

**GEOCHEMISTRY AND EXPLORATION
SIGNIFICANCE OF CRUDE OILS
AND SEEPS FROM PERU**

**GEOMARK
RESEARCH, INC.**

Prospectus

GEOCHEMISTRY AND EXPLORATION SIGNIFICANCE OF CRUDE OILS AND OIL SEEPS FROM PERU

Introduction

GeoMark Research, Inc. has completed a detailed, country-wide investigation of the geochemistry of crude oils and surface seeps from Peru. GeoMark scientists have undertaken this investigation with considerable technical authority having successfully completed an inter-basinal study focusing on Ecuador but including 50 oils from the Marañón and Santiago basins of Peru (Illich et al., 1994). These oils provided important insight into the evolution of the Cretaceous (Napo-Chonta) source system. Sample density was insufficient, however, to describe and resolve other systems known to exist in the northern Marañón. Other important Peruvian basins were not considered in the project.

The source systems of northern Peruvian Subandean basins are mainly Cretaceous in age. Sources in the southern Marañón, Ucayali, and Madre de Dios basins are mainly pre-Cretaceous. Multiple sources in several separate depocenters, bacterial degradation, oil mixing and re-migration, and fractionation occurring during migration are processes that have contributed to the present-day composition of Peruvian oils (Illich et al., 1977; del Solar, 1982; Illich et al. 1985; Sofer et al., 1986; Arias, 1991; and, Mathalone and Montoya, 1994). The complexity of the petroleum systems in Peru provides a variety of exploration opportunities, some of which remain only partly tested. These systems are not easily approached by study of rock samples. Many of the actual sources have not been penetrated or are no longer available to be sampled.

Large numbers of oil samples provide an efficient way to define and describe the complex petroleum systems of Peru. This was demonstrated in the project most recently completed in the Ecuadorian Oriente. With the benefit of high sample density, differences often dismissed as normal compositional variations were sufficient to establish the existence of multiple sources, source facies and source depocenters. This knowledge profoundly contributes to the definition of the petroleum systems in the Ecuadorian and Peruvian basins.

Refinements to the definition and description of the petroleum systems of Peru will contribute to the discovery of subtle traps. The origin of many Peruvian oil accumulations may most successfully be addressed by the kind of sampling density and analytical capabilities proposed in this project. Over 200 oils have been analyzed. The majority are from Peru but some come from boundary areas in Ecuador. Additionally, a few oils from outside areas have been included to illustrate special compositional attributes shared with Peruvian oils.

Oil Geochemistry

Enormous insight into petroleum systems can be gained by the analysis and interpretation of a large collection of oils from a basin. Table 1 provides a list of oils included in the Peruvian project. Their distribution is shown on the map of the area (Figure 1). Each oil has been characterized by an analytical program that includes bulk compositional data, quantitative biomarker analysis of terpanes and steranes, and determinations of stable isotope composition of the saturate and aromatic hydrocarbon fractions. Rigorous comparison of geochemical data has been accomplished using cluster and principal component analyses (Moldowan et al., 1985 and Zumberge, 1987). These statistical techniques are conformed in a way that permits predictions regarding depositional environments of the source rocks. Data from oil geochemistry has been used to evaluate important exploration issues.

- The number of sources (or source facies) responsible for the oils
- The number of depocenters (“kitchens”) for the oils derived from a common source
- Identification of secondarily altered oils and assignment of these to their propercompositional families
- Identification and evaluation of oil mixing
- Maturity of oils and condensates

A special effort has been made in the study of the Peruvian samples to compare thermal maturities of the oils. It is of interest to determine the relative distribution of maturities of oils belonging to the same compositional family. A range of maturities may indicate multiple and separate source depocenters for the oils, or complex generation and accumulation histories. Maturities have been estimated using C_{15+} biomarker techniques (Peters and Moldowan, 1993).

