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Sourcing WA's offshore natural gases

New isotope data uncover the history of North West Shelf accumulations

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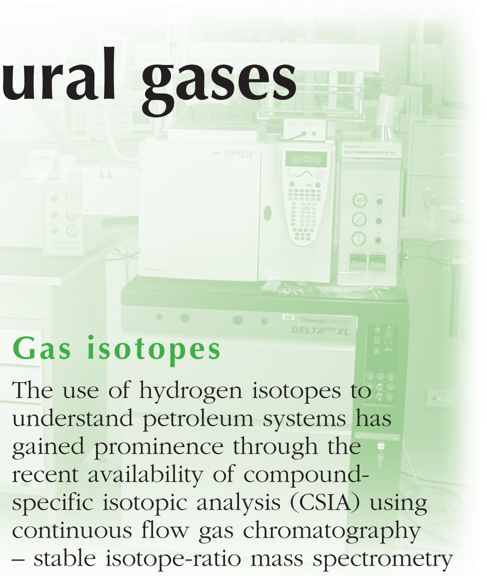

Molecular and stable isotopic (carbon and hydrogen) analyses of fluid samples from Australia's offshore natural gas accumulations are being undertaken as part of a Geoscience Australia initiative to understand the origin, thermal maturity and degree of preservation of these economic resources.

Isotopic signatures of the natural gases from the Exmouth Plateau and Exmouth Sub-basin (figure 1) show that many accumulations have complex fill histories. Natural gas accumulations on the Exmouth Plateau comprise mixtures of non-combustible and combustible gases derived from numerous sources. The combustible hydrocarbon gases have a thermogenic origin, with the non-combustible carbon dioxide and nitrogen gases originating from both organic and inorganic sources. With the exception of Scarborough, the Exmouth Plateau natural gas accumulations have not been biodegraded. The natural gases from the majority of the Exmouth Sub-basin accumulations show differing degrees of biodegradation.

