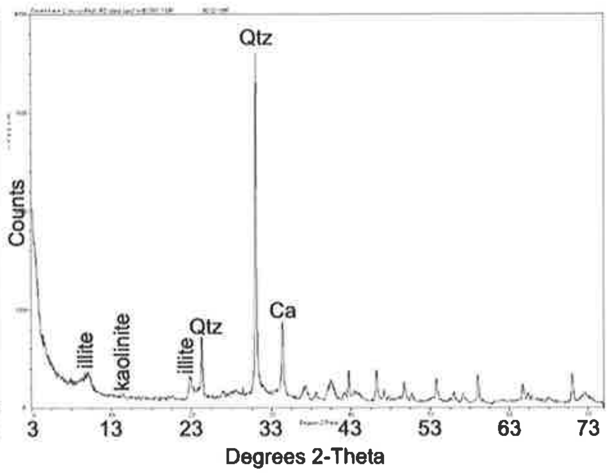



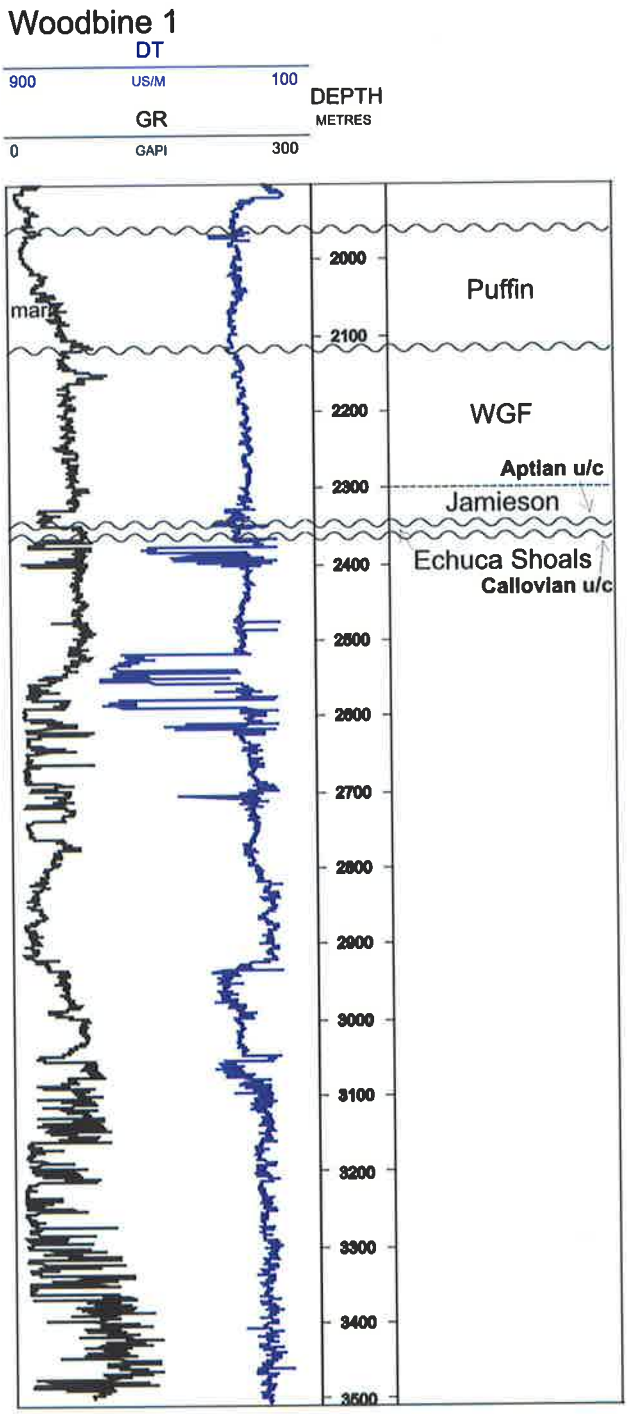




Depth: 2350-2355m cuttings Pth 2481psi SC: 509m oil

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Puffin
WGF
Aptian u/c
Jamieson
Echuca Shoals
Callovian u/c