An Innovative Soil Geochemical Tool for Focused Hydrocarbon Exploration and Regional or Local Prospectivity

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The trace element content of petroleum, natural gas, associated brines, coal and their host rocks has been established using sophisticated analytical procedures by hydrocarbon explorers/producers and the academic community. These trace element contents or “fingerprints” can be used to differentiate and characterize hydrocarbon geological environments globally. In effect, hydrocarbon reservoirs represent “metal-sources” comprising variable amounts of trace elements and compounds. This suite of trace elements can also be used to define exploration targets by measuring their concentrations in near-surface soils subsequent to a new and innovative approach to geochemical exploration. This technique is referred to as Mobile Metal Ions Process Technology or “MMI”.

Mobile Metal Ions are ions that have moved from buried metal-source to near-surface environments where they become weakly or loosely attached to the surface of soil particles. These are the ions that are measured by the MMI geochemical technique to target metal-sources at depth. The weakly attached ions are at very low concentrations in soil however because the ions have recently arrived at the surface they provide a precise ‘signal’ on where the sources of metal are located. When the mobile metal ions arrive in the near-surface environment they have a limited lifetime as ‘mobile’ ions. At the surface the ions are subject to weathering and are mantled or incorporated by crystalline Fe and Mn oxides formed during soil forming processes (i.e. they become part of the soil during pedogenesis). Bound ions are subject to lateral movement away from the mineralization. The mobile ions, however, do not move away from the metal source because they have a limited lifetime before they are converted to a bound form.

By measuring Mobile Metal Ions and related metals and compounds in surface soils, the technology can document the presence of focused apical responses directly over the metal sources. This source may be any accumulation of metals or compounds that are in contrast with surrounding rocks such as oil, gas and coal. Chemical analysis of petroleum has documented characteristic trace elements within the oil and its surrounding host rocks. These trace elements will move to surface and be indicative of a buried hydrocarbon accumulation. Regardless of the type of “metal-enriched zone” at depth, metal ions that comprise that zone will be released to the surface. A schematic representation of element movement, resultant mineralogical changes in rocks overlying the source region (after Schumacher, 1996) and measurement using the MMI process is presented in Figure 1.

Vertical Migration of Metals

The phenomena of vertical migration of metals and related compounds from source to surface has been examined closely for many years in and around oil and gas reservoirs, base and precious metal mineral deposits and unique lithologies such as kimberlite and carbonatite. Metal ions migrate to the surface under the influence of a variety of mechanisms including vapor phase transport (light hydrocarbon gases, Hg-vapor, carbon dioxide), electrochemical, evaporation and evapo-transpiration, convection and simple diffusion. The relative importance of each of these mechanisms can be variable depending on the nature of the source region, presence of “plumbing systems” to channel metal-rich gases, depth to water table and numerous other variables. However, research and case studies over known metal-bearing zones have shown that mobile metal ions and additional compounds accumulate in surface soils above these metal sources. Hydrocarbons present in the subsurface “leak” from their structural and stratigraphic traps and move upward to the surface along geological pathways. Hydrocarbon micro-seepage has been documented at less than 1 metre per day to tens of metres per day and is evidence for a dynamic geochemical system at work. Zoned mineralogical and geochemical “haloes” have been documented in plumes above oil and gas reservoirs (*cf.* Figure 1) for some time. Surficial geochemical exploration has a long and varied history in its application to the search for petroleum. Much of this exploration has been directed towards the surface or near-surface occurrences of hydrocarbons. The hydrocarbons may present themselves as surface seeps of visible oil and gas (“macro-seeps”) or as traces of hydrocarbons determined by sophisticated analytical methods (“micro-seeps”). Much of the geochemical exploration currently undertaken focuses on the collection and analysis of soil gases and the integration of the chemical expression of hydrocarbon micro-seepage with geological and geophysical (seismic) databases. Currently, and well into the foreseeable future, the seismic approach will likely be unsurpassed for the definition of oil and gas reservoirs. MMI technology can identify and quantify metals associated with hydrocarbon micro-seepage and differentiate between “productive” and “non-productive” reservoirs that are presented as seismic targets.

Sampling and Analytical Protocols

A recently developed multi-element ligand-based partial extraction for soil sample analysis utilizes inductively coupled mass spectrometry (ICP-MS) to determine 45 elements at part per billion and sub-part per billion concentrations. These elements are recognized as constituents of hydrocarbons and associated “alteration/mineralogical haloes”. Additional pathfinder elements and parameters are included in the analytical suite utilized for exploration and these act as adjuncts to the MMI technology. Extensive research in Australia and North America and application worldwide has identified the specific location in the overburden profile where soil samples must be collected. Combined with proprietary sampling and analytical approaches, the interpretive strategies applied to analytical results provide a rapid and cost-effective approach to geochemical exploration for hydrocarbons.

