Emerging Plays in Australasia

17-19 July 2007

The Petroleum Group would like to thank BP and Salamander Energy for their support of this event:
# Emerging Plays in Australasia

**17-19th July 2007**  
**Programme – Day 1**

## Tuesday 17 July 2007

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<td><strong>Alan Roberts, Nick Kusznir, Richard Woodfine, Steve Matthews, Andrei Belopolsky, Cheree Stover, Alexey Goncharov</strong>&lt;br&gt;Crustal stretching estimates in the Browse Basin: from 2D basin modelling and 3D gravity inversion</td>
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<td><strong>Chris Uruski</strong>&lt;br&gt;Deepwater Taranaki Basin, New Zealand</td>
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Challenges of defining structural style in the Kohat fold and thrust belt, Pakistan: A workflow integrating pre-stack depth migration with multiple geologic datasets.

B. Dockrill, J. Doherty, T. Maqsood, R. Hardy, J. Letouzey, J. Gargani, D. Colombo and M. Mantovani

The Kohat Plateau occurs on the southern fringes of the Pakistani Himalayan orogenic belt and consists of a foreland fold and thrust belt bounded by the Main Frontal Thrust (MFT) to the south and the Main Boundary Thrust (MBT) to the north. Tullow Oil is operator of a block immediately south of the MBT, proximal to the town of Kohat. The block contains outcrops of Cretaceous to Pleistocene sedimentary rocks, including sandstones, shales, limestones and evaporites. The surficial structural geology is dominated by east-west trending tight folds that are tens of kilometres long, generally less than 2km wide and commonly overturned. Due to the structural complexity of the region, defining the prospectivity of this block has required an innovative workflow incorporating reflection seismic with surface geological data. A coarse 2D seismic grid was acquired using a combination of dynamite and vibroseis sources to define the subsurface structure. Pre-stack time migration of the reflection seismic provided insight into this complex structure, but poor imaging below near surface anticlinal structures occurred due to complex raypath bending, a problem addressed using a prestack depth migration workflow developed by Geosystem. Defining the velocity model for the pre-stack depth migration was challenging due to subsurface structural complexity and lack of wells in the region. This was overcome by tying surface geology with pre-stack time migrated seismic data to define the major structural elements in the block and hence identify the critical velocity changes for the model. The resultant pre-stack depth migration product provided a superior image that resulted in the reinterpretation of the structural style of the block and definition of multiple leads prospects that are now being evaluated for drilling.
Structure and Stratigraphy of the Offshore Indus Basin Pakistan

Shakeel Akhtar, John Bennett, Scott Carmichael, Mansoor Fatimi, Bob Jones, Mark Longacre, Mark Osborne, Richard Tozer

During 2006 and early 2007, BP acquired a significant acreage position in 7 deepwater blocks covering 30,000sqkm in the Indus Basin offshore Pakistan. The paper will present a summary of the structure and stratigraphy of the Offshore Indus Basin based on regional studies using 2D seismic, well and potential field datasets.

The Offshore Indus Basin occurs in a rift and passive margin setting offshore Pakistan and Western India. The basin is bounded by two major structural highs – the Murray Ridge in the northwest and the Saurashtra Arch in the southeast. The deepwater basin is underexplored with only 1 well drilled on the Pakistan side and 3 offshore India. Rifting associated with break up of the India and Madagascar plates began during Late Cretaceous and was followed by Late Cretaceous –Early Paleocene Deccan volcanics which infill the late rift structure and tend to mask the underlying Late Cretaceous rift geometries. A chain of NE-SW trending volcanic seamounts were formed in the deepwater basin. These formed topographic highs for the development of shallow water carbonates flanked by basins with deeper water facies during the initial Paleocene-Eocene post rift phase. Up to 9000m of Oligocene-Recent sediments are present associated with the influx of deepwater clastics from the Indus River system. Spectacular channel-levee systems are present in Miocene and Plio-Pleistocene intervals and represent potential reservoir targets. 14 major channel levee systems have been identified in the Plio-Pleistocene interval. Trap types include folds associated with strike slip motion along the Murray Ridge, extensional rollover anticlines at the shelf edge, drape structures over the Eocene carbonate highs and stratigraphic traps along the basement ridges. A key challenge for future exploration is to determine whether source rocks are present in sufficient quality for commercial discoveries.
**Emerging Plays in Australasia**

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**Exploration for Subtle Stratigraphic Traps**  
in the Lower Cretaceous Lower Goru Play Fairway, South-central Pakistan

*Nadeem Ahmad*

In the Lower Cretaceous Lower Goru paralic sandstone play fairway on the Lower and Middle Indus platform in Pakistan, significant potential remains untapped in the stratigraphic traps in structural settings such as flanks of the highs, down-thrown fault blocks and in the depressions conventionally thought to be non-prospective. Creaming curve and yet-to-find estimates support that. An out-of-box unconventional integrated approach using sequence stratigraphy as predictive tool is required to de-risk the reservoir sandstone distribution at play level and subtle stratigraphic entrapment at the prospect scale. The Sembar-Lower Goru petroleum system and plays extend further east into the western Rajasthan, India.

A regional sequence stratigraphic framework reconstructed through an integrated use of core sedimentology, wireline log motifs, stratigraphic correlations and seismic stratigraphy shows that the following sequences exist on the Middle Indus platform, from bottom upwards: Sembar-1, Sembar-2, Lower Goru “A,” “B,” “C,” and “D.” The Sembar-2 and “A” lowstand built an extensive ramp on which retrogradational to aggradational paralic sequences were deposited. Between each of the sequences, a normal succession of gradual vertical facies stacking is interrupted, with the offshore to lower shoreface fines directly overlain by coarse-grained proximal sand. A sharp-based blocky to fining-up log motif represents this stratal arrangement. Such ‘out-of-sequence’ sandy wedges, characterized on seismic sections by an abrupt basinward shift of the coastal onlap, are forced-regressive wedges or detached shoreface wedges (FRW/DSW). An active wave and current action along with a northwesterly strong longshore drift piles up the shoreface sands, eastward of previous Sembar-2 shelf margin. These FRW/DSW sand bodies tend to shale out away from the sedimentary feeders, laterally towards north and south, distally towards west and northwest, and terminate eastwards against the previous highstand or slope. On the seismic, a unique or a composite response in the form of an amplitude anomaly related to sigmoidal seismic reflection geometry is evident. The amplitudes dim out laterally towards north and south, distally towards west (corresponding to the offlap break on sigmoidal reflection), and terminate abruptly towards east. Eastward termination, corresponding to the coastal onlap, is important for establishing a proximity to the fluvial input which means coarser grained sand emplacement and fresh-to-marine water mixing facilitating the early Fe-Chlorite coatings around quartz grains. Such depositional and diagenetic settings are crucial for porosity-permeability development and preservation during deep burial diagenesis.

Dry-hole and seismic stratigraphic analysis indicates that the subsequent transgressive ravinement erosion can shave off the reservoir quality coarse-grained upper shoreface sandstone, the main geologic risk in the area. Seal is provided by the regionally extensive black shales deposited during mid to late transgressive phase. Subtle stratigraphic traps in these sandstone wedges are provided by an eastward structural tilt. Entrapment in the westward tilted FRW sandstones is yet to be proven.
What Barmer Basin stratigraphy might tell us about the plate tectonic evolution of India during the Late Cretaceous and Early Tertiary

Paul Compton

The Barmer Basin is the northernmost member of chain of broadly NNW-SSE rifts which extends through the Cambay Basin and runs offshore along the western side of India. The rifts were initiated at about the Cretaceous / Palaeocene boundary, and are somehow coeval with the massive outpouring of basalts and associated acid and alkaline volcanics of the Deccan igneous province. Published age dates indicate the volcanism migrated southwards with time, and it has been frequently suggested that the volcanism may trace the path of a supposed hot spot now under Reunion. If so, the Barmer Basin is of interest because it should contain geological evidence for the earliest appearance of this tectonic / volcanic feature.

The fill of the Barmer Basin comprises Late Cretaceous(?), Palaeocene and Eocene fluvial, deltaic and lacustrine sediments. The basal unit of interbedded sands and shales is called the Fatehgarh Group, and is divided into Lower and Upper Fatehgarh Formations. Thickness variations indicate that the Lower was deposited in a pre-rift setting, while the Upper was early syn-rift. Lower Fatehgarh sands are predominantly sheetflood and braided fluvial in origin, derived from the north, interbedded with lacustrine shales. There is no evidence of contemporary volcanic activity. The Upper Fatehgarh sands, mainly deposited by meandering fluvial channels, show evidence of a mixing of volcanioclastic input with quartz sands derived from the NE and NW flanks.

The Barmer Basin and its flanks contain the most northerly occurrences of Deccan related volcanics. Alkaline volcanics of the Sarnu Dandali complex (on the eastern rift flank) have been dated as 68.5 MY. In the centre of the Barmer rift, so far undated basalts and acid tuffs typical of the Deccan traps have been encountered in deep wells, underlying a sequence resembling the Upper Fatehgarh. The relationships imply that the Lower Fatehgarh Formation predates the Deccan volcanism, while the Upper Fatehgarh was synchronous or slightly younger than the Deccan volcanism.

The model proposed here is that the Lower Fatehgarh Formation was deposited in an intra-continental basin formed by the uplift of the northern rim of the Indian plate, perhaps during the Late Cretaceous. Erosion of a terrain dominated by older Mesozoic sandstones resulted in an excellent source of mature quartz sediment, which was deposited in the north of the Barmer Basin. The main site of lithosphere uplift moved southwards into the continental interior, and initiated the Barmer rift, with associated volcanicity. The northern source terrain was still contributing some quartzose sediment during the deposition of the Upper Fatehgarh Formation, but southwards across the Barmer Basin, clastic material derived from Deccan volcanics predominated, resulting in a significant deterioration of reservoir quality towards the south.

