Geology and Geochemistry of the Al Lajjun Oil Shale Deposit, Central Jordan*

Jerry C. DeWolfe[1], Emmett J. Horne[2] and Christopher A. Morgan[3]

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[1]Marston Canada Ltd., Calgary, AB, Canada. (jdewolfe@marston.com)
[2]Terracon Geotechnique Ltd, Calgary, AB, Canada.
[3]Jordan Energy and Mining Ltd., London, United Kingdom.

Abstract

The Al Lajjun Oil Shale Deposit is located approximately 110 km south of the Jordanian capital of Amman. Al Lajjun is one of 26 oil shale deposits occurring in the sedimentary basins of Central Jordan. Jordan is ranked 8th in the world with identified oil shale resources in excess of 65 billion tonnes; however, to date no commercial hydrocarbon production from Jordanian oil shale has taken place. Jordan has no conventional hydrocarbon resources and relies entirely on imports from neighbouring countries; market and political factors have highlighted oil shale as a potential domestic hydrocarbon source to meet Jordanian demands.

The Al Lajjun Oil Shale Deposit was discovered in the late 1960's by a joint Jordanian-German geological study. In the decades following discovery intermittent exploration activity at Al Lajjun has resulted in 198 drill holes totaling in excess of 11 km of drilling. Recent estimates for the entire Al Lajjun deposit have identified approximately 1 billion tonnes of oil shale resources at a mean grade of 11 wt. % oil (standard Fischer assay).

Al Lajjun is categorized as a Marinite oil shale deposit, hosted by marine sedimentary rocks of the Belqua Group that were deposited as syn-tectonic basin infill within the late Cretaceous to early Paleocene Al Lajjun Graben. The oil shale occurs as massive beds of brown-black, kerogen-rich chalk-marl that comprise the ~30 m thick Lower Member of the Muwaqqar Chalk-Marl Formation (MCM). The Lower Member is overlain by ~30 m of barren chalk-marl known as the Upper Member of the MCM. Differential throw on the graben bounding faults resulted in asymmetric graben floor that is tilted slightly to the west. Strata in the graben are sub-horizontal with dips typically in the 2-4 degree range. Micropaleontological studies indicate the depositional age of the MCM is transitional between Masstrichian to Paleocene, with deposition of the oil shale bearing Lower Member occurring during Masstrichtian to Danian time.

This presentation focuses on reviewing the regional and deposit scale stratigraphic and structural controls on oil shale deposition along with the oil shale geochemical characteristics. The aim is to evaluate the hydrocarbon production potential of the Al Lajjun Oil Shale Deposit via surface mining and pyrolysis processing methods.

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GEOLOGY AND GEOCHEMISTRY OF THE AL LAJJUN OIL SHALE DEPOSIT, CENTRAL JORDAN

AAPG International Conference & Exhibition

September 13, 2010

Jerry C. DeWolfe (Marston Canada Ltd.)
Emmett J. Horne (Terracon Geotechnique Ltd.)
Christopher A. Morgan (JEML Ltd.)

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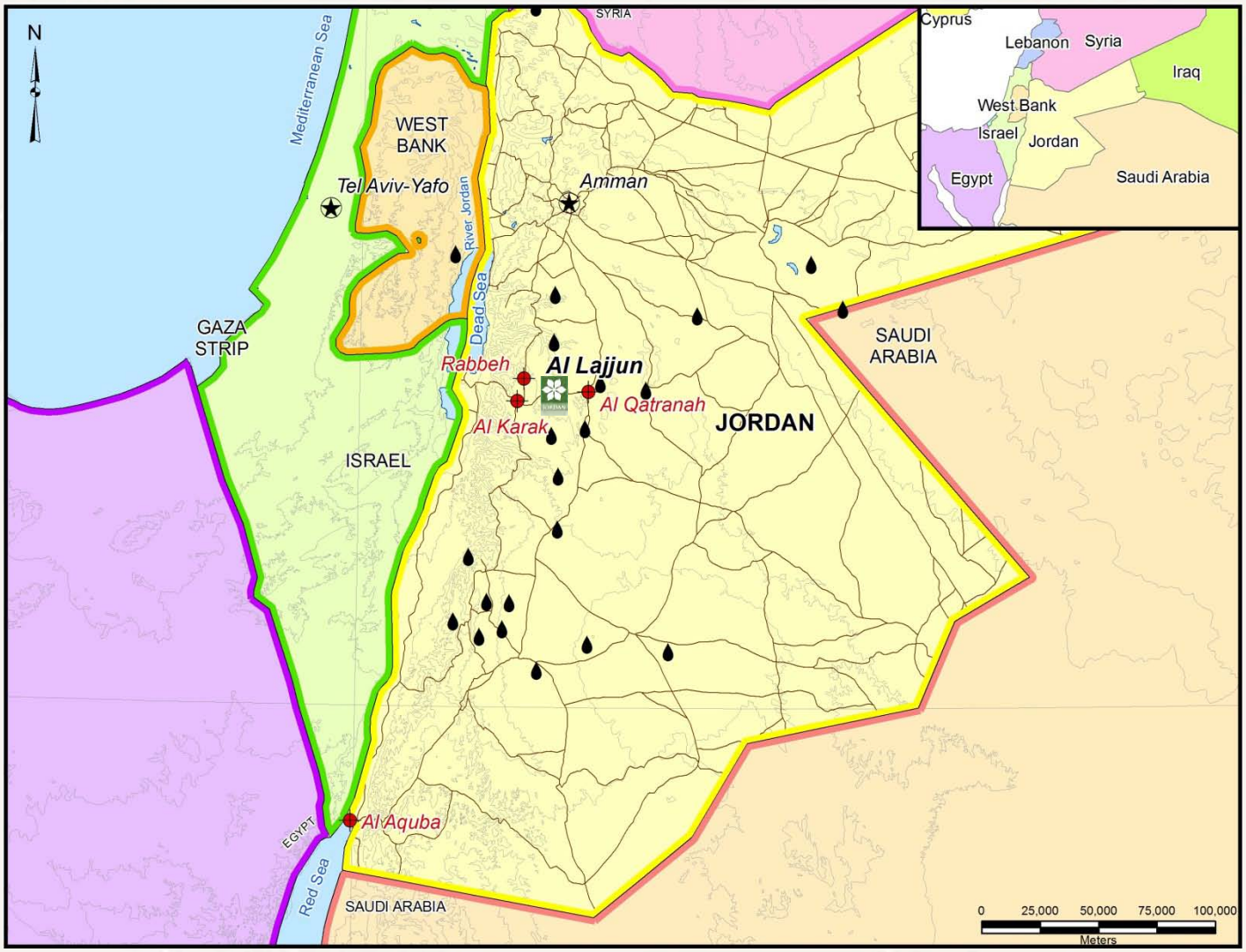
Note: This photo is the Marston Corporate title slide and is not Al Lajjun or JEML

