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Genetic Comparison of Crude Oils from West Africa and South American Conjugate Basins

Craig Schiefelbein (1)*, William Dickson (2), Carlos Urien (3), John Zumberge (4)

*Geochemical Solutions International, Inc. (craigs@geochemsol.com)

Abstract

Geochemical data for 1500+ oils from the South Atlantic margin were used to establish genetic relationships, distinguish source palaeoenvironments and age, and identify different petroleum systems. Multivariate statistical techniques (PCA & HCA) using key isoprenoid, isotope and biomarker ratios were used to separate the oils into two broad groups: 'lacustrine' and 'marine'. The multiplicity and type of effective source rocks were determined using the geochemical characteristics of the representative samples to recognize compositionally distinct oil families and thereby inferring the paleoenvironmental conditions of source rock deposition and possible age. Oil families composed of genetically related oils were identified, several of which contain oils from both sides of the margin.

Keywords: Petroleum Systems, South Atlantic, Conjugate Basins

Introduction

Continuing research has clarified the tectono-structural history of the Atlantic conjugate margins. This includes the creation and segmentation of source rock depocenters. Petroleum geochemists have concurrently examined the nature and distribution of these associated source rocks by characterizing crude oils within a field, then a basin and across a series of basins. Crude oils possess important biological clues that can be used to unravel their genetic history from source to trap and beyond. Lacustrine source distributions of the South Atlantic were investigated by Brice et al., 1980; then comparisons of oil chemistries from both margins were published by Schiefelbein et al. (1999; and 2001).

Methods

Key geochemical indicators of source-rock paleo-environments and age in the South Atlantic Margin (Mello, et al., 1988; Schiefelbein et al., 1999; Schiefelbein et al., 2001) have developed along with increasing numbers of samples and a broadening range of data (i.e., deuterium isotopes, diamondoids) extracted from each sample. Our multi-parameter approach relied on a combination of parameters corresponding to the 'black oil' (>C15) component that are primarily influenced by source, but can also be affected by maturity and/or other alteration processes such as bio-degradation. Genetic relationships are established based on compositional similarity.

Multivariate statistical analyses [principal component analysis (PCA) and cluster analysis; Pirouette™, Infometrix, Seattle, WA.] are used to more clearly distinguish the different types of oils present throughout the South Atlantic Margin. Briefly, in PCA new independent variables are created (i.e., principal components) that are linear combinations of the original variables (i.e., geochemical parameters). The primary objective of PCA is to reduce the dimensionality of the data to a few important components that best explain the variation in the data. The geochemical variables responsible for the PC axes can be viewed as a Loadings plot and the oil samples can be plotted in principal component space, PC1 versus PC2, as a Scores plot. Hierarchal Cluster analysis (HCA) is an ancillary technique to PCA whereby a distance matrix is created from the scaled data; the distance between any two samples is a measure of their similarity. The dendrogram is the output of a cluster analysis and shows groupings or clusters of oils.

Input variables are primarily source dependent and based on information obtained from the detailed analysis of the C15+ saturate and aromatic hydrocarbon fractions ('black oil'). The sixteen (16) source dependent variables used in the multivariate statistical analyses describe 68% of the variance and include the pristane/phytane ratio, the stable carbon isotopic compositions of the C15+ saturate and aromatic hydrocarbon fractions, and thirteen biomarker ratios, including the distribution of the 14β, 17β-C_{27}, -C_{28} and –C_{29} steranes (from m/z 218), C_{27} Ts/Tm hopanes, C_{31-35} hopanes/C_{30}-hopane, gammacerane/C_{30}-hopane, oleanane/C_{30}-hopane, total steranes/total hopanes, and C_{29}-demethylated norhopane/C_{30}-hopane. Ratios based on the distribution of tricyclic and tetracyclic terpanes were also used: C_{21}-

Tri/C_{23}-Tri, C_{26}-Tri/C_{25}-Tri, C_{24}-Tetra/C_{26}-Tri and the C_{30}-Tetra/C_{27} diasteranes index (TTP; m/z 259).

Results and Discussion

Geochemical data utilized in this study are entirely non-exclusive and provided by Geochemical Solutions International and Geomark Research (Figure 1). Our interpretive work began with the assembly of a data set and development of data intimacy through detailed inspection (e.g., see Dickson et al., 2016). Values from different laboratories that employed different analytical schemes required a determination of which measurements were common to all samples (the Lowest Common Denominator). Missing parameters from specific samples were supplied from analogues, sample averaging and standard relationships from other geochemical parameters based on physical proximity of sample sites and author experience.

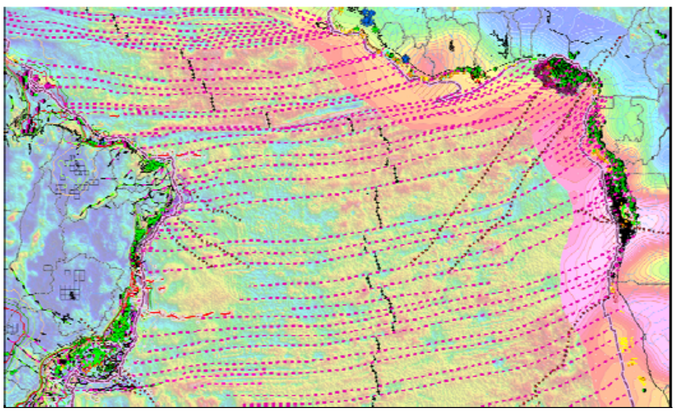

Figure 1. Distribution of crude oil, piston core, and source rock samples plus heat flow locations. The data set includes information from more than 1600 crude oils, 30,000+ source rocks from 220+ wells, 4000+ piston cores and 500+ heat flow measurements. (Gravity image compliments of GrizGeo)

Recognition and characterization of compositionally distinct oil types or families infers paleo-environmental conditions of source rock deposition and possible age. Clearest results are obtained from pure end-member oils from a single lithology, single paleo-environment source but this is uncommon to the South Atlantic margin with its compound basins, usually with drift-age marine fans overlying multi-stage rifts. Depositional environments may grade episodically from lacustrine to marine so that in late rift to sag phases, source rocks composed of mixed kerogens are deposited. Oils from such sources in similar phases of maturity may mimic mixed oils from discrete sources co-mingled in a common reservoir.

Conclusions

Statistical analysis of some 1500 oils allows separation into five major families: Early SynRift; Late SynRift/Sag; Marine/Mixed; Marine; Tertiary Deltaic. The strongest genetic relationships are observed between oils from central Brazil and West Africa that originated from Barremian (Lower Rift/SynRift I) source rocks deposited in deep, freshwater lacustrine environments. Great Campos oils appear to have a unique source chemistry. Additional samples are necessary to ensure that laboratory and sample bias are minimized. Incorporation of additional geologic constraints from tectono-structural mapping suggest that oil family and sub-family distributions often relate to sediment thickness and basin to sub-basin structure; lacustrine oils show strong correlations of age and location between conjugate salt basins; and marine oils demonstrate age correlations related to global ocean anoxic events. Post-generative alteration processes such as biodegradation, phase separation and/or late episodes of migration are considered. Valuable insights are gained by incorporation of additional geologic constraints from tectono-structural mapping including basement depth, sediment thickness and crustal type with their influences on thermal maturity and migration pathways.

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