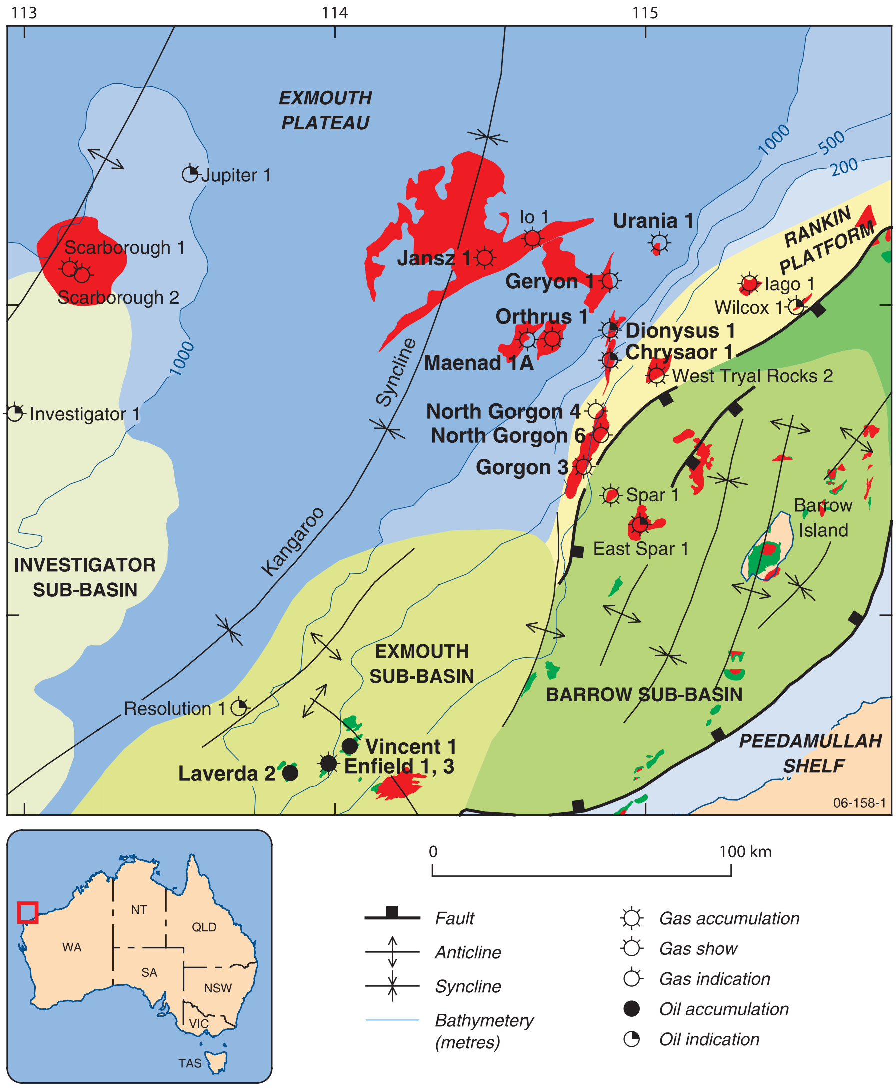

Figure 1. Location map of the hydrocarbon accumulations on the Exmouth Plateau and in the Exmouth Sub-basin. Gas samples analysed in this study are shown in bold.

Gas isotopes

The use of hydrogen isotopes to understand petroleum systems has gained prominence through the recent availability of compound-specific isotopic analysis (CSIA) using continuous flow gas chromatography – stable isotope-ratio mass spectrometry (GC-IRMS).

Reported here are the initial results of a study using stable hydrogen (deuterium) isotopes ($^{2}H/^{1}H$ ratio or δD) applied to natural gases on the North West Shelf. These data complement and expand on a decade of experience in the geological application of CSIA for stable carbon isotopes ($^{13}C/^{12}C$ ratio or $\delta^{13}C$; Boreham et al 2001, Geoscience Australia & GeoMark 2006).

Exmouth Plateau

The Exmouth Plateau region contains Australia's largest undeveloped gas resources. The primary reservoirs are the Middle–Late Triassic Mungaroo Formation (Chrysaor, Dionysus, Geryon, Maenad, Orthrus and Urania), the Late Jurassic (Oxfordian–Tithonian) sands of the Dingo Claystone at Geryon and Io/Jansz, and the Early Cretaceous Barrow Group at Scarborough.

Geryon, Io/Jansz, Maenad, Orthrus and Urania (Mungaroo C sand reservoir) are dry gas accumulations with a condensate to gas ratio (CGR) of about 3 bbls/MMscf, although they contain low proportions of wet gases (average $\%C_1/\%C_1–C_5$ = 93.4%; >97% is considered to be a dry gas).

The Urania 1 gas in the shallower Mungaroo AA sand is wetter ($\%C_1/\%C_1–C_5$ = 86.8%) than the gas reservoired in the deeper Mungaroo C sand. All of these Exmouth Plateau gases have low concentrations of nitrogen (N_2 = 3.1%) and carbon dioxide (CO_2 = 1.2%).

Interestingly, although the Late Jurassic reservoir at Io/Jansz (Oxfordian Jansz sandstone) is in pressure communication with the Late Jurassic (Tithonian) reservoir and Brigadier Formation reservoir at Geryon (Jenkins et al 2003), the δ^{13}C CO_2 values differ, implying that the gases are not in chemical equilibrium.

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 2. The Geryon 1, Jansz 1, Maenad 1A, Orthrus 1 and Urania 1 gases have similarly shaped δ^{13}C isotopic profiles that show very little isotopic differentiation between ethane, propane and butane (figure 2a).

Such a flat isotopic profile in these wet gases is typical of a terrigenous gas source and may indicate either a different source for the wet gases and methane or a land-plant component to the marine Type II kerogen, as interpreted from the cross plot of δ^{13}C ethane versus δ^{13}C methane (figure 3).

The Urania 1 gas recovered from the Mungaroo C sand was generated at lower thermal maturity than the Geryon 1, Jansz 1, Maenad 1A and Orthrus 1 gases (figure 3), all of which were generated at vitrinite reflectances (Ro) between 1.3% and 1.5%.