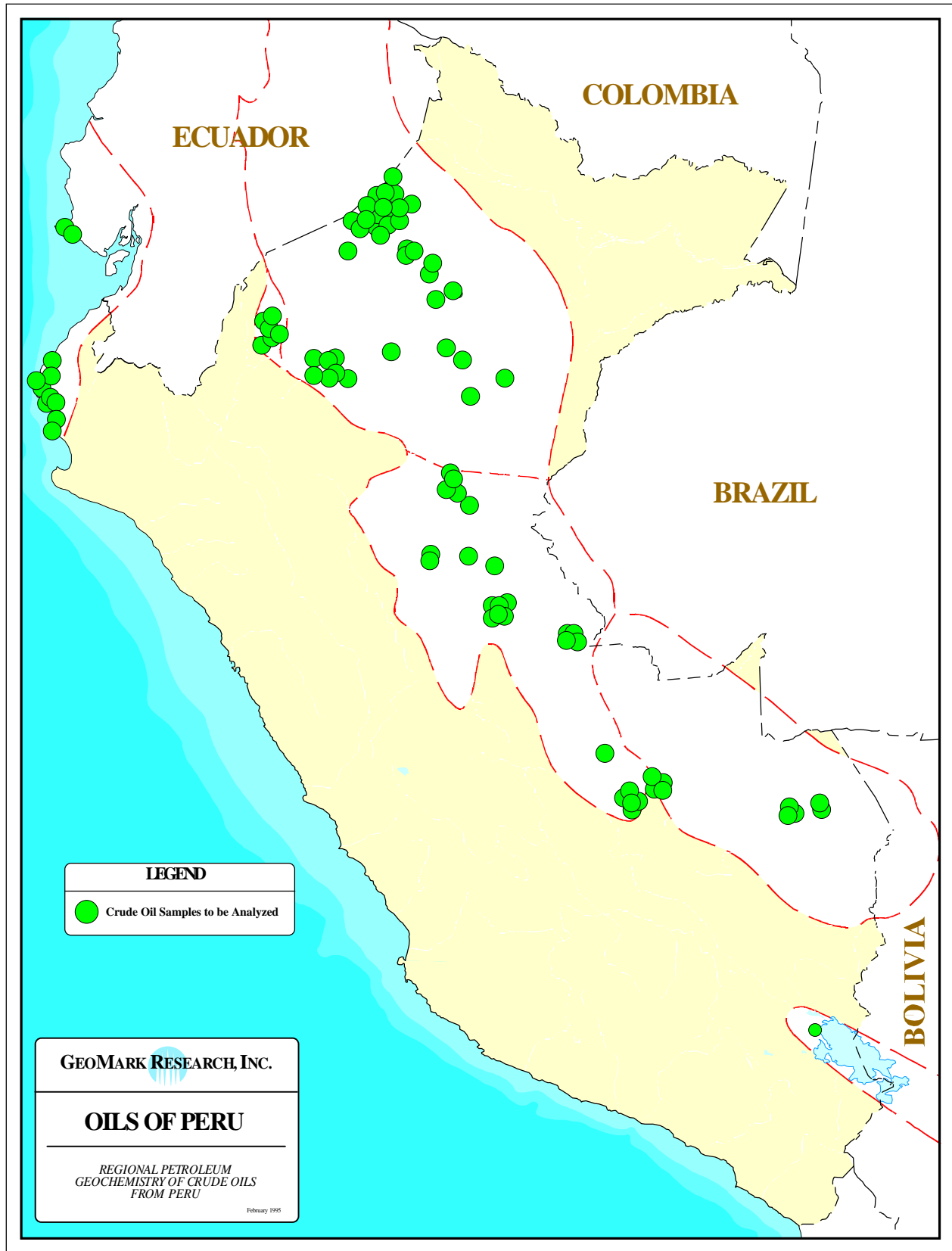


Figure 1. Location map showing distribution of samples analyzed for this study.

PRESENTATION

Data from the project has been organized in an interpretative volume and into an appropriate number of data volumes. The integrated interpretation for the study is preceded by a discussion of the regional setting and summary of oil geochemistry. A separate report for the oils is presented as an appendix of the interpretation for those explorationists who wish to consider the details of the analysis from which the oil summary was derived.

The analytical data from the oil work is provided on personal computer disks and in the data volumes. The oil data includes the following:

- Physical property data (API gravity, % Sulfur, Ni/V ratios)
- C₁₅₊ fraction versus <C₁₅₊ fraction
- Deasphalting
- Liquid chromatography (% Saturates, % Aromatics, and % NSO's)
- Capillary gas chromatography of whole crude oil
- Detailed C₇ gas chromatography
- Stable carbon isotopic composition of C₁₅₊ saturate and aromatic hydrocarbons
- Quantitative GC/MS analysis of C₁₅₊ saturate hydrocarbons for terpane and sterane distributions

Participation

The complete study is available at a cost of US \$37,500.00.

Timing

The project is complete and available for immediate delivery.

For Additional Information Contact:

Mr. Stephen W. Brown
GEOMARK RESEARCH, INC.
9748 Whithorn Drive
Houston, Texas 77095
Telephone: (281) 856-9333
Fax: (281) 856-2987
E-mail: sbrown@geomarkresearch.com

REFERENCES

Arias, G.A.S., 1991, Geological factors controlling hydrocarbon accumulation in the eastern basins, Peru. In, Petroleum Exploration in Sub-Andean Basins, Volume 1, 4th Bolivian Symposium ACGGP, pp. 131-156.

del Solar, S.C., 1982, Ocurrencia de hidrocarburos en el formacion Vivian nororiente Peruano. Simposio Exploracion Petrolera en als Cuencas Subandinas de Venezuela, Colombia, Ecuador y Peru, 13 pages.

