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"Near-Surface Hydrocarbon Migration: Mechanisms and Seepage Rates"

# The Surface Expression of Light Hydrocarbon Gas Seeps in Areas of Tilted Bedrock with Examples from the San Juan Basin, Colorado, USA; Implications for Near Surface Exploration Methods.

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Near-surface exploration methods that use soil gas geochemistry for oil and gas exploration presume that seepage occurs relatively vertical. While this phenomenon has been well documented, seeps have also been documented along low angle faulting and steeply dipping outcrops. Faults and bedding planes in complex structural regions can direct gas seepage to surface areas that do not lie vertically above the trapped hydrocarbon reservoir. This creates the potential for "false" anomaly detection, that is, anomalies not associated with vertical migration but interpreted as such. In addition, the surface manifestations of these seeps can have drastically different patterns in the same area at the surface due to differing surface geology and hydrology patterns in adjacent areas. A seep coming from the same formation can be expressed as a very narrow-spotty pattern or a broad diffuse pattern depending on whether the leaking formation outcrops or subcrops, how deep it is to ground water, or the type of valley fill sediments. It is vital to appreciate this fact since a broad pattern would allow for wider sample spacing, but a very narrow pattern requires tighter sample spacing to locate the seep and characterize its distribution. Hydrocarbons can also seep from active source areas or, in the case of coal bed methane, gases can be released when the hydrostatic equilibrium is disturbed, creating other types of "false" anomalies.

In 1995 and 1996, extensive soil gas surveys were conducted to identify and characterize gas seeps along the northern rim of the San Juan Basin in La Plata County, Colorado. The studies were funded by gas producing companies and local government agencies because of the concern about natural gas seeps in residential areas and increased coal bed methane (DBM) development in the region. The majority of the gas seep have been located in the outcrop of the Cretaceous Fruitland Formation, a major CBM producer in the basin. Less extensive gas seeps have also been identified leaking from other formations including the stratigraphically deeper Cretaceous Mesaverde and Lewis Shale Formations. Seeps from these other formations exhibited similar surface patterns, but had different gas compositions.

More than 25 miles of the Fruitland were surveyed revealing strong seeps (above hazardous levels) along 7 miles of the outcrop. Historical seeps had been previously identified (bubbles in creeks and ponds) in these areas, but their extent in the more remote and rugged terrain was not known. Other gas seep and dissolved gas studies have been conducted in conjunction with hydrogeology and reservoir modeling in this area and are reviewed in this paper.

Survey techniques included the use of portable gas detection equipment to measure total hydrocarbons, oxygen and hydrogen sulfide in the field. Visible vegetation stress was also recorded. Soil gas samples were collected at the soil/air interface and from shallow subsurface soil probes. Selected subsurface soil gas samples were collected and analyzed by FID-GC for hydrocarbon composition and by GC-IRMS for both carbon and deuterium isotopes. The concentration at the soil-air interface could approximately predict the subsurface gas concentrations in most cases. Soil gas composition combined with isotope analysis helps identify the source of the gas, and whether or not it has been altered during migration.

The gas seeps lined up parallel to the strike of the formation outcrop or subcrop indicating that most of the gas was migrating up formation bedding planes. The shape, intensity and pattern of the gas seeps vary significantly depending on the surface geology (Figure 1). Narrow, spotty seep patterns with sharp boundaries are found in areas where the formation sub-cropped under stream valleys with fine grain alluvial material. Broad, more diffuse patterns are found where the seeps crossed areas with deeper groundwater and dry outcrop or colluvial cover. It is apparent that where groundwater is shallow, gas bubbles migrate up the bedding plane in narrow patterns up to the subcrop, and then vertically in the fine grain saturated alluvium. When the top of the water table is breached, there is a very short distance to the surface, so the gas cannot diffuse into a wide pattern. In the outcrop areas, where ground water is deeper and the vadose zone is thicker, the patterns are more diffuse and broad. Diffusive mechanisms take over above the ground water table and the gas spreads over a broader area as it migrates through the dry bedrock and colluviums.

