

# **MIDDLE EAST STUDY PHASE II**

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**REGIONAL PETROLEUM GEOCHEMISTRY  
OF CRUDE OILS, CONDENSATES AND  
SOURCE ROCKS OF THE ARABIAN PLATE**

**GEOMARK  
RESEARCH, INC.**

**PROPOSAL**

## **GEOMARK MIDDLE EAST STUDY PHASE II**

### **REGIONAL PETROLEUM GEOCHEMISTRY OF CRUDE OILS, CONDENSATES AND SOURCE ROCKS OF THE ARABIAN PLATE**

#### **EXECUTIVE SUMMARY**

**GEOMARK RESEARCH** has completed a Phase II assessment of hydrocarbons and source rocks of the Arabian Plate in pursuit of exploration applications indicated by the Phase I Project. Phase II emphasizes source rock analyses on samples provided from Turkey, Syria, Iraq, Jordan, Kuwait, Saudi Arabia, UAE and Yemen.

The oils, condensates and rock samples are being characterized by a detailed analytical program which includes quantitative biomarker analysis of terpanes and steranes and determination of stable carbon isotope composition of both saturate and aromatic hydrocarbon fractions. With this information, as well as bulk compositional data, we accomplished the following:

- Augment the characterization of distinct Oil Families as defined in Phase I and further refine areal distributions.
- Emphasize deeper zone oils and condensates to further clarify the contribution to hydrocarbon pools from older source rocks of the Arabian Plate.
- Increase the number of samples from fields with stacked reservoirs and multiple zones within defined Oil Systems to assess vertical migration.
- Identify the major source rocks contributing to the defined Oil Families by direct fingerprinting of rock extracts.
- Study a suite of oils from several fields in a well defined fill/spill sequence to attempt to determine a geochemical distance from source estimator.
- Prepare Arabian Plate regional isopach maps of Tertiary to Mesozoic intervals for source rock subsidence/generation modeling.

The cost of the study is US \$75,000. Participants are not required to contribute samples.

## INTRODUCTION

The major producing sub-basins of the Arabian Plate currently are estimated to contain 60-65% of the known remaining oil reserves of the world. Gas reserves are less clearly defined but are also present in equally impressive amounts. The world's largest super giant oil fields both on- and offshore are found on the Arabian Plate. Without doubt the oil provinces of the Middle East are in a category of their own resulting from:

- Multiple rich source rock intervals
- Excellent stacked carbonate and clastic reservoirs
- Regional seals
- Variety of structures
- Largely continuous burial history
- Primarily non-destructive tectonics

At the present stage of exploration of Arabian Plate basins the major structures have been largely tested. New plays will focus on low relief structural closures, stratigraphic traps and untested reservoirs in older producing areas. Knowledge of the Plate's source rock distribution, burial history, oil-system related migration, vertical hydrocarbon movement and seal integrity will be crucial in these efforts. The data base of oil analyses and Oil-Systems evaluations provided by GeoMark Middle East Phase I and Phase II projects are of significant value to Arabian Plate exploration efforts.

## SETTING

The Arabian Plate, following a largely siliciclastic early Paleozoic depositional cycle from Permian until late Tertiary time, was one of the most extensive shallow carbonate depositing marine shelves known. Periodic clastic regressive events are documented along the southern and western shield areas in late Triassic and early to Middle Cretaceous time. However, in large measure, the shallow marine character was maintained over the greater part of the Plate. In late Cretaceous time plate collision resulted in over thrusting in the eastern Oman sector and continued interaction led to the main Zagros over thrusting and uplift in late Tertiary time. Uplift and erosion with resulting flush sedimentation produced a thick Upper Cretaceous to Tertiary sedimentary wedge in a developing foredeep fronting the Oman/Zagros/Taurus Orogen.

