Molecular and Stable Isotopic Compositions of Natural Gas from the Exmouth Plateau, Carnarvon Basin, Australia

D. Edwards, C. Boreham, J. Hope, S. LePoidevin, T. Buckler & Z. Hong.

Introduction

This study documents the composition of the natural gas found in wells on the Exmouth Plateau and compares these results to data obtained from gas accumulations on the Rankin Platform and Exmouth Sub-basin, Northern Carnarvon Basin (Figure 1). The Exmouth Plateau contains Australia's largest undeveloped gas resources. The primary reservoirs are the Middle–Late Triassic Mungaroo Formation (Eendracht, Geryon, Jupiter, Maenad, Orthrus, Sirius and Urania), the Late Jurassic sands of the Dingo Claystone at Geryon and Io/Jansz, and the Early Cretaceous Barrow Group at Scarborough.

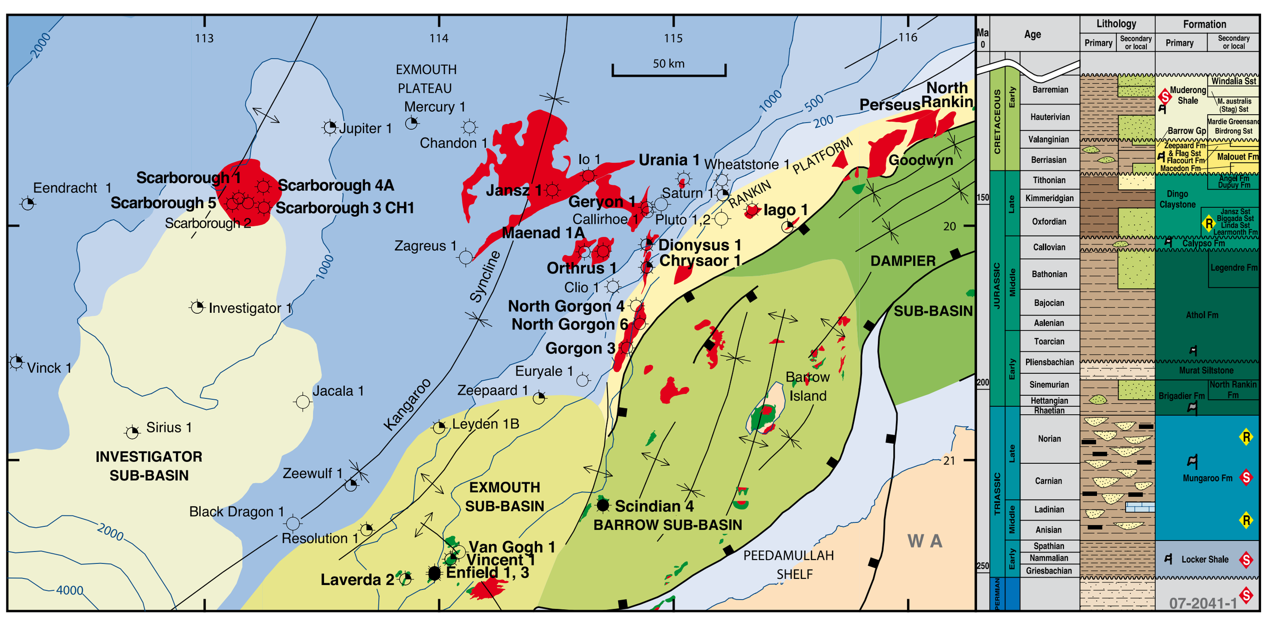


Figure 1 Location map of the hydrocarbon accumulations on the Exmouth Plateau, Rankin Platform and Exmouth Sub-basin. Gas samples analysed in this study are shown in bold.