Since the Maenad 1A, Orthrus 1 and Urania 1 gases are in reservoirs within the Mungaroo Formation, and offset from the main Mesozoic rift system, the most likely source of these gases is the regressive fluvial–deltaic Middle–Late Triassic sediments of the Mungaroo Formation.

The isotopic profile of the wet gases in the Jansz 1 sample is similar to those of the Geryon 1, Maenad 1A and Orthrus 1 gases (figure 2); however, both the carbon and hydrogen isotopes of methane in the Jansz 1 gas show a relative depletion of about –1.8‰ in δ^{13}C (–38.3‰) and –7.8‰ in δD (–164.8‰) that cannot be attributed to maturity differences.

This depletion is thought to be source-related, possibly indicating a second source of dry gas, rather than the result of biodegradation, since there is no isotopic enrichment of propane—the compound most susceptible to biodegradation.

Gorgon area

The gas accumulations from the Gorgon area (Gorgon, Central Gorgon, North Gorgon, Chrysaor and Dionysus) are primarily reservoired within the Mungaroo Formation.

These gases are slightly wetter (CGR = 9–12 bbls/MMscf) and contain higher carbon dioxide contents (CO_2 = 5.0–22.8%) than those on the adjacent Exmouth Plateau at Geryon, Io/Jansz, Maenad, Orthrus and Urania.

The Gorgon 3, North Gorgon 6 and Chrysaor 1 hydrocarbon gases display an almost linear δ^{13}C *n*-alkane profile (figure 2c).

Isotopically, the hydrocarbon gases from Dionysus 1 seem to be more similar to the gases from Maenad 1A and Jansz 1 (figure 2a, 2b) than to those from Chrysaor 1 and Gorgon 3 (figure 2c, 2d). However, the Dionysus 1 gas contains a high concentration (8.7 %) of isotopically enriched carbon dioxide (δ^{13}C CO_2 = –5.5 ‰) that is isotopically most similar to the gas from Chrysaor 1 (δ^{13}C CO_2 = –5.2 ‰). These data imply that the Dionysus gas accumulation has a different charge history from the adjacent gas accumulations and is derived from multiple sources.

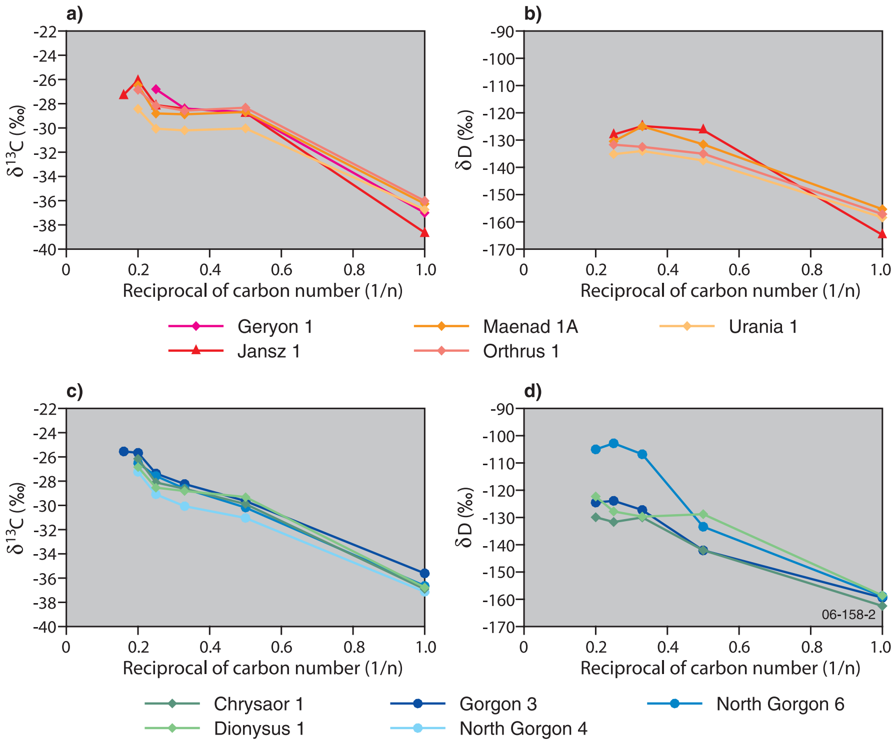

Figure 2. Carbon and hydrogen isotopic values for individual gas components from the Exmouth Plateau and Gorgon area, highlighting source differences.

