CODE EXPR-1-CS-11

PETROLEUM GEOCHEMISTRY AS AN EXPLORATION TOOL APPLIED TO SOUTH AMERICA

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INTRODUCTION

Petroleum geochemistry is a fundamental component of regional exploration and production programs and is as important to basin analysis as an understanding of regional structural fabric, regional evolution of the structural elements and regional stratigraphic relationships. Oil geochemistry is applied here to better understand and predict the occurrence of crude oil in the marginal basins of Brazil (Figure 1), onshore and offshore Cuba, and the Neuquen Basin of Argentina. This approach is supplemented by results obtained from other exploration tools such as surface geochemistry and basin modeling. For exploration companies to be successful in these areas, a firm understanding of the operative petroleum systems is necessary to make intelligent choices with regard to projects and lease acquisition.

APPROACH

A regional oil study that utilizes the detailed geochemical analysis of a representative suite of samples is an excellent way of identifying, evaluating and comparing the various petroleum systems that have contributed to the reserves of a large area. A location map of oils included in a regional study of the marginal basins of Brazil is shown in Figure 1. All oil samples were analyzed using a sophisticated suite of analyses including determination of physical properties (API and weight percent sulfur), gas chromatography, stable carbon isotopes, and gas chromatography/mass spectrometry. In order to maximize the benefits of this approach, the geochemical results were integrated within a meaningful geologic framework.

Figure 1. Location map of analyzed oils from the marginal basins of Brazil.

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 is achieved through the use of multivariate statistical techniques such as principal component (Figure 2) and hierarchal cluster analysis (Figure 3). The extent of the petroleum system can be approximated because their limits are defined by the limits of secondary migration. Since crude oils are the compositional derivatives of their sources, oil geochemistry can be used to determine the number of discrete sources in a basin and their respective stratigraphic and areal distribution, source age, lithology, organic input (marine, non-marine, lacustrine), thermal maturity, and depositional environment.

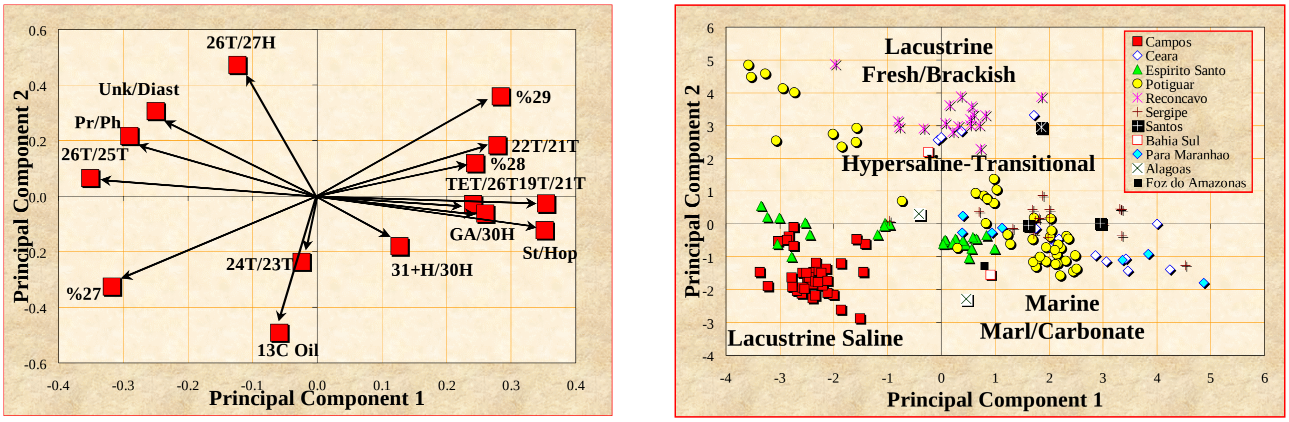

Figure 2. Principal component loads (left) and scores (right) plots from the statistical analysis of oils from the marginal basins of Brazil.

