Oil shale potential and prospects in Israel – an update

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Abstract

The demand for energy in Israel is high and rising, especially for liquid fuels and electricity. Development of the recently discovered gas resources offshore will enhance Israel's security and boost its economy but will not do much for liquid fuel demand. Oil imports will continue to rise, which is not encouraging. Oil shale resources are still important.

Oil shale deposits underlie about 15% of Israel's land surface. The geological reserves (rocks with at least 7% total organic carbon) are estimated to exceed 370 billion tons. The average oil yield, as reflected from some of the studied deposits, is supposed to be ~20 G/T. Many of the deposits are close to the surface, and some could be developed with low-cost surface mining. In some of the studied oil shale deposits, the sequence is closely associated with economic phosphate beds, a geological phenomenon that may have significance in future applications. Mineralogy of the host rocks and the quality of the shale oil are quite similar to the oil shale studied in Jordan, which could be beneficial for both countries.

Israel's oil shale has been under development, in various ways, for many years. Recent achievements include the continuous production of the oil-shale-fueled power plant at Mishor Rotem (northern Negev), exploration programs that could lead to production of shale oil by in-situ processing and additional research activities that focus on ex-situ processes.

Our cautious forecast for oil shale developments in Israel by 2020 is as follows:

- Significantly more raw oil shale will be removed, as overburden to phosphate beds (in particular, at Mishor Rotem). Mining costs will be even lower than today, and this, combined with possible advances in the beneficiation of bituminous phosphates, may lead to one or more aboveground retorting projects, perhaps producing 10,000 to 25,000 barrels per day of crude shale oil. The production may be very beneficial to the existing 90,000 barrel per day refinery in Ashdod, some 80 miles away.
- If improved heating devices become available, in situ processing may also be employed, but more likely in relatively remote locations that can avoid the environmental controversy that has troubled the presently permitted site in Central Israel.

Introduction

The demand for energy in Israel is high and rising, especially for liquid fuels and electricity. In time, renewable resources could become very important for electricity generation and space conditioning. However it is unlikely they will produce much liquid fuel. Development of the recently discovered, substantial gas resources offshore will certainly enhance Israel's security and boost its economy but will not do much to satisfy the demand for liquid fuels. Unless domestic sources of liquid fuels can be developed, oil imports will continue to rise, which has negative implications for Israel's security and economic wellbeing. The only resource that offers a solution to the liquid fuel problem is oil shale, which is found in vast quantities in Israel. To date, Israel's oil shale resources have not been significantly developed. They may become much more important in the future.

Reserves and grades

Basins that are composed of oil shale underlie about 15% of Israel's land surface. More than 30 deposits and occurrences have been described (Minster, 2009, Figure 1), although on many of these there is only preliminary data.

The geological reserves of rocks having content of more than 6.8% total organic carbon (TOC) are estimated to exceed 370 billion tons and to contain at least 200 billion barrels of potential shale oil. Data in hand point to average oil yields of about 20 gallons per short ton (G/T), but higher values of 25 to 30 G/T were recently indicated (Table 1). Many of the deposits are close to the surface, although there are few exposures, and some could be developed with low-cost surface mining. Most of the studied occurrences are of Maastrichtian age, and the host rocks are chalks and marly chalks. There is additional potential of (probably) lower grade oil shale rocks of Campanian age underlying the well-studied sequences. Preliminary studies indicate that they have considerably more free silica and relatively less carbonate minerals.

Current activities

Fuels may be recovered from oil shale either by processing it *in situ* (in place) or by mining it and processing it on the

Figure 1: Oil shale deposits and occurrences in Israel.

Table 1. Oil shale deposits and occurrences in Israel - summary of available data.