Analyses

Molecular and isotopic (carbon and hydrogen) analyses have been undertaken on natural gases to understand the origin, thermal maturity and degree of preservation of these resources. The stable hydrogen isotopes ($^2H/^1H$, δ^2H ratio or δD) complement and expand on a decade of experience in the geological application of compound specific isotopic analysis (CSIA) for stable carbon isotopes ($^{13}C/^{12}C$ ratio or $\delta^{13}C$; Boreham et al., 2001). These data are available from http://dbforms.ga.gov.au/www/npm.well.search

Regional Trends: Exmouth Plateau

The gas accumulations on the Exmouth Plateau are typically dry, with condensate to gas ratios (CGRs) of about 3 bbls/MMscf, becoming extremely dry when biodegraded, as exemplified by the gases at Jupiter and Scarborough (95.6 mol% methane; 4.3 mol% nitrogen). The Exmouth Plateau gases typically have low concentrations of carbon dioxide (CO_2 0.4 - 2.6 mol%), although slightly higher values are recorded at Investigator and Sirius (CO_2 4.4 - 4.6 mol%). Isotopic analysis of the carbon dioxide in differing accumulations show a range of values ($\delta^{13}C$ CO_2 = -15.9 to -3.5 ‰), suggesting both inorganic and thermogenic sources. However, there is no obvious trend with depth, unlike that seen in the neighbouring Dionysus, Chrysaor and Gorgon gas fields on the southern Rankin Platform (Figure 2a).

The Late Jurassic (Oxfordian) reservoir at Io/Jansz is in pressure communication with the Late Jurassic (Tithonian) and Brigadier reservoirs at Geryon (Jenkins et al., 2003; Korn et al., 2003). However, their $\delta^{13}C$ CO_2 values differ, implying that the gases are not in chemical equilibria (Figure 2b). The carbon dioxide in the gas sample recovered from Jansz 1 is depleted in ^{13}C ($\delta^{13}C$ CO_2 = -15.5 ‰), implying a strong thermogenic source component (Figure 2a). This is in contrast to the carbon dioxide in the gases reservoired in the Tithonian ($\delta^{13}C$ CO_2 = -3.5 ‰) and Brigadier ($\delta^{13}C$ CO_2 = -5.2 ‰) sandstones at Geryon 1, which are isotopically enriched in ^{13}C and indicative of an inorganic source.