The rate of rift fault growth increased during deposition of the Late Palaeocene-Early Eocene Barmer Hill and Dharvi Dungar Formations, which followed the Fatehgarh Group, but volcanicity appears to have become much diminished. The main site of volcanic activity was further south in Gujarat and Maharastra, and apparently later than in the Barmer Basin, at c.60-62 MY. In the Barmer Basin, syn-rift deposition appears to have ended during the Early Eocene, and the Late Eocene Thumbli Formation appears to belong to the thermal subsidence phase of basin evolution.
The Bangora-Lalmai field, Bengal Basin, a new play for Bangladesh

Shane Cowley, Jerome Kelly, Joe Plunkett and Eoin O’Colmain

The Bangora-Lalmai field in the Bengal basin, Block 9, Bangladesh, was discovered in 2004 with the Bangora-1 well drilled to a depth of 3636m. The objective of the well was a series of Miocene shelfal sands of the Bhuban formation on the Bangora-Lalmai anticline. This paper will present some results from Tullow Bangladesh’s appraisal program of four wells and a 630 km2 of 3D seismic. We present a new play type for Bangladesh with a stratigraphic component to the trapping mechanism for the Bangora-Lalmai field. We will also present some of the results of our highly successful 3D seismic program to place the field in its structural and stratigraphic context. This high resolution 3D dataset has enabled us to place appraisal and early field life development wells in an optimal location for reservoir development and quality resulting in high gas test rates.
Hydrocarbon basins in SE Asia: Understanding why they are there

Robert Hall

There are numerous hydrocarbon-rich sedimentary basins in Indonesia, Malaysia and southern Thailand. Almost all these basins began to form in the Early Cenozoic, they are filled with Cenozoic sediments, most are rifted basins that are the product of regional extension, and they formed mainly on continental crust. Why the basins are there, and why they initiated in the Early Cenozoic is not understood. They are not a consequence of India-Asia collision.

Understanding basin development requires a better knowledge of the Mesozoic and Early Cenozoic history of Sundaland which mainly lacks Upper Mesozoic and Paleocene rocks, but insights can be obtained indirectly. It is a heterogeneous region assembled from different continental blocks separated by oceanic sutures. There has been significant Mesozoic and Cenozoic deformation and the Sunda ‘Shield’ or ‘Craton’ is a myth. Beneath Sundaland there is a marked difference between the deep mantle structure west and east of about 100°E reflecting different Mesozoic and Cenozoic subduction histories. To the west are several linear high velocity anomalies interpreted as subducted Tethyan oceans, whereas to the east of the southernmost linear anomaly is a broad elliptical anomaly beneath SE Asia indicating a completely different history of subduction.

Throughout most of Cretaceous there was subduction north of India, preceding collision with Asia. However, north of Australia the situation was different. Subduction beneath Java ceased in the Cretaceous after collision of a Gondwana continental fragment with the Sundaland margin. Cretaceous collision contributed to elevation of much of Sundaland. In the Late Mesozoic and Paleocene there was a passive margin south of Java and probably most of Sumatra. When Australia began to move northwards from about 45 Ma, subduction resumed at the Sunda Trench. Basins began to form at the time of subduction initiation but they are not backarc basins. Regional extension of Sundaland appears to have been ultimately driven by subduction, but is the result of a hot upper mantle, a weak lower crust, and lower crustal flow in response to changing forces at the plate edges, influenced by pre-existing crustal structure.

Java provides an illustration of the complexities. It is situated on the Sundaland margin where there are changes from continental to ophiolitic basement. Basin history is influenced by the underlying crust, Cretaceous subduction history, subsidence related to arc development, late Cenozoic contraction, and arc-parallel extension. Recognising new exploration opportunities in Java, and elsewhere in Sundaland, requires a better understanding of the regional tectonics, particularly the early history of the region.
Emerging Plays in Australasia


Ian Cross

Since 1860 over 1,540 discoveries exceeding 250 million barrels of oil equivalent (MMboe) have been found outside of North America. These discoveries are comprised of 433 of over 1 billion, 53 over 10 billion and three over 100 billion. However, in recent years the number of 250 MMboe discoveries made each year, which peaked at 50 in 1969, is worryingly down to a trickle. In 2006, preliminary data suggest that only 14 of this size were made, although impressively half were recorded in Asia-Pacific.

This talk will first look at historic discovery trends, including a review of the past two years, which will help give us an idea of what we can expect in the future. The presentation will then discuss some of the high-impact wells in the Asia-Pacific region which are likely to be drilled during the next three years.

The high-impact wells reviewed will focus on play openers and those in excess of 250 MMboe in size. IHS has identified over 400 in this range globally with approximately 25% in Asia-Pacific.

The aim of this discussion will be to give an understanding of who are the main players, strategy, location of prospects, opportunities to participate, play and hydrocarbon types, plus implications of the key wells in this region.

With the world quickly running out of places to find new “elephants”, this talk will highlight the provinces in this important region that may offer hope for the discovery of big fields.
The Neftex sequence stratigraphic model provides an accurate and reliable framework with which to identify, map and correlate petroleum system elements such as lowstand reservoirs and transgressive source rocks. This model, therefore, has significant implications in its application to future petroleum exploration and production in the Southeast Asia region.

Early work on this model demonstrated the occurrence of 65 synchronous late Precambrian – Phanerozoic Maximum Flooding Surfaces (MFS) across the Arabian Plate (Sharland et al., 2001, 2004) and further, ongoing work has identified additional 1st, 2nd and 3rd order flooding sequences together with intervening sequence boundaries (SB). Each MFS and SB is defined in a reference section where good sedimentological and/or wireline log evidence is present and biostratigraphically supported.

Good biostratigraphic control provides the opportunity to correlate these surfaces worldwide. The surfaces have been identified in basins with different subsidence and sedimentation histories and are clearly synchronous leading to the conclusion that they are eustatic in origin. It can be demonstrated that the Neftex sequence stratigraphic model, originally developed in the Middle East, can be successfully applied to North Africa, the western former Soviet Union, South and Central America, North America and the Arctic, and now Southeast Asia.

For example, the Ng10 MFS (20 Ma) recorded from the base of the Euphrates Fars Formation in Iraq (Sharland et al., 2004) and also identified in E Syria, Iran, UAE, Qatar and Oman can now be recognised in the Early Burdigalian N5 planktonic foraminifera biozone of the Dua Formation in the Nam Con Son Basin, Vietnam (Matthews et al., 1997) and the Tuban Formation of the East Java Basin, Indonesia (Sharaf 2006).

A robust calibrated sequence stratigraphic framework provides an excellent means for correlating well and outcrop data, producing high-resolution facies maps and, ultimately, common risk segment mapping and play fairway analysis.

References


A multi-basin study of the South China Sea (SCS) region examined source presence, burial and reservoir distribution. Source rock control was derived from a detailed synthesis of the literature, combined with an early Tertiary reconstruction of the SCS. Maturity was calibrated to publications and extrapolated across the region using sediment thicknesses derived from potential field data. Structural analysis provided insights into features that controlled the deposition of coarse-grained sediments. We present examples in three basins on the north, west and south flanks of SCS.

Deep-water sand bodies were deposited around the South China Sea (SCS) margin in distinctive tectonic environments distinguished and mapped on various inversions of gravity data trained by published examples. Three selected systems lie in tectonically defined compartments of sediment thicks with onshore-to-offshore distributary patterns often channelized into corridors by coastline segmentation. Oil potential is overprinted with gas likelihood in the main thicks.

The Pearl River Mouth Basin (PRB) sand delivery system was established probably in earliest Tertiary. Since the Oligocene, sands have been confined to one segment of the south China coast by NW-SE accommodation structures. Large areas (up to 250 km x 250 km) of thick Neogene and pre-Neogene sediments cause similarly large variation in maturity potential. The predominance of gas discovered to date correlates to burial rather than to a source type bias.

The Northwest Borneo system has been continually deformed, first by convergence of Borneo with the SCS margin and then by gravity-driven toe thrusting. Deltaic sediments of this margin northeast of the Luconia platform overtop the convergent system. Most shallow-water deltaic sediment was concentrated near the coast on the southeast flank of the sediment thick, while deep-water fan bodies were trapped behind the distal toe thrust system to the northwest. Migration pathways and seals versus leakage are a main risk as source burial is generally adequate for oil and gas generation.

In southern East Vietnam offshore, deep-water fan systems appear to dominate sediment fill in the narrow, continental-borderland-related Phu Khanh basin. Sediment input was localized across a narrow continental shelf into the also narrow, strike-slip related basins with little if any shallow-water architecture developed. Source presence is illustrated in a key publication by Phan 1995; burial varies from inadequate to probable gas.
The Makassar Straits: What lies beneath?

Robert Hall, Stephen J. Calvert, Ian R. Cloke, Christopher F. Elders, Siti Nur'Aini & Sinchia Dewi Puspita

The Makassar Straits separate Borneo from Sulawesi. Since the Eocene they have been an important deep water barrier between west and east Indonesia and currently play an important role in the oceanic thermohaline circulation system, as a passage for water from the Pacific to the Indian Ocean. In the last few million years they have become narrower as the result of the eastward progradation of the Mahakam delta from Borneo, and of sediment building out, associated with thrusting and folding, from Sulawesi. It has been accepted for many years that east Borneo and west Sulawesi were close together in the Late Cretaceous but the mechanism and age of formation of the Makassar Straits have been less widely agreed. There have been suggestions that they are a foreland basin, a remnant oceanic basin or a rift. Geological studies on land, and offshore seismic data, now show the straits have an extensional origin and probably formed in the Eocene by rifting. However, the nature of the crust beneath the straits remains controversial: is it oceanic or continental? The southern parts of the straits east of the Paternoster Platform are about one kilometre deep, relatively narrow, and lack a thick sedimentary cover above basement. Granite is known from boreholes that reach basement. This part of the straits is likely to be underlain by slightly extended continental crust. However, the northern Makassar Straits have water depths up to 2500 metres, with a very thick undeformed sedimentary cover above basement that is not well imaged on seismic lines. There is no way of directly sampling the basement, although field studies from the Borneo and Sulawesi margins can be used to sample possible equivalents. The rift and its margins are asymmetrical and wide. There is approximately 400 km of stretched crust on the Borneo margin and about 200 km on the Sulawesi margin, separated by about 200 km of the deepest crust in the northern Makassar Straits. Gravity data and flexural modelling on the Borneo side have been used to interpret a junction between continental and oceanic crust beneath the Mahakam delta. The oceanic crust is inferred to be of similar Middle Eocene age to the Celebes Sea to the north; apparent conical structures on seismic lines have been interpreted as volcanic edifices. However, on the Sulawesi side half graben and graben are interpreted beneath thick sediments, there are low angle extensional faults, and lineaments crossing basement can be traced into the deepest parts of the straits. These structures suggest an origin by oblique rifting of continental crust in which the apparent conical structures are interpreted as carbonate build-ups on tilted fault blocks. The character of the basement beneath the Makassar Straits is important for the petroleum system since it determines subsidence, thermal history and consequently source rock maturation. If there is oceanic crust beneath the Makassar Straits, it is unlikely that an Eocene lacustrine source rock would be present and Miocene source material transported into deep water would be required for the petroleum system to work.
Relationships between plate tectonics, slab windows, stress regimes and heat flow in Indonesia from 80 Ma to the present

