Insights from stable and noble gas isotopes on the evolution of coal-bed methane in Southeast Qinshui Basin, China

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The late Carboniferous-early Permian coal seams of the Qinshui Basin in Shanxi Province host the largest coalbed methane (CBM) resource in China. Methane formed in the late Triassic during deep burial and reheating in late Jurassic-early Cretaceous driven by magmatic underplating. Basin inversion brought the coal seams to 400-700 m from the surface in the mid-late Cenozoic.

Here we present results of a study aimed at understanding the origin of the methane, and how it was affected by Cenozoic exhumation of the basin. Methane from a 12 km traverse perpendicular to the basin margin in the southeast part of the basin have stable isotope compositions ($\delta^{13}C$ = -30.2 to -35.1 ‰, and δD = -155 to -194 ‰) indicating a thermogenic origin. $\delta^{13}C$ values are, however, ~8 ‰ lighter than expected based on coal maturity, and $C_1/(C_2+C_3)$ (>2000) are significantly higher than typical thermogenic methane (<50). This is due largely to diffusive fractionation during commercial gas extraction. He-Ne-Ar isotopes are a mixture of crustal-radiogenic gas with air-derived noble gases. ^4He concentrations (0.52 to 33.3 ppmv) and $^4He/^{40}Ar^*$ ratios (0.06-1.7) are unusually low. He-Ne-Ar concentrations are consistent with the open system Rayleigh fractionation of noble gases derived from air-saturated water with $^4He/^{40}Ar^*$ = 1 during gas extraction. The low $^4He/^{40}Ar^*$ implies that more than 95% of the radiogenic ^4He produced in the coals has been lost prior to equilibrium between gas and water phase in the reservoir. This likely occurred in response to gas loss during rapid exhumation in the Cenozoic. Methane contents of the SQB coal seams are high, though quantifying loss during the Cenozoic exhumation is difficult. We show that $^{40}Ar^*$ concentrations can be used to trace the methane retention.