

# **ZAGROS FOLD BELT OIL STUDY**

**PETROLEUM GEOCHEMISTRY OF CRUDE OILS  
FROM THE GREATER ZAGROS FOLD BELT  
TREND TURKEY, SYRIA, IRAQ, IRAN,  
SAUDI ARABIA, AND UAE**

**GEOMARK**

**A PROPOSAL**

## **ZAGROS FOLD BELT OIL STUDY**

### **PETROLEUM GEOCHEMISTRY OF CRUDE OILS FROM THE GREATER ZAGROS FOLD BELT TREND**

#### **EXECUTIVE SUMMARY**

GEOMARK RESEARCH has performed a regional assessment of the Zagros Fold Belt of the Arabian Plate by geochemically analyzing a suite of 312 crude oil samples listed in the Appendix. Each oil sample has been characterized by a detailed analytical program that includes bulk compositional data, quantitative biomarker analysis of terpanes and steranes, distribution of aromatic biomarkers, and determination of stable carbon isotope composition of saturate and aromatic hydrocarbon fractions. By using the oil data in conjunction with cluster and principal component analyses, the following has been accomplished:

- Determine the number of genetically distinct oil families reservoired along the entire Zagros Belt.
- Map the stratigraphic and geographic distribution of the oil families and degree of mixing. Compare families along the Belt and distinguish areas with single oil families (single sources) from those with multiple oil families (multiple sources).
- Utilize geochemical characteristics of the oil families to deduce variations in source depositional facies, thermal maturity level, and preservation.
- Determine the most likely source unit(s) in each region by comparing the distribution of oil families and their inferred source facies with regional stratigraphy, burial history, and available source rock data.
- Estimate migration directions and pathways by comparing oil family distributions and mixing patterns distributions with the location of known depocenters.
- Utilize the geographic, stratigraphic, and structural distribution of source rocks and genetically related oils to identify, map, and rank the petroleum systems.
- Evaluate the effects of secondary oil alterations (migration, biodegradation, etc.) on oil composition, producibility and economic value.

All of the analytical data generated from the oils is presently available in digital form. An interpretive report is completed and available for delivery.

The cost of the study is US \$37,500.

## **ZAGROS FOLD BELT OIL STUDY**

### **PETROLEUM GEOCHEMISTRY OF CRUDE OILS FROM THE GREATER ZAGROS FOLD BELT TREND**

#### **INTRODUCTION**

The Zagros Hydrocarbon Province borders the northern and northwestern Arabian Plate. Conditions for hydrocarbon accumulation occurred on the Arabian plate to the southwest of the Zagros. Subsequent deformation along this plate margin modified but did not reduce the occurrence of hydrocarbons along the deformed Zagros belt. The early Paleozoic history of this province was dominated by clastics. The deep geology is poorly understood but the crucial potential occurrence of Silurian source rock and the relationship of this Silurian shale source to gas resources in the Zagros makes the results of the geochemistry of this suite of samples particularly important.

Carbonates dominate the reservoirs of the Mesozoic stable platform history of the Zagros. Multiple potential source rock intervals (Triassic, Middle Jurassic, Upper Jurassic, lower Cretaceous, and middle Cretaceous) with discontinuous facies resulting in the combination of high structural relief and discontinuous facies relationships give further importance to the results of the geochemistry of these samples.

Stratigraphic facies beginning from the late Cretaceous and through the Cenozoic are complicated by the concurrent deformation of the Zagros event. Multiple potential source rock intervals (late Cretaceous and Paleogene) of both carbonate and detrital lithology may be either immature, mature, or even over-mature. These source rock intervals may be discontinuous. These relationships demand the geochemical results from these samples.

Large areas of the Zagros province have not been explored with the advantage of up-to-date technology. The combination of the anticipation of large resources, significant political risk, and the high entry costs create a need for careful understanding of exploration and production risk.

This regional report fills in some of the gaps in our knowledge of hydrocarbon systems of the Zagros Province. Refinements to the definition and description of the petroleum systems of region contributes to the more efficient development of existing plays, and offer the possibility for identification of unknown or underdeveloped opportunities. Detailed, data-based appreciation of petroleum systems is as essential in exploration as is knowledge of structural and stratigraphic relationships. And, the resulting study also serves as base line study for production engineers.

## TECHNICAL PROGRAM

GeoMark has assembled a collection of three hundred twelve (312) crude oil samples from along the entire length of the Zagros Fold Belt. Ninety-seven (97) oils are new samples from Iran not previously analyzed by GeoMark. The sample locations are shown in **Figure 1**, and listed in the **Appendix** at the back of this proposal. Each of these samples was analyzed using the analytical program discussed later in this proposal. In producing the Interpretive Volume, we integrated the geochemical results with regional and local geology to assess age and type of source rocks, thermal maturity trends, degree of petroleum system mixing, and oil quality.

Specifically, we attempted the following:

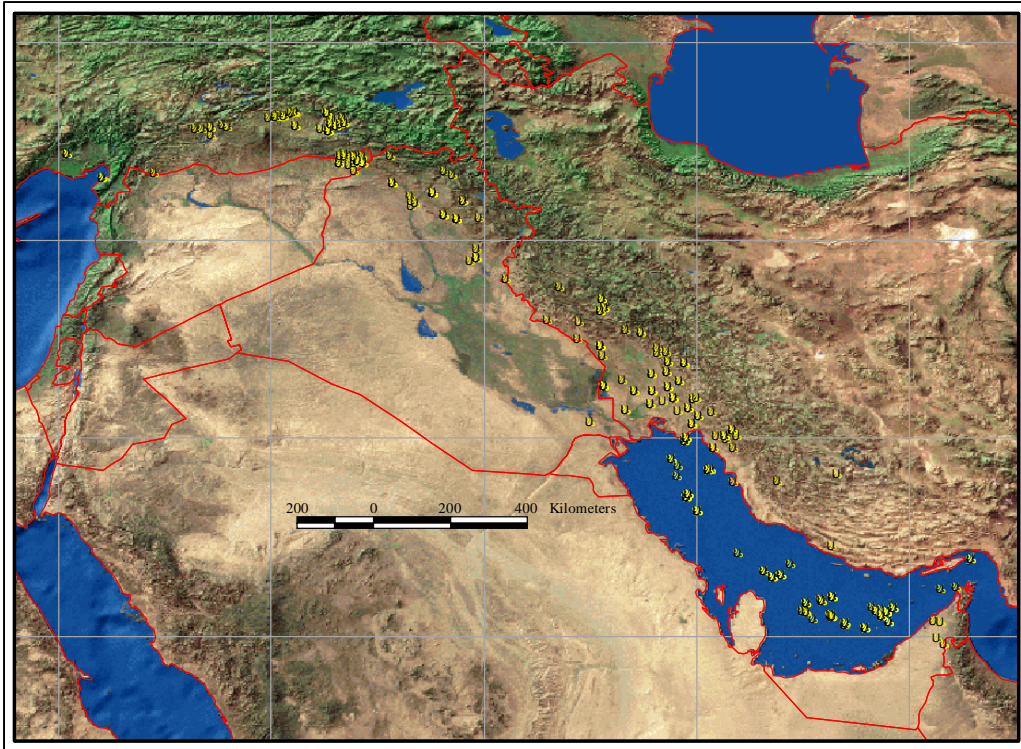
- Describe the Geologic Context of the geochemical samples.
- Determine the number of distinct oil families represented along the fold belt and predict depositional environments of corresponding source rocks.
- Estimate the source rock ages of these various oil families.
- Establish the degree of mixing from Silurian/Jurassic/Cretaceous/Tertiary sources.
- Compare the Zagros oils to the classic Jurassic carbonate-sourced oils to the south.
- Determine the thermal maturity range and trend within each of the oil families.
- Synthesize the geology and geochemistry with the objective of providing an interpretive background for the elements of the hydrocarbon systems of the Zagros

## METHODOLOGY AND EXPLORATION APPLICATIONS

A regional oil study is an excellent way of identifying, evaluating and comparing the various petroleum systems that exist in the region. The regional petroleum systems within the study area have been evaluated by first determining the number of effective source units within a region by establishing the number of compositionally distinct oil families using multivariate statistical techniques. The source facies of each oil family was then deduced from the oil geochemistry. Conclusions were reached regarding source lithology, anoxicity, salinity, organic input (marine, non-marine or marginal marine) and thermal maturity using a variety of parameters based on molecular and bulk composition. In most cases it was possible to bracket the age of the source from the oil data.

The predicted source facies were compared to the known stratigraphy, sedimentology, and burial history of each basin to determine the most probable source units. The aerial extent and burial depth of the source units were then combined with the geographic and stratigraphic distributions of their associated oil families and degree of mixing to determine the location of the various oil generating depocenters and the most probable migration pathways.

The relative potential of the petroleum systems in each basin were ranked by incorporating geological information on source thickness and sedimentary environment, and source potential of the various source units. The results were evaluated in an effort to identify areas where particular petroleum systems exist but have been overlooked or poorly tested.



**Figure 1.** Map showing location of oil and seep samples analyzed for this study.

### ANALYTICAL PROGRAM

The following techniques were performed on each sample and form the analytical database of this report/project:

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

## PRESENTATION OF RESULTS

Results of the study are presented in both analytical and interpretive formats to insure all findings are accessible to explorationists and research personnel. Analytical data are presented within an **Access Database File** on a CD or over the **Internet**, and include the following:

- physical property data
- liquid chromatographic data
- gas chromatographic results
- stable carbon isotope data
- GC/MS mass chromatograms
- key biomarker data

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

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

## PARTICIPATION

The cost of the study is US \$37,500.

## TIMING

The report is completed and available for delivery.

## FOR ADDITIONAL INFORMATION CONTACT:

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## Appendix Samples Analyzed for the Zagros Study