Extremely rich source rocks were deposited within intracratonic basins which developed at a number of locations over the stable Arabian shelf. Studies have identified source intervals ranging in age from InfraCambrian to the early Tertiary. Particularly important deposits have been identified in the InfraCambrian of South and Central Oman; extensive Silurian shales from North Africa to Iran and including wide areas of the Arabian Plate; Jurassic Oxfordian carbonate sources in Saudi Arabia, UAE, Kuwait and Iraq; Middle Cretaceous marls in UAE, Iran and Iraq; and early Tertiary shales of Oman and Iran.

Other sources are inferred from the GeoMark Phase I studies of Arabian Plate Oils and await further evaluation.

## OBJECTIVES

The Arabian Plate Phase I project substantiated the close inferred relationship of the defined Oil Families to source areas identified in published studies. The importance of understanding the extent of source basins and distance of migration within each oil system was underscored. The **Phase II Study**, by including samples of known source rocks, clarified the genesis of Oil Families by extract analysis of the rocks and comparison to the currently defined oil groupings.

Phase I Studies also demonstrated the importance of vertical migration at many locations on the Arabian Plate. Hydrocarbon pools are present at numerous horizons across the Arabian Basin but the transient nature of many accumulations is revealed by the Oil Family groupings which commonly span several ages of reservoir units. Common source bed origin is indicated by these groupings with vertical migration being one of the most important means of transport. Additional oils, analyzed in **Phase II**, were selected from stacked reservoirs in individual fields or multiple horizons within a single oil system to present evidence of the extent of vertical migration. A thorough knowledge of seal distribution and competence within each system has led to new play concepts based on source distribution, migration latitude and multiple reservoir opportunity.

Phase I analyses indicated the widespread distribution of a Paleozoic source which to date has been poorly tested across much of the Arabian Plate. In Phase I, oils most likely sourced from Silurian shales were identified in Turkey, central Saudi Arabia and Oman in Phase I. Published source rock work from North Africa to Saudi Arabia, Oman and Iran indicates that the Silurian and/or Devonian has been an important contributor to discovered oil pools. **The Phase II Project** analyzed oils and condensates from deep reservoirs from across the Plate and contributes to an expanded understanding of the Paleozoic potential. The InfraCambian source elucidated by these new deep zones has contributions from this oldest known source.

**Phase II** oils, condensates and source rock analyses were further enhanced by the development of a series of Arabian Plate isopachs of critical intervals to demonstrate the general burial history of significant source rock areas.

In summary, the elements and objectives of the Phase II Study were:

### **I - SOURCE ROCK IDENTIFICATION**

Phase I work inferred oil origins from identified source rocks published by various companies (based on crude oil geochemistry). Phase II attempted to directly link oil families defined in Phase I to source rocks by comparing extract analyses of the rocks. Selected high quality source rocks identified by various companies during broader basin studies were used.

### **II - OLDER SOURCE EVALUATION**

The majority of the oils analyzed in Phase I were drawn from the Upper Jurassic to Tertiary reservoirs. A few oils believed to be sourced from the InfraCambrian, and several oils from Oman, Saudi Arabia, and Turkey (most likely from Silurian shales), were of great interest. Many of the oil and condensate samples included in Phase II came from deep reservoirs in an effort to clarify the role of older source rocks in hydrocarbon generation across the Arabian Plate.

### **III - MIGRATION EFFECTS**

The Phase I study showed that specific Oil Families are spatially confined fairly near the limits of the inferred source basins. Another goal of Phase II was the analysis of geochemical parameters considered to be the most sensitive to migration alteration. Once defined, a geochemical distance from source evaluation was estimated for each oil system. Phase I work indicated that the El Haba Field Arab-A sample was included within the Family III group of oils believed to be sourced from the Mesopotamian (Gotnia) Basin and, as such, was probably the example of the greatest migration distance recorded in that study. In Phase II we attempted to evaluate suites of oils from the Minagish Field in Kuwait through the Rimthan, Dibdibah, Suban, War'iah and El Haba Fields in Saudi Arabia as a pilot case of applying geochemical migration distance estimates to analyzed oils.

