THE EXPLORATION POTENTIAL OF THE TIMOR GAP TREATY AREA[1]

By Dr. Jaap Poll*

INTRODUCTION

The author was invited to provide a 'technical backdrop' against which to assess the legal and commercial ramifications of the Timor Gap Treaty.

The Treaty between the Australian and Indonesian governments to form the Zone of Co-operation (ZOC), effectively closes the 'Timor Gap' in the eastern Timor Sea and opens up the area for hydrocarbon exploration for the first time since the late 1970s. The ZOC in the eastern Timor Sea represents one of the few relatively poorly explored areas on the continental shelf around Australia that has obvious and immediate exploration potential for hydrocarbons.

The ZOC comprises three component areas (Figure 1). A joint development regime will be established in the central Area A under the control of a Ministerial Council and Joint Authority made up of representatives of both countries. The boundary between Areas A and B is the median line between Timor and Australia and the boundary between Areas A and C is the simplified 1500 m. isobath. The northern boundary of Area C is the simplified bathymetric axis of the Timor Trough. The southern boundary of the ZOC is the 200 nautical mile line measured from the Indonesian archipelagic baseline in Timor. The western and eastern boundaries are simple equidistance lines. In the southern Area B the relevant Australian legal regime will apply, while Area C will be under Indonesian control.

The ZOC covers an area of 62,000 km^2. This compares with just over 50,000 km^2 for the heavily explored Ashmore-Cartier area, some 150 km. west of the ZOC. Communication by air to the area is possible from Dili and Kupang, the capitals of East Timor and West Timor respectively, and from Darwin. The northern boundary of the ZOC is some 120 km. south of Dili and the eastern boundary just under 300 km. west of Darwin. The area is remote, although some infrastructure exists along the coast and islands of northwest Australia, to service currently active exploration programs and producing fields in the Ashmore-Cartier area.

The ZOC is subject to cyclonic activity during the monsoon period of December to March. Offshore facilities must therefore be constructed to withstand weather extremes. Water depths in the ZOC vary from around 50 m. in the south to over 1500 m. in the north, with the majority

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1 The information contained in this paper represents contributions from all explorationists from Petroz. Thanks are especially due to Peter Botten as this paper draws heavily on his joint paper with Keiran Wulff entitled 'Exploration Potential of the Timor Gap Zone of Co-operation', unpublished paper presented at APEA Conference in Darwin on 18 June 1990.

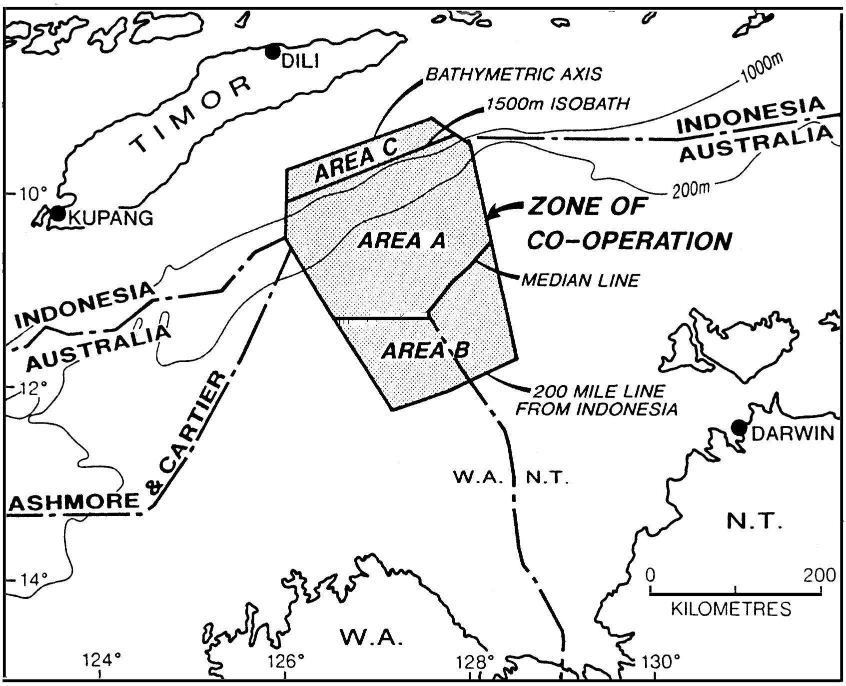

Figure 1 — Locality map of the Timor Gap Treaty Zone of Cooperation (ZOC)

lying between 90 and 150 m. This water depth range is similar to that of the bulk of the offshore exploration and production activities on the Australian shelves, but is significantly deeper than the traditional Indonesian offshore producing areas.

Technical comparisons can be made between the area covered by the ZOC and the Ashmore-Cartier region, where exploration has been actively progressing for over fifteen years. Lessons learnt in exploration techniques and philosophy can be applied to the ZOC leading to more rapid and cost effective assessment of the potential hydrocarbon reserves in the area. This paper summarises the present technical status of the ZOC and discusses these comparisons prior to the major exploration effort that will take place in the area over at least the next five years.

EXPLORATION HISTORY — EASTERN TIMOR SEA

Five wells and just under 20,000 km. of seismic are present within the ZOC. This compares with an equivalent 1972 exploration level in the Ashmore-Cartier region. The results of wells in the ZOC are given on Table 1. The location of these wells and others outside the ZOC are shown on Figure 2.

