1990, Treatise of Petroleum Geology, Atlas of oil and Gas Fields Structural Trap IV - Tectonic and nontectonic fold traps - compiled by E.A. Beaumont and N.H. Foster.

Helez-Brur-Kokhav Field—Israel
Southern Coastal Plain

Y. GILBOA
Lapidoth
Israel Oil Prospectors Corp. Ltd.

H. FLIGELMAN
Oil Exploration (Investments) Ltd.

B. DERIN
Israel National Oil Company

FIELD CLASSIFICATION

BASIN: Eastern Mediterranean
BASIN TYPE: Passive Margin
RESERVOIR ROCK TYPE: Sandstone, Some Carbonates
RESERVOIR ENVIRONMENT OF DEPOSITION: Platform
RESERVOIR AGE: Lower Cretaceous
PETROLEUM TYPE: Oil
TRAP TYPE: Stratigraphic-Structural

LOCATION

The Helez field, a complex of three fields, Helez, Brur, and Kokhav, is located some 55 km (34 mi) south of Tel Aviv and 12 km (7.5 mi) east of the Mediterranean coast line. It was the first oil field discovered in the Eastern Mediterranean (1955) and is Israel's most significant oil-producing field.

The main producing formations are Neocomian sand beds and fringing dolomitic reef, with Oxfordian barrier reefs and Middle Jurassic calcarenite of secondary importance. The producing beds are overlain by Cretaceous and Tertiary sediments, the latter becoming very thick to the west. The field is 11 km (7 mi) long and 1 to 1.8 km (0.6 to 1.1 mi) wide with a producing area of 12.5 km² (30.9 mi²) (Figure 1).

The field is operated by Lapidoth-Israel Prospectors Corp. Ltd. Recently, Lapidoth granted limited farmouts to other operators (Naphtha-Israel Petroleum Crop. Ltd. and Delek Oil Exploration Ltd.) for exploration and development activities. The ultimate recovery is estimated to be about 19 million bbl

HISTORY

Pre-Discovery

During the British Mandate government, the Iraq Petroleum Co. (IPC) carried out gravity surveys in the coastal area of Israel. The surveys revealed a 50 km (31 mi) long trend of positive anomalies in its southern part, between Ashqelon and the Sinai border. Seismic surveys across the gravity maximum of the Huleiqat feature (now Helez) led to the spudding of the Huleiqat #1 well on 25 September 1947 (Tschopp, 1956). The first target, the Cenomanian dolomites, which are the country's major aquifer were encountered containing brackish water, and the underlying Albian-Aptian beds were found to predominantly carbonates with no hydrocarb shows. At a depth of 1055 m (3641 ft), 11¾-in. ca was set. Because of political unrest, drilling suspended without any positive results in Feb 1948.

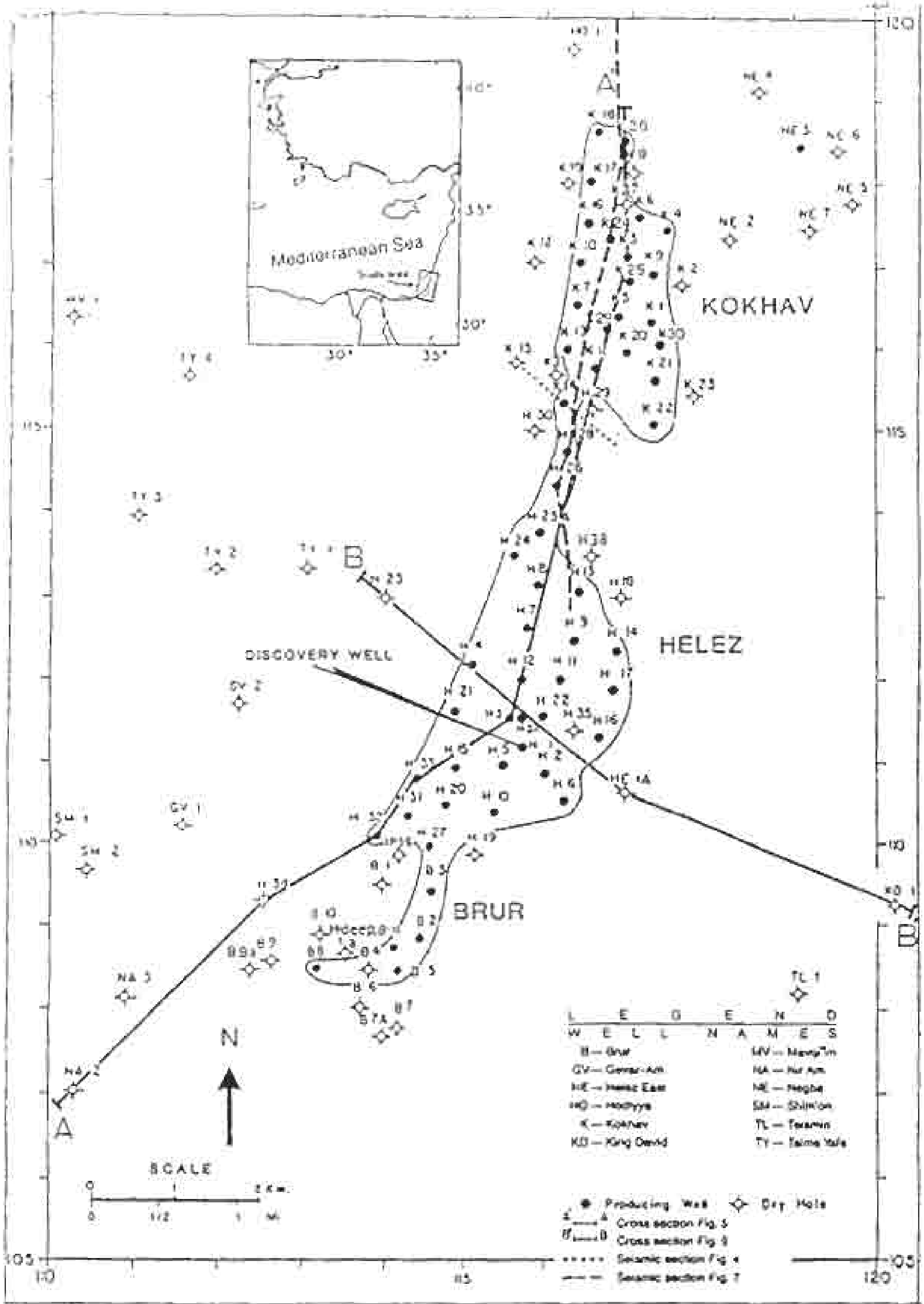

Figure 1. Map of the Helez oil field showing well locations, geologic cross sections, and seismic sections.

After the establishment of the State of Israel in 1948, the Weizmann Institute of Sciences carried out seismic surveys in the area. Based on these findings, the Beeri-Helez-Negba area was qualified as a good prospect (Ball and Ball, 1953). The gravity maximum prospect in that area was granted to the joint enterprise of Lapidoth and Israel Oil Prospectors (I.O.P.).

The coincidence of seismic structures with a gravity maximum, plus gas seepages detected during structural hole drilling, led Lapidoth-I.O.P. in 1954 to drill a test well at Beeri, 24 km (15 mi) south of the Huleiqat well. The Beeri 1 well was abandoned at a depth of 3646 m (11,962 ft) in Lower Jurassic beds without encountering any particular indications of hydrocarbons.

In spite of the disappointing results, Lapidoth's chief geologist, H. J. Tschopp, insisted on the oil possibilities of this major structural trend. Upon concluding that the Huleiqat well did not penetrate the sand-bearing section of Neocomian age, he recommended deepening it.

Discovery

With the data from five structural holes, the drilling of Huleiqat 1 well was resumed on 26 August 1955 and the well, renamed Helez 1, was deepened to 1515 m (4971 ft) (Figure 1) and completed as an oil producer on 12 October 1955. The initial production of the discovery well was approximately 400 bbl/d of 29° API oil from the porous Middle sandstone of the Helez Formation (Valanginian-Barremian age) at the depth of 1480 m (4856 ft) (Figure 2).

Post-Discovery

Field expansion and subsequent development started in 1955 and proceeded in several stages. Initial development of the field was concentrated in the central part, the Helez field, and in the southern part, the Brur field (Figure 1).

1. 1955–August 1962: Drilling of 29 development and stepout wells in the Helez area and six wells in the Brur area. Production was limited to the "middle sand member" of the Helez Formation (the "K," "W," "A," and "Z" sands, Figure 2). The northernmost stepout well (Helez 29 in Block E, Figure 3) was dry and considered the boundary of the field in that direction. One well, Helez 22 (TD 4477 m, 14,690 ft) in Block B tested deeper formations of Early Jurassic age without encountering new pay zones.
2. September 1962–1968: The drilling of 25 additional wells, following the oil discovery of Kokhav 1, located 1.2 km (0.75 mi) to the northeast of Helez 29. This well was recommended by W. Randall, Chief Geologist of Lapidoth, as another stepout trial to the north of the Helez field. As a result, 24 wells were drilled and production found mainly in two new horizons: the lower sandstone member, "B" sandstone, and the Kokhav dolomite (Figure 2). In addition there was minor production from the top Jurassic limestone. Only one well (Kokhav 7) was deepened to the Middle Jurassic and found no significant shows. Simultaneously, 14 wells were drilled in the Helez and Brur fields, some of them producing from the Kokhav dolomite and Jurassic limestones (Brur Calcarenite). Weeks (1962) was the first to define the Helez field as a hinge zone, and thus established a new exploration approach for the area. The hinge zone reflects the unstable conditions of the shelf margins.
3. 1969–end 1983: Except for one well in the Kokhav field (Kokhav 25) and a deep test to the basement in the southern portion (Helez Deep 1A), which was drilled by O.E.I.L., no drilling took place. The Helez Deep 1A was dry and abandoned at total depth of 6093 m (19,991 ft) in basement rocks.
4. End 1983–today: Drilling was resumed after granting farmouts to other operators. To date seven wells have been drilled (five in Kokhav, one in Helez, and one in Brur) with some success. Lapidoth itself opened new pay zones and deepened existing wells. This last phase of drilling is mainly responsible for the present field production rate of 450 bbl/d (October 1988). Older wells, each producing less than 8 bbl/d, are noncommercial.

A total of 82 wells were drilled in the Helez field, 55 of them producers.

Twenty-one wildcats surrounding the Helez field were drilled and abandoned within the Helez lease, finding no production.

All of the wells were drilled with rotary equipment using water-based mud. A typical completion consists of 300 m (985 ft) of surface casing (13⅜-in. or 9⅝-in.), a 1000 to 1200 m (3280 to 3940 ft) intermediate casing (9⅝-in. or 7-in.) to seal off the Upper Cretaceous loss of circulation zone, and a 7-in. or 5½-in. producing string to total depth (1500 to 1700 m, 4920 to 5580 ft). The most common tubing size is 2⅞-in. Some of the wells were dual producers, and in a few, several reservoirs were commingled.

Only electric resistivity logs and micrologs, and occasionally sonic and GR/neutron logs were run in the older wells (to 1970). A fuller suite of logs (induction, gamma ray, compensated neutron, sonic, density, and dipmeter) is now commonly run.

STRUCTURE

The Helez field is located on a faulted anticline, tilted with a gentle dip to the east and downfaulted to the west (Figure 3). The folding is related to deep-seated compressional faults (Figure 4). Truncated Upper Jurassic beds reflect the high position of the structure during the Late Jurassic and probably

