Geochemical Exploration for Conventional and Unconventional Petroleum Resources

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Micro- and macro-hydrocarbon seeps have been detected over offshore and onshore oil and gas reservoirs since the 1930's. The seeps were defined by anomalous hydrocarbon concentrations and compositions in ocean bottom sediment cores and onshore soil, shot-hole sediment, soil gas and groundwater samples. While the mapping the spatial distribution of hydrocarbon seeps is important, it is also important to identify the source of the seeps from both exploration and environmental standpoints. In some cases, the seeps can be linked to subsurface sources through the use of carbon and deuterium isotopic ratios of light hydrocarbons. Crude oil macroseeps can also be linked to reservoirs and source rocks using biomarkers, which are high molecular weight (>C20+) fossils of the organic matter from which the oil was formed. In many cases, however, only trace amounts of hydrocarbons (i.e. invisible microseeps) are detected in various surface sampling media. In such cases, insufficient hydrocarbon concentrations preclude the use of isotopes and biomarkers as compositional links to subsurface sources (e.g. reservoirs, source rocks, etc.). In addition, biodegradation of the hydrocarbons in near surface media may further obliterate any possible connection of the microseeps to their source.

In some cases, crude oil microseeps can be directly linked with reservoir fluids using Synchronous Scanned Fluorescence (SSF) analysis of surface media (e.g. soils, shot-hole sediments, lake sediments), which can detect as little as 1 part per million crude oil. The analysis involves dissolution of crude oil in soil or sediment samples with an organic solvent and analysis of the extract in a spectrophotometer for aromatic (ring-type) hydrocarbons in the C6 to C24 range. The aromatic fraction of crude oil is less susceptible to biodegradation than the straight-chain alkanes. Live oil microseeps at surface can therefore be compositionally linked to their source by matching their aromatic compositions with reservoir oil. An example will be given from the Michigan Basin where crude oil microseeps are compositionally similar to produced oil and drilling on the microseeps resulted in commercial oil discoveries.

In very leaky basins, oil-field brine fluids can ascend faults to surface resulting in unique halide and metal anomalies in soils and groundwater above petroleum reservoirs. A case study from Nevada will be shown where alkali and alkaline-earth metal anomalies in soils can be compositionally linked to leaking oil-field brines.

Oil & gas reservoirs can contain appreciable concentrations of helium, which is swept into the reservoir and trapped by overlying salt or shale seals. Helium, which is an inert labile gas, can be detected in soil gas and serve as a valuable inorganic link to underlying petroleum accumulations. The use of helium as a link to petroleum reservoirs will be demonstrated in a soil gas survey over a helium-rich (>3%) petroleum reservoir in southeast Colorado.

Passive gas collectors are also effective for the detection of trace amounts of hydrocarbons above oil & gas reservoirs. The AGI passive sample module is capable of detecting trace levels (i.e. nanograms) of 86 volatile and semi-volatile organic compounds in the C2 to C20 range that are relevant to petroleum exploration. Statistical pattern recognition techniques are used to make predictions about the hydrocarbon potential of geological and geophysical petroleum targets. A case study from the Red Sea area will be presented to show how this technique correctly predicted the discovery of an 800 BO/D well under 2,500 meters of interbedded salt and shale cover.

Although it is not possible to always link surface seeps with their source, particularly in the case of multiple pay zones, soil gas surveys can be used to determine whether an exploration play is more likely to produce oil or gas. More specifically, the magnitude of light hydrocarbon ratios (e.g. C1/C2) in soil gas can predict whether a particular basin is oil or gas prone. Examples will be given from soil gas surveys in Mongolia and Colorado to show how predictions of reservoir fluids can be made from these light hydrocarbon ratios. Prediction of reservoir fluid composition is very important in remote areas (i.e. Mongolia) where oil is the preferred pay because of the lack of infrastructure to treat and transport gas.

Unconventional shale oil and gas plays have become economic with more efficient horizontal drilling and fracking techniques in recent years. In these plays, geochemical applications mainly involve assessment of the shale reservoir itself to determine its moveable oil and gas content for reserve calculations and its brittleness based on mineralogy determinations for fracturing predictions. Environmental geochemical applications also play an important role in monitoring the quality of shallow groundwater aquifers before and after fracking campaigns. The application of surface geochemical techniques to the exploration and development of unconventional reservoirs has not been fully evaluated, but two case studies will be presented to show the potential of surface geochemical methods for predicting overpressure and structural anomalies in unconventional petroleum reservoirs in Wyoming and Saskatchewan respectively.