

OILS HAVE THE ANSWERS – DEFINING PETROLEUM SYSTEMS USING GEOCHEMISTRY

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The answers to key issues facing exploration companies acquiring new concessions or assessing charge risk for a lead or prospect can often be found in the geochemistry of oils. Subsurface samples of the effective source rocks are difficult to obtain because they are typically located much deeper than drilling targets. However, because oils are the compositional derivatives of their source(s), they carry important information about the character and thermal history of the source rocks which would otherwise be unattainable. Today, oil geochemistry is a fundamental component of successful exploration programs in mature or in frontier areas. It is an excellent way of identifying and delineating petroleum systems present in a region (Schiefelbein and Requejo, 2002).

For a prospect to be charged with economic quantities of oil and gas, a series of essential elements and processes must occur in space and time, which collectively are referred to as a *petroleum system* (Demaison and Huizinga, 1991; Magoon and Dow, 1994). These include the existence of source, reservoir, seal and overburden as well as hydrocarbon generation-migration-accumulation along with trap formation (Figure 1).

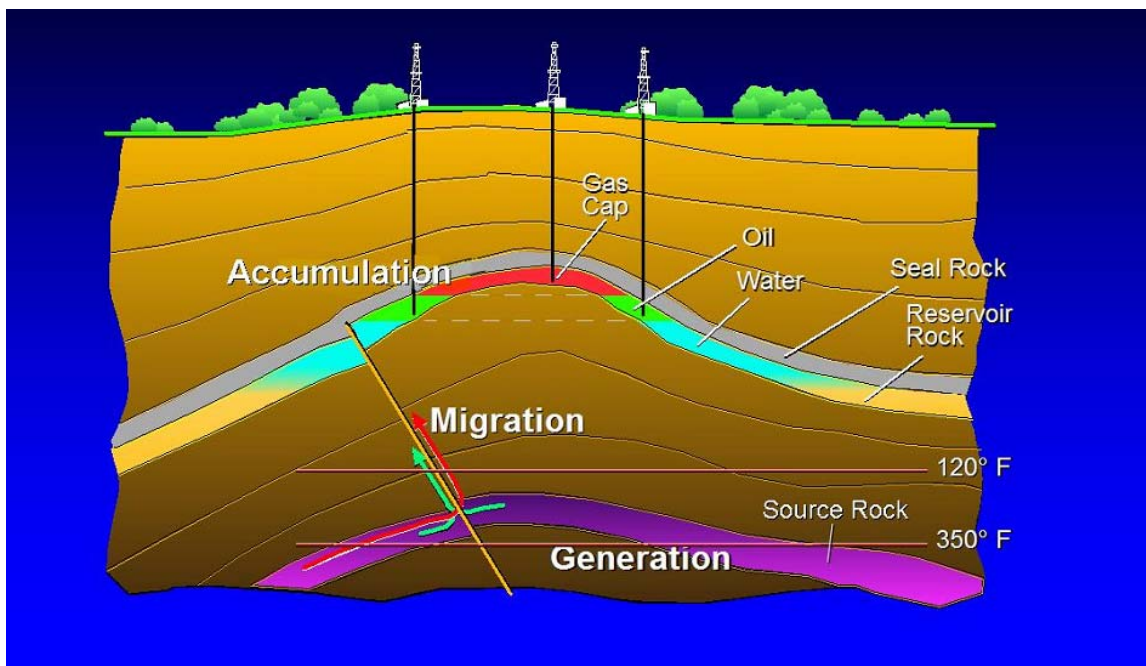


Figure 1. Petroleum System Elements and Processes.

In areas where a petroleum system is already indicated by known oil and gas fields, charge risk is diminished. Still, to ensure that a prospect is not located in a high-risk sector of the basin or in a migration “shadow”, pre-drill charge assessment using a combination of geochemistry and petroleum systems assessment is a cost-effective technical approach.



A regional oil study approach is particularly useful because the accumulated hydrocarbons are representative of the “volumetric average” of a given source rock section, which can exhibit extreme variations in its geochemical characteristics (Moldowan, *et al.*, 1992; Katz, *et al.*, 1997). The value of information obtained from the detailed analysis of a large suite of representative oils increases when integrated within a meaningful geologic framework — including an understanding of the regional stratigraphy, structural fabric and evolution of structural elements. By understanding these relationships, factors that influence and control the various elements that contribute to active petroleum systems can be identified, thereby reducing exploration risk.