J. M. Whittaker, R. D. Müller, M. Sdrolias, C. Heine

The kinematics and time-dependence of back-arc extension or compression is one of the most poorly understood aspects of plate tectonics, and has nearly exclusively been studied from snapshots of present-day observations. Here we combine absolute and relative plate motions with reconstructions of now subducted ocean floor to analyse subduction kinematics and upper plate strain from geological observations since 80 Ma along the 3200 km long Sunda-Java trench, one of the largest subduction systems on Earth. Combining plate motions and slab geometries enables us to reconstruct a time-dependent slab window beneath Sundaland, formed through Wharton spreading ridge subduction. We find that upper plate advance and retreat is the main influence on upper plate strain, but subduction of large bathymetric ridges, and slab-window effects, also play a significant, and at times dominant, role. Compression in the Sundaland back-arc region can be linked to advance of the upper plate. Extension of the Sundaland back-arc region correlates with two patterns of upper plate motion, (a) retreat of the upper plate, and (b) advance of the upper plate combined with more rapid advance of the Sundaland margin due to hinge-rollback. Subduction of large bathymetric ridges cause compression in the upper plate, especially Wharton Ridge subduction underneath Sumatra over the period 15-0 Ma. Our reconstructions unravel the evolving geometry of a slab window underlying the Java-South Sumatra region, and we propose that decreased mantle wedge viscosities associated with this slab window exacerbated Palaeogene extension in the Java Sea region via active rifting, and enabled Sumatran continental extension to continue at 50-35 Ma when upper plate advance would otherwise have led to compression.

The relationships between plate motions and upper plate stresses observed at the Indonesian subduction zone should be applicable to other subduction zones, enabling predictions of palaeo-stress regimes to be made from plate reconstruction models. Reconstruction of slab windows beneath plate edges is useful when estimating palaeo-heat flows. An underlying slab window results in increased heat flow to the overlying crust, with implications for maturation processes.
Emerging Plays in Australasia

Exploration hotspots of SE Asia

Ian Longley

The current exploration hotspots of SE Asia surround recent significant discoveries and comprise the Cuu Long Basin of Vietnam, the Bengal Basin in Myanmar, the East Java Basin in Indonesia and the deep water portions of the Pearl River Mouth (China) and offshore Sabah (Malaysia). The recent discoveries and the local petroleum geology for each of these areas are reviewed and the known future activities in each of these areas are detailed.

Possible future exploration hotspots are difficult to predict but many areas have been heavily licensed and will see considerable exploration activity in the next few years. Some examples of these prospective but unproven areas include the Thai-Cambodia disputed area covering an extension of the Pettani Trough, the Makassar Straits of Indonesia and the Phu Khanh Basin of Vietnam. Drilling success in these (or other) unproven areas is likely and demonstrates that significant exploration potential remains in the region and that politics, technology and simple wildcat drilling all have a role to play in the regions exciting future.
A New Tectonic Model for the Petroleum Systems of Northwest Borneo

Andrew Cullen

The world-class petroleum systems of Northwest Borneo have a complex geological history. Oligocene sandstone and Early Miocene carbonate reservoirs of the gas-prone Luconia system lie southwest of the Baram-Tinjar zone. To the northeast, the Baram-Balabac system contains oil and gas in Middle Miocene to Pliocene sandstones. Recent wildcat exploration has focused on the deepwater segment of the Baram-Balabac system where a fold-thrust belt has over ridden a “lower plate” of attenuated continental crust. Pelagic shales above the regional Mid-Miocene Unconformity on the “lower plate” provide decollement surfaces.

Recently Shell has undertaken a “bottoms up” approach towards rebuilding an understanding of these petroleum systems in relation to regional tectonics. Currently cited tectonic models for Borneo, although differing in detail, show Oligocene through Early Miocene subduction of Mesozoic proto-South China Sea oceanic crust beneath Borneo. Subduction purportedly ended in the Middle Miocene owing to collision of attenuated continental crust.

A synthesis of new biostratigraphic data, regional mapping (~150,000 km²) of 8 key sequences, results from recent wells plus a review of older wells, and a critical review of prior internal and published studies coupled with considerations from gravity, magnetic, and tomographic data call into question Oligo-Miocene subduction under NW Borneo. An alternate tectonic model for NW Borneo is presented in which the interplay of “extrusion tectonics,” crustal thickening under Borneo, and older “basement” features, control the Neogene basins and orogenesis. The following results and ideas stemming from this model are discussed:

1. The implications that follow from new biostratigraphic data indicating an Eocene age for West Crocker formation.
2. A regional early Middle Miocene extensional event in Sabah that resulted in deep local basins that underwent Late Miocene to Pliocene inversion.
3. Segmentation of the shelf and deepwater fold belt into linked structural domains whose NW striking boundaries coincide with structural trends in the lower plate.
4. Two of these domain boundaries represent deep plate-scale crustal elements that extend across Borneo into the Celebes Sea.
5. The relation of the petroleum systems and giant fields to domain boundaries.

This alternative model highlights the fact that many fundamental questions regarding the tectonic evolution of Borneo remain unanswered. There is clearly a need for continued basic geological and geophysical studies with greater cooperation between industry, academia, and governments.
Emerging Plays in Australasia

Deepwater NW Borneo – An emerging play with implications for more mature deepwater plays?

Sam Algar

Exploration in Deepwater NW Borneo began in the 1990’s with the discovery of a number of small to moderate sized gas accumulations. With no obvious marine or lacustrine source rock model, the concern was that the gas was coming from land-plant organic matter and that the volumes of oil might be very limited. This perception was overturned in 2002 when Murphy Oil drilled Kikeh-1. Kikeh-1 discovered significant quantities of oil in Late Miocene deepwater sands. Murphy quickly appraised the discovery and the field is due to come on stream in the second half of 2007, only 5 years after discovery. In the process of appraisal Murphy acquired a significant amount of data including over 220m of conventional core. This data, when combined with extensive logging suites, 3D seismic and data from other wells in the area have significantly changed the perception of the region’s petroleum systems. As well as constraining the source rock model for the area, reservoir and in some ways more importantly, inter-reservoir depositional processes are beginning to be better understood. A key component of this is the mass transport deposits (MTDs). The presence of MTDs has played a key role in the petroleum systems and it is suggested that more careful study of them might lead to significant changes in our understanding of other deepwater plays in the region and around the world.
Deepwater Hydrocarbon Potential of the Sandakan Basin, Philippines Sulu Sea

*Paul Bransden, Peter Stickland*

The shallow water part of the Palaeogene to Recent Sandakan Delta has been moderately explored over three decades, with some technical success; however activity has only recently been extended into the deepwater area. This paper demonstrates that all elements of the proven deepwater systems of the Borneo margins are similarly present in the deepwater Sandakan Basin.

The age-equivalent reservoir packages which contain the bulk of the reserves in deepwater systems of the Kutei and Baram Deltas appear to be also present in the Sandakan Basin. In ODP 768C in the axis of the Sulu Sea, the relatively sudden Middle Miocene influx of siliciclastic turbidites probably records the onset of uplift of Borneo and consequent major sediment input to the delta. While the only deepwater well, Wildebeest-1, failed to encounter significant thicknesses of reservoir, subsequent 2D seismic data suggests it is located in a slope bypass environment. The 2D seismic data provides strong evidence of the presence of amalgamated slope channel sand bodies along strike with Wildebeest-1. These slope channels are perceived to be the most prospective reservoirs in SC 41 and have been the target of recent 3D acquisition.

Mid Miocene deltaic sedimentation resulted in numerous compressional diapiric features and toethrust anticlines beneath the palaeoslope. The most prospective features occur where the compressional anticlines coincide the pre-kinematic amalgamated slope channel systems. The basin also demonstrates minor transpessional modification perpendicular to the slope, which provides additional trapping potential.

It is currently postulated the proven systems of the deepwater Borneo margin rely on terrigenous source rocks which have been transported and redeposited in a deepwater environment. Due to the limited data, direct evidence for this source is not available in the Sandakan Basin, however high quality oil consistent with this source type has been recovered in the Wildebeest well. Further the timing of maturity appears favourable in the deepwater Sandakan basin as thick Pliocene to Recent sedimentation in the vicinity of the Wildebeest trend results in the present day expulsion of oil and gas from the likely source kitchen deeper in the basin.
Reservoir quality and development of Cenozoic carbonate buildups and coral reef terraces

Moyra E.J. Wilson and Katie S. Roberts

Almost half of SE Asia’s considerable hydrocarbon reserves are contained in carbonates. The majority of these reservoirs are Miocene buildups up to tens of kilometres across. However, with the exception of a few fields, there is little detailed data on how local depositional and diagenetic conditions influence the considerable inhomogeneities in reservoir quality often encountered. This study focuses on factors influencing the facies, diagenetic and reservoir variability of comparable Modern, Quaternary and Neogene reef associated deposits from the Tukang Besi Archipelago, Central Indonesia.