Al Lajjun Oil Shale Deposit, Central Jordan



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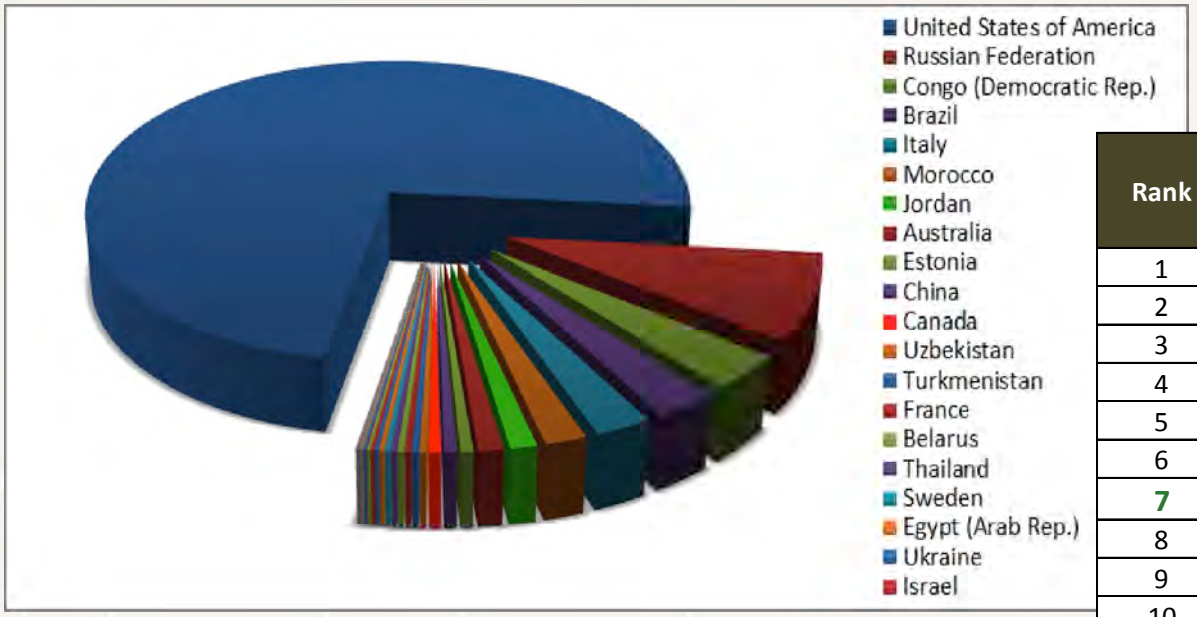
Global Oil Shale Resources



Rank	Country	In-Situ Shale Oil Resources (million barrels)
1	United States of America	2,085,000
2	Russian Federation	248,000
3	Congo (Democratic Rep.)	100,000
4	Brazil	82,000
5	Italy	73,000
6	Morocco	53,000
7	**Jordan**	**34,000**
8	Australia	32,000
9	Estonia	16,000
10	China	16,000
11	Canada	15,000
12	Uzbekistan	8,000
13	Turkmenistan	8,000
14	France	7,000
15	Belarus	7,000
16	Thailand	6,000
17	Sweden	6,000
18	Egypt (Arab Rep.)	6,000
19	Ukraine	4,000
20	Israel	4,000
Global Total		***2,826,000***

"Jordan (as a non-producing oil country) imports 97% of its energy needs…" (Alali 2006)

Data Source: 2007 Survey of Energy Resources, World Energy Council

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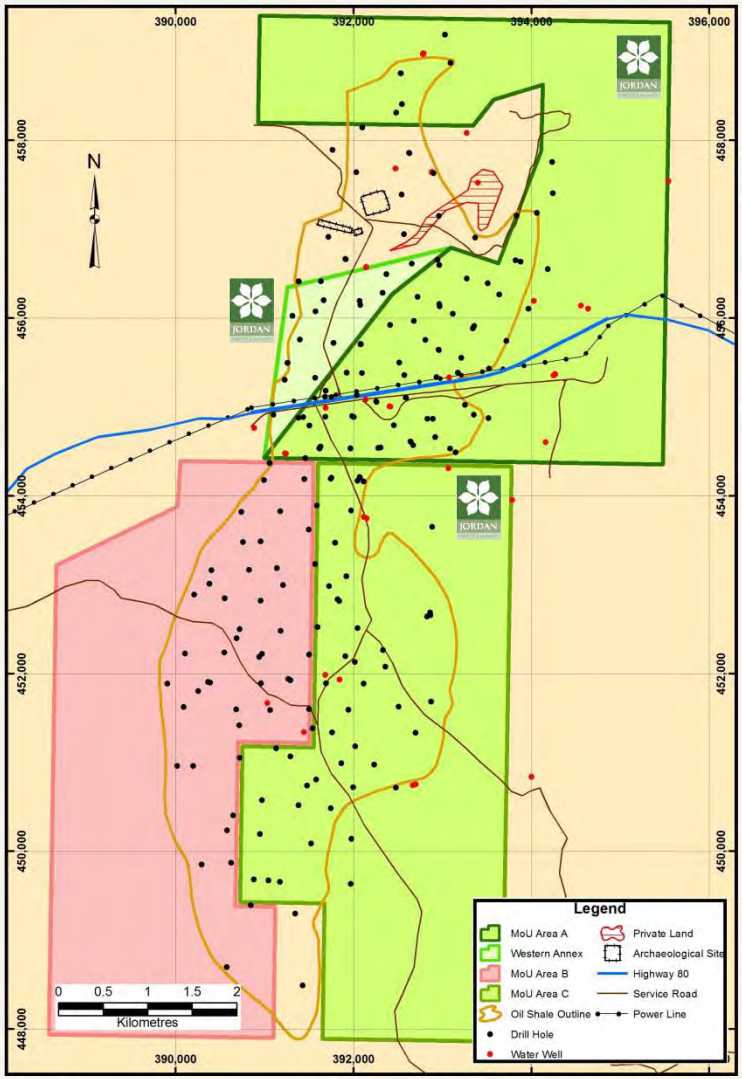
Al Lajjun Oil Shale Deposit