Illich, H.A., F.R. Haney, and T.J. Jackson, 1977, Hydrocarbon geochemistry of oils from Marañon basin, Peru. AAPG, v. 61, pp. 2103-2114.

Illich, H.A., F.R. Haney, and J.D. Pruitt, 1985, Hydrocarbon geochemistry of oils from eastern Peru -- a model of risk reduction in new exploration ventures, 4th Latin American Geological Congress (Trinidad and Tobago, 1979), v. 1, pp. 351-363.

Illich, H.A., J.E. Zumberge, C.F. Schiefelbein, and S.W. Brown, 1994, Regional Petroleum Geochemistry of Crude Oils from the Oriente (Putumayo, Napo, Maranon, and Santiago) Basins of Colombia, Ecuador, and Peru. GeoMark Research, proprietary report prepared for project participants.

Mango, F.D., 1990, The origin of light hydrocarbons in petroleum: A kinetic test of the steady state catalytic hypothesis. Geochim. et Cosmochim. Acta, v. 54, pp. 1315-1323.

Mathalone, J.M.P. and M. Montoya, 1994, The petroleum geology of Peruvian sub-Andean basins. AAPG Annual Meeting, Denver (Abstract), p. 207.

Moldowan, J.M., W.K. Seifert, and E.J. Gallegos, 1985, Relationship between petroleum composition and depositional environment of source rocks. AAPG, v. 69, pp. 1255-1268.

Peters, K.E. and J.M. Moldowan, 1993, The Biomarker Guide. Prentice Hall, Englewood Cliffs, New Jersey, 363 pages.

Sofer, Z., J.E. Zumberge, and V. Lay, 1986, Stable carbon isotopes and biomarkers as tools in understanding genetic relationships, maturation, biodegradation, and migration of crude oils in the northern Peruvian Oriente (Marañon) basin. Organic Geochemistry, v. 10, pp. 377-389.

Zumberge, J.E., 1987, Prediction of source rock characteristic based on terpane biomarkers in crude oils: A multivariate statistical approach. *Geochim. et Cosmochim. Acta*, v. 51, pp. 1625-1637.

