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Gas Systems of the Amadeus Basin, Australia

Authors : Chris J. Boreham, Dianne S. Edwards, Amber Jarrett, Justin Davies, Robert Poreda, Alex Sessions, John Eiler

Abstract : The origins of natural gases in the Amadeus Basin have been assessed using molecular and stable isotope (C, H, N, He) systematics. A dominant end-member thermogenic, oil-associated gas is considered for the Ordovician Pacoota−Stairway sandstones of the Mereenie gas and oil field. In addition, an abiogenic end-member is identified in the latest Proterozoic lower Arumbera Sandstone of the Dingo gasfield, being most likely associated with radiolysis of methane with polymerisation to wet gases. The latter source assignment is based on a similar geochemical fingerprint derived from the laboratory gamma irradiation experiments on methane. A mixed gas source is considered for the Palm Valley gasfield in the Ordovician Pacoota Sandstone. Gas wetness ($\%\sum C_2-C_5/\sum C_1-C_5$) decreases in the order Mereenie (19.1%) > Palm Valley (9.4%) > Dingo (4.1%). Non-produced gases at Magee-1 (23.5%; Late Proterozoic Heavitree Quartzite) and Mount Kitty-1 (18.9%; Paleo-Mesoproterozoic fractured granitoid basement) are very wet. Methane thermometry based on clumped isotopes of methane ($^{13}CDH_3$) is consistent with the abiogenic origin for the Dingo gas field with methane formation temperature of 254ºC. However, the low methane formation temperature of 57°C for the Mereenie gas suggests either a mixed thermogenic-biogenic methane source or there is no thermodynamic equilibrium between the methane isotopomers. The shallow reservoir depth and present-day formation temperature below 80ºC would support microbial methanogenesis, but there is no accompanying alteration of the C- and H-isotopes of the wet gases and CO_2 that is typically associated with biodegradation. The Amadeus Basin gases show low to extremely high inorganic gas contents. Carbon dioxide is low in abundance (< 1% CO_2) and becomes increasing depleted in ^{13}C from the Palm Valley (av. $\delta^{13}C$ 0‰) to the Mereenie (av. $\delta^{13}C$ -6.6‰) and Dingo (av. $\delta^{13}C$ -14.3‰) gas fields. Although the wide range in carbon isotopes for CO_2 is consistent with multiple origins from inorganic to organic inputs, the most likely process is fluid-rock alteration with enrichment in ^{12}C in the residual gaseous CO_2 accompanying progressive carbonate precipitation within the reservoir. Nitrogen ranges from low−moderate (1.7−9.9% N_2) abundance (Palm Valley av. 1.8%; Mereenie av. 9.1%; Dingo av. 9.4%) to extremely high abundance in Magee-1 (43.6%) and Mount Kitty-1 (61.0%). The nitrogen isotopes for the production gases have $\delta^{15}N$ = -3.0‰ for Mereenie, -3.0‰ for Palm Valley and -7.1‰ for Dingo, suggest all being mixed inorganic and thermogenic nitrogen sources. Helium (He) abundance varies over a wide range from a low of 0.17% to one of the world's highest at 9% (Mereenie av. 0.23%; Palm Valley av. 0.48%, Dingo av. 0.18%, Magee-1 6.2%; Mount Kitty-1 9.0%). Complementary helium isotopes (R/Ra = $^3He/^4He_{sample}$ / $^3He/^4He_{air}$) range from 0.013 to 0.031 R/Ra, indicating a dominant crustal origin for helium with a sustained input of radiogenic 4He from the decomposition of U- and Th-bearing minerals, effectively diluting any original mantle helium input. The high helium content in the non-produced gases compared to the shallower producing wells most likely reflects their stratigraphic position relative to the Tonian Bitter Springs Group with the former below and the latter above an effective carbonate-salt seal.

Keywords : amadeus gas, thermogenic, abiogenic, C, H, N, He isotopes
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