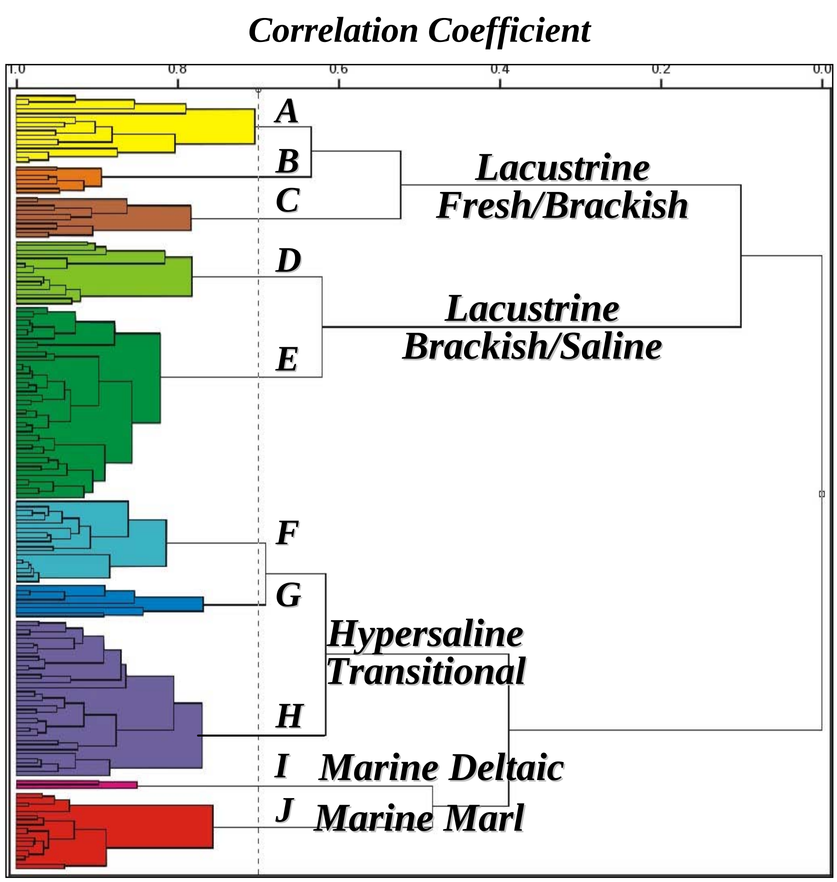

Figure 3. Cluster analysis dendrogram from the statistical analysis of oils from the marginal basins of Brazil.

In addition, areas with overlapping petroleum systems can be identified in relation to possible oil mixing from two or more sources. Processes active in the basin that act to modify the original composition of the oils 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 oil property determinants and predict them prior to obtaining acreage or drilling. Additional applications of oil geochemistry include characterization of oils in multi-reservoir fields, reservoir heterogeneity studies, "True" product value comparisons, core invasion studies, oil mixing behind casing, and environmental studies. Several different oil types have been identified in the marginal basins of Brazil based primarily on biomarker distributions. These include oils derived from source rocks deposited in different marine (post-salt) and lacustrine (pre-salt) settings (Figure 4).

