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THE GEOLOGY OF THE SOUTHEASTERN MEDITERRANEAN SEA

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ABSTRACT

A sharp divide between different facies and perhaps also tectonic provinces is formed by the NNE-trending Pelusium compressional line which extends some 80 to 100 km off the coasts of Israel.

Two WNW-trending facies belts were identified west of this line: the Diapir Belt in the north, in which the Upper Miocene Reflector M splits into three to four reflectors, and the Belt of No M in the south. Compressional features with a northward component are associated with the WNW-trending Bardawil fault escarpment which marks the boundary between the Belt of No M and the Nile Delta.

It appears that the entire region from Eratosthenes Seamount in the west to the Jordan - Dead Sea Graben in the east has been intermittently affected by a NE-trending fold system since at least the Jurassic times. West of the Pelusium Line this fold system is superimposed on the WNW-trending facies belts. Differential movements (uplifting of the landward side) have also repeatedly occurred since the Jurassic along the gravity - normal fault system which extends along the coastline of Israel. The coastal hinge-line has been simultaneously developed as a positive structural zone with its specific environments. The catastrophic subsidence of the eastern Mediterranean basin has occurred only since Late Pleistocene or Early Holocene. The shelf-break off Israel is an entirely new hinge-line along which the western downwarping took place.

The Mount Carmel Block is the seaward extension of a NW-trending structural ridge. It is characterised by a thick sequence of carbonate (reedfoid) rocks which are interbedded by basic volcanics. This tensional element, which is parallel in its trend to the Red Sea and Wadi-Sirhan, is superimposed on and contemporaneous with the NE folding system.

INTRODUCTION

The southeastern corner of the Mediterranean Sea (the area bounded between the Nile Delta, Cyprus and the Levant Coast) forms the junction of three continents: Africa, southwest Asia (the Near East) and Eurasia. Bathymetric data from this region have been gathered since 1892 by research vessels of many nations and more recently geophysical data have been added. Magnetometric and gravimetric maps have been constructed but only sporadic seismic profiles were made. To date, no D. S. D. P. drillings have been made in the area. Detailed subsurface information (geophysical and deep drillings with their comprehensive and detailed studies) is available from the shelf and coastal plain of Israel. This work was carried out mainly by Belpetco Oil Co. in the offshore area and by Lapidoth Oil Prospectors Co. and others in the Coastal Plain. Between 1969 and 1971 the Marine Geology Division of the Geological Survey of Israel and the Israel Oceanographic Research Ltd. carried out a series of continuous seismic profiles, covering the submarine area between the Nile Cone, Eratosthenos Seamount and the coast of Israel (Figs. 1 and 4). The energy sources that were used were a 40 cu. in. air gun and a 1 KJ EG&G sparkarray and boomer. The seismic reflections were received by two 200 ceramic cylinder (AQ-1) element hydrophoe arrays, and by Alpine "eel"-type array. The recording was made on a graphic recorder at different sweep speeds; therefore the superimposed depth scale varies. Depths in the seismic and line-drawing profiles were cited only according to the recorder's scale (2 seconds equal to 1,500 meters) and should not be read as absolute subbottom depth. Navigation was by celestial observations, radar fix and dead reckoning.

Along with these observations we have attempted to incorporate in the present paper all the relevant data which are considered as key-points or corner-stones for the understanding of the regional geology. These include information obtained by others, but compiled and interpreted by the authors. The conclusions and hypotheses concerning the regional tectonic framework and its evolution, will be discussed, however, in a separate paper.

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I. Physiography

a. Coastline and coastal plain

The coastline in the study area curves smoothly from north Sinai to Israel. The only irregularities are the Tineh embayment with the adjoining Bardawil Lagoon (Sab<ins>h</ins>at Bardawil), and <ins>H</ins>aifa Bay. The coast of Lebanon, to the north, is notably more indented.

The coastal plain of the Nile Delta and northern Sinai forms flat or dune-covered lowlands and is bordered on the land side by hills consisting of Eocene to Cretaceous sedimentary formations (Fig. 1). The coastal plain can be divided into a western and an eastern segment.

The western segment, a part of the Nile Delta proper, with its prograded coastlines and brackish lagoons, reaches eastward as far as the embayment of Tineh, on the western end of Bardawil Lagoon (Fig. 1). The easternmost arm of the Nile birdfoot, the Pelusiac branch (now defunct), terminated this embayment (Sneh and Weissbrod, 1973).

The eastern segment extends eastward as far as Rafah and includes the 80 km long, partly hypersaline Bardawil Lagoon. The western half of the Bardawil arcuate bar, which ends seaward at the 60 m high dune of Mount Cassius, forms a northeastward extension of a low dunal ridge which starts at Qantara on the Suez Canal (Neev, 1967). A parallel ridge reaches the coastline at El Kharube, east of El 'Arish. Abrasional escarpments are found where these two ridges meet the water line, exposing Holocene dune sands interbedded with brownish loam (hamra) and overlying green and dark brown clays. Hypersaline lagoons, and sabkhas occur in the lowlands between these two ridges.

The Mediterranean coast north of Sinai can be divided into a southern and northern segment.

The southern segment, from Rafah to the southern plunge of the Mount Carmel Block, was described by Emery and Neev (1960). The coastline is bordered by a continuous low linear escarpment (10 to 50 m) which is breached by several gaps formed by Late Pleistocene rivers. These old estuaries have been filled more recently by sandy beaches and swampy alluvial plains. The coastal cliff is composed of carbonate-cemented quartz sandstones (kurkar), originally deposited as NE-facing barkhan dunes, interbedded with brown reddish loams (hamra). The cliff reaches its greatest height in the central part of this segment, between Tel Aviv and Netanya, where the beaches are narrowest (as little as 10 m). Several hundred meters off-shore, a rocky (kurkar) and sandy strip extends along this segment, forming rimmed terraces at sea level as well as submerged knolls. This strip terminates seawards with a low step (0-3 m) which forms patchy straight line, parallel to the coastline. The coastal plain of this segment narrows from about 50 km in the south to about 20 km in the north where it approaches Mount Carmel. Three logditudinal kurkar ridges, trending subparallel to the coastline, occur in this segment.

The northern segment extends northward along Mount Carmel and the Lebanon coast. Along this segment the inland hills, composed mostly of Cretaceous chalk, limestone and dolomite, occasionally approach the coastline, leaving a narrow or no coastal plain. Mount Carmel appears to be a large tilted block, plunging to the SSW and terminating northward at a NW-trending, steep fault escarpment long known as the Yagur Fault. The Haifa Nose, a notable shelf feature, is the seaward extension of this escarpment. Along the Lebanon coast, high and steep escarpments are formed where the mountains reach the shore. In places, wide and flat coastal plains breach the mountainous coastline, such as the Qishon Valley and Zevulun Plain north of Haifa, and the plains north of Tripoli and south of Lataqia (Fig. 1).

b. <u>The continental margin (shelf and slope)</u> (Fig. 1)

The shelf off northern Sinai is wide, flat and smooth, except at its edge (70-80 m depth) where the bottom is rocky. It narrows eastward from 60-80 km width off Damietta and the Tineh embayment to about 40 km width off El 'Arish. The shelf terminates seaward as a steep WNW-trending escarpment, here named the Bardawil Excarpment. The height of this escarpment at its western end is about 400 m, decreasing eastward to about 100 m off Mount Cassius (Bardawil Lagoon). The continental slope in this area begins at the escarpment, and falls off in a series of several steps. Further eastward, i.e. off El 'Arish, the escarpment changes to a moderate slope.

The continental shelf off Israel, which reaches about 100 m depth, is about 25 km wide off Rafah, and narrows toward the north to 10 km off Mount Carmel. Mount Carmel itself extends some 12 km offshore to form a notable topographic hump across the shelf - the Haifa Nose.

From Mount Carmel northward, the shape of the shelf, and especially the slope become irregular. Two pronounced canyons, the Qishon Canyon (which is an extension of the Qishon Graben) and the Akhziv Canyon, cross the shelf as the extensions of onshore river valleys. Between them the shelf broadens to about 15 km, forming a prominence somewhat similar to the Haifa Nose - the 'Akko (Acre) Nose. North of the Akhziv Canyon the shelf may narrow to 3 - 0.5 km, and is dissected by numerous structures and canyons (Boulos, 1962; Carlisle, 1965).

Emery and Bentor (1960) divided the shelf off Israel into two main topographic belts: the first, a near-shore belt, extends from the shoreline to the 30 m isobath about 3 km offshore. The slope of this belt is relatively steep ($\frac{1}{2}^{o} - 1^{o}$). The second belt forms a wide and flat (10' - 20' slope) area extending approximately to the 80 m isobath. The transition zone between these two belts, approximately between the 30 and 50 m isobaths, is characterized along most of the shelf by a patchy, reef-like rocky ridge, subparallel to the coastline, and protruding sharply through the sedimentary cover (Emery and Bentor, 1960; Neev, Edgerton, Almagor and Bakler, 1966).

Between Rafah and the southern plunge of Mount Carmel, the continental slope drops gently from 80 to about 1,000 m, with slopes increasing from 2^{o} in the south to 8^{o} in the north. However, certain topographic irregularities were noted such as asymmetric hillocks on the upper slope, niches on its middle and lower parts, and a rought bottom which is acoustically fuzzy below the niches. The main feature interrupting this segment of the slope is a 10 km wide, NW-trending depression off Palmahim (southwest of Tel Aviv) - the Palmahim Graben (Fig. 1). The continental slope, from the southern plunge of Mount Carmel northward, steepens to an average of about 10^{o}.

c. Deep sea floor

Below the continental slope the southeastern corner of the Mediterranean forms a broad and roughly rectangular, very slightly northward sloping platform -

the Levant Platform. From a depth of about 1,000 m it deepens toward the NNE (average slope of 24'), finally leveling again at 1,900-2,100 m southeast of Cyprus.

The most notable feature on the Levant Platform is Eratosthenses Seamount, a great NNE-trending seamount about 100 km south of Limassol, Cyprus (central point: 33°40'N; 32°40'E). Eratosthenes Seamount rises about 1,220-1,700 m Above the surrounding sea floor, its summits reaching 790 m below sea level. The seamount is surrounded by several moat-like depressions.

Toward the north, the Levant Platform narrows between Cyprus and the Syrian coast. Westward it is bordered by the elevated masses of Cyprus and Eratosthenes Seamount and the depressed area between them. Between Eratosthenes Seamount and the Nile cone, the Levant Platform slopes from 1,500 to over 2,000 m toward the deeper parts of the basin that extend into the Herodotus Abyssal Plain. This slope, together with the steep western flanks of Eratosthenes Seamount, marks the western boundary of the Levant Platform. Between Eratosthenes Seamount and the slope off northern Israel and northern Lebanon, the Levant Platform displays hummocky topography. The hummocks are small-relief, mostly symmetric hills (up to 100 m) protruding from an otherwise smooth seafloor. Seismic profiles show these hills to be surface expressions of diapiric structures, and the area is accordingly named the Diapir Belt. South of this belt and up to the Bardawil Escarpment, the bottom topography is rugged, forming sharp ravines and steep, asymmetric slopes with relief up to approximately 100 metres. As the prominent Neogene Reflector M (to be discussed later) is not observed in this area, it has been named the Belt of No M.

The continental slope of southern and central Israel is separated from the Levant Platform by a shallow (about 100 m) trough which is relatively narrow in the south but broadens and loses its identity northwards (Fig. 1). This part of the platform is very slightly arched between the shallow sub-slope trough in the east and the slope toward the Herodotus Abyssal Plain in the west.

II. Continental Margin off Israel - Geological Background Based on Oil Companies Data

During 1968-1971, Belpetco Israel Ltd. carried out an extensive exploration program on the Mediterranean shelf of Israel. The program consisted primarily of a seismic survey (C. D. P. 900 cu. in. air gun) and the drilling of 6 wildcat boreholes (Fig. 1). Four of these seismic profiles extended beyond the shelf, almost to the bottom of the continental slope. The main results of this exploration program (Buchbinder, 1971; Derin, 1970; Derin and Gerry, 1971; Ginzburg, 1971) are compiled and interpreted herein to provide a stratigraphic and structural background and to link the offshore findings with the onshore geology. The interpretations, however, are not necessarily in agreement with those of the respective authors. The 4, 096 m thick sequence which was penetrated in the Bravo 1 borehole, located about 15 km off Ashqelon (Fig. 2) at coordinates $31^{o}47.7'N$; $34^{o}25.2'E$, in 78 m of water, is presented below to provide a stratigraphic reference for the seismic reflecting horizons.

220 - 450 m Kurkar Group and uppermost Yafo Formation (Pleistocene): carbonate-cemented sandstones and sandy shales.

450 - 1,190 m Yafo Formation - Upper Member (Upper Pliocene): Sandy shales.

1,190 - 1,320 m Yafo Formation - Lower Member (Lower Pliocene): shales.

1,320 - 1,395 m Mavqi'im Formation (Messinian - Upper Miocene to Lower Pliocene): anhydrite with sands and marls.

1,395 - 1,650 m Ziqim Formation (Middle to Upper Miocene): sandy and pyritic marls.

1,650 - 2,225 m Beit Guvrin Formation (Upper Eocene to Lower Miocene): sandy shales, marls and chalks.

2,225 - 2,950 m Shefela Group (Senonian to Middle Eocene): chalks, marls and limestones with chert.

2,950 - 3,315 m Talmei Yaffe Formation (Albian to Turonian): shales, marls, chalks and limestones.

3,315 - 4,095 m (T.D.) Gevar'am Formation (Neocomian to Aptian): shales with some sands.

The stratigraphic and structural relationships within the continental slope, shelf and coastal plain of southern Israel are demonstrated in Fig. 2a (Belpetco offshore seismic profile 32) and Fig. 2b (section compiled from profile 32, Lapidoth Oil Company's data from the Helez-Kokhav oil field, and various data from the coastal plain). These sections show: (a) Considerable thinning of the Gevar'am, Talmei Yaffe, Shefela Group and Beit Guvrin Formations (Lower Cretaceous to Lower Miocene) from the locality of Bravo 1 toward a seismically observed deep structure, located close to the base of the slope, which we have name Offshore Chain of Structures No. 1 (or OSS 1). Partial reflections close to the core of OSS 1 and within the Gevar'am Formation indicate the existence of some relief prior to deposition of the latter (i.e., Upper Jurassic). (b) Bravo 1 is located on another structural high but thinning of sediments toward it is only observed in the Beit Guvrin Formation. It would, therefore, appear that this structure was folded and formed mostly during Upper Eocene and Oliogocene times. (c) The boundary of the Beit Guvrin and Ziqim Formations (Lower and Middle Miocene respectively) is marked by a bio-stratigraphic hiatus all over the region, both off and on shore (B. Derin - personal communication). All along profile 32 this contact is not notably sharp although there appears to be an angular unconformity. On land, however, it is associated with a strong vertical differential movement (about 1,500 m) which was followed by deep erosion (Neev, 1960; Gvirtzman, 1970). (d) The Ziqim Formation (Middle to Upper Miocene) is characterized by low seismic reflectivity. It is the first formation that displays no thinning - and even thickens - on top of OSS 1. (e) The strong reflection marking the top of the Ziqim Formation is assumed to be derived from the unconformable contact between the Ziqim marls and the overlying anhydrites of the Mavqi'im Formation (Mio-Pliocene transition). This surface is considered here to be identical with Reflector M, which is known from the entire Mediterranean Sea (Ryan, 1970). Moreover, Reflector M was also found at localities where evaporites of the Mavqi'im Formation are missing (e.g. in the offshore wildcat Delta 1). The Mavqi'im Formation itself is irregular in thickness, apparently due to its erosional lower boundary. Irregular reflections and diffraction patterns associated with Reflector M are found on top of OSS 1, where they form a lenticular feature (reef ?), and also east of it, under the present-day slope (turbidites ?). (f) The contact with the overlying sedimentary unit, the lower member of the Yafo Formation (Lower Pliocene) appears in profile 32 to be gradual, although Gvirtzman (1970) considers it to be also erosional. These sediments are characterized by regular, undisturbed bedding and low reflectivity. Like the Ziqim Formation they show no thinning on top of OSS 1. According to Derin and Gerry (1971) this interval belongs to the Globorotalia margaritae zone, which is uniform throughout the Mediterranean area. (g) The transition to the upper member of the Yafo Formation (Upper Pliocene) is gradual and not easy to determine. This formation, as well as the overlying units of the Kurkar Group (Pleistocene), is characterized by high reflectivity. Unlike the Lower Yafo Formation these younger units thicken appreciably eastward from OSS 1, reaching their greatest thickness below the present upper slope and shelf edge. They wedge out completely within the Coastal Plain of Israel. (h) The lenticular-basinal shape of the entire sedimentary column accumulated on the shelf and slope is therefore well pronounced in almost all the formations, except the Ziqim and Lower Yafo Formations. The center line or thickest segment of this basin is located below the upper or middle part of the present-day continental slope. (i) The thinning, wedging-out and change of facies intensify between the coastline and the Helez Structure; the facies changes occur rather abruptly along a NNE-trending hinge-line (Gvirtzman and Klang, 1972; Rahamim, 1969; Rosenberg, 1970) located just to the west of the Helez axis. These changes include the eastward transition of: (1) the basinal marly Talmei Yaffe Formation to the cavernous dolomite of the Judea Group (Middle Cretaceous), (2) the shaly Gevar'am Formation to the sandy Helez Formation (Lower Cretaceous), and (3) the basinal shaly limestone of Upper Jurassic age into lenticular reefs. (j) The west flank of the Helez Structure is downfaulted to the west by a system of several step faults (Neev, 1960; Gvirtzman, 1970). Stratigraphic relationships on both sides of the faults indicate phases of activity during Jurassic, Upper Cretaceous, Early Miocene and, in the case of the western fault (which coincides with the present day coastline), a rejuvenation in the Holocene (Neev et al., 1973). Faulting along the eastern fault-line (closer to Helez) is corroborated by recently conducted magneto-telluric soundings (Gvirtzman and Klang, 1972) which indicate great vertical displacement of the basement. Structural analysis made by the same authors indicates that there has been no strike-slip motion along those faults and that they are therefore normal-gravity faults.

Two other offshore boreholes, Joshua 2 (31°55.7'N; 34°33.4'E) and Echo (31°49.2'N; 34°33.7'E) were drilled in the southern segment of the shelf in relatively shallow water (70 m and 87 m respectively). Joshua 2 is located off Palmahim, where Belpetco's seismic survey indicated a NW-trending graben (Fig. 5). Its stratigraphic log indicates that the sequence from the upper part of the Shefela Group (Lower Eocene at bottom of hole - 2,653 m) to the top of the Beit Guvrin Formation (Lower Miocene - 2,318 m) is similar to (and even more condensed than) that found in Bravo 1. Eighteen meters of volcanic material (alkali-olivine basalts) in Joshua 2 (2,300 - 2,318 m) mark the break between the Beit Guvrin Formation (Upper Eocene - Lower Miocene) and the Ziqim Formation (Middle Miocene) which is so pronounced on land. Other findings of alkali-olivine basalts of about the same age were found in the subsurface along the Coastal Plain of Israel (the National Park Volcanics, Gvirtzman, 1970), as well as in the eastern Galilee and the Jordan Valley, although here it cannot be dated so precisely because of the absence of marine bio-zones. The overlying Ziqim Formation (2,225 - 2,300 m) is thinner than in Bravo 1 (probably due to more intensive truncation of its top). It is more sandy and contains reworked (Cretaceous to Eocene) dolomite and limestone fragments. The Mavqi'im Formation (Messinian - Upper Miocene to Lower Pliocene) here includes 140 m of rock-salt and anhydrite (2,088 - 2,225 m). Pollen analyses of the salt point to a nearby arid environment. This agrees with the absence of reworked carbonate fragments or any other high energy fluviatile sediments in this formation. Within the limits of this graben the seismic reflection above Reflector M are strongly contorted, possibly indicating diapirism. The Plio-Pleistocene sequence is extremely thick in this borehole (about 2,000 m) indicating rapid deposition and is lithologically rather uniform (shale, sand and reworked carbonate clastics). The Plio-Pleistocene boundary is not entirely clear in this well (occurring at either 940 m or 1,100 m depth); in either case making this the thickest marine Pleistocene sequence recorded in Israel. It appears therefore that the Palmahim Graben started to develop only since Upper Miocene but that subsidence continues at present.

More anhydrite beds of younger ages than the Mavqi'im Formation were found south of the Helez Structure (Sa'ad and Be'eri structure holes and the Be'eri sulphur quarries) whithin the Upper Yafo Formation (Upper Pliocene) and the lower part of the (Pleistocene) Kurkar Group (Gvirtzman, 1970).

Three holes were drilled off the northern segment of the Israel shelf: Delta 1 (32°22.6' N; 34°40.7'E) off Netanya, Item, east of Delta (32°22.9'N; 34°49.2'E) and Foxtrot, off Haifa on the Haifa Nose (32°52.3'N; 34°52.7'E). The stratigraphic sequences observed in the first two boreholes indicate that basinal environments existed on the shelf off Netanya all through the stratigraphic column since the Jurassic and until the end of the Pliocene. This situation is similar to that found in Bravo 1, Joshua 2 and Echo. The onshore and offshore borehole data suggest that the hinge-line and coastal fault system extend northward up to the southern plunge of the Mount Carmel Block and that they have been active during several faulting phases at least since the Jurassic. Unfortunately Belpetco's E-W seismic profiles were not extended far enough here to investigate the western flank of the basin. However,the reef-type limestone found as clastics in Jurassic turbidites close to the bottom (4, 235 - 4, 423 m) of Delta 1 (Friedman, Barzel and Derin, 1971) suggest the existence of a structure similar to OSS 1 in close proximity to the west. The Jurassic turbidites are inter-bedded with black shales of a so-called "basin margin" facies.

The stratigraphic sequence in Foxtrot 1 is similar in facies to that found on Mount Carmel (Haifa 1 and Zikhron 1). The dominant rock in this sequence, from the oldest beds penetrated (Middle Bathonian at 2, 153 m), to the uppermost sample recovered (Upper Cenomnaina at 250 m), are dolomites and limestones, mostly cavernous, which typify the entire Judea Group in Israel. Figure 3 presents a S-N cross-section between the Delta and Foxtrot boreholes, showing the facies changes and wedging out the Cretaceous and Tertiary units, from the basinal facies at the Delta site to the structural high facies at the Foxtrot site. This is expressed by a change from the shaly-marly sediments of the Talmei Yaffe and Gevar'am Formations to the cavernous carbonates of the Judea and unnamed Lower Cretaceous groups; the Shefela and Saqiye (Neogene) Groups appear to wedge out completely. The Haifa Nose is bordered on the south by a deep-seated fault which displaces Jurassic, and possibly also Lower Cretaceous Formations in what appears to be a low-angle thrust (Fig. 3). The fault is overlain and masked by the subsequent sedimentary column, and is probably associated with the initial uplifting of the Mount Carmel Block.