General Location/ Region	*Deposit / Occurrence*	*Approx. Area (km^2)*	*Oil Shale Thickness (m, Ghareb Fm)*	*Approx. Overburden (in m)*	*Average TOC (%)*	*Oil Yield (%)*	*Oil Yield (~G/T)*	*Reserve Estimate (Million Tons)*
Mishor Rotem	Mishor Rotem	24	30-80	15-110	9.9	7.2	19.0	2,500
Yamin	Mishor Yamin	38	30-90	100-150	10.2	7.4	19.6	3,500
Oron -	Oron North	10.5	15-40	0-70 1	0.5	7.7	20.3	750
	Oron South	9	20-30	20-75	10.9	7.9	20.9	700
Biq'at Zin	Nahash-Zameh	5	10-30	5-30	8.5	6.2	16.4	250
	Biq'at Zin	28.5	40-80	20-140	9.5	6.9	18.2	2,700
Nahal Zin	Hagor	1	7-15	20-40	11.2	8.2	21.7	
	Saraf	1	7-12	12-25	11.2	8.2	21.7	
	Hor-Ha'har West	1.5	15-30	15-35	9.5	6.9	18.2	
	Hor-Ha'har	0.5	5-11	12-30	11.2	8.2	21.7	250
	Yorke'am South	0.5	25-35					
	Yorke'am North	0.7	4-9	20-35	15	10.9	28.8	
	Akrabbim	0.7	30-40					
Northern Negev	Sde-Boker - Avedat	21	20-80	50-150	9.5-12.9	6.9-9.4	18.2-24.8	1,800
	Shivta	12.5	25-80	50-70	5.4-11.6	4-8.4	10.6-22.2	500
	Yeroham	4.5	30-50	40-130	6.8-10.2	5-7.4	13.2-19.6	300
	Zavo'a	1.5	15	60-70	8.8	6.4	16.9	50
	Nevatim	12	40-60	140-340	8.2-10.2	6-7.4	10.6-19.6	1,000
	Mash'abim	75	150-250	30-300	?	?	?	*10,000
	En-Bokek	3.5	180	0-50	?	?	?	100
	Gidron	9	5-18	20-35	6.8	5	13.2	100
	Shahak	17.5	10-25	20-70	6.8	5	13.2	500
Dead-Sea, Arava & Central Negev	Shilhav - Omer	14.5	20-65	10-40	6.8-8.8	6.4-7.4	13.2-19.6	900
	Har Nishpe	4.5	20-55	5-65	8.2-9.5	6-7.4	10.6-19.6	
	HaMeishar	3.5	20-40	20-40	?	?	?	300
	Paran (Zihor)	5	20-40	20-40	?	?	?	150
	Zenifim (Nahal Hiyyon)	185	20-60	50-150	5.4	4	10.6	*2,000
Coastal Plain	HaShefela	1000	30-300	25-300	10.2-10.9	7.4-7.9*	19.6-20.9*	*300,000
	Hadera-East	35	30-180	20-140	?	?	?	*7,000
Northern	Emek Zevulun	36	50-300	40-100	?	?	?	*4,000
Israel,	Arbel	10	50-90	40-350	6.8-10.2	5-7.4	13.2-19.6	*1,200
Galilee	Ramat-HaGolan, South	?	250-400	30-300	?	?	?	*4000
Jordan Valley	Nabi-Musa	?	25-40	0-50	11.6	8.4	22.2	100
** IEI G/T Figures - 25-30 G/T*								369,450

surface, or *ex situ*. Both types of processes are being evaluated in Israel.

Current activities

Ex-situ approach

The oil shale mine in Mishor Rotem (Nachmias 2001, Minster 2007, and Figures 2, 3, 4) was opened in 1989 and continues to supply approximately 450,000 tons per year of raw oil shale to a nearby 12.5 MW power station that also delivers steam to a phosphate processing operation. In addition, as of October 2012, there were three permits