SampleID	Country	USGS Province	Field	Well	U. Depth (ft)	L. Depth (ft)	Res. Age	Formation
BA0012	Bahrain	Mesopotamian Foredeep	Al Wassmi	1	5420		LowerCretaceous	Yamama
IN0001	Iran	Zagros Fold Belt	Malah Kuh	MK-1	1500		Middle Cretaceous	Sarvak
IN0002	Iran	Zagros Fold Belt	Sarkhan	SK-1	3700		MiddleCretaceous	Sarvak
IN0003	Iran	Zagros Fold Belt	Lab-E-Safid	LS-1	5000		Oligocene	Asmari
IN0004	Iran	Zagros Fold Belt	Cheshmeh Kush	CK-2	10500		Oligocene	Asmari
IN0005	Iran	Zagros Fold Belt	Karun	KN-1	10500		Oligocene	Asmari
IN0006	Iran	Zagros Fold Belt	Mulla Sani	MS-2	12500		Oligocene	Asmari
IN0007	Iran	Mesopotamian Foredeep	Susangard	SD-1	7750		Oligocene	Asmari
IN0008	Iran	Mesopotamian Foredeep	Ab-e-Teymur	AT-1	10700		Middle Cretaceous	Sarvak
IN0009	Iran	Zagros Fold Belt	Ahwaz	PU2	7500		Oligocene	Asmari
IN0010	Iran	Zagros Fold Belt	Marun	MN-28	7200		Oligocene	Asmari
IN0011	Iran	Zagros Fold Belt	Kupal	KL-3	13500		Middle Cretaceous	Bangestan
IN0012	Iran	Zagros Fold Belt	Naft Safid	PU9	2500		Oligocene	Asmari
IN0013	Iran	Zagros Fold Belt	Par-E-Siah	PS-1	4250		Oligocene	Asmari
IN0014	Iran	Zagros Fold Belt	Haft Kel	PU1	1000		Oligocene	Asmari
IN0015	Iran	Zagros Fold Belt	Pazanan	PU1	4750		Oligocene	Asmari
IN0016	Iran	Zagros Fold Belt	Gachsaran	PU3	450		Oligocene	Asmari
IN0017	Iran	Zagros Fold Belt	Bibi Hakimeh	PU8	1100		Oligocene	Asmari
IN0018	Iran	Zagros Fold Belt	Kilur Karim	KK-1	6500		MiddleCretaceous	Bangestan
IN0019	Iran	Mesopotamian Foredeep	Sorush (Cyrus)	2	7000		Middle Cretaceous	Burgan
IN0020	Iran	Mesopotamian Foredeep	Doroud (Darius)		10500		LowerCretaceous	Ratawi
IN0021	Iran	Zagros Fold Belt	Bushire	3	11000		Lower Cretaceous	Khami
IN0022	Iran	Rub Al Khali Basin	Resalat (Rostam)		7200		LowerCretaceous	Shu Aiba
IN0023	Iran	Rub Al Khali Basin	Salman (Sassan)	1	7600		UpperJurassic	Arab
IN0024	Iran	Zagros Fold Belt	Karanj	1	4000		Oligocene	Asmari
IN0025	Iran	Zagros Fold Belt	Karanj	1	5500		Miocene	
IN0026	Iran	Zagros Fold Belt	Agha Jari	PU1	3700		Oligocene	Asmari
IN0027	Iran	Zagros Fold Belt	Shadegan	SG-1	9500		Oligocene	Asmari
IN0028	Iran	Zagros Fold Belt	Ramshir	1	9000		Oligocene	Asmari
IN0029	Iran	Mesopotamian Foredeep	Kharg (A)				LowerCretaceous	Ratawi
IN0030	Iran	Zagros Fold Belt	Masjid-I-Suleiman(MIS)	1	300		Oligocene	Asmari
IN0031	Iran	Mesopotamian Foredeep	Foroozan	Fereidoon 12	3845		MiddleCretaceous	Burgan
IN0032	Iran	Zagros Fold Belt	Rag-e-Safid	PU-1	4500		Oligocene	Asmari
IN0033	Iran	Mesopotamian Foredeep	Kharg	7			Lower Cretaceous	Khami
IN0034	Iran	Zagros Fold Belt	Kupal	1	10000		Oligocene	Asmari
IN0035	Iran	Zagros Fold Belt	Bushgan	1	2000		Oligocene	Asmari
IN0036	Iran	Zagros Fold Belt	Binak	1	10500		Middle Cretaceous	Bangestan
IN0037	Iran	Zagros Fold Belt	Lali	PU 9	3000		Oligocene	Asmari
IN0038	Iran	Zagros Fold Belt	Marun	MN-21	8000		MiddleCretaceous	Bangestan
IN0039	Iran	Zagros Fold Belt	Gachsaran	CH-36	4500		MiddleCretaceous	Bangestan
IN0040	Iran	Zagros Fold Belt	Shahabad	1	8778	8798	MiddleCretaceous	Sarvak
IN0041	Iran	Zagros Fold Belt	Hopeco	HA-1	14940	15210	MiddleCretaceous	Sarvak
IN0042	Iran	Zagros Fold Belt	Hopeco	HA-1	14188	14279	MiddleCretaceous	Sarvak
IN0043	Iran	Zagros Fold Belt	Shahabad	1	7710	7845	UpperCretaceous	Ilam
IN0044	Iran	Zagros Fold Belt	Darbadam	1	1417		UpperCretaceous	Gurpi
IN0045	Iran	Rub Al Khali Basin					Lower Cretaceous	Shu Aiba
IN0046	Iran	Rub Al Khali Basin	Reshadat		7550		Upper Jurassic	Arab
IN0050	Iran	Zagros Fold Belt	Agha-Jari		8989	10997	Middle Cretaceous	Bangestan
IN0051	Iran	Mesopotamian Foredeep	Mansuri		7198	8300	Oligocene	Asmari
IN0052	Iran	Zagros Fold Belt	Bibi-Hakimeh		10990	11318	Oligocene	Asmari
IN0053	Iran	Zagros Fold Belt	Marun		7808	9186	Middle Cretaceous	Bangestan
IN0054	Iran	Zagros Fold Belt	Magid-1-Soleiman		5380	8202	Oligocene	Asmari
IN0055	Iran	Zagros Fold Belt	Pazanan		6499	7299	Oligocene	Asmari
IN0056	Iran	Zagros Fold Belt	Paydar		9629	10000	Oligocene	Asmari
IN0057	Iran	Zagros Fold Belt	Ramin		12496	12696	Oligocene	Asmari
IN0058	Iran	Zagros Fold Belt	Binak		5997	6797	Middle Cretaceous	Bangestan
IN0059	Iran	Zagros Fold Belt	Naft-Safid		5777	6499	Oligocene	Asmari
IN0060	Iran	Zagros Fold Belt	Masurabad		7677	8530	Oligocene	Asmari
IN0061	Iran	Mesopotamian Foredeep	Azedegan	#3	11811	12204	Lower Cretaceous	Daryian
IN0062	Iran	Mesopotamian Foredeep	Darguin	#3	12270	12631	Lower Cretaceous	Gadvan
IN0063	Iran	Zagros Fold Belt	Marun	#222	15223	15419	Lower Cretaceous	Gadvan
IN0064	Iran	Zagros Fold Belt	Karanj		20669	22637	Oligocene	Asmari
IN0065	Iran		Kushk		13287	14501	Lower Cretaceous	Fahliyan
IN0066	Iran	Mesopotamian Foredeep	Azedegan	#3	12434	12926	Lower Cretaceous	Gadvan
IN0067	Iran	Zagros Fold Belt	Siak-Makan		13336	13897	Middle Cretaceous	Bangestan
IN0068	Iran	Zagros Fold Belt	Haft-Kel		7677	9186	Oligocene	Asmari
IN0069	Iran	Zagros Fold Belt	Pareh Siah		6948	7496	Oligocene	Asmari
IN0070	Iran	Zagros Fold Belt	Changuleh		12296	12696	Middle Cretaceous	Bangestan
IN0071	Iran	Zagros Fold Belt	Cheshmeh-Khush		13615	14107	Middle Cretaceous	Bangestan
IN0072	Iran	Zagros Fold Belt	Zeloi		11318	11811	Oligocene	Asmari
IN0073	Iran	Mesopotamian Foredeep	Mansuri		10898	11499	Middle Cretaceous	Bangestan
IN0074	Iran	Zagros Fold Belt	Parsi(Paris)		4498	5196	Oligocene	Asmari