III. Continuous Seismic Profiling (C. S. P.)

A seismic survey of the southeastern Mediterranean corner was carried out by the authors, in two phases, between 1969 and 1971, covering the marine area between the Nile Cone, Eratosthenes Seamount and the coast of Israel (Fig. 1). A total of 15,000 km of seismic lines were obtained (Fig. 4). Representative profiles (seismograms and line-drawings) are shown in Figures 7 to 9 and 11 to 19. A structural contour map of the M Reflector and an isopach map of the interval between the sea-floor and Reflector M are presented in Figures 5 and 6. Relevant structural and stratigraphic data from the Coastal Plain and shelf (mainly Gvirtzman, 1970, and Ginzburg, 1971) were also compiled and incorporated in these maps. The following paragraphs describe the most important subsurface findings within each pyhsiographic provinces:

a. Continental margin of Israel

Offshore Structure No. 1, corssed by Belpetco profile 32 (Fig. 2), is pronounced on the isopach map (Fig. 6) as a chain of elongated areas of thinning "highs", close to the base of the continental slope, the chain extending from off Rafah in the south to the southern plunge of Mount Carmel in the north. The relief on Reflector M in profile 125

(Fig. 7) as well as that on top of the Shefela Group (Fig. 2) indicate that OSS 1 is asymmetric (steeper to the SE). Profile 84 (Fig. 7) which transects Profile 125, shows rejuvenation of folding in the Pleistocene sequence (Kurkar Group and uppermost Yafo Formation) on top of the same structure. The Pleistocene sequence was identified throughout the survey by correlation with the offshore boreholes, where it was identified by lithology, and is seismically characterised by highly reflective layers overlying the relatively transparent (non-reflecting) layers of the Yafo Formation.

Between OSS 1 and the buried onshore highs (which parallel the hinge-line system), isopachs show a series of low areas which apparently represents a Plio-Pleistocene paleobasin. Two NW-trending secondary troughs diagonally transect the paleobasin; one is associated with the Palmahim Graben and the other with the seaward extension of the early Neogene channel off Gaza (Figs. 5, 6 and 8). Deeper subsurface data (see previous chapter) indicate that the area has probably been basinal since Jurassic times. The line that marks today's shelf-slope boundary is approximately above the centerline of this paleobasin.

A south-north sparker profile (Fig. 9, profile 90A) along the middle part of the slope shows a series of rectangular gaps, or gouged scars, that incise the sedimentary surface along the middle slope. The scars are one to five km wide and have steep, nearly rectangular, sidewalls, about 50 to 70 metres high. This phenomenon was observed mostly south of the Palmahim Graben. East-west profile 96 (Fig. 9, profile 96A) which runs the length of one of these scars, shows the longitudinal shape and possible mode of formation of these features: upslope the bottom is terminated abruptly by a near-perpendicular scarp and the entire uppermost sedimentary layer seems to have slid downslope and crumpled (fuzzy reflection), leaving a broad scar that exposes a slide surface on the underlying layer.

On the shelf and upper slope, the uppermost (Holocene) unit overlies a highly irregular and probably erosional surface (Neev, Edgerton, Almagor and Bakler, 1966). This erosional surface includes several low ridges, separated by broad, sediment-filled depressions, which extend subparallel to the present coastline (Fig. 10). The seismic reflections within and below the ridges indicate that these are residual sedimentary features and not tectonic (Fig. 11). Analogy with similar onshore Pleistocene ridges suggests they may be eolinanite (Emery and Bentor, 1960). They are probably formed as coastal dunes, accumulated, stabilized and eroded during various late Pleistocene phases.

The uppermost (Holocene) sedimentary unit can be divided into two complexes: (1) a lower one consisting of irregular continental deposits such as dune sands, red loams and swamp deposits. These were found in several cores in Haifa Bay, off Netanya etc., and are indicated by certain shallow reflections off Gaza, which resemble asymmetric dunes (Fig. 11, profile 26.6). Within the troughs this unit may reach 20-30 m in thickness. (2) an upper complex of regularly bedded marine sediments, up to 20 m thick, which gradually change westward from well sorted beach-sands to clay (Nir, 1965; Neev, Edgerton, Almagor and Bakler, 1966). The young cover on top of the ridge located at the uppermost continental slope, thins out in many cases with almost complete wedging-out (Fig. 12, profiles 30, 41, 61). The uppermost clayey sediments, east and west of this ridge, show, by their reflections, asymmetric crumpling with their steep side facing east (upslope). The crumpling is not observed on top of the buried ridge (Fig. 9, profile 40). These young sediments were evidently deposited on a horizontal sea floor but are today deformed due to westward down-tilting. It seems that the buried ridge acts as some kind of interceptor to this creep.

The easternmost ridge, located along the 30 to 40 m isobaths, protrudes in many cases through the cover of the youngest sedimentary unit (Fig. 9, profile 40; Fig. 11, profiles 25.3, 26.5; Fig. 12, profiles 30, 41). High-resolution seismic profiles (using the 200 joules boomer) show the Holocene sediments east of the ridge thickenning eastward until they are cut by an abrupt rise of the unconformity surface, probably caused by upfaulting of the Kurkar Group (Fig. 11, profile 25.3). This boundary coincides with the western edge of the rocky strip (patchy abraded terrace) that extends parallel to the coastline (see Physiography). It is considered by Neev et al. (1973) to be part of a fault system rejuvenated during the Holocene and extending along the entire coastline of Israel.

The most notable tectonic feature on the upper shelf is the Haifa Nose (the northern segment of the Carmel Block), which terminates the eastern flank of the Neogene paleobasin on the north along the transverse NW-trending Tira Fault (Fig. 5). South to north profiles along the shelf in this area, as well as the Foxtrot borehole, indicate that the massive dolomites of the Judea Group are overlain here only by a thinning wedge of Neogene (Saqiye Group) sediments and a thin veneer of the Pleistocene Kurkar Group (Fig. 3); a situation typical of the onshore Coastal Plain.

East to west profiles off the Carmel Block show the shelf to be relatively narrow here, with relatively short faults of high throw, running along part of its length as far south as the transverse Nahal Tanninim fault ((Fig. 1 and 5, and Fig. 12, profile 61). These faults are not always clearly identified on the seismic profiles (i.e. Fig. 3). It seems that much of the Carmel Block's uplifting occurred in pre-Neogene times and that the rejuvenated tectonic movements involved mostly thinning and overlapping of the basinal younger sequences toward the uplifted blocks, thereby masking the deep seated faults. The location of some of these faults on Figure 5 is therefore not very precise although they properly define the limits of the Carmel Block. No indications were found for a northward extension of OSS 1 off the Carmel Block or farther north. The elevated Haifa Nose is separated from the 'Akko Nose by the narrow Qishon Graben (about 5 km wide), which is filled by a relatively thick Neogene-Quaternary sequence (at least 240 m of sand and shale - Kafri and Ecker, 1964) (Figs. 5 and 6). The 'Akko Nose is bordered to the north by the WNW-trending Akhziv fault. North of this fault thick Neogene-Quaternary sediments wedge steeply against the coastline fault of Lebanon (Carlisle, 1965). The Akhziv Canyon (Emery and Bentor, 1960; Nir, 1965) is incised into this sequence. Both the Haifa and 'Akko Noses protrude westward beyong the shelf and are terminated seaward by the same major fault.

b. The continental margin of Sinai and the Nile Delta

The structural and isopach maps (Figs. 5 and 6) indicate a general but irregular seaward deepening of Reflector M below a gently sloping sea bottom off the coast of Sinai. However, an appreciable change in the direction of contours are noticed on both maps between the eastern and western parts. The approximate line of divide parallels the western half of the Bardawil bar, and runs shoreward toward the defunct Pelusiac mouth. That part of the bar has structural significance onshore, possibly marking a weak marginal fold of the Negev and North Sinai system (Neev, 1967). The NE-trending line of divide is hence called the Pelusium Line (Figs. 5 and 22). The shelf-slope transition east of this line is marked by a change in slope. The slope is moderate - 1.8° - with no indications of subrecent slumps or erosion channels (Fig. 12, profiles 27, 89; Fig. 13). West of the Pelusium Line, however, the shelf-slope transition is sharp and associated with several north facing step-fault escarpments (Figs. 12 and 13, profile 112). The pattern of sediment accumulation and deformation within the step-faults (dominant southward initial dips) indicate deposition on a relief that was already partly faulted, and which continued to be deformed, apparently by south to north compression during deposition. The entire step-faulted zone forms a morphological escarpment, running WNW, which is here named the Bardawil Escarpment. Indications for faulting associated with compression were noticed also at the southern part of profile 101 (Fig. 13). Unfortunately this profile terminates north of Damietta (the eastern arm of the Nile Delta) before reaching the bottom of the slope, where the topographic gradient is still northward but moderate (average of 0.4°). This sparkarray profile shows a series of northward facing tilted blocks with deformation and accumulation patterns similar to those noticed in the step faults of profile 112. The tilted blocks region was crossed also by the WNW profiles 102 (Fig. 14) and 107 (Fig. 13). In this direction, however, no systematic trend of tilting was noticed. A probable reverse fault was detected close to the southern end of Profile 101 (Fig. 13). The northern side of this fault was thrown up, opposite to the trend expected due to gravitational gliding. Another probable reverse fault with similar physiography (close to the Bardawil Escarpment and with a northward bottom gradient of 0.4^0) was also noticed close to the southern end of profile 97 (Fig. 13).

c. The Levant Platform

Reflector M has not been recognized over a large area in the southern part of the Levant Platform. This area was therefore named the Belt of No M (Figs. 1 and 22, and also 5 and 6). This belt is also characterized by a rugged topographic nature (see Physiography) as well as by a notable thinning of the Quaternary sediments - the highly reflective sequence which rests at an angular unconformity on top of the acoustically more transparent Neogene (?) units (Fig. 9, profile 96A; Fig. 14, profiles 102 and 144; Fig. 15, profile 86A and B; Fig. 16, profile 96B). Profiles 102 and 144, which traverse this belt in a WNW-direction, reveal however a few elongated depressions in which the younger sediments double or triple in thickness (from less than one hundred to several hundreds of meters). It appears that these troughs divide the belt into three broad NE-plunging structures (Fig. 22). Compressional features of recent and possibly also older ages (steep, high-frequency, near-imbricated, small folds and thrusts), are most prominent on the western flank of the easternmost of these three structures (Fig. 15, profile 86B). The eastern flank of this structure (which is also the eastern limit of the belt) is marked by a set of

NNE-trending and eastward facing fault escarpments (Fig. 15, profile 86A). The cumulative magnitude of these escarpemnts diminishes northwards from approximately 200 m to 50-20 m.

Features indicating compressional stresses were also noticed in the subsurface all along the shallow trough which separates the Belt of No M from the continental slope of Israel. These features, which are best recognized in the sparkarray profiles, are sharp and narrow down-kinks and, at least in two cases (profiles 96 and 102), there appears to be some overthrusting of the transparent sediments in the west over a thickened highly reflective sequence in the sub-slope trough to the east (Fig. 14, profile 102; Fig. 15, profile 86B; Fig. 16, profiles 96B, 98 and 116). Another phenomenon which has been observed in all air-gun profiles north of the latitude of Tel Aviv and west of OSS 1 is the apparent westward splitting, or divergence, of Reflector M into three to four separate reflectors (Fig. 14, profile 143; Fig. 16, profiles 143C and 148; Fig. 17, profiles 115 and 136). The isopach map (Fig. 6) based on the lowermost of these reflectors, indicates thickening of the Neogene-Quaternary sequence just west of OSS 1 toward a line which marks the divergence. Kinks, similar to those found beneath the sub-slope trough off southern Israel, were also noticed to be associated with this zone of thickening and splitting of Reflector M.

It appears, therefore, that a zone of compressional features extends west of the entire continental margin of Israel and probably also off Lebanon. It also seems that this zone is the extension of the Pelusium Line, and therefore, the entire zone, from the Suez Canal to the area off Lebanon, is named the Pelusium Line (Figs. 5 and 22).

West of the continental margin and north of the Belt of No M, the Levant Platform displays diapiric features over a large area (Fig. 1; Fig. 14, profiles 100, 101, 107, 143, 144, and Fig. 18). The northern extent of the Diapir Belt is not known, although it does not occur on Eratosthenes Seamount. The latter is overlain only by a thin veneer (50 to 150 m) of Quaternary (highly reflecting) sediments, which, as in the structural highs of the Belt of No M, are resting with an angular unconformity over acoustically more transparent layers (Fig. 14, profiles 100, 101,and Fig. 19).

Diapiric structures "invade" southward into the Belt of No M along the NE-trending troughs where the Quaternary sequence shows thickening. The southern boundary of the Diapir Belt thus shows a sinuous overlap over the northern part of the Belt of No M.

Two types of diapiric structures are observed:

(1) Those which are associated with Reflector M have moved vertically upward like narrow necks, resembling the Zechstein types (Figure 6 in Murray, 1968). These diapirs have affected (pierced through or merely crumpled) the upper three out of the four reflectors that diverge from the single Reflector M (Fig. 13, profile 97; Fig. 18, profile 92, 114). It is unlikely that these upper three reflectors are time-equivalents of the single and unquestionable Reflector M which separates the Ziqim and Mavqi'im Formations (Late Miocene, see above: Oil Companies Data). With the high rates of deposition expected in this basinal area it is probable that the age of at least the uppermost one of these three reflectors is Quaternary or at the most

Late Pliocene in age. This deduction is supported by the findings of D. S. D. P., Leg XIII, Site 131, drilled to sample such a reflector NW of the Nile Delta; this reflector was assumed to be Reflector M but finding it to be a mid-Pleistocene calcareous layer (Ryan et al., 1973). It is assumed that the origin of these diapirs is in the Mavqi'im evaporites (Messinian, uppermost Miocene). Therefore, only the lowest reflector split from the single Reflector M, which is least affected by diapirism, was taken as the equivalent of the Mediterranean-wide Reflector M.

(2) The other type of diapiric structure was noticed to have been derived from depths greater than Reflector M and to be of much greater areal dimensions (Fig. 18, profile 143 A and B), resembling the Mexican Gulf type of structure (Figure 7 in Murray, 1968). They were detected southwest of Eratosthenes Seamount and perhaps also between the latter and Haifa Bay.

Several areas of thinning are noticed on the isopach map within the eastern part of the Diapir Belt, west of and parallel to the Pelusium Line. These, together with their southern extension (the easternmost structure within the Belt of No M), appear to be another chain of structures, parallel to OSS 1, which have been called OSS 2. This western chain appears to extend all the way from the Bardawil Escarpment northward opposite Lebanon. The westernmost structure within the Belt of No M appears to be associated with the Eratosthenes structure and its southward extension.

IV. Magnetometric Data

Magnetometric surveys have been carried out in the region by the U. S. Naval Oceanographic Office (shipboard measurements, 1968), Domzalsky (1967), and

Folkman (1972). In the latter two are aeromagnetic surveys of Israel and its adjacent offshore areas. Figure 20 is a simplified residual magnetic intensity map compiled from the above-mentioned data. The discrepancy of values between areas of coverage is probably due to differences in reference fields and times of the measurements. The regional field strength (not shown) increases from 42, 500 gammas in the south to 45, 500 gammas in the north, and the strike of geomagnetic gradients is approximately N70°W.

As regarded by the present authors, the most prominent offshore positive anomaly is eliptical in shape, its long axis trending northeast parallel to the morphological axis of Eratosthenes Seamount, which runs 30-40 km to the northwest. The anomaly appears to extend both to the northeast (east of Cyprus) and to the southwest along a saddle, toward the northwestern part of the Nile Delta. Another prominent positive anomaly is observed 80 to 100 km off the coast of Israel, coinciding roughly with the above-suggested OSS 2. A large elongated negative anomaly trends parallel to and east of the latter, coinciding with the northern half of the Pelusium Line (where it displays compressional features). A positive anomaly to the east coincides with the Helez Structure, and the tectonic hinge-line along the present day coast of central Israel. Folkman (1972) finds a sharp increase in the westward gradient of the magnetic basement approximately 20 km off Ashqelon. This steepening roughly coincides with the elongated gravity high (+20 mgls) marked on the Belpetco Ltd. offshore Bouguer anomaly map (unpublished) and both are associated with OSS 1 off Ashqelon.

A change to a more eastward lineation in contour trends is mentioned by Folkman in the southern part of the Hebron Mountains, extending offshore south of Gaza. He ascribes this change to a possible fault line and/or to a change in the basement composition from acidic in the south to more basic in the north.

A very prominent positive anomaly runs along the upthrown part of the Yagur Fault, which borders the Carmel Block on the northeast. It extends from the offshore end of the Haifa Nose toward the southeast up to Ya'bad (southwest of Mount Gilboa'). Another positive anomaly, en echelon and parallel to it, extends from Mount Gilboa' to the Jordan Rift. A slight negative trend separates the Haifa and 'Akko Noses.

V. Gravimetry

Published gravity maps for the Eastern Mediterranean and Levant (De Bruyn, 1955; Rabinowitz and Ryan, 1969; Woodside and Bowin, 1970) show a regional gradient from the large positive Bouguer anomalies in the eastern Mediterranean to the negative anomalies in the onshore areas adjacent to it (Levant, Israel and Sinai), the zero contour conforms roughly to the present day coastline. This may indicate a crustual thinning from the land seawards. Eratosthenes Seamount is expressed as a prominent positive anomaly. Unpublished gravity maps (Ginzburg, 1960) indicate the Helez Structure and its northern extension along the hinge-line, the Judean Mountains and the Carmel Block, to possess positive gravity anomalies. An elongated gravity high (Bouguer anomaly of 20 mg) is associated also with the OSS 1 off Ashqelon.

VI. Seismicity

A note on earthquakes in the southeastern Mediterranean corner (31^{o} - 35^{o} N; 33^{o} - 36^{o} E) by E. Arieh (Geological Survey of Israel):

Figure 21 shows the distribution of epicenters in the southern Levant (including offshore) during the period of 1954-1971. The earthquakes were recorded by the Jerusalem, Haifa and Qesara (Lebanon) stations, and preliminarily determined on the basis of S-P readings and Jeffrey-Bullen travel time tables. Major quakes ($5\frac{1}{2}$ or higher) which occurred during the period 1918-1963 (Arieh, 1967, p. 9-10) are also shown.

The present setting of local seismograph stations and the lack of data on local crustal seismic velocities prevented more precise calculations and evaluation of standard errors. It is not improbable that earthquakes of small magnitude occurred in the offshore areas also south of latitude 32^{o}N, but their epicenters cannot be determined by the present local network of seismography stations. Inland epicenters of the period 1963-1971 were not presented here because an attempt is now being made to refine their dubious determination. However, it should be noted that distribution of these inland epicenters is roughly similar to the ones of the period 1954-1963. Most of the earthquake epicenters mentioned above (of magnitudes less than 4.5) are not shown in maps describing the seismicity of the region (such as Barazangi and Dorman, 1967; McKenzie, 1970).

In spite of these limitations, Figure 20 shows that seismic activity is presently concentrated along two zones: The Dea Sea - Jordan Graben, and a broad zone off the coast of Israel and Lebanon. Although a NNE-SSW trend may be discerned in the offshore zone, it is premature to relate the recorded seismic events to a specific structural pattern.

DISCUSSION AND CONCLUSIONS

Most of the tectonic and other features described above can be classified into four groups. according to their general trends. These are: (1) NE, (2) NNE, (3) NW, (4) WNW (and E-W). These features, together with the associated plaeo-geographic implications, are discussed below, and schematically shown in Fig. 22.

(1) NE-folding system

The offshore Chain of Structures No. 1 (OSS 1), which developed at least since Jurassic times, appear to be similar in trend, nature and history, to the folding system of Sinai, Israel and the Levant (Picard, 1943). The asymmetry (southwest side is steeper) of OSS 1 resembles the asymmetry of the Sinai and Negev structures. Goldberg (1970) and Druckman (1973), on the basis of facies and isopach features, found evidence for structural activity along NE-trends in the northern Negev in both Jurassic and Triassic times. The Helez Structure and other structures found along and slightly diagonal to the NNE-trending coastal hinge-line have also started to develop no later than the Upper Jurassic (Rahamim, 1969; Cohen, 1969; Shilo, 1970-71; Rosenberg, 1970; Bein, 1971; Friedman, Barzel and Derin, 1971). The folding activity of the entire system seems to have been temporarily terminated during the interval

Miocene to Lower Pliocene as indicated by the history of OSS 1.

The NE-trending features west of the Pelusium Line (mainly OSS 2 and Eratosthenes Seamount) also seem to be related to this folding system. This comparison is based, in the absence of deep and detailed stratigraphic information, on the similarity of the axial trends as expressed by the magnetic anomalies, the thinning and thickening behavior and the associated lobes of diapirs in the troughs, as well as physiographic features (such as Eratosthenes Seamount etc.).

It is assumed therefore that southeast to northwest has intermittently affected the entire offshore area, as well as onshore Sinai, Israel and the Levant, at least since Jurassic times.

(2) NNE-trending elements

These elements, are suprimposed on the NE-folding system. They are distributed from the continental margin off Israel to the Jordan - Dead Sea Graben. They appear to be different features but nevertheless seem to be inter-related in origin. Toward the north they gradually converge and change their trends more northward.

(a) The Pelusium Line forms a sharp divide between different provinces and facies on both of its sides. It is characterised by compressional features which have been active at least since Neogene times. Strike-slip movement along this line cannot be ruled out. Its significance to the regional tectonic evolution will be discussed in a separate paper.

(b) The shelf-break off Israel is an entirely new hinge-line, along which the eastern Mediterranean basin has recently been downwarped and subsided. This is mainly indicated by two sets of findings:

(i) Thinning of sediments as young as upper Pleistocene along the axis of OSS 1 which is located along the lower part of the present continental slope (2-5°). It is improbable that such an eastward thickening and dipping could have occurred on the present-day westward slope (see chapters II and III as well as Fig. 23). It is also clear that OSS 1 did not act as a dam for sediments derived from the east, as similar accumulation, thickening and dipping features are also recognized west of its axis.

(ii) The westward creeping of sediments not older than Holocene which occur only from the shelf-break westward. These sediments have symmetrically filled up the broad morphological troughs, one of which is located west of and parallel to the shelf break. It therefore seems that these sediments were originally deposited as nearly horizontal layers but later on the western half of this trough was tilted to the west (see chapter III and Fig. 24).

A similar history was recorded by Finetti and Morelli (1972) for the western border of this basin. ".... the foundering of the Ionian area is relatively recent .... and probably still in act .....". Their interpretation is based on structural-stratigraphic evidence similar to that used in this paper, i.e. "The thin Plio-Quaternary interval is deepening not toward the basin, as logical sedimentary position should show, but toward the margin."