The Archipelago includes 5 large atolls, a number of smaller buildups and 4 main islands each with modern rimmed shelves or fringing reefs. On the islands, over ten late Neogene and Quaternary coral reef terraces have been uplifted to maximum heights of ~300 m. Analysis of the modern deposits allows initial reservoir potential to be assessed and related to local environmental conditions. The influence of diagenesis on final reservoir quality is evaluated for the depositional facies exposed in the uplifted terraces. The overall spatial distribution in effective porosity across the area is strongly dependent on local energy conditions, water depth, carbonate producers, size of atolls or islands, climate and local meteoric diagenetic processes. This evaluation of spatial variability in carbonate reservoir characteristics provides much needed analogue data as the hydrocarbon industry focuses on improving recovery from existing fields and exploring for new reserves.
Emerging Plays in Australasia

Tectonic evolution and hydrocarbon prospect of Java Island, Indonesia

Benyamin Sapiie

The present tectonic development and framework of Java Island cannot be considered in isolation, as they are the product of the tectonic history of Southeast Asia, extending from Late Mesozoic and Tertiary. Therefore, the main portion of the study focused on the understanding of the complex plate tectonic history of Southeast Asia. Understanding the tectonic history of this region is critical to the acceptance of the concept of geodynamic evolution of all Tertiary basins in Indonesia. The complex processes resulting in basin formation of Indonesia owe their origin to the interaction of plate movements between the Indian, Eurasian, Australian and Pacific plates. Within the framework of these major plate movements, a large number of rigid micro-plates may be incorporated, the boundaries of which influence basin formation and deformation.

The Java basinal area is one of the major petroliferous basins in Indonesia. However, understanding of the tectonic development of the area is still subject to ongoing debate. Detailed regional geologic investigation was carried out to study and evaluate tectonic history and basin development in relation to hydrocarbon potential of the area. Recently acquired seismic data at East Java triggered a new interpretation of tectonism and basin development especially during Paleogene time. In addition, re-interpretation of old data (surface and sub-surface), and assessment of hydrocarbon plays using newly developed concepts, may result in a new understanding of the geologic history of the basin and previously unrecognized hydrocarbon systems can be deduced. The result of this study reveals a new target for hydrocarbon exploration in the area.
Thrusting of a volcanic arc: A New structural model for JAVA

Benjamin Clements, Robert Hall, Helen R. Smyth & Mike Cottam

Java is a volcanic island arc situated in the Indonesian archipelago at the southern margin of the Eurasian Plate. Sundaland continental crust, accreted to Eurasia by the Early Mesozoic, now underlies the shallow seas to the north of Java where there has been considerable petroleum exploration. Java has an apparently simple structure in which the east-west physiographic zones identified by van Bemmelen broadly correspond to structural zones. In the north there is the margin of the Sunda Shelf, and in southern Java are Cenozoic volcanic arc rocks produced by spatially and temporally discrete episodes of subduction-related volcanism. Between the Sunda Shelf and the volcanic rocks are Cenozoic depocentres of different ages containing sedimentary and volcanic material derived from north and south. This simplicity is complicated by structures inherited from the oldest period of subduction identified beneath Java, in the Cretaceous, by extension related to development of the volcanic arcs, by extension related to development of the Makassar Straits, by late Cenozoic contraction, and by cross-arc extensional faults which are active today.

Based on field observations in different parts of Java we suggest that major thrusting in southern Java has been overlooked. The thrusting has displaced some of the Early Cenozoic volcanic arc rocks northwards by up to 50 km. We suggest Java can be separated into three distinct structural sectors which broadly correspond to the regions of West, Central and East Java. Central Java displays the deepest structural levels of a series of north-directed thrusts, and Cretaceous basement is exposed; the overthrust volcanic arc has been largely removed by erosion. In West and East Java the overthrust volcanic arc is still preserved. In West Java the arc is now thrust onto the shelf sequences that formed on the Sundaland continental margin. In East Java the volcanic arc is thrust onto a thick volcanic/sedimentary sequence formed north of the arc in a flexural basin due largely to volcanic arc loading. This hypothesis is yet to be tested by seismic studies and drilling, but if correct there may be unexplored petroleum systems in south Java that are worth investigating.
Arc rocks reveal a Gondwanan fragment at depth beneath East Java, Indonesia

Helen Smyth and Robert Hall

The island of Java is located in the Indonesian archipelago in SE Asia between Asia and Australia. To the south of Java there has been long-lived subduction of the Indo-Australian Plate along the Java Trench since the Early Cenozoic. As a result Java is a volcanic island; it contains the products of active and ancient volcanism. The volcanic products of an Early Cenozoic Arc are well preserved and include a significant amount of acidic volcanism that has been overlooked in previous studies of the area. In particular, quartz sandstone, previously considered to be of terrigenous clastic origin, are now known to be of volcanic origin. Activity in the Early Cenozoic Arc culminated in the Early Miocene with a phase of intense eruptions, including a previously unrecognised eruption, the Semilir Event. Following the cessation of the Early Cenozoic arc volcanism, there followed a period of volcanic quiescence. Subsequently, arc volcanism resumed in the Late Miocene in the modern Sunda Arc, the axis of which lies 50 km north of the older arc.

Dating of zircons within the arc rocks indicates that the acidic character of the volcanism can be related to contamination by a fragment of Archean to Cambrian continental crust that lay beneath the arc. The igneous rocks of the Early Cenozoic arc, found along the southeast coast, contain only Archean to Cambrian zircons. In contrast, clastic rocks of north and west of East Java contain Cretaceous zircons, which are not found in the arc rocks to the south. The presence of Cretaceous zircons supports previous interpretations that much of East Java is underlain by arc and ophiolitic rocks, accreted to the Southeast Asian margin during Cretaceous subduction. However, such accreted material cannot account for the older zircons. The age populations of Archean to Cambrian zircons in the arc rocks are similar to Gondwana crust. We interpret the East Java Early Cenozoic arc to be underlain by a continental fragment of Gondwana origin and not Cretaceous material as previously suggested. Melts rising through the crust, feeding the Early Cenozoic arc, picked up the ancient zircons through assimilation or partial melting. We suggest a Western Australian origin for the fragment, which rifted from Australia during the Mesozoic and collided with Southeast Asia, resulting in the termination of Cretaceous subduction. Continental crust was therefore present at depth beneath the arc in south Java when Cenozoic subduction began in the Eocene.
Maleo Gas Field, North Java

John Bates

The Maleo field is located in the Madura Offshore PSC, offshore East Java. The field was discovered in June 2002 by the Maleo-1 exploration well which encountered a 49 metre thick gas column in the Pliocene Paciran and Mundu Sequences. Maleo-1 established a current free-water level of 582 mss whereas Maleo-2 subsequently found a slightly deeper gas-water contact on the northwestern flank of the field (586 mss). The structure is a 4-way dip closure modified by numerous normal faults and is only partly filled. Gas in the Maleo field is approximately 99% methane and is primarily of biogenic origin.

The gas in the Maleo field is reservoired in detrital carbonates. Framework grains within these unusual reservoirs consist almost entirely of the hollow tests, both intact and broken, of the planktonic foraminifera *Globigerina*. Lime mud matrix is also present and the proportion of matrix is the primary control on reservoir quality. Both inter-particle and intra-particle porosity types are present and porosity can be as high as 60% in the grainstone facies. The *Globigerina* carbonates are interpreted to have been deposited in moderately deep water, 150 – 250 m, possibly on a detached platform.

Although there has been some historical oil production from *Globigerina* reservoirs in shallow fields of onshore East Java, Maleo is the first offshore discovery of this reservoir type to be commercialized and it has presented some significant challenges. Four horizontal development wells were drilled from a location constrained by shallow gas zones and the likelihood of significant sea floor subsidence over the field life. Production began on 29 September 2006 and offtake rates reached 100 MMcfd before the rupture of the East Java Gas Pipeline in November 2006 necessitated reduced production rates. 2P field reserves are 241 bcf recoverable and field life is expected to be 8 years.
Eocene rifting and its relationship to strike slip faulting in the western Gulf of Thailand

Chris Elders, Ian Watkinson and Anongporn Intawong

Large scale strike slip faults such as the Red River and Mae Ping Faults form a prominent part of the geology of SE Asia. In the past it had been assumed that basin formation in the Gulf of Thailand and offshore Vietnam was a result of extensional splays developed at the termination of such faults (Nam Con Son Basin), or as a result of dextral shear between parallel strike-slip faults (Gulf of Thailand). The availability of 3D seismic data from these areas shows that although the faults form prominent features onshore, their offshore extent is limited. Thus it would appear that the offshore basins have a dominantly extensional mode of deformation.

However, there is a close spatial relationship between sedimentary basins in the Western Gulf of Thailand and NE-SW trending strike-slip faults (the Khlong Marui and Ranong Faults) that cut the Thai Peninsula. Although these faults are frequently shown on geological maps, there are no published field descriptions. Newly acquired data provides evidence of an early phase of ductile dextral displacement followed by later brittle sinistral movement. In this sense they are conjugate to the NW-SE trending Mae Ping Fault and Red River Faults which show early ductile sinistral and later brittle dextral displacement.

It has also been assumed that start of basin formation in the Gulf of Thailand coincides with the switch in movement on the Mae Ping Fault in the late Oligocene. However, there is clear evidence of an Eocene phase of extension in the western Gulf of Thailand. If these basins are strike slip controlled, they would require sinistral movement on the Khlong Marui and Ranong Faults. Although the timing of movement on these faults has yet to be established, analogy with the Mae Ping Fault would suggest that the Eocene phase of extension overlaps with the earlier phase of dextral movement. Furthermore, the sedimentary basins are more extensive than the strike-slip faults, suggesting that they do not control basin formation. Instead changes in basin polarity the Khlong Marui Fault suggest that it is an older structure that was reactivated as an accommodation zone in a predominantly extensional setting. A final phase of brittle dextral movement is consistent with the fault acting in a similar manner during later inversion. Understanding the formation of the half graben developed during the Eocene rift event is important as they could form favourable sites for the deposition of lacustrine source rocks.
The Permo-Triassic gas play in the Khorat Plateau Basin, NE Thailand – its renaissance following the development of the Phu Horm gas field

John Booth, John Smallwood, Jo Henson, Rod Warters, Nick Comrie-Smith

Exploratory drilling in the Khorat Plateau Basin began in 1972 and by 2000 some 24 separate prospects had been drilled. ExxonMobil had brought the Nam Phong gas field on stream in 1991, but recoverable reserves were significantly reduced during development. A number of other discoveries had been made, including Phu Horm, Dong Mun and SiThat-2 but flow rates on test were modest. Consequently exploration and appraisal activity in the Khorat Plateau Basin declined as companies perceived the area as gas prone, with tight, low deliverability reservoirs.

