

**GEOCHEMISTRY AND EXPLORATION
SIGNIFICANCE OF CRUDE OILS
AND OIL SEEPS FROM
BOLIVIA**

**GEOMARK
RESEARCH, INC.**

A PROSPECTUS

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Introduction

GeoMark Research, Inc. has completed a detailed, country-wide investigation of the geochemistry of crude oils and surface seeps from Bolivia. This effort represents a continuation of a series of successful projects undertaken by GeoMark focusing on the Subandean basins of South America.

Bolivian oils are mainly derived from Paleozoic sources (e.g. Raedeke, 1994), but source depocenters often are not closely associated with the reservoirs. Oils that originate in stratigraphically separate Paleozoic sources often are compositionally similar and moderately difficult to distinguish. Devonian and Silurian oils of Eastern Algeria represent an example of this phenomenon (Tissot et al., 1973). The problem of classifying oils from stratigraphically different but positionally similar sources is exacerbated by fractionation occurring during cross stratigraphic migration and secondary alteration. Fractionation and bacterial degradation processes are interpreted to have contributed to the present composition of some of the Bolivian oils (Illich et al., 1981).

The interpretative importance of large numbers of oil samples was demonstrated in the Oriente Basin Oil Study project recently completed in the Subandean series (Illich et al., 1994). Differences in crude oil composition that are 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 Colombian, Ecuadorian, and Peruvian basins. The Oriente project also re-emphasized the importance of Paleozoic (Permian, Devonian, Silurian, and possibly Ordovician) sources in southern Peru and Bolivia (Arias, 1991).

Refinements to the definition and description of the petroleum systems of Bolivia will contribute to the discovery of subtle traps. The origin of many Bolivia oil accumulations are successfully addressed by the kind of sampling density and analytical capabilities utilized in this project. 147 oils have been analyzed. Upper Devonian (Tomache Fm.) source rock samples from Pando X-1 are also included in the study. Past source rock based regional studies (Brown & Ruth World Bank Study, 1989) have demonstrated that an approach of this type is necessary to conclusively evaluate the petroleum systems of Bolivia.

Oil Geochemistry

Enormous insight into petroleum systems can be gained by the analysis and interpretation of a large collection of oils from a basin. Appendix A provides a list of oils that are expected to be included in the Bolivian project. Their distribution is shown on the map of the area (Figure 1). Each oil was 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 was accomplished using cluster and principal component analyses (Moldowan et al., 1985 and Zumberge, 1987). These statistical techniques are “setup” in a way that permits predictions regarding depositional environments of the source rocks to be made. Data from oil geochemistry have been used to evaluate the following 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 proper compositional families
- Identification and evaluation of oil mixing
- Maturity of oils and condensates

A special effort was made in the study of the Bolivian samples to compare thermal maturities of oils and condensates. It is of interest to determine the relative distribution of maturities of oils belonging to the same compositional family. A range of maturities within a “small” area may indicate multiple and separate source depocenters for the oils, and complex migration and accumulation histories. It is informative to determine if maturities suggested by gravities (<25° to >60° API) are a product of thermal maturation, migration-fractionation processes, bacterial degradation, or a combination of processes. Maturities are estimated using C₁₅₊ biomarker techniques (Peters and Moldowan, 1993).