(c) The coastal fault-system and hinge-line of Israel: These normal gravity faults seem to converge northwards. The coastal fault line extends northwards from Rafah to Lebanon. The coastal hinge-line, which is interrupted by the Carmel Block and 'Akko Nose, probably re-appears along the coasts of Lebanon. The coastal fault system has developed in phases at least since Jurassic times. Figures 23 and 24 express their evolution since Oligocene and their relationship to the subsidence of the eastern Mediterranean. The eastern limit of the early Miocene Mediterranean basin was at the foot of this fault system. The intensive erosion, due to which the big and deep rivers were incised into the marginal lands, occurred (at least in this part of the eastern Mediterranean) in early Miocene times, due to the differential uplifting of these lands (about 1, 500 m above the sea level of that time - see above,and Neev, 1960, and Gvirtzman, 1970). The Ziqim marls (Middle Miocene), Mavqi'im evaporites (Messinian) and Yaffo shales (Pliocene) had already been deposited within the previously eroded deep canyons on land. These dominantly transgressive events, which continued at least until the late Pliocene, were developed mostly due to a regional (not differential, i.e. involving both sides of the coastal fault system) subsidence process. The most intensive erosional process due to which the big canyons were entrenched could not therefore have resulted, as suggested by Hsü (1972), by the complete desiccation of the Mediterranean which occurred during the Messinian (Miocene-Pliocene transition period). On land, the imprints of the two erosional phases which preceded and followed the deposition of the Mavqi'im evaporites (Messinian - Upper Miocene) were of much smaller dimensions; the deep canyons, which were partly filled by middle and upper

Miocene soft sediments (Ziqim and Mavqi'im Formations respectively), have not been appreciably re-entrenched. In the offshore, however, the relief of the erosional surface below the evaporites (Reflector M according to our version) is quite pronounced, reflecting drainage patterns (Gvirtzman, 1970). It seems that the Palmahim and Gaza Grabens (channels) served as the main conduits of these patterns.

It is clear that the sequence of events which occurred in the region during Miocene and Pliocene times (transgressions and regressions as well as changes of depositional environments) was controlled by two unrelated processes: (i) exteme fluctuations of the Mediterranean sea levels due to alternating evaporation and flooding phases; (ii) an epeirogenic differential uplifting process at the eastern limits of the basin, which was followed by a regional subsidence. Secondary fluctuations have possibly been superimposed. These two sets of processes were developed at different rates, changing with time and without any coordination or synchronization. The numerous combinations of these processes yielded sometimes odd results, such as the unconformable plastering of the Upper Miocene evaporites on top of topographic highs of the erosional surface in the coastal plain of Israel. The carbonate component, which is expected below the gypsum in a normal evaporative cycle, is missing here. Moreover, data recovered from drillings located in nearby paleotopographic lows, may indicate that these gypsum deposits have been precipitated from the surface of relatively deep water (several hundred meters).

Decima and Wezel (1973) estimate that the evaporites of central Sicily were deposited on a sea floor 200 to 500 meters below the late Miocene Atlantic sea level.

The association of potash deposits in the Sicilian evaporites may indicate that this site was situated in one of the deepest parts of the dessicated Mediterranean basin. Thus the evaporites off Israel (where potash deposits were not found) were deposited at even shallower depths. It is therefore assumed that the relief of the eastern Mediterranean basin during that period and until late Pleistocene was probably much more moderate, and its bottom appreciably more shallow (with respect to ocean levels) than it is at present.

It appears that no appreciable rejuvenation of differential faulting has occurred along the coastal faults system of Israel between Lower Miocene and Holocene; on land, within the Gaza channel, the structural elevation of the Mavqi'im evaporites (Messinian) is found at about -1,000 m below m. s. l. (Neev, 1960), while in Bravo 1 (on the shelf about 15 km offshore) it is found at about -1,300 m below m. s. l. The coastal fault line was rejuvenated, however, during Holocene. This activity was probably associated with the catastrophic subsidence of the eastern Mediterranean basin (see above Part VII (2) b on the present day shelf-break off Israel).

(d) and (e). The Structural Backbone of Israel and the Jordan-Dead Sea rift (Fig. 22) are N-S elements. Both have developed since early Pleistocene or late Pliocene (Neev, 1960; Neev and Emery, 1967) although the latter has acted as a strike-slip or transform fault-line since late Cretaceous (Freund, 1965).

(3) NW Elements

The Carmel Block and Haifa Nose are the seaward segment of a large and ancient NW-trending positive structural element, and not merely a westward protrusion of the coastal hinge-line. It extends as a positive magnetic anomaly and a gravity high (Ginzburg, 1960) down to the Jordan Graben along the en-echelon Mount Gilboa'. This trend is roughly perpendicular to that of the regional folding system and both of them have been developed contemporaneously (at least since Jurassic). Arad (1965) proved the uplifting of the ridge, from the Haifa Nose to Um el Fahm, including the Menashe syncline between them, to have taken place during Upper Cretaceous and Lower Tertiary times. Picard and Kashai (1958) and Bein (1971) noticed the dominance of a reef facies associated with repetitive extrusions of alkali-olivine basalt and tuff all through the stratigraphic sequence of the Carmel Block from top Jurassic to Upper Cretaceous times. Sass (1957) found basic and ultra-basic xenoliths in these volcanics. Sass (1968) described a similar association and history for the Um el-Fahm structure (Fig. 22). The above findings characterize the Carmel - Um el-Fahm ridge as an old positive element and mark the difference between its geological history and that of the area south of its (including the offshore paleobasin). According to Fig. 3 (Belpetco profile 46) the formations older than Lower Cretaceous of the Haifa Nose appear to have been overthrusted southward. It is therefore assumed that the Carmel - Um el-Fahm - Gilboa' ridges is a NW-trending tensional feature, assocated with uplifting and southward thrusting as well as with basic volcanism, which has been active at least since Jurassic times. It is possible that the 'Akko Nose with its landward extension, displays a similar history but with an opposite trend of upthrusting (northward). This tensional element is parallel in its trend to the Red Sea and Wadi Sirhan (at the Jordanian-Saudi Arabian border) and also to the graben off Palmahim. The latter has been formed, however, not earlier than Middle Miocene time.

(4) WNW and E-W elements

This trend appears to have a regional significance as it coincides with that of the front range of the Alpine orogenic belt in this region (Cyprus and Crete arcs) as well as the main axis of the eastern Mediterranean basin. Discussion of this group of elements includes facies belts as well as fault systems:

(a) The diapirism in the Diapir Belt is probably related to the late Miocene - early Pliocene halite and gypsum deposits, found by drillings within depressions close to the eastern limits of the basin (Joshua 1 and Echo wildcats within the Palmahim Graben, Ashqelon No. 4 and others on land). It is assumed that the distribution of the Diapir Belt marks the deepest topographic (and strucutral) part of this basin during time of deposition. The existence of evaporites of older age (diapirs which have pierced through Reflector M) may indicate that the limits of this belt also coincide with the limits of an older basin. The boundaries of this belt are irregular, as the evaporitic deposits surrounded but were not precipitated on the structural highs (such as Eratosthenes Seamount and the structures plunging to the north-east from the south).

The several reflectors recognized within the Upper Miocene to Pleistocene sequence of the Levant Platform may mark multiple desiccation (partial ?) events within the Mediterranean basin. The uppermost of these reflectors is probably equivalent to the reflector sought by site 131 of D. S. D. P. Leg XIII, which was erroneously assumed to represent the Reflector M but was proven to be of Pleistocene age (Ryan et al., 1973). The lowermost one of these split reflectors is considered in the present work to be equivalent to the Reflector M. It is not yet understood, however, why this sequence of reflectors converged and subsided to the east toward the down-kinks of the Pelusium Line. It seems, however, that recent tectonic activity along this line is expressed by the morphologic sub-slope trough.

(b) The origin of the Belt of No M is still unclear. The absence of Reflector M in this belt as well as the thinning of Pleistocene sediments which are associated with compressional features, may indicate a geological history of a structurally positive element at least since Miocene. However, the proximity to the Nile Delta and the thickening of isopachs from east and southeast toward this belt, may indicate a history of paleo-structural negative elements on which the NE-trending folding system has been superimposed. In such a case it is possible that the Reflector M does exist in this belt, but it is either too deep to be detected by the seismic system used, or that the facies were different (thick deltaic-fluviatile sediments). Accordingly, the Sinai shelf west of the Pelusium Line together with the Nile Delta proper, may represent either a separate belt (negative structural element) which differs from the Belt of No M (positive element) or that it is the southern part of the latter which was later on separated by the subsidence of the Levant basin along the Bardawil fault system.

The belt of marly-reefoid Neogene sediments (Shata, 1953, and Said, 1962), which stretches along and south of the Mediterranean coasts of the Western Desert and Cyrenaica, may be considered as another element within this WNW-trending system of facies belts.

(c) The remoteness of some of the features associated with the Bardawil Escarpment fault system from the Nile Delta proper makes it difficult to relate them to the gravity-growth faults known from other deltas in the world (Fraenkel and Cordry, 1967). The observed northward compressional features which are associated with this fault system may be related to the northward thrusting of Africa (McKenzie, 1970), and possibly also to the load of the Nile Delta.

(d) Several E-W faults were detected by Bartov (1971) in northern Sinai and the Negev. In some of these indications were found for minor dextral strike-slip movements.

(e) The E-W positive magnetic anomaly which extends from the Dead Sea to the edge of the shelf off Gaza is interpreted by Folkman (1972) as a change in basement composition from acidic in the south to more basic in the north. It may also be associated with a northward thrusting within the basement.

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Bathymetric Map
of the
Southeastern Mediterranean Sea

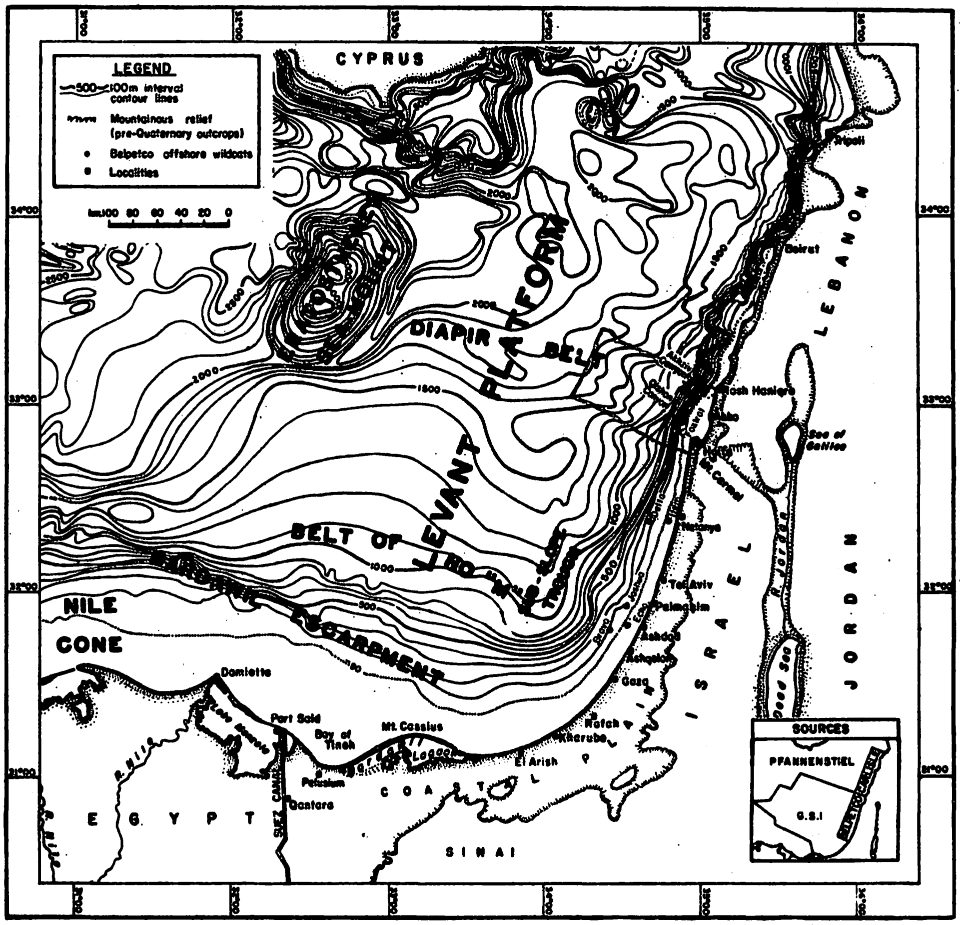


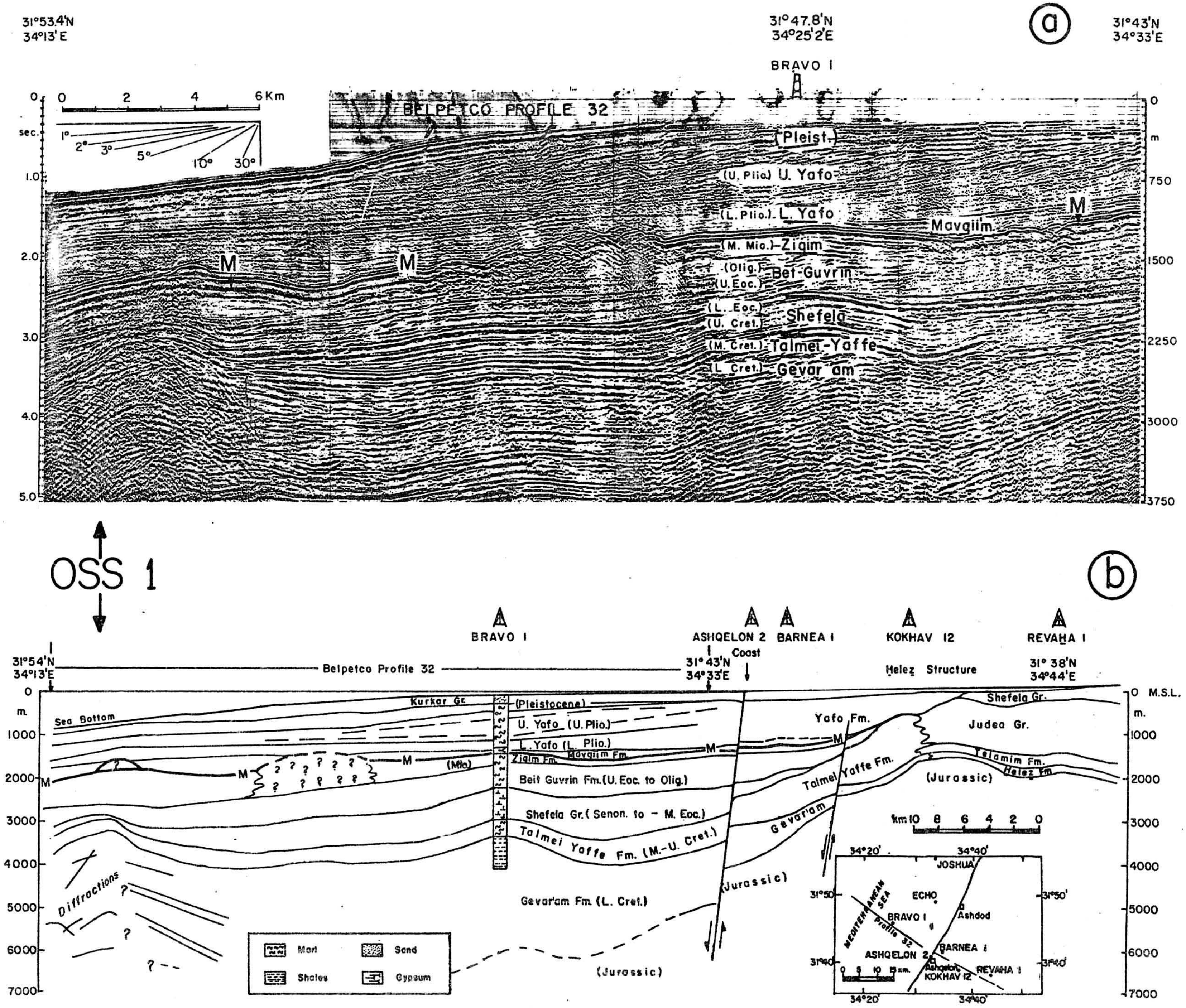
Fig. 1 **Bathymetric map of the southeastern Mediterranean Sea**

The map is compiled from data of the Geological Survey of Israel (G. S. I.), Pfannenstiel (1960), Belpetco (1971) and Carlisle (1965).

Fig. 2 An E-W seismic profile and a geological cross-section from the Helez Structure. on land to OSS 1.

a. Belpetco-Israel, E-W -trending seismic profile 32 (a 12 fold C. D. P. profile, shot with a 900 cu in air-gun, digitally recorded and processed). The stratigraphic sequence at Bravo 1 wildcat was superimposed on the seismic profile according to a velocity survey. Depth scale is according to the recorder's scale (2 sec. equal 1,500 m).

b. Geological cross section from the western end of seismic profile 32 (OSS 1) to the Helez Structure on land. The depth scale is corrected according to a velocity survey. The onshore section was compiled from Bein (1971), Buchbinder (1971), Cohen (1971), Derin (1971), Gvirtzman (1970) and Gvirtzman and Klang (1972).

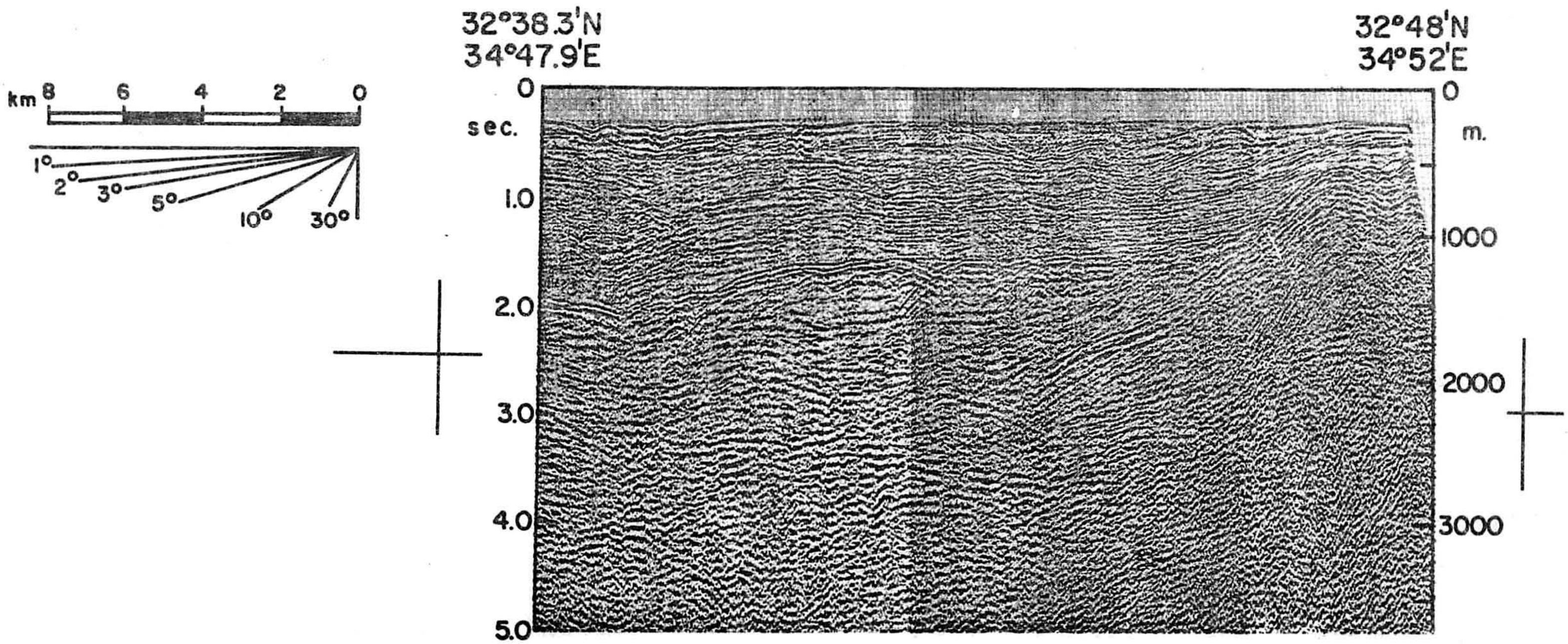


a
31°53.4'N
34°13'E
31°47.8'N
34°25'2'E
31°43'N
34°33'E
BRAVO I
0
2
4
6 Km
1°
2°
3°
5°
10°
30°
BELPETCO PROFILE 32
sec.
1.0
2.0
3.0
4.0
5.0
0
m
750
1500
2250
3000
3750
(Pleist.)
(U. Plio.) U. Yafo
(L. Plio.) L. Yafo
M
Mavqiim
(M. Mio.) Ziqim
(Olig.)
(U. Eoc.)
Bet-Guvrin
(L. Eoc.)
(U. Cret.)
Shefela
(M. Cret.) Talmei-Yaffe
(L. Cret.) Gevar'am
OSS 1
b
BRAVO I
ASHQELON 2
BARNEA I
KOKHAV 12
REVAHA I
31°54'N
34°13'E
Belpetco Profile 32
31° 43'N
34°33'E
Coast
Helez Structure
31° 38'N
34°44'E
0 M.S.L.
m.
1000
2000
3000
4000
5000
6000
7000
Sea Bottom
Kurkar Gr.
(Pleistocene)
U. Yafo (U. Plio.)
L. Yafo (L. Plio.)
Ziqim Fm.
Mavqiim Fm.
(Mio.)
Beit Guvrin Fm. (U. Eoc. to Olig.)
Shefela Gr. (Senon. to - M. Eoc.)
Talmei Yoffe Fm. (M.-U. Cret.)
Gevar'am Fm. (L. Cret.)
(Jurassic)
Diffractions
Yafo Fm.
Shefela Gr.
Judea Gr.
Talmei Yaffe Fm.
Telamim Fm.
Helez Fm.
Gevar'am
Marl
Sand
Shales
Gypsum
km 10 8 6 4 2 0
34°20'
34°40'
JOSHUA
MEDITERRANEAN SEA
ECHO
Ashdod
BRAVO I
Profile 32
BARNEA I
ASHQELON 2
Ashqelon
KOKHAV 12
REVAHA I
31°50'
31°40'
0 5 10 15 km.