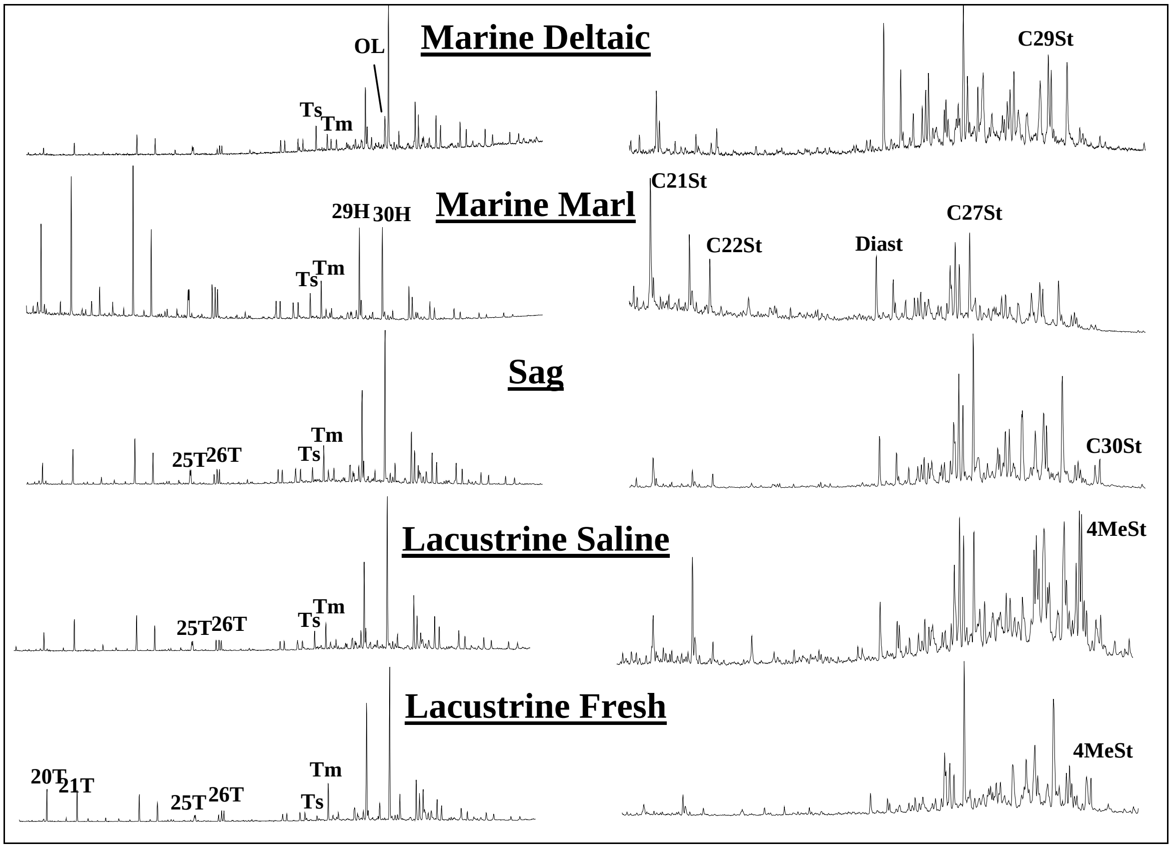

Figure 4. Terpane (m/z 191, left) and sterane (m/z 217, right) mass chromatograms representing the different oil types present in the marginal basins of Brazil.

Surface geochemical exploration studies (piston coring) and remote sensing techniques (SAR) are cost effective means of obtaining information ahead of the drill bit. The high cost of offshore exploration has made the identification of seeps a well-accepted risk assessment methodology. These techniques have been instrumental in defining active Petroleum Systems in the Gulf of Mexico and along both sides of the South Atlantic margin.

The advantages of piston coring are that the presence of macro-seepage and/or micro-seepage of oil and gas in near-surface seafloor sediments provides evidence of active oil generation and migration, it allows assessment of most prospective areas, and it provides an integrated seep signal over time. In addition, samples are available to characterize oil properties, maturity and source rock type. Terpane (m/z 191) and sterane biomarker results from the detailed analysis of a piston core from the Santos Basin are compared to similar results for representative lacustrine oils from Brazil in Figure 5. The mass chromatograms for the piston core extract are very similar to those shown for the representative lacustrine crude oil. These similarities, which support an origin from a pre-salt lacustrine source, are substantiated by seismic data presented in Figure 6.

