CONTROLS ON SANDSTONE RESERVOIR QUALITY: PERMIAN TO EARLY CRETACEOUS SEQUENCES, BARROW SUB-BASIN, NORTH WEST SHELF, WESTERN AUSTRALIA

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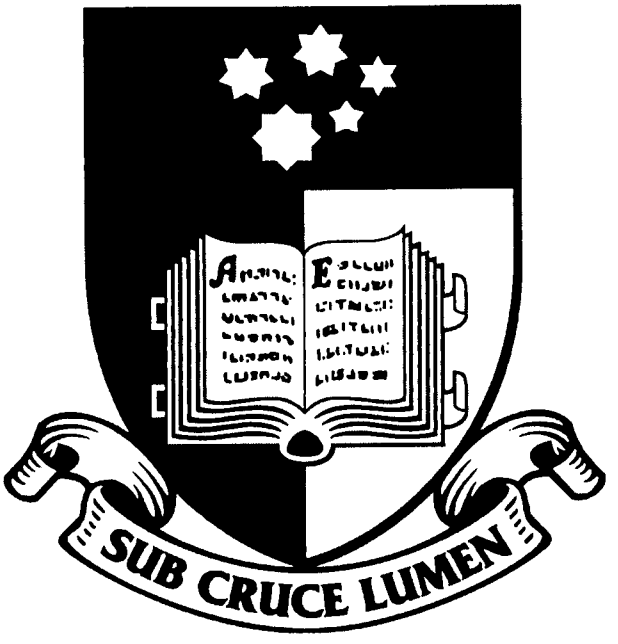
STATEMENT OF AUTHENTICITY AND AVAILABILITY



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Ghazi Kraishan

July 1997

Dedicated

To My Parents

And

To my Fiancée Deema

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ABSTRACT

The Barrow Sub-basin, situated offshore on the North West Shelf of Australia, is one of the most prospective hydrocarbon among the provinces in the country with numerous commercial oil and gas accumulations. In spite of the number of papers written on the sub-basin, diagenetic effects on reservoir quality and the distribution of the porosity and permeability have received little attention.

The study examines the diagenetic history of the sandstones in the Barrow Sub-basin. The specific aim of this study is to investigate their diagenetic evolution and to determine both depositional and post-depositional factors that influenced the porosity, permeability and reservoir properties in the Barrow Sub-basin. Relative timing of these factors is determined and absolute timing is constrained by reference to factors such as exposure on unconformities, periods of rapid burial and compaction, heating events and major water migration episodes.

This integrated approach involves identification of all controls on the reservoir quality, including tectonic setting, burial history and clay minerals diagenesis, as well as the chemical evolution of the pore-water. The present reservoir properties described to ensure maximum hydrocarbon recovery and to predict reservoir quality in less explored areas. Techniques used include: interpretation of depositional environments; textural; chemical, isotopic and petrophysical analysis.

The sandstones of the Barrow Sub-basin were deposited in environments ranging from fluvio-deltaic to shelf to deep marine turbidites are generally extremely well sorted and display a unimodal grain-size distribution. These sediments have undergone a complex diagenetic history that can be related to pore-water evolution and to progressive burial history.

The precipitation of authigenic minerals has greatly reduced the reservoir quality of the Barrow Sub-basin sandstones. Fourteen authigenic minerals have been identified. Quartz, kaolinite and authigenic carbonate minerals are volumetrically significant, whilst glauconite, pyrite, feldspar, albite, other clay minerals and barite are present in minor to trace amounts. These authigenic minerals are distributed on a regional scale and cover a wide stratigraphic and depth range. Because these minerals are not all present in a single formation, a paragenetic sequence has been drafted which represents a composite sequence from different stratigraphic ages. This sequence is based on petrographic, isotopic and fluid

inclusion studies, all aided by the burial history curves. The geothermal gradients, the heat flow and the thermal history of sub-basin were taken into consideration during the interpretation of the sequence of diagenetic events.

Post-depositional precipitation of the authigenic minerals began early in the diagenetic history with the formation of glauconite fecal pellets. Shortly after deposition, framboidal pyrite started to precipitate during sulfate reduction followed by the precipitation of micritic siderites. An invasion of acidic meteoric waters occurred during a later uplift of the sub-basin, resulting in partial dissolution of feldspars and precipitation of an early feldspar overgrowths and kaolinite. Subsequent water modification resulted in local precipitation of poikilotopic calcite, which overlaps the previous authigenic minerals. In the middle stage of the diagenetic history and during the early maturation of the organic matter, early and second phases of the quartz overgrowths and siderite (sparry siderite) occurred. Later, ankerite cement was precipitated during deep burial from water expelled from the underlying shale and during smectite to illite conversion. The latest diagenetic mineral was probably cubic pyrite, which occurs in association with oil entrapment. The timing of barite precipitation and albitisation is uncertain.

Authigenic carbonate minerals reveal a complex evolution of the chemical and isotopic signatures of the pore-waters. The early authigenic carbonate minerals were precipitated from marine pore-water and have almost identical chemical and isotopic ratios. After the rifting of the sub-basin (Callovian mid-Jurassic), a slight uplift occurred and introduced meteoric water to the system along the eastern margin and resulted in precipitation of the middle stage carbonate phases. The later phases of carbonate occurred when the sandstone was buried enough to produce modified diagenetic water from the thick shale beds that underlying these sandstones. The strontium isotopic ratios are consistent with the model proposed by the carbon and oxygen isotopic ratios for the authigenic carbonates. The $^{87}Sr/^{86}Sr$ ratios of the early carbonate indicate an early occurrence from Cretaceous marine water. In contrast, the middle and late carbonate phases have higher Sr ratios, suggesting involvement of radiogenic Sr, which could be liberated from the dissolution of the silicate minerals or during the shale diagenesis.

Isotopic ratios of the cubic pyrite associated with oil, are extremely enriched with ^{34}S, indicating late precipitation during extensive sulfate reduction.

The reservoir quality is highly affected by depositional and post-depositional factors. Sandstones deposited in slope/basin marine environments contain abundant clay matrix, which may exceed 14 per cent of the whole-rock volume compared with about 7 per cent in the marine shelf environments. Transitional to non-marine environments have less than 3 per cent detrital clay matrix on average. In addition, it seems that the authigenic clays have developed mostly in those facies enriched in depositional matrix making the possibility of enhancement of reservoir quality complex.

Post-depositional factors, the precipitation of authigenic minerals and mechanical and chemical compaction, have worked together to reduce the primary intergranular porosity. In general, both processes have had nearly equal effect in destroying the original intergranular porosity. The precipitation of the authigenic minerals has reduced, on average, the primary intergranular porosity up to 15 per cent of the whole rock-volume. The mechanical and chemical compaction processes have further contributed to porosity loss. They show less

effect on porosity due to the rapid deposition of the sandstones and early precipitation of some authigenic minerals, which slightly inhibit the effects of compaction.

The development of secondary porosity has greatly enhanced the reservoir quality of the Barrow Sub-basin sandstones. More than one mechanism for the development of secondary porosity is apparent. The invasion of acidic meteoric water and the release of organic acids during organic-matter maturation have both played a significant part upon the enhancement of the reservoir quality. The first mechanism occurred during the several episodes of uplift which occurred during the development of the sub-basin. Organic acids released during the organic-matter maturation, migrated up-dip along the fault axes to develop secondary porosity of carbonate cemented zones. Secondary porosity developed by dissolution in carbonate-cements (especially calcite) has greatly enhanced the reservoir quality of the Barrow Sub-basin sandstones, especially around the basin margins, along the Rankin Trend and in the southern part of the sub-basin.

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