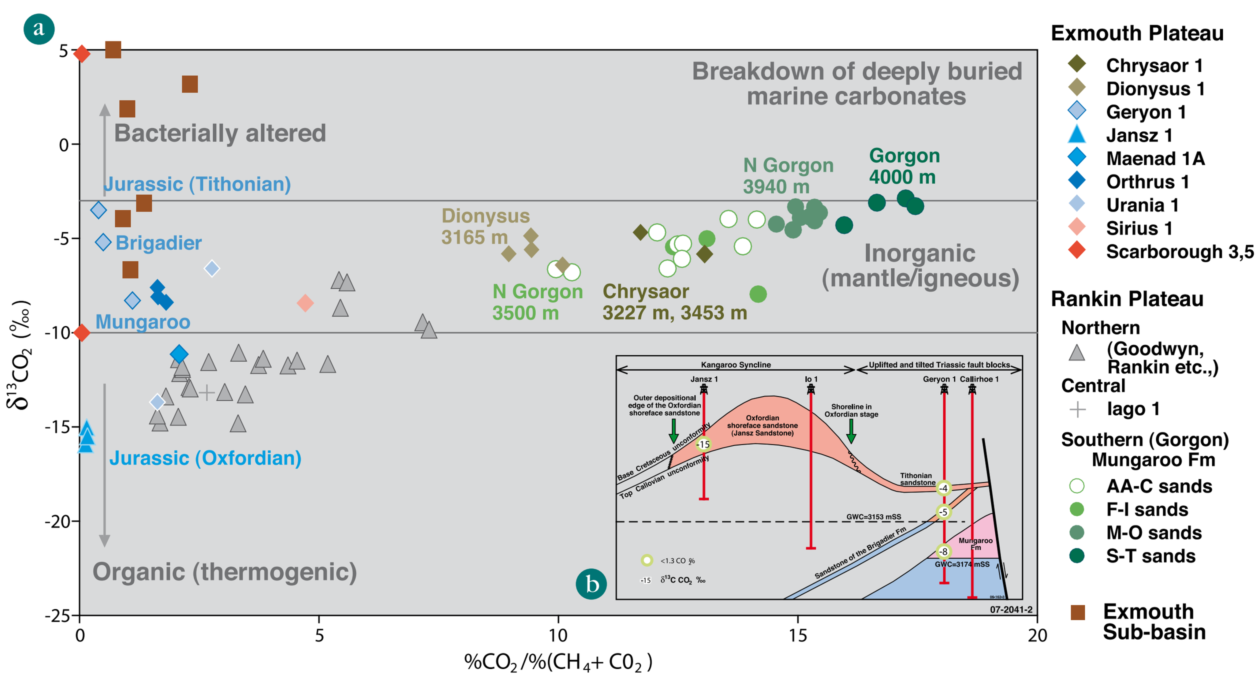


Figure 2a: Origin of carbon dioxide in Exmouth Plateau gas accumulations; comparison to neighbouring gas accumulations.
Figure 2b: Molecular and isotopic compositions of carbon dioxide in the Io/Jansz and Geryon natural gas accumulations.

Regional Trends: Gorgon Area

High concentrations of inorganic carbon dioxide occur within the Dionysus, Chrysaor and Gorgon gases (CO_2 = 5—23 %; Figure 2a). Increasing concentrations of isotopically enriched carbon dioxide occur from the shallower reservoirs in the Mungaroo AA sands (~ 10 %; $\delta^{13}C$ CO_2 = -6 ‰) to the deeper Mungaroo S and T sands (~ 22 %; $\delta^{13}C$ CO_2 = -3 ‰; Figure 3).