The implication of these effects is two fold in terms of near-surface geochemical exploration. The assumption has been that seep anomalies are generally broad features detectable with wide sample spacing. In areas with deep ground water tables, this is probably the case. However, in areas with very shallow ground water, narrow patchy anomalies may occur. Sample spacing would need to be tightened in order to detect these patterns. The other implication is that false anomalies can occur due to gas migrating laterally long distances along bedding plains. These gases may be similar to vertically migrated hydrocarbons, or may have been altered due to their different migration pathway. A broad diffuse pattern would more likely be interpreted as a vertically migrated micro-seepage phenomenon. The narrow sharp seep patterns seen in these surveys would have easily been missed in most exploration type projects with typical sample spacing. They would form sharp one-point anomalies, and there probably wouldn't be enough sample points to identify the associated linear feature such as a fault or bedding strike.

These patterns were seen as a result of macro-seepage as opposed to micro-seepage. Since micro-seepage mechanisms are not well understood, these affects may or may not apply to the patterns caused by micro-seepage. If the seepage is vertical, but along limited fault or fracture planes, similar patterns may appear. If seepage is along numerous and dense microfractures, these affects may not be seen. However, in structurally complex areas, anomalous macro-seepage patterns following low angle bedding or faulting will easily distract attention from weaker patterns formed from micro-seepage and could be incorrectly interpreted as vertical seepage.

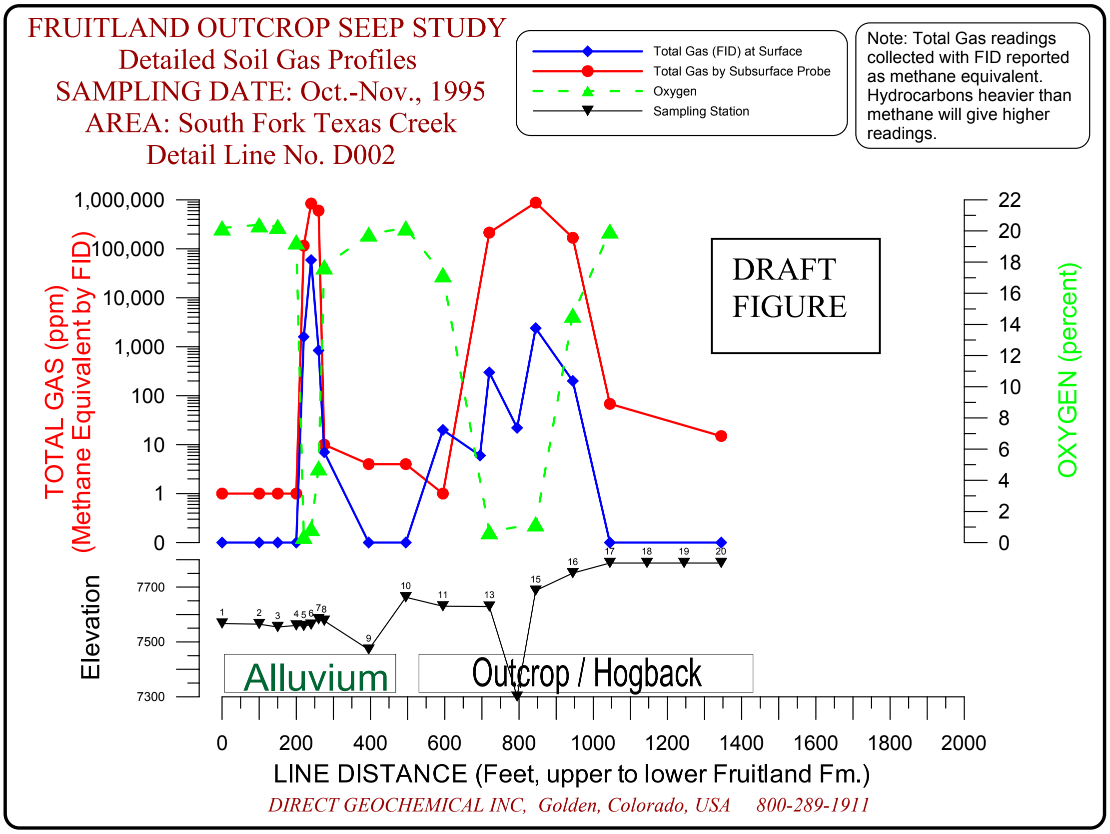


**Figure 1. Soil gas profile over Fruitland Formation outcrop showing narrow seep features in alluvial valley area and broader seep feature in higher elevation outcrop area. Note areas of low oxygen where soils are saturated with hydrocarbons.**