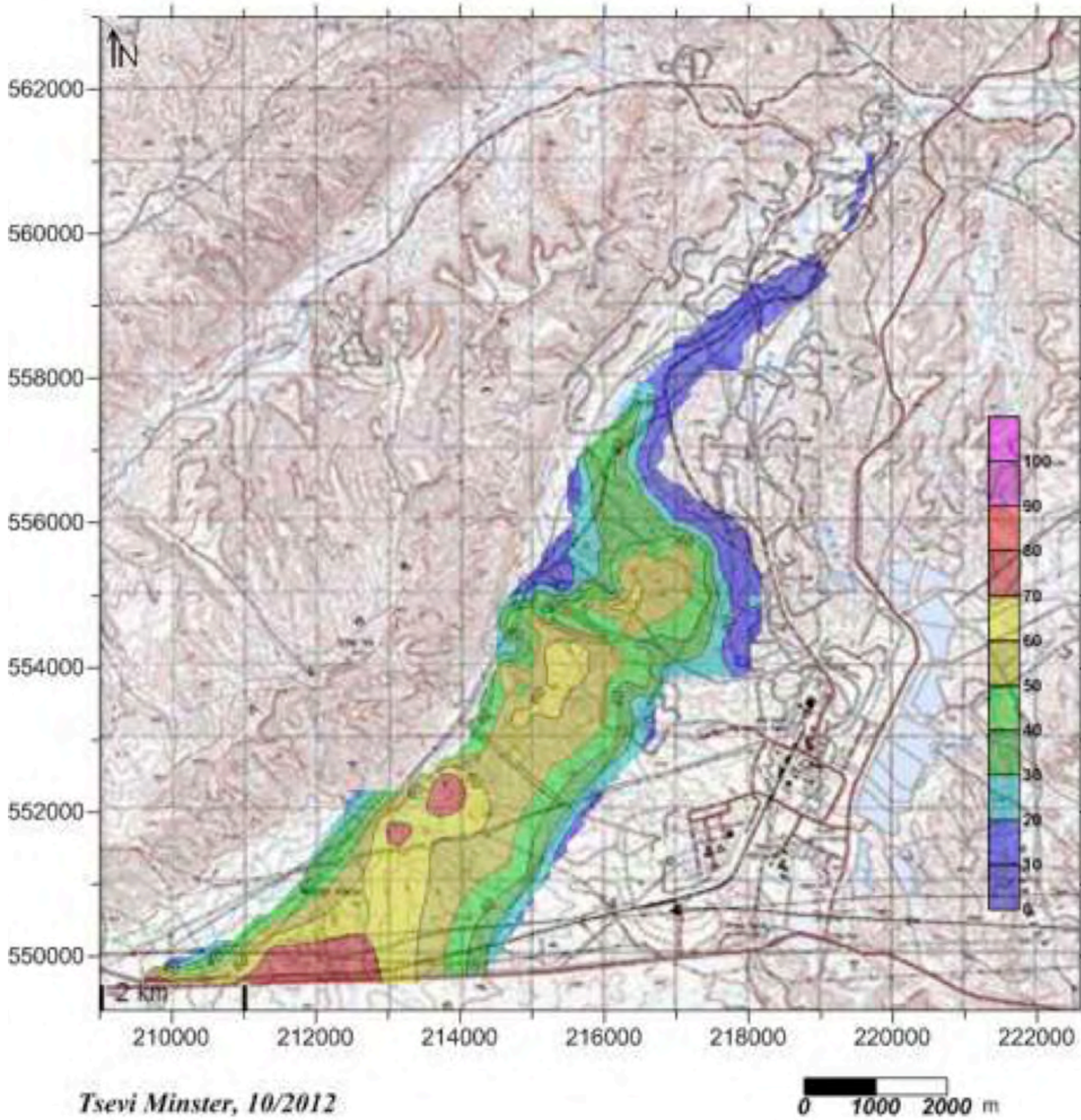

Figure 2: Mishor Rotem oil shale (TOC>6.8%) thickness (m)

for oil shale research activities in the north-central portion of the Mishor Rotem deposit. Activities in the permit areas include drilling of boreholes and studies to identify an appropriate recovery technology, most likely involving aboveground (*ex-situ*) retorting.

The mining license is held by Rotem Amfert Negev Ltd (RAN), which also operates the power station. RAN is a major producer of advanced phosphate-based agricultural fertilizers and additional industrial products. RAN operates several phosphate mines and excavates a total of about 51 million tons per year of phosphate rock and overburden materials. Mishor Rotem is one of the largest of RAN's mines. Market prices for phosphate rock have been very high ($180 - $200 per ton) for several years, whereas the costs of mining the rock have declined steadily over that same interval and stripping ratios have also improved. All of these factors have favored RAN's operations and have encouraged the company to seek other ways to improve profitability, such as the use of oil shale as an energy resource.