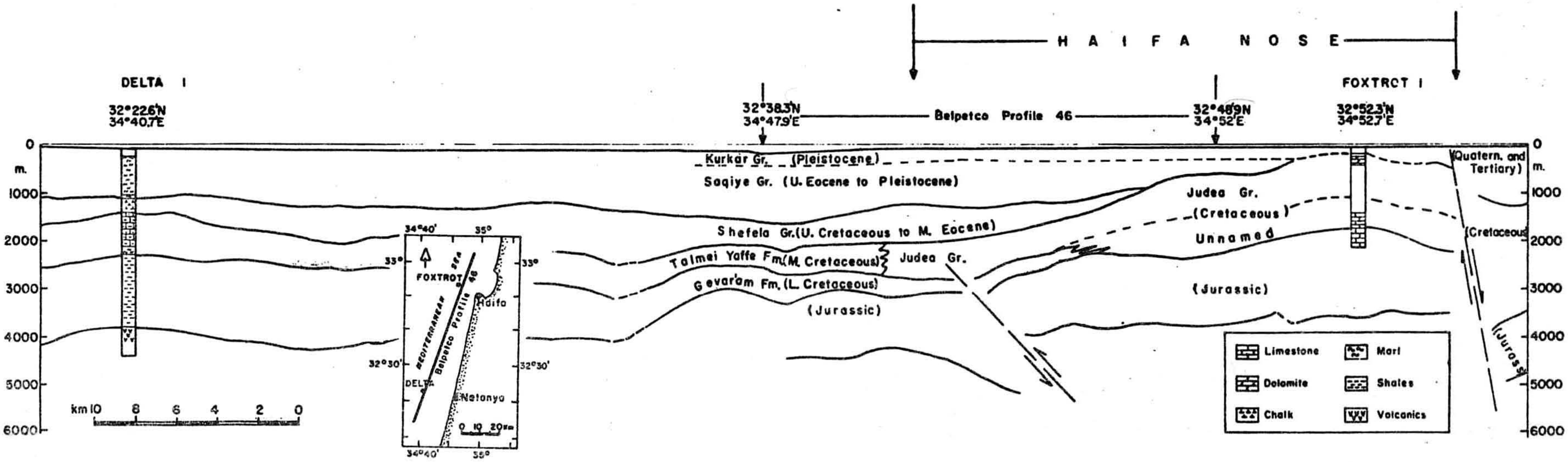
Fig. 3 S-N profiles through the Carmel Block

a. Part of the Belpetco-Israel S-N-trending seismic profile 46 (a 12 fold C. D. P. profile, shot with a 900 cu.in.air-gun, digitally recorded and processed). The depth scale is according to the recorder's scale (2 sec equals 1,500 m).

b. Geological cross section from Foxtrot wildcat (Haifa Nose) to the Delta 1 (off Netanya) demonstrates the faulted contact of the Haifa Nose and the paleobasin south of it; a possible reverse fault shows the southward overthrusting of the Haifa Nose, which occurred in pre-Cretaceous times. The depth scale is corrected according to a velocity survey.



32°38.3'N
34°47.9'E
32°48'N
34°52'E
km 8 6 4 2 0
1° 2° 3° 5° 10° 30°
sec.
0
1.0
2.0
3.0
4.0
5.0
m.
1000
2000
3000



HAIFA NOSE
DELTA I
32°22.6'N
34°40.7'E
32°38.3'N
34°47.9'E
Belpetco Profile 46
32°48.9'N
34°52'E
FOXTROT I
32°52.3'N
34°52.7'E
m.
0
1000
2000
3000
4000
5000
6000
Kurkar Gr. (Pleistocene)
Saqiye Gr. (U. Eocene to Pleistocene)
Shefela Gr. (U. Cretaceous to M. Eocene)
Talmei Yaffe Fm. (M. Cretaceous)
Judea Gr.
Gevar'am Fm. (L. Cretaceous)
(Jurassic)
Judea Gr.
(Cretaceous)
Unnamed
(Jurassic)
(Quatern. and Tertiary)
(Cretaceous)
(Jurassic)
km 10 8 6 4 2 0
34°40'
35°
33°
FOXTROT
MEDITERRANEAN SEA
Belpetco Profile 46
Haifa
32°30'
DELTA
Netanya
0 10 20 km
Limestone
Dolomite
Chalk
Marl
Shales
Volcanics

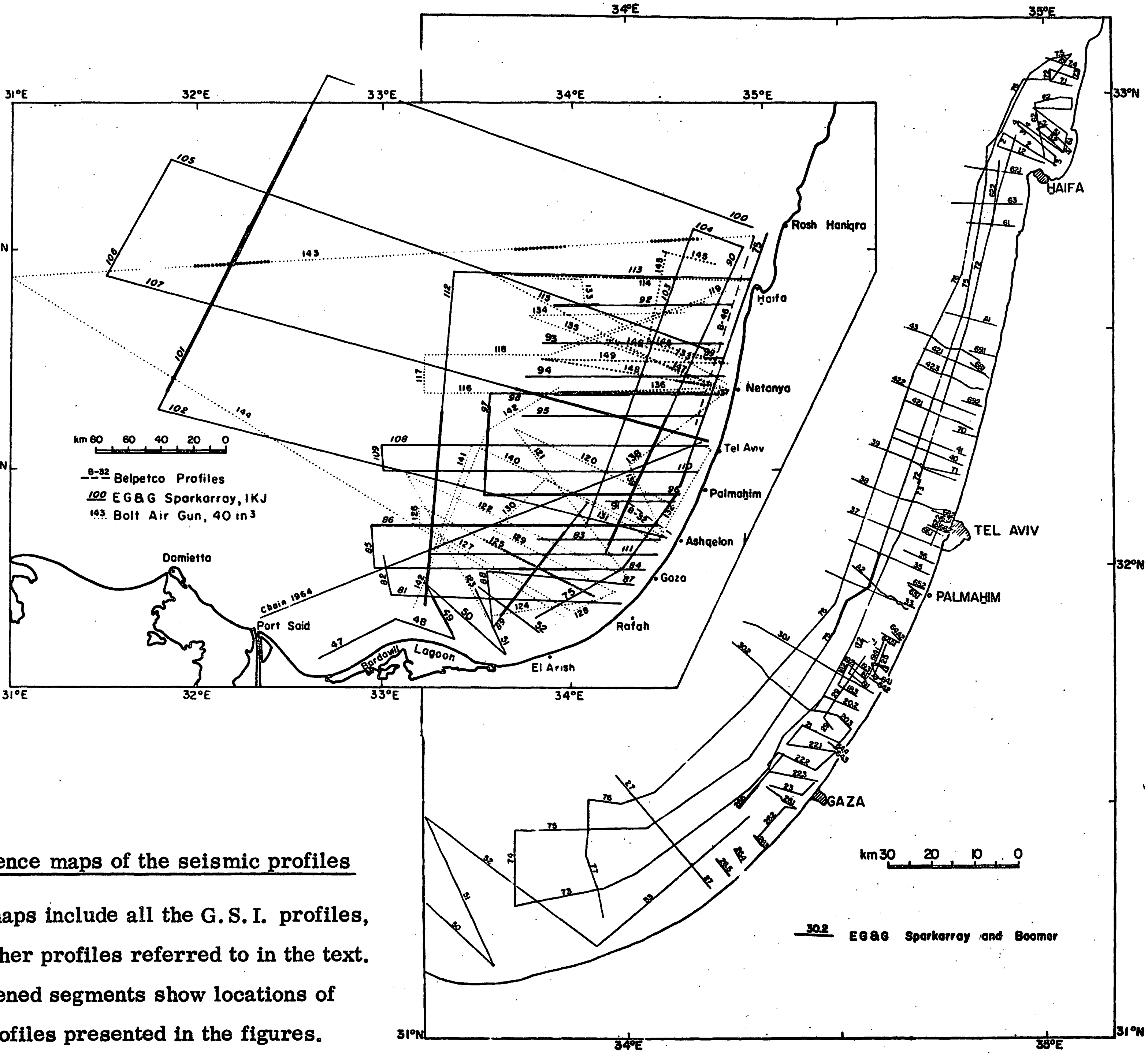
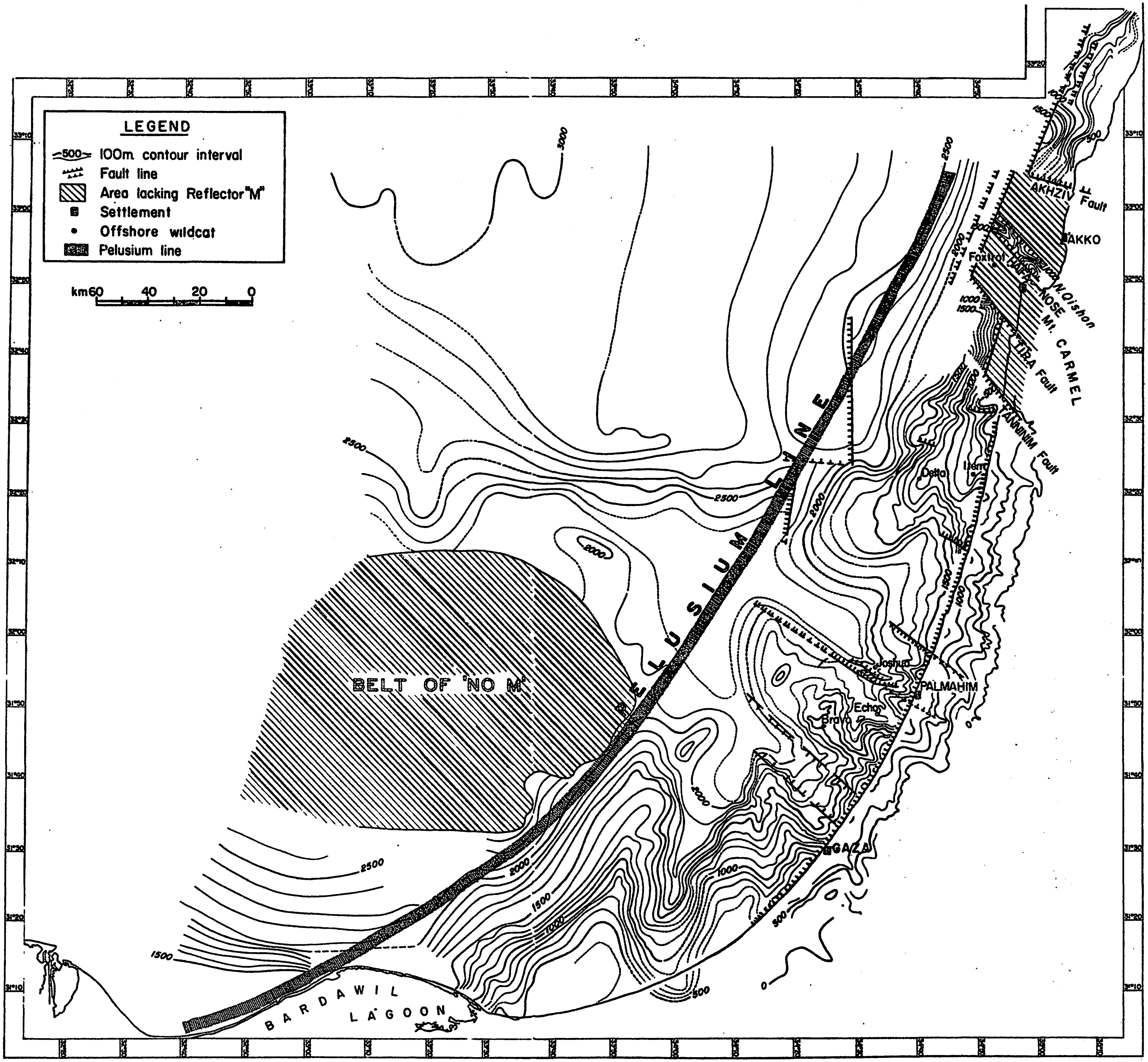


Fig. 4 Reference maps of the seismic profiles

The maps include all the G.S.I. profiles, and other profiles referred to in the text. Thickened segments show locations of the profiles presented in the figures.

Fig. 5 Structural Map based on Reflector M. The main features are the westward bending of the continental margin of Israel, the NW-trending Haifa (Carmel and 'Akko Noses, and the Palmahim and the inferred Gaza Grabens. The Offshore Chain of Structures No. 1 (OSS 1) is partly masked by the recent westward downwarping (see also isopach map, Fig. 6). The sources are: G. S. I. Marine Geology Division profiles (1969-1971, southeastern Mediterranean), Belpetco Israel (in Ginzburg, 1971, Israel Shelf), Gvirtzman (1970, central coastal plain of Israel where the base of Neogene sequence was used as the datum), Carlisle (1965, off Lebanon), and Ginzburg and Amitai (1968, northern Sinai). Slight discrepancies between the structural (as well as the isopach) and the bathymetric maps were derived because of the different navigation systems used in the various surveys.



LEGEND
500 100m. contour interval
Fault line
Area lacking Reflector "M"
Settlement
Offshore wildcat
Pelusium line
km 60 40 20 0
BELT OF 'NO M'
PELUSIUM LINE
BARDAWIL LAGOON
GAZA
PALMAHIM
Joshua
Echo
Bravo
Delta
AKKO
AKHZIV Fault
Foxtrot
HAIFA NOSE
N. Qishon
Mt. CARMEL
TIRA Fault
TANNINIM Fault
3000
2500
2000
1500
1000
500
0

Fig. 6 Isopach map based on the interval M to present-day sea bottom. The main features are the Offshore Chain of Structures No. 1 (OSS 1), which extends from Rafah to Mount Carmel, and OSS 2 which extends from the Belt of No M to the northeast. Neogene sediments are completely lacking, or extremely thin on the Haifa (Carmel) and 'Akko Noses. For sources see caption of structural map, Fig. 5.

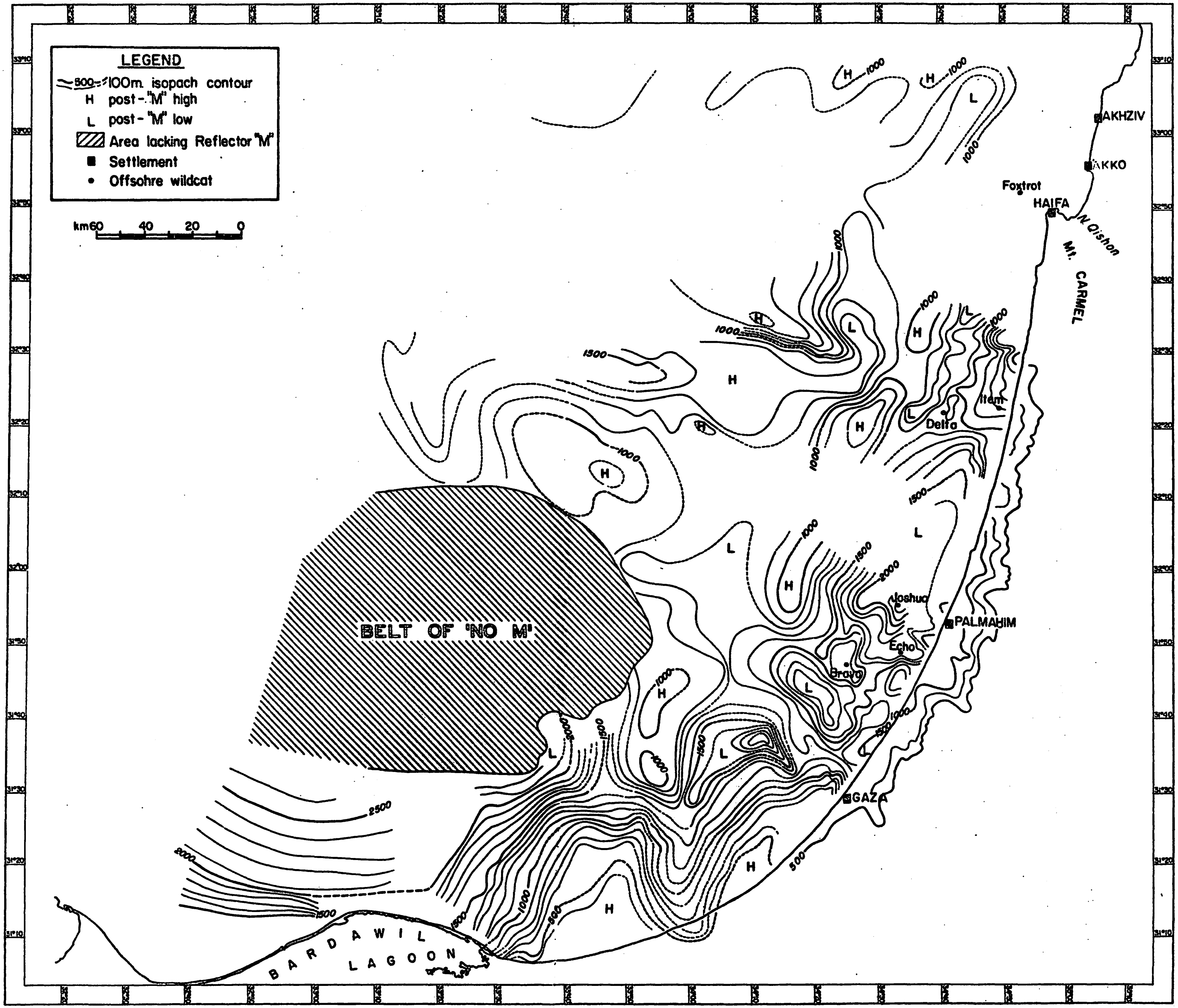
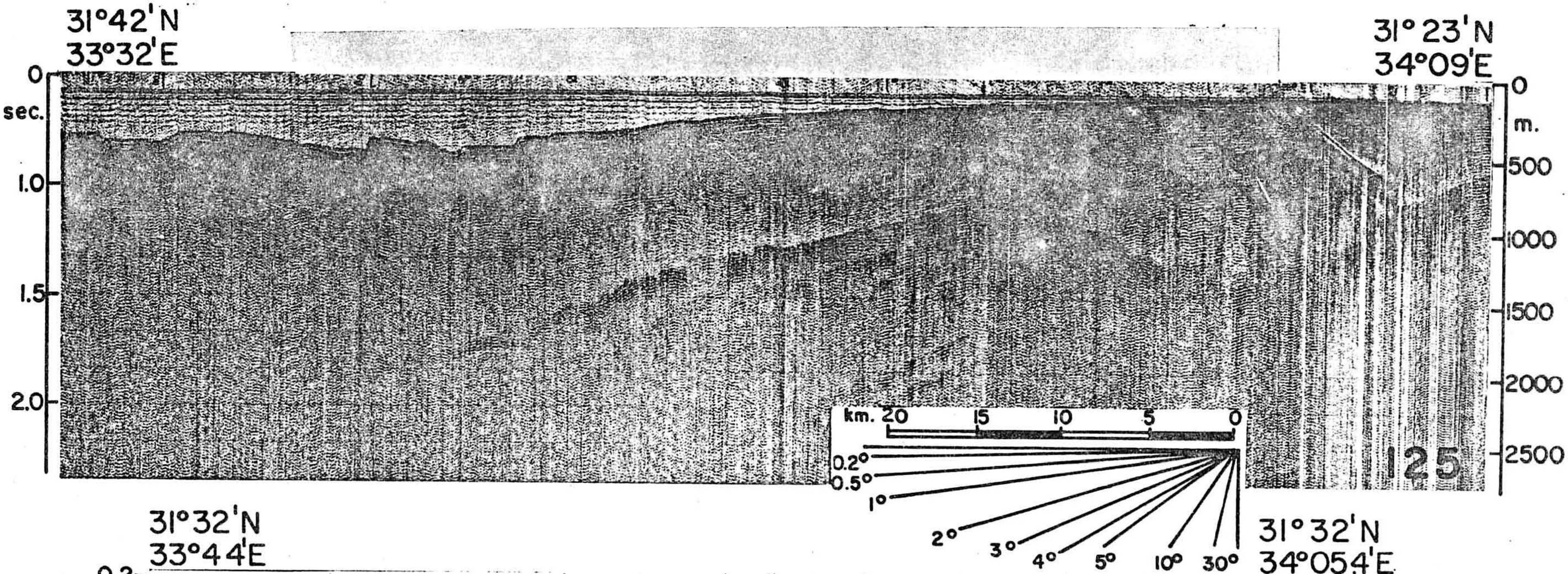

LEGEND
500 100m. isopach contour
H post-"M" high
L post-"M" low
Area lacking Reflector "M"
Settlement
Offsohre wildcat
km 60 40 20 0
BELT OF 'NO M'
AKHZIV
AKKO
Foxtrot
HAIFA
N. Qishon
Mt. CARMEL
Item
Delta
Joshua
PALMAHIM
Echo
Bravo
GAZA
BARDAWIL LAGOON
2500
2000
1500
1000
500

Fig. 7 Offshore Chain of Structures No. 1 (OSS 1)

Prof. 125 - NW-SE air gun profile off southern Israel across the southern structure of OSS 1. The asymmetric folding is expressed by Reflector M. The transition to the Belt of No M occurs in the left side of the profile, where the bottom topography is irregular (fault escarpments).

Prof. 84 - E-W sparkarray profile off southern Israel (Intersection of profiles 84 and 125 occurs on top of OSS 1).

Rejuvenation of folding activity is indicated by the folded shape of Quaternary reflectors.