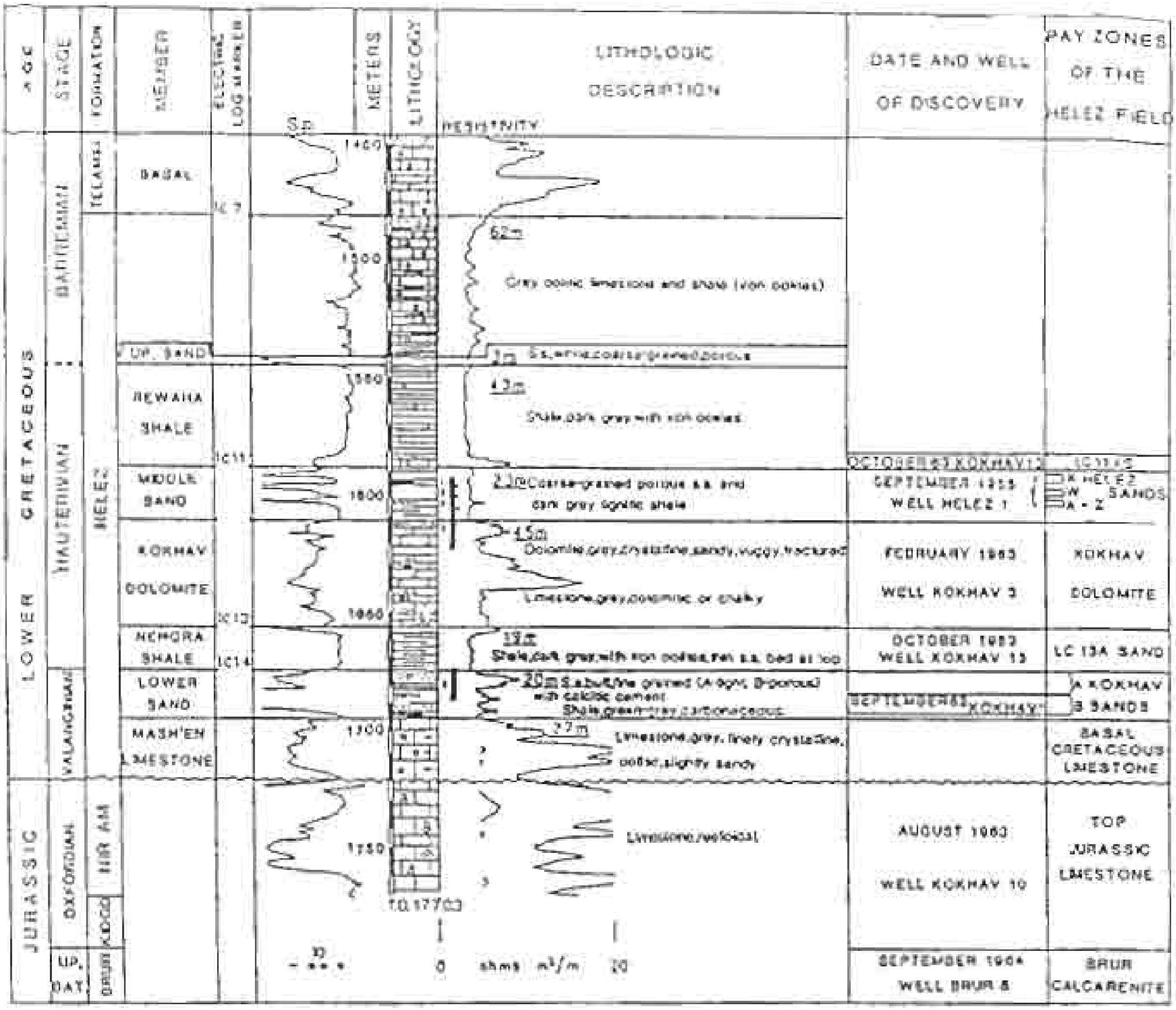

Figure 2. Producing zone of the Helez field, presented on the log of Kokhav-2 well (see Figure 1). In this well the Gevar-Am Formation is missing. Kidod shale and Brur not penetrated. (Modified from Shenav, 1971.)

earlier (Rosenberg, 1979). Pre-Cretaceous erosion carved a canyon that crosses the Helez oil field in a northwesterly direction (Figures 5 and 6). Within the field this canyon formed a channel 16 km (9.9 mi) long and 7 km (4.3 mi) wide with wall slopes of about 40°. The canyon is filled with up to 1000 m (3280 ft) of shales belonging to the Lower Cretaceous Gevar-Am Formation.

The Helez structure is characterized by two axial trends (Figure 3), a north-south Jurassic trend, predominant in the northern part of Helez and Kokhav, and a northeast-southwest Late Cretaceous-early Tertiary structural trend, dominant in the southern blocks of Helez and Brur.

The known faults that affected the area are related to the following events:

1. Uplifting and tilting at the end of the Jurassic.
2. The Alpine folding phase of Late Cretaceous and early Tertiary times.
3. Neogene tensional movements (Rosenberg, 1979).

During the Neogene events, transverse faults divided the Helez field into several blocks (Figures 3 and 7).

STRATIGRAPHY

Israel is located on the northern margin of the Arabo-Nubian massif that stabilized during the Precambrian, some 600 m.y.a. The geological history of the country is closely related to the interplay of this huge, rigid cratonic mass and the sea lying to the north and northwest of it. The vast, shallow epeiric seas that characterized the area during long

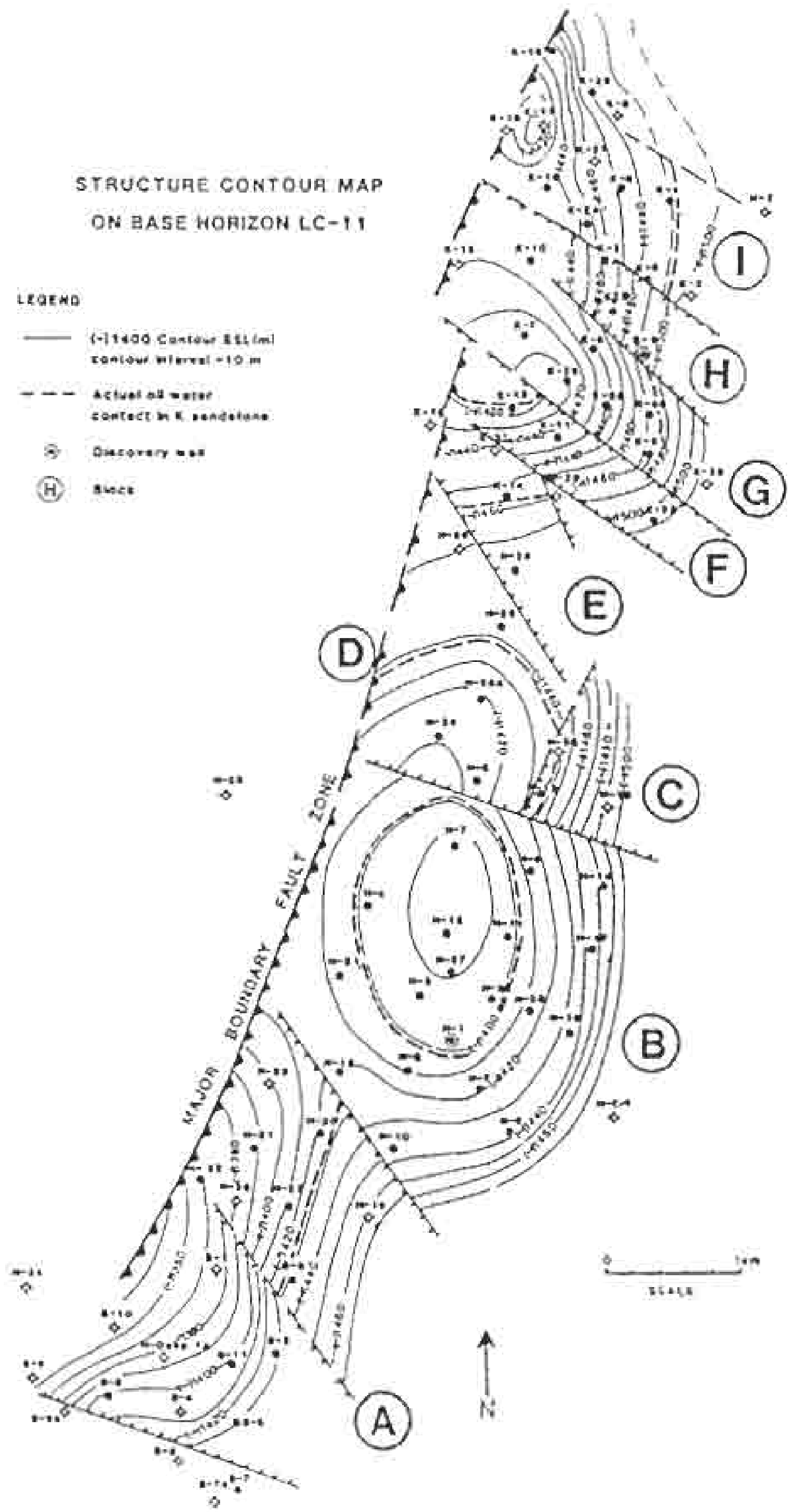

Figure 3. Helez-Brur-Kokhav field structure contour map on base horizon LC-11. C.I. = 10 m.

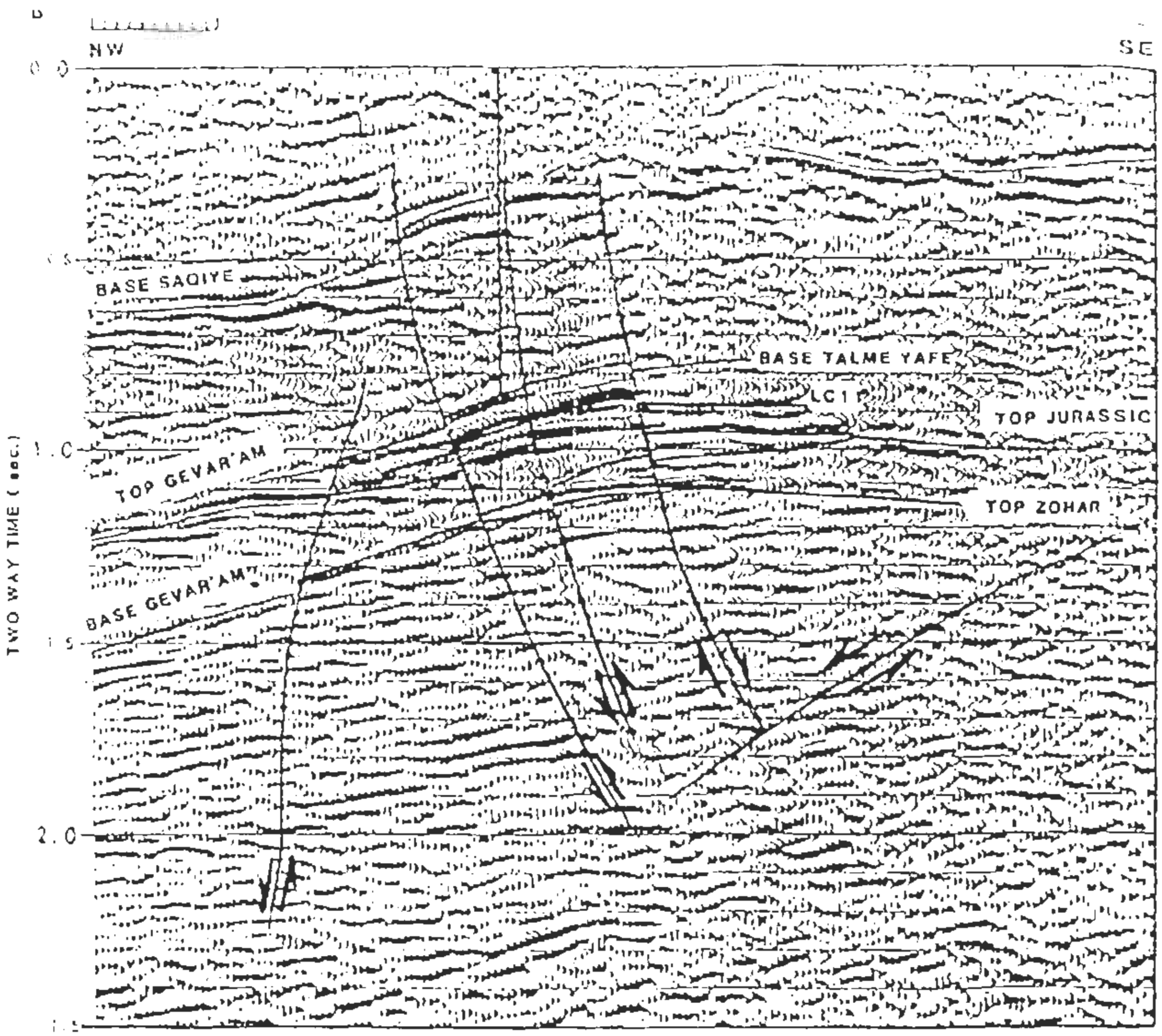

Figure 4. Kokhav field. (A) Interpreted transverse seismic cross section, (B) Uninterpreted seismic cross section. (For location, see Figure 1, B–B'.)

geological periods are a direct result of the shield's proximity. Most of the sediments were deposited on a platform under varying continental and epicontinental environments. The stratigraphic column in the platform area is considered to be not more than 6.5 km (21,000 ft) thick, mostly of Mesozoic age. In the early Tertiary, on the other hand, the topographic relief was high and the sea began to retreat. West of this platform, beyond the hinge line, a thicker sedimentary column was deposited on the Cretaceous and Neogene continental slope and outer shelf underlying the present-day coastal plain and shelf (Bein and Gvirtzman, 1977).

The Arabo-Nubian massif contributed enormous quantities of clastic sediments of Mesozoic age to the shallow, adjacent basin. In the Tertiary the Nile River also distributed the massif's clastics on the ancient shores of Israel. The clastics intermingled with shallow sea carbonates of biogenic origin, and their very fine detrital derivates also spilled over the shelf edge, accumulating at the base of the continental slope (Bein and Weiler, 1976).

The Helez field is located on the edge of this platform. Here, only one well (Helez Deep 1A) penetrated the entire sedimentary column, commencing in Pleistocene sediments and drilling through the Middle Triassic (Paleozoic and early Triassic sediments are missing). The stratigraphy of the area (Table 1) is summarized below.