The regional petroleum systems within a specific study area can be evaluated by first determining the number of effective source units within a region by establishing the number of compositionally distinct oil families. This can be achieved through the use of multivariate statistical techniques such as principal component and hierarchical cluster analysis (Zumberge, 1987; Schiefelbein, *et al.*, 1997). The chemical attributes of these oil families, such as the distribution of biological markers which serve as fingerprints in much the same manner as DNA, can also be used to determine the stratigraphic and aerial distribution of the source(s), source age, lithology, organic input, thermal maturity and depositional environment. In addition, the extent of the petroleum system can be approximated because their limits are defined by the limits of secondary migration. Areas with overlapping petroleum systems can be identified in relation to possible oil mixing from two or more sources (Schiefelbein, *et al.*, 1996). Processes active in a basin that act to modify the original oil composition can also be assessed. Because oil properties (quality) often determine the economics of exploration on a prospect-by-prospect and/or basin-wide scale, it is imperative to understand controls on oil property and predict them prior to obtaining acreage or drilling.

One example of applied petroleum geochemistry is a project undertaken for PeruPetro S.A. by a consortium of companies and funded by a Technical Assistance grant from the U.S. Trade Development Agency (USTDA). The project is designed to develop information tools to help PeruPetro S.A. and the private sector identify unexplored areas in Peru that represent the most promising prospects for investment. It requires collection, consolidation and quality control of all geochemical data from PERUPETRO into a standardized and accessible database. A second aspect of the project calls for the creation of maps based on a collection and review of diverse geologic data to define petroleum systems in the eighteen (18) hydrocarbon-bearing sedimentary basins located in Peru. By defining the location of petroleum systems, the risk involved in identifying the most promising areas of commercial interest is reduced.

The Houston based companies conducting this project have extensive expertise in petroleum systems evaluation (**Geochemical Solutions International, Inc.**), data management and software development (**Infologic**) and geochemical analyses (**Baseline Resolution, Inc.**). The dataset includes geochemical data from more than 10,000 samples (see Figure 2 for locations) and 50+ gigabytes of structured and unstructured information from regional studies, operator data reports, open literature and other sources.