Exploration activity in both areas commenced in the early 1960s when two consortia headed by Woodside and ARCO were awarded concessions covering almost all of the offshore Bonaparte and Browse basins

Table 1 — Summary of drilling results in the ZOC

Well name	*Operator*	*Permit*	*Date*	*Total depth (m RKB)*	*Objectives*	*Shows*
Gull-1	ARCO	WA-16-P	1970	3421.4 in Triassic	Upper Jurassic (deep salt induced high)	— 3% oil saturation in interval 2852–2854m
Flamingo-1	ARCO	WA-16-P	1971	3700 in Plover Fm. Middle Jurassic	Upper Jurassic (large NE–SW anticline)	— Gas shows basal BIF — Gas column 3266–3413.5m, 146.5m gross, 42.5m net in Flamingo Gp. — Live oil in 1m sand in Plover Fm. 3624.8–3625.8m
Curlew-1	ARCO	NT/P3	1975	2035 in Flamingo Gp. Upper Jurassic	Upper Jurassic (salt dome)	— Gas and oil show in Upper BIF sand — Fluorescence in sandstones in Flamingo Gp.
Jacaranda-1	Tricentrol	NT/P33	1984	3783 in Flamingo Gp. Upper Jurassic	Upper Jurassic/Basal Cretaceous (rollover on downthrown side of basin margin fault)	— Good gas shows in Upper BIF and Mid BIF sandstones — Weak gas and trace oil shows in Flamingo Gp.
Darwinia-1	Tricentrol	NT/P33	1985	2426 in BIF Upper Cretaceous	Upper Cretaceous Maastrichtian sands (small four-way dip closure)	— Trace gas shows in Upper Cretaceous sands

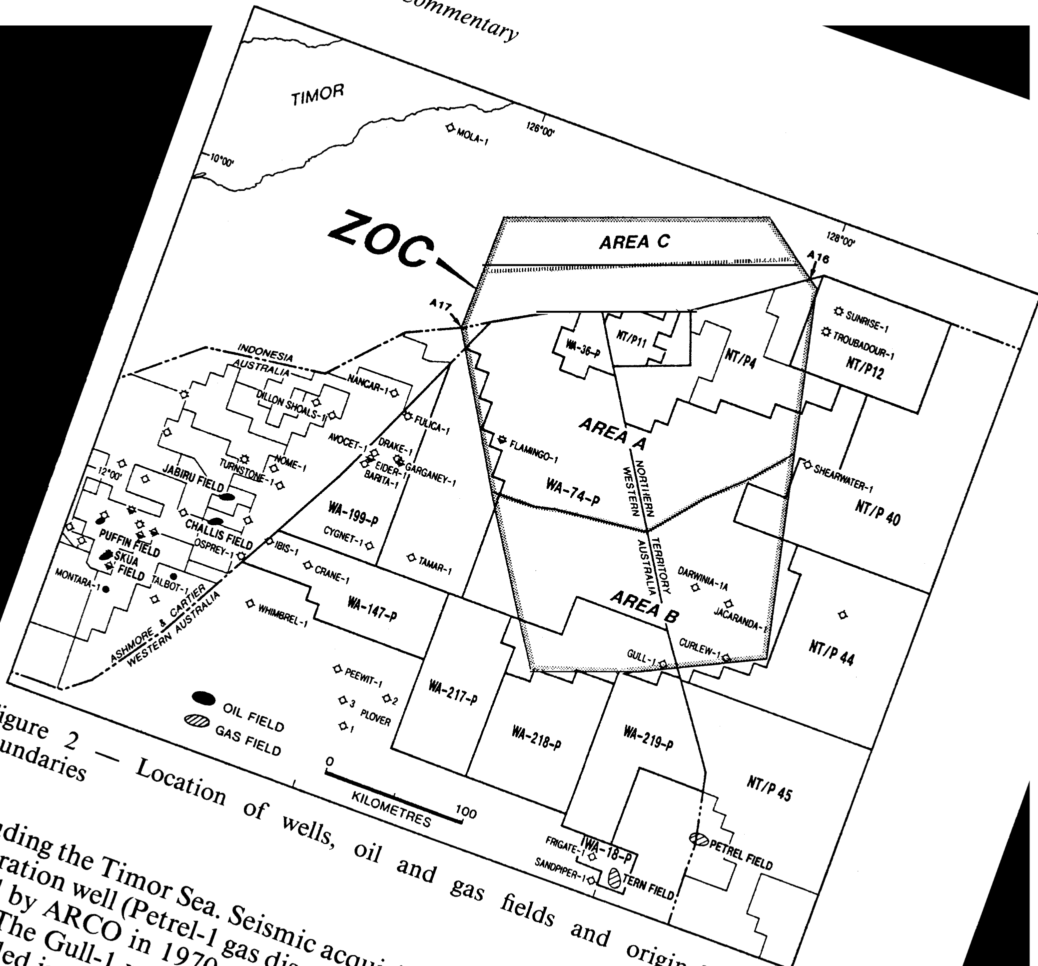

Figure 2 — Location of wells, oil and gas fields and original permit boundaries

including the Timor Sea. Seismic acquisition began in 1964 with the first exploration well (Petrel-1 gas discovery) in the northern Bonaparte Basin drilled by ARCO in 1970.

The Gull-1 well, situated in the southeastern corner of the ZOC, was drilled in 1970 to test a complex salt induced feature. This well was plugged and abandoned having encountered minor hydrocarbon shows at several stratigraphic levels. Seismic data at that time did not resolve complex faulting over the feature and the well is now considered to be not in an optimal structural position. The main reservoir objectives in this well, the Cretaceous Bathurst Island Formation and the Jurassic Plover Formation and Flamingo Group (Figure 3), exhibit diagenetic destruction of original reservoir characteristics. The extent of these diagenetic changes to reservoirs in the southern ZOC are a significant exploration uncertainty and risk.