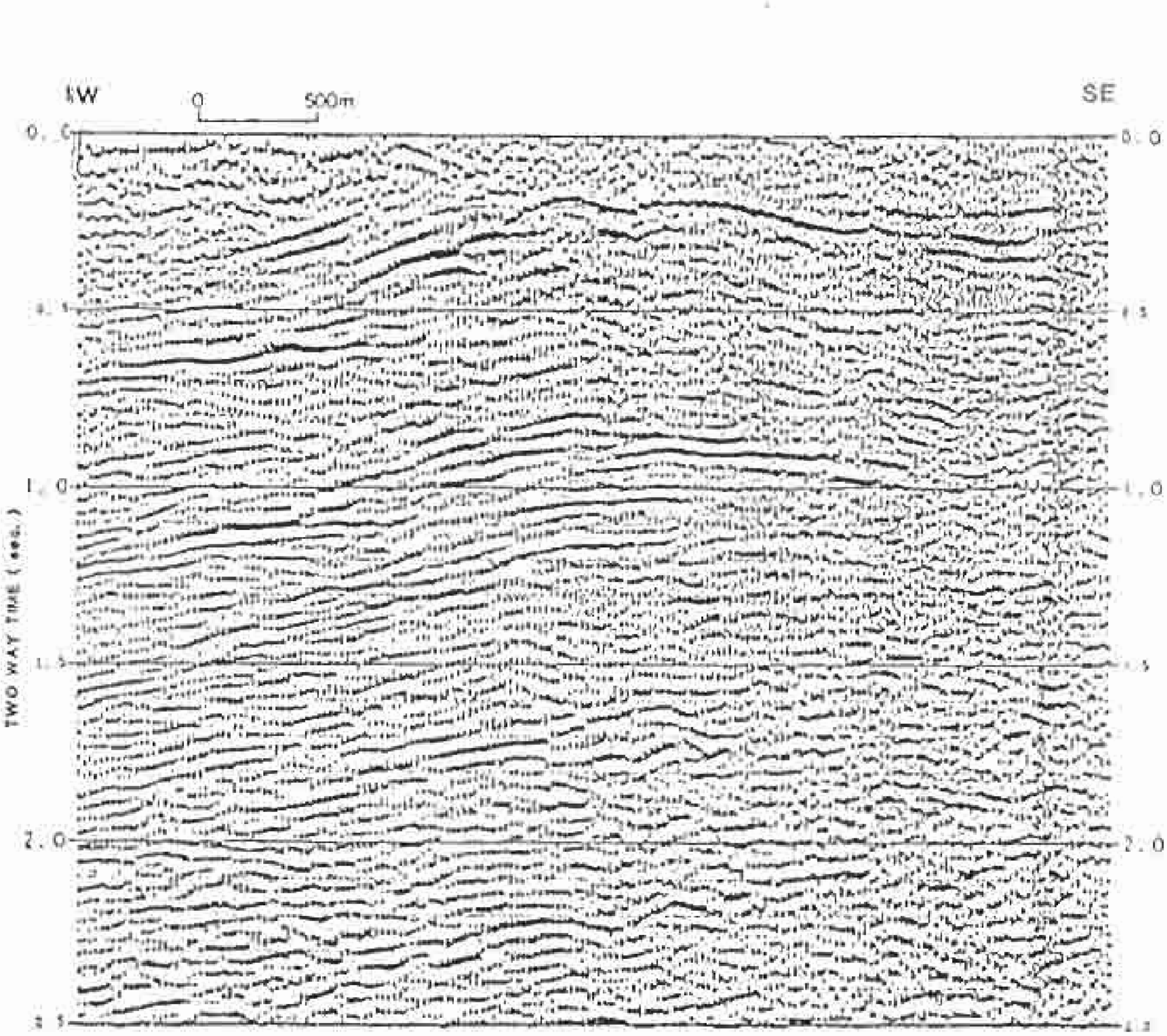

Figure 4B.

Paleozoic

Acid volcanics (Erez Porphyr), probably of Paleozoic age, overlie older, green Doroth schists at a depth of 6000 m (19,690 ft) in Helez Deep 1A.

Triassic

The Erez volcanics are overlain by a 315 m (1033 ft) thick section of Middle Triassic Or Haner Conglomerate (Garfunkel and Derin, 1983). The missing Paleozoic section was eroded during intra-Triassic movements. A sequence of Upper Triassic shallow-marine dolomites and limestones overlies the conglomerate.

Jurassic

The Jurassic sequence in the Helez area is extremely thick, being almost 3000 m (9840 ft). It is subdivided into three distinct units (Derin and Gerry, 1972; Derin, 1974; Rahamim, 1973):

1. The Lower Jurassic unit penetrated completely in the Helez Deep 1A well consists of 1400 m (4590 ft) of shallow-marine carbonates.
2. The Middle Jurassic unit is characterized by intercalation of open-marine spiculitic limestone (Barnea Limestone) and shale, as well as high energy, oolitic shoal and shallow shelf sediments (Derin, 1974).
3. In the Late Jurassic, the Helez area was located on a high energy barrier reef trend (Derin, 1974). This threshold zone separates a deep, open-marine area and probably a "starved basin" to the west from a shallow, inner shale basin and shelf carbonates to the east (Figure 8).

The uplift and tilting at the end of the Jurassic exposed Jurassic rocks in parts of the Helez field area

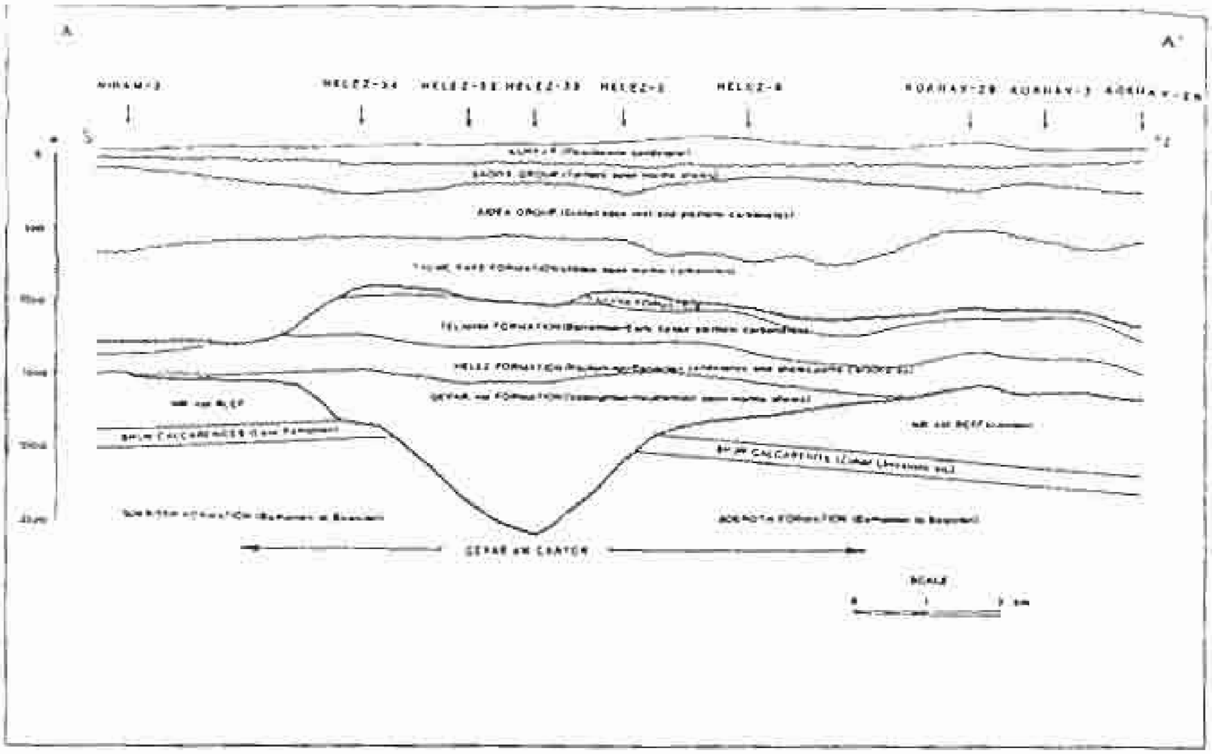

Figure 5. Geologic cross section in the Helez oil field showing the position and shape of the Gevar-Am canyon. (Location is shown on Figure 1.)

to subaerial erosion, forming the latest Jurassic-earliest Cretaceous unconformity phase. This erosional phase probably coincides with the initial development of a submarine canyon (Gevar-Am channel) and the karstic phenomena in the Jurassic Nir-Am Barrier Reef.

Lower Cretaceous

During Early Cretaceous time, as in the Late Jurassic, the Helez field area was located on a "shelf break" or hinge zone (Garfunkel and Derin, 1983). Here Lower Cretaceous platform sediments were deposited over a gently inclined Jurassic erosional surface, and the shaly facies equivalent was formed on the basinward side. During the Neocomian-Lower Aptian, the interplay between the rate of subsidence and the rate of supply of sedimentary material as well as temporary periods of minor uplift continuously shifted the position of the hinge line and along with it, the related environments (Grader and Reiss, 1958; Z. Cohen, 1964, 1969, 1971, 1976; Gvirtzman and Klang, 1972; Bein, 1974; Bein and Weiler, 1976; Bein and Gvirtzman, 1977; A. Cohen, 1983).

The Lower Cretaceous is divided into five formations, easily distinguished by their lithological properties (Cohen, 1971 and Table 1):

1. Gevar-Am Formation: Berriasian to Barremian; 0-940 m (3084 ft). A series of gray silty shales bounding the field to the west and filling the old erosional Gevar-Am channel that traverses the Helez field. Consequent dark shales with a few pyritic sand lenses filled the deep basin west of the continental slope and the submarine channels that cut it, followed by the sedimentation of the transgressive Helez Formation that extended far to the east (Shenav, 1971; Cohen, 1969, 1976). Simultaneously the shaly Gevar-Am Formation continued to be deposited in the deeper basin (Figures 6 and 9).
2. Helez Formation: Valanginian-Barremian; 160-370 m (525-1215 ft). This formation is comprised of a series of alternating beds of shale, sandstone, and a subordinate amount of limestone and dolomite. Overall, the sediments tend to be thinner continental sediments in the east, and in the west, thicker, marine deposits (Figure 2).
3. Telamim Formation: Upper Barremian-Lower Aptian; 160-290 m (525-950 ft). This formation

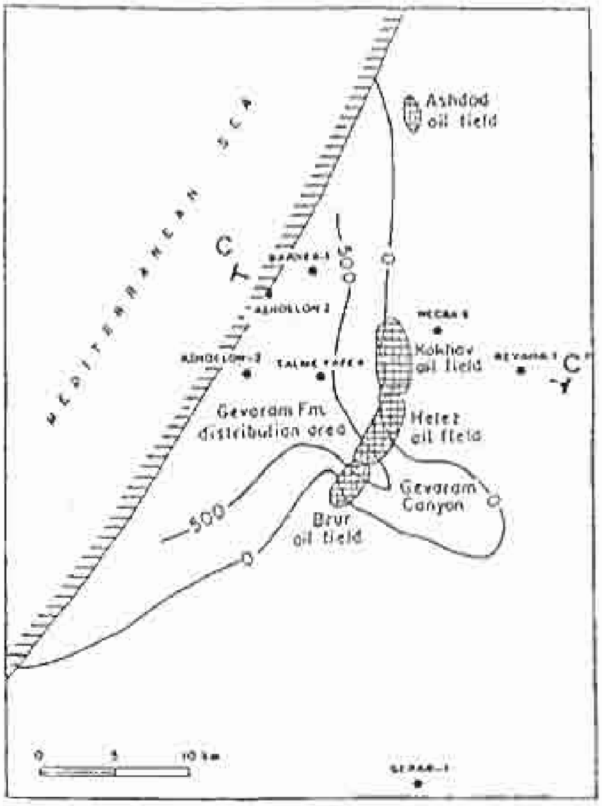

Figure 6. Thickness of the Gevar-Am Formation in the Helez area (contour interval, 500 m). C-C' indicates location of section in Figure 11. (From Bein and Sofer, 1987.)

is comprised of a section containing dolomitic, oolitic, or sandy limestone with several sandstone beds at the base and a reef bank at the top.

4. Yakhini Formation: Upper Aptian; 430–530 m (1410–1740 ft). This formation is comprised of a sequence of limestone, chalky limestone, dolomitic limestone, dolomite, and marl.
5. Talme Yafe Formation: Late Aptian-Albian; 0–850 m (0–2790 ft). This formation is comprised of a series of light gray marlstones with streaks of gray to buff pelitic limestone, thickening westward in the form of a wedge.

Generally, two environments of deposition can be distinguished in the Helez area: (1) platform or shallow marine-littoral deposits of shale, sandstone, limestone, dolomite, and dolomitic reefoidal limestone of the Helez, Telamim, and Yakhini formations (Bein, 1974), and (2) deep basin sediments deposited west of the continental slope consisting of dark shales of Berriasian–Aptian age (Gevar-Am Formation) and clastic marls with conglomerate and carbonate detritus of Albian age (Talme Yafe Formation). The two basinal formations overlie unconformably older strata without being congruent in their extension or direction of development (Figures 5 and 9).

Upper Cretaceous

The Upper Cretaceous sequence consists of Cenomanian–Turonian-aged (Judea Group) shelf carbonates (dolomites and limestones).

Senonian beds were not encountered in the field area.

Tertiary

Paleocene and Eocene formations are missing in the Helez area and a thick section of shale and marl of late Eocene to Pleistocene age (Saqiye Group) overlie unconformably the Cretaceous beds. The Tertiary sequence is clearly divided into two main parts separated by an unconformity: (1) the late Eocene–Miocene and (2) Pliocene–Pleistocene. Late Miocene-aged evaporites are developed generally west of the Helez field as well as in the whole Mediterranean basin (the Messinian crisis).

Pleistocene–Holocene

The youngest sediments in the area consist of calcareous sandstones (Kurkar Group) covered by soils.