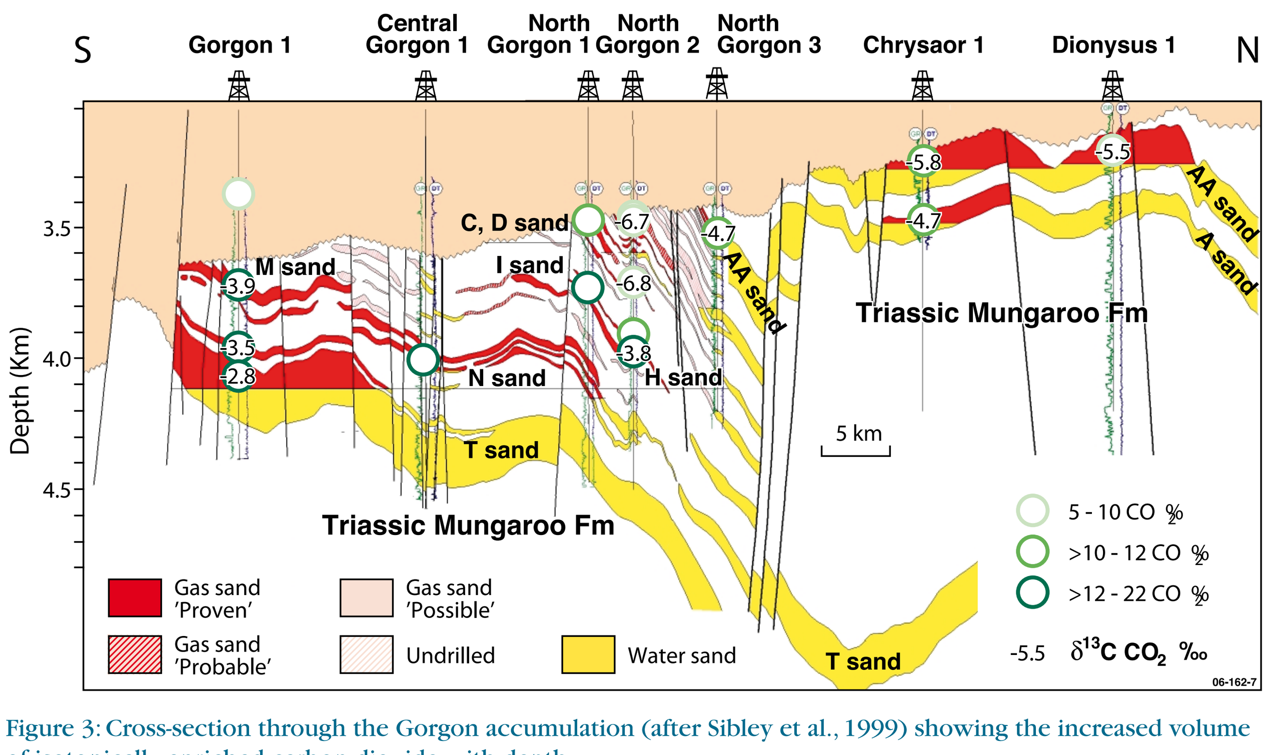


Figure 3: Cross-section through the Gorgon accumulation (after Sibley et al., 1999) showing the increased volume of isotopically enriched carbon dioxide with depth.

References

Boreham, C.J., Hope, J.M., Hartung-Kagi, B., 2001. APPEA Journal, 41(1), 523-47.

Boreham and Edwards, 2007. Organic Geochemistry (in press).

James, A.T., 1990. AAPG Bulletin 74, 1441-58.

James, A.T. and Burns, B.J., 1984. AAPG Bulletin 68 (8), 957-60.

Jenkins, C.C., Maughan, D.M., Acton, J.H., Duckett, A., Korn, B.E. and Teakle, R.P. 2003. APPEA Journal, 43(1), 303-24.

Korn, B.E., Teakle, R.P., Maughan, D.M. and Siffleet, P.B., 2003. APPEA Journal, 43(1), 285-301.

Sibley, D., Herkenhoff, F., Criddle, D. and McLerie, M., 1999. APPEA Journal, 39(1), 128-48.

Whiticar, J.M., 1994. In: Magoon, L.B. and Dow, W.G. (eds), The Petroleum System—From Source to Trap. AAPG Memoir 50, 261-83.

Gas–Gas Correlations

Gas–gas correlations based on the carbon and hydrogen isotopic compositions of individual hydrocarbons from methane to *n*-pentane (C_1–C_5) are shown in Figure 4. The Geryon 1, Jansz 1, Maenad 1A, Orthrus 1 and Urania 1 gases have similarly shaped ^{13}C isotopic profiles that show very little differentiation between ethane, propane and butane. Such a flat isotopic profile in these wet gases is typical of a terrigenous gas source (James, 1990). Figure 4 also shows significant source differences between the Exmouth Plateau gases and the nearby southern Rankin Platform gases, with mixing of gases apparent at Dionysus.