Flamingo-1 and Eider-1, drilled in 1971 and 1972, were situated to test horst block features on the flank of the Sahul Syncline and on the structural crest of the Londonderry High. Flamingo-1 is a key test in the central western part of the ZOC in that it provides vital information on stratigraphy, reservoir, seal, source and hydrocarbon type present in the Sahul Syncline. The well was drilled to a total depth of 3700 m. and was terminated in Jurassic rocks of the Plover Formation. The Flamingo

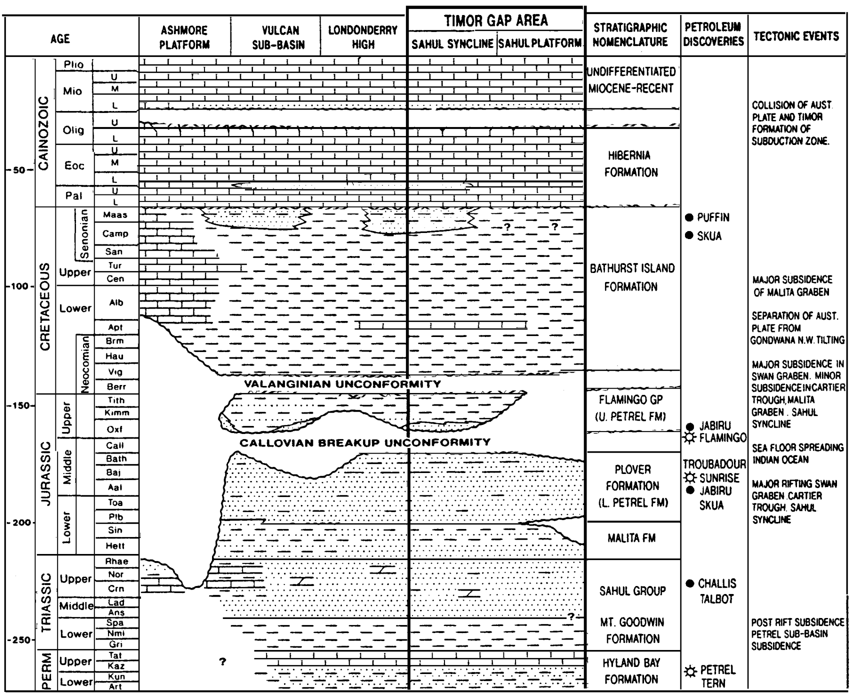

Figure 3 — Chronostratigraphic column for the Timor Sea

structure was originally mapped as a northeast to southwest trending anticline with some fault-dependent closure. The feature was defined by a 6.5 km. by 7.5 km. seismic grid which is insufficient to define the complex faulting seen over the structure. Current mapping by Petroz places the well downdip from the crest of the feature. The well is interpreted to have intersected a net 57 m. thick gas accumulation, in sandstones of the Flamingo Group. Live oil was also identified in cores from the Plover Formation. The well was plugged and abandoned as being non-commercial at that time.

Eider-1 encountered what is interpreted to be a residual oil column in the Plover Formation and Flamingo Group immediately underlying the Bathurst Island Formation.

In 1974, the Woodside consortium confirmed gas and minor condensate discoveries at Sunrise-1 and Troubadour-1 on the eastern Sahul Platform immediately east of the ZOC. Wireline log and flow test information, including pressure data, suggest the presence of 106 m. and 84 m. gross gas columns in these wells. Both are reservoired in Jurassic sandstones of the Plover Formation.

The Curlew-1 well (1975), in the southeastern corner of the ZOC, was situated to test a complex salt-induced anticline. The well encountered poor to moderate gas and oil shows in Cretaceous sandstones of the Bathurst Island Formation and Jurassic sandstones of the Flamingo Group. Curlew-1 was the first well in the area to have major drilling problems, with lost circulation in the shallow Tertiary section and overpressures in the Cretaceous Bathurst Island Formation.

Following acquisition of over 4400 km. of seismic data in 1978, the Getty Joint Venture drilled Tamar-1 in permit WA-70-P west of the ZOC. This well was situated to test a fault bounded horst with primary reservoir objectives in the Plover and Flamingo sections. No hydrocarbon shows were encountered. A review of seismic mapping of the Tamar feature suggests the well is outside structural closure.

The Jacaranda-1 (1984) and Darwinia-1 (1985) wells, drilled by Tricentrol, provide important well control in the central Malita Graben in the southeastern part of the ZOC. Jacaranda-1 was drilled to test a large mapped anticline associated with a major growth fault marking the edge of the Malita Graben. The main reservoir objectives were sandstones of the Flamingo Group. Moderate to fair gas shows were encountered, however most objective reservoirs show porosity destruction by diagenesis. The Jacaranda feature is interpreted to be primarily Tertiary in age and thus formed after major hydrocarbon expulsion from the Malita Graben had taken place.

Darwinia-1 tested a small anticlinal closure at top Cretaceous level. A deeper and larger fault-dependent closure was also tested. The well encountered Cretaceous sandstones displaying good reservoir quality but no hydrocarbon shows. This well highlights the presence of good Upper Cretaceous reservoir rocks in the southern portion of the ZOC. It also displays the potential difficulty in charging Upper Cretaceous and younger reservoirs with hydrocarbons generated from below the regional seal horizon, the Bathurst Island Formation.

Activities in permits WA-199-P (Bond and others) and WA-147-P (WMC and others) have since been instrumental in formulating the current technical understanding of much of the western part of the ZOC. All seven wells in WA-199-P have tested horst block fault-dependent closures with primary reservoir objectives in Jurassic sandstones sealed by Cretaceous claystones. The prevalence of migrating oil within reservoir objectives intersected in these wells, and the sensitivity of traps to the integrity of fault seal is of great importance to much of the ZOC. Analysis of such data indicates actively expelling hydrocarbon source rocks within the Sahul Syncline.

TECTONIC ELEMENTS AND STRUCTURAL HISTORY

The geological history of the area covered by the ZOC is conjectural due to the lack of well control and poor seismic coverage and resolution.