TRAP

The Helez field is a combination stratigraphic-structural trap located on a northeast–southwest-trending faulted anticline that is tilted gently to the east and downfaulted to the west (Figures 3, 4, and 7).

The structural configuration of the field area was probably developed during the Late Cretaceous to the Eocene folding phase, coinciding with the above-mentioned depositional hinge belt. Prominent Upper Jurassic reef fronts acted as a barrier to the Lower Cretaceous sands carried from the land by the rivers (Rosenberg, 1979). The importance of the Jurassic barrier reefs and the Lower Cretaceous patch reef (Kokhav Dolomite) does not lie only in their reservoir characteristics but in their effect on the sedimentation on the lagoonal (eastern) side of the oil-bearing sand beds. Under these environmental conditions the sands were deposited westward toward the crests of the underlying reefs. Since thinning and shaling out of these sands occurred in the same direction (updip), stratigraphic traps were later formed. The Helez sandstone reservoir rocks themselves are sealed by overlying and interbedded shales (Shenav, 1971, and Figure 2).

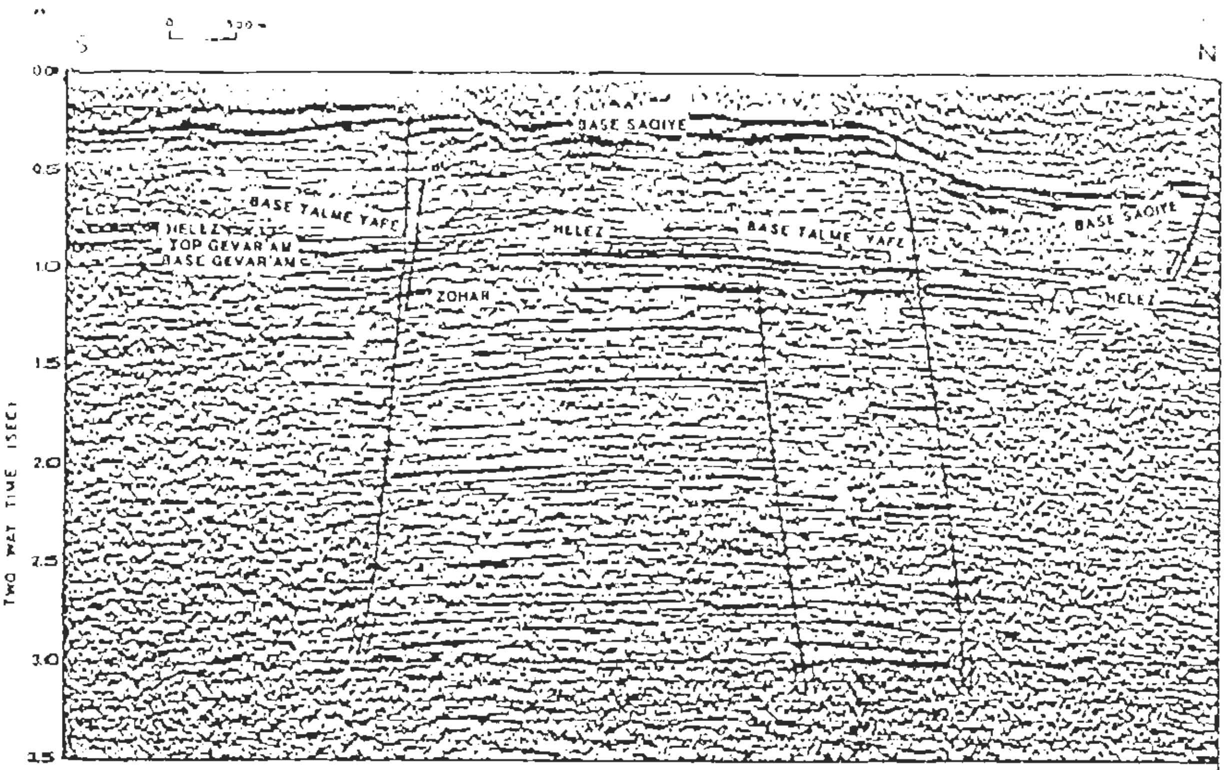

Figure 7. Helez-Kokhav field. (A) Interpreted longitudinal seismic cross section. (B) Uninterpreted seismic crosssection. (For location see Figure 1, A–A'.)

SOURCE

The Helez oil source rock and the oil migration path remain a matter for discussion. As described above, part of the Helez field is crossed by the deep Gevar-Am canyon that cut approximately 1000 m (3280 ft) into Jurassic limestones during Early Cretaceous time, which was subsequently filled by shales of the Gevar-Am Formation (Cohen, 1976). The dark shale basinal environment of Gevar-Am deposition is limited to the east by the hinge belt of Late Jurassic age. In places these shales interfinger with the Helez Formation in which most of the oil has been found, and they also lie in contact with Jurassic limestones containing oil produced in the Helez-Kokhav trend as well as in the Ashdod field wells farther north (Figure 6). Therefore, it was logical to conclude that the Gevar-Am shales are the source rocks of the Helez oil (Cohen, 1971, 1976). Later, Amit (1978) noted that the Gevar-Am shales in the Helez area are immature for oil generation, while in the west, near Ashqelon where they are buried much deeper, they have a higher degree of maturation. These facts led Amit (1978) to consider the more deeply buried Gevar-Am shale in the west as the potential source rock.

In a recent study, Bein and Sofer (1987) have made significant progress in understanding the mechanism of the Helez oil migration. They analyzed extracts of the Middle Jurassic Barnea Formation and found a geochemical similarity between them and the oil accumulations and shows found in the Helez-Kokhav, Ashdod, and Ashqelon wells (Figures 6 and 10). Average total organic carbon (TOC) of the Barnea limestone is 0.5%, reaching a maximum of 2.6%, and its kerogen type is II. No similarity with the hydrocarbons was found in the extracts of the Gevar-Am Formation (Figure 10).

OIL MIGRATION

These findings led Bein and Sofer (1987) to suggest that the oil generated in the west at the depth of 4500–5000 m (14,760–16,400 ft) by a common source rock, the Jurassic Barnea Limestone, was later expelled, migrated updip eastwards below the blanket of the Gevar-Am shale, and then accumulated in the Helez sands and Upper Jurassic limestones. The migration was possibly aided by faulting and fracturing (Figure 11).

However, it is not yet clear whether the bitumen extracted from the Barnea Limestone is indigenous or a product of migration from other sources. Therefore, in addition to the Barnea Limestone and

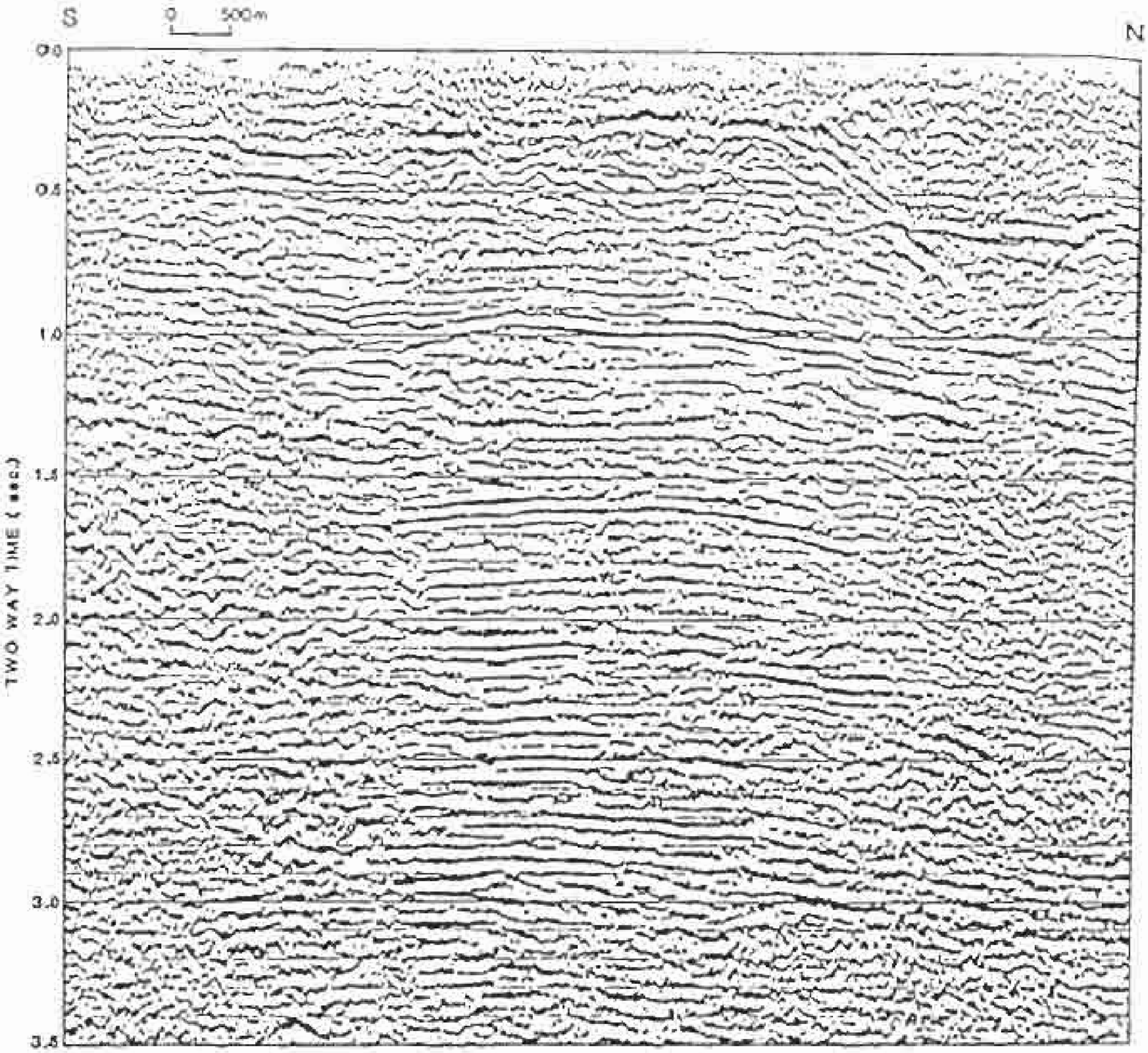

Figure 7B.

Gevar-Am shales, deeper Triassic beds are considered a potential source. The existence of such Triassic source rocks best explains the oil shows in the Lower Jurassic in the Ramallah wildcat (north of Jerusalem) and in the Triassic in Ga'ash 2 well located in the central Coastal Plain (May, 1981, 1984).

Because the exact source rock of the Helez oil is not clearly identified, the timing of migration and the trapping can only be speculative. It seems that the oil migrated and was trapped in the Helez field reservoirs during the Neogene, after the major tectonic movements. Intensive Oligocene–early Miocene erosion enabled the flushing of the formation's earlier fluids by the intrusion of the late Neogene sea that penetrated the exposed older (probably Cretaceous) beds. It is most likely that the oil trapping process occurred through the post-folding tensional transverse faults that cross the Helez field, ascending from deep layers in the western basin.

RESERVOIRS

General Description

The Helez field produced oil from the Lower Cretaceous Helez Formation (several sandstones and two carbonate zones) and to a lesser extent from Upper and Middle Jurassic porous limestones (Figure 2). The Helez sandstones are the main oil reservoirs. The

Table 1. Generalized stratigraphic column for the Helez area.

Age			Group or Formation: Basin	Group or Formation: Platform
Pleistocene-Holocene				Kurkar
Neogene			Saqiye	
Upper Cretaceous		Cenomanian-Turonian		Judea
Lower Cretaceous		Albian	Talme Yafe	Yakhini
		Upper Aptian		
		Lower Aptian	Gevar-Am	Telamim
	Neocomian	Barremian		
	Neocomian	Hauterivian		Helez
	Neocomian	Valanginian		
	Neocomian	Bernasian		
Jurassic	Late	Oxfordian		Nir-Am/Beer Sheva Kidod
	Middle	Bathonian		Karmon
		Bajocian	Barrea	Sderoth
		Aalinian		Upper Nirim
	Upper	Lias		Nirim Upper/Lower Mish'hor
Triassic	Late			Shefayim (Mohilla equiv.)
	Middle			Or Haner Col.
Paleozoic ?			Erez Porphyr	
Precambrian			Doroth Schist	

upper sandstone reservoirs ("K," "W," and "A-Z") are related to the middle sandstone member and are found at an average depth of 1500–1550 m (4920–5090 ft) (1390–1490 m or 4560–4890 ft SSL). These sandstone beds, ranging in thickness from 1 to 12 m (3 to 40 ft), are separated by shale layers (Figure 2). The "A-Z" sandstone that appears as one sandstone body off structure to the east is separated updip into two sandstones, "A" and "Z" (see Figure 12). The "B" sandstone (the lower sand member) is the most important producing sandstone in the Kokhav field and is found at an average depth of 1650 m (5400 ft) (1525–1600 m or 5000–5250 ft SSL).

A permeability barrier, the Gevar-Am shale, is located at the updip western limit of the sandstone. Commonly, production becomes poorer toward the west in spite of a relatively higher structural position owing to increasing shaliness or pinchout of the producing sandstones. Conversely, on the eastern and downdip flank of the structure, the sandstones have better porosity.

