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Application of hydrodynamics to sub-basin-scale static and dynamic reservoir models

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Abstract

In mature hydrocarbon provinces, the impact of production induced pressure depletion on un-produced or undiscovered reserves is a concern. Reduced formation pressure has an adverse effect on recoverability, but more problematic are accumulations that are filled to spill, where a reduction of formation pressure results either in gas exsolution or gas cap expansion and loss of liquids from the trap. In the Australian context, the latter is of significant concern owing to the gas rich nature of many of its sedimentary basins. Standard reservoir engineering techniques have been used to evaluate the impact of pressure depletion with mixed results.

There are three assumptions typically made in the reservoir models that are normally valid for a single pool, but can add significant uncertainty when applied to a region of several pools, or worse yet, at the sub-basin or basin-scale. The first assumption is that the virgin pressure state of the aquifer at the base of the hydrocarbon column can be approximated by an average hydrostatic formation water pressure gradient. The second is that all pressure data can be referenced to a common reservoir datum by correcting each measured formation pressure using an assumed fluid pressure gradient. The third is that the aquifer which supports one or more hydrocarbon pools has a fixed volume.

The study of basin hydrodynamics uses techniques that take into account the fact that, while the pre-production trapped hydrocarbon phase is static, the aquifer at the base of the hydrocarbon accumulation is dynamic. Regional boundary conditions can be identified that drive formation water flow and help define formation water influx and discharge from an aquifer system rather than assuming a fixed aquifer volume. Pressures in an aquifer may therefore vary for a given depth, due to variations in the hydraulic potential field resulting from differences in aquifer properties across a sub-basin. Hydrodynamic techniques also characterise formation pressure data using a hydraulic head to avoid the requirement of referencing a formation pressure to a depth datum. It removes the need to assume a particular fluid pressure gradient when the fluid composition is not known. This paper describes how hydrodynamic techniques can be incorporated into the static and dynamic reservoir models to reduce errors and uncertainty in the model results. These include the use of a potentiometric energy distribution for the aquifer to obtain aquifer pressure rather than an average hydrostatic gradient and a basin wide depth datum, and the characterisation of natural inflows and discharges rather than assuming a fixed aquifer volume. The approach is exemplified with data from various basins.
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1. Introduction

For sedimentary basins that have multiple hydrocarbon accumulations within the same reservoir horizon, a

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long term holistic development strategy is required to mitigate the effects of sub-basin scale (10's to 100 km distances) aquifer pressure depletion on unproduced and undiscovered reserves. The West Australian Department of Industry and Resources (DOIR) state in "Petroleum in Western Australia" (2004), that observations from newly discovered fields in the Exmouth, Barrow and Dampier Sub-basins of Western Australia (Fig. 1) suggest sub-basin scale pressure depletion has occurred. Yassir and Otto (1997) describe pressure depletion of the aquifer in the Challis Field region of the Vulcan Sub-basin in the Timor Sea, and sub-basin scale pressure depletion of the Latrobe Group strata in the Gippsland Basin (Fig. 1) has been documented by Walker (1992) Gibson-Poole et al. (2004), Hatton et al. (2004), and Root et al. (2004).

Regionally reduced aquifer pressure has a generally adverse effect on oil and gas recoverability, since there is less pressure support from water influx. More problematic, are single phase reservoirs that are near to the bubble point, or two phase accumulations that are filled to spill. In the case of a single phase reservoir, if the reservoir pressure falls below the bubble point, a gas phase will come out of solution (Craft et al., 1991). With the volumetric expansion, some of the oil may be lost from the trap if it was filled to spill. Similarly, a reduction of reservoir pressure for a two phase reservoir results in gas cap expansion and the potential loss of liquids from the trap. In the Australian context, the latter is of significant concern owing to the gas rich nature of many of its sedimentary basins and the fact that many of its basins have the bulk of their hydrocarbon production from only a few reservoir horizons. Malek (2004a,b) suggest that the potential loss in state royalties due to

Table 1
Estimated royalty loss from the Carnarvon Basin by 2030 due to aquifer pressure depletion assuming 10% royalty and a $50/bbl (AUS) oil price (summarized from Malek (2004a,b)).

	Possible royalty loss $million (AUS)		
Assumed volume of unproduced oil in place (MMSTB)	15 psi depletion	50 psi depletion	500 psi depletion
3200	30	130	2080
6050	60	240	3930

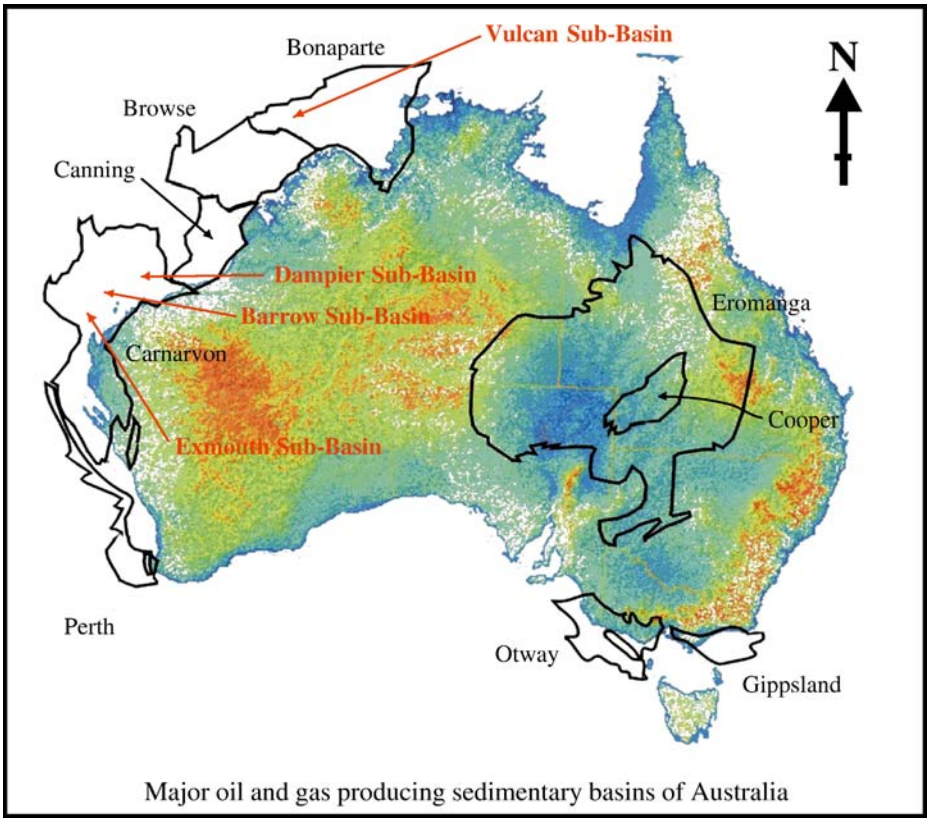

Fig. 1. Major oil and gas producing sedimentary basins of Australia.

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