The presently recognised tectonic elements in the Timor Sea are shown on Figure 4. Immediately south of the ZOC is the broad northwest trending Paleozoic to Cretaceous Petrel Sub-basin. A northwest structural grain is dominant in this region and is reflected in the orientation of the Sahul Syncline. Superimposition of a younger northeast Upper Jurassic trend, seen over much of the North West Shelf has resulted in the present structural configuration. East–west faulting of Tertiary age is also present over much of the area and in some cases has rejuvenated older trends.

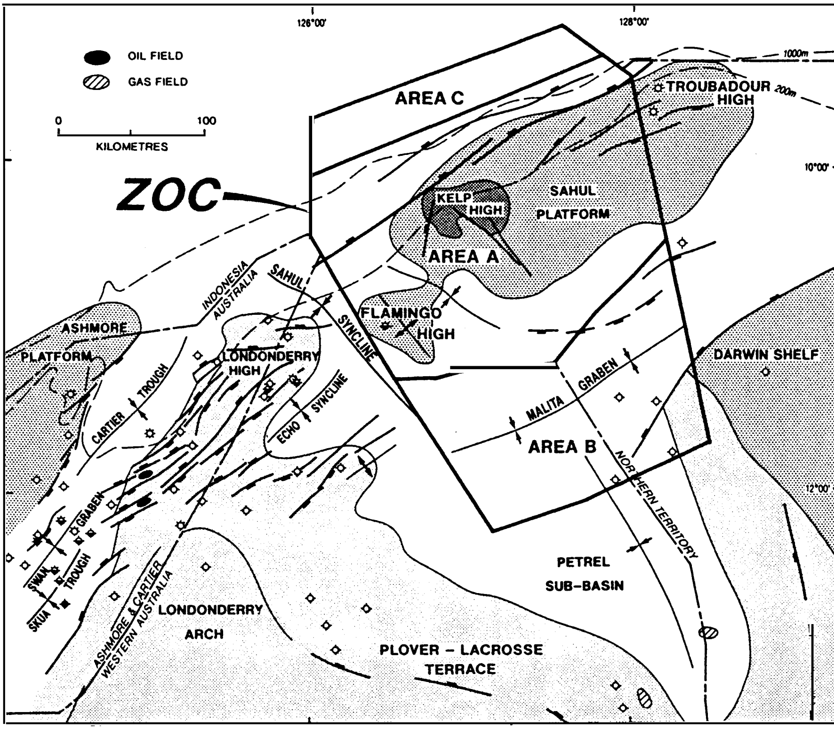

Figure 4 — Tectonic elements of the Timor Sea region

The present day tectonic elements in the ZOC and adjacent areas are dominated by five structural terrains, the northwest trending Sahul Syncline, the northeast–southwest trending Malita Graben and the platform and terrace areas of the Sahul Platform, the Londonderry High and the southern Plover–Lacrosse Terrace.

The Sahul Syncline separates the platform and terraces of the Londonderry High to the west and Sahul Platform to the east. This syncline represents a sag basin which formed as a continuation of a pre-existing Permo-Triassic rift trend. Subsidence continued through to the Lower Cretaceous. Formation of the Sahul Syncline was contemporaneous with that of the northeast trending Skua and Cartier Troughs of the eastern Timor Sea and the Echo Syncline immediately southwest of the Sahul Syncline. Major thickening of the Late Triassic–Mid Jurassic section, including the Plover Formation took place in these areas. Schematic cross sections (Figure 5) across the major tectonic elements in the Timor Sea display the relationship of sedimentation and structural styles.

Timing of major subsidence in the Sahul Syncline is also indicated by thickening of the base Cretaceous to Triassic interval. There is little evidence for the presence of the northeast trending Malita Graben during this time.

Major uplift associated with the breakup of Gondwanaland and separation of Australia and India, took place towards the end of the Mid-

