Noble gas characteristics of the Carboniferous Rotliegend hydrocarbon system, NW Germany

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Noble gases are primarily introduced into hydrocarbon reservoirs through exchange with formation waters. The origin and subsequent migration history of noble gases can be identified by isotopic characteristics and relative elemental abundance ratios. By targeting air-derived noble gas isotopes, we can assess the extent of exchange between hydrocarbon phases and formation waters that have previously equilibrated with the atmosphere. The resulting elemental ratios are controlled by phase partitioning, which provide constraints on reservoir conditions (e.g., pressure, temperature and salinity) and gas to water volume ratios.

We present compositional and isotopic data for hydrocarbon and non-hydrocarbon compounds as well as noble gas isotope and abundance data from two distinct Rotliegend natural gas fields of NW Germany. These fields produce from the Permian Rotliegend sandstones and are sealed by the Zechstein salt. The hydrocarbons in this system are thought to be sourced from type III coals and carbonaceous shales of the Westphalian aged (Carboniferous) Coal Measures [1], with vitrinite reflectance between 1-3%.

Gases are composed of N_2 (8-15%) and hydrocarbons (83-92%), which are predominantly (~98%) methane. Helium isotopes ($^3He/^4He$) range from 0.042 to 0.084 R_A, suggesting a negligible mantle contribution, consistent with Ne isotope results. We observe systematically higher $^{20}Ne/^{36}Ar$, and lower $^{84}Kr/^{36}Ar$ and $^{132}Xe/^{36}Ar$ values relative to air saturated water ratios. These data cannot be explained by a simple Rayleigh degassing and closed-system mixing model, suggesting that samples have been modified by an additional process. Accordingly, we have developed a two-stage closed-system solubility-controlled degassing and re-dissolution model that is consistent with the entire data set. Using this approach we can estimate hydrocarbon-gas to water volume ratios in the Carboniferous-Rotliegend hydrocarbon system.

[1] Gautier, D.L. (2003) *USGS Bulletin* **2211**.