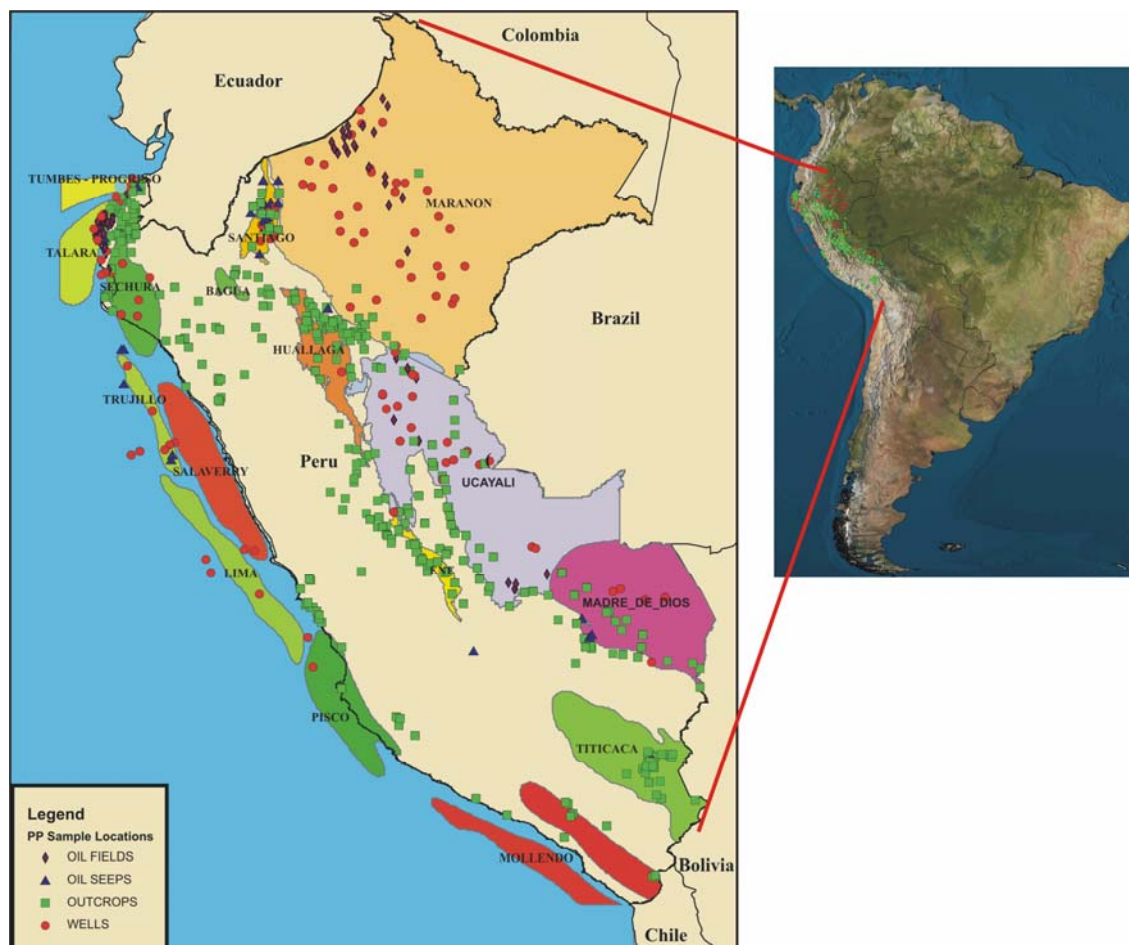


Figure 2. Location of Peruvian crude oil (red), outcrop (green) and seep (blue) samples for which geochemical data are available.

When this approach is used on a country-scale, the number of compositionally distinct oil types or families found throughout Peru can be identified. These data can be further statistically analyzed or ‘tortured’ to objectively answer questions like: ‘What are the geographic limits to Cenozoic, Mesozoic and/or Paleozoic oil types?’ When applied on a basin-scale, other questions such as, ‘How many different oil types are present in the Ucayali Basin and where do they overlap?’ can be addressed. By comparing and contrasting detailed information from potential source rocks, source-to-oil correlations can be established and new plays identified.

Example outputs of the statistical analyses of data from approximately 250 oils from Peru (performed using Pirouette from Infometrix©) are a cluster analysis dendrogram and principal component loadings and scores plots shown in Figures 3 and 4, respectively. Oils that cluster together in the dendrogram have similar chemical compositions and therefore are genetically related; this means that the oils either originated from the same source or from different source rocks composed of the same organic matter. The study conducted for PERUPETRO includes geochemical data for the same samples generated by several different labs over time. The application of statistical methods provides a measure of control with respect to data quality and compatibility.