31°42'N
33°32'E
31° 23'N
34°09'E
0
sec.
1.0
1.5
2.0
0
m.
500
1000
1500
2000
2500
km. 20 15 10 5 0
0.2°
0.5°
1°
2°
3°
4°
5°
10°
30°
125

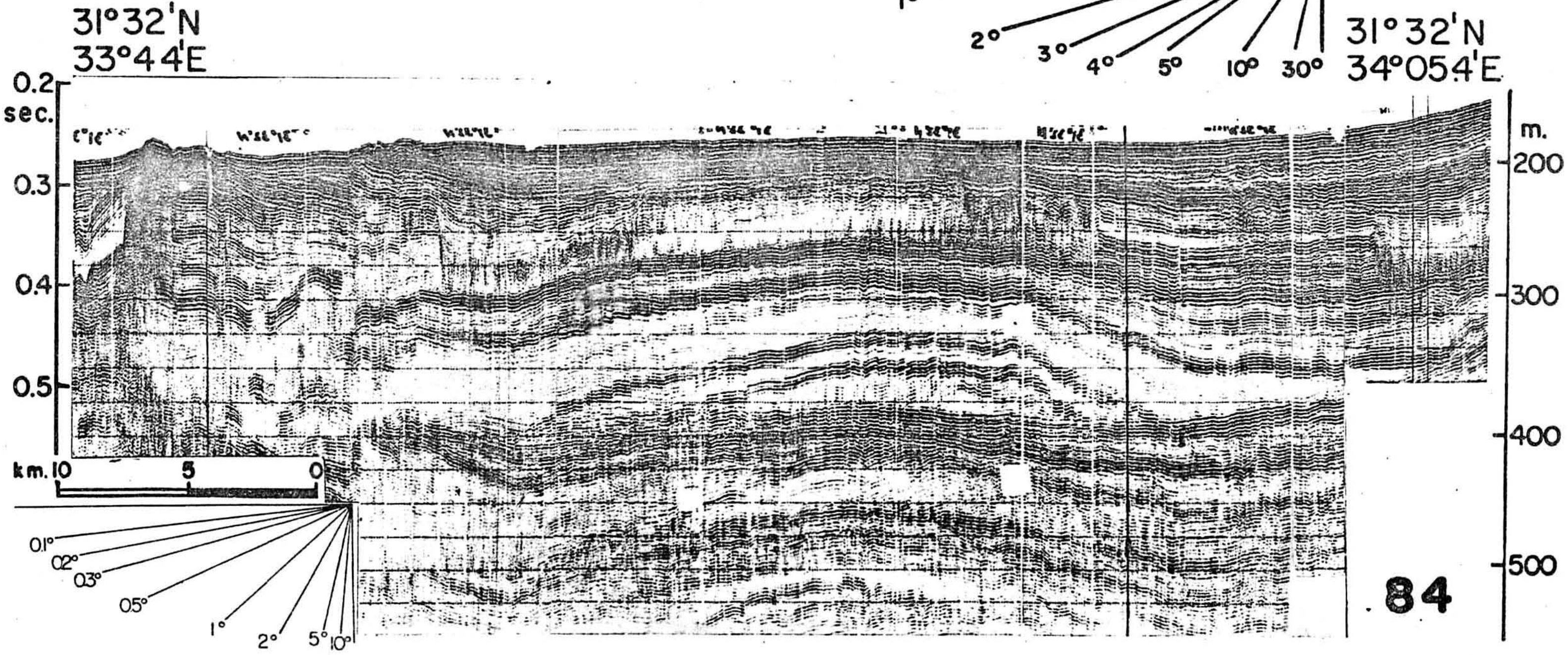
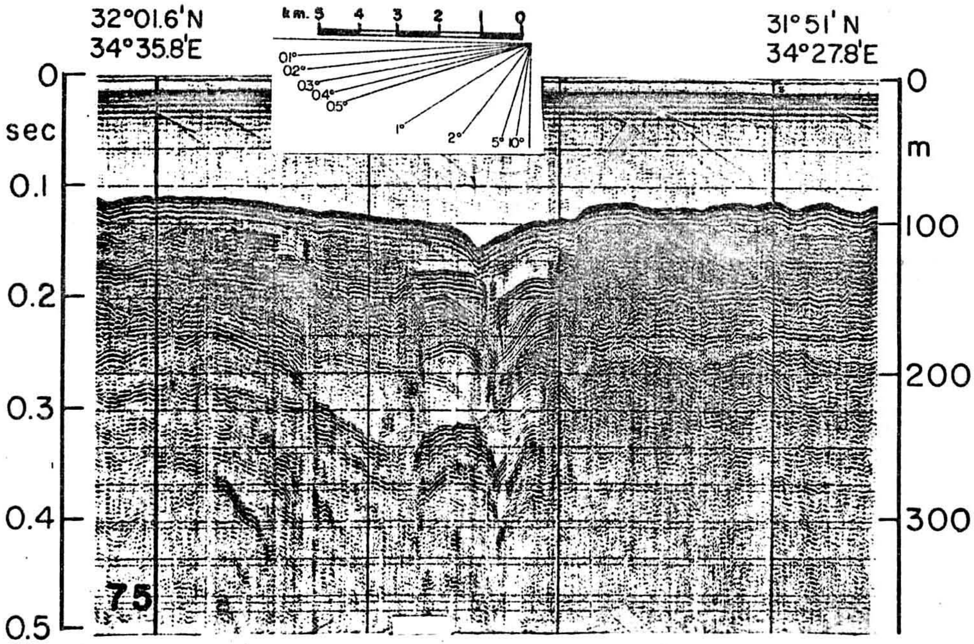

31°32'N
33°44'E
31° 32'N
34°05.4'E
0.2
sec.
0.3
0.4
0.5
m.
200
300
400
500
km. 10 5 0
0.1°
0.2°
0.3°
0.5°
1°
2°
5°
10°
84

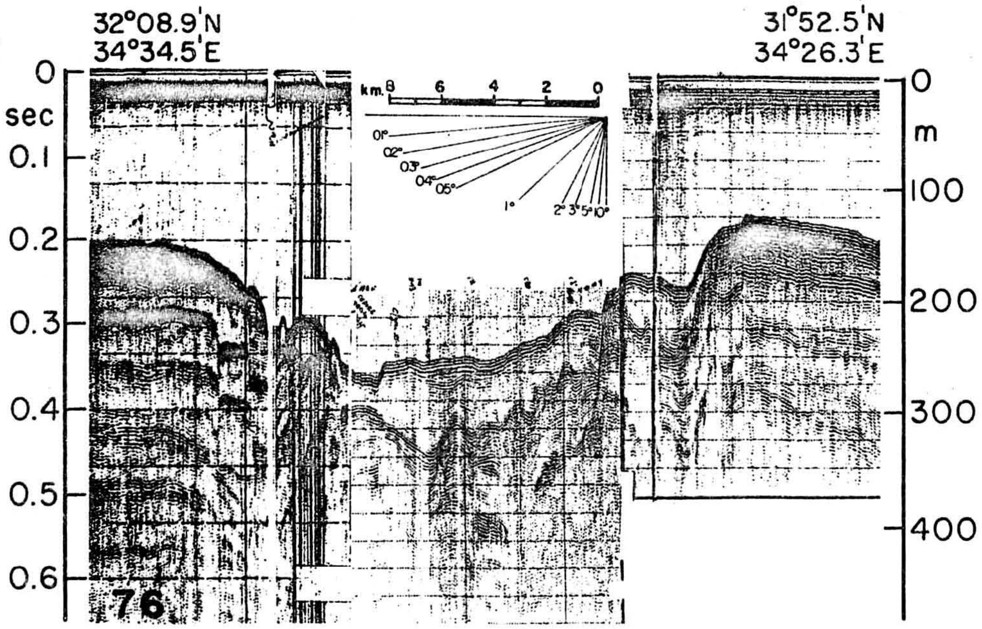
Fig. 8 Palmahim Graben. Three successive S-N sparkarray profiles across the Palmahim Graben in the outer shelf and slope:

Prof. 75 - At 80 m.depth. The graben is narrow, and is hardly expressed in the topography.

Prof. 76 - At 150 m depth. The graben widens and deepens toward the continental slope, is bordered by deep faults, and has a clear negative topographic expression.

Prof. 90B - At 400 m depth where the graben is wide. It is bordered by deep, nearly vertical faults, the throw of which becomes greater with the stratigraphical depth. An anticlinal structure in the center of the graben, probably formed by underneath diapiric activity, nearly rises to the height of the adjacent uplifted blocks.


32°01.6'N
34°35.8'E
31°51'N
34°27.8'E
km 5 4 3 2 1 0
sec
0
0.1
0.2
0.3
0.4
0.5
m
0
100
200
300
75


32°08.9'N
34°34.5'E
31°52.5'N
34°26.3'E
km 8 6 4 2 0
sec
0
0.1
0.2
0.3
0.4
0.5
0.6
m
0
100
200
300
400
76

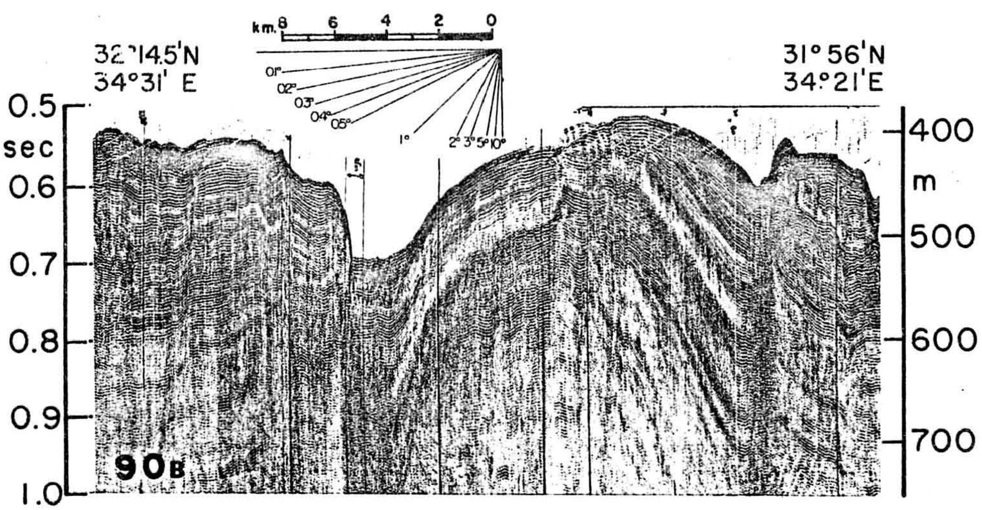
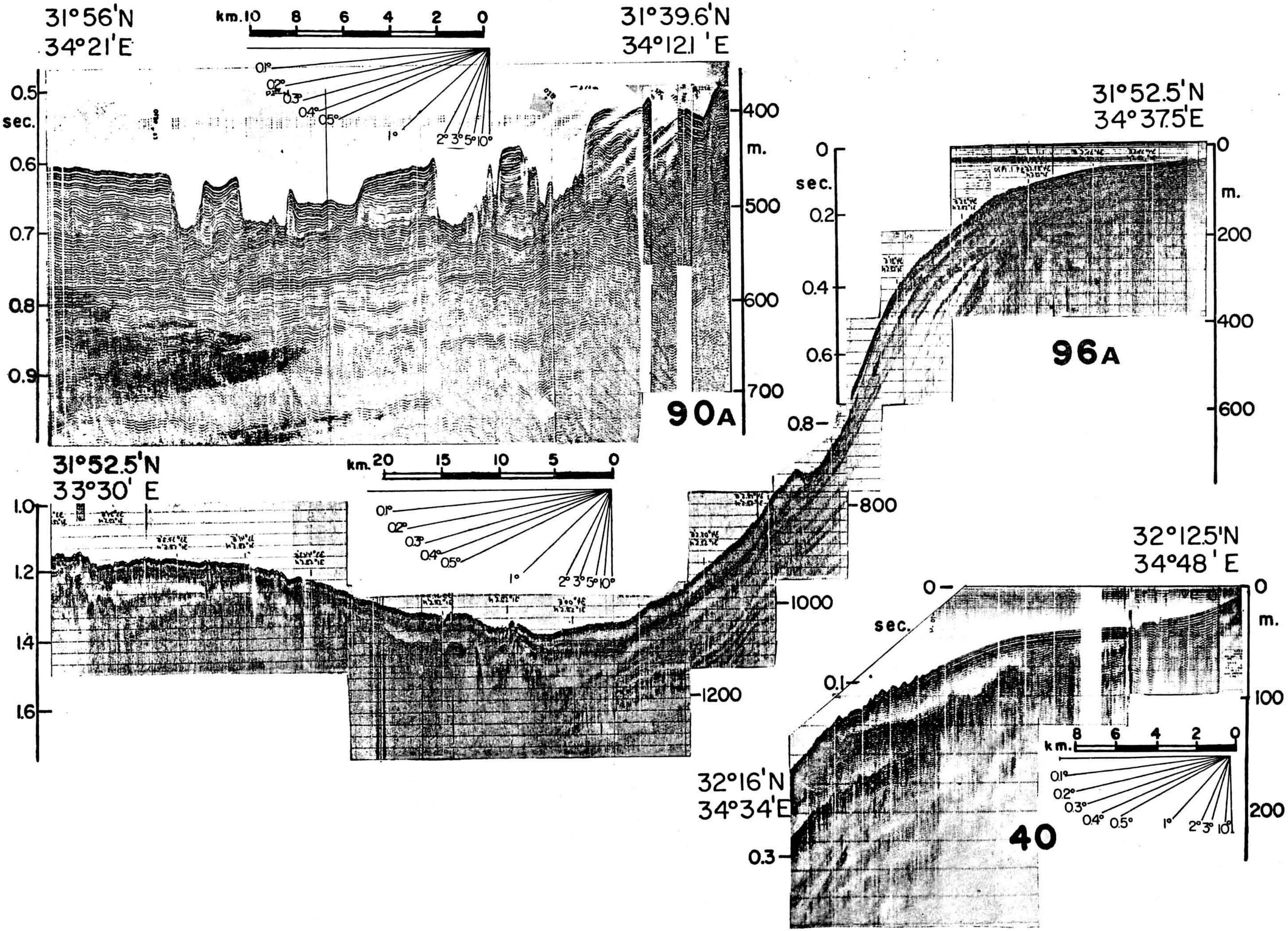

32°14.5'N
34°31' E
31° 56'N
34°21'E
km 8 6 4 2 0
sec
0.5
0.6
0.7
0.8
0.9
1.0
m
400
500
600
700
90B

Fig. 9 Slumping on the continental slope

Prof. 96A - E-W sparkarray profile off southern Israel. The scar of the mid-slope was formed by downslope gravitational gliding of the uppermost sedimentary layer. The sub-slope trough (Pelusium Line) is clearly displayed. The bottom to the west of the trough is irregular, due to numerous faults.

Prof. 90A - SSW-NNE sparkarray profile off southern Israel, perpendicular to profile 96A. The gaps are the scars formed by downslope gravitational gliding of the uppermost sedimentary layer.

Prof. 40 - E-W sparkarray profile off central Israel. Three kurkar ridges of the uppermost erosional surface are shown. The eastern ridge crops out, the middle ridge is buried by thick covering Holocene sediments, and the western ridge nearly crops out. Recent seaward bending caused the tilting of the originally horizontal Holocene layers which fill the trough between the western and central ridges. The gliding of the uppermost sedimentary layer is expressed by the asymmetric knolls to the west of the shelf-edge. The western ridge chokes the gliding (see also Fig. 24).


31°56'N
34°21'E
km. 10 8 6 4 2 0
31°39.6'N
34°12.1'E
0.1° 0.2° 0.3° 0.4° 0.5° 1° 2° 3° 5° 10°
0.5
sec.
0.6
0.7
0.8
0.9
400
m.
500
600
700
90A
31°52.5'N
34°37.5'E
0
sec.
0.2
0.4
0.6
0.8
0
m.
200
400
600
800
1000
1200
96A
31°52.5'N
33°30' E
km. 20 15 10 5 0
0.1° 0.2° 0.3° 0.4° 0.5° 1° 2° 3° 5° 10°
1.0
1.2
1.4
1.6
32°12.5'N
34°48' E
0
sec.
0.1
0.3
0
m.
100
200
32°16'N
34°34'E
km. 8 6 4 2 0
0.1° 0.2° 0.3° 0.4° 0.5° 1° 2° 3° 10°
40

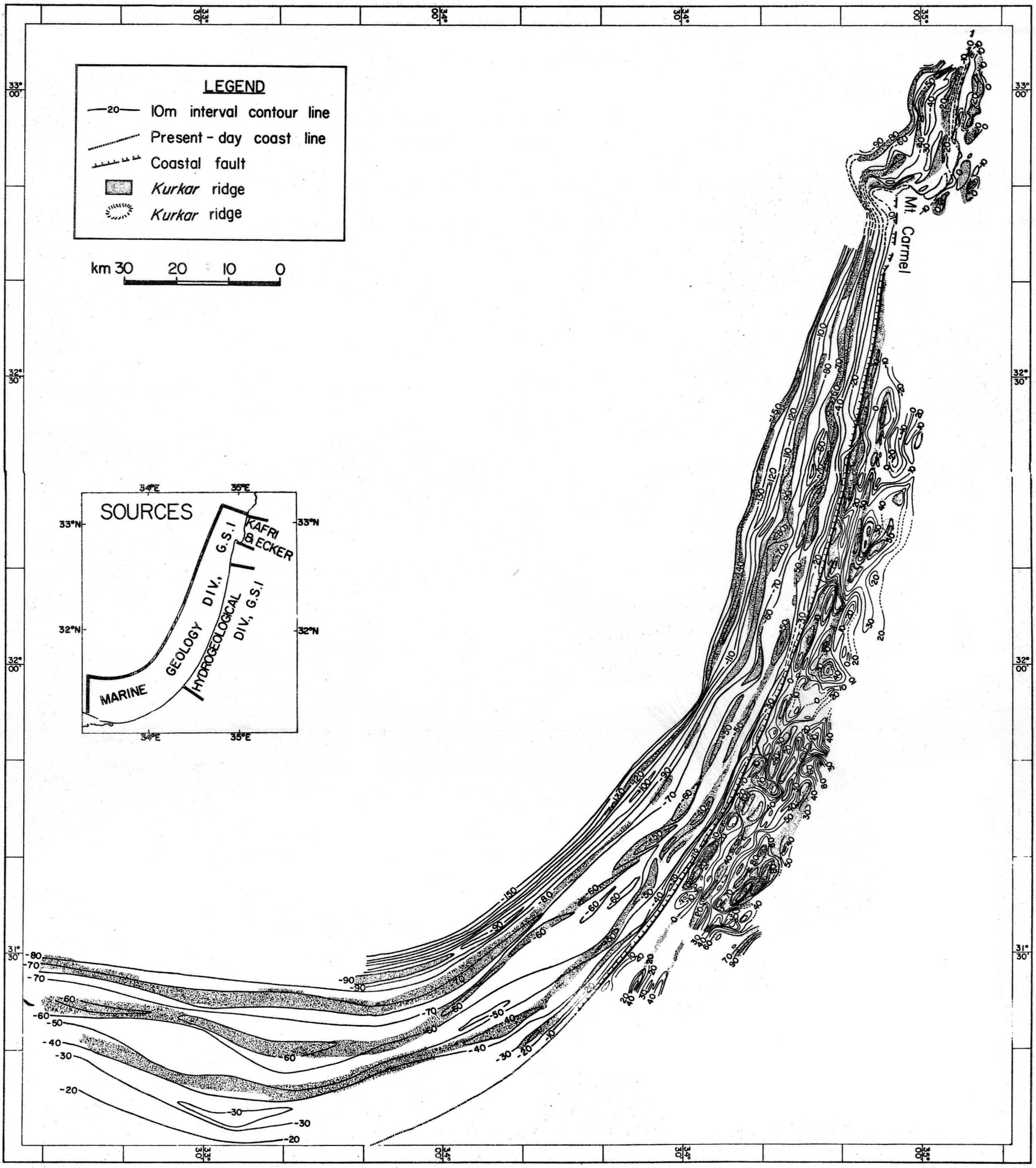


Fig. 10 Paleogeographic map of the uppermost erosional surface (Wurm)

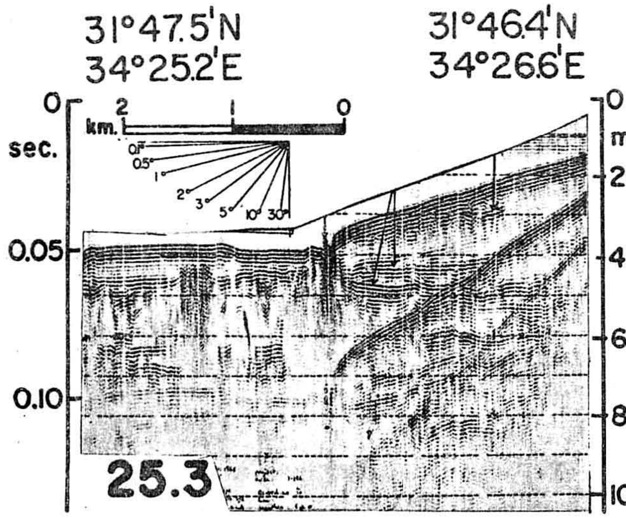
Note the system of 200 km long, low ridges and troughs that stretch on and offshore subparallel to the present coastline. The ridges consist of carbonate-cemented quartz sandstones (kurkar), which are probably lithified coastal dunes that were accumulated during the Wurm or pre-Wurm low sea levels. The onshore data is based on profiles of the G. S. I., Hydrogeological Division.

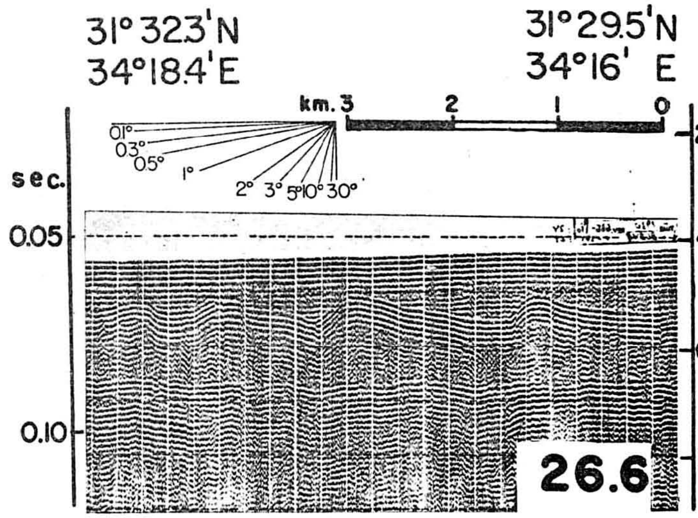
Fig. 11 Nearshore shallow features

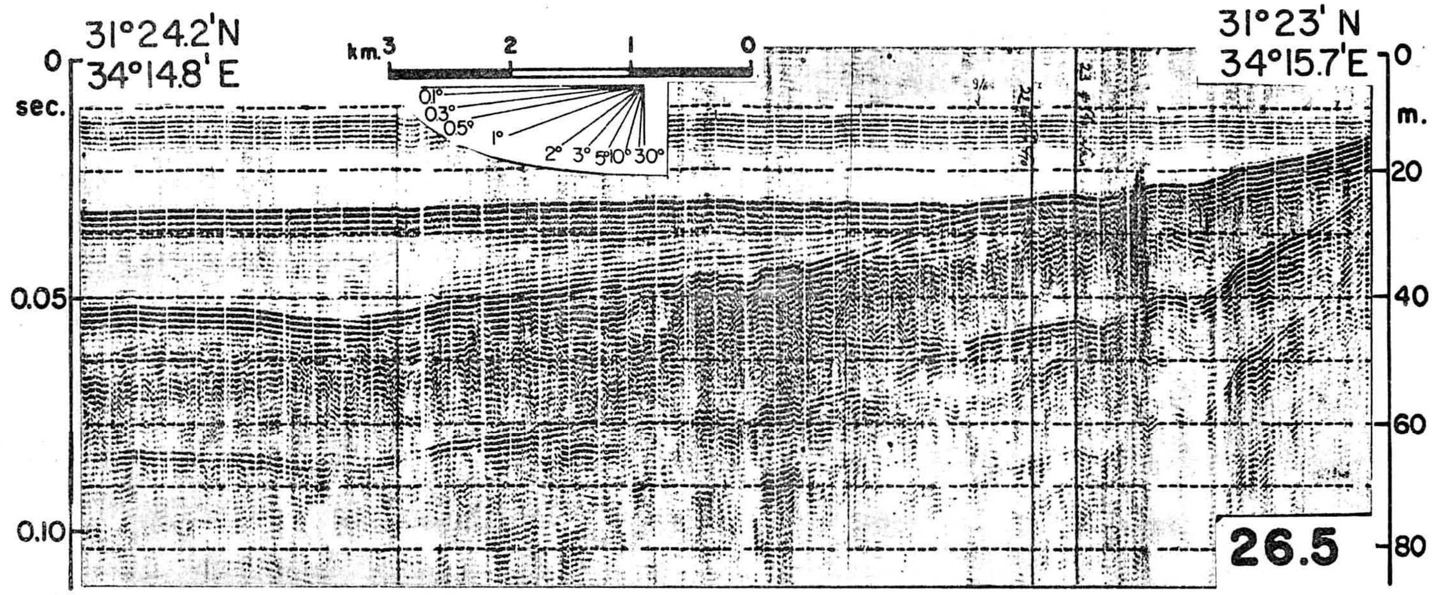
Profiles 25.3 and 26.5 - E-W sparkarray profiles off southern Israel. The easternmost kurkar ridge, associated with the uppermost erosional surface, crops out. The Holocene covering sediments thicken both to the east and west of this ridge.