APPENDIX A

Samples Analyzed for this Study

Basin	Well	Basin	Well	Basin	Well	Basin	Well
Huallaga	Tiraco Dome Seep	Maranon	Corrientes-10XC	Maranon	Querrada	Talara	Leones-4953
Madre de Dios	Pariamanu 47-23-1X	Maranon	Corrientes-10XC	Maranon	San Jacinto	Talara	Parinas
Madre de Dios	Pariamanu-47	Maranon	Corrientes-10XC	Maranon	San Jacinto-1	Talara	Patria-141
Madre de Dios	Pariamanu	Maranon	Corrientes-12XC	Maranon	San Jacinto-B	Talara	Patria-239
Madre de Dios	Pariamanu Andes	Maranon	Corrientes-12XC	Maranon	San Jacinto-2	Talara	Patria-232
Madre de Dios	Puerto Prima 47-25-2x	Maranon	Corrientes-12XC	Maranon	San Jacinto	Talara	Pena Negra-1827
Madre de Dios	Que. Petroleo Seep	Maranon	Corrientes-12XC	Maranon	San Jacinto-4	Talara	Portachuelo-5164
Maranon	Bartra V-14	Maranon	Corrientes-16XCD	Maranon	San Jacinto-B	Talara	Portachuelo-5241
Maranon	Bartra-2	Maranon	Corrientes-6XC	Maranon	San Jacinto-A	Talara	S. Organos-1944
Maranon	Bartra-2	Maranon	Corrientes-45XCD	Maranon	San Jacinto-10	Talara	Somatito-1951
Maranon	Bartra-2	Maranon	Corrientes 8-21-1X	Maranon	San Juan-77XD	Talara	Tunel-5186
Maranon	Bartra-20	Maranon	Corrientes-45XCD	Maranon	Shiviyacu 4-52-2X	Talara	Tunel-19
Maranon	Bartra-43	Maranon	Cunambo-1	Maranon	Shiviyacu-33	Talara	#5009
Maranon	Bartra 1B-2	Maranon	Dorissa-4	Maranon	Shiviyacu	Talara	#4646
Maranon	Bartra	Maranon	Dorissa	Maranon	Shiviyacu	Ucayali	Agua Caliente-9
Maranon	Bartra 1B-17-5	Maranon	Dorissa-18	Maranon	Shiviyacu V-26	Ucayali	Agua Caliente-30
Maranon	Bartra 1B-17-3	Maranon	Dorissa 1A-1	Maranon	Sun-1X	Ucayali	Agua Caliente-33
Maranon	Bartra 1B-17-5	Maranon	Dorissa	Maranon	Trompetera	Ucayali	Agua Caliente-26
Maranon	Bartra 1B-17-2	Maranon	Dorissa-1	Maranon	Valencia-25X	Ucayali	Agua Caliente-26
Maranon	Bartra (thermal-4)	Maranon	Dorissa 1A-49-1	Maranon	Valencia-25X	Ucayali	Aguyatia-1
Maranon	Bretana	Maranon	Dorissa 49-2	Maranon	Valencia-25X	Ucayali	Aguyatia-1
Maranon	Capahuari 41-1X	Maranon	Forestal-30	Maranon	Valencia-100D	Ucayali	Campo Maquia-30
Maranon	Capahuari	Maranon	Forestal	Maranon	Valencia-25X	Ucayali	Campo Maquia-16
Maranon	Capahuari-54	Maranon	Forestal CH-10	Maranon	Yanayacu-32X	Ucayali	Campo Maquia-16
Maranon	Capahuari 41-1X	Maranon	Forestal-31	Maranon	Yanayacu-32XC	Ucayali	Campo Maquia-16
Maranon	Capahuari 41-XZ	Maranon	Forestal V	Maranon	Yanayacu-61XCD	Ucayali	Campo Maquia-17
Maranon	Capahuari	Maranon	Forestal-5	Maranon	Yanayacu-32X	Ucayali	Campo Maquia-11
Maranon	Capahuari 41-2X	Maranon	Forestal-9	Maranon	Yanayacu-38XC	Ucayali	Campo Maquia-1
Maranon	Capahuari-45	Maranon	Huasaga X-1	Maranon	Yanayacu-38XCD	Ucayali	Cashiriari-1X
Maranon	Capahuari-46	Maranon	Huasaga 1X	Santiago	Aceite River Seep	Ucayali	Cashiriari
Maranon	Capahuari Norte	Maranon	Huasaga	Santiago	Apingraza Co. Seep	Ucayali	Cashiriari-1X
Maranon	Capahuari S-27	Maranon	Huasaga X-1	Santiago	Apingraza Co. Seep	Ucayali	Cashiriari
Maranon	Capahuari S 1A-43-14	Maranon	Huasaga 2-8-1X	Santiago	Atzacuza Seep	Ucayali	Ganso Azul Seep
Maranon	Capahuari S 1A-43-5	Maranon	Huayuri	Santiago	Candungos Seep	Ucayali	Huaya-4X
Maranon	Capahuari S 1A-43-13	Maranon	Huayuri-50	Santiago	Caterpiza Seep	Ucayali	La Colpa-1X
Maranon	Capahuari S-11	Maranon	Huayuri	Santiago	Cayamaza-Seep	Ucayali	La Colpa-1X
Maranon	Capahuari S V-4	Maranon	Huayuri-51	Santiago	Chingana Seep	Ucayali	La Colpa-1X
Maranon	Capahuari S-14	Maranon	Huayuri V-3	Santiago	Dominguza-1	Ucayali	La Colpa-1X
Maranon	Capirona-2X	Maranon	Huayuri S	Santiago	Dominguza-1	Ucayali	PCS-17
Maranon	Capirona-2X	Maranon	Huayuri S-13	Santiago	Dominguza-1	Ucayali	Quebrada Co. Seep
Maranon	Capirona-2X	Maranon	Huayuri S-2	Santiago	Piuntza Seep	Ucayali	San Martin
Maranon	Capirona-2X	Maranon	Huayuri S 1A-48-1	Santiago	Piuntza-1	Ucayali	Sepa 38-45-1X
Maranon	Capirona-2X	Maranon	Jibarito	Santiago	Putuime-1	Ucayali	Seep
Maranon	Ceci	Maranon	Jibarito-1	Talara	Carrizo-1812	Titicaca	Pirin
Maranon	Corrientes 30-X6	Maranon	Jibaro	Talara	Echino	Santa Elena	Ancon
Maranon	Corrientes-28XCD	Maranon	Nuevo Esperanza-77X	Talara	Helico	Santa Elena	Ecuador
Maranon	Corrientes-20XCD	Maranon	Nuevo Esperanza-77X	Talara	Hualtacal-5		
Maranon	Corrientes-33XC	Maranon	Pavayacu-70XC	Talara	Hualtacal-113		
Maranon	Corrientes-10XC	Maranon	Phillips-1	Talara	Leones-5104		