Transverse adjustment faults that divide the Helez structure into blocks separate the Lower Cretaceous sandstone pay zones into different reservoirs. These relatively small faults were located on the basis of production anomalies, seismic interpretation, structural mis-ties, and reservoir pressure differences that could not be explained otherwise (Figure 3).

The LC 11 Limestone is found immediately above the middle sand member and produced from only one well (Kokhav 13).

The reefoidal Kokhav Dolomite developed on the margin of the elevated platform and extends along the Helez field's anticlinal structure. Its productive limits are affected by the same faulting system as the producing Helez sands as well as by lithologic changes into limestone or shale.

The basal Lower Cretaceous oolitic limestone, the Mashen Member of the Helez Formation, and the Jurassic Nir-Am Reef are considered as one thick continuous reservoir underlain by one common aquifer, since no apparent separation between the two formations exists. Even faulting does not necessarily isolate the oil trapped in different fault blocks owing to the considerable thickness of the Jurassic beds and the apparently common fracture systems of both formations. In most areas, the fractured limestones of the two formations have a very low matrix porosity. Any significant porosity, therefore, is mainly secondary and developed in fractures and solution vugs. The oil-producing limestones were found at the depth of 1600–1700 m (5250–5580 ft).

The Middle Jurassic Brur Calcarenite producing area is limited to the southern extreme of the Helez field.

Petrography of Sandstone Reservoirs

The major reservoirs of the Helez field are the middle and lower sand members of the Helez Formation (Shenav, 1971, and Figure 2). The sandstones of the Helez Formation constitute about 10% of the total formation and are partly mixed with tuff. Quartz, which is the dominant mineral, was

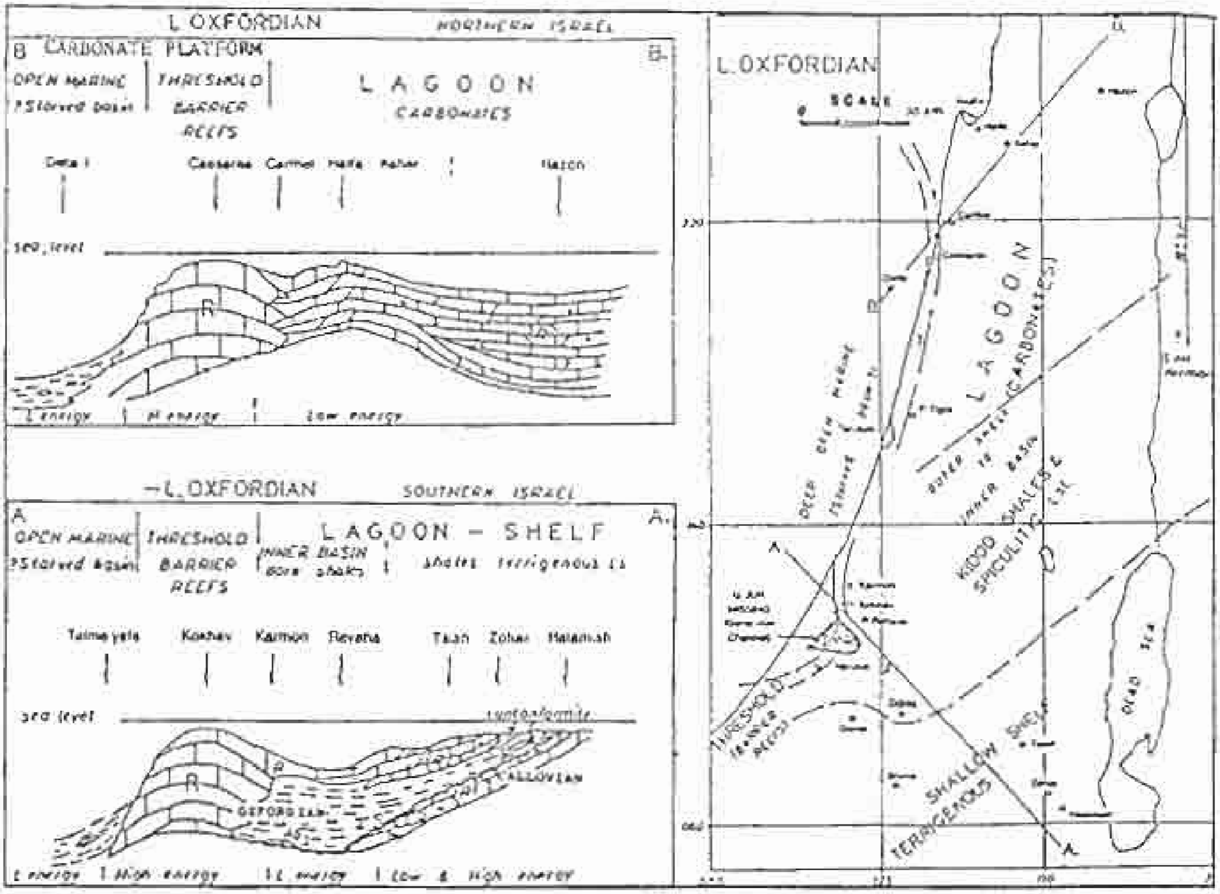

Figure 8. Upper Jurassic environments of deposition. R, reef. (From Derin, 1974.)

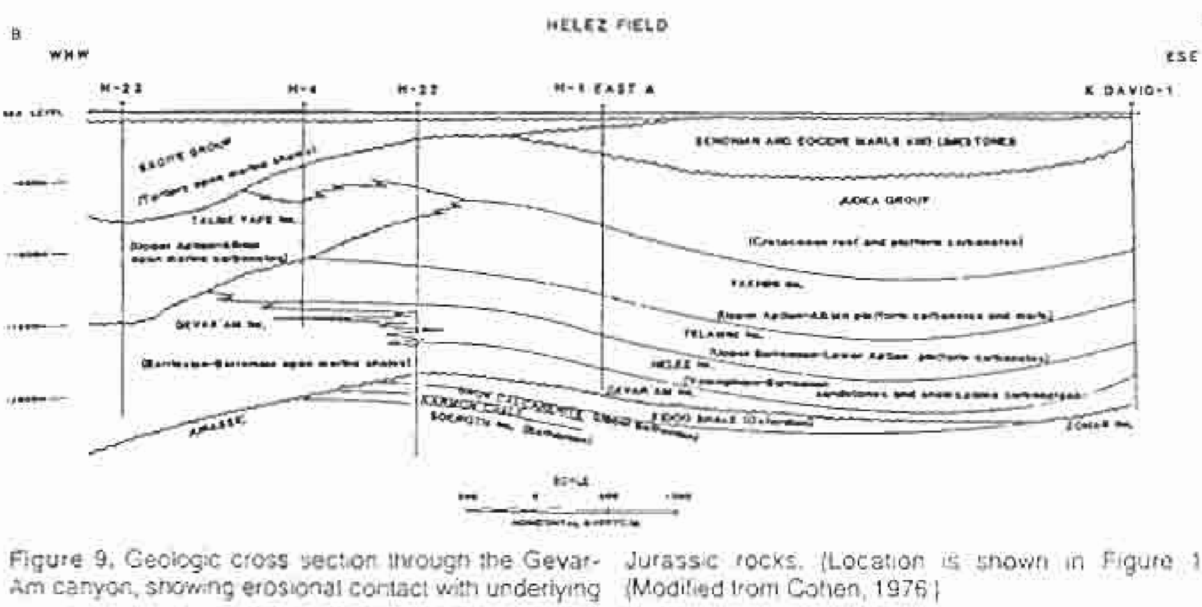

Figure 9. Geologic cross section through the Gevar-Am canyon, showing erosional contact with underlying Jurassic rocks. (Location is shown in Figure 1.) (Modified from Cohen, 1976.)

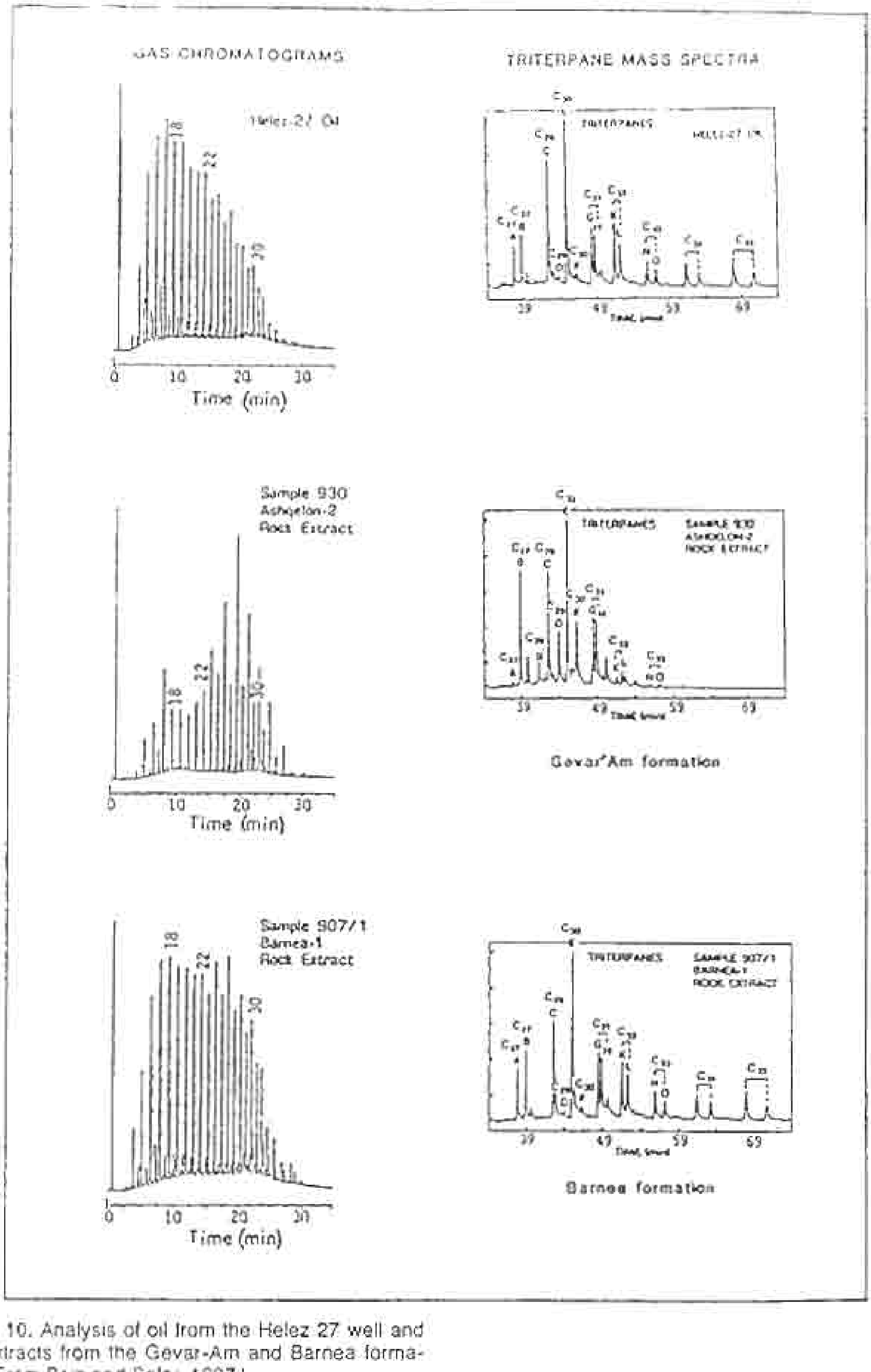

Figure 10. Analysis of oil from the Helez 27 well and rock extracts from the Gevar-Am and Barnea formations. (From Bein and Sofer, 1987.)

