THE MINISTRY OF NATIONAL
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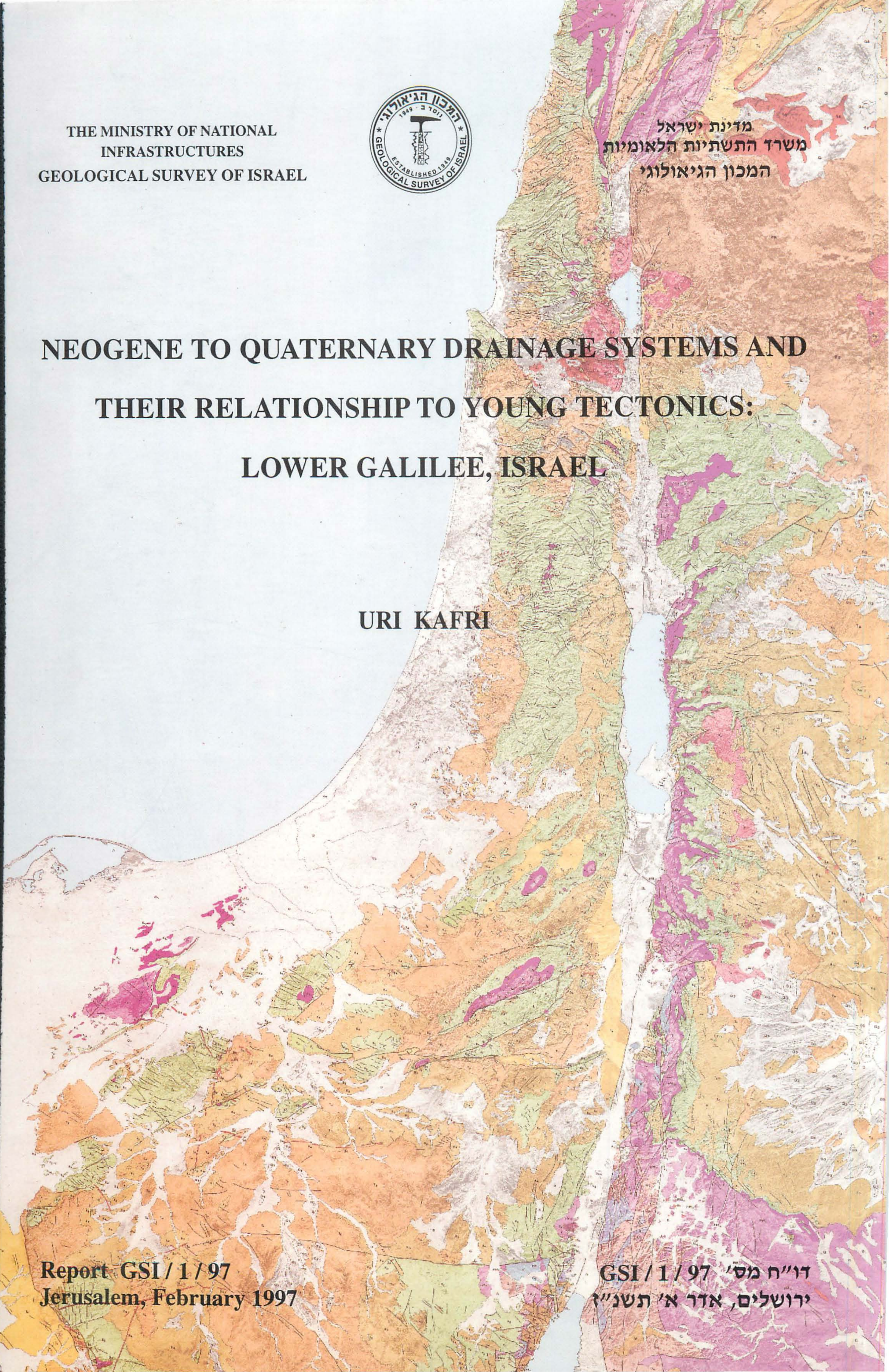

NEOGENE TO QUATERNARY DRAINAGE SYSTEMS AND THEIR RELATIONSHIP TO YOUNG TECTONICS: LOWER GALILEE, ISRAEL

URI KAFRI

Report GSI / 1 / 97
Jerusalem, February 1997

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ABSTRACT

Palaeodrainage systems predating the Cover Basalt could be delineated and reconstructed based on Hordos and Bet Nir Conglomerate occurrences and geomorphological phenomena in the Galilee. These systems drained areas east of the present Rift Valley across the Galilee to the Mediterranean base level .

Subsequent tectonic movements formed the eastern Rift Valley base level, deepened the Yizre'el intermediate base level and were responsible for uplift and block tilting throughout the entire Galilee. As a result the younger and current drainage systems were formed, partly utilizing segments of the palaeo-systems, albeit in places, in opposite directions. Palaeodrainage systems were captured to the east and south, and the control of the tectonic movements on the shape and symmetry of the young basins is evident.

INTRODUCTION

The present study deals with Neogene to Quaternary continental conglomerates in Lower Galilee, northern Israel, which indicate palaeo-drainage systems that do not necessarily coincide with those of the present ones.

The main objective of the study was to analyze and reconstruct the configurations and locations of the palaeodrainage systems and their respective base levels in time and space, through the distribution and abundance of the conglomerates. In addition, the relationship between the location and change of the drainage systems and young tectonics was also studied.

Continental fluviatile conglomerates are known from several places in the Galilee. The study concentrates, however, mostly on Lower Galilee, where exposures are more abundant in comparison to Upper Galilee, where exposures are scarce due to subsequent erosion or non-deposition. The study is based mainly on exposures, some mapped and described in several previous works and some discovered and studied in the course of the present study. Subsurface data from boreholes are also incorporated (Fig. 1 and Table 1).

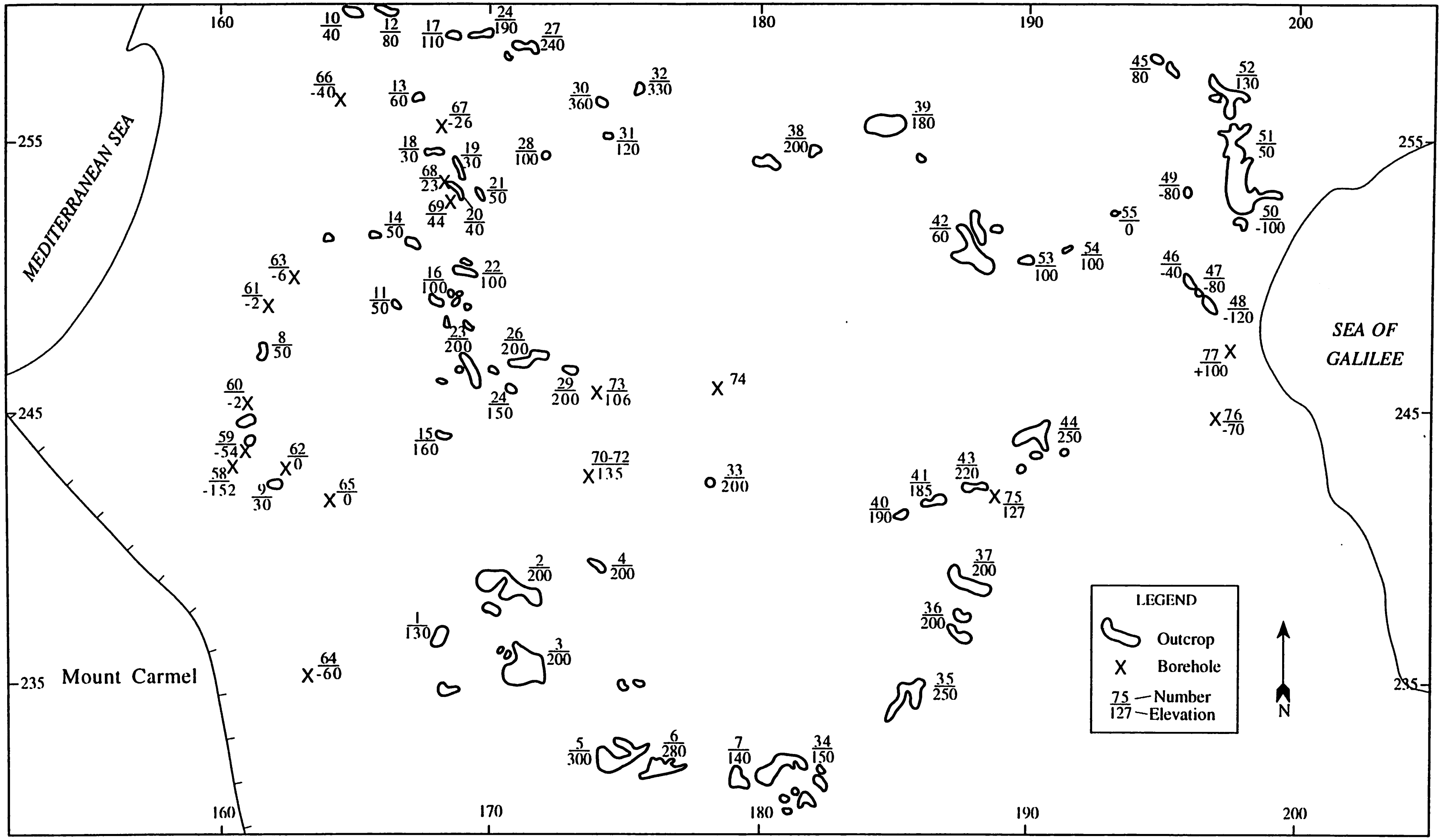


Figure 1: Location map of the conglomerates in exposures and boreholes, and their absolute elevation.