This perception changed following the drilling of Phu Horm-3 by Hess in 2002. In this well the Permian Pha Nok Khao carbonate reservoir was drilled with an “underbalance” mud system, which solved the massive loss circulation problems experienced earlier, and reduced formation damage. During the underbalance drilling the well flowed at a sustained rate of 47 mmscfd. The success of Phu Horm-3 was followed by two further “underbalance” wells, both of which flowed at sustained commercial rates. This paved the way for gas marketing and a gas sales agreement in 2005. The field was brought onstream in November 2006 and is currently producing around 100 MMscfd, and supplies a local gas fired power plant.

The surface expression of Phu Horm field is a 30km long, north-south orientated hill, rising some 340 meters above the surrounding landscape. This is an anticlinal feature of Tertiary age, underlain by a large Permo-Triassic horst, which forms the trap for the field. To the east and west of the horst are deep grabens, thought to contain thick open marine lateral equivalents of the Pha Nok Khao carbonates. These basinal sediments probably source the gas, with possibly some contribution from Triassic, Hua Hin Lat shales. The main proven reservoir is a sequence of Middle to Late Permian age carbonates (Pha Nok Khao Formation), consisting of apparently interbedded layers of recrystallized limestones and dolomite. Production testing indicates that the field has a dual porosity system, with the presence of open fractures and matrix porosity in the dolomite. There may also be a contribution from preserved karst related porosity.

Due to field complexity and data acquisition difficulties, there remain a number of major uncertainties, which leave the true size and reservoir potential of the Phu Horm field to be determined. Several exploration and appraisal wells are planned to address these uncertainties and to attempt to extend the success of the play.

This talk will further address these uncertainties and future drilling objectives. In addition the play will be further discussed within the context of the basin tectonostratigraphy and regional structural elements.
The Deepwater Tertiary Ulleung Basin Play, Korea: KNOC and Woodside partnering for success.

Longley, I.M, Im., H, Choi, B., Clark, W. and Bekkers, P.

In February 2007 KNOC and Woodside signed a concession agreement to jointly explore a 13000km² area in the deepwater portion of the Ulleung Basin located off the east coast of the Korean peninsular. The block area is wholly within undisputed Korean territorial waters and represents the first involvement of a foreign oil company in Korea since 1985 and the first dedicated deepwater exploration program in Korean history.

The Ulleung Basin is a Tertiary basin which was initiated as a rift/pull apart basin in the late Oligocene related to the opening of the East Sea. A large hinterland drainage area from the east China shelf subsequently focused quartzose sands into the southern end of the basin during the Miocene leading to a large 8-10km thick prograding then aggrading deltaic wedge which partially filled the marine basin. This deltaic complex is analogous to the productive Kutei and Baram deltaic sequences which flank the east and northwest coasts of Borneo respectively. During the Middle Miocene the East Sea changed from an extensional to a compressional system caused by Back arc closure. This change in the regional tectonics resulted in a series of uplift, oblique slip and large scale fault reactivation/inversion events. A series of uplift pulses during the Mid - Late Miocene resulted in several low stand events, leading to a series of massive canyon incisions of the delta top and reworking of deltaic material into the deep basin area. As a result, large turbidite sequences were deposited to the north which have been identified and mapped on the available reconnaissance 2D seismic data. In the latest Miocene/Pliocene a regional phase of inversion, associated with the reactivation of large basin forming faults, has folded the deepwater fan deposits in the deep basin area forming potential structural traps. This event also changed the hinterland drainage patterns re-routing the coarse clastic supply away from the Ulleung Basin and resulting in the deposition of thick open marine shales. ODP/DSDP wells indicate that high quality oil prone marine source rocks may be present throughout the Miocene-Pliocene section. The early Tertiary section is now within the oil and gas generative windows under the turbidite targets and was deposited within a partially silled basin. This marine source material is not present under the explored southern portion of the deltaic wedge where deltaic and fluvial sediments dominate.

Exploration to date has been led by KNOC in shallower shelfal areas where modest but significant gas-condensate discoveries have been made. These discoveries are in combination structural-stratigraphic traps within the non-marine to deltaic Miocene section. The deepwater area where the structured deepwater turbidite fans have been mapped remains untested and is the new focus of the KNOC/Woodside frontier exploration program in the new concession area which if successful will deliver a significant new indigenous hydrocarbon supply to the Korean people.
Challenging Paradigms: Integrating Sequence Stratigraphy, Petroleum System analysis and rigorous well failure analysis to redefine the Nam Con Son Basin exploration potential.

Rob Satter, Alasdair Duncan, Tran Quang Hoan, Albertus Pranoto, Tran Ngoc Lan, James Stewart

BP stopped exploring in the Nam Con Son Basin offshore Vietnam in 1996, after drilling several gas discoveries and a number of dry holes. The assertion at the time was that the basin had limited additional hydrocarbon potential, as there was believed to be a limited distribution of source rock. This paradigm of a charge limited basin appeared to be justified by the occurrence of under-filled traps and the interpretation of a predominantly biogenic source for many of the gas discoveries. In addition, some apparently valid three-way closures mapped on 2D seismic were found water bearing by the drill bit.

A preliminary re-examination of well data in late 2003 and 2004 suggested that Late Oligocene and Early Miocene coals are more widely distributed than previously recognized. During 2005 and 2006 a complete re-evaluation of the basin was conducted, essentially shattering the source limited paradigm for the basin. Integration of depositional environment mapping with petroleum systems analysis demonstrated widespread mature source rocks throughout most of the basin. Key to this new model was the realization that the deposition of coals occurred in a broad delta plain setting during the pre-rift megasequence, rather than being concentrated in syn-rift graben areas. Meanwhile, detailed gas isotope analysis indicated that biodegradation of thermogenic hydrocarbons, rather than biogenic sourcing, has caused the relative enrichment in methane in the shallower gas pools.

As part of BP’s Exploration Common Process, a rigorous success / failure analysis on all of the key exploration wells in the basin was conducted. This work revealed that poor trap definition on 2D seismic data and locally ineffective seals were the dominant failure modes, not lack of source rock. New structure maps based on high quality 3D seismic clearly demonstrate that the densely faulted terrains in the central basin can not be effectively explored with 2D data alone. An evaluation of hydrocarbon column heights in the basin confirmed the model of a leaky petroleum system creating stacked pays separated by imperfect seals, limiting column heights. Hence, many of the older wells were targeted too far down-dip to test structures within the expected hydrocarbon column. Cross-fault seal failure was identified as another important failure mode, highlighting the importance of understanding hanging wall geometry and facies.

This radical shift in understanding of the controls on hydrocarbon distribution in the basin has facilitated a re-definition of the remaining hydrocarbon potential and provided future growth opportunities beyond the existing discoveries.
Evolution of Plio-Pleistocene slope clinoforms and the link between shelf edge trajectory, incision and basinal sedimentation, offshore Vietnam

Xianbin Zeng & Robert Gawthorpe

Seismic sequence stratigraphic interpretation and attributes analysis of 3D seismic data from offshore Vietnam, during Late Miocene to Pleistocene, well imaged the slope clinoforms evolution and different sediment architectures or deposit elements on the slope clinothems. The sediment process and distribution of deposit elements are controlled by the combination of sea level change, sediment flux variations, tectonic forcing and basin physiography. The slope clinothems built up from a ramp setting and then developed on slope clinoforms setting with 22 cyclically changes of relative sea level during the evolution of Plio-Pleistocene slope clinoforms.

Ramp setting and sea level rising cycles presented the initial slope building up phase from the Late Miocene. The initial slope is characterized by parallel to sub-parallel, continue, weak and wedge-shape reflection in seismic data that is interpreted to be alluvial deltas and fans infill during the cooling subsides of post rifting phase.

Following the ramp setting, a typical slope clinothem is observed on the offshore Vietnam. During this evolution stage of slope clinoforms, two types of shelf-edge trajectories are identified: rising and flat trajectories. During a rising trajectory, sea level is rising and sediment supply is high ratio, which resulted in a shelf-edge delta and associated facies on shelf margin, and normal lobes on slope. During flat trajectory, sea level is falling, which resulted in some incisions and channel infill facies on shelf-edge and slope, and eventually generated frontal splays and associated facies on basin floor.

In large scale, the evolution of slope clinoforms of Nam Con Son basin started form ramp setting sequence S1 (Late Miocene) downlapped by the slope clinoform setting sequences (S2-S7) that were terminated by the maximum falling of sea level (end of Early Pliocene). During this development of sequences S2-S7, each cycle of sea level fall generate a basin floor fan system on deep-water setting. The continuous sea level rising sequences (S8-S22) dominated the Late Pliocene to Pleistocene, which are characterized by shelf-edge deltas on shelf margin as high stand system and transgression units onlapping on the upper slope. The cycles of sea level change and sediment response can be comparative with Phu Khanh basin and third-order global cycles.
Renewed exploration activity in the search for deep water assets in the Timor Sea

Dino Da Silva, Amandio Gusmao Soares, Stephen Thompson & Rosalind Waddams

A geological model for the Timor Trough derived from newly acquired seismic data significantly enhances prospectivity. Future exploration will focus on enhanced seismic imaging of reservoirs and on the implementation of new deep water exploration methods such as Controlled Source Electromagnetic (CSEM) surveys.

Seismic acquisition and reprocessing undertaken in the Timor Sea in 2005 focused on the Timor Trough and its flanks. Over 10,600 km of seismic data were acquired and 6,000 km of existing 2D data reprocessed. These new data along with inaugural acreage releases by the government of Timor-Leste and the newly reorganised Timor Sea Designated Authority (which administers the Joint Petroleum Development Area, or JPDA, between Australia and Timor-Leste) have rekindled hydrocarbon exploration in this deep water frontier area.

