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AUSTRALIA AND EASTERN INDONESIA AT THE CROSS-ROADS OF GONDWANA AND TETHYS - THE IMPLICATIONS FOR PETROLEUM RESOURCES.

Since Wallace drew his line, the Australasian region has been recognised as a pivotal place on the earth's surface, where across a sharp gradient we step from one world to another. In the biological realm, Asian elephants, tigers and weaver birds are juxtaposed to Australian cockatoos, giant goannas and marsupials across a narrow gap of deep water running between Borneo and Sulawesi and continuing between Bali and Lombok (van Oosterzee, 1997). These faunal changes reflect a geological history along the border zone between the great southern continent of Gondwana, the ancient Tethyan ocean and an evolving Asian landmass.

The legacy of this history for petroleum exploration is a complex and diverse region where a multitude of petroleum systems, ranging in age from the Cambrian to the Neogene, can be exploited (Bradshaw et al., 1997). Hydrocarbons have been generated from marine, lacustrine, deltaic and coal swamp facies; and both carbonate and siliciclastic source rocks occur. The most prolific petroleum systems are the product of organic-rich rocks accumulated in tropical environments, not unlike the present day regime.

In the Cambrian-Ordovician a shallow carbonate platform stretched through central and northern Australia, across the southern half of what is now the island of New Guinea, and onto the continental blocks that later amalgamated to form China and south-east Asia (Metcalfe, 1997). Carbon-rich oil prone source rocks were deposited in these warm shallow waters of the palaeo-tropics. Today there is oil production from Ordovician reservoirs at the opposite ends of this now dismembered shallow seaway - in central Australia (Mereenie field, Amadeus Basin) and in the Tarim Basin of western China. Significant oil shows derived from Cambrian source rocks are recorded from the Arafura Basin (Bradshaw et al., 1990; Edwards et al., 1997) and the prospective zone for this petroleum system extends across the stable platform from northern Australia into eastern Indonesia (Fig. 1).

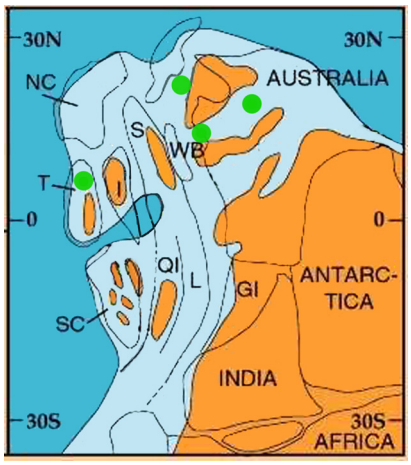

Figure 1. Reconstruction of eastern Gondwana for the Cambro-Ordovician from Metcalfe (1997). Land shown in orange, shallow seas in light blue, deep sea in dark blue and basins with Cambro-Ordovician petroleum systems shown in green. NC = North China, SC = South China, T = Tarim, I = Indochina, QI = Qiangtang, L = Lhasa, S = Sibumasu, MB = West Burma, GI = Greater India.

In the late Devonian, the Palaeo-Tethys ocean opened separating the South China, Tarim, Indochina and North China blocks from Gondwana (Metcalfe, 1997). The Caledonia Orogeny in China and the Alice Springs Orogeny in Australia signal these events; and from this time onwards the geological histories of Australia and China diverged dramatically. Australia as part of Gondwana, shifted southwards into polar regions, and by the Late Carboniferous-earliest Permian was partially covered by an ice sheet. Tropical conditions continued on

the Chinese continental fragments, with the characteristic Cathaysian faunas being in sharp contrast to the glacial deposits and high latitude coals typical of the Gondwanan continents.

Onshore Permian coal basins are important suppliers of domestic gas in Australia (Bowen and Cooper basins) and undeveloped Permian gas accumulations also occur offshore in the Petrel Sub-basin, of the Bonaparte Basin. There is a close similarity of the Late Permian sedimentary sequences from northern Australia and Irian Jaya. The geological and geochemical evidence (Perkins & Livsey, 1993; Bradshaw et al., 1997) indicates that the coals and associated shales of the Permian Ainim Formation are the likely source of the giant gas fields (Wiriagar, Vorwata) in the Bird's Head.

By the Triassic, the Meso-Tethys had opened as the Cimmerian continent rifted off from the Gondwanan core (Metcalfe, 1997). The Mesozoic carbonate belt running along the northern shores of Tethys is well known from the Austrian Alps to the Middle East, and evidence has accumulated in recent years of a similar zone mirrored on the southern shores of Tethys. ODP drilling unexpectedly recovered Rhaetian reefal carbonates from the northern margin of Australia's Exmouth Plateau (Exon et al., 1991). There is also some geochemical evidence to suggest that the oils sourced from Mesozoic carbonate facies seen in Seram, Buton, Buru and Timor may also extend to the outer Bonaparte and Browse basins (Edwards et al., in press) and to the Carnarvon Basin (George, et al., 1998). A picture is emerging of another petroleum system developed out beyond the typical Westralian system of the North West Shelf. This new system is characterised by hydrocarbons sourced from deep water marls rather than marine shales with a significant higher plant input as found in the inboard failed rifts (Bradshaw et al., 1994).

By the Cretaceous, the last of the continental fragments had rifted from Australia's north-west margin, and the Indian Ocean opened as the major blocks of Gondwana separated. Cretaceous petroleum systems are now proven in the Browse and Bonaparte basins (Blevin et al 1998; Preston & Edwards, 2000), but in the global context the Australasian region is very under-represented in oil reserves derived from mid Cretaceous (Aptian-Turonian) source rocks (Klemme & Ulmishek, 1991). This gap in the distribution may be filled with further finds on the North West Shelf and into eastern Indonesia, as well as along Australia's southern margin (Totterdell et al., 2000).

The region has had a dramatic Cainozoic tectonic history as the Australian, Pacific and Asian plates have collided, subducted, buckled, fragmented and sheared (Hall, 1999) producing a host of young petroliferous basins. Cainozoic petroleum systems are dominant in Indonesia, ranging from Eocene lake basins in Sumatra, deltaic complexes in Kalimantan to Miocene carbonates in the Salawati Basin of the Bird's Head (ten Haven & Schiefelbein, 1995). In contrast, on the old Gondwanan core of Australia most known hydrocarbons are derived from Mesozoic and Palaeozoic sources. The one significant exception being the Gippsland Basin in southeastern Australia where the Late Cretaceous to Eocene lower delta plain deposits of the Latrobe Group are the accepted source rock. However, Eocene oil shales occur onshore in Queensland in small lake basins close to the current coastline where a pilot plant has been established to retort oil from the crushed shale. Perhaps these organic-rich facies may also occur offshore in basins where it may be mature for oil generation.