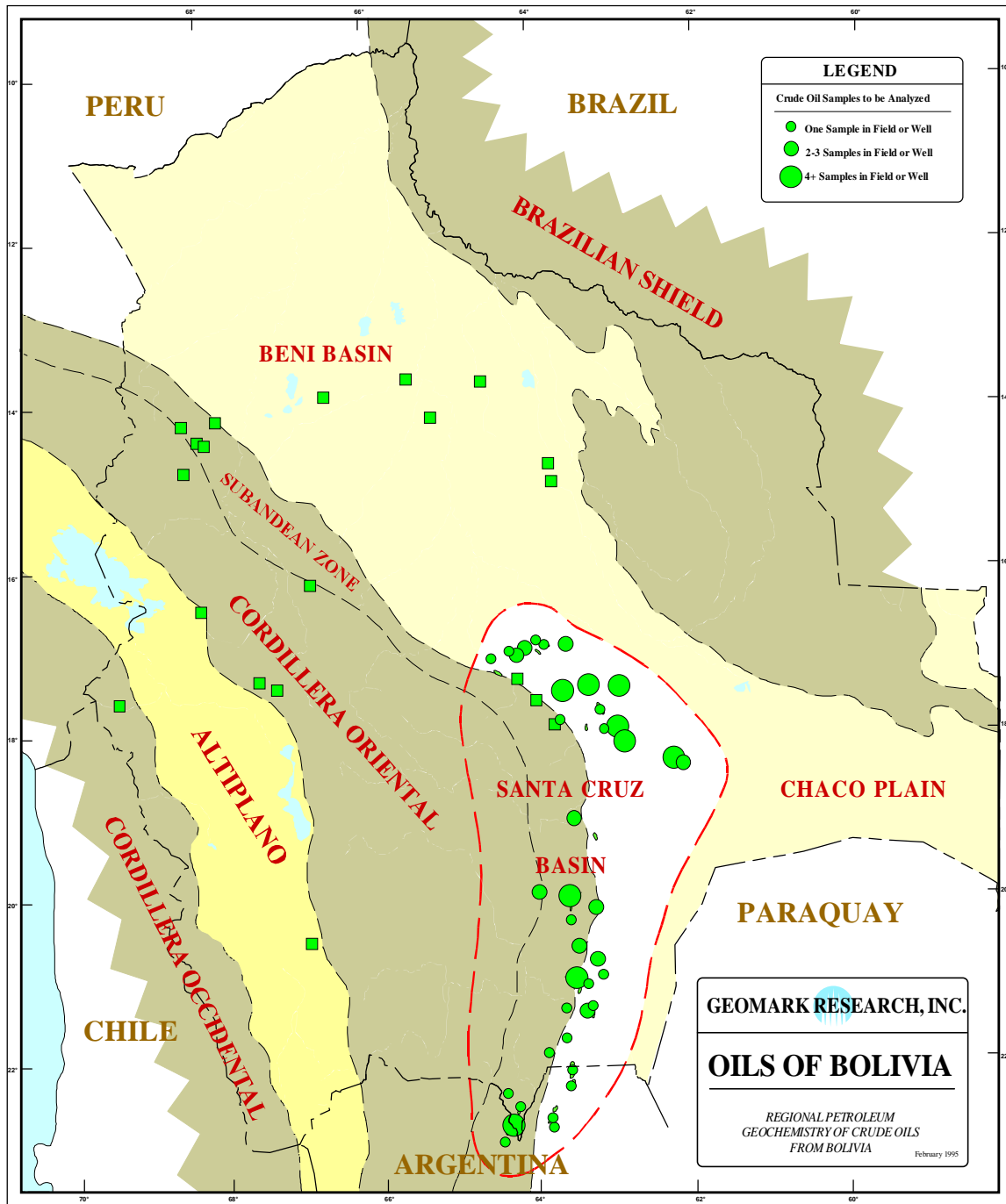


Figure 1. Location map showing distribution of oil samples for this study.

Presentation

Data from the project is organized in an interpretative volume and into three (3) data volumes. The integrated interpretation for the study is preceded by a discussion of the regional setting and summary of oil geochemistry. A detailed report for the oils is presented separately (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
- Stable carbon isotopic composition of C₁₅₊ saturate and aromatic hydrocarbons
- Quantitative GC/MS analysis of C₁₅₊ saturate hydrocarbons for terpane and sterane distributions
- GC/MS of aromatic hydrocarbon fraction

Participation

The complete study is available at a cost of US \$32,500.00.

Timing

This project is complete and available for immediate delivery.