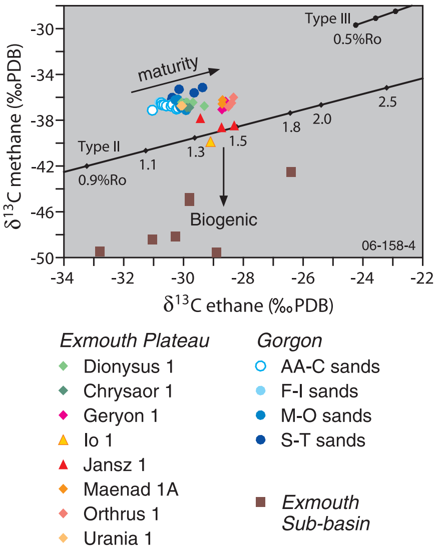

Figure 3. Plot of δ^{13}C ethane versus δ^{13}C methane showing kerogen type and maturity trends for the Exmouth Plateau and Rankin Platform gases, and the effect of biodegradation on gases from the Exmouth Sub-basin.

Biodegradation

Methane depleted in ^{13}C (range $\delta^{13}C$ = –41.5 to –48.4‰) is recorded in the gases from the Exmouth Sub-basin at Enfield 1, 3, Laverda 2 and Vincent 1 (figure 4).

As well as the addition of secondary biogenic methane to these accumulations, the remaining wet gases (propane in particular) show increasing enrichment in their $\delta^{13}C$ and δD values as a result of increasing levels of biodegradation. These accumulations show a range of gas wetness ($\%C_1/\%C_1–C_5$ = 96.5–99.9%) corresponding to the differing degrees of biodegradation.

Extremely dry gas is encountered at Scarborough 1 and 2 (mean 95.6 mol % methane; 0.1 mol % ethane; 4.3 mol % nitrogen; 0.04 mol % carbon dioxide). The $\delta^{13}C$ isotopic value of –42.3‰ for the Scarborough 1 gas, when compared with the biodegraded gases in the Exmouth Sub-basin (figure 4), indicates incorporation of isotopically light secondary biogenic methane into this accumulation.

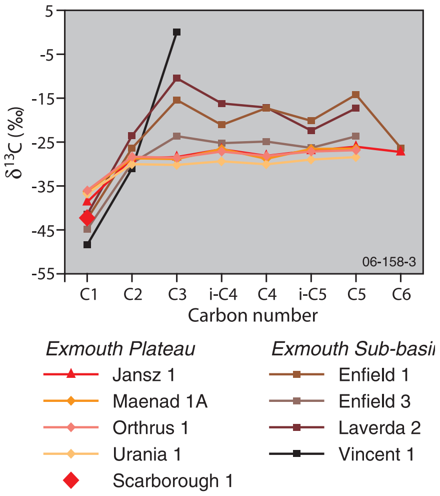

Figure 4. Carbon isotopic values for individual gas components from the Exmouth Sub-basin, emphasising the effects of biodegradation.

Summary

Molecular and isotopic data for natural gases in the Exmouth Plateau and Gorgon areas indicate several source provinces for the thermogenic hydrocarbon gases with carbon dioxide and nitrogen originating from both organic and inorganic sources.

Within the Exmouth Plateau gas accumulations, biodegradation is only apparent at Scarborough. However, biodegradation is widespread within the Exmouth Sub-basin accumulations, resulting in the overprinting of their isotopic signatures and destruction of source information.

Gas–source correlation studies are proposed to determine the origin and level of thermal maturity required for gas generation in offshore Australian basins, and to understand the factors that control gas wetness.

This article is based on a paper presented at the Combined National Conference of the Australian Organic Geochemists and the Natural Organic Matter Interest Group, Rottnest Island, Perth, WA, February 2006 (Edwards et al 2006).

Gas chromatography – stable isotope mass spectrometer used in hydrocarbon isotope analysis.

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