Table 1: Location, elevation and underlying formations of the different conglomerate occurrences in exposures and boreholes

No.	Site/Borehole	Coordinates	Elevation Top cgl. relative to MSL (m)	Elevation Top Judea G relative to MSL (m)	Underlying Formation and its age	Description/Remarks
	Sites					
1	Allone Abba	1682/2368	120-130	-400	Avedat (E)	
2	Givat Shimshit	1710/2384	150-200	-400	Avedat (E)	
3	Shimron	1710/2355	150-200	-400	Avedat (E)	
4	Hasolelim	1740/2390	190	-300	Avedat (E)	
5	Ginnegar	1745/2310	250-300	-150	Avedat (E)	
6	Mualaqa	1760/2313	270-280	270-280	Top Judea (C-T)	
7	Mt.Qedumim	1792/2313	140	400	Judea (C-T)	
8	Gal'am	1615/2470	50	-250	Avedat (E)	
9	Ibtin	1620/2423	30	-250	Avedat (E)	
10	Jdeida	1646/2597	40	-150	Mt.Scopus (S)	
11	Iblin	1655/2489	50	-120	Avedat (E)	
12	Jdeida	1660/2596	80	-50	Mt.Scopus (S)	
13	Ahihud	1673/2565	60	-50	Mt.Scopus (S)	
14	Tamra	1673/2511	50	-100	Mt.Scopus (S)	
15	Shefaram	1683/2441	160	50	Mt.Scopus (S)	
16	Mizpe Aviv	1686/2490	100	-30	Mt. Scopus (S)	
17	Nahal Izhar	1686/2588	110	250	U. Judea (C-T)	
18	Zomet Yavor	1680/2545	30	-100	Mt.Scopus (S)	
19	Zomet Yavor	1688/2540	30	-50	Mt.Scopus (S)	
20	Kabul	1685/2534	40	-70	Mt.Scopus (S)	
21	Kabul	1696/2530	50	-20	Mt.Scopus (S)	
22	Tamra	1690/2500	100	0	Mt.Scopus (S)	
23	Iblin	1693/2465	200	50	Mt.Scopus (S)	
24	Mearat Yonim	1696/2588	190	300	U. Judea (C-T)	
25	Nahal Evlayim	1707/2457	150	100	L.Mt. Scopus (S)	Ahuzam Conglomerate?
26	El Dumeida	171/246	200	50	Mt. Scopus (S)	

Table 1: Location, elevation and underlying formations of the different conglomerate occurrences in exposures and boreholes (cont.)

No.	Site/Borehole	Coordinates	Elevation Top cgl. relative to MSL (m)	Elevation Top Judea G relative to MSL (m)	Underlying Formation and its age	Description/Remarks
27	Har Hagamal	1715/2584	240	400	U. Judea (C-T)	
28	Shaab	1722/2544	100	20	Mt.Scopus (S)	
29	Kafr Manda	1730/2464	200	50	Mt.Scopus (S)	
30	Zurit	1741/2564	360	350	L. Mt.Scopus (S)	
31	Shorashim	1743/2552	120	80	L. Mt.Scopus (S)	
32	Har Karmi	1756/2568	330	300	L. Mt.Scopus (S)	
33	Bet Netofa	1783/2423	200	200	top Judea (C-T)	
34	Iksal	1800/2315	150	-70	Mt.Scopus (S)	
35	Dabburiya	1855/2345	200-250	300	top Judea (C-T))	
36	Bet Qeshet	1875/2365	200	-100	Avedat (E)	
37	Ilanyya	1880/2385	200	-100	Avedat (E)	
38	Maale Zvia	1818/2546	205	450	M. Judea (CT)	
39	Nahal Zalmon	1845/2555	180	460	M. Judea (CT)	
40	Turan	1853/2412	190	250	U. Judea (C-T)	
41	Turan	1865/2415	185	250	U. Judea (C-T)	
42	Zalmon reservoir	1880/2510	60	360	Judea (C-T)	
43	Zomet Golani	1885/2423	220	220	top Judea (C-T)	Cgl. intruded by dykes, "baked" and overlain by Cover Basalt
44	Lavi	1905/2442	250	~ 0	L. Avedat (E)	
45	Hananya stream	1945/2578	80	80	top Judea (C-T)	
46	Migdal	1960/2500	-40	-500	Avedat (E)	Cgl. underlying Cover Basalt
47	Migdal	1965/2495	-80	-550	Avedat (E)	"
48	Migdal	1970/2490	-120	-600	Avedat (E)	"
49	Huqoq	1980/2528	-80	-600	Avedat (E)	"
50	Ammud stream	1975/2525	-100	-450	Avedat (E)	
51	Ammud stream	1980/2544	50	-350	Avedat (E)	
52	Ammud stream	1980/2567	130	-400	Avedat (E)	

Table 1: Location, elevation and underlying formations of the different conglomerate occurrences in exposures and boreholes (end)

No.	Site/Borehole	Coordinates	Elevation Top cgl. relative to MSL (m)	Elevation Top Judea G relative to MSL (m)	Underlying Formation and its age	Description/Remarks
	Boreholes					
53	Masad	1900/2506	100	150	U. Judea (CT)	
54	Mimlah	1915/2510	100	150	U. Judea (CT)	
55	Zomet Zalmon	1933/2521	0	-20	M. Scopus (S)	
56	K. Ha-Maccabi 354	16055/24293	-152	-500	L. Avedat (E)	18-166 m - Alternations of cgl,marl & limest.(inside channel
57	Usha 7	16095/24373	-54	-500	L. Avedat (E)	0-69,5 m - Cgl & Kurdane pebbles
58	Usha 12	16110/24522	-2	-300	L. Avedat (E)	0-22 m - Cgl.-limestone & chert pebbles
59	Afeq 3	16186/24880	-2	-150	Mt.Scopus (S)	10-17 m - Pebbles
60	Shefar'am	1624/2428	0	-500	Avedat (E)	0-18 m - limestone & chert pebbles
61	Afeq 2	16285/24998	-6	-100	Mt.Scopus (S)	12-22.5 m - Pebbles & silt
62	Allonim	16315/23515	-60	-500	Avedat (E)	0-78 m - Alternations of silts & pebbles (also basalt pebbl
63	W. Malik 42	16410/24165	0	-400	Avedat (E)	0-31 m - limestone & chert pebbles
64	Akko T/5	16436/25651	-40	-180	Avedat (E)	37-49 m - limestone, chert & Kurdane pebbles
65	Akko T/3	16832/25566	-26	-100	Mt. Scopus (S)	0-40 m - Pebbles & clay
66	Yasur 2	168343/253468	23	-114	Mt. Scopus (S)	0-11 m - Limestone pebbles
67	Yasur 3	168605/252741	44	-50	Mt. Scopus (S)	0-11.5 m - " "
68	Eshkol 2	173376/242417	135	-50	Mt. Scopus (S)	0-10 m - Pebbles
69	Eshkol 1	173750/242806	131	-50	Mt. Scopus (S)	0-14 m - "
70	Eshkol 3	174101/242558	136	-50	Mt. Scopus (S)	0- 9 m - "
71	Netofa 2	174029/245768	106	0	Mt. Scopus (S)	0-49 m - Pebbles & silts
72	Sejera 16	1873/2418	127	50	L. Mt.Scopus (S)	20-90 m - cgl. & clay underlying cover basalt
73	Hitim	1970/2447	-70	-500	L. Basalt (Ne)	80.5-218.2 m - limestone, chert & basalt pebbles with red cla
74	Arbel AB 1	19790/24704	102	-400	Avedat (E)	33-50 m - Cgl. underlying Cover Basalt

It should be noted that due to poor exposure and the calcrete (Nari) crust which masks most of the exposures, it is very often difficult to locate or precisely delineate the extent of the conglomerates. Thus, the exposures described herein do not necessarily represent the entire distribution of the latter.

The present study focuses on the old conglomerates, and does not deal with the young river terraces (Ahuzam Formation?) found in places along the present drainage systems. Also, in a few rare cases (Ahihud, Shimron, Zalmon) some boulders which consist of an even "earlier" conglomerate were found among the clasts. Due to the rarity of phenomena it is assumed that they do not exhibit an early widespread phase, but rather an "intraformational" conglomerate within the formation discussed.

