Oil Shales in Israel

Occurrences, Grades and Prospects

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Oil Shale in Israel – the host rocks

In most of the rocks in Israel termed oil shale, the main inorganic constituent is carbonate - namely chalks, marly chalks and chalky marls. Those domestic rocks are sometimes called 'bituminous' (e.g., bituminous chalks), though only a small portion of the organic matter in the rock belongs to the organic group termed bitumen. Other rock types enriched in places in organic matter (mostly of Campanian age) are porcelanites (silica-rich) and phosphoritic beds.
Sequences having Organic Matter Anomaly in Israel

Their age is late Turonian to Pliocene. Found largely in the Senonian, also in the Paleocene, in synclines.

The occurrences are part of the Upper Cretaceous Global Anoxic Event. Most of them belong to the Mount Scopus Group Sequence and include:

1. The Oil Shale Member, Ghareb Formation.
3. The correlative En-Zeitim Formation in Central and Northern Israel.
How the grade of Israeli oil shale was determined?

Based on an analysis method in which the organic material is oxidised (EOM - Easily Oxidized Material, given in %)

- A fast, cheap and simple analytical method.
- Good correlation with the Organic Carbon content (TOC).

- It is estimated that tens of thousands analyses were carried out on Israeli oil shale sample.

Relation between EOM & TOC (Nathan et al., 1983)
Some Properties of Israeli Oil Shales

- In most of the investigated sequences (Ghareb Formation) the host rocks are carbonates.
- The organic matter is mostly Type II Kerogen (Spiro, 1980).
- On the basis of Hutton’s (1987) classification they are marine oil shale of the Marinite type; their origin is probably marine phytoplankton.
- The organic matter content (EOM) is 4-26%. Higher values are rare and were found in a few silica-rich samples.
- In geo-economical studies a Cut-off value of 10% EOM is still in use.
More Information about Israeli Oil Shales

- The rock density is 1.7-2.1 gr/cm³. As the EOM content increases, the density decreases.
- The “moisture” (uncombined water) content is relatively high, 20-24%.
- The given properties are typical to the Maastrichtian Ghareb Formation, in studied basins. There are possibly more varieties of domestic oil shale, such as:
  1) In the sequence of the underlying Mishash Formation, which has higher silica and phosphorous content and considerably lower moisture values.
  2) In some of the basins (e.g. - higher Mg values in En-Boqeq, basin of Nabi-Musa).
- Oil Shale is considered to be an important source rock for hydrocarbons generation, especially in the Dead-Sea Graben area.
Vertical trends of some elements in the oil shale sequence, Ghareb Formation, Northern Negev
Vertical changes in the organic matter content are similar in distant basins. Demonstrated by the Sea of Galilee (Mount Arbel, AB-1 borehole) section.
The vertical distribution of the organic matter does have similarities when different basins are compared.

Gradual increase in EOM content from top to bottom of the Ghareb Formation sequence.

Sharp increase in EOM content in the transition between the Ghareb to the underlying Mishash Formation.

Sharp kick around EOM values of 15%, Ghreb Formation. This transition may have stratigraphic significance and may be used to determine between two subunits in the Oil Shale Member.

These transitions and some others that can be defined in the Mishash Formation may be useful for stratigraphical studies.
Vertical Organic Matter (EOM) in 2 boreholes (NS-28 & BG-1) from Sde-Boker occurrence and from Nahal Zin, Northern Negev

- Defined by Gamma-logging method
Enrichment in Organic Matter, in the Mishash Formation sequence

1. Typical to some beds below the ‘main phosphorite’ unit in the northern & central Negev.
2. The inorganic composition (host rock) is carbonatic - silicatic - phosphatic.
3. Some physical properties of the rocks enriched in organic material differ from those of the Ghareb Fm. and may have advantages for in-situ techniques implications.
4. The lower part of the thick oil shale sequences in the Coastal Plain is correlative and may have similar properties.
No real news under the sun....
Leo Picard’s schematic columnar section carried out in 1924 at the Nabi Musa area
Indications on mineral composition in oil shale rocks from Israel & Jordan

- Silica/Alumina ratios based on limited data from Jordan.
- High content of free silica is indicated from some main Jordanian Oil Shale deposits, including Sultani, Attarat and El-Lajjun (lower beds).
- Similarity between the oil shale of the Ghareb Fm., Israel and the Jordanian Yarmouk (A-Shalala), Jurf Ed-Darawish and El-Lajjun (upper layers) deposits.
Mishor Rotem Oil Shale Deposit – approximate boundaries and boreholes locations