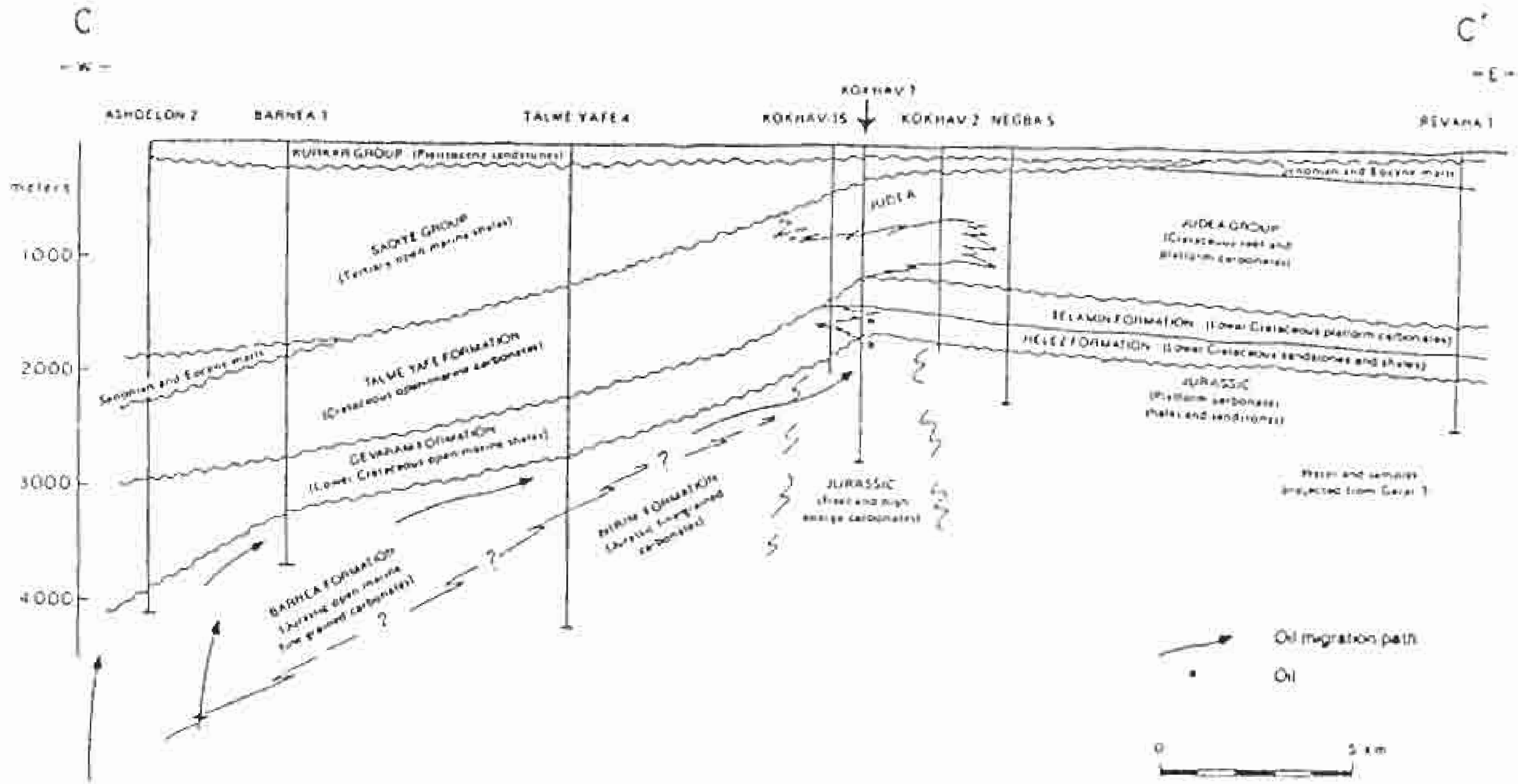

Figure 11. Oil migration paths in the Helez area. (Location is shown on Figure 6.) (After Bein and Sofer, 1987.)

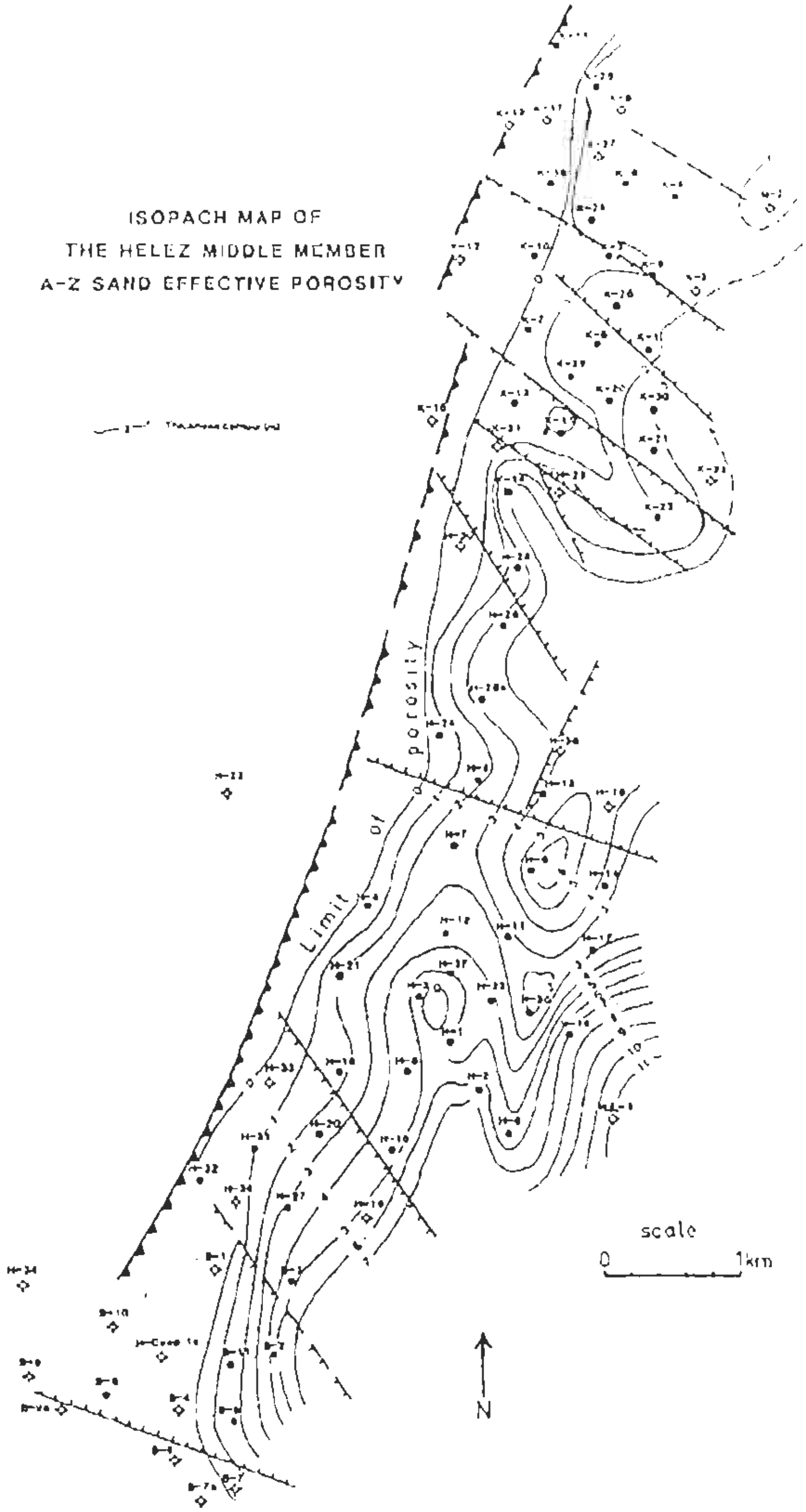

Figure 12. Helez-Brur-Kokhav field. Isopach map of the Helez middle member "A-Z" sand effective porosity. C.I. = 1 m.

derived by weathering and redeposition of Nubian sandstones exposed to the east and southeast. Other grains found in the sandstone include sanidine, volcanic rock fragments, and various carbonate, phosphate, and iron (oolite) allochems. Calcite cement tends to be found in marine sandstones, whereas dolomite cement is found in sandstones that were deposited in the coastal area (Shenav, 1971).

Four porosity types were defined, of which intergranular and intercrystalline porosities are the principal types.

The reservoir sandstones of the Helez Formation were divided by Shenav (1971) into three types (Figure 13):

Type I — Sandstone includes part of the lower sands and part of the middle sand "K." Deposited in an offshore marine environment, it contains marine fossils and is cemented generally by sparry calcite. Average grain size is medium to fine. The grains are moderately to poorly sorted. Porosity is intercrystalline and reaches 16%. Permeability is less than 30 md.

Type II — Sandstone includes middle member sands, "A-Z," "W," and part of the "K" sand, deposited in a tidal channel and/or lagoonal environment. It is composed of sands of medium grain size, with moderate or poor sorting and few marine fossils. Cement is calcitic and/or dolomitic. Porosity values may reach 30% (average 16%), and permeability may be up to 2000 md (average 50 md). The lower values are related to moderate sorting and to high clay content.

Type III — Sandstone includes part of the middle member sands "A-Z," "W," and the lower sand ("B" or Kokhav sand) and is probably of eolian origin, deposited in a coastal area. These sands, with average mean grain size ranging from very fine to medium, do not contain marine fossils. The grains are mostly well sorted, loosely packed, and with low cement content. Porosity can reach 32% (average 24%), and permeability may exceed 2000 md (average 200 md).

Most of the oil (about 38 million bbl of oil in place) is found in the more porous sandstones (types III and II) that were deposited in coastal environment, either eolian, tidal channels, or lagoons. Marine sandstones (type I), where the porosity values are generally low, contain almost no oil.

Rock and Fluid Characteristics

Based on core analysis data in conjunction with log calculations, typical values of porosity and original water saturation for each zone have been obtained (Table 2). Permeability values are significantly variable in the sandstone reservoirs, as illustrated by their distribution in the Helez main producer, "A-Z" sand (Table 3). Saturation dependent data of oil/water relative permeability is not available. A PVT analysis has never been performed on the Helez oil. Physical reservoir conditions including temperature, pressure, and fluid properties measured in the field are as follows:

Bottomhole temperature	150°F
Initial pressure	2000 psig @ 1402 m SSL
Oil gravity	27.5-31.0 API
Solution gas-oil ratio	200-275 SCF/STB
Gas gravity	0.75 (air = 1)

Based on the above data, the bubble point pressure is estimated at 1000–1500 psia, the original formation volume factor at 1.05–1.15, and the original oil viscosity at about 2.0 cp. A typical composition of the Helez oil is presented in Table 4.

Two types of formation water are encountered in the Helez field: Helez Formation water related to Group I, and the Jurassic formation water related to Group III (Fleisher, 1987). Analysis of most of the Helez Formation water (Group I) shows total dissolved solids values of around 55 g/L and characteristic ionic ratios of Na/Cl = 0.86-0.97, (Ca+Mg)/Na = 0.12-0.19, and Cl/Br = around 300 (Table 5). The formation brines of Group III are characterized by the ratio Na/Cl = 0.75, a high Ca/Mg ratio, (Ca+Mg/Na) > 0.27 $\delta^{18}O$, and δD values suggesting the presence of meteoric water components. Waters of a similar composition to Group III are present in the Paleozoic, Triassic, and Jurassic strata of Israel.

Production and Reserves

The Helez field was put on production in October 1955 and to the end of July 1988 it has produced approximately 16.5 million barrels of oil. About 97% of the oil comes from Lower Cretaceous beds (Helez Formation, Figure 2), while the remaining 3% comes from Upper and Middle Jurassic limestones.

The original oil in place of the four principal producing zones of the Helez field, the "A-Z," "B," "K," and "W" sands, was estimated volumetrically to be about 40.3 million barrels (Table 2). Each zone is divided into multiple reservoirs separated by the various faults. For the most part, the fault system leaves the reservoirs open downdip to a large aquifer to the east, thus allowing an active water influx. The various reservoirs are characterized by the different water/oil levels and exhibit different pressure-production decline behavior. Original pressure in the main "A-Z" sand was approximately 2000 psig at 1402 m (4600 ft) SSL. According to its pressure history it appears that the water influx arrested the pressure decline at 900 to 1000 psi and pressure increases were later observed as offtake rates declined. The lowest reservoir pressures