The study area is bounded geographically (Fig. 1) by the Jordan Rift Valley in the east, the Yizre'el and Qishon valleys in the south, the Galilee coastal plain including the Zevulun Plain in the west, and the Bet Kerem Valley in the north, which separates between the lower and upper Galilee. Drainage basins in western upper Galilee are also analyzed.

PREVIOUS STUDIES

Neogene and young conglomerates within and close to the study area were previously described and discussed, among the others, by Rabinowitz (1954), Weiler (1961), Greenberg (1962), Buchbinder (1964), Hayati (1964), Saltzman (1964), Kafri and Ecker (1964), Kafri (1965), Movshovitz (1965), Issar and Kafri (1972), Vishkin (1973), Levy (1983), Buchbinder *et al.* (1983), Shaliv (1991), Peltz and Kafri (1992), Kafri and Heimann (1994), Kafri (1995, 1996) and Kafri and Sass (1995, 1996).

Some of the works briefly describe the findings and some discuss the regional palaeogeographical bearing of the findings. The results of the above are incorporated and discussed in the present study.

THE BET NIR-HORDOS CONGLOMERATES

Lithology and facies

The different exposures of the Neogene conglomerates in the study area and its neighbourhood were mapped and named previously as "Neogene Conglomerates" (Weiler, 1961; Greenberg, 1962; Movshovitz, 1965), "Hordos Formation" (Saltzman, 1964; Michelson,1979), "Umm Sabune Conglomerate" (Shaliv, 1991) or "Bet Nir Conglomerate" (Levy, 1983). Except for the Rift Valley proper and the internal valleys, where the Neogene conglomerate sequence is thick, these conglomerates appear throughout most of the study area as a very thin cover, ranging in thickness between a few to a few tens of meters. In the Rift Valley the present study only deals with its uppermost portion that immediately underlying the Cover Basalt (see below). Therefore, in spite of the different names, they seem to be time-equivalent (see below) and can be divided, based on their appearance, composition and distribution into two main types or facies: (a) a western one, defined herein as the "Bet Nir Conglomerate", and (b) an eastern one defined as the upper conglomerate of the Hordos Formation.

Both seem to occupy the same morphostratigraphic position passing laterally into each other and both belong to the same palaeodrainage system.

(a) The Bet Nir Conglomerate (Gvirtzman and Buchbinder, 1969) (western facies) is a light colored conglomerate which consists of a groundmass of "sterile" redeposited chalk derived from the underlying Senonian to Eocene formations and clasts of different lithology, size and shape. The chalk groundmass is usually covered by a surficial calcrete (Nari) crust which obscures its appearance. Hence, it is often difficult to differentiate between the conglomerate proper and the underlying or adjacent, calcrete covered chalk formations. For the same reason, the exact delineation of the conglomerate exposures is difficult or impossible.

The conglomerate is usually polymictic and the lithological composition of the clasts is usually that of the underlying or adjacent rock formations. Thus, the conglomerates on top of the Judea (Cenomanian-Turonian) Group contain mostly limestone, dolomite, chert and quartzolite pebbles, those overlying the Mount Scopus (Senonian) Group (Fig. 2) contain mostly chalk and chert pebbles and those overlying the 'Avedat (Eocene) Group (Fig. 3) contain mostly Eocene, sometimes dark "baked" limestone and chert pebbles. All the above indicates that the transport of material along the palaeodrainage systems, was relatively short.

In the west, on the eastern margins of the Zevulun Plain, calcareous sandstone pebbles of the Kurdane Formation of Neogene to Quaternary age are also found as components of these conglomerates, close to the Kurdane plaeo-shore line (Hayati, 1964; Kafri and Ecker, 1964). Notably, usually **no** basalt pebbles are found in the conglomerates (see below).

Figure 2: Bet Nir Conglomerate consisting of chalk and limestone pebbles within a chalk groundmass overlying a relief on top of Mt. Scopus Group. El Dumeida, coord. 171/247.

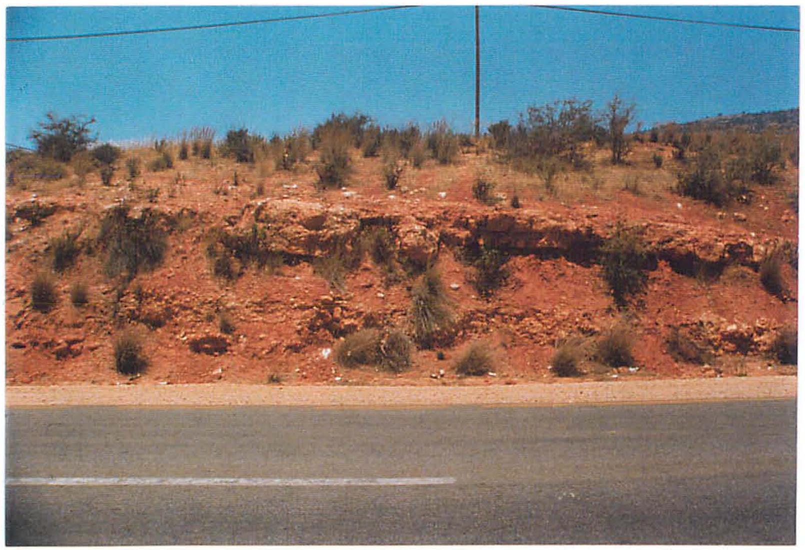


Figure 4: Hordos conglomerate, consisting of brownish pebbles cemented by a carbonate groundmass alternating with brownish mudstones. Tilted toward SE. Zalmon, coord. 184/255.

Figure 3: A poorly sorted well rounded Bet Nir conglomerate, consisting mostly of 'Avedat Group pebbles. Allone Abba,coord. 168/236.

The conglomerates are unsorted with clast sizes ranging from a sand size (a few mm) to cobbles and large boulders of several tens of cm, mostly subrounded to rounded (Fig. 3), but sometimes subangular.

(b) The Hordos Formation Conglomerate, uppermost portion (eastern facies) has a general reddish color. Lithologically, it consists of alternations of conglomerates and brown-reddish siltstones and mudstones (Fig. 4). The coarse clasts represent the high-energy stream bed whereas the fine mudstones were deposited in low-energy slack waters of the floodplains. The groundmass consists either of siltstones or travertine-like brown carbonate cement. The clasts have basically the same polymictic composition as in the western Bet Nir Conglomerate, and they usually reflect the nearby underlying formations from where they were derived (Fig. 5).

Some of the conglomerates along the Zalmon Valley contain a particular phenomenon of "hollow pebbles" (Fig. 6). These are mostly dolomite pebbles which underwent surficial dedolomitization and subsequent partial solution of the inner part of the pebbles (Kafri and Sass, 1995, 1996).

The clasts in the Hordos Formation conglomerates are basically of the same size and shape as those of the Bet Nir Conglomerate described above (Fig.7).

The boundary between the Hordos and the Bet Nir conglomerates

The light colored Bet Nir conglomerates are found mostly in the western and southern parts of the study area, whereas the reddish Hordos conglomerates are confined to the eastern part, and the boundary between them is along a schematic N-S directed passage line or zone (Fig. 8).

Surprisingly this boundary approximately coincides with, or is close to, the westernmost boundary of the exposed Cover Basalt (Fig. 8) which overlies the Hordos conglomerates. The conglomerates found in this eastern volcanic province are always the red colored Hordos facies, whereas the others, outside the province, are of the light colored Bet Nir facies. Therefore it can be assumed that the eastern facies coloration is epigenetic and was contributed by the overlying volcanics whereas the light color of the western facies is connected to the redeposited chalks that host the conglomerates.

As noted above, the two boundaries coincide with each other, with the exception of the northern part of the study area where the Hordos facies is still found somewhat

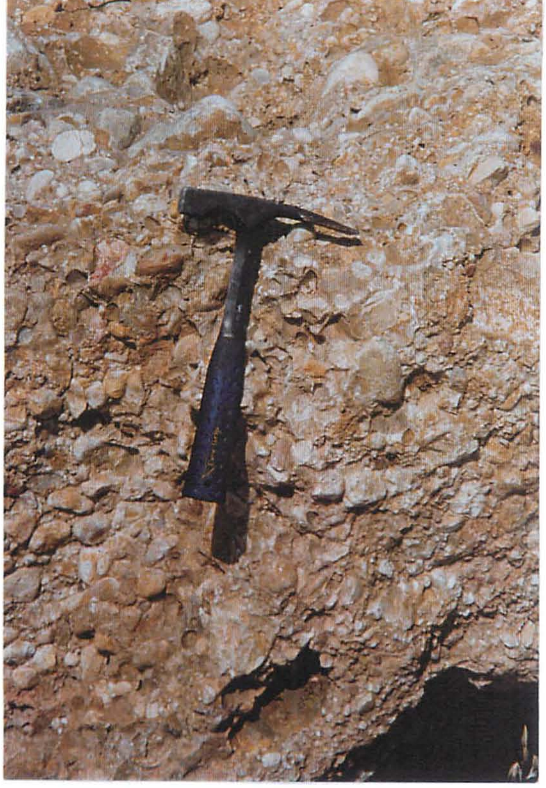


Figure 5: Hordos conglomerate, polymictic, poorly sorted and subrounded pebbles. Tabgha, coord. 199/252.