- Mishor Rotem Oil Shale Deposit is the most thoroughly investigated oil shale deposit in Israel.
- During 40 years of prospection some 400 boreholes were drilled, many thousands analyses carried out and variety of aspects studied.
- The oil shale member is usually 30-75 m thick, some 48 m on average (~200 boreholes).
- The deposit covers an area of ~25 km² and the reserves (EOM>10%) are about 2.5 billion tons.
- Some more information is shown in the coming figures:
Mishor Rotem Oil Shale Deposit

Isopach map of the Oil shale sequence
(Oil Shale Member, Ghareb Fm)
(EOM>10%):

Based on data from ~260 boreholes
Mishor Rotem Oil Shale Deposit –

Isograde map of the Ghareb Fm sequence (Oil Shale Member, Ghareb Fm) (EOM>10%):

GIS model based on average values calculated for ~260 boreholes
Map of Overburden Ratio (between the overlying rocks and the oil shale body)

The map indicates sites in the deposit that may be recommended for designing a new open-pit mine.
Oil Shale occurrences in the northeastern Negev, Israel:

Some trends in thicknesses and EOM values between basins
Oron (north) oil shale deposit

- Oil shale field located in the western & northwestern edge of the Oron Syncline, close to some of the Oron phosphate mines.
- In the southwestern part of the deposit (Giv’at Mador) parts of the oil shale sequence are exposed.
- The reserves are about 750 million tons, in both Ghareb & Mishash formations.
- The oil shales are higher in their EOM content than in Mishor Rotem. The Mishash Fm sequence is better developed and has higher average EOM values.
- One of few locations in which composite open-pit mining of oil shale and phosphorite may be plausible.
Oil shale occurrences in the (Nahal) Zin Syncline

Relatively small occurrences adjacent to phosphate mining areas. Thin sequence (>10 m), but rich in organic matter. Most reserves are below the phosphorite sequence, in the Mishash Fm sequence. Possible reserve figure is tens to few hundred million tons. A composite mining of oil shale and phosphates may be possible.
There are several additional oil shale occurrences in the Negev with very limited data

- Some of those: Mishor Yamin, Revivim – Mashabim, Sde-Boker, Shivta, Yeroham, central Arava

- In some of these occurrences there are no indications on significantly associated phosphate sequence.

- Unlikelihood for any future open-pit development.
The Shefela Oil Shale Occurrence

1. Probably the largest in Israel.
2. The area ~1,000 km². Located below rural areas and some population centers and infrastructures.
3. Oil Shale sequence is 25 m to almost 400 m thick.
4. Relatively rich sequence (EOM – 15-16%) is indicated.
5. The possible, geological reserves are very large, > 250 billion tons.
6. May be exploited, in places, by In-situ methods
### Oil Shale in Israel
### Occurrences and reserve estimations

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Israeli Oil Shale Reserves
(on USGS Reserve classification)

![Figure 1: Major Elements of Mineral Resource Classification, Excluding Reserve Base and Inferred Reserve Base](image)

- **Identified Resources**
  - Cumulative Production
  - Identified Resources
    - Demonstrated
      - Measured
      - Indicated
    - Inferred
  - Undiscovered Resources
    - Probability Range
      - Hypothetical
      - Speculative

- **Economic**
  - Mineable
    - Reserves
    - Inferred Reserves
  - Marginal Reserves
    - Marginal Reserves
    - Inferred Marginal Reserves

- **Subeconomic**
  - Demonstrated Subeconomic Resources
  - Inferred Subeconomic Resources

- **Other Occurrences**

Includes nonconventional and low-grade materials.
So, how much Oil Shale do we have in Israel?