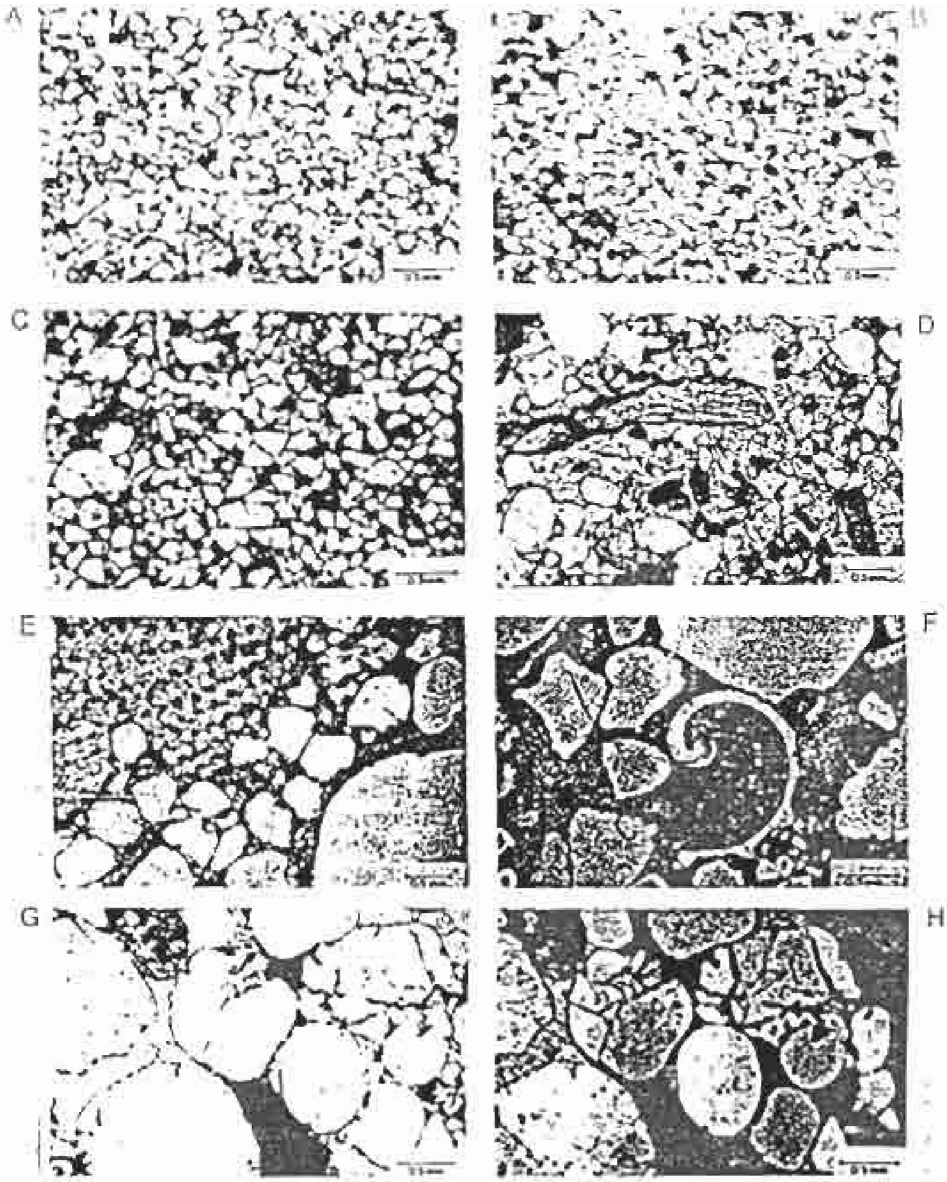

Figure 13. (A) Type III sandstone (eolian coastal sands). The cement crystals are dolomite (plug 29, Kokhav 6, 1651 m. The lower sand member—"Kokhav B"). (B) Type III sandstone (eolian coastal sands). The cement consists of dolomite crystals and some pyrite (plug 1, Kokhav 9, 1661 m. The lower sand member—"Kokhav B"). (C) Type III sandstone (eolian coastal sands); general view. The cement is dolomite and some pyrite (plug 6, Kokhav 6, 1669 m. The lower sand member—"Kokhav B"). (D) Type I sandstone (offshore marine sand). This rock is transitional between sandstone and limestone. The components are quartz grains, faunal fragments, and iron oolites. The cement consists of dense calcite crystals (sample HS-54, Kokhav 2, 1677 m. The lower sand member—"Kokhav A"). (E) Type I sandstone (offshore marine sand). The grains are quartz (poorly sorted, in part well rounded) and a big coral fragment that has undergone dolomitization. The cement consists of dolomite crystals (sample HS-466, Kokhav 7, 1517 m. The middle sand member—"Helez A"). (F) Type I sandstone (offshore marine sand). The grains are quartz and faunal fragments. Micritic calcite that forms the matrix has undergone recrystallization (plug 1, Kokhav 6, 1558 m. The middle sand member—"Helez W"). (G) Type II sandstone (tidal channel or lagoonal sand). The grains are quartz and volcanic rock fragments rich in pyrite. The cement is a single (poikilotopic) calcite crystal. The quartz grains are well rounded, have a high sphericity, and are partly shattered (sample HS-458, Helez 8, 1568 m. The middle sand member—"Helez A"). (H) As in G crossed nicols (sample HS-458, Helez 8, 1568 m. The middle sand member—"Helez A"). (From Shenav, 1971.)

Table 2. Helez oil field tabulation of reservoir parameters and production (end of July 1988).

Pay Zone and Fault Segment	Acre Feet	Porosity, Fraction	Water Saturation	Original Barrels per Acre Feet	Original Oil in Place MSTB	Estimated Cumulative Production MSTB	Remaining Oil in Place MSTB	Percent Produced	Remaining Oil Saturation Percent
"K" Sand									
Segment A	454	0.220*	0.370*	1,014.4	461	366.3	94.7	79	13
Segment B	3,818	0.220*	0.370*	1,014.4	3,873	1,070.1	2,807.9	28	45
Segment C+D	235	0.133*	0.420*	564.6	133	5.0	128	28	57
Segment E	397	0.133*	0.420*	564.6	224	310.0	-86	138**	-22
Segment G	332	0.133*	0.420*	564.6	187	90.0	97	48	30
Segment H	146	0.133*	0.420*	564.6	82	0.0	82	0	50
Segment I	316	0.133*	0.420*	564.6	170	17.0	151.0	10	53
Total	5,698				5,136	1,858.4	3,279.6	36	33
"W" Sand									
Segment B	2,553	0.240	0.360	1,009.0	2,780	1,116.0	1,664	40	37
Segment C+D	705*	0.124*	0.430	517.3	365	29.8	335.2	8	52
Segment E+F	1,078*	0.124*	0.430	517.3	558	768.6	-210.6	138**	-22
Segment G	446	0.268	0.343	1,288.7	575	284.6	290.4	50	33
Total	4,782				4,278	2,189.0	2,079.0	52	25
"A-Z" Sands									
Segment A	3,520	0.220*	0.380*	998.3	3,514	1,282.7	2,231.3	37	39
Segment B	16,026	0.220*	0.380*	998.3	15,999	7,195.8	8,803.2	45	34
Segment C	1,872	0.160	0.430	667.5	1,250	135.0	1,115.0	11	51
Segment D	1,965	0.160	0.430	667.5	1,312	835.0	476.1	64	21
Segment E	1,056	0.126	0.430	525.6	1,555	198.2	356.8	36	37
Segment F	664	0.126	0.430	525.6	1,349	—	349.0	0	57
Segment G	1,699	0.160*	0.390*	714.3	1,214	182.3	1,031.7	15	52
Segment H	237	0.165*	0.410*	712.5	169	13.2	155.8	8	54
Segment I	190	0.170*	0.430*	709.2	135	40.5	94.5	30	40
Total					24,497	9,803.6	14,613.4	40	43
"B" Sand									
Segment F	1,100	0.268	0.441*	1,036.5	1,206	277.6	928.4	23	43
Segment G	1,794	0.272*	0.438*	1,118.8	2,007	149.0	1,858.0	7	52
Segment H	1,079	0.276*	0.434*	1,143.3	1,234	516.8	717.2	42	24
Segment I	1,947	0.220	0.390	982.2	1,912	371.3	1,540.7	20	49
Total					6,359	1,314.7	5,044.3	21	42

(continued)

Table 2. (Continued)

Pay Zone and Fault Segment[†]	Acre Feet	Porosity, Fraction	Water Saturation	Original Barrels per Acre Feet	Original Oil in Place MSTB	Estimated Cumulative Production MSTB	Remaining Oil in Place MSTB	Percent Produced	Remaining Oil Saturation Percent
Kokhav Dolomite									
Segment A	877	0.1	0.45	460.5	360	104.1	255.9	29	39
Segment B	4,370	0.1	0.45	408.5	1,705	5.9	1,779.1	0.3	54.8
Segment D	800	0.1	0.45	405.0	324	7.2	316.8	2.2	53.8
Segment F	3,250	0.1	0.45	502.5	1,303	—	1,308.0	0.0	55
Segment G	7,750	0.1	0.45	398.7	3,090	383.3	2,706.7	12.4	48.2
Segment H	3,920	0.1	0.45	400.5	1,570	131.0	1,439.0	8.3	50.4
Segment I	4,900	0.1	0.45	400.2	1,961	6.9	1,954.1	0.4	54.8
Total					10,393	638.4	9,759.6	6.1	

Oil volume factor used in computations is 1.06

[†]The reservoirs consist of pay zones ("K" sand etc.) divided by faults into segments on Blocks (A,B, etc.; see Figure 3).

*Value is estimated.

**Cumulative production obviously includes oil originating from other sources.

Table 3. Helez oil field permeability distribution in Helez "A" sand

Upper Limit of X Class	Median of X Class	Sampling Frequency	Smoothed Frequency
.0709	.0533	.0180	.0385
.1256	.0943	.0721	.0451
.2224	.1671	.0541	.0517
.3939	.2960	.0360	.0581
.6976	.5242	.0721	.0641
1.2356	.9284	.0721	.0693
2.1885	1.6444	.0721	.0736
3.8762	2.9126	.0991	.0766
6.4655	5.1587	.0541	.0781
12.1600	9.1370	.0090	.0782
21.5376	16.1833	.0811	.0768
38.1470	28.6635	.0360	.0740
67.5651	50.7681	.0270	.0699
119.0698	89.9194	.0360	.0648
211.9567	159.2634	.1081	.0589
375.4131	282.0839	.0631	.0525
664.9237	499.6209	.0450	.0459
1177.6985	884.9178	.0360	.0394
2085.9143	1567.3475	.0000	.0331
3694.5266	2776.0522	.0090	.0273

The sample mean is 7.1225
The sample median is 4.0654
The standard deviation of sample data is 64.8705
Ratio of mean to median is 1.3998
The coefficient of variation is 147.9326
The 95% confidence limits on estimate of true mean are 4.1220 and 12.3071
The 99% confidence limits on estimate of true mean are 3.4543 and 14.6860

Source: Courtesy of Lapidoth.

Table 4. Helez oil field separator oil analysis
Podbielniak Analysis

Component	Mol%	Wt%	Liq Vol%
Ethane	0.21	0.03	0.06
Propane	0.56	0.10	0.18
Iso-butane	0.85	0.21	0.32
N-butane	0.99	0.24	0.36
Iso-pentane	1.41	0.43	0.59
N-pentane	1.98	0.60	0.83
Hexanes	5.65	2.03	2.68
Heptanes plus	88.35	96.36	94.98
	100.00	100.00	100.00

Heptanes Plus (calculated)	
Specific gravity at 60°F (water = 1)	0.8860
API gravity at 60°F	28.207
Molecular weight	261.000
Ft³ vap/gal at 14.65 psia and 60°F	10.77
Total Sample	
Liq. specific gravity at 60°F (water = 1)	0.8733
API gravity at 60°F	30.535
Ft³ vap/gal at 14.65 psia	11.593
Specific gravity as a vapor	10.752
Molecular weight	239.288

Table 5. Chemical composition of formation waters from oil wells in the Helez field

No.	B.H.	Stratigr.	Depth m	TDS	Ca	Mg	Na	K	Cl	SO_4	HCO_3	Cl/Br	Na/Cl	Ca/Na	Ca+Mg/Na	^{18}O	D	Group
1	Brur 2	L.Cr(Tl)	1142-1154	51.5	61	34	796	—	886	6	3	—	0.89	0.08	0.12	+1.92	—	I
2	Brur 2	L.Cr(Hz)	1500-1502	53.3	66	38	804	7.9	913	0	3	—	0.88	0.08	0.13	+1.42	—	I
3	Helez 1A	L.Cr(Hz)	1669-1679	55.6	93	41	807	13.1	938	12	2	207	0.86	0.12	0.17	+1.19		I
4	Helez 2	L.Cr(Hz)	1521-1522	64.1	72	48	957	10.0	1108	1	3	275	0.86	0.08	0.13	+1.64	-6.01	I
5	Helez 6	L.Cr(Hz)	1536-1548	52.3	71	42	862	—	971	9	4	—	0.89	0.08	0.13	+1.68	—	I
6	Helez 10	L.Cr(Hz)	1540-1545	64.1	91	46	970	9.4	1095	—	3	—	0.89	0.09	0.14	+2.55	—	I
7	Helez 20	L.Cr(Hz)	1507-1530	56.6	80	44	855	—	976	2	1	—	0.88	0.09	0.15	+5.33	+21.3	I
8	Helez 21	L.Cr(Hz)	1520-1524	61.7	93	54	975	—	1121	—	1	—	0.87	0.10	0.15	+4.31	+15.3	I
9	Helez 22	L.Cr(Hz)	—	61.4	67	45	922	10.3	1058	0	4	265	0.87	0.07	0.12	+1.50	+15.35	I
10	Helez 22	J(Zr)	2000-2014	45.5	82	43	658	6.5	783	3	3	—	0.84	0.12	0.19	—	—	I
11	Helez 22	J(Nir)	3377-3408	64.2	515	60	507	18.6	1106	9	2	—	0.46	1.01	1.13	—	—	III
12	Helez 25A	L.Cr(Hz)	1571-1575	71.1	111	50	1007	6.5	1261	2	1	—	0.80	0.11	0.16	+2.58	—	I
13	Helez 25A	L.Cr(Hz)	1576-1578	74.5	112	51	1134	—	1294	1	1	—	0.88	0.10	0.14	+2.65	—	I
14	Helez 27	L.Cr(Hz)	1505	57.6	69	42	870	8.7	974	11	2	—	0.89	0.08	0.13	+1.55	—	I
15	Helez 29	L.Cr(Hz)	1587-1603	47.9	55	37	731	9.2	800	10	3	—	0.91	0.08	0.13	+0.98	+1.5	I
16	Kokhav 1	L.Cr(Hz)	1593-1600	37.2	43	30	544	12.2	640	1	3	—	0.85	0.08	0.13	+0.02	+2.4	I
17	Kokhav 3	L.Cr(Hz)	1560-1590	29.5	35	24	426	6.8	477	27	3	—	0.89	0.08	0.14	- 2.19	—	I
18	Kokhav 7	L.Cr(Hz)	1493-1510	82.8	143	77	1200	12.2	1424	2	4	282	0.84	0.12	0.18	+1.02	—	I
19	Kokhav 7	J(Zr)	2485-2495	110.0	578	126	1195	23.6	1902	10	3	137	0.63	0.48	0.59	—	—	III
20	Kokhav 11	L.Cr(Hz)	1547-1549	47.0	54	34	713	8.7	812	10	4	260	0.88	0.08	0.12	+1.00	-2.68	I

Abbreviations used in Table 5:

Time Units:
- L.Cr, Lower Cretaceous
- J, Jurassic

Rock Units:
- Tl, Telamim Fm.
- Hz, Helez Fm.
- Zr, Zohar Fm.
- Nir, Nirim Fm.