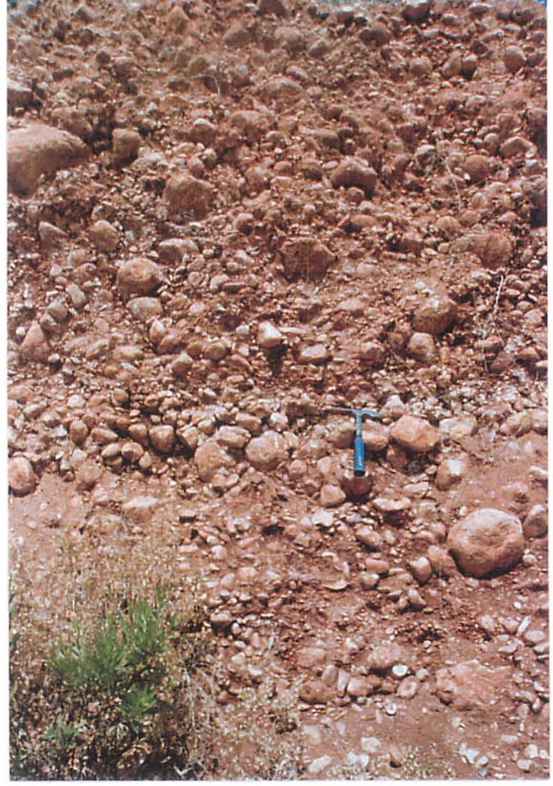


Figure 7: Hordos conglomerate, rounded, poorly sorted pebbles. Huqoq, coord. 1990/2527.

Figure 6: Hollow pebbles of the Hordos conglomerate. Zalmon, coord. 184/255.

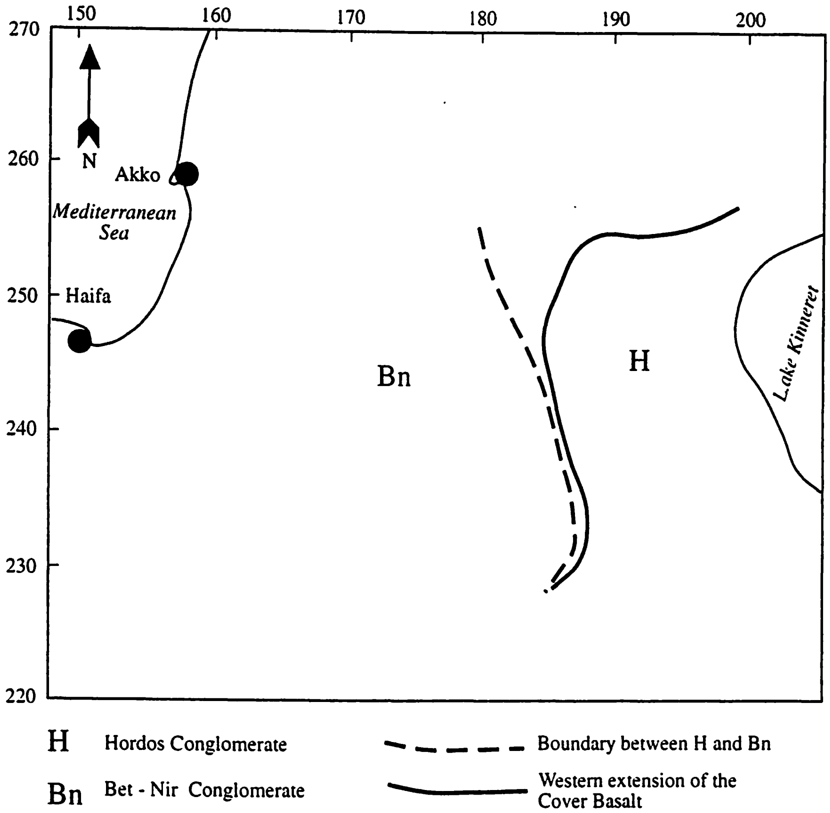


Figure 8: Map showing the boundary between the Hordos and Bet Nir facies, and the westernmost extension of the Cover Basalt.

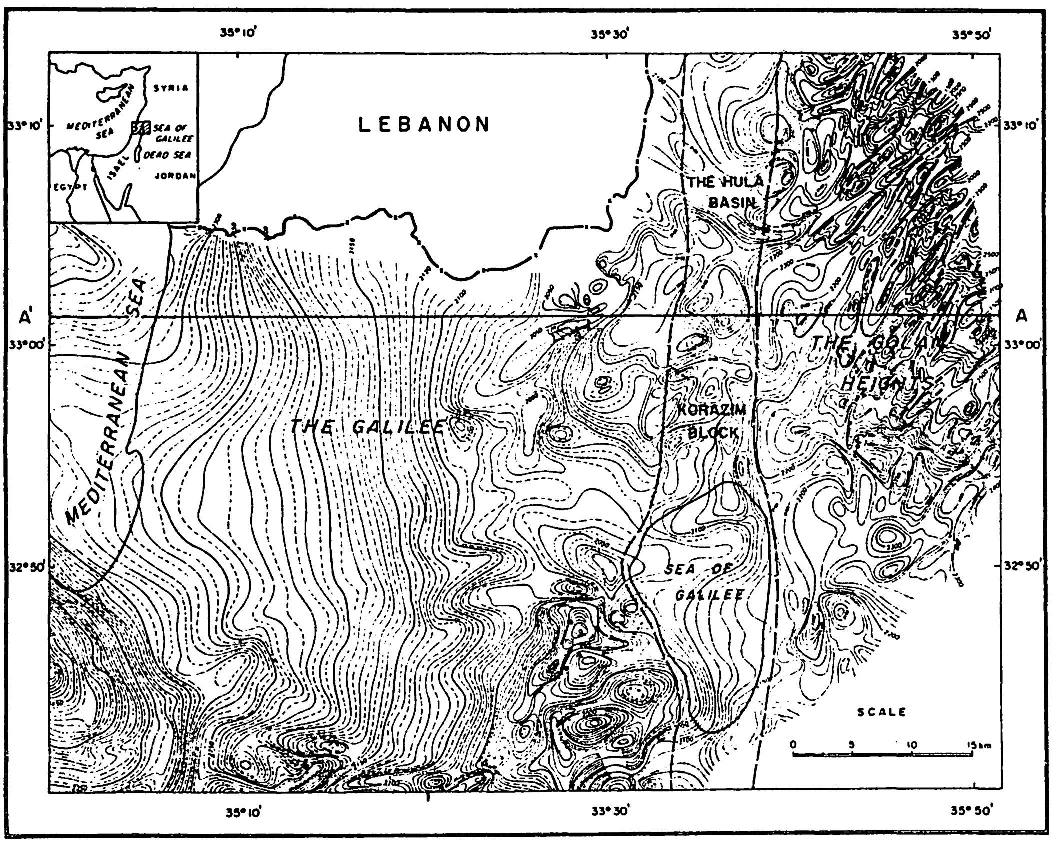


Figure 9: Aeromagnetic map of northern Israel (Folkman, 1980).

west of the westernmost Cover Basalt exposures. There are two alternative explanations for this discrepancy:

1) The rather short wavelength magnetic anomalies of the study area typify the volcanic province (Folkman, 1980). The aeromagnetic map (Fig.9) indeed shows that in this region this pattern extends somewhat west of the westernmost volcanic exposures which might indicate their buried extension there.
2) The Hordos conglomerates discussed are situated somewhat west of, and downstream, the volcanic province and therefore could be affected by it, due to the short transport.

Thicknesses (Table 1)

In most places where the conglomerate is exposed and not covered by any younger formation and its upper boundary is eroded, it is usually a few to a few tens of meters thick; nothing is known in these places about the original thickness.

However, in some places, where subsurface information is available, more complete thicknesses were obtained: in the Zevulun Plain in the west, greater thicknesses seem to occur in the Hillazon (40 m in Akko T/3) and Qishon (69 m in Usha, 150 m in Kefar HaMaccabi) grabens (Kafri and Ecker, 1964), whereas in the central block inbetween the thickness is around 10 m (*i.e.*, Afeq region).

In the eastern extension of the Qishon Graben, namely the Yizre'el and Bet Shean valleys, thicknesses attain several tens of meters (Shefar'am and Allonim regions, and also in Shaliv, 1991).