Description	Deposit Total
Overburden Tonnes (Mt)	1050
Oil Shale Tonnes (Mt)	900
Stripping Ratio (tonnes:tonnes)	1.2
Oil Grade (wt%)	11%
Oil Yield (L/tonne)	111
SCO Volume (million barrels)	~615
Total Organic Carbon (wt%)	13%
Total Sulphur (wt%)	3%
Free Moisture (wt%)	3-6%

Oil Shale Stock Pile (Aug 2008)

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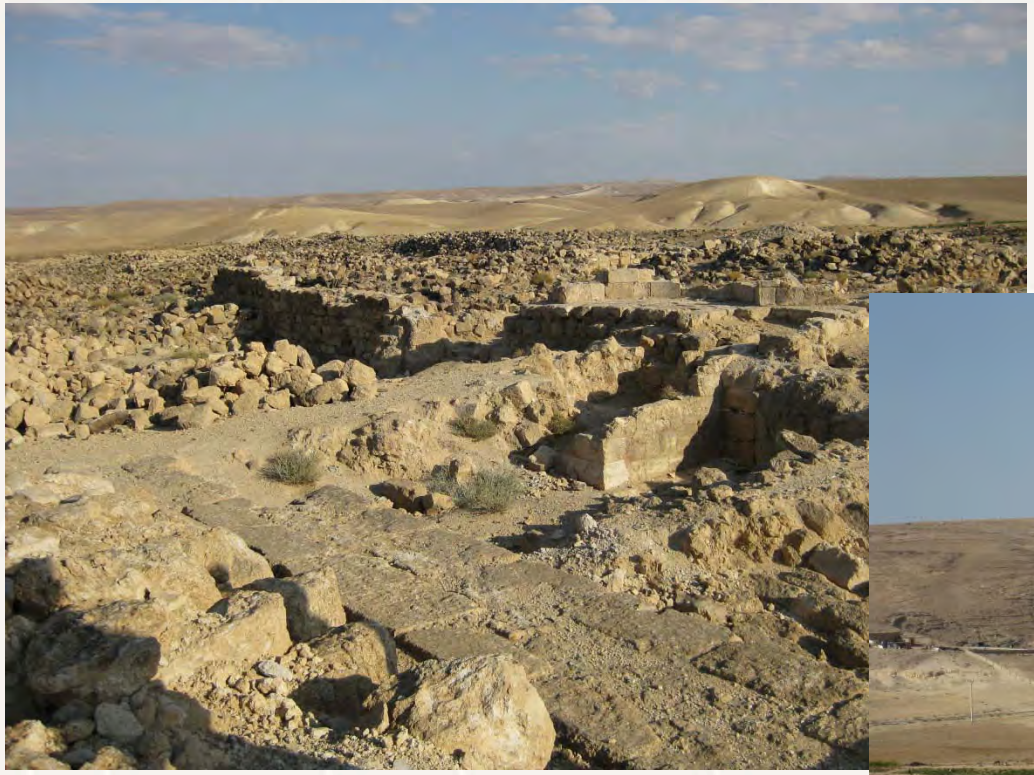
Al Lajjun Area



- Semi-arid transitional climate zone
- Temperature: 22°C (-5 to 40°C)
- Precipitation: 340 mm annually
- Elevation: 590-840 m (amsl)

- Population Al Lajjun: <1,000
- Governorate of Al Karak: 204,000
- Land use: Livestock grazing
- Infrastructure: paved HWY & power lines
- Mosque, school, & pumping station
- Roman ruins

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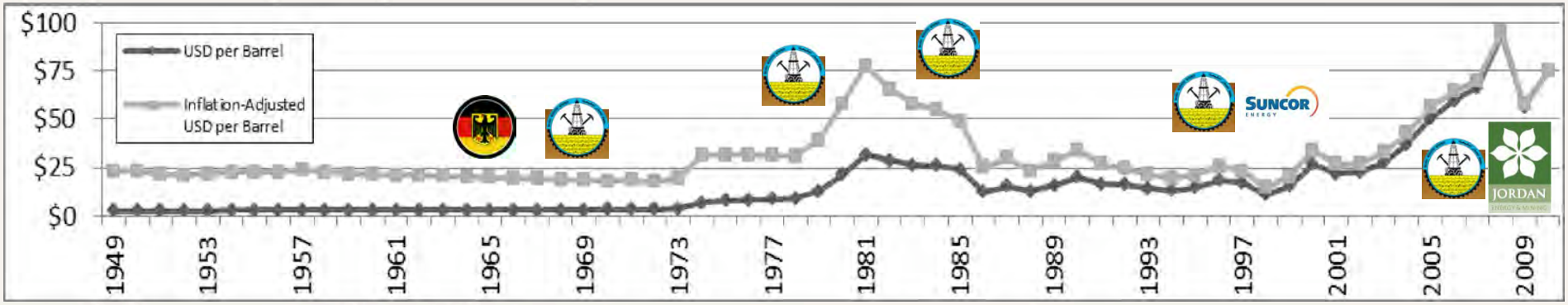
Al Lajjun Exploration History

Exploration Drilling (Nov 2008)

Bulk Sample (Aug 2008)