Fundamental to the prospectivity of this area is the nature of the Timor Trough, with water depths up to 3700m, between the south coast of Timor and the JPDA. Long regarded as a classic subduction zone marking the junction between the Australian and Asian plates, new seismic profiles clearly define the trough as the thrust front of an accretionary wedge formed as a result of collision. This wedge and the weight of sediments shed from the rapidly rising island of Timor have depressed the continental shelf, producing the unusual water depths of the Timor Trough. Although the Timor Trough delineates the boundary between two distinct geological provinces with different structural settings, the stratigraphy of these two provinces is in part similar with equivalents of producing horizons on the Australian continental margin occurring onshore Timor-Leste.

Onshore Timor-Leste is a highly prospective petroleum province with approximately 50 documented oil and gas seeps from formations ranging in age from Permian to Pleistocene. Source potential has been documented in Upper Triassic to Jurassic restricted marine sequences. Primary reservoir targets include Upper Triassic to Jurassic shallow marine siliciclastics equivalent to those encountered in the Banli-1 well in West Timor and to the Malita, Plover, Elang and Laminaria formations in the JPDA. These formations are viable reservoirs in the producing Bayu-Undan field (4 tcf, 500 mmboe), the Sunrise discovery (7.8 tcf) and approximately twenty other hydrocarbon finds across the northern Bonaparte Basin. Nine PSC contract areas in sovereign Timor-Leste waters and the JPDA were awarded in 2006. Numerous seismic anomalies have already been identified at Plover Formation level in the new seismic data. Several indicate large prospects which could contain major gas-condensate accumulations.
The headline news from Australia in recent years has been the numerous giant gas discoveries on the North West Shelf of Australia, and the accelerating pace of development of previously ‘stranded’ resources for liquefied natural gas (LNG) exports. Recent gas discoveries and the appraisal of existing accumulations in the Bonaparte, Browse and Carnarvon basins have significantly increased reserves in the region.

Recent exploration in the Carnarvon Basin has focussed on establishing a new oil producing area in the Exmouth Sub-basin and commercialising gas accumulations on the Rankin Platform and Exmouth Plateau. Most of the gas is hosted in Triassic horst blocks, as targeted by the recent Clio, Chandon and Pluto wells. However, the gas at Io/Jansz is reservoired in Late Jurassic lower-shoreface sandstones. Recent drilling also continued the appraisal of the deep water Scarborough gas accumulation that is reservoired in Early Cretaceous sandstones and trapped within a Cretaceous inversion structure.

Exploration and appraisal drilling is continuing in the Browse Basin and includes Brewster/Ichthys and Prelude in the Caswell Sub-basin, and Scott Reef/Torosa, Brecknock and Brecknock South/Calliance on the Scott Reef Trend. Continued appraisal of Crux in the Heywood Graben of the Browse Basin has highlighted the existence of near-shore gas accumulations, albeit still considerable distances from population centres and infrastructure.

Recent gas discoveries in the northern Bonaparte Basin include those at Caldita and Barossa on the Lynedoch structure, which are located within the Malita and Calder graben, a gas province that is now proven to extend into Indonesian waters at Abadi. In proximity to these discoveries are the gas accumulations at Evans Shoal and Evans Shoal South, which along with those on the Sahul Platform (Greater Sunrise and Chuditch) and Flamingo High (Bayu/Undan), makes this region a significant gas province.

Australian opportunities are not limited to the proven world class hydrocarbon province of the North West Shelf. There are many under-explored and unexplored basins, in both deep and shallow water around the continent. The Australian government has an active program of pre-competitive data acquisition in frontier basins to develop new areas for petroleum exploration. Areas under investigation include the deep water basins of the southern and south-western margins (Mentelle, and Bight basins), the remote Capel and Faust basins off the eastern margin and older, more complex basins in shallow water in northern Australia, such as the Arafura and Offshore Canning.
Australian Deep Water – The Holy Grail or an Expensive Myth?

Paul Rheinberg

Deep water, which for the purposes of this presentation is considered to be water depths in excess of 200m, has long been considered the future of global oil and gas exploration. This is partly as a result of both the growing energy demand and the diminishing number of shallow water and onshore opportunities of economically significant magnitudes.

The petroleum systems in Australia’s deep waters can be differentiated from many others of the world as sediments are mostly Jurassic and Cretaceous in age, while those from deep water areas in other parts of the world tend to be Tertiary. As technology has advanced, so has the feasibility of more extreme developments. Deep water has been a key source of production growth in recent years - a trend likely to continue into the future. Analysis of the comprehensive IHS regional dataset indicates in excess of 150 Tcf of in-place, undeveloped gas reserves off the north and west coasts, of which roughly two thirds sit in deep water. Until recently, these have been stranded, due mainly to the remote location and a lack of market. However, with world demand for LNG expected to double to more than 280MMt by 2010, many of these projects are now moving through the appraisal stage and are set for development.

This presentation will investigate the theory that in Australia, since the 1970’s, companies have progressively spent a smaller proportion of their exploration budgets on onshore and shallow water targets, where discoveries have been regular yet unspectacular, in favour of the deeper waters where higher risks are involved but the potential exists for significantly higher returns. The deep water, shelf and onshore environments will be compared and contrasted. Principle topics will include reserve additions by year, acreage release and licensing opportunities, discovery locations and future forecasts. The presentation will use the IHS database, containing historical and current data, to illustrate and examine the increasing interest in the Australian deep water environment.
Petroleum Systems and Supersystems of the Australian North West Shelf: A Geochemical Approach

Dianne S. Edwards, John E. Zumberge, Christopher J. Boreham, John M. Kennard, Andrew Barrett and Marita T. Bradshaw

Geochemical characterisation of liquid and gaseous hydrocarbons has shown that the petroleum accumulations of the Bonaparte, Browse and Carnarvon basins can be attributed to source rocks of Early Carboniferous, Permian, Triassic, Jurassic and Early Cretaceous age. With few exceptions, most economic oil and gas accumulations are sourced from Mesozoic (Triassic–Jurassic) sediments. This study builds on those by Boreham et al. (2001), Longley et al. (2001) and Geoscience Australia and GeoMark (2005).

The Western Australian margin has been formed by a prolonged sequence of tectonic events that commenced with extension in the Archaean and Proterozoic and continued through to continental convergence in the Miocene–Pliocene. Proven petroleum systems rely on source rocks deposited within Palaeozoic rift-fill sediments, Permo-Triassic pre-rift intracratonic sediments, Jurassic rift-fill sediments and Cretaceous post-rift sediments.

By combining the geological framework with the geochemical composition of the hydrocarbons, Bradshaw et al (1994) proposed a broad classification of petroleum supersystems (Larapintine and Westralian) for the North West Shelf, linking individual petroleum systems that shared the same age and facies of source rock. This study documents the biomarker and carbon isotopic composition of several hundred North West Shelf oils/condensates, along with the molecular, carbon and hydrogen isotopic compositions of 50 gas samples, including many gas-oil/condensate pairs. The results validate and refine the earlier work by classifying the major hydrocarbon discoveries into genetically related oil and gas families and integrating them into the petroleum system/super system framework.


Geoscience Australia and GeoMark, 2005. The Oils of Western Australia II. Geoscience Australia and GeoMark Research, Ltd., Proprietary report, Canberra and Houston, unpublished.

Basement and Crustal Controls on Hydrocarbon Maturation: Towards Holistic Approach

A. Goncharov, I. Deighton, L. Duffy, S. McLaren, and C. Heine

The need to develop a consistent approach to the assessment of basement and crustal controls on hydrocarbon maturation was driven by the results of maturation modelling in the Bremer Sub-Basin (offshore SW Australia) and in the Exmouth Plateau (Australian NW Margin). Advanced burial and thermal geo-history modelling in these areas was carried out using Fobos Pro modelling software for the first time in Australia without relying on default or inferred values (such as heat flow or geothermal gradient). This has become possible because several data sets, some of which are not commonly collected by industry, are available in these areas. In the first place, high quality refraction seismic data recorded by sonobuoys or ocean-bottom seismographs are needed to put constraints on basement depth, composition and crustal thickness. Also essential are interpreted reflection seismic profiles, heat flow measurements, contents of radioactive elements in rock samples taken from basement outcrops onshore or dredge samples, and high quality vitrinite reflectance and temperature data in the wells.

Our research suggests that seismic interpretation of deep basins structure should be carried out interactively with quantitative analysis of possible basin formation mechanisms because only certain volume of sediments accommodation space can be generated in the model without stepping outside of crustal stretching rate limits dictated by refraction seismic data. Surprisingly, some very significant changes in variables tested in our modelling are not differentiable by observable parameters in wells above TD, but they lead to significant changes below TD; therefore deeper wells, or new and better geophysical data are needed to better constrain subsidence and maturation models for deeper section. Enhanced maturity studies, such as VIRF, are necessary to remove analyst bias in vitrinite reflectance determination. Basement heat flow is sensitive to depth to basement, because of the variation in stretching required. However, in deep basins, sediment radioactivity above basement may compensate for the reduced stretching so there is much less variation in surface heat flow and that at TD. Interplay between heat production above and below basement emerges as the main driver of model temperature prediction, particularly when heat generation in basement is low and sediments above it are thick.

In summary, we have identified 5 major basement and crustal controlling factors that determine depth to hydrocarbon maturation windows:

1. Depth of subsidence
2. Thickness of the crust
3. Thickness of the lithosphere
4. Heat production in the crust
5. Heat production in sediments.

First-pass estimates of relative significance of some of these parameters lead to a conclusion that variation in subsidence has relatively minor effect on position of maturation windows, because sediment radioactivity effectively replaces basement radioactivity if the crustal heat production is low. Effects of basement heat production and crustal thickness are 1.4 – 3.4 times greater (varying from top oil to base dry gas maturity windows). These estimates allow formulating requirements to accuracy of underlying measurements, eg. accuracies of $\pm 1.08$ km for basement depth (when far below TD), $\pm 0.06 \mu Wm^{-3}$ for basement heat production and $\pm 0.54$ km for crustal thickness are required to position base of dry gas maturity window within $\pm 50$ m accuracy.
Stretching estimates across the Browse Basin continental margin NW Australia: from 2D basin-modelling and 3D gravity-inversion

Alan Roberts, Nick Kusznir, Richard Woodfine, Steve Matthews, Andrei Belopolsky, Cheree Stover & Alexey Goncharov

Three Regional 2D seismic lines across the Browse Basin and Scott Plateau, NWS Australia (AGSO Lines 130-09/119-04, 128-01/119-06, 128-02/119-02), have been interpreted and analysed by application of 2D flexural-backstripping & 2D fault-forward-modelling. 3D satellite gravity inversion, incorporating a lithosphere-thinning thermal correction, has been used to map crustal thickness and lithosphere stretching/thinning factors for the full area of the Browse Basin continental margin.