More to the east, thicknesses of the Hordos Formation conglomerates of several tens of meters and up to 140 m are known from Sejera and close to the Jordan Rift Valley in Hittim and near Tabgha.

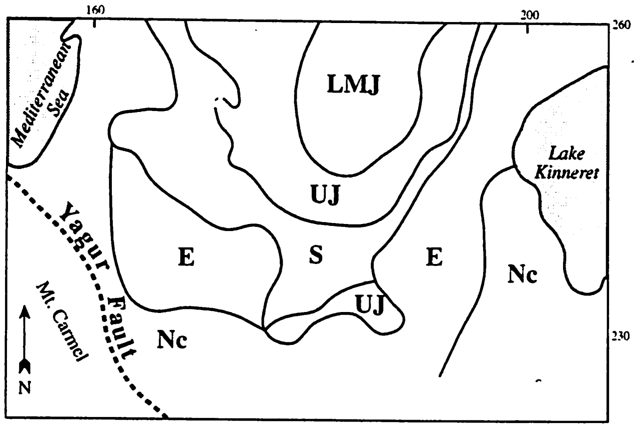
The greater thicknesses seem to be found along WNW directed palaeodrainage systems which extend from the east, sometimes east of the present Rift Valley, to the Neogene base levels, or the Neogene coastlines in the west (see below).

Boundaries and age

Being a continental deposit the nature of the lower boundary of the conglomerate is unconformable (Fig. 10); it overlies, or is incised into, rock formations ranging in age from Cenomanian to Neogene (Table 1). A generalized subcrop map of the conglomerates, interpolated from the scattered available outcrops and occurrences (Fig. 11) shows that the underlying erosional surface (peneplain) is rather flat. In central

Figure 10: Hordos conglomerate overlying a relief on top of the 'Avedat Group, and overlain by the Cover Basalt.

Figure 12: Bet Nir Conglomerate alternating with Bira Marl. Allone Abba, coord. 168/236.



Nc Neogene formations
E Avedat Group
S Mt. Scopus Group
UJ Upper Judea Group
LMJ Lower to Middle Judea Group

Figure 11: Subcrop map of the Hordos and Bet Nir conglomerates.

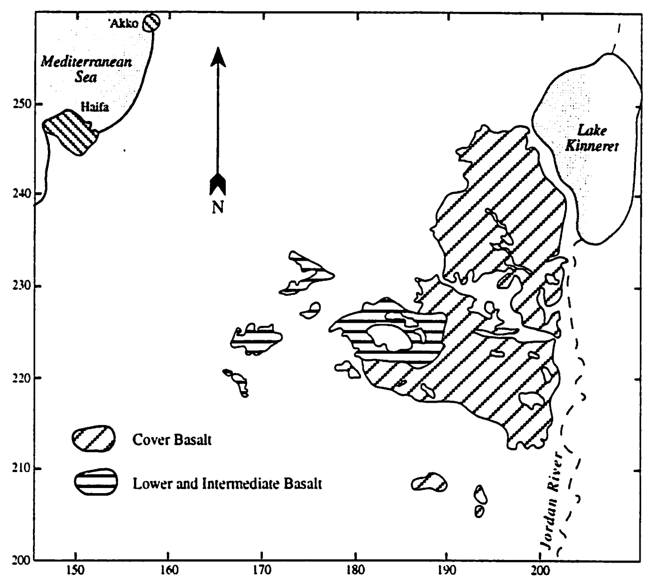
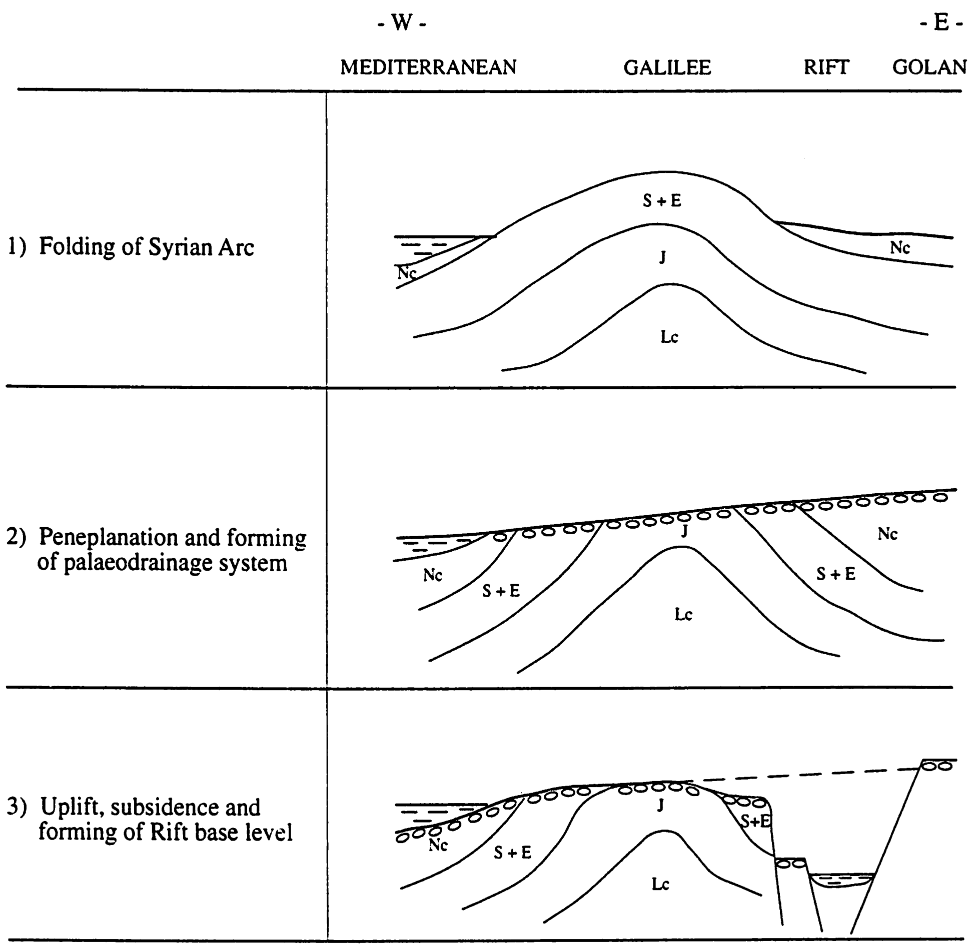


Figure 14: Distribution of Neogene basalts in northern Israel (after Shaliv, 1991).



LEGEND

J	Judea Gr.	Nc	Neogene Fms.	ooo	Hordos and Bet-Nir Cgls.
Lc	Kurnub Gr.	S + E	Mt. Scopus and Avedat Gr.		

Figure 15: Scheme showing the different tectonic phases and the respective configurations of the conglomerates.

Galilee, it is incised as deep as and into the Cenomanian Deir Hanna Formation. Symmetrically, towards east, west and south, this erosional surface overlies progressively younger formations. The youngest underlying formation is the lower part and the Hordos Formation of Miocene age in the Jordan Rift Valley and the internal Yizre'el and Bet Shean valleys, as shown also by Shaliv (1991).

The conglomerates are overlain by the Bira (Pliocene) Formation in the Yizre'el and Bet Shean valleys (Shaliv, 1991), but are also seen to interfinger with the latter (*i.e.* near Allone Abba, coord. 168/237) (Fig. 12). In most other places outside the limits of the distribution of the Bira Formation. the conglomerates are overlain by the Cover Basalt, which determines their upper time limit (Figs. 10, 13.)

The relationship between the conglomerates and the Neogene volcanism is of major importance in reconstructing the age and the history of the conglomerates. The extent of the Neogene volcanic province of Lower Galilee was illustrated, among others, by Shaliv (1991) (Fig. 14). The western limit of this province is reflected on the aeromagnetic map (Fig. 9) (Folkman, 1980), where the complicated "highs" and "lows" pattern passes into a smooth contour pattern of increasing magnetic field toward the west.

In the study area the Lower and Intermediate Basalts of Miocene age occur mostly close to the Rift Valley and in the Yizre'el Valley, whereas the Cover Basalt of Pliocene age covers most of the rest of the volcanic province.

Most of the conglomerates within the volcanic province contain no basalt pebbles, even in those places where they are directly overlain by, or exposed adjacent to, Cover Basalt occurrences. This is recognized in the Zalmon and Tur'an valleys, as well as in the Tiv'on and Huqoq-'Ammud areas. In addition, in some places (*i.e.*, Huqoq) the Cover Basalt on top of the conglomerates is seen to intrude and "bake" the contact with the conglomerates, i.e. in a road-cut in Zomet Golani.

Only in those areas where the Lower and Intermediate Basalts underlie the conglomerates near Tiberias and in the Bet Shean and Yizre'el valleys, do the conglomerates contain also basalt pebbles derived from these basalts.

The upper age limit of the conglomerates can be obtained since the precise ages of the overlying Bira Formation and the Cover Basalt are known. Radiometric (K/Ar) dating of Cover Basalt samples in the study area was carried out in the course of the present study by the dating lab. of the Geological Survey Israel, yielding the ages detailed in Table 2.