Crude Oil Price Data: US EIA Website, August 2010

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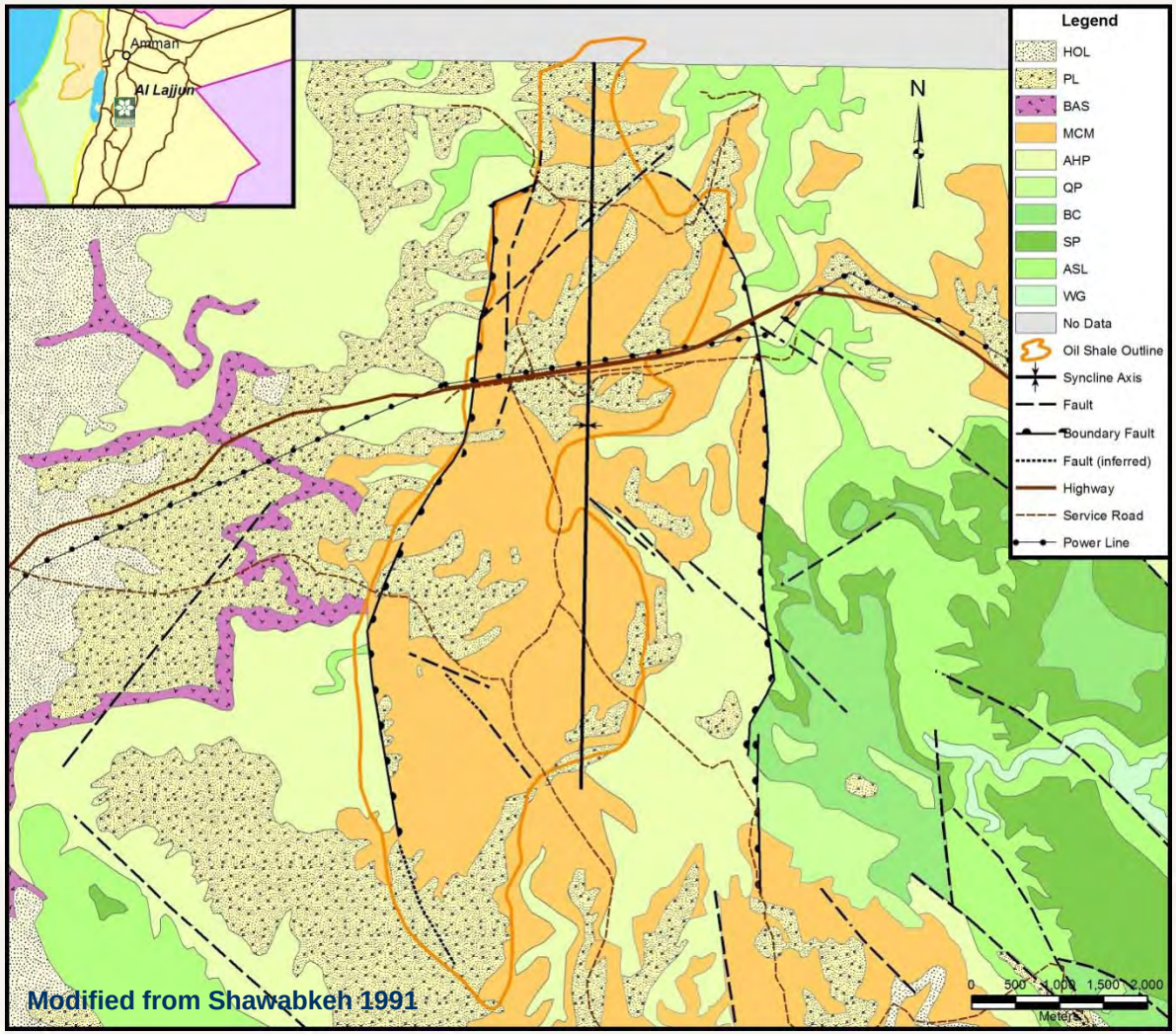
Regional Geology Map



Modified from Shawabkeh 1991

Eonothem Eon	Erathem Era	System Period	Series Epoch	Stage Age	Age Ma
Phanerozoic	Cenozoic	Quaternary	Holocene		0.0117
			Pleistocene	Upper	0.126
				"Ionian"	0.781
				Calabrian	1.806
				Gelasian	2.588
		Neogene	Pliocene	Piacenzian	3.600
				Zanclean	5.332
			Miocene	Messinian	7.246
				Tortonian	11.608
				Serravallian	13.82
				Langhian	15.97
				Burdigalian	20.43
				Aquitanian	23.03
		Paleogene	Oligocene	Chattian	28.4 ±0.1
				Rupelian	33.9 ±0.1
			Eocene	Priabonian	37.2 ±0.1
				Bartonian	40.4 ±0.2
				Lutetian	48.6 ±0.2
				Ypresian	55.8 ±0.2
			Paleocene	Thanetian	58.7 ±0.2
				Selandian	~ 61.1
				Danian	65.5 ±0.3
	Mesozoic	Cretaceous	Upper	Maastrichtian	70.6 ±0.6
				Campanian	83.5 ±0.7
				Santonian	85.8 ±0.7
				Coniacian	~ 88.6
				Turonian	93.6 ±0.8
				Cenomanian	99.6 ±0.9
			Lower	Albian	112.0 ±1.0
				Aptian	125.0 ±1.0
				Barremian	130.0 ±1.5
				Hauterivian	~ 133.9
				Valanginian	140.2 ±3.0
				Berriasian	145.5 ±4.0