Profile 26.6 - S-N sparkarray profiles off southern Israel. A series of asymmetric dunes is buried beneath the youngest marine sediments. The Reflector of the uppermost erosional surface is observed beneath the dunes.

Prof. 49 - ESE-WNW sparkarray profile off Bardawil Lagoon. The profile crosses two folded structures, the western one is the seaward extension of the Qantara - Mount Cassius structure.


31°47.5'N
34°25.2'E
31°46.4'N
34°26.6'E
km. 2 1 0
sec.
m.
0.1° 0.5° 1° 2° 3° 5° 10° 30°
0.05
0.10
0 20 40 60 80 100
25.3


31° 32.3'N
34°18.4'E
31°29.5'N
34°16' E
km. 3 2 1 0
0.1° 0.3° 0.5° 1° 2° 3° 5° 10° 30°
sec.
m.
0.05
0.10
20 40 60 80
26.6


31°24.2'N
34°14.8'E
31°23' N
34°15.7'E
km. 3 2 1 0
0.1° 0.3° 0.5° 1° 2° 3° 5° 10° 30°
sec.
m.
0
0.05
0.10
0 20 40 60 80
26.5

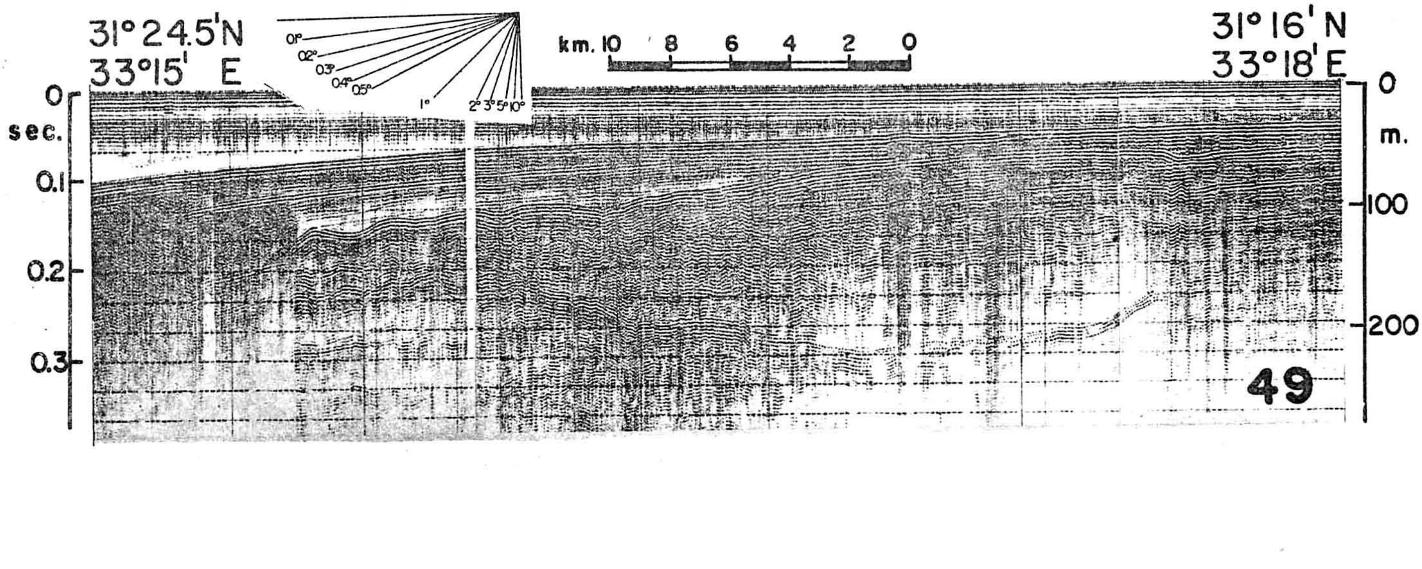
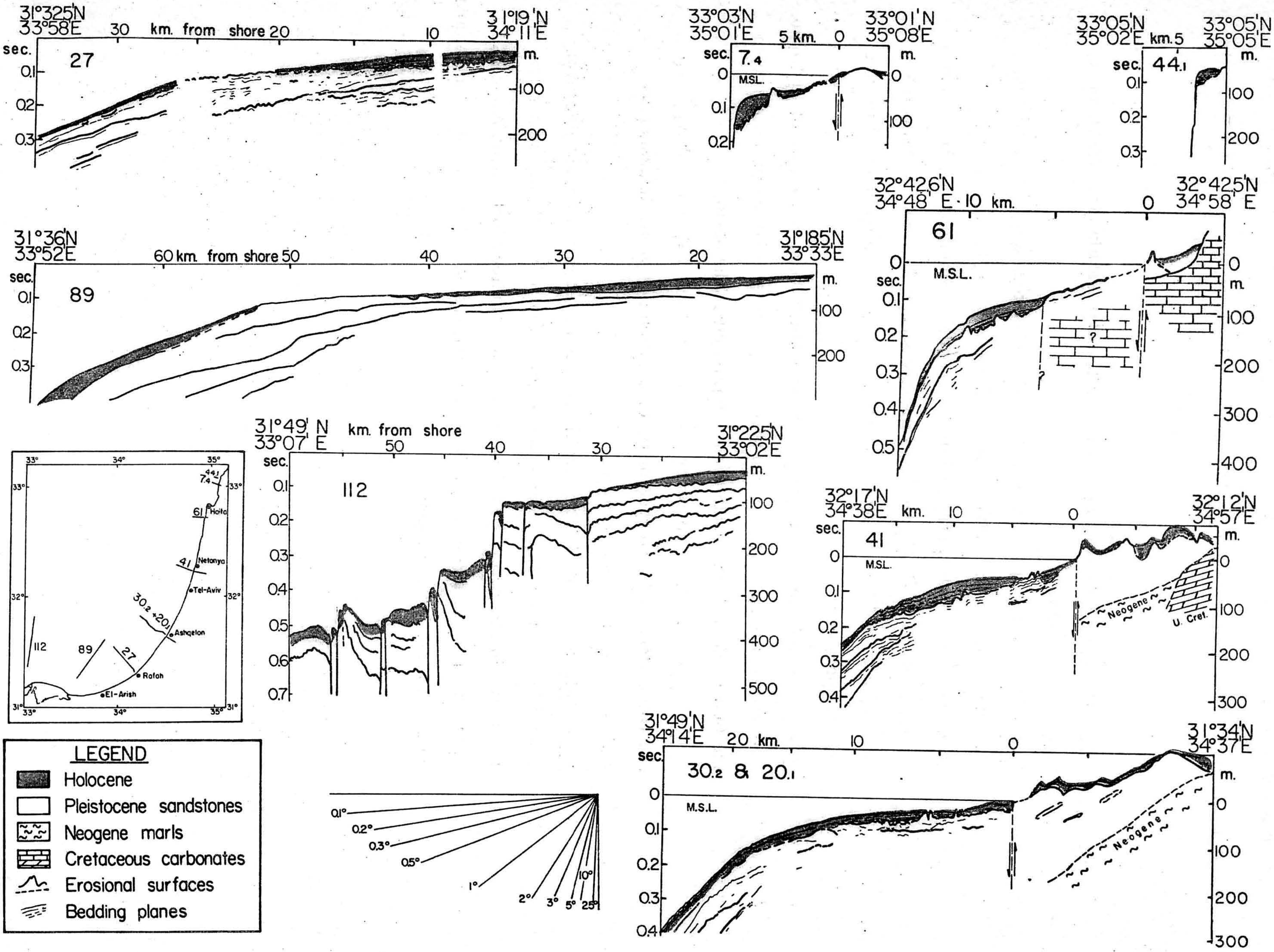

31°24.5'N
33°15' E
31°16'N
33°18'E
0.1° 0.2° 0.3° 0.4° 0.5° 1° 2° 3° 5° 10°
km. 10 8 6 4 2 0
sec.
m.
0
0.1
0.2
0.3
0 100 200
49

Fig. 12 Shelf and upper slope (line-drawn profile). The shelf narrows northward. While off Israel and eastern north Sinai the upper slope gently bends downward, it is faulted off western north Sinai (112). The Israel coastline is fault-controlled. A succession of several Pleistocene markers, reflecting highly irregular erosional surfaces, is recognized on the shelf. The uppermost erosional surface exhibits a system of depressions and ridges. The ridge nearest to the shore protrudes through the Holocene covering sediments.



31°32.5'N 33°58'E
30 km. from shore 20 10
31°19'N 34°11'E
27
sec. 0.1 0.2 0.3
m. 100 200
33°03'N 35°01'E
5 km. 0
33°01'N 35°08'E
7.4
M.S.L.
33°05'N 35°02'E km. 5
33°05'N 35°05'E
44.1
31°36'N 33°52'E
60 km. from shore 50 40 30 20
31°18.5'N 33°33'E
89
32°42.6'N 34°48'E · 10 km. 0
32°42.5'N 34°58'E
61
?
31°49'N 33°07'E
km. from shore 50 40 30
31°22.5'N 33°02'E
112
sec. 0.1 0.2 0.3 0.4 0.5 0.6 0.7
m. 100 200 300 400 500
32°17'N 34°38'E km. 10 0
32°12'N 34°57'E
41
Neogene
U. Cret.
31°49'N 34°14'E 20 km. 10 0
31°34'N 34°37'E
30.2 & 20.1
Neogene
33° 34° 35°
Haifa
Netonya
Tel-Aviv
Ashqelon
Rafah
El-Arish
30.2 + 20.1
LEGEND
Holocene
Pleistocene sandstones
Neogene marls
Cretaceous carbonates
Erosional surfaces
Bedding planes
0.1° 0.2° 0.3° 0.5° 1° 2° 3° 5° 10° 25°

Fig. 13 Faulting features associated with the continental margin of northern Sinai and the Nile Delta.

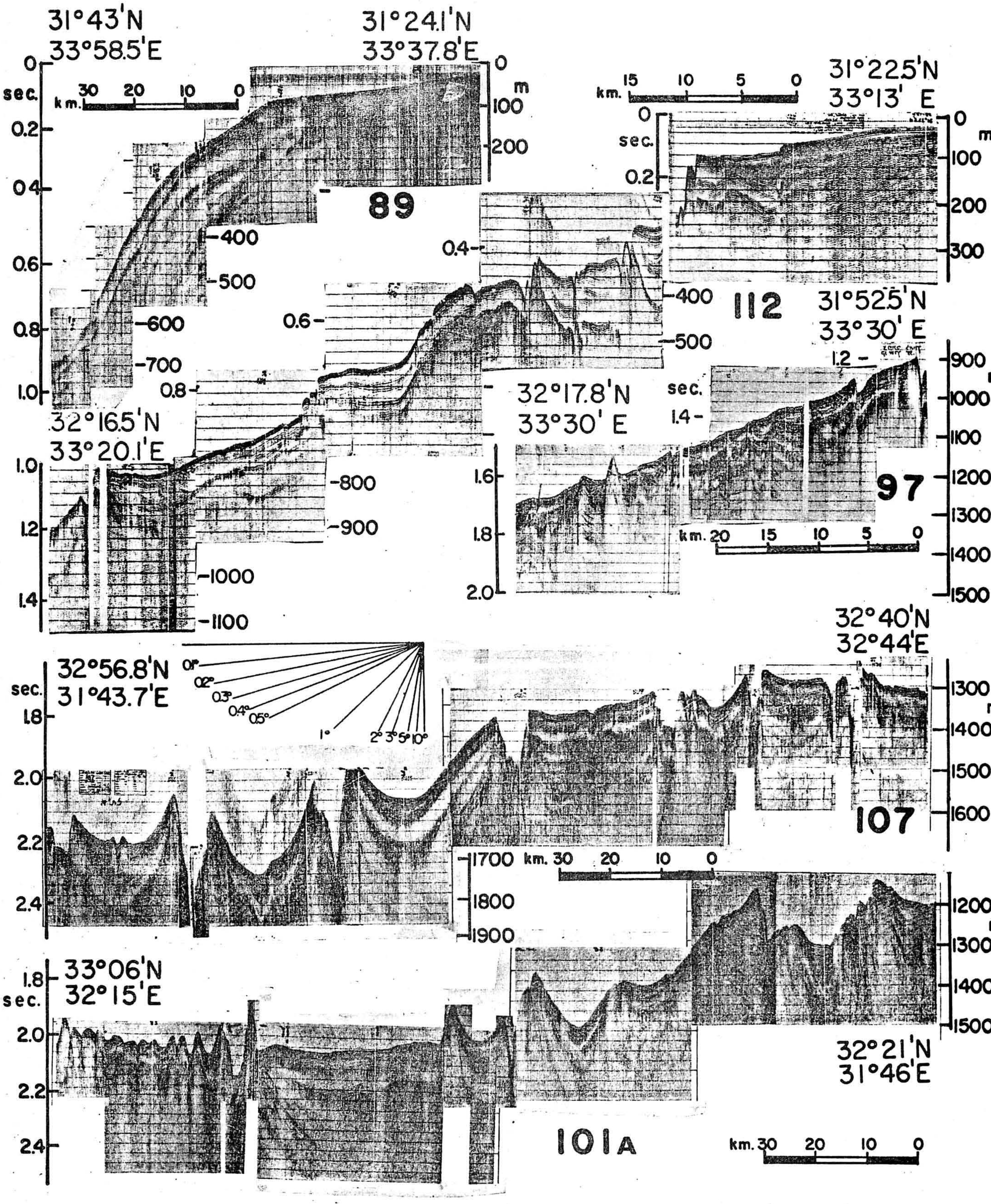
Prof. 89 - SW-NE sparkarray profile off the eastern coasts of north Sinai. The shelf-edge is downwarped and the slope is smooth.

Prof. 112 - S-N sparkarray profile, off northern Sinai across the Bardawil Escarpment. The shelf edge and slope are steeply faulted. Asymmetric accumulation of Pleistocene sediments on the step-faulted blocks indicates S-N compression.

Prof. 97 - S-N Sparkarray profile in the southern part of the Levant Platform. Note the recent southward facing thrust (right side), and the transition from the Belt of No M in the south to the Diapir Belt in the north.

Prof. 107 - ESE-WNW sparkarray profile off central Israel. Chopped-up and tilted blocks with no systematic orientation are probably associated with S-N compressional features.

Prof. 101A - S-N sparkarray profile across the southern Levant Platform. Transition from the Diapir Belt (left side) to the Belt of No M (right side). The latter is characterized by chopped-up and faulted blocks with dominant north-facing escarpments. Close to the southern end of the profile a southward facing reverse fault is found.



31°43'N
33°58.5'E
31°24.1'N
33°37.8'E
89
31°22.5'N
33°13' E
112
31°52.5'N
33°30' E
32°17.8'N
33°30' E
97
32°16.5'N
33°20.1'E
32°40'N
32°44'E
32°56.8'N
31°43.7'E
107
33°06'N
32°15'E
32°21'N
31°46'E
101A
sec.
m.
km.

Fig. 14 Deep sea - line-drawn profiles

The southern part of the Levant Platform forms a rather broad and gentle arch (102, 107, 143). The southern part of the platform is dissected by many compressional faults that form tilted blocks. However, no systematic orientation of the blocks is observed along this (E-W) direction. A deep moat separates Eratosthenes Seamount from the Levant Platform (100, 101). Numerous diapirs are associated with the layers overlying Reflector M (100, 101, 107, 143). Older diapirs, piercing through Reflector M, are also recognized (143, 144).

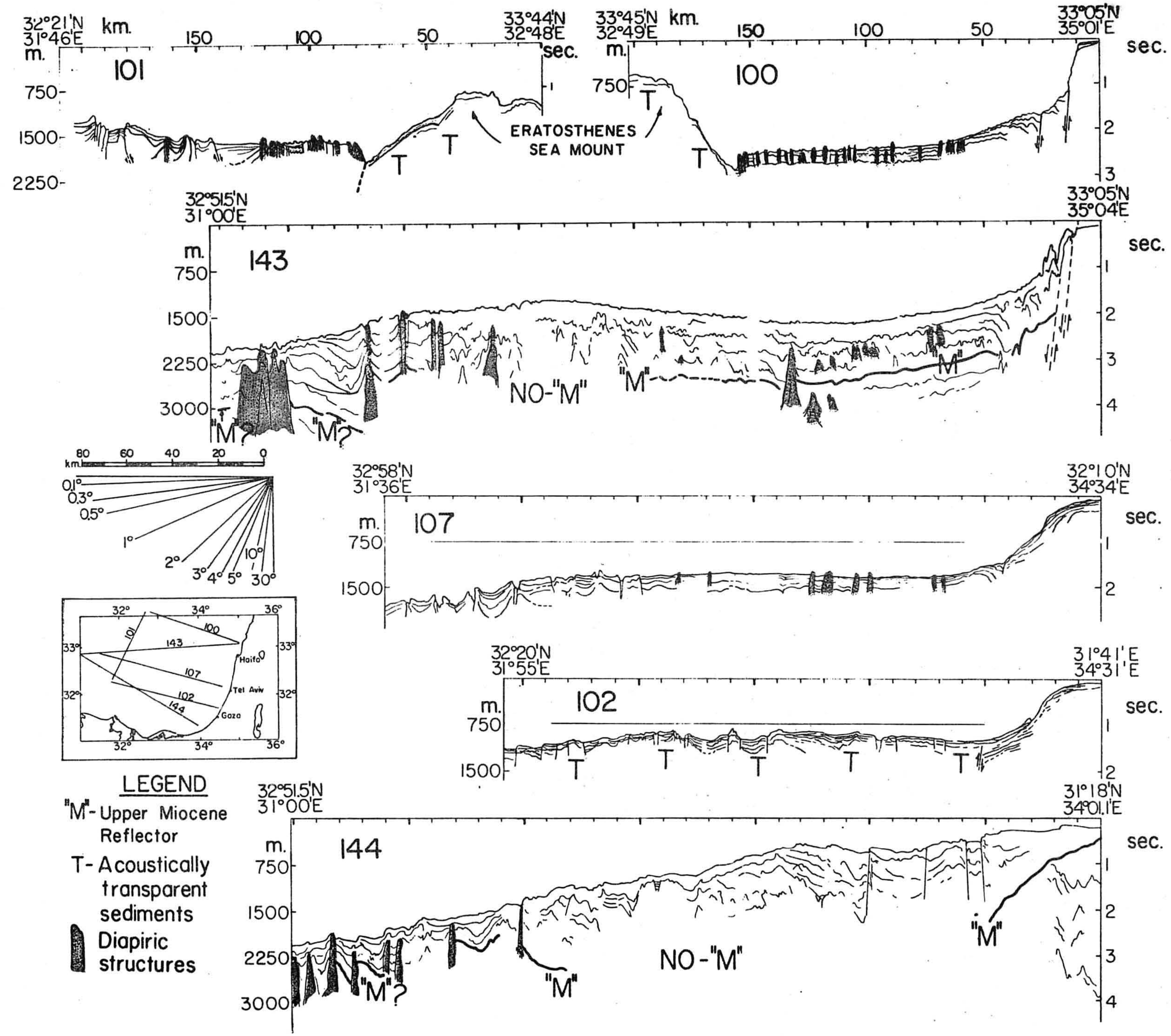

32°21'N 31°46'E
km.
150
100
50
33°44'N 32°48'E
m.
sec.
101
750
1500
2250
T
T
ERATOSTHENES SEA MOUNT
33°45'N 32°49'E
km.
150
100
50
33°05'N 35°01'E
sec.
100
750
T
T
1
2
3
32°51.5'N 31°00'E
33°05'N 35°04'E
143
m.
750
1500
2250
3000
sec.
1
2
3
4
"M"?
"M"?
NO-"M"
"M"
"M"
80 60 40 20 0
km.
0.1°
0.3°
0.5°
1°
2°
3°
4°
5°
10°
30°
32°58'N 31°36'E
32°10'N 34°34'E
107
m.
750
1500
sec.
1
2
32°
34°
36°
33°
32°
101
100
143
107
102
144
Haifa
Tel Aviv
Gaza
32°20'N 31°55'E
31°41'E 34°31'E
102
m.
750
1500
sec.
1
2
T
T
T
T
T
LEGEND
"M"- Upper Miocene Reflector
T- Acoustically transparent sediments
Diapiric structures
32°51.5'N 31°00'E
31°18'N 34°01.1'E
144
m.
750
1500
2250
3000
sec.
1
2
3
4
"M"?
"M"
NO-"M"
"M"

Fig. 15 Sub-slope trough and Offshore Chain of Structures No. 2 (OSS 2)

Prof. 86A - E-W sparkarray profile across the continental margin of southern Israel. The profile runs across the shelf, slope (note the tensional gravity faults at the mid-slope), the sub-slope trough (Pelusium Line), and OSS 2, up to a syncline west of it where diapirs seem to exist. OSS 1 (not visible in this profile) is located beneath the mid-slope.

Prof. 86B - Minor eastward-facing thrust faults of recent age on the western flank of OSS 2.

Prof. 86C - The sub-slope trough (the Pelusium Line) which is associated with the sharp downkinking of the Pleistocene reflectors and the thickening of the Quaternary sequence indicate continuous compressional activity. The Pleistocene reflectors in the trough about the acoustically transparent sediments to the west. Note the gliding scar on the lowermost slope to the east, and the fuzzy-looking bottom further downslope.