Figure 13: Alternations of Hordos conglomerates and mudstones overlain by Cover Basalt. Livnim, coord. 1962/2530.

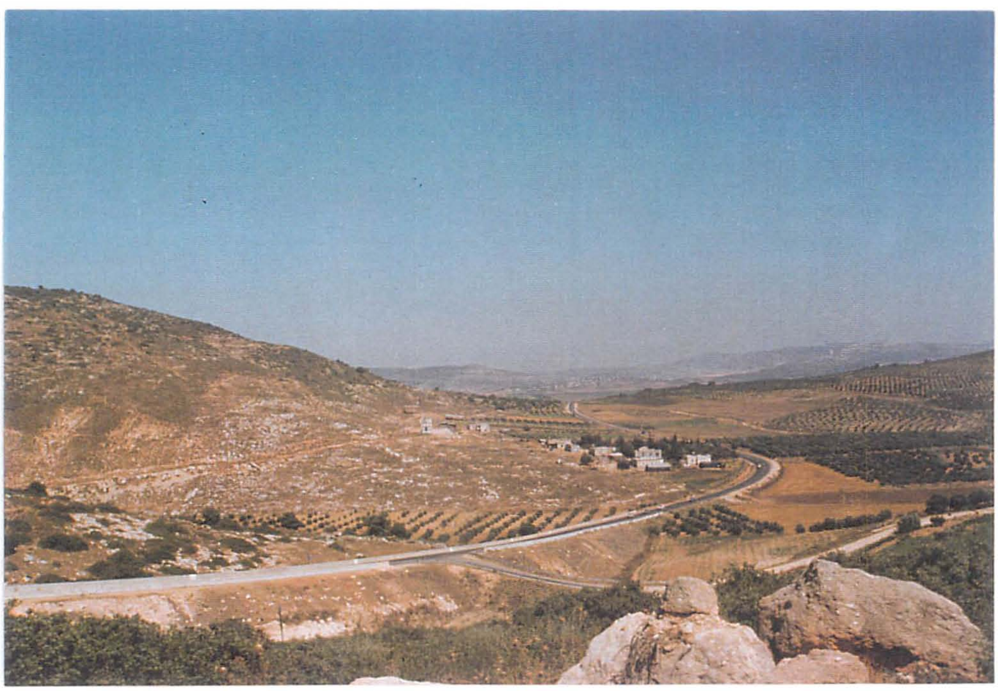


Figure 16: View to the E on the Kefar Manda windgap (coord. 171/246), on top of a divide between the Yiftahel and Evlayim streams. The Bet Netofa valley is seen in the background.

Table 2 : K/Ar dating of some basalt occurrences.

Sample #	Coord	Location	Description	Age (ma)	Error
UK 4114	1884/2422	Zomet Golani	Dyke intruding cgl.	4.61	0.16
UK 4115	1864/2449	Mizpe Netofa	Dyke	3.82	0.08
UK 4116	1858/2445	Mt. Tur'an	Large dyke	4.33	0.10
UK 4117	1858/2445	Mt. Tur'an	Large dyke	4.16	0.09
UK 4118	1869/2516	Roadcut, west Zalmon Valley	Pebble inside a channel	4.23	0.22
UK 4119	1867/2520	Roadcut, west Zalmon Valley	Basalt flow	4.27	0.16
UK 4120	1961/2531	Livnim ridge	Basalt flow overlying Hordos cgl.	3.21	0.30

In addition, radiometric ages of the Cover Basalt in the study area were obtained from Heimann (1990) and Shaliv (1991), yielding altogether an age of 5.3-3.5 Ma. The age of the Bira Formation is, according to Shaliv (1991), Late Miocene to Early Pliocene, between 8.4 and 5.3 Ma.

Thus, the age of the conglomerates is apparently Late Miocene to Pliocene. Occurrences of younger basalts and their relationship to younger conglomerates in the study area are discussed separately.

Distribution

The Bet Nir and Hordos conglomerates are abundant mostly in the lower Galilee, south of the E-W directed Bet Kerem fault zone which separates between the lower and upper Galilee. In the upper Galilee, exposures are relatively scarce, either due to initial non-deposition or to subsequent erosion of the tectonically uplifted Upper Galilee.

The distribution of the exposures is not continuous but rather of a patchy nature (Fig. 1). However, more exposures, not yet recognized, due to the difficulties in recognition and delineation of the conglomerates, noted above, may exist.

The conglomerates, as a rule, do not necessarily coincide with, and are not confined to the young or current drainage systems which, in fact, are incised into them. Also, the elevations of the exposures do not correspond to the present or young systems which contain in places younger conglomerates of the Ahuzam Formation.

From the dimensions and geometry of the exposures it can be seen that are not confined to narrow streams but rather represent wide and flat floodplains.

A rough N-S directed boundary between the western Bet Nir and the eastern Hordos facies can be delineated. This boundary roughly coincides with the westernmost extension of the young, Neogene to Quaternary, volcanic province of the Galilee (Fig. 8), also reflected on the aeromagnetic maps (Fig. 9), i.e., the eastern (reddish) facies is confined to the volcanic province, whereas west of the province the facies is that of the Bet Nir Conglomerate. This is evidently not a coincidence, and the relationship between the two is discussed below.

Elevation of the conglomerates and the tectonic control

As already mentioned, the thin conglomerates cover unconformably overlie formations that range in age from Early Cenomanian to Neogene, older in central Galilee, and gradually younger ones to the west, south and east (Fig. 11). This implies that the rather flat erosive surface (peneplain) formed by the palaeodrainage systems had truncated the already existing structure of the Galilee anticlinorium, a segment of the "Syrian Arc", which started to be formed as early as Late Cretaceous times.

The present elevation of the conglomerates is controlled by the following:

a) The amount of erosion they were subjected to. Therefore, small differences in elevations, in the range of a few tens of meters do not necessarily indicate the flow direction and the gradient.

b) The distance from the palaeo-base level in the west. The conglomerates seem to represent a very flat erosive and mature wide floodplains morphology. Gradients of such mature systems are less than 1‰, similar to the present Qishon River. Therefore, the original elevation differences along the palaeo-flow path between east and west in the study area might be only a few tens of meters, within the range of the erosive differences noted above.

c) Subsequent tectonic deformation of subsidence, uplift and tilting which can result in elevation differences between exposures, which exceed the former ones.

The different stages leading to the present configuration of the conglomerates are schematically shown on Figure 15.

Judging from the elevations obtained in the study area (Fig. 1, Table 1), the following is concluded:

In most of the central part of the study area gradients are, as expected, very mild and elevations are around 200 m above m.s.l. The conglomerates slope in the west to elevations close to the present sea level or even considerably below it and below the palaeo-base level, indicating a subsequent tectonic subsidence. Similarly and for the same reasons, conglomerates slope toward the south into the Yizre'el morphotectonic valley.

In the east, the conglomerates are downfaulted, sometimes stepwise (*e.g.*, Zalmon exposures), towards the east to elevations considerably below sea level. In some places (*e.g.*, Zalmon exposures) eastern dips, steeper than depositional ones (Fig. 4) indicate a post-depositional tectonic tilt (Kafri and Sass, 1996). In the 'Ammud area, the western palaeo-gradient is retained in spite of the fact that the exposures are already downfaulted toward the east (Kafri and Heimann, 1994).

In the central part of the study area, no major regional uplift or subsidence is evident. Uplifting of local scale and relatively small magnitude is recognized on young elevated structures such as the Mt. Gilon area and the Nazareth mountains. Downfaulting and tilting of regional blocks sometimes displace the conglomerates to elevations below the original one. A few examples illustrating this configuration are as follows:

1) The conglomerates found on top of the Kefar Manda saddle (Fig. 16), at an elevation of +200 m and at an elevation of +106 m in the nearby Netofa 2 borehole. This displacement of approximately 100 m is due to the NW regional tilting of the Tur'an-Bet Netofa block and the uplift of the NE-SW ridge, north of the Bet Netofa Valley which diverted the WNW palaeo-direction of Yiftahel stream to the south (see below).
2) The conglomerates found in the Tur'an Valley at elevations of +180-190 m, some 20 m below the expected, due to the NW tilting of the Mt. Yona block toward the uplifted Mt. Tur'an block.
3) The Hordos conglomerates, in the AB/1 borehole at the top of the Mt. Arbel tilted block, are found at an elevation of +102 m, whereas downslope in Hitim 1 borehole they are found at an elevation of -70 m, which is in accordance with the SW direction and the amount of the post depositional tilting of the Arbel block. The amount of displacement of the conglomerates by the Arbel fault is 220 m, the elevation difference between their occurrence on top of the block (+102 m) and those in Migdal (-120 m).