HOL
PL
BAS

MCM (CM)
MCM (OS)
AHP
ASL
WG

Modified from ICoS 2009

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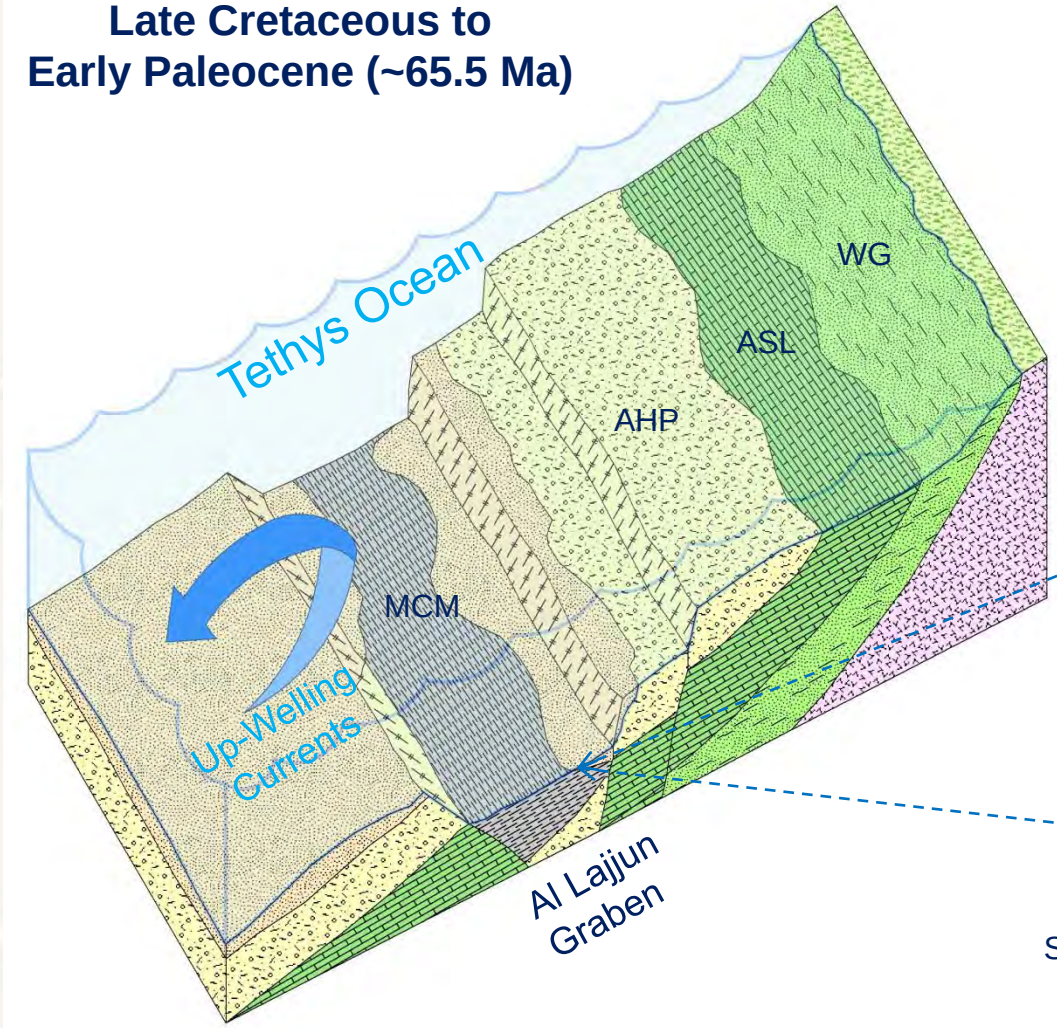
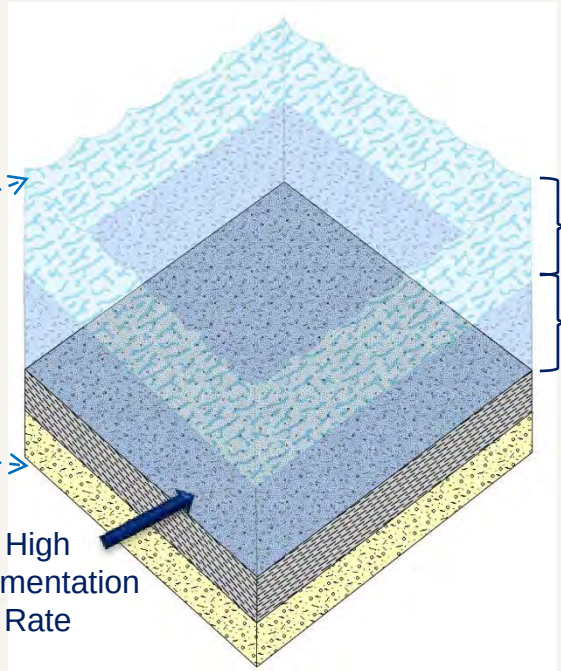
Depositional Environment

Late Cretaceous to Early Paleocene (~65.5 Ma)



Depositional models based on interpretations and theory presented in Shawabkeh 1991; Pufahl, Grimm, Abed, & Sadaqah 2006; Abed & Arouri 2006; Alali & Sawaqed 2006; Dyni 2005.