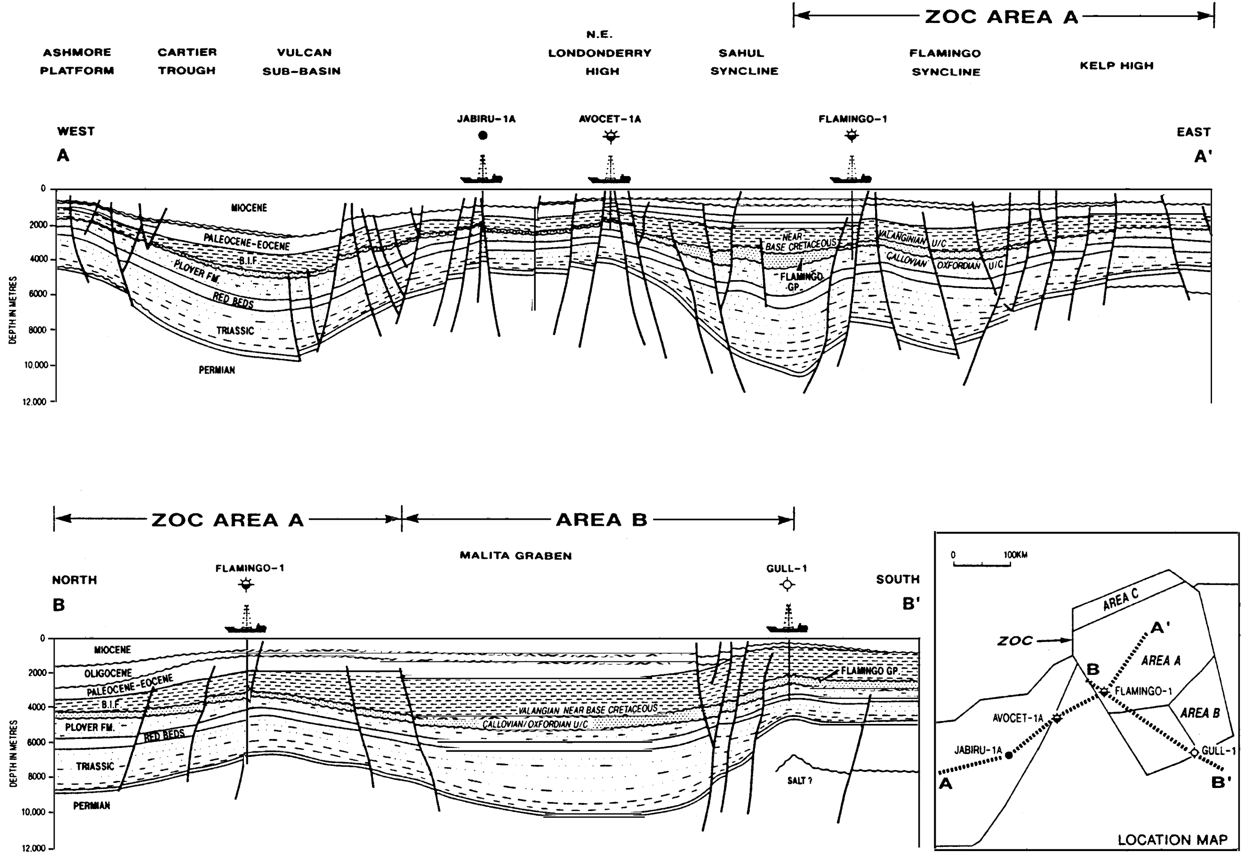

Figure 5 — Schematic cross sections across major tectonic elements in the Timor Sea

dle Jurassic. This resulted in the development of a regional unconformity separating the Plover Formation from the Flamingo Group. Deposition continued in the Sahul Syncline and Echo Syncline over post breakup topography. Formation of the Malita Graben took place at this time contemporaneously with further subsidence in the Cartier Trough and Swan Graben in the western Timor Sea.

Final breakup of Gondwanaland occurred during early Cretaceous resulting in a basin-wide hiatus and fault rejuvenation on horst trends. Major subsidence of the Malita Graben occurred during the Lower–Middle Cretaceous and continued into the Tertiary.

A period of structural readjustment took place during the Late Cretaceous resulting in structural inversion in the northern Sahul Syncline and northwest regional tilting. Reactivation of Middle and Late Jurassic faulting took place during the Late Miocene to Holocene as a result of convergence of the Australian continental margin with the Eurasia plate.

In the Sahul Syncline and Malita Graben, claystones represented by the Flamingo Shale provide a potential top seal for turbidite sands of the Flamingo Group.

Intraformational shale and claystone intervals are postulated as potential seals within the Plover Formation, for the Upper Cretaceous and Cenozoic sand plays.

POTENTIAL SOURCE ROCKS

Three potential oil prone source rock intervals exist within the ZOC. These include the Plover Formation, the Flamingo Group and basal Bathurst Island Formation.

Regional studies indicate that the Plover Formation may be subdivided into two geographically discrete units based on source rock potential and facies distribution. Excellent oil source rock characteristics have been identified within the paludal–lacustrine shales within the Mid–Upper Plover Formation.

The second potential source rock within the Plover Formation exists within the uppermost marine shales identified in Flamingo-1. These shales display dominantly marine affinities with contribution from terrestrial organic matter.

The Plover Formation is an established source rock interval in the Vulcan Sub-Basin.

Only two wells have intersected the Flamingo Group close to the depocentre axes. These are Flamingo-1 in the Sahul Syncline and Heron-1 in the Malita Graben. Only Flamingo-1 has intersected a thick Flamingo Group section which displays oil generative characteristics.

Significant differences may be present between the Flamingo Group deposited in the Vulcan Graben and Sahul Syncline and the Malita Graben. The Flamingo in the Vulcan Graben has moderate to good source potential in a section thickness exceeding 1000 m. The hydrocarbon generative potential of the Flamingo Group in the Malita Graben is speculative.

A significant improvement in source rock quality occurs within the basinal, deeper marine sediments of the basal Bathurst Island Formation in the Sahul Syncline area as intersected by Flamingo-1. The kerogenous basinal marine shales have significant oil generative potential and moderate gas/condensate potential.

OIL-SOURCE CORRELATION

The oils reservoired in the basal Bathurst Island Formation and Flamingo Group in Avocet-1A on the northeast Londonderry High were not generated in situ. The relationship between the recovered oils and paleoburial modelling indicates that the source of the Avocet and Barita oil must have been present within the Sahul Syncline.

Paleoburial modelling indicates that only the Plover Formation within the deeper, central Sahul Syncline had reached sufficient maturity levels prior to the Middle-Miocene tectonic episode. The source for the Avocet oil is therefore likely to be the Plover Formation generating prior to the Middle-Miocene from the Sahul Syncline. The source rock characteristics of the upper Plover shales at Flamingo-1, correlate very closely to the oils recovered from the wells on the Londonderry High.

HYDROCARBON GENERATION AND EXPULSION

Integration of paleoburial and maturity modelling with regional isochrons from geophysical mapping has provided Petroz with a better understanding of the migration pathways. Delineation of migration pathways and timing of hydrocarbon expulsion is of crucial importance to exploration within the ZOC.

Based upon Flamingo-1, the top of the present day early oil generation window is approximately 3200 m. and the depth to the top of the peak oil generative window is 3700 m.

Paleoburial and maturity reconstruction plots and hydrocarbon generation, maturity versus depth plots for the Sahul Syncline, show that the basal Bathurst Island Formation is at early oil generative maturity present day and is capable of generating minor amounts of oil. The Flamingo Shale and Top of the Plover Formation are at the onset of peak oil generative maturity and are generating moderate amounts of oil with minor amounts of gas.