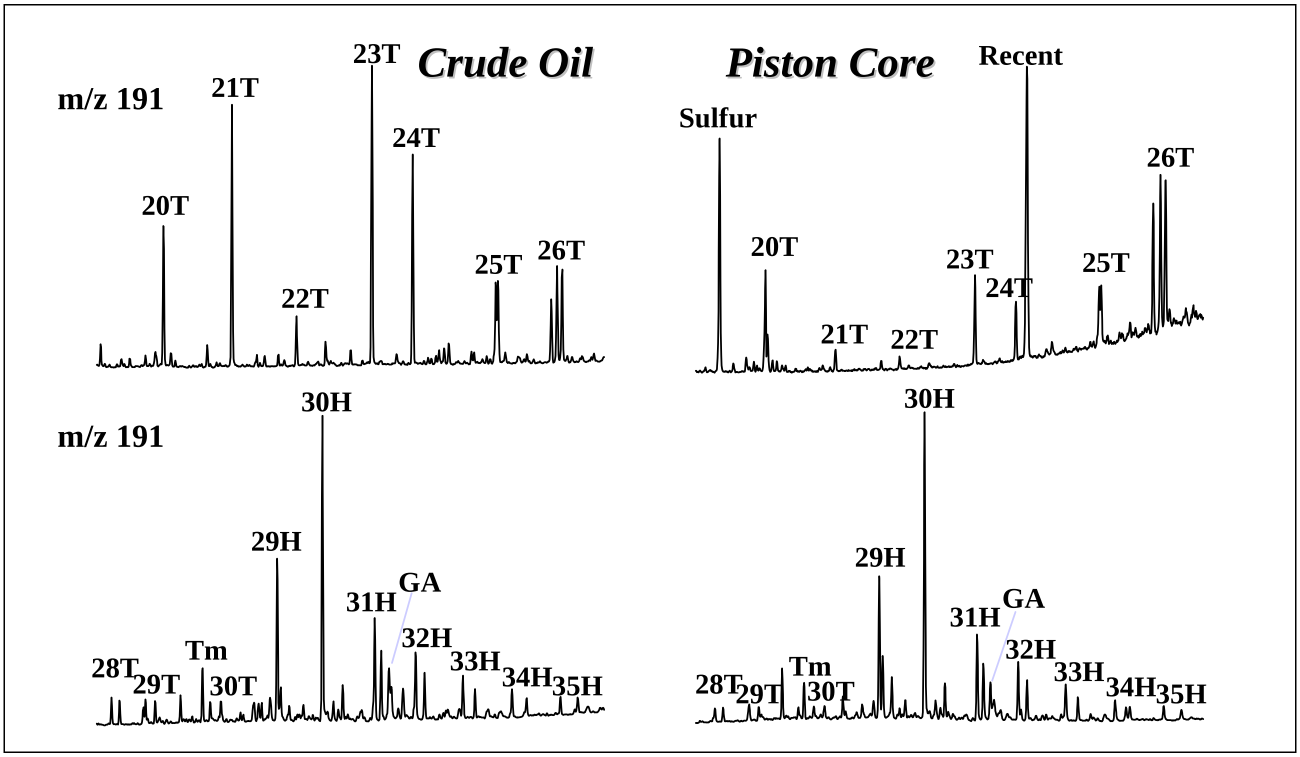

Figure 5a. Comparison of Terpane (m/z 191) mass chromatograms obtained from the analysis of a piston core extract from the Santos Basin (right) and a lacustrine crude oil from Brazil (left).

