Petroleum Prospectivity of West Australian Basins I
Auditorium
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Structural and Depositional Style of the Syn-rift Systems of the Northwest Australian Margin: A Comparison with Atlantic Passive Margin Systems

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Many passive continental margins are characterized by a regional distribution and thickness of syn-rift and post-rift sediment packages that are not consistent with the minor amounts of brittle deformation observed in either seismic sections across the margin (e.g., Exmouth Plateau, northwest Australia; Marion Plateau, northeast Australia; Grand Banks; Brazilian and West African margins; and West of Shetlands basins). While the geological details and sedimentary facies differ between the various margins, the style of deformation and the regional distribution of accommodation are remarkably similar. The development of significant post-rift accommodation in the same region characterized earlier by minor syn-rift faulting and shallow depositional environments has been explained in terms of depth-dependent extension that is partitioned vertically across a zone of decoupling that results in the development of a relatively non-deforming upper crust (i.e., the upper plate) from a ductile-deforming lower crust and lithospheric mantle (i.e., the lower plate), the boundary between them having a ramp-flat-ramp geometry. Exactly how the lithospheric extension is balanced was the rationale for R/V Ewing cruise EW0113, which collected over 2000 km of multi-channel seismic reflection and more than 800 km of OBS wide-angle refraction data across the continent-ocean transition zone of the Exmouth Plateau and Cuvier margin. Seismic reflection and refraction data has allowed the mapping of the ocean-continent transition, which appears to a broad zone ~200 km wide containing landward and seaward dipping reflectors, “rafted” crustal blocks, and supposedly exposed continental mantle. Underplating has occurred, but is relatively minor and has helped source the basalts that comprise the seaward- and landward-dipping reflectors - excessive magma production is independant of mantle plumes.

Basement Control on Basin Evolution in Northwestern Australia

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The basement of any basin provides the foundation onto which the sediments are deposited. The rheology, or mechanical behaviour, of the basement controls the rate of subsidence and geometry of each phase of the evolving basin. The composition of the basement determines its strength or stiffness. The age and early history of each basement terrane dictates the intensity and character of the structural fabric. This inherent fabric plays a major role in the manner in which the crust deforms during major periods of extension or compression.

Basement Terranes of NW Australia, interpreted from gravity, magnetic and geological data, include at least 4 major Archean to Early Proterozoic cratonic blocks separated by younger mobile belts. The cratons tend to resist deformation causing extensional strain and associated accommodation space to preferentially partition into surrounding mobile belts. Thus the thickest sediment accumulation tends to develop over mobile basement. The orientation and effective length of internal mobile belt fabric controls the direction and amount of extension that can be accommodated for a particular tectonic event. For example, NE-SW directed extension during the Devonian focused in the Canning and Petrel basins with minor, if any, extension of the intervening Kimberly block. Compressional strain is also preferentially partitioned into mobile belts such that basin cores tend to be inverted. In major compression events mobile belts are exhumed with foreland sedimentation and older basin preservation localised over adjacent cratonic basement.

In this paper we present an overview of the basement terranes of Northwestern Australia from the OZ SEEBASETM project demonstrating the difference in rheological behaviour of cratonic blocks and mobile belts, and their predicted control on basin evolution through time.

Dynamic topography and intraplate basins - an explanation for anomalous subsidence?

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Wide intraplate basins often show a component of anomalous tectonic subsidence which cannot be explained using conventional rift basin models. It has been proposed that a special type of basement (”accretionary crust”) underlying those basins is more susceptible to changes in the plate-tectonic configuration / far-field stresses and this is reflected by anomalous subsidence behaviour. However, the link between the basement heterogeneity and subsidence remains enigmatic. In order to investigate the driving force behind this anomalous subsidence we have analysed crustal structure data for a global set of more than 250 intraplate basins to compute anomalous tectonic subsidence and differential stretching factor grids. By using the EarthByte/Torsvik plate rotation model and a global mantle convection framework, we extracted the dynamic topography through time from the Mid-Jurassic to present to investigate the long-term influence of mantle convection on intraplate basin evolution. Our study shows that many typical “sag basins” moved from a geoid high, centered on Gondwana, towards relative geoid lows due to the dispersal of Gondwana. This resulted in increasing negative dynamic topography of those basins and thus the creation of “anomalous” accomodation space which cannot be accounted for using conventional basin modelling techniques. It appears that dynamic topography may explain the observed anomalous tectonic subsidence and basin inversion in those long-term depositional regions and it needs to be considered for regional basin modelling studies.

The Neogene Tectonic history of the North West Shelf

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Australia's North West Shelf represents a continuum from early-stage collision (Timor Sea) to present-day passive margin (Carnarvon Basin) due to diachronous collision of the Australian Plate with the Banda Arc.
In the Timor Sea continental crust reached and jammed the subduction zone sometime in the region 15 Ma to 3 Ma. This ongoing collision has resulted in less than 1% shortening of the Timor Sea, and paradoxically the dominant offshore structures are large normal faults, from near the Timor Trough axis inboard to the producing basins. We interpret the normal faults to be the result of elastic flexure of the plate during collision, re-amplifying the inherited structural highs and lows, whilst not yet resulting in discrete brittle failure. One result of this is that the main depocentres remain in the same place through time, despite the change in tectonic regime from extensional to collisional.
The Carnarvon Basin has not yet reached collision. It preserves the complete passive margin sequence, and is affected mainly by far-field stress from the Indian Ocean and Himalayan thrust front. Discrete contractional failure occurs in narrow zones on the inboard part of the margin, coeval with similar onshore deformation. The preservation of this passive margin allows us some unique insights into the collision geometries that must have occurred along strike, and their subsequent effects on the petroleum systems.
This paper will present results from both the passive and collisional segments of this margin, explore the resulting structural styles and their effects of the petroleum systems

Hydrocarbon Families of the Australian North West Shelf: A Regional Synthesis of the Bulk, Molecular and Isotopic Composition of Oils and Gases

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Petroleum accumulations have been discovered in the Bonaparte, Browse and Carnarvon basins over the last fifty years. However, a regional synthesis of the geochemistry of these North West Shelf hydrocarbons has not been published. To address this, we document the biomarker and isotopic analyses of ~300 North West Shelf oils/condensate samples that have been statistically characterised into genetically related families. Additionally, carbon and hydrogen isotopic signatures of ~50 gas samples, together with existing molecular data for ~1000 gas samples, show regional trends in wetness and abundance of non-combustible gases.
These petroleum accumulations can be attributed to source rocks of Early Carboniferous, Permian, Triassic, Jurassic and Early Cretaceous age; however, most economic oil and gas accumulations are sourced from Mesozoic (Triassic–Jurassic) sediments. The oils produced from the Bonaparte (Vulcan Sub-basin, northern Bonaparte) and Carnarvon (Dampier, Barrow and Exmouth sub-basins) basins are geochemically similar, being sourced from Late Jurassic marine rift-fill sediments (lower Vulcan Formation/Dingo Claystone) that contain variable amounts of terrigenous (particularly gymnosperm-derived) organic matter. Variations in their biomarker signatures can be explained by maturity differences, multiple charging and secondary alteration processes. Gas produced from the northern Rankin Platform is predominantly sourced from Triassic–Jurassic fluvio-deltaic sediments. Proven and potential supergiant and giant gas accumulations occur in the deepwater areas of the North West Shelf. Case studies focussing on the geochemistry of the outer Browse (Scott Reef trend) and Carnarvon (deepwater Exmouth Plateau and Rankin Platform) gas accumulations will be presented with emphasis on their $\delta^{13}C$ and $\delta^{2}H$ isotopic signatures.