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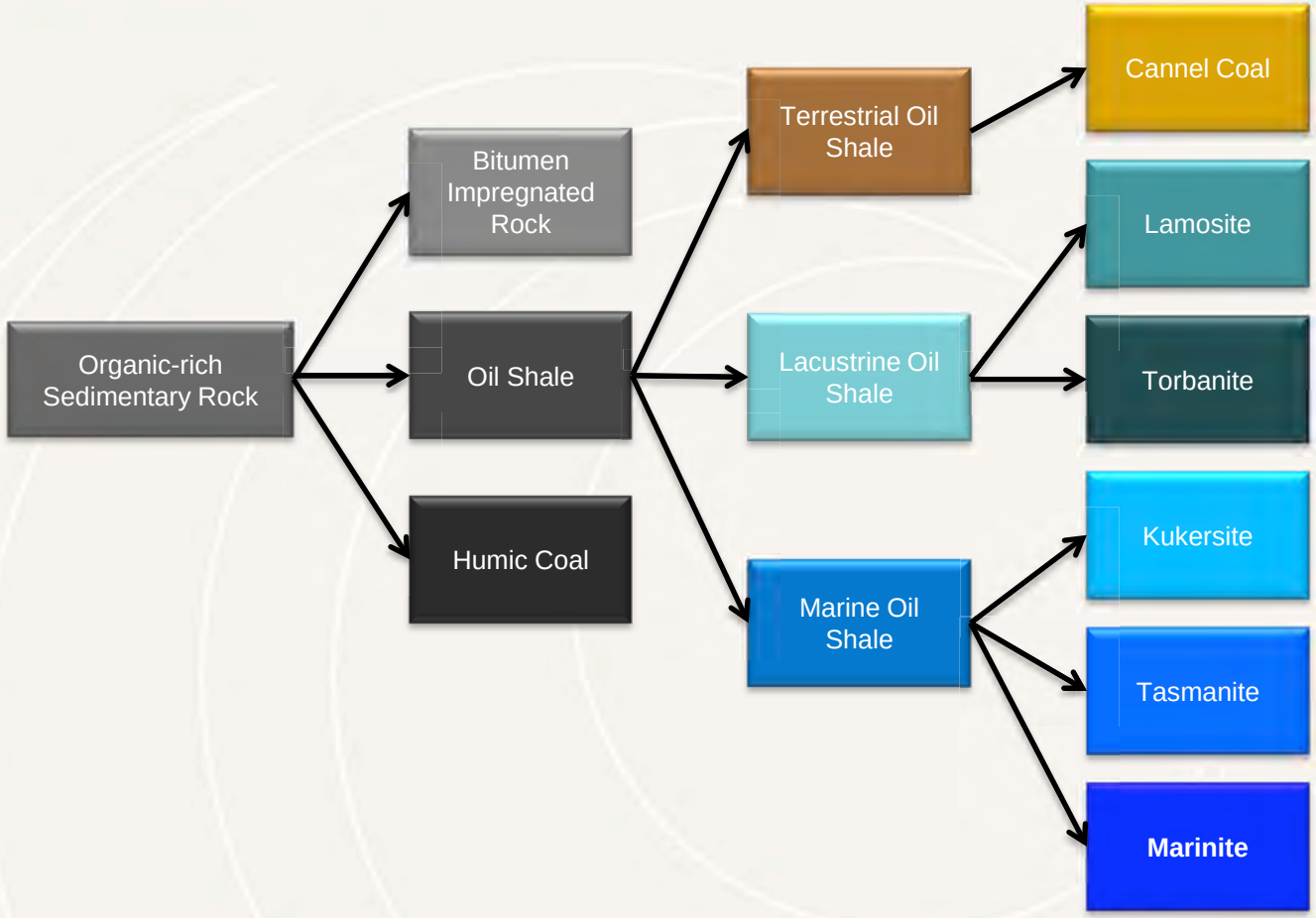
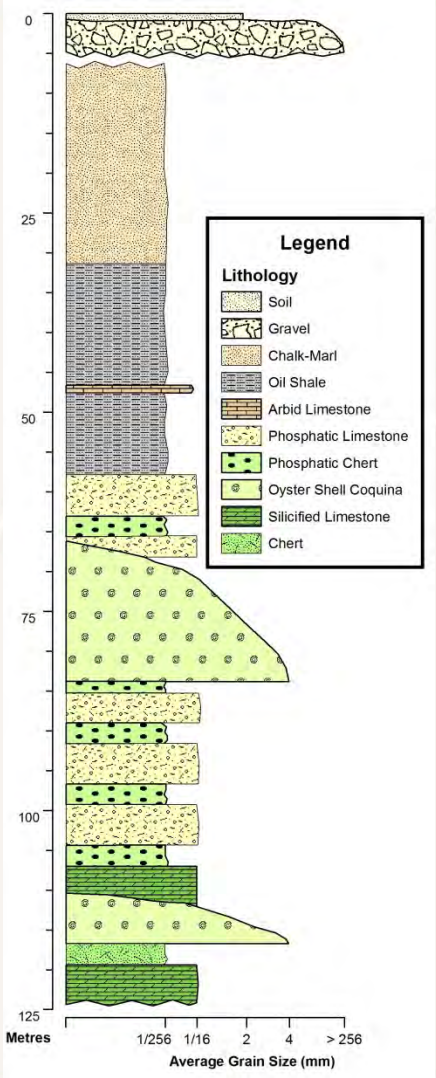
Oil Shale Classification