Hydrocarbon generation versus time plots for the top and base of the Plover Formation in the central Sahul Syncline indicate that the top of the Plover Formation may have been generating oil since the Late Cretaceous (80 million years). The base of the Plover Formation started generating both oil and gas as early as 120 million years and reached a peak generative potential at around 80 million years with significant amounts of oil and gas generated between 80 million years and 20 million years. Gas is now the dominantly generating hydrocarbon type.

Maturity models and transformation ratios for the central Malita Graben suggest that 95 per cent. of hydrocarbons capable of being generated from the Plover Formation had done so by Late Cretaceous times.

In the central Malita Graben basal Bathurst Island shales and Flamingo Shale began to generate hydrocarbons, predominantly oil as early as the Late Cretaceous/Early Tertiary. The Flamingo Shale reached

Table 2 — Summary of play types and reservoirs in and adjacent to the ZOC

Play concepts	*Reservoir*	*Reservoir thickness (m) porosity (%)*	*Seal*	*Area*	*Risks*
Fault dependent closures (Play types 1, 2 & 4)	— Eocene turbidites	100–270m (18–37%)	Calcilutites	Malita Graben	Hydrocarbon charge Seal
	— Maastrichtian sands	26–180m (20–28%)	Upper BIF shales	Malita Graben	Hydrocarbon charge Seal
	— Campanian/ Santonian sands	20–30m (20–28%)	Upper BIF shales	Malita Graben	Reservoir quality Hydrocarbon charge
	— Valanginian turbidites?	10–90m (5–12%)	BIF shales	Malita Graben	Reservoir quality
	— Flamingo Gp. sandstone	20–270m (8–25%)	Basal BIF shales	Sahul Platform Malita Graben flanks	Seal (radiolarite juxtaposition) Reservoir quality
	— Basal Flamingo Gp. basin floor fan sands	20–200m+ (2–27%)	Flamingo shales	Sahul Syncline Malita Graben?	Reservoir quality
	— Plover Fm. sands	220–500m+ (4–27%)	Basal BIF shales Intraformational shales	Sahul Platform Sahul Platform	Reservoir quality Reservoir quality and seal

	— Malita Fm.	10–339m (10–18%)	Intraformational shales	Sahul Platform	Seal Gas charge
	— Triassic sands	145m+ (10–19%)	Intraformational shales	Sahul Platform	Seal Gas charge
Stratigraphic Pinchout (Play types 3 & 4)	— Eocene turbidites	100–270m (18–37%)	Calcilutites	Malita Graben	Base seal & hydrocarbon charge
	— Maastrichtian sands	26–180m (20–28%)	Upper BIF shales	Malita Graben	
	— Base Flamingo Gp. turbidites	20–200m+ (2–27%)	Flamingo shales	Sahul Syncline Malita Graben?	Base Seal
4 Way dip closures (Play type 4)	— Maastrichtian sands	26–180m (20–28%)	Upper BIF shales		Hydrocarbon charge Seal
Salt diapirs (Play type 5)	— Stacked Cretaceous Jurassic & Triassic			Southern Malita & Northern Petrel Sub-Basin	

Table 3 — Timing of hydrocarbon generation in the ZOC

Source kitchen	*Source*	*Oil generation (peak) my*	*Gas generation (peak) my*
Central Sahul Syncline	Plover Fm	85–PD (10–PD)	70–PD (PD)
	Flamingo Gp. (including Flamingo Shale)	30–PD (PD)	10–PD (PD)
	Basal Bathurst Island Shales	10–PD (PD)	6–PD (PD)
Central Malita Graben	Plover Fm.	140–60 (90)	110–PD (80)
	Flamingo Gp. (including Flamingo Shale)	100–20 (80)	90–PD (80)
	Basal Bathurst Island Shales	80–0 (20)	75–PD (15)

PD = Present day
my = million years

peak hydrocarbon generation during the Late Cretaceous while the basal Bathurst Island Shales reached maximum generative potential during the Oligocene–Miocene. Both source intervals are now generating gas.

Over much of the Sahul Platform, on the flanks of the Sahul Syncline and on the margins of the Malita Graben, the Plover Formation is at optimum oil generative potential present day. A summary of the timing of hydrocarbon generation for potential source rocks is given as Table 3.

Hydrocarbon expulsion and migration in the Sahul Syncline source kitchen began as early as the Mid Cretaceous from the Plover Formation. Due to the lack of post Jurassic faulting prior to the Middle-Miocene, lateral migration distances from source kitchen areas could have been extensive.

Westerly migrating oil was responsible for filling existing structures on the Eider Horst block. Oil migrating east would have charged existing structures on the flank of the Kelp High on the Sahul Platform.

Present day hydrocarbon migration pathways for gas/condensate being generated from the Plover Formation and oil from the basal Bathurst Island Formation Shales and Flamingo Shales within the Sahul Syncline are likely laterally restricted due to the extensive Middle-Miocene to recent faulting. Tertiary faulting provides vertical migration conduits for recently generated hydrocarbons.

Present day migration pathways from the Malita Graben are considered to spread radially with a dominant northern flow direction within the ZOC towards the structural apices of the Sahul Platform, the Kelp and Troubadour Highs.

PLAY TYPES IN THE ZOC

A summary of possible reservoirs, seals, trap types and their distribution is given together with the presently perceived major associated risks on Table 2. A schematic diagram of potential play types is shown in Figure 6.