### **IV - VERTICAL MIGRATION**

Phase I analyses indicated that widespread and important vertical migration has occurred in all of the identified Oil Systems across the Arabian Plate. **Phase II** studies continued the evaluation of this phenomena by adding oils from additional reservoirs from fields with stacked pays and oils from multiple zones in each of the oil systems defined in Phase I. Characterization of the oils from these vertically related series may shed new light on changes occurring during this type migration and the effectiveness of local and regional seals.

### **V - DEPTH OF BURIAL**

In the Phase II study a series of Arabian Plate isopach maps of several intervals from the Upper Jurassic to late Tertiary have been produced to give a measure of the burial history of the several oil system source areas. The maps are regional in nature and allow each participant a means of applying subsidence analysis to the source rock and oil data generated in Phase I and II.

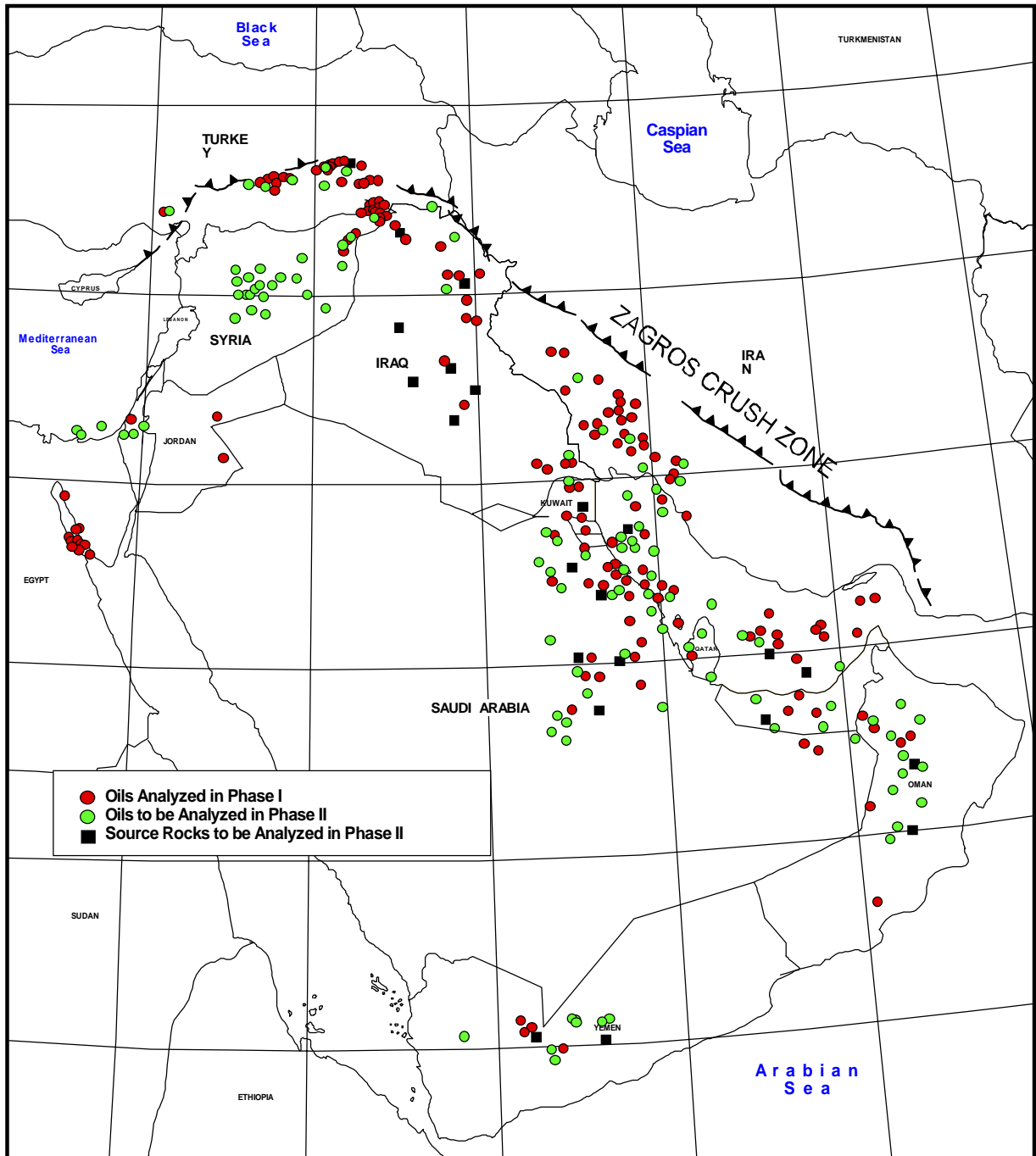


Figure 1. Location map showing oil and source rock samples analyzed for this study.

## **ANALYTICAL PROGRAM**

### **SOURCE ROCK SAMPLES**

The source rock samples were analyzed by the following techniques:

- Lithological Description
- Total Organic Carbon (TOC)
- Rock-Eval Pyrolysis
- Kerogen Maceral Analysis (TAI)
- Vitrinite Reflectance (% Ro)
- Bitumen Analysis (This includes all the analytical procedures listed below for oils, with the exception of API gravity, Ni/V and %S)

### **OIL SAMPLES**

The following techniques were employed on each of the oil samples:

- API Gravity
- % Sulfur
- Nickel/Vanadium concentrations
- C15+ vs. <C15+
- Deasphalting (% Asph)
- Liquid Chromatography (%Sat %Aro %NSO)
- Capillary GC of Whole Crudes
- Stable Carbon Isotopes for both Sat and Aro Hydrocarbon Fractions
- GC/MS of Saturates for Terpane/Sterane Distributions (quantitative)

All results are available in digital form. This includes tabulated data as well as raw gas chromatograms and mass fragmentograms if desired.

## PRESENTATION OF RESULTS

Results of the study are presented in both analytical and interpretive formats to insure that all findings are readily accessible to explorationists and research personnel. All of the analytical data is provided in hard copy and on personal computer disks.

Analytical data are presented within **Regional Data Volumes**, and include the following:

- Source rock data
- Basic Oil Data
  - Physical property oil data
  - Stable carbon isotope data
  - Liquid chromatographic data
- Gas chromatographic results
- GC/MS mass chromatograms

A synthesis and interpretation of all information is presented in a comprehensive **Final Report**. The **Final Report** includes sections for:

- Regional Geology
- Interpretation of Oil Characteristics
- Differentiation of Oil Families
  - Using Multivariate Statistics
- Source Rock Quality Maps
- Inferred Oil/Source Correlations
- Oil Generation and Migration
- Production Histories
- Overall Exploration Potential

**PARTICIPATION**

The cost of the study is US \$75,000.

**TIMING**

The study is completed and available for immediate delivery.