Phosphates are mined mainly in the northeastern and northwestern edges of Mishor Rotem basin. In these areas, the oil shale sequence lies above the economic phosphate beds and constitutes a major portion of the overburden.

Figure 3: The active oil shale mine in Mishor Rotem in September 2012, viewed from the east.

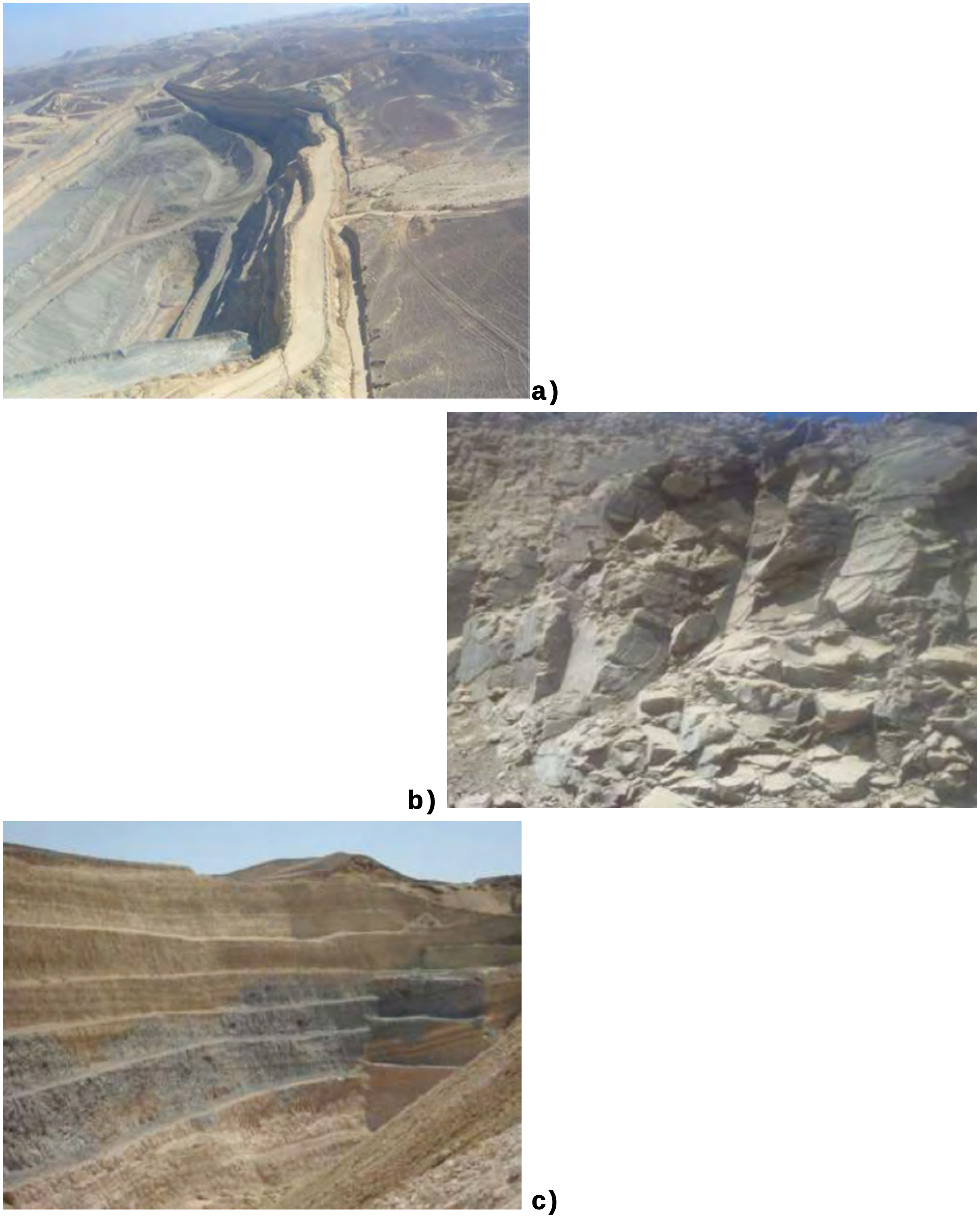

Figure 4: Additional views of oil shale and phosphate mines in Mishor Rotem: a) The open pit oil shale mine in Mishor Rotem in 2008, viewed from the mine's western edge, looking east. b) Oil shale "cliff" in the open-pit mine, Mishor Rotem. May 2012. c) Elongated phosphate mine in which the western edge of the oil shale body was exposed. September 2012