## Appendix Samples Analyzed for the Zagros Study

SampleID	Country	USGS Province	Field	Well	U. Depth (ft)	L. Depth (ft)	Res. Age	Formation
IN0075	Iran	Zagros Fold Belt	Agha-Jari		5898	6998	Oligocene	Asmari
IN0076	Iran	Zagros Fold Belt	Kupal		11154	11998	Oligocene	Asmari
IN0077	Iran	Zagros Fold Belt	Bibi-Hakimeh		6499	7398	Middle Cretaceous	Bangestan
IN0078	Iran		Kushk		11745	11975	Lower Cretaceous	Daryian
IN0079	Iran		Kushk		7837	7867		Tarbur
IN0080	Iran		Mand		1312	1476	Oligocene	Asmari
IN0081	Iran		Mand		4002	4199	Middle Cretaceous	Sarvak (Mishrif)
IN0082	Iran		Kushk		12559	12591	Lower Cretaceous	Gadvan
IN0083	Iran	Mesopotamian Foredeep	Azadegan	#1	9448	9488	Middle Cretaceous	Sarvak (Mishrif)
IN0084	Iran	Zagros Fold Belt	Lab-Safid		8202	8858	Oligocene	Asmari
IN0085	Iran	Zagros Fold Belt	Chesme-Khush		10826	11318	Oligocene	Asmari
IN0086	Iran	Zagros Fold Belt	Ahwaz		8530	9514	Oligocene	Asmari
IN0087	Iran	Zagros Fold Belt	Ahwaz		11975	12467	Middle Cretaceous	Bangestan
IN0088	Iran	Zagros Fold Belt	Sarvestan		9186	9842	Middle Cretaceous	Sarvak (Mishrif)
IN0089	Iran	Zagros Fold Belt	Gachsaran		6233	9186	Middle Cretaceous	Bangestan
IN0090	Iran	Zagros Fold Belt	Gachsaran		10170	11154	Oligocene	Asmari
IN0091	Iran	Mesopotamian Foredeep	Ab-Teymur		11318	11811	Middle Cretaceous	Bangestan
IN0092	Iran	Zagros Fold Belt	Marun		7808	8858	Oligocene	Asmari
IN0093	Iran	Zagros Fold Belt	Qaleh-Nar		9514	10170	Oligocene	Asmari
IN0094	Iran	Zagros Fold Belt	Sarkan		5085	5249	Middle Cretaceous	Sarvak (Mishrif)
IN0095	Iran	Zagros Fold Belt	Maleh-Kuh		4593	4855	Middle Cretaceous	Sarvak (Mishrif)
IN0096	Iran	Zagros Fold Belt	Dehluran		12795	13451	Middle Cretaceous	Sarvak (Mishrif)
IN0097	Iran	Zagros Fold Belt	Rag-Safid		5577	6069	Oligocene	Asmari
IN0098	Iran	Zagros Fold Belt	Rag-Safid		8202	8858	Middle Cretaceous	Sarvak (Mishrif)
IN0099	Iran	Zagros Fold Belt	Changuleh	#2	16131	16197	Lower Cretaceous	Fahilyan
IN0100	Iran	Zagros Fold Belt	Changuleh	#2	17388	17486		Sum
IN0101	Iran	Mesopotamian Foredeep	Darquain	#3	14786	14806	Lower Cretaceous	Fahilyan
IN0102	Iran	Zagros Fold Belt	Naft-Shar		3215	3608	Oligocene	Asmari
IN0103	Iran	Mesopotamian Foredeep	Azadegan	#1	8038	8074	Upper Cretaceous	Gurpi
IN0104	Iran	Mesopotamian Foredeep	Azadegan	#2	12417	12637	Lower Cretaceous	Gadvan
IN0105	Iran	Mesopotamian Foredeep	Azadegan	#2	9242	9340	Middle Cretaceous	Sarvak (Mishrif)
IN0106	Iran		Hossinieh	#1	9019	9061	Middle Cretaceous	Sarvak (Mishrif)
IN0107	Iran	Zagros Fold Belt	Shor		10498	10662	Oligocene	Asmari
IN0108	Iran	Zagros Fold Belt	Chilingar		10170	11154		Sum
IN0109	Iran	Rub Al Khali Basin	Salman		8202	8858	Upper Jurassic	Arab D (Sm)
IN0110	Iran	Rub Al Khali Basin	Salman		5905	5980	Lower Cretaceous	Gadvan (Buwaiba)