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## APPENDIX A

## Samples Analyzed for this Study

Well	Well	Well	Well	Well	Well	Well
<b>Bahrain</b>	<b>Iran</b>	<b>Israel</b>	<b>Saudi Arabia</b>	<b>Saudi Arabia</b>	<b>Syria</b>	<b>Turkey</b>
Awali-269	Karanj	Heletz	Faridah-1	Hasbah-1	Chibli-101	Yenikoy
Awali-290	Agha Jari-PU1	Heletz	Farhah-1	Hasbah-1	Chibli-101	Sincain
Awali B3-1	Shadegan SG-1	Ashdod-2	Qirdi-2	Lawhah-2	At Tabiyeh-103	Beykan
Awali-379	Ramshir	Heletz-1	Qirdi-2	Marjan-26	Marad-101	Barbes
Awali-475	Masjid-I-Suleiman	<b>Jordan</b>	Qirdi-2	Marjan-26	Jafra-104	Malatepe
Awali-490	Rag-e-Safid PU	Hamzeh-1	Ramlah-2	Marjan-26	Jebel Bishri Seep	Yatir East
Awali-353	Kupal-1	Hamzeh-1	Shaybah	Marjan-26	Al Kadir-1	Katin
Awali-468	Binak PU	Wadi Sirhan-6	Suhul-1	Marjan-29	Souediah-614	Sebyan
Awali-331	Lali-PU8	Wadi Sirhan-4	Tinat-2	Hamur-1	Tel el Ardus	Baysu
Awali	Marun-21	NRA Core Hole-1	Manifa-7	Hamur-1	Al Hail-1	Yesildere
Awali	Gachsaran CH-36	<b>Kuwait</b>	Khursaniyah	Hamur-1	Al Hail-2	Kervan
Al Wassmi-1	Bushgan-1	Raudhatain	Berri-57	Hamur-1	Tishrin-113	Bektas
<b>Egypt</b>	Malah Kuh-1	Sabriya	Fadhili-8	Harqus-1	Jebissa-204	East Yenikoy
Ras Bakr-24	Sarkan-1	Magwa	Ghawar	Harqus-1	Al Hol-105	Selmo
Umm el Yusr-25	Lab-E-Safid-1	Minagish	Ghawar -2	Jana-2	Al Hol-1	Raman
E. Belayim-33	Shahabad-1	Wafra	Abqaiq-84	Jawb-1	Salheih-1	Garzan
W. Belayim-4	Shahabad-1	<b>Oman</b>	Qatif-5	Maghrib-1	Sheikh Suleiman-6	Magrip
Gharib-97	Darbadam-1	Fahud-76	Harmaliyah-1	Maghrib-1	Shedadeh-1	B. Raman
July-16	Soroush	N. Fahud-89	Ghawar-56	Rimthan-1	Arak-1	Celikli
Ramadan 6-13	Doroud	Shibkhah-1	Samin-1	Rimthan	Dbissan-1	
El Morgan-64	Bushire	Natih-55	Sharar-3	El Haba-2	Sfayeh-32	G.Germik
Shuheir Bay-1	Kharg	Saih Nihayda-10	Ghawar	Rimthan-1	Al Kadir-1	Kurtalan
GS-382-1B	Fereidon F-12	Sahmah-1	Ghawar	Rimthan-3	Al Kadir-1	B.Selmo
Ras Budran	Kharg-7	Safah-3X	Berri-57	Rimthan-1	Ash Shaer-5	Silvanka
Amal-6	Resalat	Safah-3X	Berri-7	Rimthan-2	Souedie?	Silvanka
GS277-1	Salman	Safah-7	Berri-133	Didbidbah	Twinan-2	Pasinler Seep
July-1	Hopeco HA-1	Safah-8	Berri-36	Rimthan	Mudawara-1	Cakirbey Seep
El Morgan-1	Hopeco HA-1	Safah-3X	Berri-35	Rimthan	Wadi Abeid-1	Cankiri
El Morgan-1	<b>Iraq</b>	Safah-5	Abqaiq-8	Jaham-3	Sheikh Mansour-2	<b>UAE</b>