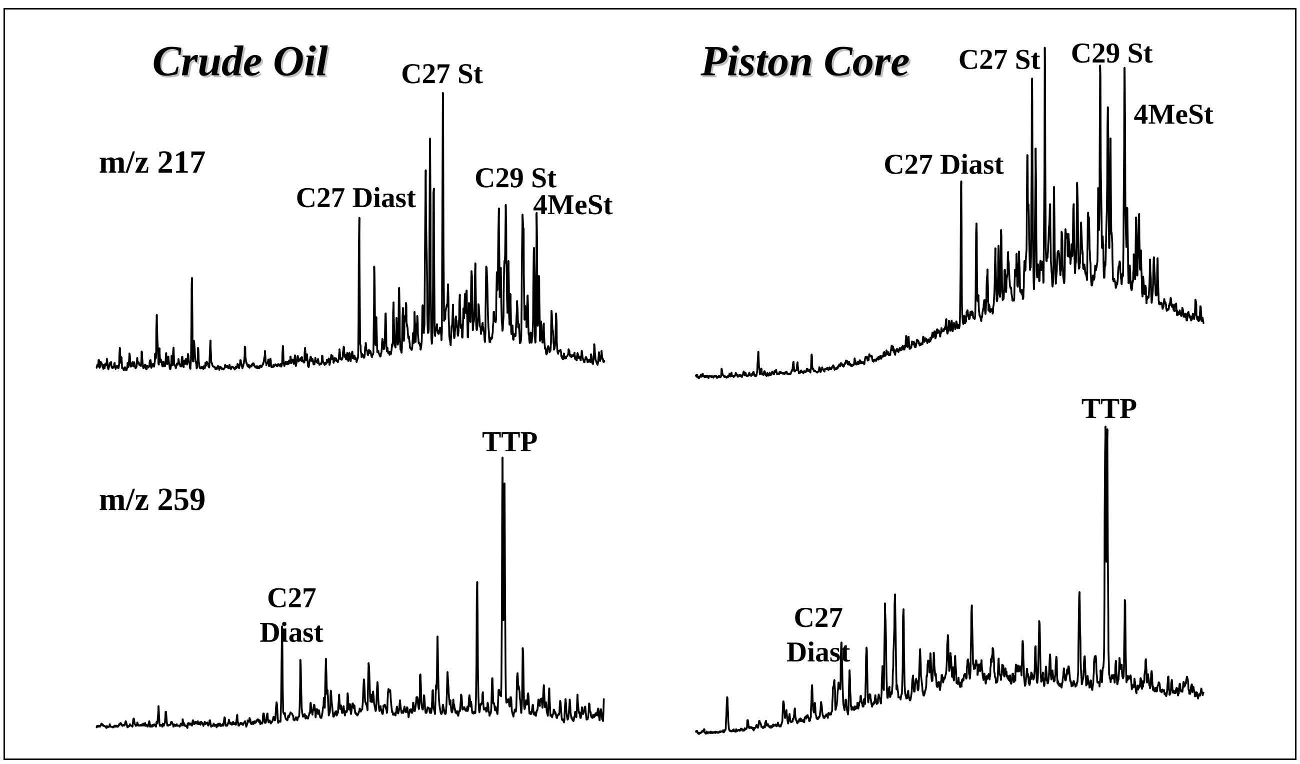

Figure 5b. Comparison of sterane (m/z 217) mass chromatograms obtained from the analysis of a piston core extract from the Santos Basin (right) and a lacustrine crude oil from Brazil (left).