Sequential flexural backstripping of the three 2D lines to the Jurassic syn-breakup timestep (i.e. ~160Ma) was performed to investigate beta (\( \beta \)) stretching-factors and syn-rift basin geometries across the margin. Structural forward modelling was performed to determine the magnitude of fault-controlled rift/breakup extension and enabled comparison of results with lithosphere beta-factors derived from backstripping.

The flexural backstripping involves layer-by-layer removal of the stratigraphic/volcanic sequence back to the 160Ma syn-rift stage. Importantly the validity of the sequential restorations has been QC’d against available geological data calibrating bathymetry, emergence and erosion through time. In this way each sequential structural restoration was linked directly to the corresponding regional Gross Depositional Environment map.

3D gravity inversion is critically dependent on the mapping of total sediment thickness (as input to the inversion scheme) across the whole Browse Basin margin. As there is clearly uncertainty in definition of the sediment thickness, particularly in the outer margin Scott Plateau area, a number of sensitivity tests were run applying sediment thickness models mapped by different methods.

Primary results of the combined basin-modelling & gravity-inversion analysis indicate that:

i) east of the Buffon/Brecknock/Barcoo area, the Browse Basin is a “normal” fault-controlled rift basin (\( \beta \) factors reaching ~1.5)

ii) west of Brecknock/Buffon/Barcoo the Scott Plateau is a “transitional” area of highly-stretched continental crust (\( \beta \) ~3-6)

iii) the Wilson Spur on the extreme outer margin is a moderately-stretched continental block (\( \beta \) ~2) separated from the continental plate by the failed breakup-basin of the Scott Plateau (c.f. Hatton Bank and the Faeroe Islands in the North Atlantic)

iv) upper crustal extension/faulting cannot account for the high lithosphere \( \beta \) factors (3-6) across the Scott Plateau derived from backstripping and gravity inversion, indicating that depth-dependent lithosphere stretching during continental breakup has occurred.
Predicting basin inversion and reactivation on the Northwest Australian Shelf with modelled stress regimes

S. Dyksterhuis, R. D. Müller and P. Untemehr

We use a library of modelled palaeo-stress regimes for the Australian Plate to investigate the relationship between observed fault reactivation events to major changes in plate driving forces around Australia. The palaeo-stress library encompasses digital grids at a resolution of 0.2 degrees for the present day (0 – 6Ma), late Miocene (6Ma – 11Ma), mid Miocene (11Ma – 23Ma), Oligocene (23Ma – 25Ma), Eocene (~55Ma), mid Cretaceous (~100Ma) and early Cretaceous (~135Ma). Using modelled $S_{\text{Hmax}}$ fields we interpret the reactivation and inversion events observed on the Northwest Australian Shelf since the early Cretaceous and constrain the timing of previously enigmatic anticline generation on the Northwest Shelf. Modelled north-northeast trending $S_{\text{Hmax}}$ directions in the Browse Basin during the Cretaceous agree well with observed transpressional reactivation of the steeply dipping northeast trending Lombardina and Lyner inversion structures. The north-south orientation of $S_{\text{Hmax}}$ in the Exmouth Basin during the Cretaceous corresponds well with the formation of the east-west trending Ningaloo arch at this time. Modelled $S_{\text{Hmax}}$ orientations on the Northwest shelf rotate roughly $90^\circ$ by the Eocene and to assume a general west-northwest orientation. This modelled $S_{\text{Hmax}}$ orientation remains similar during the Oligocene and early Miocene, however, modelled $S_{\text{Hmax}}$ magnitudes increase through time. The timing of significant northeast trending anticlines observed on the North West Shelf has remained enigmatic. Here we interpret the establishment of roughly west-northwest modelled $S_{\text{Hmax}}$ orientations to in the Eocene along with an increase in amplitude of modelled $S_{\text{Hmax}}$ in the late Oligocene as evidence to support a late Oligocene age as a likely time of anticline growth. This is a time when hard collision between India and Eurasia was initiated, paired with the initiation of mountain building along Australia's eastern plate boundary along the Alpine Fault. Together, these increased boundary forces resulted in a more compressive stress field on the Northwest Shelf.

The modelled $S_{\text{Hmax}}$ regime changes considerably at this time with the onset of collision at the Papua New Guinea margin. In the late Miocene $S_{\text{Hmax}}$ orientations rotate in a clockwise direction over the North West Shelf, from east-west in the Carnarvon Basin to north-east in the Timor Sea. The mean $S_{\text{Hmax}}$ orientation of $67^\circ$ in the Browse basin at this time indicates that transpressional reactivation of north-east trending structures is likely. Transpressional reactivation of northeast trending faults with a right-lateral sense of movement at this time agrees with the general east-west trend of modelled $S_{\text{Hmax}}$ directions at this time.
Plate tectonic and palaeo-stress field evolution of Australia since the Early Cretaceous

R. D. Müller and S. Dyksterhuis

Plate tectonic reconstructions usually rely on reconstructing the outlines of continents and tectonic features through time based on a series of finite rotations, which are constrained by the preserved seafloor spreading record and continental paleomagnetic data. In order to understand the effect of time-dependent geometries of mid-ocean ridges, subduction zones and collisional plate boundaries on basin evolution and reactivation through time, we need to reconstruct now subducted ocean floor, including tectonic plates which have now entirely vanished, restore their plate boundary configurations, and model the effect of time-dependent plate driving forces on the intraplate stress field. We reconstruct paleo-oceans by creating “synthetic plates”, the locations and geometry of which is established on the basis of magnetic lineations and fracture zones, geological data and the rules of plate tectonics. We use complete maps of the age-area distribution of ocean floor through time and associated plate boundary geometries to estimate plate driving forces. A digital 2D finite element model of the (Indo-) Australian Plate is created that distinguishes cratons, fold belts, basins, and ocean crust in terms of their relative differences in mechanical stiffness. We model intraplate palaeo-stress models for six time slices since the Early Cretaceous, validated by published fault-reactivation histories. The roughly north-south oriented Australian intraplate stress field in the Cretaceous was dominated by ridge push from the now subducted northern Wharton Basin Ridge in the Neo Tethys Ocean. In the early Tertiary, the Australian stress field changed dramatically due to a balancing of plate driving forces around Australia, which was then surrounded by mid-ocean ridges to the east, south and west. After the Eocene, the Wharton Basin Ridge between the Indian and Australian plates became extinct, forming the Indo-Australian Plate and the initial collision between Greater India and Eurasia started. The resulting intraplate stress patterns in Australia were much more complex than in the Cretaceous, and resulted in major tectonic reactivation episodes in the Eocene and Miocene. Between the Miocene and the present, the main change in Australian plate-driving forces was represented by the onset of collision along Papua New Guinea and the enhanced collision between India and Eurasia, paired with subduction plate segments between the Java Trench and the Banda Arc that exert slab pull on Australia. Our reconstructions of tectonic plates, including the complete restoration of now subducted ocean floor around Australia, paired with numerical palaeo-stress models, provide an improved exploration framework for Australia.
New Australia-Antarctica reconstruction model dramatically alters reconstructed rift basin geometry

Joanne Whittaker and Dietmar Müller

Plate reconstruction models for the rifting and spreading between Australia and East Antarctica continue to be poorly constrained prior to 50 Ma, due to an historical paucity of magnetic anomaly data close to the margins and a slow initial spreading rate. Published reconstructions result either in large overlaps between the South Tasman Rise and Antarctica, or in the partial misfitting of conjugate magnetic anomalies. Utilizing the new 1-minute gravity grid by Sandwell and Smith, we have identified several NW-SE oriented small-offset fracture zones on the conjugate Australian and East Antarctic plates which display a bend to N-S oriented spreading at around Chron 22/21 time, suggesting a major plate reorganization at that time. Previous plate reconstructions for Australia-Antarctica match the Leeuwin Fracture Zone (eastern side of the Naturaliste Plateau) with the Vincennes fracture zone (eastern side of the Bruce Rise), which results in reconstructions where the Naturaliste Plateau is located to the north of the Bruce Rise, as well as in a major plate reorganization at around Chron 34, which does not correspond to a time of regional or global plate reorganization. Juxtaposition of the Naturaliste Plateau to the north of the Bruce Rise is problematic due to the identification of M-series magnetic anomalies which likely reflect Antarctic-India separation. Using a NW-SE direction of motion for separation prior to Chron 22/21, the Naturaliste Fracture Zone (western side of the Naturaliste Plateau) matches with the Vincennes Fracture Zone, resulting in reconstructions that place the Naturaliste Plateau to east of the Bruce Rise. Use of the revised spreading direction for times prior to chron 22/21 results in location of Australia approximately 500 km further east then previous reconstructions. This results in reduced amounts of overlap between the South Tasman Rise and Cape Adare, alignment of geological terranes in Australia and Antarctica that were offset in previous reconstructions and provides improved constraints on motion between East and West Antarctica and global plate circuit closure. Our reconstructions show that NW motion of Australia relative to Antarctica from the more easterly initial location would have created a narrow restricted basin between Australia and Antarctica extending across most of the southern Australian coastline. This basin likely existed for around 20 million years rather than being open at the western end as implied by earlier reconstructions. This has direct implications for sedimentation patterns and play developments along the Southern Australian margin.
Proterozoic Oils in the Roper Superbasin, Northern Australia

A. Dutkiewicz, H. Volk, J. Ridley and S.C. George

The Mesoproterozoic intracratonic Roper Superbasin comprising the 1400 Ma Roper Group in northern Australia is the oldest basin known to contain widespread live oils and hydrocarbon shows (e.g., Jackson et al., 1986; George et al., 1994). The Velkerri Formation is the most prolific source rock in this basin, and is comparable in terms of richness, thickness and quality to world-class source rocks in Phanerozoic petroliferous basins. The Roper Superbasin has been the subject of intermittent exploration interest, which reached its peak during the late 1980s with 11 exploration wells. However, these were drilled in rapid succession in poorly defined targets during a time when there was little concern for global oil reserves. There is now renewed industry interest in the prospectivity of the basin (Silverman et al., 2007).