It has been estimated that below each square km of the oil shale body are ~10 million tons of phosphate rock (Shiloni and Minster, 1984). However, it is important to note that most of this resource is bituminous phosphate which cannot be used in most industrial applications without substantial beneficiation to reduce the content of organic carbon. Currently, Mishor Rotem is one of the largest oil shale mining operations in the world, with up to 2 million tons of oil shale mined per year, mostly to expose the phosphate beds. Some of the oil shale is burned in the power station, but most of it is discarded. In recent years, RAN has encountered a serious problem with its oil shale – spontaneous combustion both in the oil shale mine and in some of the dumping sites. The fires have had a substantial environmental impact, especially with unpleasant odors that have spread for tens of kilometers under certain weather conditions. The ensuing controversy almost led to the closure of the power station and the oil shale mine. RAN has launched a major program to solve the spontaneous combustion problem. A practical technology that will utilize the energy values in the mined oil shale, while promoting production of phosphate fertilizers, could have substantial environmental and economic effects on the operations at Mishor Rotem.

The Mishor Rotem oil shale deposit covers an area of approximately 25 km^2. The oil shale reserves (EOM > 6.8%) in the Ghareb Formation are estimated to be about 2.2 billion tons. The geological reserves of the bituminous phosphates below the oil shale body are estimated to be ~250 million tons. This is a very significant resource for RAN (and for Israel's domestic economy), given the unlikelihood of finding new phosphate deposits in southern Israel and the environmental controversy that impedes the permitting of new mining operations.

In-situ approach

A major research project to demonstrate the *in-situ* utilization of oil shale has been underway in Israel since 2008. The Jerusalem-based company Israel Energy Initiative Ltd. (IEI), which is associated with the American company Genie Oil and Gas, acquired a research permit for an area of 237 km^2 in the Ha'Shefelah oil shale deposit in central Israel, about 30 km west to southwest of Jerusalem. The permit covers almost a quarter of the inferred area of the entire deposit, which is probably the largest in Israel. The company reported activity included drilling and analysis of some 6 coreholes; hydrological, geotechnical and geophysical studies; establishment of an analytical lab in the Beer-Sheva campus of Ben-Gurion University; and execution of numerous analyses of organic geochemistry, heating parameters, and other characteristics. The company has reported that portions of the penetrated oil shale sequence contain beds at least 100 m thick with oil yields of 25 to 30 G/T (Bartov, 2012 and Fig. 5), which is above the average values reported for deposits in the northern Negev. The devices that will be used to heat the oil shale in future field experiments will likely be based on experience in Israel and the USA. For additional information, see the research contributions in Nguyen et al. (2012), and Gersman et al. (2011).

IEI's initiatives have attracted criticism from environmental groups and the general public because of the possible