The ZOC can be broadly divided into two areas on the basis of potential play type distribution. Reservoir objectives in the Plover For-

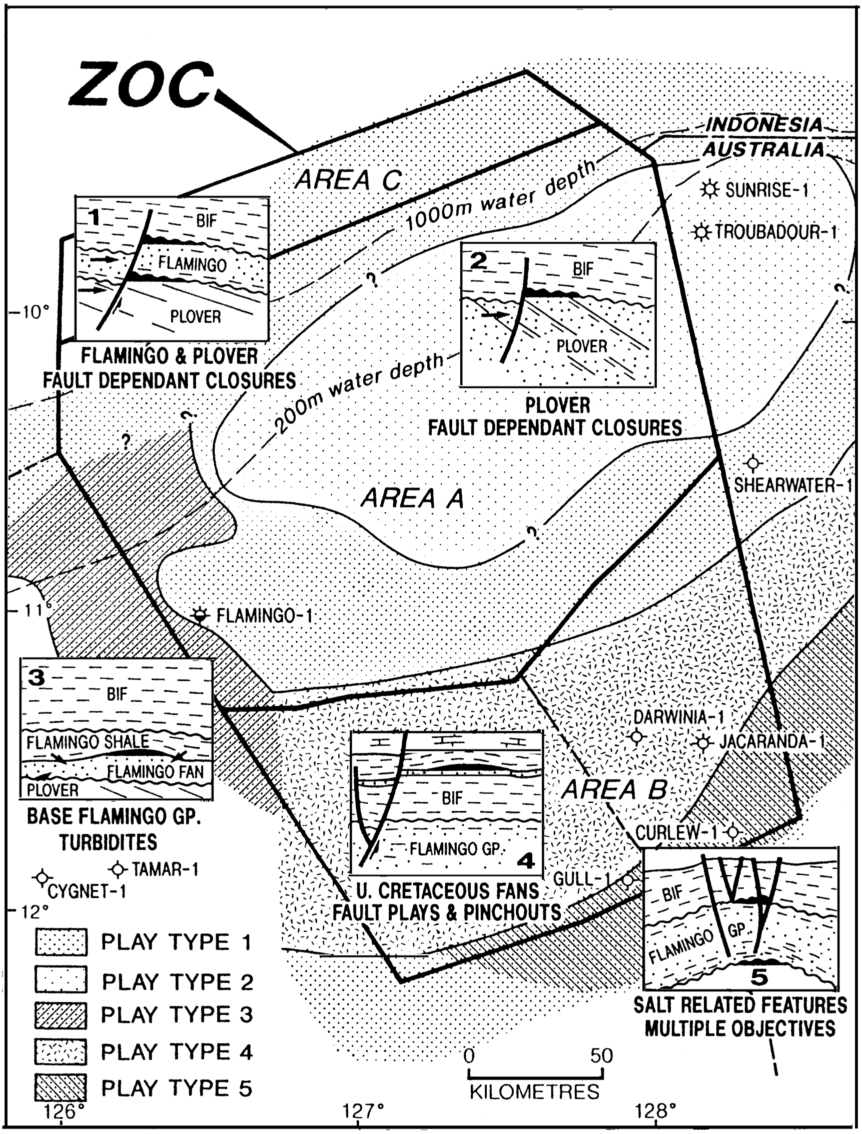

Figure 6 — Schematic diagram of potential play types in and adjacent to the ZOC

mation and Flamingo Group dominate the Sahul Platform, whereas sandstones of the Upper Cretaceous and Tertiary sequences are the primary objectives in the south.

SAHUL PLATFORM AND SAHUL SYNCLINE

Tilted Horst and Fault Block Fault-Dependent Closures (Play Types 1 and 2)

Plover Formation and Flamingo Group reservoirs, tilted horst and fault blocks, commonly showing fault-dependent closure, represent the major trap style of the region. Similar styles of traps have been tested by numerous wells in the western Timor Sea, where success has been achieved at Jabiru, Skua and elsewhere.

Regional seal for this play type is provided by the Bathurst Island Formation which, although thinning onto the Sahul Platform, is interpreted to transgress the whole area.

Resolution of fault patterns and consequent closure size and morphology is difficult using existing widely-spaced, poor quality seismic data. Faulting appears highly complex. Experience from exploration activities in the western Timor Sea Ashmore-Cartier region has shown that seismic grids, with line spacing of less than half a kilometre, and in some cases 3D acquisition, is required to resolve fault configurations and closure size.

Flamingo Group Fan Plays (Play Type 3)

Basal Flamingo Group Sandstones deposited in fan turbidites on the margins of the Sahul Syncline and sealed by the Flamingo Shale, as intersected at Flamingo-1, represent a possible exploration objective. Existing seismic data quality does not allow resolution of the facies types, possible mound forms, scours, progrades, etc. required for detailed sequence stratigraphy and prospect definition.

Cretaceous Structural and Stratigraphic Plays (Play Type 4)

Reservoir objectives in the Bathurst Island Formation are present in the southern and western part of the Sahul Syncline. As this play type is prevalent in the Malita Graben area description and associated risk summaries are given in the next section.

MALITA GRABEN AND ASSOCIATED TERRACES

Sandstones within the Bathurst Island Formation and the Cenozoic section represent the primary reservoir objectives in the southern part of the ZOC. The Flamingo Group is also a reservoir objective on the flanks of the Malita Graben where it occurs at viable depths.

Cretaceous Structural and Stratigraphic Plays (Play Type 4)

Preliminary mapping using the existing widely spaced seismic grid indicates the presence of anticlinal closures at the near top Cretaceous level. The prime reservoir objective at this level is Maastrichtian-aged sandstones of the Bathurst Island Formation. These sandstones display good reservoir characteristics in both Gull-1 and Jacaranda-1. They are potentially sealed by younger Cretaceous claystones. Sandstones of similar age are reservoir objectives in the western Timor Sea (Ashmore-Cartier area), where oil has been recovered from Puffin and East Swan.