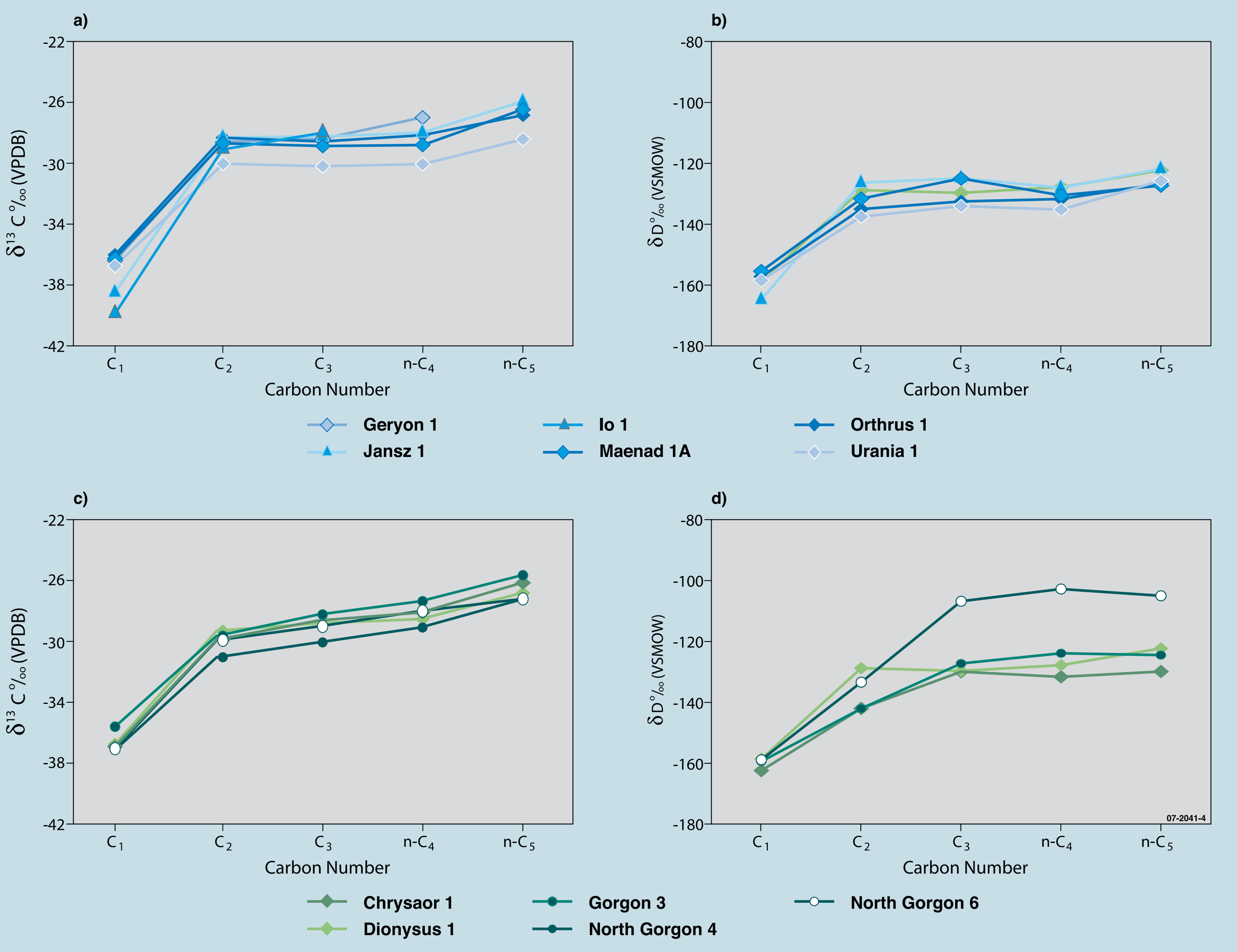


Figure 4: Carbon and hydrogen isotopic values for *n*-alkanes in natural gases from the Exmouth Plateau and southern Rankin Platform highlighting source differences.

The plot of $\delta^{13}C$ ethane versus $\delta^{13}C$ methane in Figure 5 shows that the Geryon 1, Jansz 1, Maenad 1A and Orthrus 1 gases were generated at vitrinite reflectances (Ro) between 1.3 and 1.5 %, and are more mature than the gas from Urania 1 (Mungaroo C sand), as well as the gases from the Rankin Platform. Interestingly, these gases plot along the trend of the marine Type II kerogen rather than that of the Type III kerogen, as established by Whiticar (1994). These data imply that suspected Type III source inputs are isotopically distinct from those of Whiticar (1994).