Source: From Fleisher, 1987

measured were those of the "K" sand, being less than 500 psig at 1400 m (4595 ft) SSL in some fault blocks. Because no increase in gas/oil ratio has been reported, it is believed that the Helez oil was undersaturated during its history in most of the reservoir.

The Kokhav Dolomite volume was estimated in a similar manner to be about 10.0 million barrels of oil in place whereas the volume of the oil in the Jurassic limestone is still unknown.

At their current status of development the primary recovery from the reservoirs is calculated to vary from 5 to more than 50% of the original oil in place. The higher values occur in the reservoirs that are adequately developed, where the number and the location of completions allow high areal sweep efficiency for the encroaching water. In addition, in some fault segments that are evidently in partial contact with an aquifer, the producing mechanism is a combination of pressure depletion and water drive, and the primary recovery is low. The main producing formations mentioned above are nearing depletion. Most of the swept area should be at or near residual oil saturation although isolated sand lenses or low permeability streaks might currently have very high oil saturation.

Assuming an ultimate recovery of 45% for the sand zones, and 10% for the Kokhav Dolomite, about 19 million stock tank barrels of oil are expected to be produced.

EXPLORATION AND DEVELOPMENT CONCEPTS

The Helez field is nearing the end of its primary production phase (16.5 MMBO cumulative production at the end of 1988 vs. 19 MMBO of estimated recoverable reserves). Nevertheless, because of the field structure, which is composed of numerous, separate small reservoirs, some of the fault segments in certain reservoirs have not been adequately drained by the existing wells. The "attic" oil in these segments, which could amount to more than 1 million barrels, is planned to be produced by: (1) drilling new wells, (2) opening new pay zones in existing wells, and (3) deepening or recompleting existing wells.

A second possibility for increasing current production is the application of secondary recovery by water flooding in fault blocks where the natural water drive is weak. The thin Helez "K" sandstone seems to be a good candidate for such an operation.

Even after primary recovery has been made more efficient by adding new completions, 40 to 60% of the original oil in place will remain in the ground. Because these reservoirs will have been swept by encroaching water, secondary recovery was discarded and only a tertiary recovery scheme should be considered. Miscible displacement with carbon dioxide seems to be the most efficient known method for increasing production in the Helez field. The additional oil recovery might be from 5 to 10 million barrels. A more definite estimate can only be made after further data concerning saturation distribution are obtained. Perhaps most important is the feasibility of tertiary recovery, which is closely related to oil prices and availability; under current conditions, the application of tertiary procedures is not economic.

ACKNOWLEDGMENTS

Mr. J. Fisher, Managing Director of the Israel National Oil Company Ltd. and Mr. E. Roih, Managing Director of Lapidoth Israel Oil Prospectors Corporation Ltd., permitted the publication of this paper.

Unpublished studies and reports of Lapidoth Israel Oil Prospectors Corporation Ltd. are the basis of the Helez field presentation.

REFERENCES

Amit, O., 1978, Organochemical evaluation of Gevar-Am shales (Lower Cretaceous), Israel, as possible oil source rock: American Association of Petroleum Geologists Bulletin, v. 62, p. 827-836.

Ball, M. W., and D. Ball, 1953, Oil prospects of Israel: American Association of Petroleum Geologists Bulletin, v. 37, n. 1, p. 1-113.

Bein, A., 1974, Reef development in the Judea Group from the Carmel and the Coastal Plain, Israel: Ph.D. thesis, the Hebrew University, Jerusalem (in Hebrew).

Bein, A., and G. Gvirtzman, 1977, A Mesozoic fossil edge of the Arabian plate along the Levant coastline and its bearing on the evolution of the eastern Mediterranean, *in* B. Biju-Duval and L. Montadert, eds., Structural history of the Mediterranean basins: Paris, Edition Technip, p. 95-110.

Bein, A., and Z. Sofer, 1987, Origin of oils in the Helez Region, Israel—implication for exploration in the Eastern Mediterranean: American Association of Petroleum Geologists Bulletin, v. 71, p. 65-75.

Bein, A., and Y. Weiler, 1976, The Cretaceous Talme Yafe Formation: a contour current shape sedimentary prism of calcareous detritus at the continental margin of the Arabian Craton: Sedimentology, v. 23, n. 4, p. 511-532.

Cohen, A., 1983, Lithofacies and environments of deposition of the Lower Cretaceous Helez & Telamim Formations, Israel: GSI Report S/5/83.

Cohen, Z., 1964, The geology of Heletz-Brur-Kokhav field: Isr. J. Earth-Sci. v. 13, p. 179-183.

Cohen, Z., 1969, The geology of the Lower Cretaceous in the Coastal Plain: Israel Inst. Petroleum Research & Geophysics (unpublished).

Cohen, Z., 1971, The geology of the Lower Cretaceous of the Heletz Field, Israel: Ph.D. thesis, the Hebrew University, Jerusalem (in Hebrew).

Cohen, Z., 1976, Early Cretaceous buried canyon: influence on accumulation of hydrocarbons in Helez oil field, Israel. American Association of Petroleum Geologists Bulletin, v. 60, p. 108-114.

Derin, B., 1974, The Jurassic of central and northern Israel: Ph.D thesis, the Hebrew University, Jerusalem (in Hebrew, with English abstract), 152 p.

Derin, B., and E. Gerry, 1972, Jurassic biostratigraphy and environments of deposition in Israel: Israel Inst. Petroleum Micropaleontological Lab, Report 2/72, 5 p.

Fleisher, E., 1987, The geochemistry of formation water in Israel. OEII. Report 87/20.

Garfunkel, Z., and B. Derin, 1983, Permian-early Mesozoic tectonism and continental margin formation in Israel and its implication for the history of the Eastern Mediterranean, *in* J. E. Dixon and R. H. F. Robertson, eds., The geological evolution of the Eastern Mediterranean: Geological Society (London) Spec. Publication No. 12, p. 187-202.

Grader, P., and Z. Reiss, 1958, The Lower Cretaceous of the Heletz area: Geological Survey of Israel Bulletin No. 16, 14 p.

Gruy H. J. & Associates Inc., 1975, A preliminary study of enhanced recovery from the Heletz-Brur-Kokhav fields, Israel (submitted to Lapidoth).

Gvirtzman, G., and A. Klang, 1972, A structural and depositional hinge line along the Coastal Plain of Israel, evidenced by magneto-tellurics: Geological Survey of Israel Bulletin No. 55, 18 p.

Lapidoth-Israel Oil Prospectors Corporation Ltd., 1969, Various reports and maps (unpublished).

May, P. R., 1981, Ashdod-Gan Yavne area: review, evaluation and recommendations: Oil Exploration (Investments) Ltd. Report 81/31, 56 p.

May, P. R., 1984, Hydrocarbon migration and primary trapping in central Coastal Plain and Hashefela region, Israel: Oil Exploration (Investments) Ltd. Report 84/29, 11 p.

Rahamim, S., 1973, Geological report on Talme Yafe 4—deepened well: Lapidoth.

Rosenberg, E., 1979, The remaining oil potential of the Helez field—geology and exploration. Report to Lapidoth.

Shenav, H., 1971, Lower Cretaceous sandstone reservoirs, Israel: petrography, porosity, permeability: American Association of Petroleum Geologists Bulletin, v. 55, p. 2194-2224.

Starinsky, A., 1974, Relationship between Ca-chloride brines and sedimentary rocks in Israel: Ph.D. thesis, the Hebrew University, Jerusalem (in Hebrew, with English abstract), 84 p.

Tschopp, H. J., 1956, The oilfield of Heletz, Israel: Bull. Swiss Assoc. Pet. Geol., v. 22, p. 41-54.

Weeks, L. G., 1962, Israel's petroleum problem: Report to Ministry of Development.

Appendix 1. Field Description

Field name .... Helez-Brur-Kokhav

Ultimate recoverable reserves .... 18 million bbl

Field location:

Country .... Israel

State

Basin/Province .... Eastern Mediterranean

Field discovery:

Year first pay discovered .... (L. Cret.) Valanginian/Barremian Helez Formation 1955

Year second pay discovered .... Helez Formation zones and Jur. Brur Calcarenite 1962

Third pay .... Additional zones of L. Cret. and Jur. February 1963

Fourth pay .... August 1963

Fifth pay .... October 1963

Discovery well name and general location:

First pay .... Helez 1, 10 km southeast of Ashqelon

Second pay .... Kokhav 1

Third pay .... Kokhav 5

Fourth pay .... Kokhav 10

Fifth pay .... Kokhav 13

Discovery well operator .... Lapidoth (for all pays)

Second pay

Third pay

IP in barrels per day and/or cubic feet or cubic meters per day:

First pay .... 400 BOPD (A-Z sand)

Second pay .... 190 BOPD (B sand)

Third pay .... 200 BOPD (K dolomite)

Fourth pay .... 500 BOPD in Kokhav 16 (Jurassic ls.)

Fifth pay .... 140 BOPD (LC 11 ls.)

All other zones with shows of oil and gas in the field:

Age	Formation	Type of Show
Upper Barremian-lower Aptian	*Telamim*	*Oil*
Valanginian-Barremian	*Helez Lc 13A*	*Oil*
Jurassic	*Brur calcarenite*	*Oil*

Geologic concept leading to discovery and method or methods used to delineate prospect, e.g., surface geology, subsurface geology, seeps, magnetic data, gravity data, seismic data, seismic refraction, nontechnical:

Structure inferred and mapped using surface, gravity data complemented by seismics during trend development.

Structure:

Province/basin type .... Bally 1141; Klemme IIC a/b

Tectonic history

Elevated structure since Jurassic. Upper Jurassic high was truncated and deep canyon was formed (Gevar-Am channel). Faulting is related to uplifting and tilting at the end of the Jurassic, to the folding of the Cretaceous-lower Tertiary and to Neogene movements.

Regional structure

Field lies on a hinge line, defining boundary between platform and basinal environments

Seals:

- Upper
  - Formation, fault, or other feature … *Helez Formation and faults*
  - Lithology … *Shales*
- Lateral
  - Formation, fault, or other feature … *Permeability loss due to facies changes and pinchout*
  - Lithology … *Shales*

Source:

- Formation and age … *Unconfirmed; thus far can only suggest a possible source or a conduit (Middle Jurassic Barnea Formation)*
- Lithology … *Limestone*
- Average total organic carbon (TOC) … *0.5%*
- Maximum TOC … *2.6%*
- Kerogen type (I, II, or III) … *II*
- Vitrinite reflectance (maturation) … *R_o = 0.52–0.75 (immature in sampled location)*
- Time of hydrocarbon expulsion
- Present depth to top of source … *4000–5000 m*
- Thickness
- Potential yield

Appendix 2. Production Data

Field name … *Helez-Brur-Kokhav*

Field size:

- Proved acres … *1250 ha*
- Number of wells all years … *82, of these 55 producers*
- Current number of wells … *9 producers*
- Well spacing … *Most on 50 ac, some 90 ac*
- Ultimate recoverable … *19 million bbl*
- Cumulative production (1988) … *16.5 million bbl*
- Annual production (1988) … *0.15 million bbl*
- Present decline rate … *15%*
  - Initial decline rate … *10% (est.)*
  - Overall decline rate … *15% (est.)*
- Annual water production … *0.115 million bbl*
- In place, total reserves … *50 million bbl*
- In place, per acre-foot … *712 bbl*
- Primary recovery … *19 million bbl*
- Secondary recovery
- Enhanced recovery … *5–10 million bbl*
- Cumulative water production … *30 million bbl*

Drilling and casing practices:

- Amount of surface casing set … *250–300 m*
- Casing program … *13⅜-in. or 9⅝-in. to 300 m; 9⅝-in. or 7-in. to 1000–1250 m; 7-in. or 5½-in. to TD; 2⅞-in. tubing*
- Drilling mud … *Freshwater based*
- Bit program … *Varies*

High pressure zones .... None
Total loss circulation zone .... *Upper Cretaceous section 250–800 m drilling blind*

Completion practices:

Interval(s) perforated .... *Each pay zone separately*
Well treatment .... *Acidized in dolomite and limestone, also in calcareous sandstone; scarcely fractured*

Formation evaluation:

Logging suites .... *Older wells: GR, sonic, neutron, resistivity, microlog; modern wells: GR, CNL, density, sonic, induction, dipmeter*
Testing practices .... *Typically production tested (mainly swabbing); frequently DST while drilling*
Mud logging techniques
Not typically done in uppermost 250–300 m and while drilling blind between 300 and 1000 m; deeper—continuous with gas detector and chromatograph

Oil characteristics:

Type .... *Normal hydrocarbon*
API gravity *27.5–31.0*
Base
Initial GOR .... *200–275 SCF/STB*
Sulfur, wt%
Viscosity, SUS .... *2.0 cp*
Pour point
Gas-oil distillate

Field characteristics:

Average elevation .... *1200–1300 m*
Initial pressure .... *2000 psi*
Present pressure .... *900–1100 psi*
Pressure gradient
Temperature .... *150°F*
Geothermal gradient
Drive .... *Water*
Oil column thickness .... *Multiple thin pay zones*
Oil-water contact .... *Multiple*
Connate water
Water salinity, TDS .... *55,000 ppm but variable*
Resistivity of water .... *0.065 ohm, 150°F*
Bulk volume water (%)

Transportation method and market for oil and gas:
Pipeline