IN0111	Iran	Rub Al Khali Basin	Salman		7591	7874	Upper Jurassic	Arab A (Sm)
IN0112	Iran	Rub Al Khali Basin	Reshadat		4921	5347	Lower Cretaceous	Shu'aba (Dr)
IN0113	Iran	Rub Al Khali Basin	Reshadat		4166	4199	Middle Cretaceous	Sarvak (Mishrif)
IN0114	Iran	Rub Al Khali Basin	Resalat		5413	5807	Lower Cretaceous	Shu'aba (Dr)
IN0115	Iran	Rub Al Khali Basin	Resalat		7529	7611	Upper Jurassic	Arab C
IN0116	Iran	Rub Al Khali Basin	Resalat		4461	4757	Middle Cretaceous	Sarvak (Mishrif)
IN0117	Iran	Qatar Arch	South Pars		3398	3805	Lower Cretaceous	Daryian
IN0118	Iran	Mesopotamian Foredeep	Now Rouz		7473	8103	Middle Cretaceous	Nahr-Umr (KZ)
IN0119	Iran	Mesopotamian Foredeep	Now Rouz		8136	8530	Lower Cretaceous	Daryian
IN0120	Iran	Mesopotamian Foredeep	Bahregan		9251	9399	Middle Cretaceous	Sarvak (Mishrif)
IN0121	Iran	Mesopotamian Foredeep	Bahregan		6938	7611	Oligocene	Asmari
IN0122	Iran	Mesopotamian Foredeep	Foroozan		7178	7283	Lower Cretaceous	Shu'aba (Dr)
IN0123	Iran	Mesopotamian Foredeep	Foroozan		6748	6807	Middle Cretaceous	Burgan B (KZ)
IN0124	Iran	Mesopotamian Foredeep	Foroozan		6807	7178	Middle Cretaceous	Burgan A
IN0125	Iran	Mesopotamian Foredeep	Hendijan		6348	10269	Middle Cretaceous	Sarvak (Mishrif)
IN0126	Iran	Mesopotamian Foredeep	Hendijan		10656	10925	Middle Cretaceous	Nahr-Umr (KZ)
IN0127	Iran	Mesopotamian Foredeep	Hendijan		7513	7808	Lower Miocene	Ghar
IN0128	Iran	Rub Al Khali Basin	Sirri S		7808	7939	Middle Cretaceous	Sarvak (Mishrif)
IN0129	Iran	Rub Al Khali Basin	Sirri E		9639	9855	Middle Cretaceous	Sarvak (Mishrif)
IN0130	Iran	Rub Al Khali Basin	Sirri D		8120	8431	Middle Cretaceous	Sarvak (Mishrif)
IN0131	Iran	Rub Al Khali Basin	Sirri A		6541	6850	Upper Cretaceous	Illam
IN0132	Iran	Rub Al Khali Basin	Sirri E		9363	9580	Middle Cretaceous	Nahr-Umr (KZ)
IN0133	Iran	Mesopotamian Foredeep	Abouzar		2595	3100	Lower Miocene	Ghar
IN0134	Iran	Mesopotamian Foredeep	Doround (Kharg)		10761	12335	Lower Cretaceous	Yamama
IN0135	Iran	Mesopotamian Foredeep	Doround (Kharg)		13123	13877	Lower Cretaceous	Manifa
IN0136	Iran	Mesopotamian Foredeep	Foroozan		8379	9055	Lower Cretaceous	Yamama
IN0137	Iran		Arask (Ghadir)	#1	12238	12467	Lower Cretaceous	Gadvan
IN0138	Iran		Tunbe	#2	10974	11272	Upper Cretaceous	Tusar/Illam
IN0139	Iran		Hava (Homa)	#1			Upper Permian	U. Dalan
IN0140	Iran	Rub Al Khali Basin	Salman (SK1)	#1			Upper Permian	U. Dalan
IN0141	Iran	Zagros Fold Belt	Tabnak	#1			Upper Permian	U. Dalan
IN0142	Iran	Zagros Fold Belt	Samand	#1			Upper Permian	U. Dalan
IQ0001	Iraq	Zagros Fold Belt	Alan	2	7900	8090	Triassic	Kurra Chine
IQ0002	Iraq	Zagros Fold Belt	Alan	1	9044	9230	Triassic	Kurra Chine
IQ0003	Iraq	Zagros Fold Belt	Kirkuk	117	6880		Middle Cretaceous	Quamchuqa
IQ0004	Iraq	Zagros Fold Belt	Damir Dagh	1	5217	5272	Upper Cretaceous	Shiranish