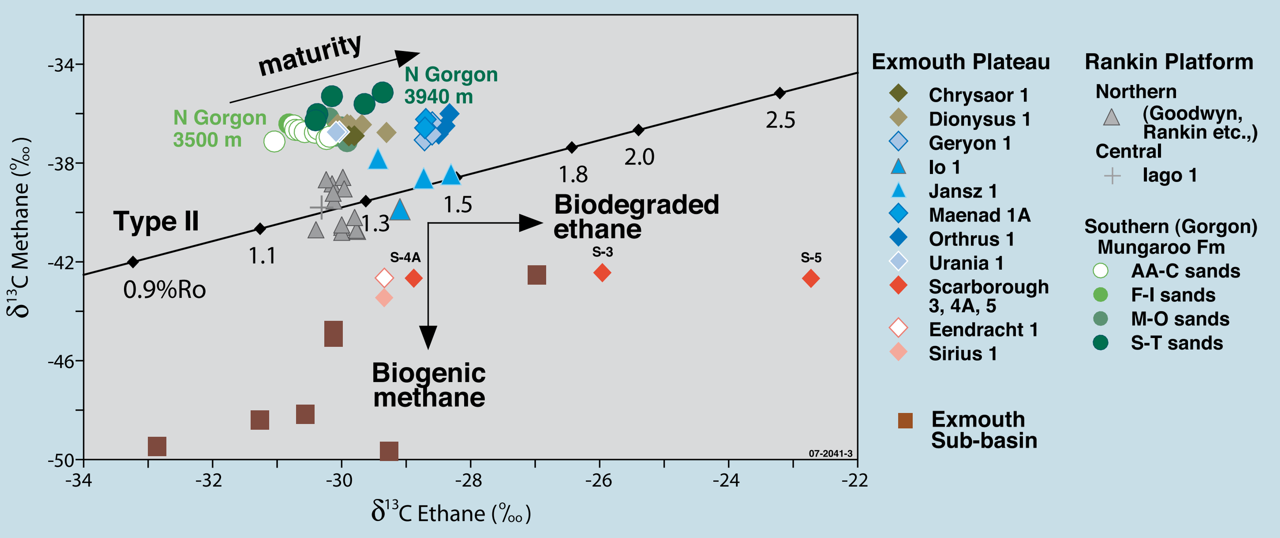


Figure 5: Carbon isotopic values of ethane versus methane showing kerogen type, maturity trends and the effect of biodegradation on gases.

Biodegradation

The dry gases at Eendracht, Sirius and Scarborough result from the microbial alteration of thermogenic-sourced gases, as shown by the carbon and hydrogen isotopic profiles in Figure 6. These profiles are similar to the biodegraded gases from the Exmouth Sub-basin. Methane is depleted in $\delta^{13}C$ and δD due to the addition of secondary biogenic methane, whereas the remaining wet gases (ethane and propane) show increasing enrichment in their $\delta^{13}C$ and δD values with increasing levels of biodegradation. However, even in the most biodegraded gas from Scarborough, the isotopic value of *neo*-pentane is unaltered (Figure 7), as has been reported in other gases by Boreham and Edwards (2007).