Our recent evaluation of archived samples from the Roper Superbasin reveals the presence of abundant oil inclusions within potential reservoir horizons indicating that oil migration was relatively widespread in the basin. Key samples of a sandstone and dolerite contain oil inclusions in sufficient amounts to allow reconstruction of oil migration and its potential sources to be made through detailed microthermometric and molecular compositional analysis (e.g., Dutkiewicz et al., 2007). For example, in the Bessie Creek Sandstone, oil migration is interpreted to have taken place in fracture porosity after the sandstone had been well cemented, following extensive diagenesis and dolerite emplacement, and at minimum temperatures of 60 ± 5°C. Oil-bearing fluid inclusions in the overlying dolerite were trapped at about 110°C, after the dolerite had cooled significantly towards ambient diagenetic temperatures.

Gas chromatography-mass spectrometry of the inclusion oils reveals non-biodegraded oils, which are very mature in the Bessie Creek Sandstone and a mixture of a high-maturity gas-condensate and a lower-maturity oil in the dolerite sill. Biomarkers suggest a source rock dominated by cyanobacterial organic matter, with a small contribution from eukaryotes in the case of the dolerite sill oil. Based on its organic richness and proximity, the most likely source for the oils is the organic-rich marine Velkerri Formation, deposited at ca 1430 Ma, with a possible component in the mixed oil from the ca 1600 Ma Barney Creek Formation of the underlying McArthur Group. The most likely timing of migration is interpreted to be before significant uplift, during structural inversion between 1300–1000 Ma.

References:


Beneath down under: integrating mantle convection and plate kinematics to model Australia's Cenozoic paleogeography

Christian Heine, R. Dietmar Mueller & Bernhard Steinberger

Mantle convection-induced dynamic topography has been identified as one important component affecting the paleogeography of continents. However, the amplitude and spatio-temporal effects of these transient up- and downwellings on the surface topography through time are controversial. Here, we present an integrated approach using plate kinematic and global mantle convection models with paleogeographic maps and geological data constraining continental subsidence, uplift, erosion and sedimentation to quantify the combined effects of eustasy and mantle convection on Australian paleogeography.

We use the well-established analytical flow model approach for mantle convection modelling for the Tertiary, based on mantle density anomalies derived from the S20RTS shear-wave tomography model for the present day and backward advection for past times. Time-dependent dynamic surface topography is computed from this convection model using a free upper surface, and combined with a global sealevel curve to model continental inundation. Sediments in two major Tertiary depocentres onshore, the Murray-Darling and Eucla basins, are backstripped through time to adjust the topographic baseline of the elevation model.

We demonstrate that a combined eustasy and mantle-driven dynamic topography effect, validated with published geological observations including denudation estimates from fission-track data, can successfully reconstruct Australia’s changing paleogeography through time. Our model accounts for regional episodes of subsidence and uplift, whose origin were previously unknown and have important implications for hinterland sediment sourcing systems and the understanding of the basin infill architecture. We find that eustasy and scaled mantle-driven dynamic topography are of similar magnitude for the Late Tertiary in Australia. As first-order sea level dropped due to progressive glaciation, much of Australia was drawn down as it moved towards the southeast Asian slab burial grounds, alleviating the eustatic effect for much of Australia during its northward motion away from Antarctica.

Our integrated approach shows that understanding the interplay between eustasy and mantle-driven dynamic topography is critical for a holistic perspective of hydrocarbon systems of a given region. The presented model provides a crucial step forward in understanding causes of hinterland uplift, basin subsidence, the formation and destruction of shallow epeiric seas and lakes and their facies distribution, bearing important implications for the analysis of hydrocarbon systems. Our workflow design is readily extensible and allows this approach to be easily ported to other regions to analyse the integrated effects of dynamic topography, plate motions and eustatic sea level variations.
The petroleum potential of on and offshore South Australia

Elinor Alexander

South Australia is situated between the ancient Archaean Shield of Western Australia and the mobile Phanerozoic orogenic belts of the eastern states. As a result, the geological record in South Australia has preserved a unique history of sedimentation from the Neoproterozoic to Cenozoic. Sedimentary basins with oil and gas potential may be subdivided based on their relative age:

- Basins of Mesozoic age which either overlie older intracratonic basins or are developed on Australia’s rifted Southern Margin. Onshore, these include the Eromanga and Simpson Basins in northern SA and the Berri Basin. Offshore are the Bight, Polda and Otway Basins, which also extend onshore.
- Permo-Carboniferous to Early Triassic basins which overlie Early Palaeozoic basins in northern and southern parts of the state. These include the Cooper, Pedirka and Arckaringa Basins in northern SA.
- Early Palaeozoic basins of Cambrian to Ordovician age which include the foreland style Warburton Basin, extensional Arrowie and Stansbury Basins and intracratonic Officer Basin. The latter three basins are underlain by extensive Neoproterozoic sediments which are largely unmetamorphosed and thus also prospective for hydrocarbons. The Officer Basin contains a Devonian section preserved in a foreland trough setting.

The intracratonic Cooper and Eromanga Basins are Australia’s largest onshore petroleum province and supply gas to southeastern Australian markets, gas liquids and oil are processed for local markets and export. Continental margin basins on and offshore have very thick Cretaceous fill and the Otway Basin produces gas from on and offshore fields and also has significant oil potential.

The petroleum potential of the state is considered to be at least as significant as discoveries made to date. New explorers in the Cooper and Eromanga Basins have sustained world-class success rates and large areas remain under-explored. The offshore Otway and Bight Basins and the onshore Officer Basin are considered to have potential for giant new petroleum discoveries and are also under-explored. The onshore Late Cretaceous oil play in the Otway Basin and a number of frontier Cambrian and older basins are yet to be explored with modern techniques.
Deepwater Taranaki Basin, New Zealand

Chris Uruski

The islands of New Zealand occupy less than 10% of the area of the New Zealand Exclusive Economic Zone (EEZ). The EEZ forms part of the New Zealand mini-continent, which extends from the sub-Antarctic islands in the south to New Caledonia in the north. The New Zealand mini-continent formed part of the subduction margin of Gondwana for much of the Paleozoic and Mesozoic. During this time, the New Zealand region accreted a series of terranes and back-arc rifting was active for much of the Mesozoic. In the Late Cretaceous, the New Zealand mini-continent rifted away from Antarctica and Australia as the Southern Ocean and Tasman Sea formed. Cretaceous rifting created a series of basins which trapped and preserved thick accumulations of terrestrial sediments, including voluminous coaly sequences. As New Zealand drifted away from the new continents, it subsided, with land area and sediment supply consequently gradually reducing until little remained above sea-level by the Oligocene. The modern compound plate boundary was initiated near the start of the Miocene, resulting in uplift of the New Zealand land mass and a renewed sediment supply to the surrounding basins, which commonly buried the Cretaceous coal measures deeply enough to generate and expel petroleum.

In Taranaki, New Zealand’s only currently producing petroleum basin, oil and gas, sourced from Cretaceous and Paleogene sequences has been trapped in a range of reservoirs, including Paleogene shoreface sands, Oligocene fractured limestone and Miocene and Pliocene turbidite sandstones. The giant Maui field, discovered in 1969 and operated by Shell-Todd Oil Services, has been the mainstay of the New Zealand petroleum industry since it went into production in 1979, having produced 171 million of oil, from recoverable reserves of 235 million barrels, along with more than 3 TCF of gas. Its current decline, combined with the present healthy oil price has re-kindled interest in exploration in New Zealand.

No wells have yet been drilled in the deep waters beyond the Taranaki shelf edge where a major Cretaceous delta was discovered in 1996 and confirmed by a regional 2D seismic survey in 2001. In common with many other basins around the world, it is likely that Taranaki is more oil prone in deep water as terrestrial source rocks had greater marine influence and the presence of fully marine source rocks is likely. Deepwater Taranaki contains up to 10 km of sedimentary rocks as old as the Jurassic, with large volumes of source rock mature for petroleum generation and expulsion today. New basin modelling suggests that there may be 20 billion barrels of oil awaiting discovery in the deepwater part of Taranaki Basin. Numerous large structures are revealed after integrating all available seismic data and reprocessing key lines to make deepwater Taranaki an extremely attractive exploration venue.
Burlington House
Fire Safety Information

If you hear the Alarm

Alarm Bells are situated throughout the building and will ring continuously for an evacuation. Do not stop to collect your personal belongings. Leave the building via the nearest and safest exit or the exit that you are advised to by the Fire Marshall on that floor.

Fire Exits from the Geological Society Conference Rooms

Lower Library:
Exit via Piccadilly entrance or main reception entrance.

Lecture Theatre
Exit at front of theatre (by screen) onto Courtyard or via side door out to Piccadilly entrance or via the doors that link to the Lower Library and to the main reception entrance.

Piccadilly Entrance
Straight out door and walk around to the Courtyard or via the main reception entrance.

Close the doors when leaving a room. **DO NOT SWITCH OFF THE LIGHTS.**

Assemble in the Courtyard in front of the Royal Academy, outside the Royal Astronomical Society.

Please do not re-enter the building except when you are advised that it is safe to do so by the Fire Brigade.

First Aid

All accidents should be reported to Reception and First Aid assistance will be provided if necessary.

Facilities

The ladies toilets are situated in the basement at the bottom of the staircase outside the Lecture Theatre.

The Gents toilets are situated on the ground floor in the corridor leading to the Arthur Holmes Room.

The cloakroom is located along the corridor to the Arthur Holmes Room.
Ground Floor Plan of the Geological Society, Burlington House, Piccadilly