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Reassessment of the Petroleum Prospectivity of the Browse Basin, Offshore North West Australia

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The Browse Basin, located offshore on Australia's North West Shelf, is a proven hydrocarbon province that hosts large gas accumulations with associated condensate. Small light oil accumulations are found mostly within the Cretaceous succession. Geoscience Australia undertook a multi-disciplinary study of the Browse Basin to better understand the regional hydrocarbon prospectivity and high-grade areas with increased liquids potential in Cretaceous supersequences. The sequence stratigraphy and structural framework of the Cretaceous succession were analysed to determine the spatial relationship of reservoir and seal pairs, and areas of source rock development. Updated biostratigraphy, well lithology and log analysis, seismic stratal geometry, facies, palaeogeographic and play fairway interpretations were completed for seven supersequences from the late Tithonian to Maastrichtian (K10–K60 supersequences). These data, together with geochemical studies of source rocks and fluids (gases and liquids), were integrated in a regional petroleum systems model to better understand source rock distribution, character, generation potential, and play prospectivity. The regional deposition of the Permo-Carboniferous, Triassic, Jurassic and Cenozoic successions were mapped to constrain the burial history model.

Supersequence cross-sections and palaeogeographic maps show the distribution of gross depositional facies, revealing three main Cretaceous stratigraphic play types across the basin. These are basin-margin, clinof orm topset and submarine fan plays. Geochemical analyses using molecular and stable carbon and hydrogen isotopic signatures correlate fluids in these plays with potential source rocks. The geochemical fingerprints enabled the identification of four Mesozoic petroleum systems. Burial history modelling demonstrates hydrocarbon generation from potential source rocks within the Jurassic and Lower Cretaceous supersequences. Many accumulations have a complex charge history with the mixing of hydrocarbon fluids from multiple Mesozoic source rocks, as recognised from the deconvolution of their geochemical compositions

The basin margin play occurs within the K10–K40 supersequences (Early Cretaceous upper Vulcan and Echuca Shoals formations) along the inboard Yampi and Leveque shelves. The K20–K30 (Echuca Shoals Formation) basin margin play received gas (Caspar 1A) potentially sourced from the J10–J20 supersequences (Plover Formation) and oil (Gwydion 1) sourced from the K20–K30 supersequences (Echuca Shoals Formation). Seal quality and thickness are good except where the seal facies pinch out around basement highs on the Yampi Shelf, and where they are truncated by the K50 sequence boundary (Wangarlu Formation) inboard on the Leveque Shelf. The K40 basin margin play (Jamieson Formation) received gas (Gwydion 1, Cornea field) that is most likely sourced from the J10–J20 supersequences (Plover Formation) and oil (Cornea field) sourced from the K20–K30 supersequences (Echuca Shoals Formation). The marine shales in the K20–K30 supersequences (Echuca Shoals Formation) have low hydrogen indices (around 200 mg hydrocarbons/gTOC) and hence may only be able to expel sufficient hydrocarbons to sustain

migration over short distances. The co-existence of oil sourced from these successions and gas sourced from the J10–J20 supersequences (Plover Formation) suggests that Cretaceous-sourced liquids were possibly mobilised and carried to the shelf edge by co-migrating Early–Middle Jurassic Plover-derived gas. Once present within these shallow reservoirs, further loss of the low and mid-chain hydrocarbons occurred through leakage, water washing and biodegradation. Together, the migration and secondary alteration processes have enhanced the liquids potential on the basin margin.

The clinoform topset play extends between the basin-margin and the shelf-edge. These plays consist of higher order progradational sandstone units overlain by intraformational and top seals. The K10 clinoform topset play (namely the Brewster Member of the Upper Vulcan Formation) hosts gas in the Ichthys/Prelude and Burnside accumulations. The gas is probably largely sourced from the organic-rich shales of the J30–K10 supersequences (Vulcan Formation), with an additional contribution from the J10–J20 supersequences (Plover Formation) in satellite fields, such as observed at Concerto-1 ST1. Other similar K10 plays are mapped in the southern Caswell and Oobagooma sub-basins and could receive charge from J30–K10 potential source pods. The K30 clinoform topset play (*M. australis* sand of the Echuca Shoals Formation) is a reservoir for gas on the Leveque Shelf at Psepotus-1, with additional evidence for oil migration into this play at Braveheart-1 in the northern Caswell Sub-basin. This play extends in underexplored prospective areas on the Leveque Shelf to the inboard Barcoo Sub-basin and on the southern Yampi Shelf to the outboard Caswell Sub-basin. The K40 clinoform topset play (*D. davidii* sand of the Jamieson Formation) hosts gas (Adele-1) and light oil (Caswell-1). The light oil is probably sourced primarily from the K20–K30 supersequences (Echuca Shoals Formation) in the central Caswell Sub-basin. This play extends outboard in the Caswell Sub-basin to Caswell-2 ST2 and Phrixus-1.

The submarine fan play comprises sandstone-prone basin floor fans that extend across the basin floor from the toe of the slope and are sealed by down-lapping mudstone facies. This play may overlie either second, third, fourth or fifth-order sequence boundaries and are particularly well developed within the Upper Cretaceous K60 supersequence (Wangarlu Formation). The K30 submarine fan play (Echuca Shoals Formation) hosts gas in the outboard northern Caswell Sub-basin (Abalone Deep-1 and Adele-1). Isotopic evidence for the gas at Adele-1 suggests that the K20–K30 supersequences (Echuca Shoals Formation) is the most likely source. This play is largely underexplored and includes the tentatively interpreted play around Omar 1 in the Barcoo Sub-basin. There is evidence for oil migration through the K50 (Wangarlu Formation) submarine fan play at Discorbis-1, with the source of hydrocarbons possibly being from the K20–K30 supersequences (Echuca Shoals Formation). This play extends into the inboard northern Caswell Sub-basin. The K60 submarine fan (Wangarlu Formation) play either hosts oil and gas (Abalone-1, Caswell-2 and Marabou-1) or contains evidence of hydrocarbon migration (Discorbis-1 and Gryphaea-1) in numerous wells. The most likely source of hydrocarbons is from the K20–K30 supersequences (Echuca Shoals Formation).

The results of this study reveal multiple stacked Cretaceous plays in the basin, including those in underexplored vacant acreage.

Speaker Biography

Dr Nadege Rollet is a senior geoscientist at Geoscience Australia. Nadege graduated from the University of Paris – Pierre et Marie Curie, France where she obtained a MSc and a PhD (1999) in geology and geophysics. Her studies focused on structural framework and geodynamic of the Ligurian Sea, Western Mediterranean. Since joining Geoscience Australia, she contributed to assessments of the petroleum prospectivity, seepage studies and CO₂ storage of Australian sedimentary basins. Nadege is currently investigating depositional framework and petroleum systems in the Browse Basin. Member: PESA.