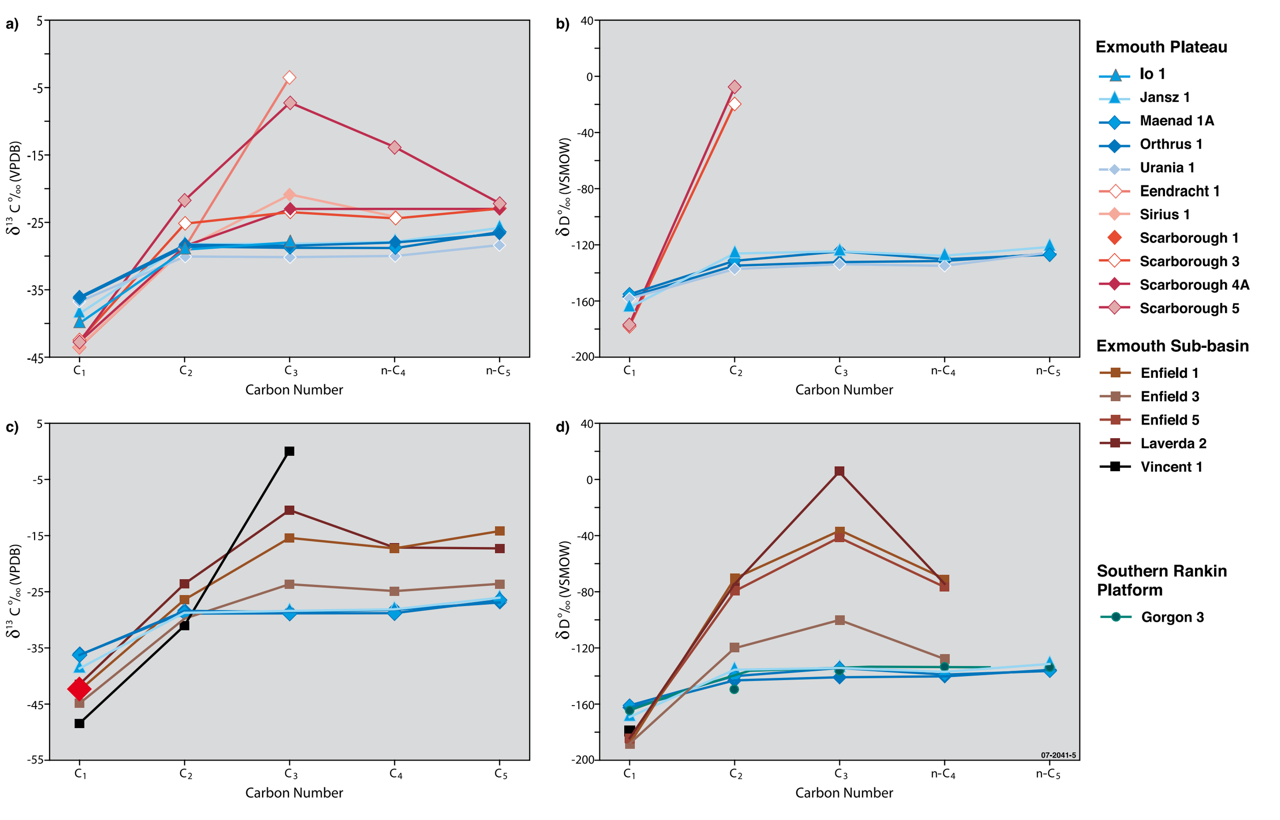
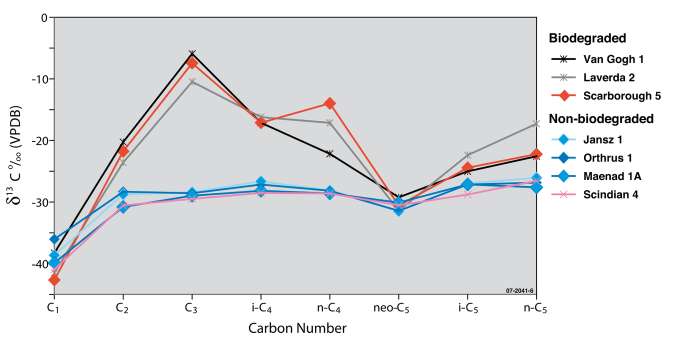


Figure 6: Carbon and hydrogen isotopic values for *n*-alkanes in natural gases from the Exmouth Plateau and comparison to Exmouth Sub-basin gases to emphasise the effects of biodegradation. Eendracht and Sirius data from James and Burns (1984).



"The dry gases at Eendracht, Sirius and Scarborough result from the microbial alteration of thermogenic-sourced gases"

Figure 7: Carbon isotopic values for individual gas components from the Exmouth Plateau including *neo*-pentane.

Acknowledgements

We thank BHP Billiton Petroleum for provision of samples and permission to publish.

Summary

The Exmouth Plateau hydrocarbon gases are most likely sourced from the regressive fluvial–deltaic Middle–Late Triassic Mungaroo Formation, in particular the coaly facies known to occur in the upper part of this formation. These gases are relatively more mature than the gases from the Rankin Platform. The Rankin Platform gases are presumably sourced from multiple source units within the Triassic–Jurassic sediments underlying and juxtaposed against this structural high.

The gas accumulations at Eendracht, Jupiter, Scarborough and Sirius are biodegraded to differing degrees. Nevertheless, the carbon isotopic value of *neo*-pentane in the Scarborough gas implies a similar thermogenic origin to other gases in the region.

For more information phone
Dianne Edwards on +61 2 62499782 or email dianne.edwards@ga.gov.au
www.ga.gov.au