Stratigraphic fans, moundings, scours and pinchout plays have all been recognised within the Mesozoic section of the western Timor Sea. It is likely that similar plays are present in the ZOC.

Salt Related Structures with Multiple Reservoir Objectives (Play Type 5)

Structures associated with salt diapirism and possible dissolution features have been identified on the margins of the Malita Graben. The possibility of having stacked reservoir objectives in potentially large closures is attractive. Gull-1, near the southern boundary of the ZOC, is interpreted to have tested one of the these features.

COMPARISONS BETWEEN THE ZOC AND THE ASHMORE-CARTIER AREA

EXPLORATION DATA BASE

Relevant comparisons can be made between the exploration base of the western Timor Sea and that of the area within and adjacent to the ZOC. The ZOC covers approximately 62,000 km^2 whilst the Ashmore-Cartier region covers just over 50,000 km^2.

In exploration terms, the ZOC remains very immature with only five wells and just under 20,000 km. of seismic shot. This reflects total exploration activity in the area since the late 1970s. A similar level of exploration database was achieved in the Ashmore-Cartier area by 1972.

By the end of December 1989, over 70 wildcat appraisal and development wells have been drilled in the Ashmore-Cartier area with over 130,000 km. of seismic data shot in 2D and 3D modes at line spacings down to 60 m.

Various vintages of seismic data are present in the ZOC. Apart from data shot in the southeastern part of the ZOC, the bulk was acquired prior to 1981. Much of the available early data is of poor quality. Some improvement of data quality has been achieved through reprocessing, though it is still considered to be far below the standard required for accurate lead definition and assessment. Seismic line spacing is rarely less than two kilometres and commonly exceeds five kilometres.

Many parts of the ZOC have very poor seismic control. The Jabiru-1A discovery well was drilled on a three kilometre by four kilometre seismic grid. Subsequent appraisal drilling in the Jabiru Field has highlighted the need for detailed resolution of fault patterns and identification of narrow individual fault blocks. Detailed seismic coverage with line spacing down to 60 m., was then undertaken over Jabiru. Considerable variations in the potential structural configuration of Jabiru and associated reserves have taken place through time, highlighting the complexity and ambiguity of interpretation of this play type. Similar complexities and data requirements are expected in exploring for fault bounded plays in the ZOC. Additional well control is necessary to define reservoir, seal and source characterisitics in the ZOC. Much of the potential of the ZOC has been inferred from the results of wells outside the ZOC.

TECHNICAL COMPARISONS

The play types, reservoir objectives, hydrocarbon sources and trap seals are interpreted to be similar in the oil producing Ashmore-Cartier area and the ZOC.

One of the key differences between the two regions is the tectonic history of the Malita Graben compared with the Sahul Syncline and the Vulcan Sub-Basin and the effects this difference may have had on the source potential of the Flamingo Group in the Malita Graben area. Active subsidence took place in both the Sahul Syncline and the Vulcan Sub-basin during the Mid to Late Jurassic, resulting in a thick section of Flamingo Group being deposited in these areas. This section has proven oil source potential. Subsidence rates in the Malita Graben during this time are not known. Deposition was apparently not controlled by simple rift bounding faults as it was in the Vulcan Sub-Basin. Sedimentation in this open system may not have been conducive to source rock formation and preservation in the Malita Graben.

THE LESSONS LEARNT

A review of some of the problems encountered in the Ashmore-Cartier area and how they have been addressed is relevant to the exploration techniques and philosophies to be used over the coming years in the ZOC.

The first major oil discovery in the Ashmore-Cartier area was the Jabiru Field in August 1983, some eleven years after the equivalent exploration data base benchmark in the ZOC (1972). Obviously, factors such as politics and oil price contributed to the inordinate time taken to go from basic levels of exploration, as seen in the ZOC now, to the first discovery in the Ashmore-Cartier region.

Lessons learnt in exploration activities in the western Timor Sea are applicable to the ZOC and application of this experience will reduce finding costs from those of the Ashmore-Cartier area. These costs have been estimated to be as high as $9.00 per barrel if all exploration work in the area is counted. This cost has been significantly reduced to less than $4 per barrel for the period 1983 to 1987 with the application of better exploration techniques and strategies. Application of a harsher fiscal regime in Area A of the ZOC than that seen in Australian permits makes the reduction in finding costs, below the historical levels of the western Timor Sea essential.

Seismic resolution for accurate delineation of objective horizons, fault configurations and structural integrity of prospects remains a problem in the Ashmore-Cartier area. These problems are exacerbated by difficulties in velocity conversions caused by variations in the Upper

Cretaceous and Tertiary sections and the presence of shallow reefal carbonates throughout the area. These concerns have also been identified in the ZOC.

The acquisition of close-spaced seismic grids of generally less than half a kilometre for 2D data and 60 m. for 3D data in the Ashmore-Cartier area, has allowed more confident resolution of complex structural patterns necessary in prospect evaluation.

This will also be necessary within the ZOC. Accurate picking of horizons is required to assess the timing of trap formation and the risks encountered with lack of lateral seal across faults. The timing of trap formation is fundamental in assessing the likely presence of gas rather than oil.

Problems of lost circulation in the Tertiary and Upper Cretaceous sequence and hole instability in overpressured sections of the Bathurst Island Formation have been experienced in the western Timor Sea and in wells drilled within the ZOC. These have been overcome by judicious casing design and development of suitable mud programs. Techniques in drilling deviated holes have been improved by necessity as initial structural interpretations have often proved to be inaccurate when tested by the initial well.

In conclusion the definition of exploration 'sweet spots', where reservoir, source, seal, migration pathways and hydrocarbon type are all favourable, will only come from intensive seismic and drilling activity. The assessment of risks at this stage of exploration activity remain highly speculative.