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Episodic Migration of Natural Gases: A Worldwide Phenomenon of Dynamic Filling of Oil and Gas Reservoirs and Resulting Practical Applications in Exploration and Production

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Natural gases can be ubiquitously detected in the subsurface, either as traces in sediments or as accumulations in oil and gas reservoirs. Hydrocarbon gases form through bacterial and thermogenic conversion of organic matter over extended geological time. The higher molecular compounds in gases (ethane, propane, and butane or C_{2+} hydrocarbons) tend to be retained in the rock fabric during migration from source to reservoir (migration fractionation) so that natural gases become enriched in methane in the reservoir. Isotopic properties of methane and C_{2+} hydrocarbons are controlled by temperature dependent kinetic fractionation during maturation and by mixing during migration in reservoirs.

Gas fields are actively and repeatedly charged over extended periods of gas formation (episodic migration), during which gases change isotopically. Isotopic signatures of gases are, therefore, sensitive tracers for the filling histories of oil and gas fields and the dynamic processes that drive episodic migration of oils and gases, a ubiquitous phenomenon observed in small and giant gas fields throughout the world.

Gulf of Mexico: The Gulf of Mexico is a unique natural laboratory for the study of natural gas formation and migration. The dynamics of salt removal and formation of mini-basins with high sedimentation rates play together in the formation of bacterial and thermogenic gases. Pervasive mixing of bacterial and multiple episodes of thermogenic gas charging result in large variations in isotopic signatures on a field and reservoir scale. Bacterial gases form in mini basins and migrate against rising salt structures and active growth faults. Different episodes of thermogenic gas charging can be identified from C_{2+} isotope variations. Variations in isotopic signatures in one field often change from reservoir to reservoir as a result of different mixing ratios of bacterial and thermogenic gases.

Angola : Giant oil fields offshore Cabinda contain thermogenic gases with different isotopic signatures in the gas cap and the oil leg, indicating a multi-phased migration of thermogenic gases from mature to post-mature sources. The giant oil fields form in several migration episodes whereby late charges of deep post-mature gases displace oils.

Yacheng Gas Field: Gas composition and isotopic signatures of methane change from west to east in this giant field in the South China Sea. Inert gas contents also vary vertically in the reservoir, suggesting a late charge of a CO_2 rich gas into the structure.

These worldwide observations help us to appreciate in oil and gas migration what is a commonplace for hydrothermal systems, i.e. that sedimentary basins release fluids in a pulsating dynamic fashion, ever changing in composition and filling reservoirs with complex mixtures that reflect deep processes in the basin. With this insight into the dynamic nature of reservoir filling processes we will be able to use our geochemical data with more confidence.

Biographical Sketch

Martin Schoell received his Ph.D. at University of Clausthal/Germany in 1970 and obtained a lecturer degree (Habilitation) in 1983 at the University of Bochum in Germany. Martin worked for 13 years at the German Geological Survey and joined Chevron Petroleum Technology Company in 1984. He conducts research and regional studies in petroleum and natural gas geochemistry. He lectures extensively in Chevron on natural gas geochemistry and works with affiliate offices on large regional studies. He is editor of many special publications on natural gas geochemistry and has himself published more than 70 papers on petroleum geochemistry. Martin just completed the 1996/97 AAPG Distinguished Lecture series with presentations at 16 universities and societies in the U.S. and Canada. ■