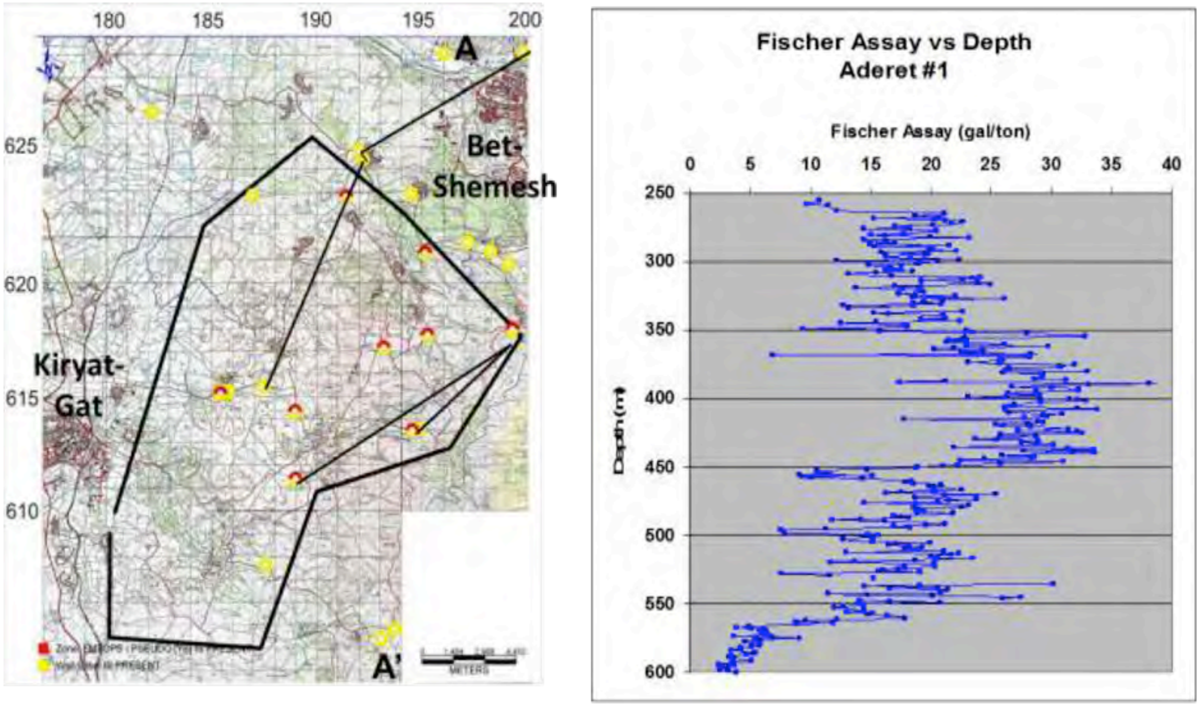

Figure 5. Location of IEI's permit area and oil yield results for one of their coreholes. Courtesy: Dr Y. Bartov, IEI.

negative consequences of *in situ* experiments on the resources of the Ha'Shefela area, which is populated and has numerous important archaeological sites.

Forecast to the year 2020

IEI's *in situ* work in Ha'Shefela may continue, if improved devices can be developed to heat the subsurface formations. Or the company may look elsewhere for development sites, such as in Nevatim (Figure 6), Sde-Boker, Ovdat, Nizzana, or Mash'abim. Prospecting programs may be required to confirm and extend the existing body of geological information. Mishor Rotem will continue to be the most important location for oil shale activities in Israel. RAN will continue to use surface mining to recover both oil shale and bituminous phosphate ore. The oil shale will be retorted to produce 10,000 to 25,000 barrels of shale oil per day, and bituminous phosphates will be beneficiated and used in fertilizer production. The integrated approach will avoid the need for a separate oil shale mining and disposal system and will solve the serious environmental problem of fires in the oil shale piles. Expanded mining at Mishor Rotem could also lead to the reclamation of lands disturbed by previous mining activities, such as those shown in the aerial views in Figure 7.

Feasibility studies by the lessees of research tracts in Mishor Rotem could lead to cooperative agreements with developers of advanced oil shale processing technologies. This could have important implications for oil shale development in many other countries.

The forecast breakthroughs at Mishor Rotem are likely to be replicated at other phosphate mining sites where there is a close association of oil shale and phosphates, such as at Oron North and Hahal Zin. Success in the joint exploitation of oil shale and phosphate ore and in the economical usage of bituminous phosphates could significantly increase the estimates of phosphate reserves in those areas. Advance prospecting of the sequence below the

