USING 2D AND 3D BASIN MODELLING AND SEISMIC SEEPAGE INDICATORS TO INVESTIGATE CONTROLS ON HYDROCARBON MIGRATION AND ACCUMULATION IN THE VULCAN SUB-BASIN, TIMOR SEA, NORTH-WESTERN AUSTRALIA

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ABSTRACT

2D and 3D basin models have been constructed of the southern and central parts of the Vulcan Sub-basin, which is located in the Timor Sea, north-western Australia. This work was carried out in order to better elucidate the petroleum migration and accumulation histories and exploration potential of the region. The study area extended from the southern limit of the Swan Graben in the south-west to the northern part of the Cartier Trough in the north-east. The results from the basin modelling have been compared with the seafloor bathymetry and physiography, the spatial distributions of hydrocarbon related diagenetic zones (HRDZs) in the region, as well as the distribution of other leakage and seepage indicators. A new method for identifying potential HRDZs using seismic data has also been developed.

The 2D/3D modeling results from the Swan Graben indicate that horizontal and downward oil expulsion from the source rocks of the Late Jurassic Lower Vulcan Formation into the upper Plover Formation sandstones was active from the Early Cretaceous to the present day. Oil migration from the Lower Vulcan Formation into the Late Cretaceous Puffin Formation sands in the Puffin Field was simulated via lateral migration along the bottom of an Upper Vulcan Formation seal and by vertical migration above the seal edge. Modelling also indicates that Late Jurassic sequences over the Montara Terrace are thermally immature and did not contribute to the hydrocarbon accumulations in the region. On the other hand, 3D modelling results indicate that the Middle Jurassic Plover Formation in the Montara Terrace became thermally mature after the Pliocene and hence it could have contributed to both the specific hydrocarbon accumulations and the overall hydrocarbon inventory in the area.

In the southern Cartier Trough, the Lower Vulcan Formation is typically at a lower thermal maturity than that seen in the Swan Graben, due to a combination of a relatively recent (Pliocene) increased burial and a thinner Lower Vulcan Formation. Here, horizontal and downward oil/gas expulsion from the Lower Vulcan Formation into the Plover Formation sandstone was active from the Late Tertiary to the present day, which is significantly later than the timing of the expulsion in the Swan Graben.

In the central Cartier Trough, the areal extent of both generation and expulsion increased as a result of rapid subsidence and deposition from about 5.7 Ma to the present day. This Pliocene loading has resulted in the rapid maturation of the Early to Middle and Late Jurassic source system and expulsion of oil very recently.

Oil migration from the Lower Vulcan Formation into the Jabiru structure, via the Plover Formation carrier bed, was simulated in both the 2D and the 3D modelling. In particular, the 3D modelling simulated oil migration into the Jabiru structure, both from the southern Cartier Trough (after the Miocene) and also from the northern Swan Graben (in the Early Cretaceous). Early gas migration, and the attendant formation of a gas cap, was also simulated. Importantly, this result provides a potential alternative interpretation for the formation of at least some of the residual zones in the Timor Sea, as well as in other areas.

Traditionally, most of the residual zones within the Timor Sea have been attributed to fault seal reactivation and failure. However, the simulated early gas cap in the Jabiru structure has formed as a result of gas exsolution as the migrating hydrocarbons entered the Jabiru trap (and its shallow flanks), which was then only located a few hundred metres below the surface. The rapidly decreasing pressure allowed the gas to form a separate phase, with the result that in the Early Cretaceous, in the 3D model, the Jabiru trap was composed of a relatively large gas cap with a thinner ("black oil") oil leg. Progressive burial through the Tertiary, and the attendant increase in pressure, resulted in the gas going back into solution. The associated decrease in the bulk volume of the hydrocarbon accumulation produced a "residual" oil zone at the base of the column, purely through a change in phase, rather than through loss of hydrocarbons from fault seal failure, for example.

The processes outlined in this scenario would be essentially indistinguishable from those produced by fault seal failure when assessing traps using fluid history tools such as GOI. Such a process could be critically important in the case of shallow, low-relief traps, where only the exsolved gas could be trapped, with the "black oil" component displaced below the spill of the trap. Small, sub-commercial gas fields would thus be located around the periphery of the source depocentres - though these would be the result of an early, rather than late, gas charge. Small black oil accumulations could be developed inboard from such gas fields.

A new method to extract HRDZs from 3D seismic data has predicted the location of new HRDZs in the northern Vulcan Sub-basin. Further investigation is needed to confirm/refine the method but it has the potential to significantly aid HRDZ mapping (and seal assessment and hydrocarbon migration studies). A workflow for future studies is proposed which includes inputs from basin modelling, leakage and seepage mapping, and fault seal and fault reactivation studies. Implementation of this workflow should ultimately allow a more reliable estimation of GOR prior to drilling.

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