

# ***DIRECT GEOCHEMICAL***

## **INTERPRETATION OF GEOCHEMICAL DATA**

### **INTRODUCTION**

This document describes Direct Geochemical's strategies for interpretation of geochemical data. This includes conventional hydrocarbon (C1-C6) data, Synchronous Scanning Fluorescence data, Heavy Hydrocarbon (C6-C18) data (when appropriate), trace element data, including iodine, and oxidation/reduction conditions (O<sub>2</sub>/CO<sub>2</sub>, ferric/ferrous, etc.). The data can be used as somewhat independent data sets or can be fully integrated into a single data set.

Two independent methods are used to interpret geochemical data:

- Quantitative
- Compositional

### **Quantitative Interpretation**

The absolute concentration of individual or groups of hydrocarbons is often directly related to the subsurface accumulation of hydrocarbons, especially in simply stratified environments. Ratios of hydrocarbons provide additional information on source types. These include wetness and dryness ratios, plus hydrocarbon ratios that indicate whether the samples are in the oil, gas, or background window. Ratios, as well as raw data, can be mapped directly. Most regions exhibit "apical" anomalies, but "halos" are not unknown. Multiple productive horizons, presence of intense fracturing or faulting, and other factors can make interpretation difficult and are the cause of both false positive and negative anomalies.

### **Compositional Interpretation**

The composition of soil gas can reflect the character of subsurface accumulations. It is important to identify and correlate the numerous near-surface compounds with their sources—particularly petroleum accumulations. Many compounds, including methane and ethane (plus such obvious ones as ethene and propene), have vegetative or biogenic origins. It is vital to separate the petroleum related compounds from the others. In addition, different accumulations yield different near-surface compositional signatures, which can be used to determine if the accumulation is in the oil or gas range.

### **Statistical Methods**

Two primary statistical methods are generally applied to compositionally evaluate geochemical data:

- Principal Component (Factor) Analysis.
- Discriminant Analysis.

Both Factor and Discriminant Analysis are multivariate statistical tools that allow the evaluation of large numbers of data variables simultaneously. The use of these multivariate tools permits the user

to appreciate the existence of complex factors, comprised of multiple individual variables in the data set. In oil and gas exploration, this is important because the presence of oil or gas in the subsurface is rarely imaged by one or two variables.

The basic statistical method summarizes the data set in a series of mathematical “vectors” or “factors,” which are combinations of co-varying hydrocarbon species. The Factors (when combined together) account for all of the variation in the dataset, but in fewer variables than are in the data set. For example, there may be 15 variables measured in a dataset, but there may be only 5 Factors of significance.

Factor Analysis identifies and ranks these factors in descending order of the amount of variance in the dataset that is accounted for. Factor 1 accounts for the most variance, Factor 2 the second greatest, and so on. For each Factor, it is possible to identify the mixture of variables (components) and their relative importance. An examination of the chemistry of each Factor may allow for the identification of the **source** (or cause or origin) of the mixture in the Factor.

It is very common for Factor Analysis to result in at least one Factor reflecting a mixture of light hydrocarbons (that can be related to “gas,” and at least one reflecting a mixture of heavy hydrocarbons (that can be related to “oil,” depending on the basin and environment. The other factors can be related to environmental characteristics, soil changes, or contamination, or sampling and laboratory procedural noise. Each Factor represents a group of correlated hydrocarbon components.

Correlated components are important, because they describe compounds that vary together, meaning they relate to one another genetically, and belong together. As a result, they are probably **sourced** together. Thus, a Factor can allow the user to describe the spatial and chemical relationship of surface chemistry with subsurface chemistry.

Discriminant Analysis is a form of pattern recognition and matching, in which statistically significant groups of samples are used as “models” of known geologic conditions, and then compared against grid or unknown samples. The method calculates the probability of an unknown sample being like the model composition for a given geologic condition. This method is usable under two circumstances:

- There is a sufficient number of model samples to generate a representative or statistically significant population
- The quality of the model area is appropriate

The objective of modeling is to identify two key phenomena for each known geologic condition (e.g., an oil or gas field). The first is to identify the chemical signature, which is most diagnostic of the geochemistry over oil (or gas) production. The second is to identify the **range** of chemical signature that is representative of that oil or gas production. To do so requires a potentially large number of samples, with experience showing that at least 20-25 samples per class of geologic condition being the minimum. If, however, reservoir, soil, or other conditions are variable, then a larger number of samples may be needed.

Once the statistical analysis is performed, whether using Factor Analysis or Discriminant Analysis, it is essential to evaluate the results in terms of both geology and chemistry. Both the Factor and Discriminant analyses of petroleum related geochemistry surveys reveal a compositional relationship among a number of co-varying hydrocarbon components. It is this group of components and their relative abundances that must make chemical sense when used to map a geologic phenomenon to be considered valid.