Al Lajjun

Modified from Dyni 2005

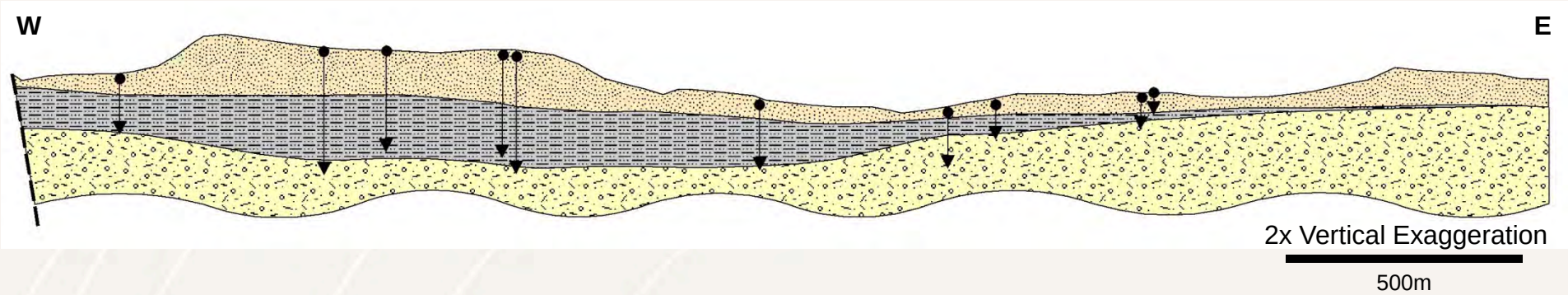
Al Lajjun Local Geology



Chalk Marl / Oil Shale Contact

Fresh Oil Shale

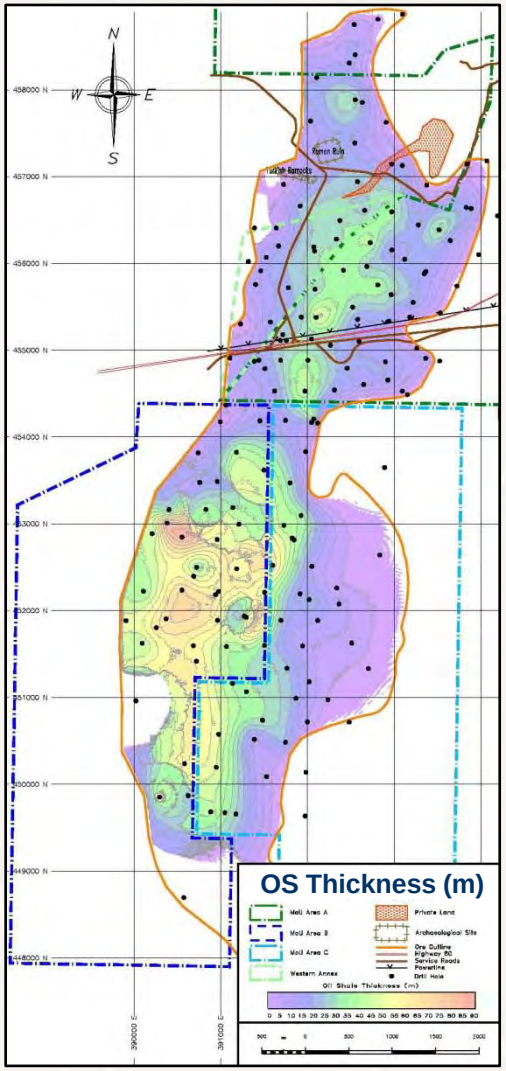
Typical Al Lajjun Geological Cross Section

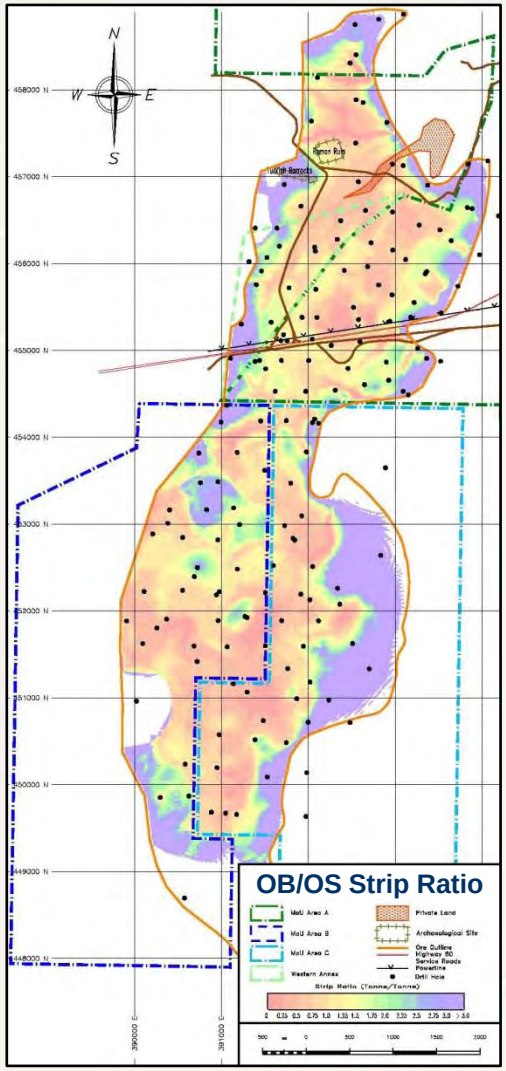


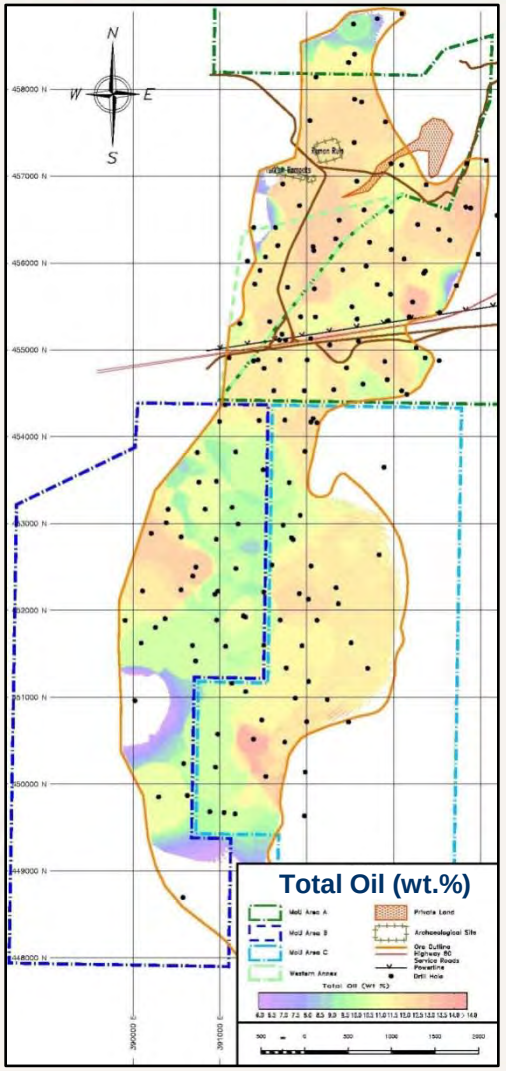
Unit	Mean Thickness (m)	Minimum Thickness (m)	Maximum Thickness (m)	Mean Density (g/cc)
Oil Shale	28	0	86	1.87
Chalk Marl	21	1	71	2.10
Total OB (Chalk Marl+Alluvium)	30	1	110	2.10

Overall Stripping Ratio ~ 1:1 (tonnes OB: tonnes OS)