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Appendix A

Samples Analyzed for the Study

Basin	Well	Basin	Well	Basin	Well
Altiplano	Mauri River Seep	Santa Cruz	MGD-15 Ingre	Santa Cruz	Bermijo 23-7
Altiplano	Quebrada "B" Co Seep	Santa Cruz	MGD-13	Santa Cruz	Bermijo 33-8
Altiplano	Quebrada Colorada	Santa Cruz	Pozo SNQ-N-2	Santa Cruz	Camatindi 3-10
Altiplano	Rio Tuichi Seep	Santa Cruz	GRY-X24	Santa Cruz	Buena Vista 6-11
Altiplano	Rio Tuichi Seep	Santa Cruz	INA X-2	Santa Cruz	Camiri 114-12
Altiplano	Esigliamas	Santa Cruz	Azeiro Field	Santa Cruz	Tatarenda 54-13
Altiplano	Coop Aria	Santa Cruz	Monte Grande	Santa Cruz	Tatarenda 2A-14
Altiplano	Rio Kerosene Seep	Santa Cruz	Compotata Remda	Santa Cruz	Caijua X3-17
Altiplano	QDA Seep	Santa Cruz	Tatarenda	Santa Cruz	Churamas X1-18
Altiplano	Condorquina	Santa Cruz	Tatarenda	Santa Cruz	Conchas X1-18
Altiplano	Arroyo Kerosene	Santa Cruz	Tatarenda TTD-33	Santa Cruz	Camatinol X10-20
Altiplano	Rio Enadere	Santa Cruz	Domotarjita	Santa Cruz	Colpa 4-21
Altiplano	Rio Alto Ichilo	Santa Cruz	Monteagudo	Santa Cruz	Colpa 12-22
Altiplano	Qda. Los Lirios	Santa Cruz	Monteagudo	Santa Cruz	Colpa 8C-23
Altiplano	Rio Mauri	Santa Cruz	Caranda 24T-31	Santa Cruz	Colpa 8T-24
Altiplano	Colchani	Santa Cruz	Caranda 34T-32	Santa Cruz	Rio Grande 23-27
Altiplano	Rio Kerosene Seep	Santa Cruz	Caranda 48T-33	Santa Cruz	La Pena 5L-29
Altiplano	Charagua Anti. Seep	Santa Cruz	Caranda 27T-34	Santa Cruz	Rio Grande-15L
Altiplano	Rio Kerosene Seep	Santa Cruz	Caranda 80T-35	Santa Cruz	Caranda-58
Altiplano	Rio Nancy	Santa Cruz	Monte Cristo-2	Santa Cruz	Bermejo-X33
Altiplano	Rio Nancy	Santa Cruz	Monteagudo 13-1	Santa Cruz	Bermejo-X44
Beni	Uchu Piamonas Seep	Santa Cruz	Rio Seco	Santa Cruz	Buena Vista-4
Beni	Caravani Seep	Santa Cruz	Rio Grande-26	Santa Cruz	Camatindi-2
Beni	Alto Quiquibey Seep	Santa Cruz	Toro 7-6	Santa Cruz	Camiri-3
Beni	Cerro Pelado Seep	Santa Cruz	Cambaeti-X3	Santa Cruz	Caranda-1
Beni	Colorado River Seep	Santa Cruz	Yapacani-6	Santa Cruz	Caranda-15
Beni	Flora River Seep	Santa Cruz	Sirari-X1	Santa Cruz	Caranda-17
Beni	Mamuque River Seep	Santa Cruz	Sirari-X1	Santa Cruz	Caranda-2
Beni	Uchu Piamonas Seep	Santa Cruz	H. Suarez-X1	Santa Cruz	Caranda-2
Beni	Yakuma River Seep	Santa Cruz	La Pena-51	Santa Cruz	Caranda-1
Beni	Quiquibey Seep	Santa Cruz	Techi-1	Santa Cruz	Casabel-X2
Beni	Quiquibey Seep	Santa Cruz	Techi-1	Santa Cruz	Colpa-22
Beni	Rio Quiquibey Seep	Santa Cruz	Anticlinal Dev.	Santa Cruz	Huayco-X1
Beni	Upchiamonas Anticline Seep	Santa Cruz	Porvenir (Cond)	Santa Cruz	Monte Cristo-1
Beni	Alto Quiquibey	Santa Cruz	Tita	Santa Cruz	Monteagudo-13
Chaco	Monte Cristo-X2	Santa Cruz	Bordo Alto-1	Santa Cruz	Pozo Ichoa-X1
Chaco	Monte Cristo-X4	Santa Cruz	Quebrada Taquru Seep	Santa Cruz	Ichoa-X1
Chaco	Tita-4	Santa Cruz	Quebrada Cuevo	Santa Cruz	Puerto Ramos-X1
Chaco	Tita-4	Santa Cruz	Espejos-X1	Santa Cruz	San Alberto-3
Chaco	Tita-4	Santa Cruz	Curanada-92T	Santa Cruz	Caigua-3
Chaco	Los Manos-10	Santa Cruz	Curanada-85T	Santa Cruz	Sirari-X1
Madre de Dios	Pando-X1	Santa Cruz	Curanada-89T	Santa Cruz	Sirari-1LL
Santa Cruz	Pozoo Ich-X1	Santa Cruz	Curanada-83T	Santa Cruz	Tatarenda-55
Santa Cruz	Tacobo-X4	Santa Cruz	Qda. Curiche Snia	Santa Cruz	San Juan Del Reai
Santa Cruz	Cambaeti-X3	Santa Cruz	Cambaeti-X3	Santa Cruz	Sirari-6LL
Santa Cruz	La Vertiente-1	Santa Cruz	Monte Cristo-X2	Santa Cruz	Vibora-4LL
Santa Cruz	Nupuco-X1	Santa Cruz	Monteagudo 23-2	Santa Cruz	Tacuru Seep
Santa Cruz	Porvenir 02	Santa Cruz	San Alberto 3-3	Santa Cruz	Bordo Alto-1
Santa Cruz	BJO 33 Tarija	Santa Cruz	Toro-8	Santa Cruz	Cuevo Seep