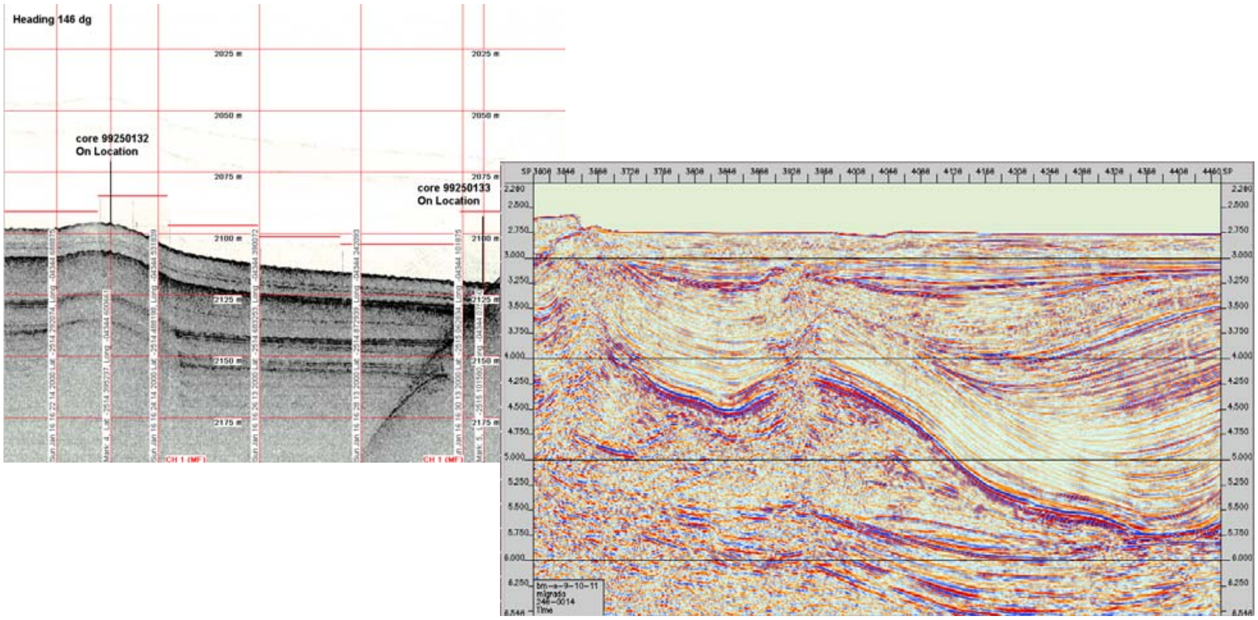

Figure 6. Sub-bottom profile (left) and seismic data illustrating location of stained piston core over break in salt though which pre-salt lacustrine hydrocarbons could migrate vertically.

Similarly, the application of remote sensing techniques to identify natural oil slicks has historically provided invaluable information to oil explorationists. Foremost, they indicate the presence of generative hydrocarbon source rocks, without which there can be no accumulations. In addition, the spatial coincidence of surface slicks and geologic structure allows for the identification of the loci of natural hydrocarbon seepage and to infer possible migration pathways from the reservoir to the sea floor (Figure 7).

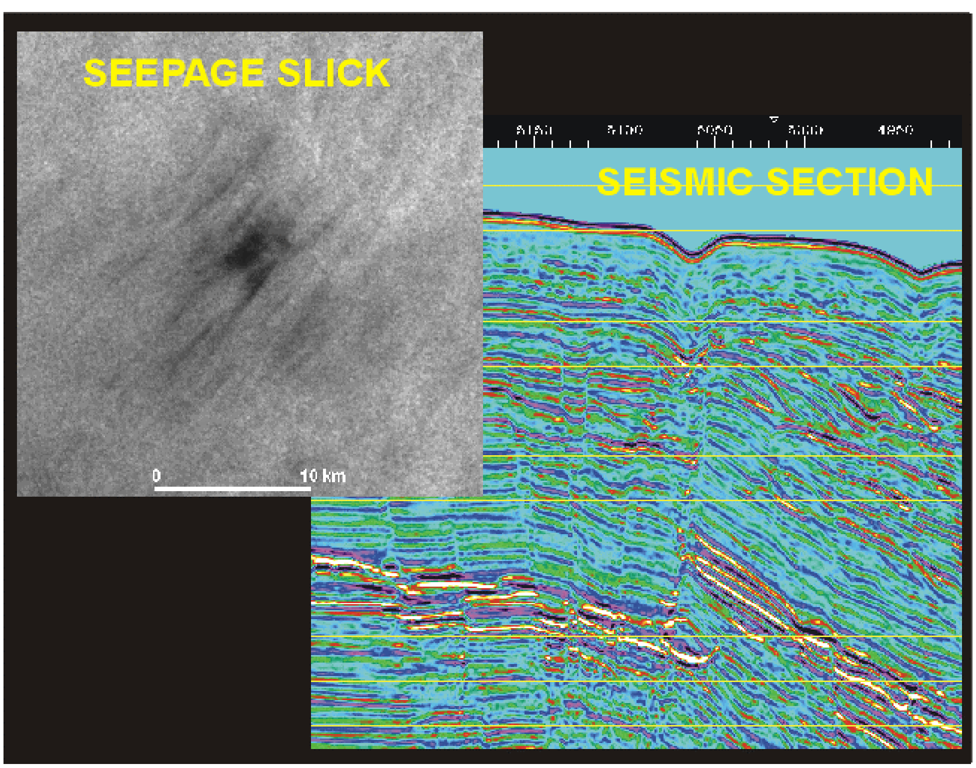

Figure 7. Thermogenically derived oil slick from remote sensing data (left) and associated seismic line illustrating possible vertical migration pathway.