Al Lajjun Contour Maps







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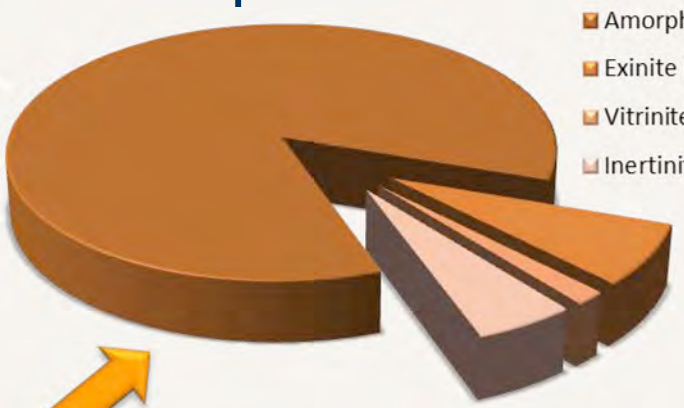
Al Lajjun Oil Shale Composition

Oil Shale Composition

Kerogen Composition



Oil Yield

Vitrinite Reflectance (Ro%): **0.20%**
Thermal Alteration Index (TAI): **2+**

Organic Matter Composition

Data Sources: Abed & Arouri 2006; Alali & Sawaqed 2006

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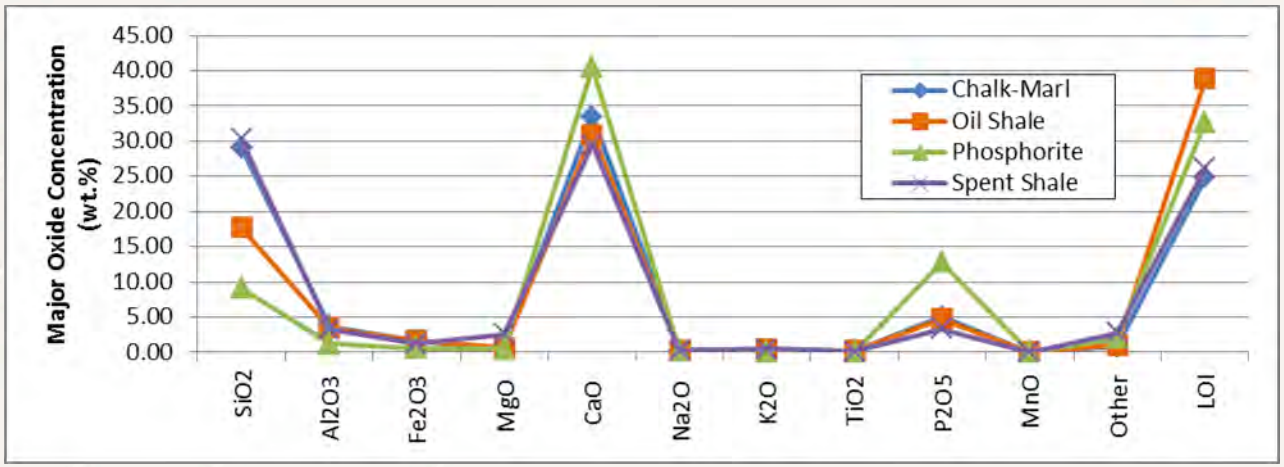
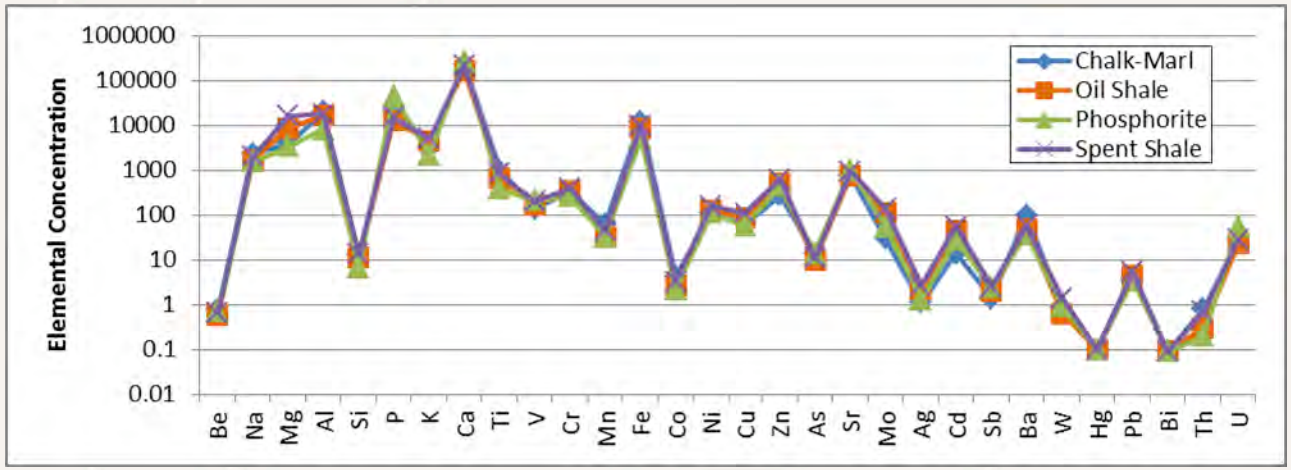
Al Lajjun Oil Shale Composition





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Al Lajjun Oil Shale Assay Data

Description	Mean
Oil Grade (wt.%, SFA - ZFM)	11%
Oil Density (g/ml)	0.9791
Oil Yield (L/tonne)	111
Total Organic Carbon (wt.%)	13%
$CaCO_3$ (wt.%)	54%
Total Sulphur (wt.%)	3%
Free Moisture (wt.%)	3%
Calorific Value (kcal/kg)	1637
Calorific Value (BTU/Lb)	2946
Oil Shale Density (g/cc)	1.87

Fushun ATP Processor under construction (Aug 2009)

Photo Courtesy of UMATEC Industrial Processes & JEML

ATP D86 Distillation Fractions

Photo Courtesy of UMATEC Industrial Processes

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Al Lajjun Summary

- **~ 65.5 Ma Marinite-type oil shale deposit**
- **Deposited in restricted basin formed by Al Lajjun Graben**
- **Depth, thickness, grade, location all favourable for surface mining methods**
- **ATP Pilot Plant and upgrading analysis favourable for SCO production**
- **Excellent Opportunity and Potential Solution for Jordanian Oil Supply**

Acknowledgements & References

www.jeml.co.uk

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