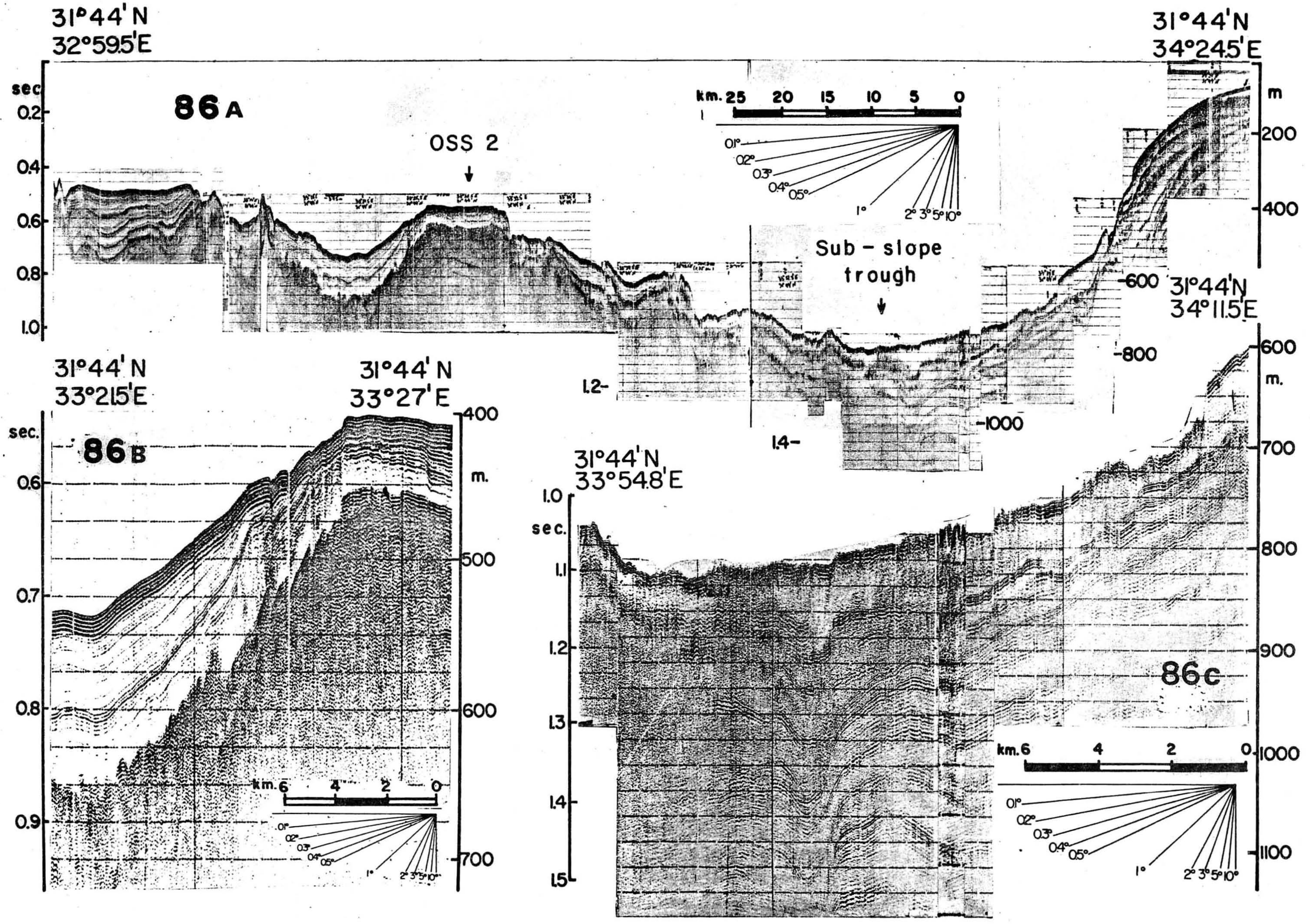

31°44'N
32°59.5'E
31°44'N
34°24.5'E
86A
OSS 2
Sub - slope
trough
31°44'N
34°11.5'E
31°44'N
33°21.5'E
31°44'N
33°27'E
86B
31°44'N
33°54.8'E
86c
sec
m
km.

Fig. 16 Compressional features associated with the Pelusium Line

Profs. 143C and 148 - E-W air gun profiles off northern and central Israel respectively. Splitting of Reflector M into 3-4 reflectors occurs from the Pelusium Line westward. Thickening,and crumpling and down-kinking of the overlying sediments occur along this line. The same pheonomena are also observed in prof. 116.

Prof. 98 - E-W sparkarray profile off central Israel. The Quaternary reflectors are sharply downkinked and the entire sequence thickens with depth due to compression. The Quaternary sequence thins westward, where diapiric structures gradually develop.

Prof. 116 - E-W air gun profile off central Israel. The compressional downkinking affects the sediments at least to the depth of Reflector M.

Prof. 96B - E-W sparkarray profile off southern Israel. The Pleistocene reflectors in the east (right side) underthrust the acoustically transparent pre-Pleistocene sedimentary sequence in the west (left side) along the Pelusium Line.

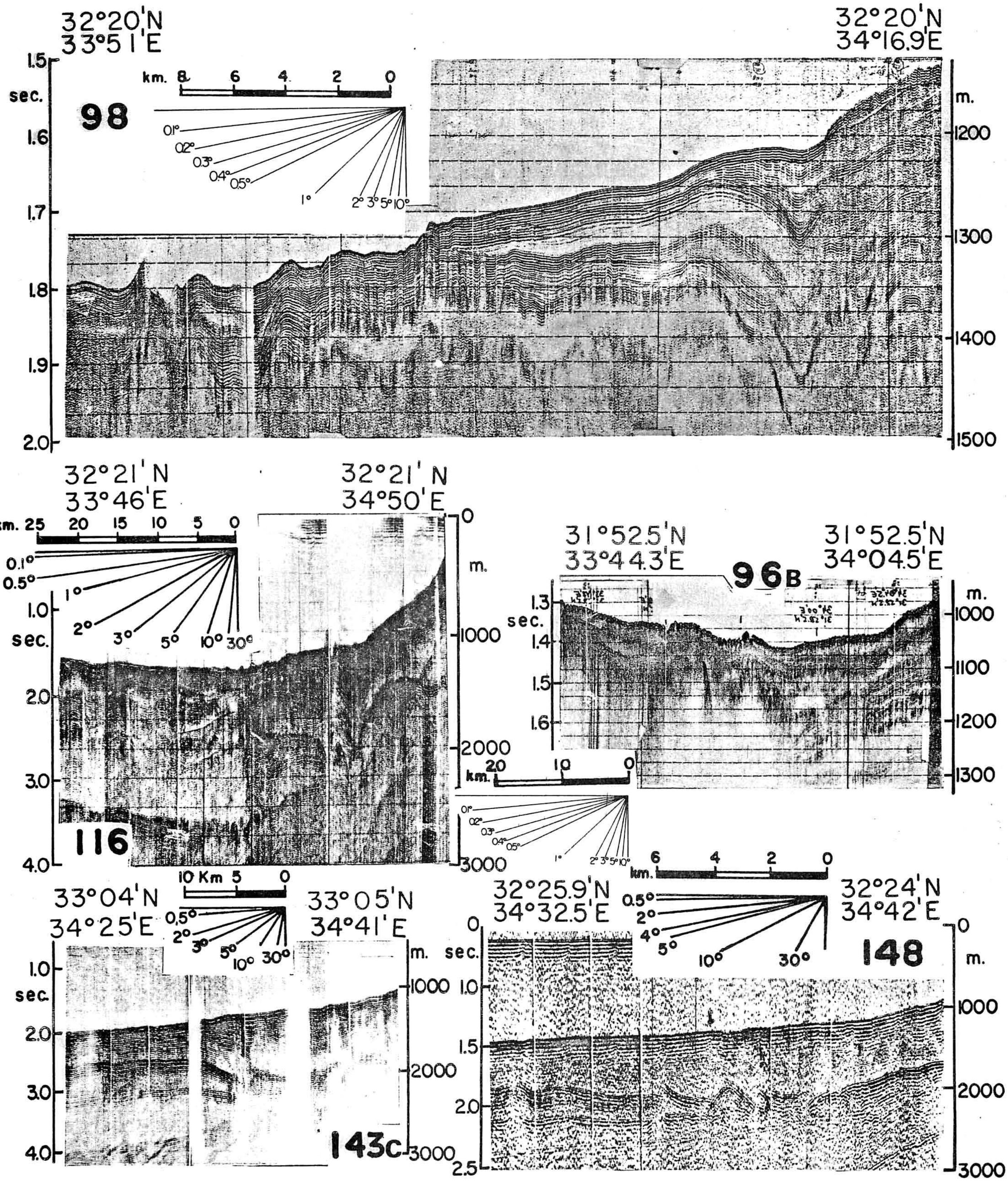
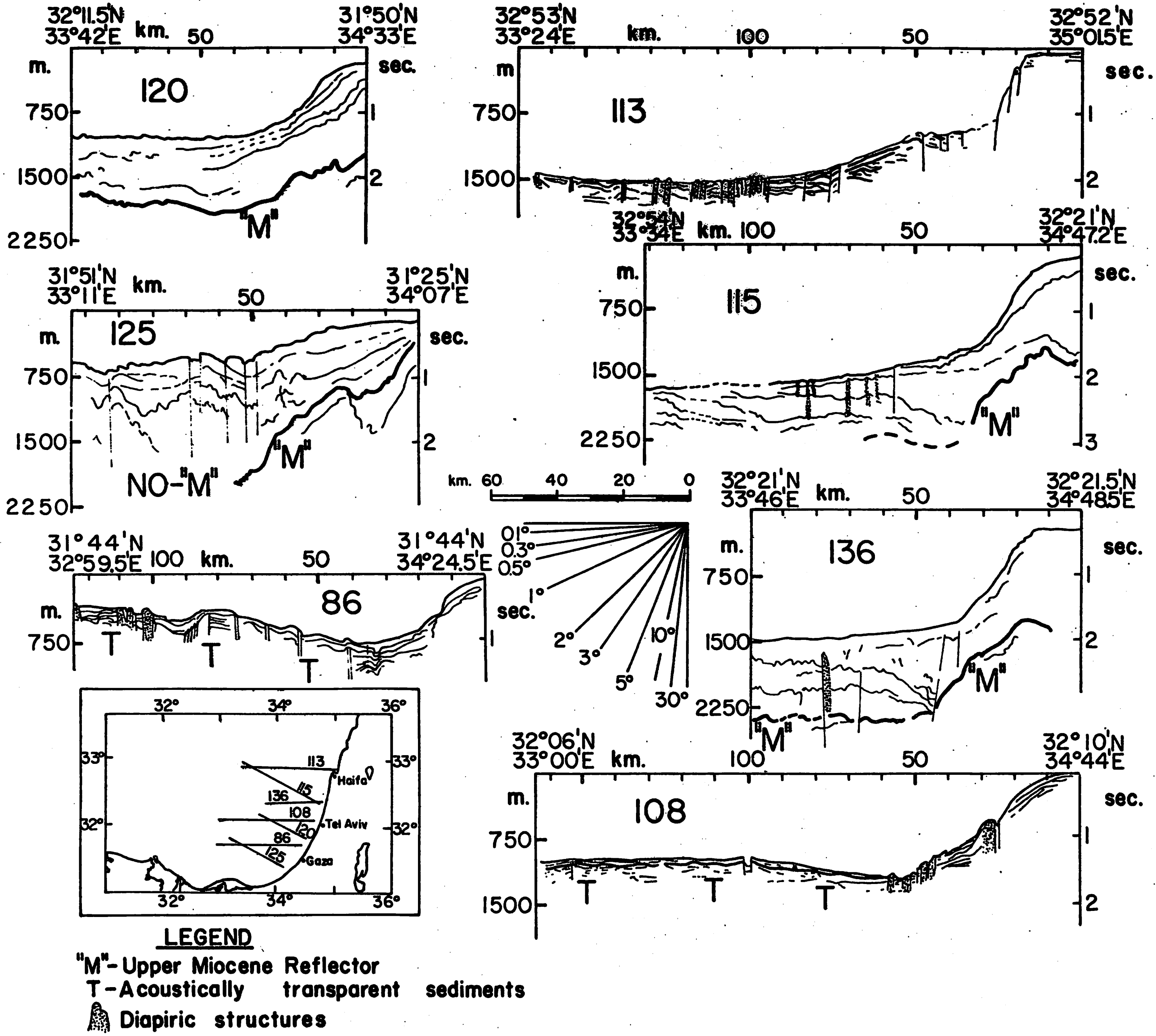

98
32°20'N
33°51'E
32°20'N
34°16.9'E
sec.
m.
km. 8 6 4 2 0
0.1° 0.2° 0.3° 0.4° 0.5° 1° 2° 3° 5° 10°
116
32°21'N
33°46'E
32°21'N
34°50'E
km. 25 20 15 10 5 0
0.1° 0.5° 1° 2° 3° 5° 10° 30°
96B
31°52.5'N
33°44.3'E
31°52.5'N
34°04.5'E
km. 20 10 0
143c
33°04'N
34°25'E
33°05'N
34°41'E
10 Km 5 0
0.5° 2° 3° 5° 10° 30°
148
32°25.9'N
34°32.5'E
32°24'N
34°42'E
km. 6 4 2 0
0.5° 2° 4° 5° 10° 30°

Fig. 17 Continental margin - line-drawn profiles

The slope steepens and deepens from south to north. The sub-slope trough is clearly depicted in the southern profiles (86, 108, 115, 120, 125). Several geological features are expressed by Reflector M. In the southern profiles (120, 125) Reflector M disappear toward the acoustically transparent sediments west of the sub-slope trough (Belt of No M). In the northern profiles (115, 136) it splits westward underneath the base of the slope into 3-4 reflectors. Numerous diapiric structures are detected in the deep sea sub-bottom north of the Belt of No M (113, 115, 136) and in the Palmahim Graben (108).

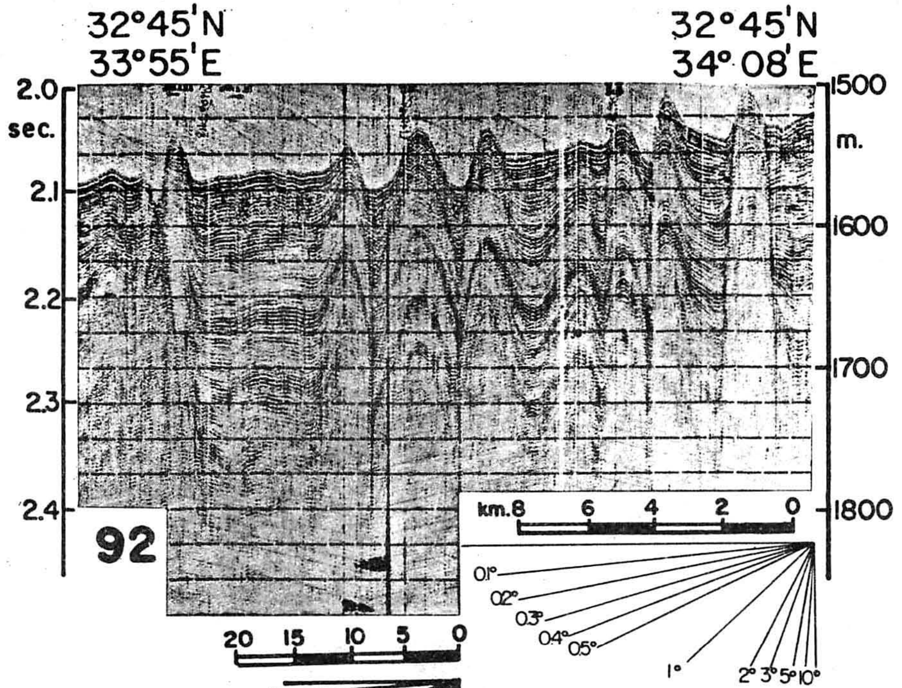


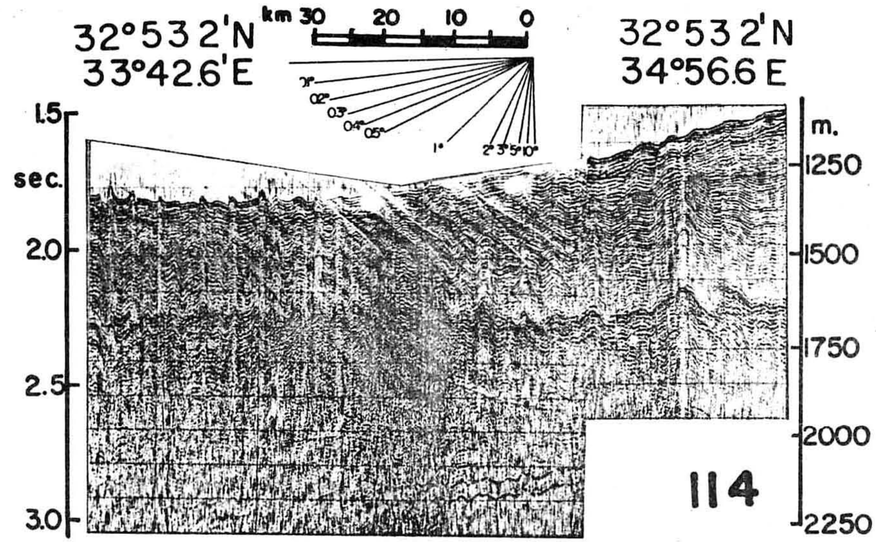
32°11.5'N 33°42'E
31°50'N 34°33'E
km. 50
m. sec.
120
750 1500 2250
"M"
32°53'N 33°24'E
32°52'N 35°01.5'E
km. 100 50
113
32°54'N 33°34'E
32°21'N 34°47.2'E
115
31°51'N 33°11'E
31°25'N 34°07'E
125
NO-"M"
km. 60 40 20 0
0.1° 0.3° 0.5° 1° 2° 3° 5° 10° 30°
32°21'N 33°46'E
32°21.5'N 34°48.5'E
136
31°44'N 32°59.5'E
31°44'N 34°24.5'E
86
T
32°06'N 33°00'E
32°10'N 34°44'E
108
32° 34° 36°
33° 32°
113 115 136 108 120 86 125
Haifa
Tel Aviv
Gaza
LEGEND
"M"- Upper Miocene Reflector
T - Acoustically transparent sediments
Diapiric structures

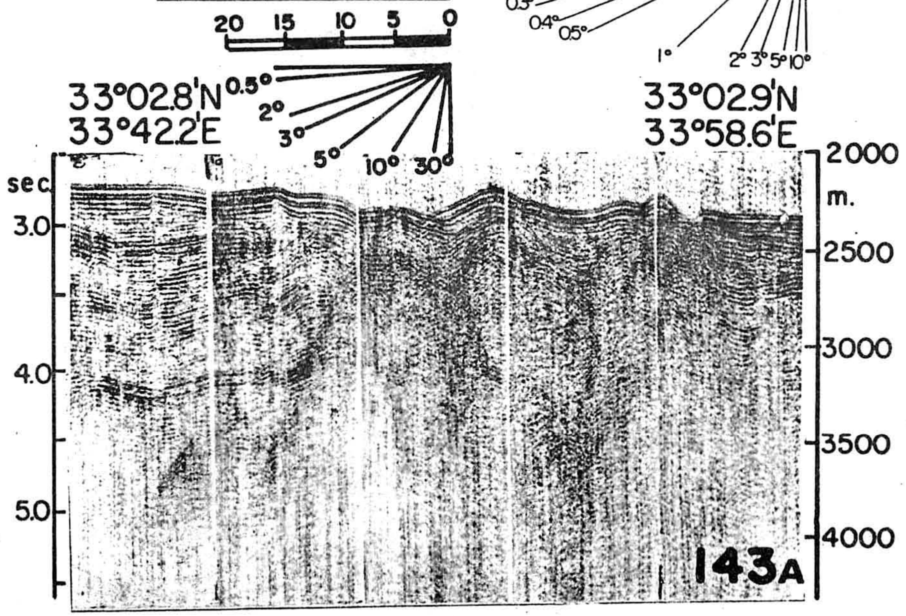
Fig. 18 Diapirs

Prof. 92 (sparkarray) and 114 (air-gun)-E-W profiles in the Diapir Belt off the Carmel Block. The diapirs are associated with the sedimentary sequence younger than Reflector M. The latter is not affected by the diapirism (114). These diapirs have moved vertically upward like narrow necks through the sediments.

Profs. 143A and 143B - E-W air-gun profile SW of Eratosthenes Seamount. Deep-seated, broad diapirs, probably of pre-Messinian evaporite source, are piercing Reflector M and the overlying sediments.


