

Contribution of crustal and mantelic fluids on the functioning of petroleum systems

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The evidence of extra-sedimentary fluids contaminating the petroleum and gas systems once quite unique is today a more common occurrence in a large proportion of sedimentary basins, as exploratory targets occur in deeper and more complex tectonic areas (foreland basins, ultra-deep offshore, etc...). These fluids, coming either from the mantle or from the continental basement, induce important impacts on the thermal history of sedimentary basins, a higher risk for non-hydrocarbon gases (CO₂ and N₂), producible helium concentrations and the adjunction of abiotic hydrocarbon generation interfering with the more commonly studied hydrocarbon generation through the thermal cracking of organic matter.

Several geochemical tracers have been studied in the past several years in order to quantify the proportion of these allochthonous fluids. Stable isotopes, noble gas isotopes, and trace metal concentrations and isotopic ratios represent excellent proxies for the characterization of different sources of fluids, related to the metamorphic and granitic basement, and to the upper mantle hydrothermalism (associated either with volcanism and/or rifting). It is reasonable to assume that their percolation into the sedimentary piles induces a transient extra source of heat, able to increase the maturity range of the potential source rocks.

As the CO₂ risk in exploration occurs more often with deep drilling, the need to understand its formation and origin (organic, carbonate decomposition, mantle fluids) has become a serious challenge and studying with the help of the associated traces of noble gases is an avenue of possibility. An accurate quantification of these proportions is thus more feasible.

N₂ risk is generally associated with a gas flux coming out of the metamorphic and granitic basement below the sediments. Its proportion is correlated with helium concentrations, which may reach producible values, as the main source of helium comes from the radioactivity of the continental basements.

Purely abiotic methane has been shown only in relatively small amounts in hydrothermal vents on oceanic ridges, and in gas seeps associated with ophiolites and hyperalkaline springs. It is always associated with H₂, and sometimes CO. The $\delta^{13}\text{C}$ of CH₄ are always heavy isotopically and may reach values as high as +5 per mil. In petroleum systems associated with volcanism, evidences of hydrocarbon gas generation involving abiotic methane generation and Fisher-Tropsch polymerization has been assessed through $\delta^{13}\text{C}$ analyses. New data from recent case studies suggest that inorganic chemical reactions change the chemical and isotopic compositions of the accumulated hydrocarbons. The question of the proportion of abiotic extra amount of hydrocarbon may then be fully addressed, and it appears that with mass balance calculation combining noble gas isotopic ratios and hydrocarbons, it is possible to quantify the global proportion of extra-hydrocarbon generated through abiotic reactions.

In summary, petroleum systems should be viewed now as a sedimentary fluid system interacting physically and chemically with other compounds (CO₂, N₂, H₂, ...) updating the paradigm of oil and gas exploration in the new century.