The Vertical Migration Model in Geochemical Exploration

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Abstract

Petroleum geochemical exploration is the science of using geochemical measurements to assess information about petroleum reservoirs before drilling. Vertical migration provides a valuable geochemical communication link between subsurface reservoirs and the surface. Vertical migration is the foundation of petroleum geochemical exploration.

Geochemical exploration techniques began about 85 years ago in Russia and about 10 years later in the USA. Horvitz, 1939, described measurement of petroleum gases in shallow soil samples in Harris, Brazoria, and Galveston Counties, Texas. Since that time geochemical exploration methods have proven successful both onshore and offshore.

Although surface expressions of vertical migration were known and documented throughout the last 75 years, the mechanisms by which hydrocarbons could move from reservoirs to the surface were not known (Horvitz, 1978). Diffusion and other vertical migration models could not explain the surface hydrocarbon expressions nor could they explain why migration was primarily vertical.

About 20 years ago the industry developed a buoyancy mechanism modeled by Klusman and Saeed, 1996, (formerly Colorado School of Mines). Below the water table gases migrate vertically as a gas phase with buoyancy providing a mechanism for predominately vertical migration. The buoyancy model explained the gradients and data contrasts observed in many surface geochemical features. Arp, 1992, (formerly ARCO) quantified the buoyancy driven migration mechanism in a form that calculated vertical migration rates. Vertical migration rates predicted by the model were verified by field measurements. The buoyancy model explained most geochemical exploration gas data.

Brooks, et al, 1986, reported sampling liquid hydrocarbons offshore was most successful over the surface expressions of seismically determined faults. Faults were conduits for petroleum to travel from reservoir depths to ocean bottom sediments in visible quantities (macroseeps).

A seismic/geochem integration project reported by Belt and Rice, 1996, in the Main Pass area, shallow offshore Louisiana, was instrumental in understanding the vertical migration mechanisms. Gases migrated up faults and also between faults. Most of the gas migration was through fractures too small to be visible on the seismic section. Petroleum liquids, even in invisible quantities (microseeps), appeared to migrate up faults. When we extended the vertical migration model to include petroleum liquids, we found that liquid hydrocarbons could migrate vertically due to buoyancy similar to gases but slower and through larger fractures and faults.

Petroleum gas surface expressions map reservoir areal size and shape. Petroleum liquids map surface expressions of faults and fractures and indicate reservoir composition. A geochemical exploration program significantly enhances reservoir information by taking advantage of natural reservoir communication with the surface.