32°45'N
33°55'E
32°45'N
34°08'E
sec.
2.0
2.1
2.2
2.3
2.4
m.
1500
1600
1700
1800
km. 8 6 4 2 0
0.1°
0.2°
0.3°
0.4°
0.5°
1°
2° 3° 5° 10°
92


km 30 20 10 0
32°53.2'N
33°42.6'E
32°53.2'N
34°56.6 E
0.1°
0.2°
0.3°
0.4°
0.5°
1°
2° 3° 5° 10°
sec.
1.5
2.0
2.5
3.0
m.
1250
1500
1750
2000
2250
114


20 15 10 5 0
0.5°
2°
3°
5°
10°
30°
33°02.8'N
33°42.2'E
33°02.9'N
33°58.6'E
sec.
3.0
4.0
5.0
m.
2000
2500
3000
3500
4000
143A

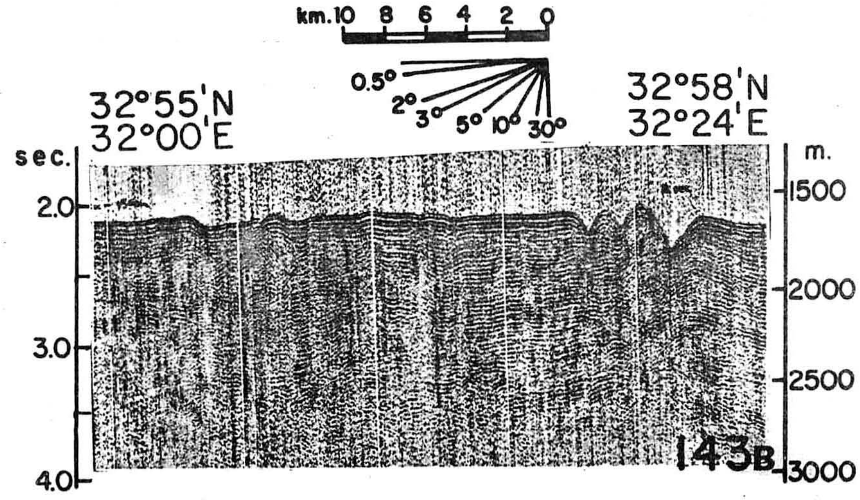
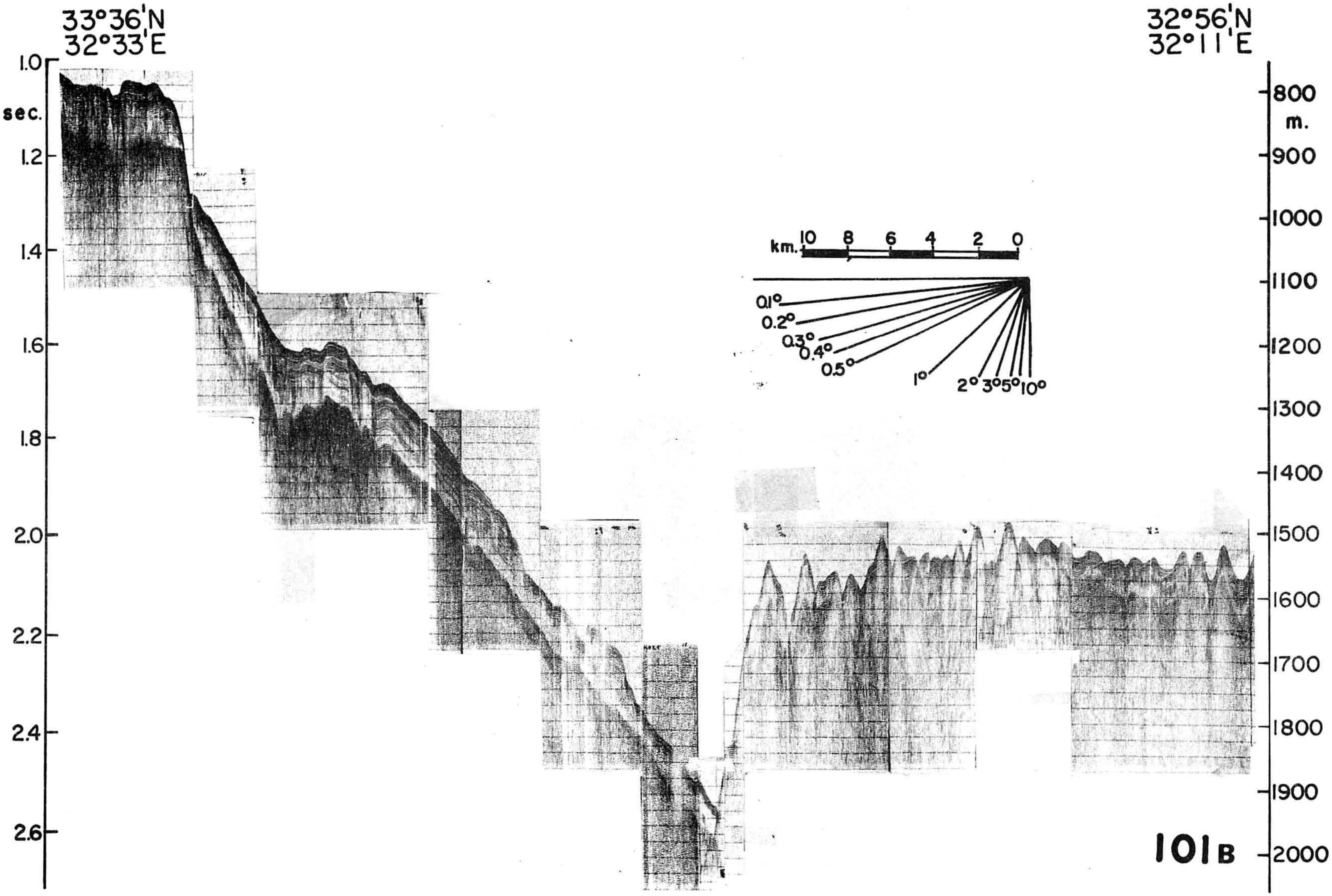

km. 10 8 6 4 2 0
0.5°
2°
3°
5°
10°
30°
32°55'N
32°00'E
32°58'N
32°24'E
sec.
2.0
3.0
4.0
m.
1500
2000
2500
3000
143B

Fig. 19 **Prof. 101B** - S-N sparkarray profile along the southern plunge of Eratosthenes Seamount. A 350 m deep moat controlled by a fault, forms the contact between the Diapir Belt in the south and Eratosthenes Seamount in the north. Note the thin Quaternary sedimentary sequence on Eratosthenes Seamount.


33°36'N
32°33'E
32°56'N
32°11'E
1.0
sec.
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
800
m.
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
km.
10
8
6
4
2
0
0.1°
0.2°
0.3°
0.4°
0.5°
1°
2°
3°
5°
10°
101B

RESIDUAL MAGNETIC INTENSITY OF THE SOUTHEASTERN MEDITERRANEAN SEA

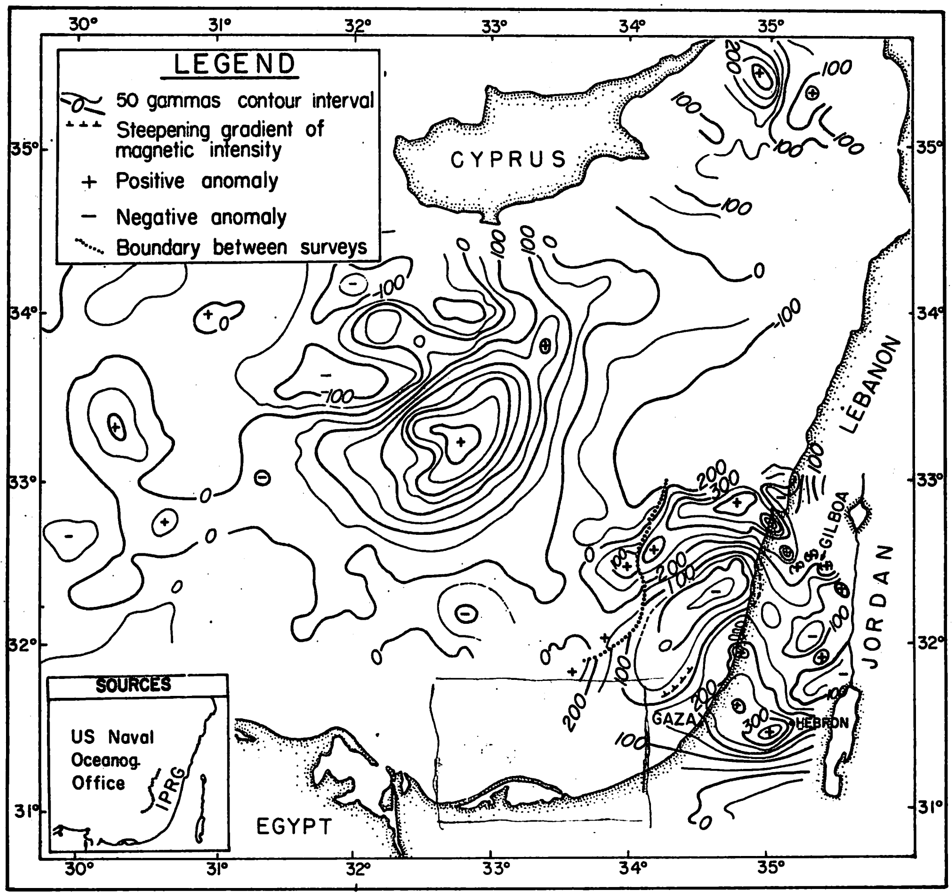
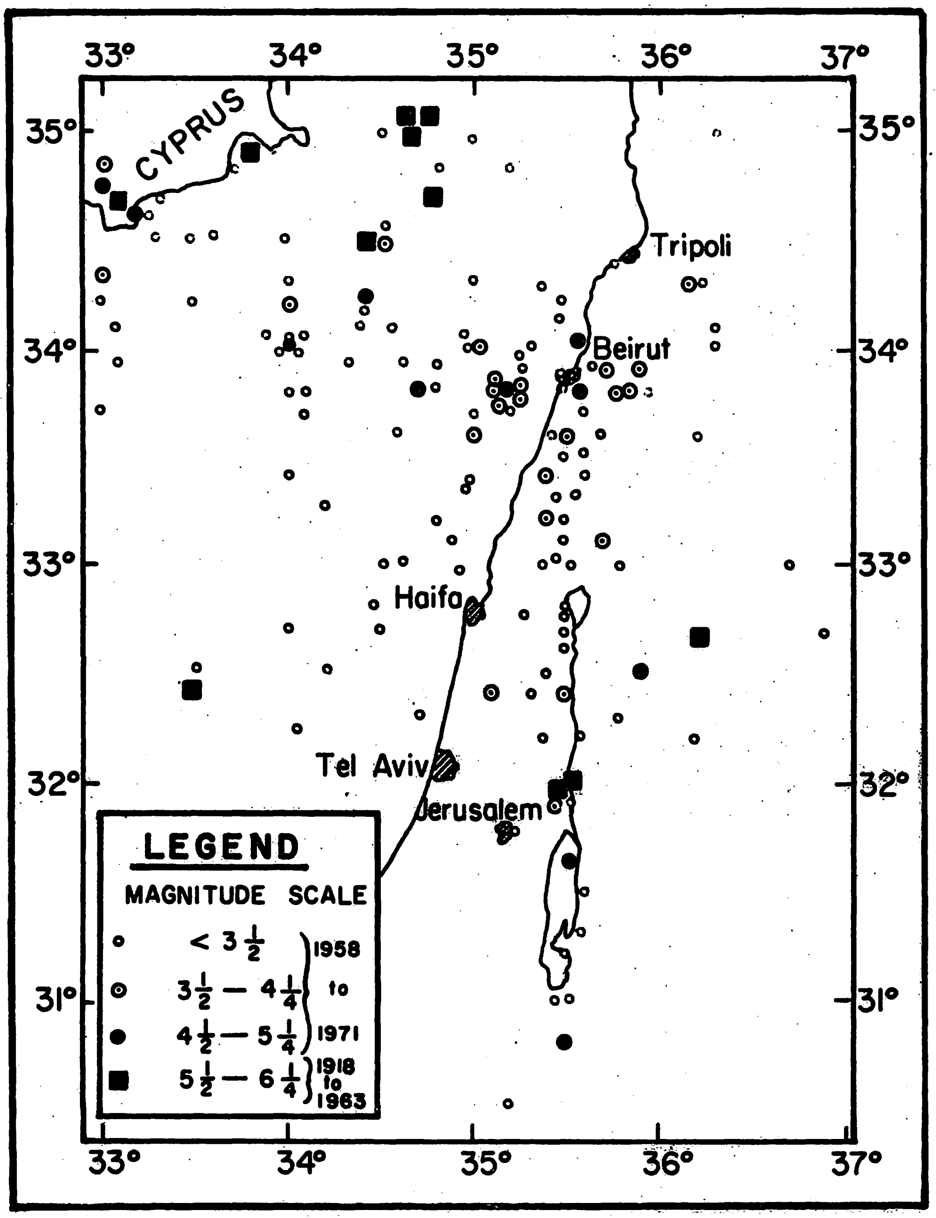


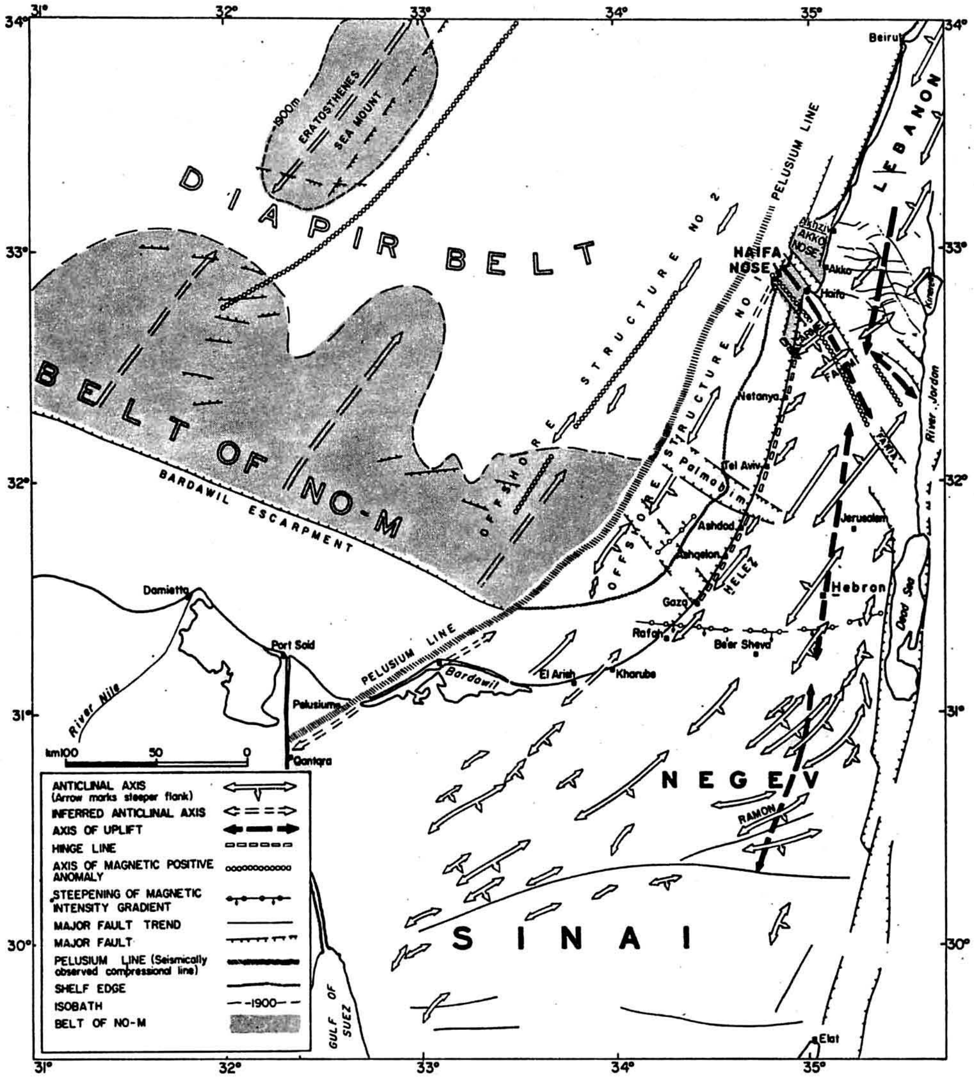
Fig. 20 Residual magnetic anomalies map

The main features are the elongated positive magnetic anomalies associated with Eratosthenes Seamount, and with OSS 2 (80-100 km off Israel). Both trend NE, parallel to the folding system of Sinai and Israel. Another prominent feature is the NW-trending set of positive anomalies of the Carmel - Um el Faḫm and Giloba' Blocks.



<u>Fig. 21</u> <u>Earthquake epicenters map</u>

The earthquake epicenters are concentrated along two zones: The Dead Sea - Jordan Rift Valley, and offshore. NNE-trends are suggested for the latter.



<u>Fig. 22</u> <u>Sketch map of major tectonic elements</u>

Four regional tectonic trends are recognized:

a. NE and NNE folds and faults system.

b. EW and WNW facies belts and major faults.

c. SE-NW Haifa Nose (Carmel) - Gilboa' <u>en-echelon</u> ridges and the Qishon, Palmahim and Gaza (?) grabens.

d. S-N Jordan - Dead Sea Graben and the structural backbone of Israel.

Compilation of the map is based on data discussed in the present paper, and additional onshore data from Bartov (1971), Freund (1965), Gvirtzman (1970), Picard (1963) and Said (1962).

EVOLUTION OF THE COASTAL FAULT AND THE SHELF OF ISRAEL

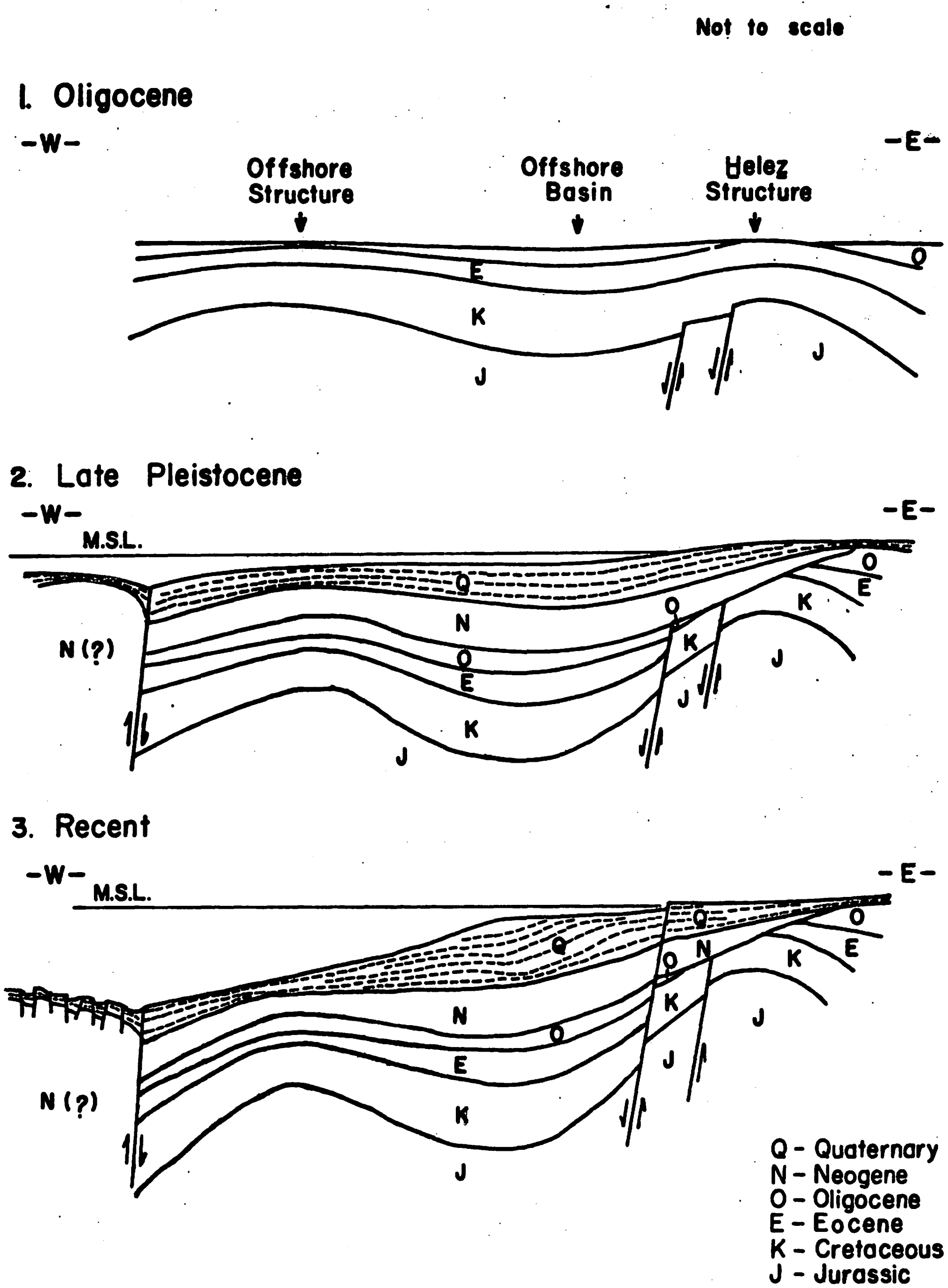


Fig. 23 Sketch of shelf and slope evolution since Oligocene

a. Similarity in structural histories of OSS 1 and the Helez Structure until Oligocene time.

b. Differential faulting (uplift of the landward side) in early Miocene, followed by general subsidence. Sediments have accumulated mostly offshore. Rejuvenation of the folding activity in OSS 1 since Middle Pliocene.

c. Westward downwarping of the present-day slope since Holocene along a new hinge-line (shelf edge).

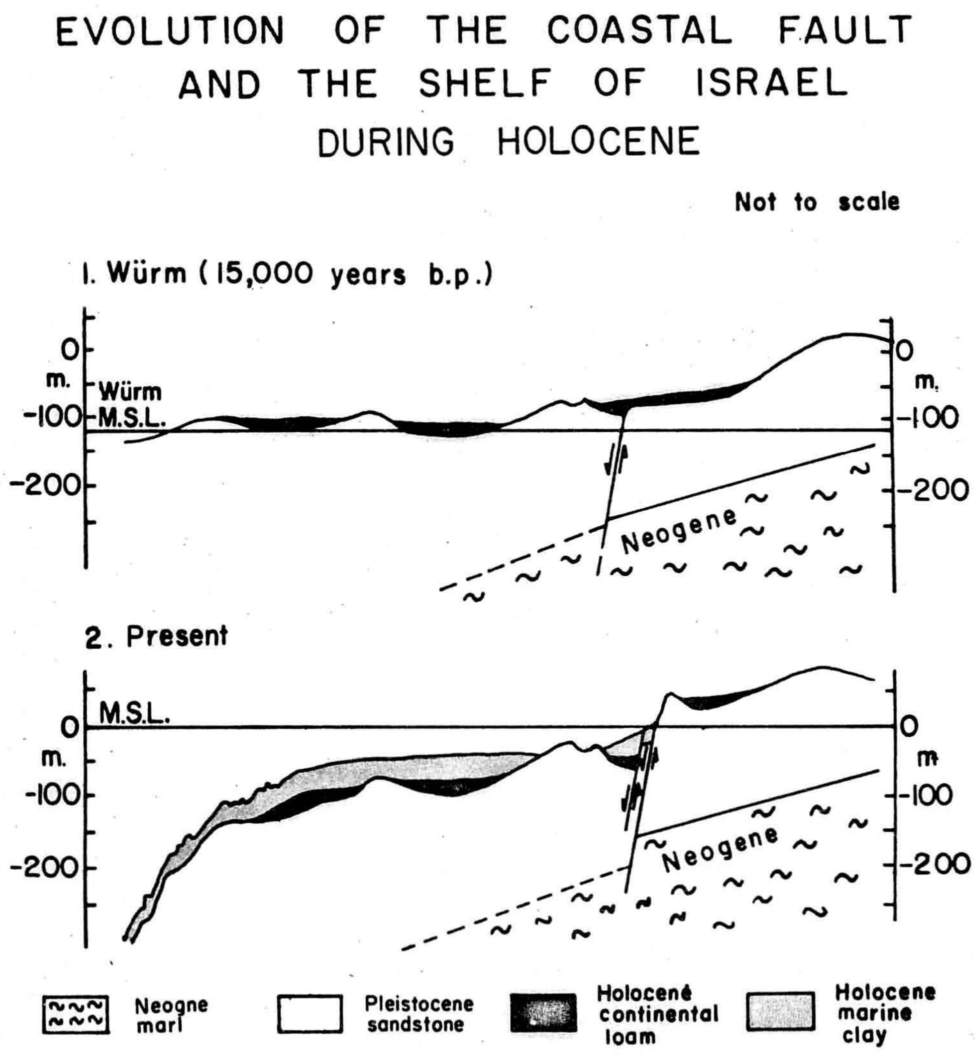


Fig. 24 Sketch of shelf and slope evolution during the Quaternary

Westward downwarping of the present-day slope occurred only since Holocene, Elevations refer to present-day scale.