## Appendix Samples Analyzed for the Zagros Study

SampleID	Country	USGS Province	Field	Well	U. Depth (ft)	L. Depth (ft)	Res. Age	Formation
IQ0005	Iraq	Zagros Fold Belt	Bai Hassan	13	4332		UpperCretaceous	Shiranish
IQ0006	Iraq	Zagros Fold Belt	ChemChemal	2	6116		UpperCretaceous	Shiranish
IQ0007	Iraq	Zagros Fold Belt	Pulkhana	5	5415		UpperCretaceous	Shiranish
IQ0009	Iraq	Zagros Fold Belt	Gilabat	1	4975		Miocene	Upper Fars
IQ0010	Iraq	Zagros Fold Belt	Injana	5	10422		MiddleCretaceous	Mishrif
IQ0019	Iraq	Zagros Fold Belt	Bai Hassan	13	5306	5430	MiddleCretaceous	Quamchuqa/Doka
IQ0020	Iraq	Zagros Fold Belt	Kirkuk	130	3516		UpperCretaceous	Kometan
IQ0021	Iraq	Zagros Fold Belt	Kirkuk	131	3952	4057	MiddleCretaceous	Quamchuqa
IQ0022	Iraq	Zagros Fold Belt	Taq Taq	3	6000		Turonian	Kometan
IQ0023	Iraq	Zagros Fold Belt	Zakho Seep					
IQ0024	Iraq	Zagros Fold Belt	Sari Sati Seep	Oil Sand				
IQ0025	Iraq	Zagros Fold Belt	Qandil Bridge	Asphalt Seams				
IQ0026	Iraq	Zagros Fold Belt	Taq Taq	3	6300		Turonian	Kometan
IQ0027	Iraq	Zagros Fold Belt	Alan (Ain Zalah)	1	9044	9230	Triassic	Kurra Chine
IQ0030	Iraq	Zagros Fold Belt	Bai Hassan	13	5378	6497	Cretaceous	Quamchuga
IQ0032	Iraq	Zagros Fold Belt	Demir Dagh (Kirkuk)	1	5200		Maastrichtian	Shiranish
IQ0033	Iraq	Zagros Fold Belt	Demir Dagh (Kirkuk)	1	5132	5170	Maastrichtian	Shiranish
IQ0034	Iraq	Zagros Fold Belt	Demir Dagh (Kirkuk)	1	5132	5250	Maastrichtian	Shiranish
IQ0035	Iraq	Zagros Fold Belt	Demir Dagh (Kirkuk)	1	5132	5252	Maastrichtian	Shiranish
IQ0036	Iraq	Zagros Fold Belt	Demir Dagh (Kirkuk)	1	5172	5200	Maastrichtian	Shiranish
IQ0038	Iraq	Zagros Fold Belt	Gilabat (Kirkuk)	1	4965	4985	Tertiary	Fars
IQ0039	Iraq	Zagros Fold Belt	Gilabat (Kirkuk)	2	4981	4997	Tertiary	Fars
IQ0042	Iraq	Zagros Fold Belt	Kirkuk	130	4401		Cretaceous	Quamchuga
IQ0044	Iraq	Zagros Fold Belt	Kirkuk	1	1200		Oligocene	
IQ0045	Iraq	Mesopotamian Foredeep	Tuba	1	10640	10660	LowerCretaceous	Zubair
IQ0048	Iraq	Zagros Fold Belt	Hammam Al-Aliel	Seep				
IQ0049	Iraq	Zagros Fold Belt	Qaiara	Seep				
IQ0050	Iraq	Zagros Fold Belt	Mishraq	Seep				
IQ0051	Iraq	Zagros Fold Belt	Al Fattha	Seep				
OM0011	Oman	Rub Al Khali Basin	Bukha	2	3494		LowerCretaceous	Lekhwair
QR0003	Qatar	Rub Al Khali Basin	Maydan Mahzan		6800		Upper Jurassic	Arab D
QR0008	Qatar	Qatar Arch	Al Shaheen	1	3320		Middle Cretaceous	Nahr Umr
QR0009	Qatar	Qatar Arch	Al Shaheen	1	3500		Lower Cretaceous	Shu'aiba
QR0010	Qatar	Qatar Arch	Al Shaheen	1	3000		Lower Cretaceous	Kharai B
QR0011	Qatar	Qatar Arch	Al Rayyan	1	4620		Lower Cretaceous	Sulaiy
QR0012	Qatar	Qatar Arch	Al Rayyan	1	4600		Upper Jurassic	Arab C
QR0013	Qatar	Rub Al Khali Basin	Bul Hanine	18	7400		Upper Jurassic	Arab D
QR0014	Qatar	Rub Al Khali Basin					Portlandia	
QR0015	Qatar	Rub Al Khali Basin					Middle Cretaceous	Natih A
QR0018	Qatar	Rub Al Khali Basin	Maydan Mahzan		6500		Upper Jurassic	Arab D
QR0019	Qatar	Rub Al Khali Basin		269				Arab D
QR0020	Qatar	Rub Al Khali Basin	Hauddad	290				
QR0021	Qatar	Qatar Arch	North Dome	NFR-1 DST6			Triassic	K-2
QR0022	Qatar	Qatar Arch	North Dome	NFR-1 DST5			Triassic	K-3
QR0023	Qatar	Qatar Arch	North Dome	NFR-1 DST7			Triassic	K
QR0024	Qatar	Qatar Arch	North Dome	NFR-1 DST2			Triassic	K-4
SA0083	Saudi Arabia	Mesopotamian Foredeep	Hasbah	1	4230	4270	Middle Cretaceous	Ahmadi
SA0084	Saudi Arabia	Mesopotamian Foredeep	Hasbah	1DST10	4455	4499	Middle Cretaceous	Mauddud
SA0085	Saudi Arabia	Mesopotamian Foredeep	Hasbah	1	9057	9082	Lower Jurassic	Marrat
SA0099	Saudi Arabia	Mesopotamian Foredeep	Marjan	26	6080	6120	Middle Cretaceous	Mauddud
SA0100	Saudi Arabia	Mesopotamian Foredeep	Marjan	26	8985	9093	Lower Cretaceous	Manifa
SA0101	Saudi Arabia	Mesopotamian Foredeep	Marjan	26	9411	9465	Upper Jurassic	Arab D
SY0001	Syria	Euphrates/Mardin	Babasi	3	4918	4978	UpperCretaceous	Shiranish
SY0002	Syria	Euphrates/Mardin	Derik	1	8290	8550	UpperCretaceous	Massive
SY0005	Syria	Euphrates/Mardin	Leilak		6808	6870	UpperCretaceous	Massive
SY0006	Syria	Zagros Fold Belt	Naour	1	11408	11631	Triassic	Kurrachine Dol.
SY0007	Syria	Euphrates/Mardin	Oudeh	108	8219	8265	Triassic	Kurrachine Dol.
SY0008	Syria	Euphrates/Mardin	Oudeh	111	7479	7490	LowerJurassic	Butmah
SY0009	Syria	Zagros Fold Belt	Rumelan	35	4518	4564	UpperCretaceous	Shiranish
SY0010	Syria	Zagros Fold Belt	Rumelan	106	8534	8691	Triassic	Kurrachine Dol.
SY0011	Syria	Zagros Fold Belt	Suwaidiyah (Souedie)	403	10151	10250	Triassic	Kurrachine Dol.
SY0012	Syria	Euphrates/Mardin	Saida	6	4341	4436	UpperCretaceous	Shiranish
SY0015	Syria	Euphrates/Mardin	Ulyan	20	4058	4131	UpperCretaceous	Shiranish
SY0016	Syria	Zagros Fold Belt	Zarabeh	6	4429	4475	UpperCretaceous	Shiranish
SY0017	Syria	Zagros Fold Belt	Suwaidiyah (Souedie)		4425		Cretaceous	
SY0020	Syria	Zagros Fold Belt	Suwaidiyah (Souedie)	614	3035	3117	Cretaceous	
SY0037	Syria	Zagros Fold Belt	Suwaidiyah (Souedie)		5000		Cretaceous	
SY0065	Syria	Euphrates/Mardin	Oudeh	101			Lower Jurassic	Butma
SY0066	Syria	Zagros Fold Belt	Oudeh	112			Triassic	Kurachina
SY0067	Syria	Zagros Fold Belt	Rumelan	15	4000	5000	UpperCretaceous	Massive
SY0068	Syria	Zagros Fold Belt	Rumelan	26	4000	5000	UpperCretaceous	Shiranish
SY0069	Syria	Zagros Fold Belt	Rumelan	42	4000	5000	UpperCretaceous	Shiranish