- Out of the enormous geological reserves only a fraction (2-4 %) may be defined as mineable, possibly around 1-2 × 10^9 tons.
- Currently areas where new open-pit mines may be operated are those associated with phosphate mining in the northwestern Negev.
- In the future, when In-situ methods will be applicable, additional sites may be available for development.
- Defining oil shale as “economical” is based upon variable parameters (location, geological conditions, rock type and properties, etc.) and most important - the economical atmosphere of a given period.
- It is suggested that significant portion of Israeli oil shale resources is within the Campanian sequence (Mishash Fm).
- Prospecting for oil shale was stopped more than 20 years ago. Renewal of that activity is highly recommended.
Technology

Technological parameters.....
Oil Yield of Israeli Oil Shale

Oil Yield to EOM, Ghareb Formation, Northern Negev

1. Useful parameter to assess oil shale grade, especially for shale oil production.

2. The oil yield (OY) of Israeli oil shales is roughly 45-100 l/t ((EOM 10-20%).

3. Average OY, no cut-off, ~62 l/t (for the Ghareb Fm).

4. Using a cut-off value of 10% EOM, the average OY is 75-80 l/t, which is around 20 gallon (US)/ton,

Lower cut-off value in the Green River Fm – 14 US gallons per ton
1. Useful Parameter to present the energetic grade of fossil fuels. Applicable for combustion methods.

2. In Israeli oil shale (Ghareb Fm) the calorific values (CV) range is 650-1450 cal/gr (for ~EOM 10-20%).

3. Using a cut-off value of 10% EOM, an average CV is around 1125 cal/gr (Ghareb Formation).
The power station, designed and built by PAMA uses oil shale rock to produce energy (electricity and steam), about 13 MW.

Active since 1989.

Profitable - on operational basis.

Annual energy production is equals to 31,000 tons of oil (2004).

Annual mining rate - ~450,000 tons of raw oil shale.
1. The FBC is the preferred mode of combustion.

2. The rate of deposition in the boiler depends mainly on the lime (free CaO) concentration in the Fly Ash (FAS).

3. The ratio Ca-carbonates to silicates (Al, Fe, etc), in the oil shale feed, determines the concentration of lime in the FAS.

4. The rate of deposition in the boiler depends also on the geometry of the boiler and on the particles aerodynamic conditions in it.

* - Summary of a recent work by Yoffe, Wohlfarth, Nathan, Cohen & Minster
Rough Estimations of expenses for producing shale oil in Israel (by PAMA Ltd.), as recalled by the Ministry of Infrastructures

1. In the late 1980’s a shale oil barrel (Paraho Process) cost was estimated to be $35 (±%25).

2. In 2001 (its closing time) PAMA Ltd. Presented estimation of producing a shale oil barrel by $27 (±%15).


Source: Dr A. Arbiv, Ministry of National Infrastructures
Some obstacles for further economic development of Israeli Oil Shale

1. Technologies being currently developed, especially the In-situ based methods. May be a long story.

2. Large investment needed in R&D and construction of commercial facilities.

3. Competition with other energy sources. In particular – the introduction of natural gas with relatively reasonable price.

4. Various environmental aspects. Fear of polluting underground water resources.

5. The ‘open areas’ debate – the growing strength of the ‘greens’. Hardiness of getting permits to develop new mines.
Economical Exploitation of Israeli Oil Shale

• The new technologies are still in developing stages. Their development into economical processes may take some years to come. If and when they become close to being economical they need to be adjusted to the domestic resources.

• Since 1989 an oil shale combustion power-plant (~13 MW) has operated in Mishor Rotem. Previous and recent recommendations encourage an upgrading of the existing reactor (of one order of magnitude and more). If done, an energetically cheaper product may be generated.

• Enlarging the oil shale mining activity could be done in association with the phosphate mining activity. There are substantial bituminous phosphorite resources in Mishor Rotem.

• In-situ techniques need to be adjusted to the properties of Israeli oil shale and to differences between basins and sequence parts. A possibility of developing gasification technologies should be also considered.
The grey color attracted stoneware artisans.
Many articles found, dated from pre-Roman time, Roman and Byzantine periods.
 Widely used for home and bigger supply articles, especially in the 2\textsuperscript{nd} temple times.
Was used for building - floors and external particles. Special use in few Byzantine churches near Jerusalem and in Central Jordan.

Raw material - oil shales, slightly metamorphosed, from quarries 10-20 miles south and southeast of Jerusalem. Some material probably came from Central Jordan.

In recent centuries - limited use as heating material (Nabi-Musa, ‘Moses Stone’).

The generated asphalt from the Dead Sea - a dear commodity, probably in the last BC centuries (Nabateans). Required for mummies (Egypt) and boat finishing.
Thank You!!

Usage of oil shale ash for the benefit of the milk makers in Israel