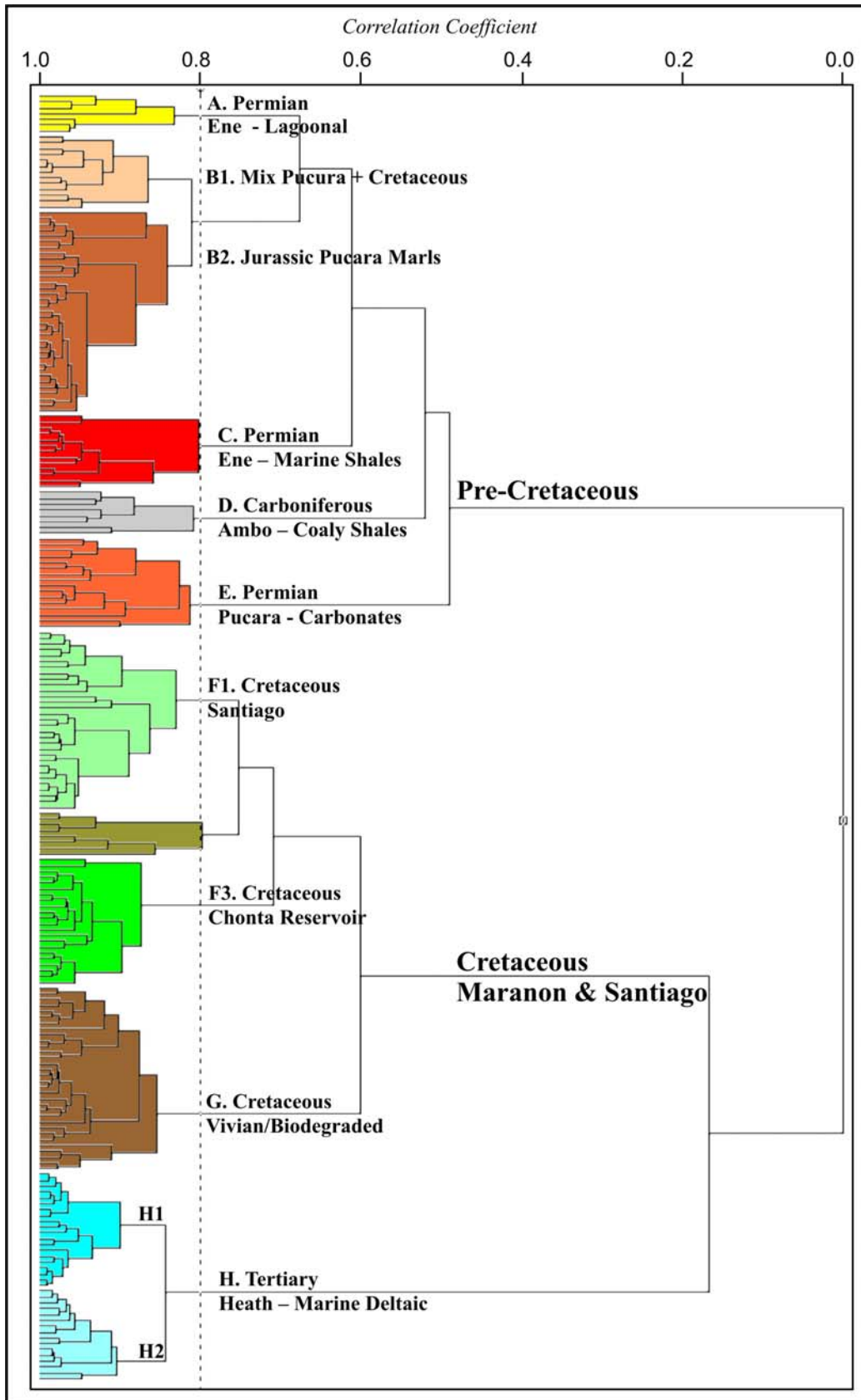


Figure 3. Cluster Analysis Dendrogram



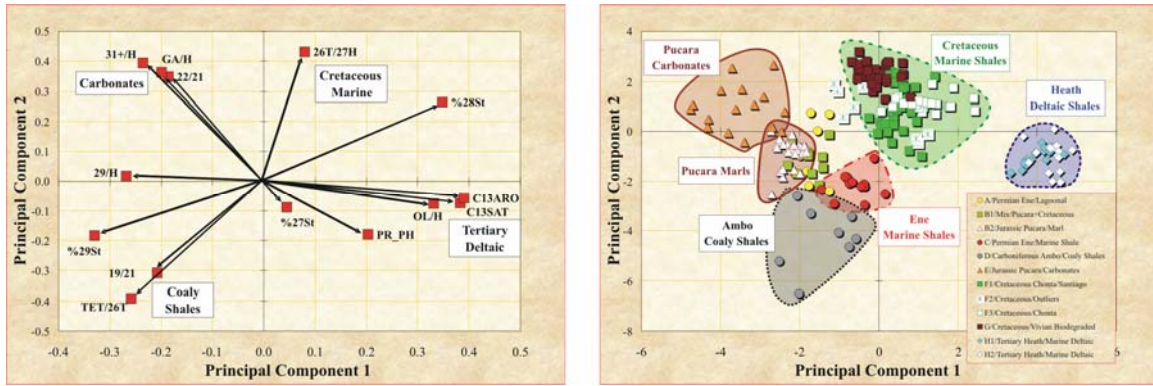


Figure 4. Principal Component Loadings (left) and Scores (right) Plots.

From the source-dependent geochemical parameters used in the statistical evaluation (displayed as principal component loadings and scores plots) information pertaining to source age, lithofacies, maturity and/or oil quality can be ascertained. By mapping the different oil families, limits of the various petroleum systems can be established and areas of overlap can be identified (Figure 5).



Figure 5. Distribution of different oil types in the sedimentary basins of Peru.

These observations illustrate how some key answers lie in the oils, but it is still up to us as explorers to ask the right questions.



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