Along the present Rift Valley in the east, the Hordos conglomerates are encountered in exposures and in the subsurface. It was already stated that at least part of the Lake Kinneret area existed as a "high" and did not serve as a base level until the Holocene (Neev, 1979; Horowitz, 1979; Folkman, 1980; Michelson *et al.,* 1987 and Kafri and Heimann, 1994). Namely, the present elevations of the conglomerate occurrences in the Rift area are due to young tectonic subsidence which formed the present base level.

Once the Rift area proper is ignored the extension of the palaeogradient, from Galilee across and outside the influence of the Rift, meets the Hordos conglomerates east of Lake Kinneret at the elevations of 250-350 m above m.s.l. (Michelson, 1979), as shown schematically in Figure 15. Assuming a post-Miocene sinistral movement along the Rift of 40 km (Freund et al., 1968) or 20 km (Michelson *et al.,* 1987), these conglomerates should be found buried under the Cover Basalt in the Golan Heights north of the Lake Kinneret. probably at similar elevations. Thus, it is concluded, according to the elevations of the Hordos conglomerates, that a palaeodrainage system to the west existed across part of the Rift area, in northern Israel at least in Late Miocene to Early Pliocene times and until at least the Quaternary.

Two W-E and WNW-ESE generalized cross sections (Figs. 17, 18) which exhibit the elevations of the conglomerates along these sections might shed light on the amount of regional post depositional tectonic deformation. It is readily seen that the amount of tectonic subsidence in Lake Kinneret area exceeds 500 m, whereas the coastal plain in the west was probably subject to subsidence of some 200 m. Assuming an age of some 5 Ma for the conglomerates, the average rates of subsidence obtained are approximately 0.1 and 0.04 mm/year respectively, similar to the rates given by Kafri *et al.* (1983).

The structural configuration of top Judea Group is a combination of both pre-conglomerate (Syrian Arc) and post-conglomerate deformation. Thus the proportion between both deformation phases is obtained knowing the amount of deformation of the latter.

The main post-Cretaceous tectonic activity may be summarized as follows (Fig. 15):

1) Arching of the Galilee anticlinorium (which is a segment of the Syrian Arc) began in the Late Cretaceous, accompanied by faulting.

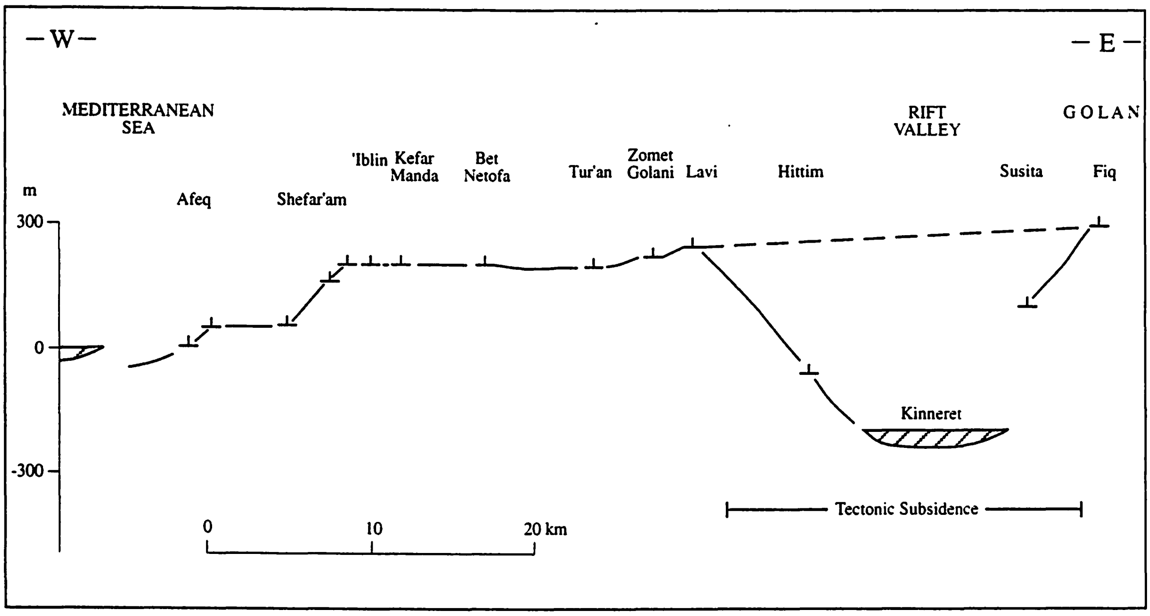


Figure 17: Generalized W (Afeq) - E (Fiq) section showing the elevation of the conglomerates.

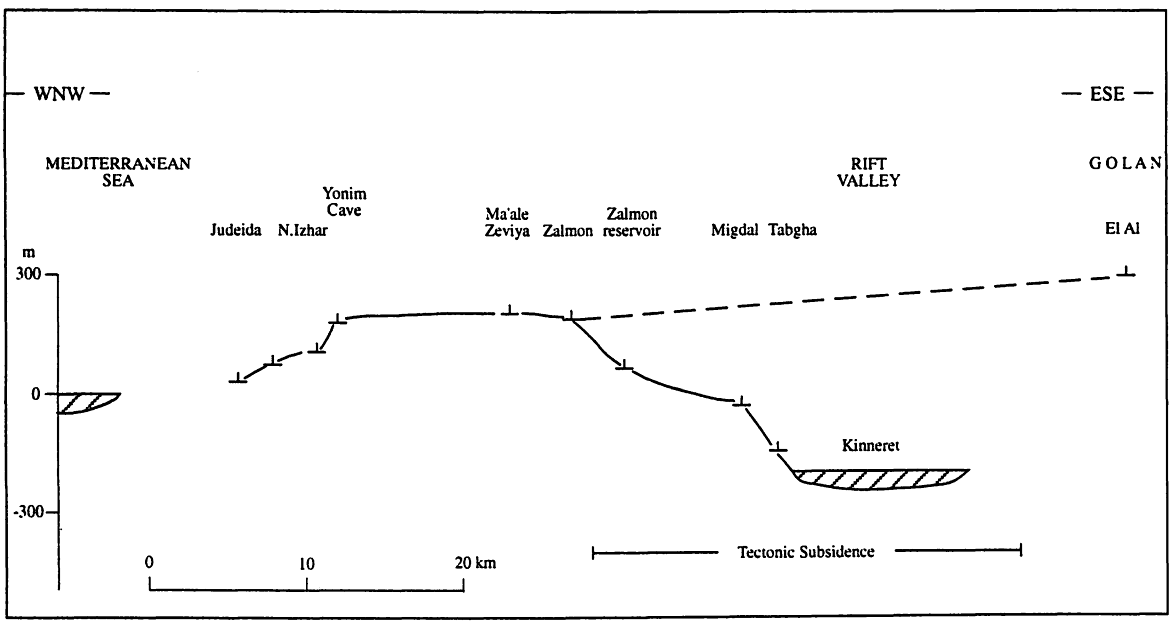


Figure 18: Generalized W (Jdeida) - E (El Al) section showing the elevation of the conglomerates.

2) Erosion of the Galilee anticlinorium structure and development of a peneplain overlain by a thin cover of conglomerate through most of the lower Galilee. These conglomerates unconformably overlie formations which range in age fron Early Cenomanian to Neogene, the older in Central Galilee and the older in the west, south and east (Fig. 11).

3) Subsequent faulting and tectonic deformation resulted in subsidence, uplift and tilting associated with the formation of the Jordan Rift Valley base level in the east.

Detailed analysis of local effects of faulting or other structural elements is not possible because of the relatively few data points in the area at present. Therefore, only a broad regional overview is possible. The initial elevation of a conglomerate is assumed to increase toward the east according to the estimated 1‰ gradient. The top Judea Group datum represents a very wide and shallow continental shelf close to the tidal zone (Kafri, 1972a). Thus, as a working hypothesis, any large-scale present-day deviations from the above levels may be attributed to post-depositional vertical movements (*i.e.*, uplift or subsidence).

Based on the above assumptions and a determination of the structural elevation of the reference surfaces, the amount of Syrian Arc arching can be estimated by deducting the effect of post-conglomerate deformation at each point. The relevant structural data of both conglomerates and top Judea Group in the lower Galilee were calculated together with calculations of the post- and pre-conglomerate vertical displacements and the ratios between these displacements. A ratio of 1 indicates an equal amount of displacement (regardless of direction) for both phases, a ratio of <1 indicates a larger displaemnt for the older phase and a ratio of >1, a larger displacement of the younger phase. The sense of vertical displacements for the different phases are also deduced.

Based on these data (Table 3), the area can be subdivided into three regions, as schematically shown in Figure 19 and described by Kafri (1996):

1) **Central Galilee**. This region is typified by uplift in both tectonic phases. Of the 16 data points in this region, half indicate that most of the displacemnt is attributable to the older Syrian Arc phase, and the other half to the younger phase.