## Appendix A

### Samples Analyzed for the Zagros Study

SampleID	Country	USGS Province	Field	Well	U. Depth (ft)	L. Depth (ft)	Res. Age	Formation
SY0070	Syria	Zagros Fold Belt	Rumelan	57	4000	5000	UpperCretaceous	Massive (Judeia)
SY0071	Syria	Euphrates/Mardin	Ulyan	20			UpperCretaceous	Massive
TK0001	Turkey	Euphrates/Mardin	Kahta		3642	3872	UpperCretaceous	Karabogaz
TK0002	Turkey	Zagros Fold Belt	Kurkan		2050		MiddleCretaceous	Karababa
TK0003	Turkey	Zagros Fold Belt	Sahaban		5374	5427	MiddleCretaceous	Karababa
TK0004	Turkey	Zagros Fold Belt	Sahaban South		3215		MiddleCretaceous	Karababa
TK0005	Turkey	Zagros Fold Belt	Kayakoy		5801	7113	MiddleCretaceous	Karababa
TK0006	Turkey	Zagros Fold Belt	Kayakoy West		5076	5154	MiddleCretaceous	Karababa
TK0007	Turkey	Zagros Thrust Zone	Cemberlitas		9843	9908	MiddleCretaceous	Derdere
TK0008	Turkey	Zagros Thrust Zone	Akpinar		10175		Campanian	Mardin
TK0009	Turkey	Zagros Fold Belt	Molla		6500		Cretaceous	Karababa C
TK0010	Turkey	Zagros Thrust Zone	Adiyaman		5135		UpperCretaceous	Karabogaz
TK0011	Turkey	Zagros Fold Belt	Yenikoy		3937	3980	MiddleCretaceous	Karababa C
TK0012	Turkey	Zagros Thrust Zone	Firat West		8125		MiddleCretaceous	Karababa C
TK0013	Turkey	Zagros Fold Belt	Sincain		4692		MiddleCretaceous	Karababa C
TK0014	Turkey	Zagros Thrust Zone	Cukurtas				MiddleCretaceous	Derdere
TK0015	Turkey	Zagros Thrust Zone	Karakus		8225		Campanian	Mardin
TK0016	Turkey	Zagros Fold Belt	Beykan		2461	2658	MiddleCretaceous	Karababa C
TK0017	Turkey	Zagros Fold Belt	Barbes		5824	5883	MiddleCretaceous	Karababa
TK0018	Turkey	Zagros Fold Belt	Selmo		5679	6378	Paleocene	Sincan LS
TK0019	Turkey	Zagros Fold Belt	Raman		656	820	UpperCretaceous	Raman
TK0020	Turkey	Zagros Fold Belt	Malatepe		4922	4958	MiddleCretaceous	Karababa C
TK0021	Turkey	Zagros Fold Belt	Garzan		6332	6628	UpperCretaceous	Garzan
TK0022	Turkey	Zagros Fold Belt	Magrip		5873	6103	UpperCretaceous	Garzan
TK0023	Turkey	Euphrates/Mardin	Camurlu		3183		MiddleCretaceous	Karababa C
TK0024	Turkey	Euphrates/Mardin	Dincer Guney		5332	5528	MiddleCretaceous	Karababa C
TK0025	Turkey	Euphrates/Mardin	Kozluca Bati (South)					
TK0026	Turkey	Zagros Fold Belt	Raman Bati (South)		1378	2034	UpperCretaceous	Garzan
TK0027	Turkey	Adana/Sivas	Bulgurdag		4593	4964	Miocene	Karaisali
TK0028	Turkey		Pasinler				Pliocene	Seep
TK0029	Turkey		Cakirbey				Pliocene	Seep
TK0030	Turkey		Cankiri				Cretaceous	
TK0032	Turkey	Adana/Sivas	Bulgurdag		5000		Miocene	
TK0033	Turkey	Zagros Fold Belt	Celikli		10499	10591	UpperCretaceous	Garzan
TK0034	Turkey	Zagros Fold Belt	Germik		6332	6552	UpperCretaceous	Garzan
TK0035	Turkey	Zagros Fold Belt	Kurtalan		5315	5449	UpperCretaceous	Germav
TK0036	Turkey	Zagros Fold Belt	Selmo Bati (South)		5577		UpperCretaceous	Sincan L.
TK0037	Turkey	Zagros Fold Belt	Silvanka		7398	7441	UpperCretaceous	Beloka
TK0038	Turkey	Zagros Fold Belt	Silvanka		6890	6932	Paleocene	Sincan
TK0039	Turkey	Zagros Fold Belt	Yatir East		4482	4603	MiddleCretaceous	Karababa C
TK0040	Turkey	Zagros Fold Belt	Katin		7218	7293	MiddleCretaceous	Karababa C
TK0041	Turkey	Zagros Fold Belt	Sebyan		4921		MiddleCretaceous	Karababa C
TK0042	Turkey	Zagros Fold Belt	Baysu		5900		Cenomanian	Mardin
TK0043	Turkey	Zagros Fold Belt	Yesildere		5750		Turonian	Mardin
TK0044	Turkey	Zagros Fold Belt	Kervan		7710		MiddleCretaceous	Karababa C
TK0045	Turkey	Zagros Fold Belt	Bektas		5900		Turonian	Mardin
TK0046	Turkey	Zagros Fold Belt	East Yenikoy		6562		MiddleCretaceous	Karababa C
TK0047	Turkey	Haleb	Yanankoy	1	5577	5741		Germav/Bozova
TK0048	Turkey	Zagros Fold Belt	Molla	1/R	6435	6450	Cretaceous	Karababa C
TK0054	Turkey	Adana/Sivas	EFE-1	1	1064			
TK0055	Turkey	Adana/Sivas		EFE-1	3507	3526		
TK0056	Turkey	Zagros Fold Belt	Garzan		6000		Cretaceous	Garzan
TK0057	Turkey	Zagros Fold Belt	Germik		6500		Cretaceous	Garzan
TK0058	Turkey	Zagros Fold Belt	Raman		5000		Cretaceous	Mardin
TK0059	Turkey	Zagros Fold Belt	Bati Raman	Bati Raman 1	4246		Tertiary	
TK0060	Turkey	Zagros Fold Belt	Raman	Raman 44	4493		Cretaceous	Mardin
TK0061	Turkey	Zagros Fold Belt	Germik	Germik 1	6443		Tertiary	
TK0062	Turkey	Zagros Fold Belt	Garzan	Garzan 9	4724		Tertiary	
TK0063	Turkey	Zagros Fold Belt	Magrip	Magrip 9	5650		Tertiary	
TK0064	Turkey	Zagros Fold Belt	Kurtalan	Kurtalan-1	4967		Cretaceous	Simak
TK0065	Turkey	Zagros Fold Belt	Kayakoy	Kayakoy 6	5700		Cretaceous	Main block
TK0066	Turkey	Zagros Fold Belt	Selmo	Selmo 1	6082	6092	Paleocene	Middle Sinan
TK0067	Turkey	Zagros Fold Belt		Bakuk 1			Jurassic	
TK0068	Turkey	Zagros Fold Belt	Tirsik				Pliocene	
UE0007	UAE	Rub Al Khali Basin	Abu al Bukhoosh					
UE0008	UAE	Rub Al Khali Basin	Fateh					
UE0009	UAE	Rub Al Khali Basin	Fateh	R-1	9620	9780	MiddleCretaceous	Mishrif
UE0010	UAE	Rub Al Khali Basin	SouthWest Fateh	DD-3	8680	8830	MiddleCretaceous	Mishrif
UE0011	UAE	Rub Al Khali Basin	Rashid	RA-1	9558	9626	MiddleCretaceous	Mishrif
UE0018	UAE	Rub Al Khali Basin	Saleh					
UE0019	UAE	Rub Al Khali Basin	Ajman	2	12970	13000	Eocene	Pabdeh
UE0020	UAE	Rub Al Khali Basin	Sajaa	S7-2	13355		Cretaceous	Thamama