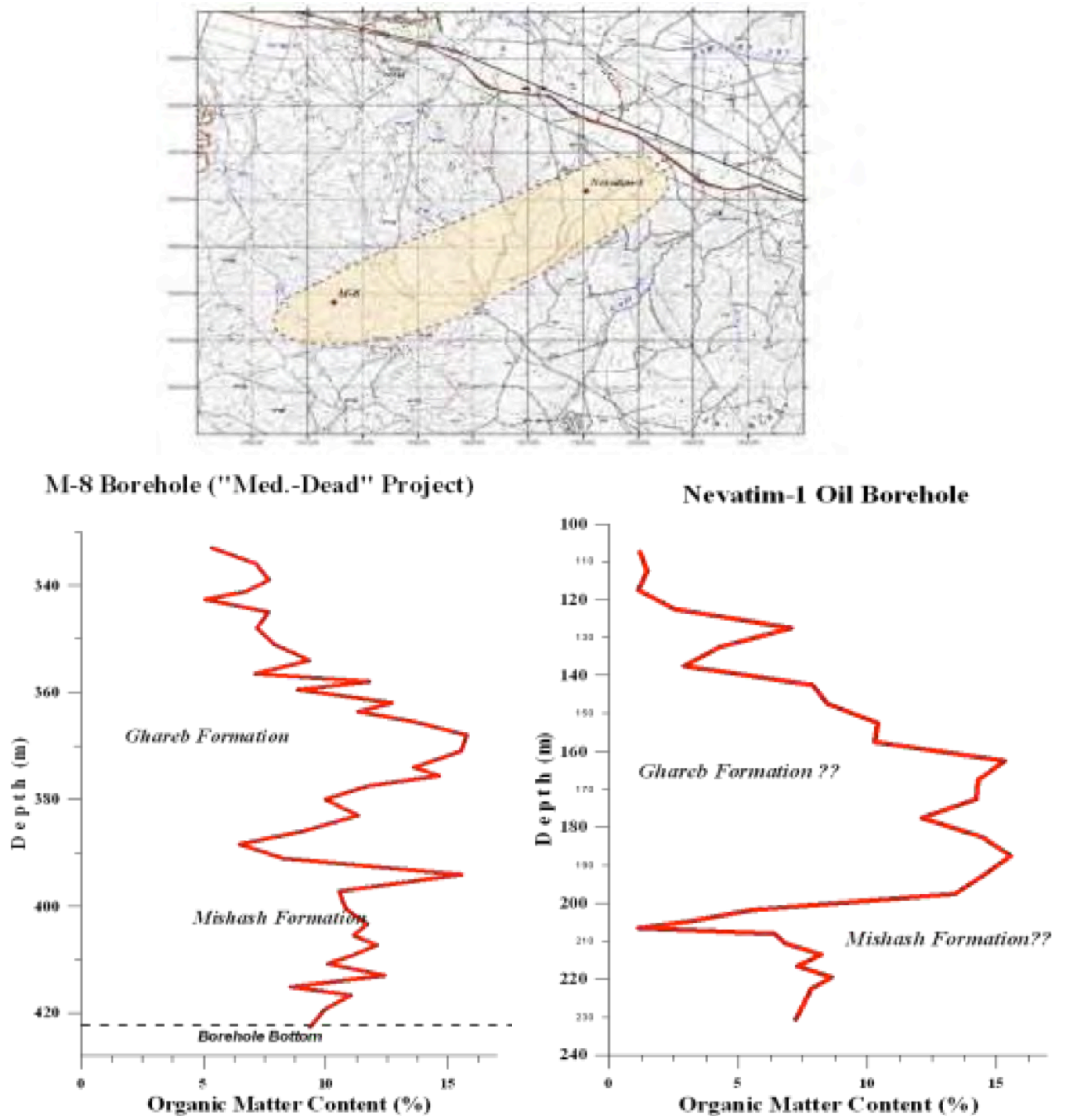

Figure 6. Nevatim oil shale occurrence. An example for a non-studied, possible deposit, that may well apply with the geological – hydrological requirements needed for in-situ experiments. It is located ~5 miles to the southeast of Beer-Sheva, and near a major railway line.

Mining benches, each ~15m high.

Oil Shale sequence below the surface

Figure 7. Google Map aerial views of some phosphate mining areas in the northern portion of the Mishor Rotem mining locality.

phosphate beds could also become important in Oron North and Nahal Zin and possibly in parts of the Mishor Rotem basin as well.

Israel's regulatory authorities may require prospective developers to share any resource information acquired during exploration programs on governmental lease tracts, as is done in Jordan, and could encourage contributions of information acquired in other areas. Such cooperative efforts, which might include development of improved standards for data acquisition and management or even the reestablishment of analytical laboratories, would enhance the national geological data base and could foster the rational and beneficial development of Israel's energy resources.

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