Conclusion

Mobile Metal Ions technology can be used to differentiate the geochemical signature of buried and blind productive sources of hydrocarbons including their alteration haloes or distinctive geochemical "fingerprint" from barren reservoirs. The geochemical response related to any hydrocarbon signature is referred to as the *Hydrocarbon Discovery Index* or *"HDI".* The HDI can be used to re-assess active fields for extensions of known resources or to delineate by-passed resources of oil and gas in "exhausted" oilfields. It can also be utilized to evaluate seismic targets for their prospectivity or pioneer areas for the presence of oil and gas potential.

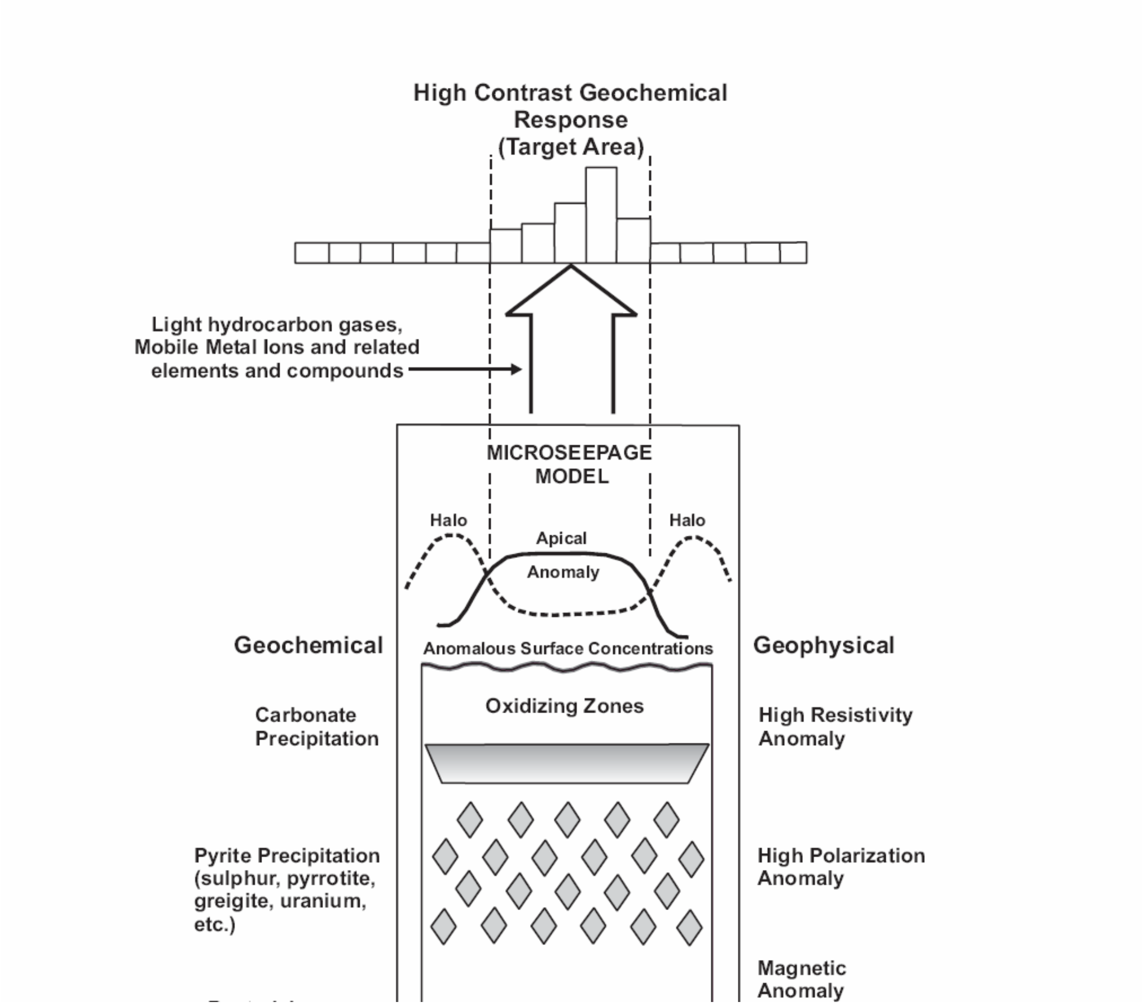

Figure 1. Vertical migration of elements and compounds, mineralogical haloes and geophysical responses over a hydrocarbon reservoir (modified after Schumacher, 1996).

References

Schumacher, D. 1996, Hydrocarbon-induced alteration of soils and sediments, in D. Schumacher and M.A. Abrams, Eds. Hydrocarbon Migration and Its Near-Surface Expression: AAPG Memoir 66, p. 71-89.