The notion that a Factor relates surface geochemistry to a subsurface accumulation is critical to its use in exploration. It is necessary to be able to relate the composition of a Factor to the chemistry of a subsurface accumulation in each basin. Figure 1 illustrates the principle that there is a meaningful chemical relationship between surface geochemistry and source by showing 4 different Factors and four known accumulations in different regions. Here, for example, is the Factor 2 (Oil Factor) at Grant Canyon, representing a nearly gas-free oil (virtually no contribution from C1-C3). Contrast that with the Trenton-Black River gas accumulation in New York: an oil-free region, whose Gas Factor exhibits virtually no contribution from the C5+ hydrocarbons. The other examples are both from the Powder River basin, where it was necessary to separate the “gas” factor of coal bed methane from the oil rich environment and then to separate the “oil” factor of Tensleep Fm production (underlying major coal seams) from the mix. Figure 2 shows the Factor spectrum for Blackburn.

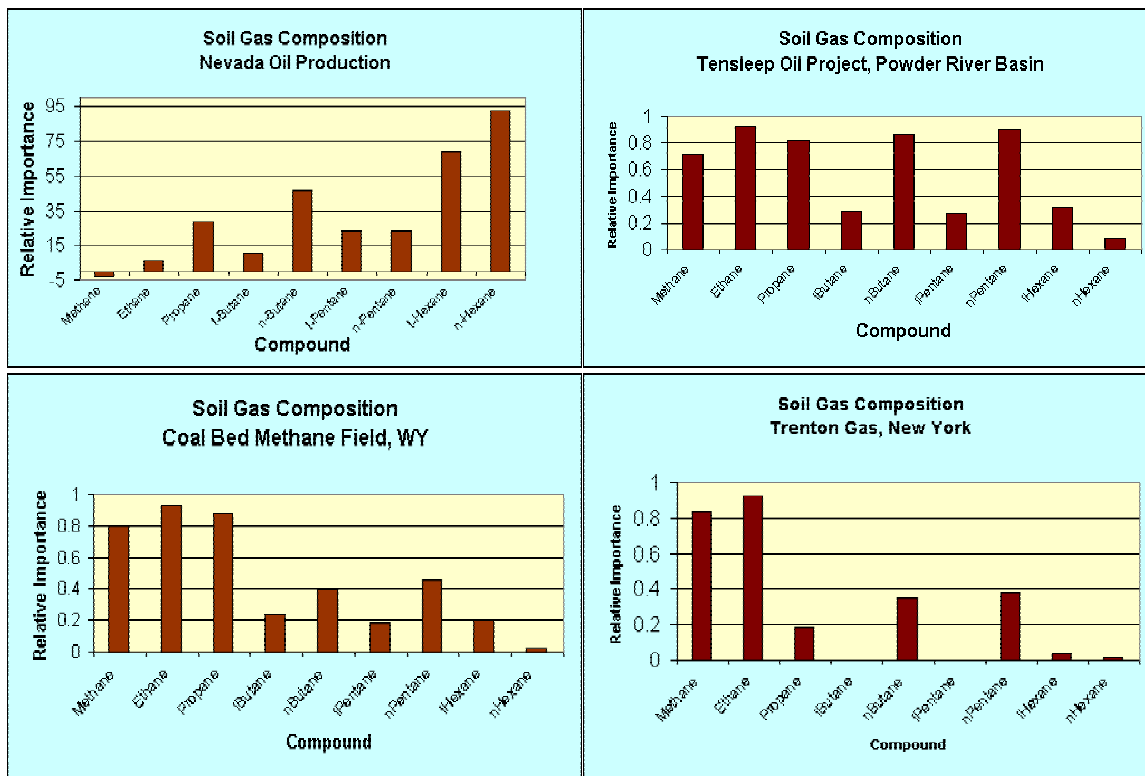


Figure 1: Factor Spectra from Various Basins and Targets Hydrocarbons

Equally important is the evaluation of compounds that are potential sources of false anomalies. The presence and high significance of biologically sourced compounds in the anomalous signature requires either re-modeling or explanation. For example, if terpene (pinene, limonene, caryophyllene, etc.), alcohols, ketones or aldehydes appear as “anomalous” components, they must be explained. None are direct indicators of oil or gas. The same is true of anomalously high molecular weight components associated with gas or condensate production.

## **COMBINING QUANTITATIVE AND COMPOSITIONAL DATA**

The application of both quantitative and compositional data as described above should be done together. Most projects benefit by integrating the two data evaluations, and further integrating the geochemical data with other (geologic, well control, paleogeomorphic, Landsat, remote sensing, seismic, etc.) information.

In context, quantitative data can reveal information about at least three issues:

1. Charge
2. Structure
3. Fluid migration

When a gas or oil compositional character is defined, the next step is to determine if there appears to be an actual accumulation. Quantitative data can be very instrumental in determining if a structure or trap is charged with hydrocarbons. The quantitation can be oriented specifically toward the types of components diagnostic of the targeted fluid type.

Quantitative data can also be useful in determining some structural qualities, particularly the existence and trend of faulting and fracturing. In many cases, tightly spaced geochemical data allow the mapping of faults and fractures and can allow inference of trap edges.

Within prospective traps—inside the geochemical anomalies—it is often possible to track fluid migration trends by examining the changes in chemistry or variation in anomalous signature or changes in oxidation/reduction characteristics.

The combination of quantitative information with compositional aids significantly in the understanding both of the present position of hydrocarbons and the processes that generated the geochemical signature.