Basin modeling has also become an essential tool for petroleum exploration. It allows the explorationist an integrated, dynamic means by which to simulate basin evolution and petroleum generation, expulsion and migration. Basin modeling also provides insights into fundamental questions such as: 1) where are the source rock "kitchens"? 2) what is the timing of petroleum generation, expulsion and migration for each source rock interval? 3) what are possible migration pathways from source rocks to reservoirs? 4) what is the significance of faults as migration pathways? 5) how effective must drains and seals be in order to have commercial accumulations? and 6) what are the expected oil and gas compositions in a hydrocarbon trap? Results obtained from the 2D modeling of a regional seismic line from the Campos Basin are shown in Figure 8. These results suggest hydrocarbon generation from a pre-salt source horizon with associated lateral and then vertical migration to the surface in an area where an oil slick was identified.

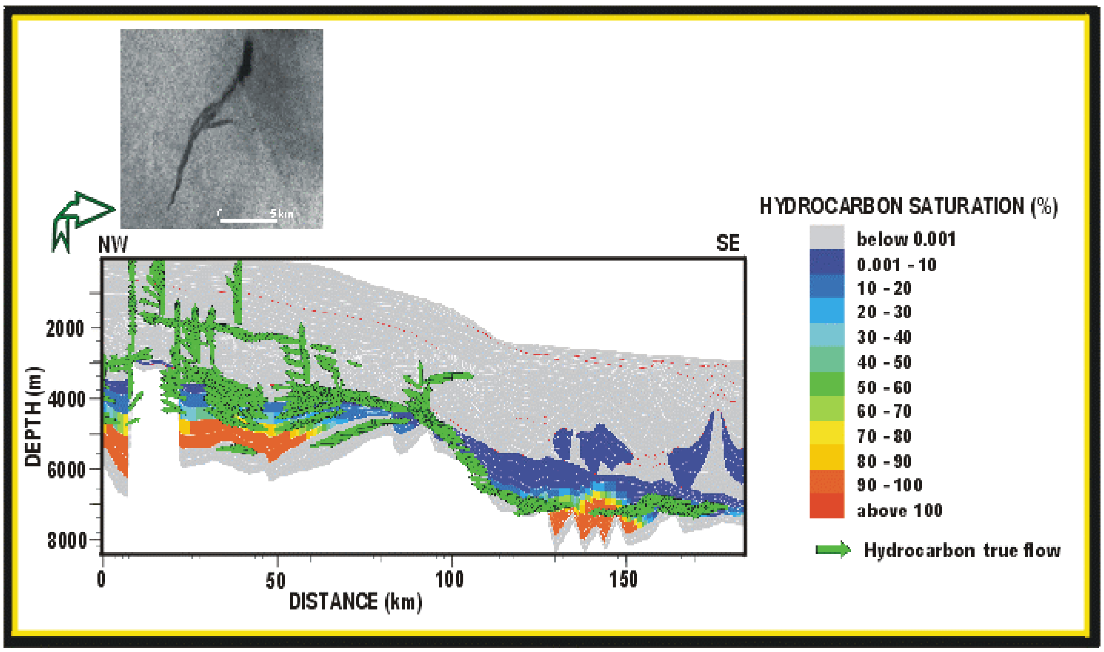

Figure 8. Results obtained from the 2D modeling of a regional seismic line from the Campos Basin.

CONCLUSIONS

This paper demonstrates how geochemical data from representative crude oils from the marginal basins of southeast Brazil can be compared and contrasted with results obtained from surface geochemical techniques, such as piston coring and remote sensing. In addition, results from basin modeling studies are interpreted within the petroleum system concept established by the oil chemistries. Results from this comparison can be applied as an exploration tool, specifically designed to assess risk associated with hydrocarbon charge. Conclusions are supported by seismic data. Other areas where this approach has been successfully employed include the onshore and offshore areas of Cuba and the Neuquen Basin in Argentina. In each of these areas, results can be used to readily distinguish different petroleum systems and to further separate these petroleum systems into unique families or groups according to differences in source paleoenvironment, source age, water chemistry, source lithofacies, and/or oil quality. Areas where mixing has occurred can also be identified.

Petroleum geochemistry should be a fundamental component of regional exploration and production programs because it is as important to basin analysis as an understanding of regional structural fabric, regional evolution of the structural elements and regional stratigraphic relationships.