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SampleID	Country	USGS Province	Field	Well	U. Depth (ft)	L. Depth (ft)	Res. Age	Formation
UE0021	UAE	Rub Al Khali Basin	Al Owaid	S7-7	10130		Jurassic?	Sumeini
UE0022	UAE	Rub Al Khali Basin	Margham	1			Lower Cretaceous	Thamama
UE0023	UAE	Rub Al Khali Basin	Al Awir	1			Eocene	Pabdeh
UE0031	Abu Dhabi	Rub Al Khali Basin	Mandous	4			Miocene	Gaschran
UE0032	Abu Dhabi	Rub Al Khali Basin	Mandous	4			Oligocene	Asmari
UE0063	Abu Dhabi	Rub Al Khali Basin	Abu al Bukloosh		7742	7840	Upper Jurassic	Arab C
UE0064	Abu Dhabi	Rub Al Khali Basin	Abu al Bukloosh		7863	7925	Upper Jurassic	Upper Arab D
UE0076	Abu Dhabi	Rub Al Khali Basin	Nasr	5	8028	8044	Lower Cretaceous	Thamama V
UE0077	Abu Dhabi	Rub Al Khali Basin	Nasr	6	9327	9345	Upper Jurassic	Arab B
UE0078	Abu Dhabi	Rub Al Khali Basin	Nasr	6	9372	9380	Upper Jurassic	Arab C
UE0095	Abu Dhabi	Rub Al Khali Basin	Mosadeq	1	3329		Eocene	Rus
UE0096	Abu Dhabi	Rub Al Khali Basin	Mosadeq	1	6290	6305	Lower Cretaceous	Shu'aiba
UE0103	Abu Dhabi	Rub Al Khali Basin	Abu al Bukloosh	1			Upper Jurassic	Arab A
UE0122	Dubai	Rub Al Khali Basin	Falah	FD-1	7952		Middle Cretaceous	Mishrif
UE0123	Dubai	Rub Al Khali Basin	Falah	FB-1	8200		Lower Cretaceous	Thamama
UE0124	Dubai	Rub Al Khali Basin	Rashid	RA-1	10438		Lower Cretaceous	Thamama
UE0125	Dubai	Rub Al Khali Basin	Rashid	RA-6	10000		Middle Cretaceous	Mishrif
UE0126	Dubai	Rub Al Khali Basin	Fateh	ZC-3	7839		Lower Cretaceous	Thamama
UE0127	Dubai	Rub Al Khali Basin	Fateh	ZC-7	7908		Middle Cretaceous	Mishrif
UE0128	Dubai	Rub Al Khali Basin	SW Fateh	CC-9	7839		Middle Cretaceous	Mishrif
UE0129	Dubai	Rub Al Khali Basin	Fateh	E-10			Upper Cretaceous	Ilam
UE0130	Dubai	Rub Al Khali Basin	SW Fateh	NN-6	7800		Lower Cretaceous	Thamama
UE0131	Dubai	Rub Al Khali Basin	SW Fateh	LL-8D	8000		Upper Cretaceous	Ilam
UE0132	Dubai	Rub Al Khali Basin	Fateh	O-4	7850		Middle Cretaceous	Mishrif