Ramadan-1	Luhais-1	Mezoon-1	Qatif-27	Rimthan-1	Al Kadir-1	Bu Hasa
Sidki-1	Rachi-1	Lekhwaier-119	Abu Hadriya-12	Dibdibah-1	Fahdeh-37	Murban/Bab
October A-1	Tuba-1	Haylat al Athl-1	Fadhili-6	Dibdibah-1	Fahdeh-23	Upper Zakum
October A-1	Zubair-1	Marmul	Harmaliyah-1	Suban-1	Akram-1	Lower Zakum
October F-1	Tuba-1	Nimr-113	Safaniya-25	Suban-1	Twinan-11	Umm Shaif
October J-4B	Tuba-1	Sayyala-1	Dammam-7	Suban-1	T. Asfar-2	Abu al Bukhoosh
July-5	Tuba-1	Bahja-1	Ghawar -212	Suban-1	Sfayeh-42	Fateh
Hilal-A2	Kirkuk-117	Amal-05	Tinat-2	Sadawi-2	Houssen-25	Fateh R-1
GS-315 C1	Damir Dagh-1	Marmul-106	Ghawar-52	Wariyah-1	Houssen-3	S.W. Fateh DD-3
Mango-1	Bai Hassan-13	Bukha-2	Berri-26	Dilam	Wahaab-1	Rashid -1
Mango-1	ChemChemal-2	<b>Qatar</b>	Manifa-5	Hawtah-1	Twinan-4	Saleh
Mango-1	Pulkhana-5	Dukhan-54	Manifa-17	Nuayyim-5	Dbissan-8	Ajman-2
Mango-1	Gilabat-1	Dukhan-40	Ghawar-196	Hazmiyah-1	<b>Turkey</b>	Sajaa S7-2
Tineh-1	Injana-5	Idd-al-Shargi	Sharar-1	Raghib-1	Camurlu	Al Owaid S7-7
Tineh-1	Kifl-1	Maydan Mahzan	Sharar-1	<b>Syria</b>	G. Dincer	Margham-1
<b>Iran</b>	Bai Hassan-13	Idd El Shargi-16	Sharar-1	Babasi-3	B. Kozluca	Al Awir-1
Cheshmeh Kush-2	Kirkuk-130	Idd El Shargi-19	Jauf-10	Derik-1	Kahta	<b>Yemen</b>
Karun-1	Kirkuk-131	Idd El Shargi-24S	Jauf-10	Al Hol-1	Cemberlitas	Sunah-1
Mulla Sani-2	Alan-2	<b>Saudi Arabia</b>	Jauf-10	Jebissa-207	Adiyaman	Hemiar-1
Susangard-1	Alan-1	Bakr-1	Jubah-1	Leilak	West Firat	Camaal-4
Ab Teymur-1	Taq Taq-3	Jaladi-9	Safaniya-124	Naour-1	Karakus	Sarar-1X
Ahwaz PU2	Zakho Seep	Abu Hadriya-1	Kurayn-1	Oudeh-108	Molcabir	Sharmah-1X
Marun-28	Sari Sati Seep	Khurais-17	Abu Sa'fah	Oudeh-111	Akpinar	Ayad
Kupal-3	Qandil Bridge Seep	Abu Jifan-1	Maharah-1	Rumelan-35	Cukurtas	Alif
Naft Safid-PU9	Taq Taq-3	Qirdi-1	Kurayn-1	Rumelan-106	Bulgurdag	Azal-1
Par-E-Siah-1	Fallujah-1	Khurais	Maharah-1	Souedie-403	Bulgurdag	Seep
Haft Kel-PU1	<b>Israel</b>	Khurais	Safaniya-89	Saida-6	District 5	Shabwa-1
Pazanan-PU1	Gurim-4	Bakr-1	Lawhah-2	Tishrin-24	Kurkan	Shabwa-2
Gachsaran-PU3	Tauk Tamru-1r	Abu Jifan-23	Lawhah	Tishrin-24	Sahaban	Shabwa-2
Bibi Hakimeh-PU8	Ziv-1	Qirdi-2	Safaniya	Ullyan-20	S. Sahaban	Wadi Bana
Kilur Karim-1	Yam-2	Faridah-1	Hasbah-1	Zarabeh-6	Kayakoy	
Karanj	Heletz	Abu Jifan-23	Safaniya	Souedie	W. Kayakoy	