2) **Foothills region.** In this region there was subsidence in the older phase and uplift in the younger. The region apparently behaved as a hinge zone and a western shift of the hinge is possibly responsible for reversals in the directions of movement. At most sites (28 of 36), much of the displacement relates to the older phase.

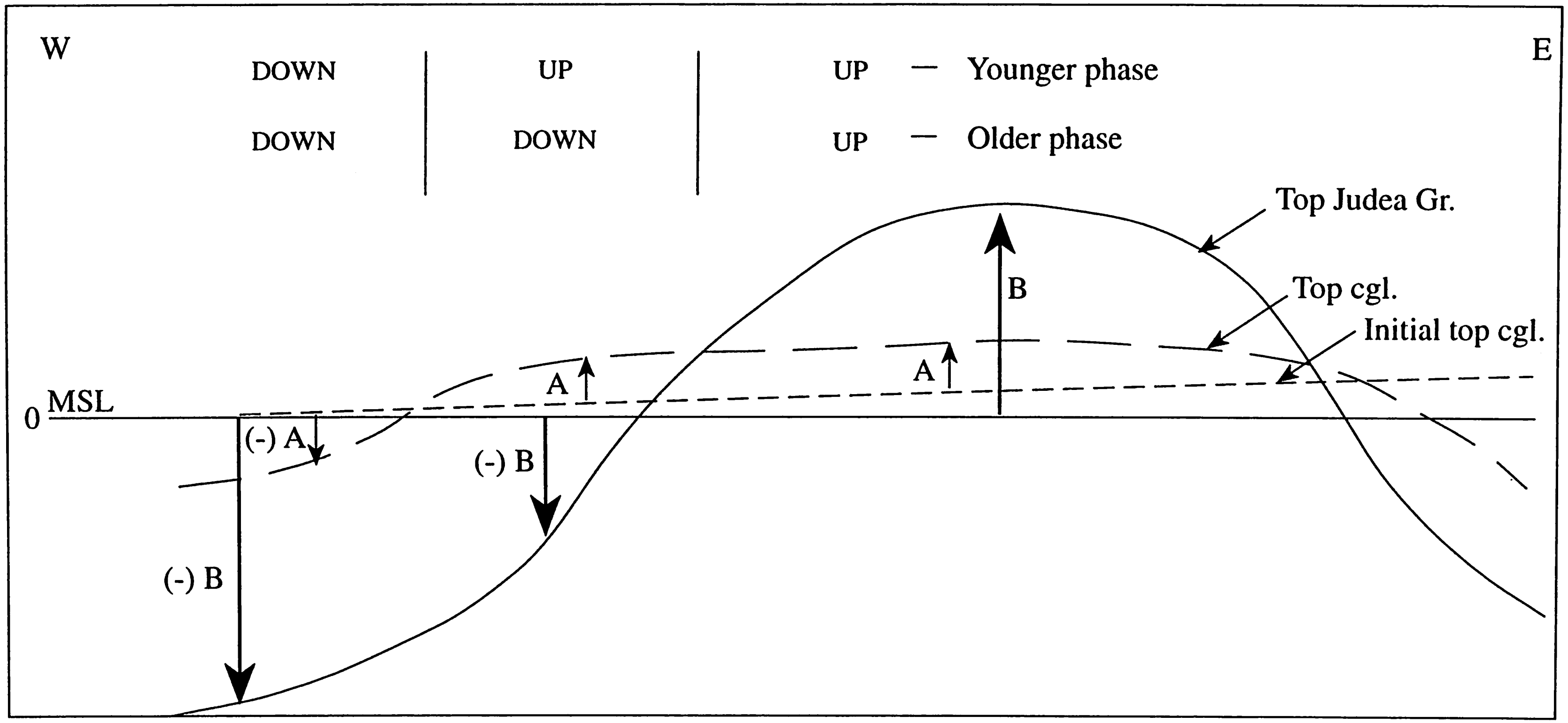


Figure 19: Schematic diagram showing the nature of the young tectonic phases.

Table 3: Direction and amount of vertical movements of the different tectonic phases

No.	Site/Borehole	Coordinates	Elevation Top Judea Gr. relative to MSL (m) A	Elevation Top cgl. relative to MSL (m) B	Initial elevation of top congl. relative of MSL (m) C	Vertical Displacement of top cgl. (m) D = B - C	Vertical pre-cgl. displacement of top Judea Gr. (m) E = A + D	Ratio between pre- and post cgl. displacements D/E	Direction of movements pre cgl.	Direction of movements post cgl.
	Sites									
1	Allone Abba	1682/2368	-400	120-130	10	120	- 520	0.23	-	+
2	Givat Shimshit	1710/2384	-400	150-200	10	160	- 560	0.28	-	+
3	Shimron	1710/2355	-400	150-200	10	160	- 560	0.28	-	+
4	Hasolelim	1740/2390	-300	190	10	180	- 480	0.37	-	+
5	Ginnegar	1745/2310	-150	250-300	20	250	-400	0.62	-	+
6	Mualaqa	1760/2313	270-280	270-280	20	250	20	8	+	+
7	Mt.Qedumim	1792/2313	400	140	30	110	- 290	0.38	+	+
8	Gal'am	1615/2470	-250	50	10	40	-290	0.14	-	+
9	Ibtin	1620/2423	-250	30	10	20	- 270	0.07	-	+
10	Jdeida	1646/2597	-150	40	10	30	- 180	0.17	-	+
11	Iblin	1655/2489	-120	50	10	40	- 160	0.25	-	+
12	Jdeida	1660/2596	-50	80	10	70	-120	0.58	-	+
13	Ahihud	1673/2565	-50	60	10	50	-100	0.5	-	+
14	Tamra	1673/2511	-100	50	10	40	-140	0.28	-	+
15	Shefaram	1683/2441	50	160	10	150	-100	1.5	-	+
16	Mizpe Aviv	1686/2490	-30	100	10	90	-120	0.75	-	+
17	Nahal Izhar	1686/2588	250	110	10	100	150	0.66	+	+
18	Zomet Yavor	1680/2545	-100	30	10	20	-120	0.17	-	+
19	Zomet Yavor	1688/2540	-50	30	10	20	-70	0.28	-	+
20	Kabul	1685/2534	-70	40	10	30	-100	0.3	-	+
21	Kabul	1696/2530	-20	50	10	40	-60	0.66	-	+
22	Tamra	1690/2500	0	100	10	90	-90	1	-	+
23	Iblin	1693/2465	50	200	10	190	-140	1.36	-	+
24	Mearat Yonim	1696/2588	300	190	10	180	120	1.5	+	+
25	Nahal Evlayim	1707/2457	100	150	10	140	-40	3.5	-	+
26	El Dumeida	171/246	50	200	10	190	-140	1.36	-	+

Table 3: Direction and amount of vertical movements of the different tectonic phases

(cont.)

No.	Site/Borehole	Coordinates	Elevation Top Judea Gr. relative to MSL (m) A	Elevation Top cgl. relative to MSL (m) B	Initial Elevation of top Cgl. relative to C	Vertical Displacement of top cgl. (m) D = B - C	Vertical pre-cgl. displacement of top Judea Gr. (m) E = A + D	Ratio between pre- and post cgl. displacements D/E	Direction of movements pre cgl.	post cgl.
27	Har Hagamal	1715/2584	400	240	10	230	170	1.35	+	+
28	Shaab	1722/2544	20	100	10	90	-70	1.29	-	+
29	Kafr Manda	1730/2464	50	200	10	190	-140	1.36	-	+
30	Zurit	1741/2564	350	360	10	350	0	0.00	-	+
31	Shorashim	1743/2552	80	120	10	110	-30	3.66	-	+
32	Har Karmi	1756/2568	300	330	10	320	-20	16.00	-	+
33	Bet Netofa	1783/2423	200	200	20	180	-20	9.00	-	+
34	Iksal	1800/2315	-70	150	25	125	-195	0.64	-	+
35	Dabburiya	1855/2345	300	200-250	40	180	120	1.50	+	+
36	Bet Qeshet	1875/2365	-100	200	40	160	-260	0.61	-	+
37	Ilanyya	1880/2385	-100	200	40	160	-260	0.65	-	+
38	Maale Zvia	1818/2546	450	205	40	165	285	0.58	+	+
39	Nahal Zalmon	1845/2555	460	180	40	140	320	0.44	+	+
40	Turan	1853/2412	250	190	30	160	90	1.78	+	+
41	Turan	1865/2415	250	185	30	155	95	1.63	+	+
42	Zalmon reservoir	1880/2510	360	60	40	20	340	0.06	+	+
43	Zomet Golani	1885/2423	220	220	30	190	30	6.33	+	+
44	Lavi	1905/2442	~ 0	250	40	210	-210	1.00	-	+
45	Hananyya stream	1945/2578	80	80	40	40	40	1.00	+	+
46	Migdal	1960/2500	-500	-40	50	90	-590	0.22	-	+
47	Migdal	1965/2495	-550	-80	50	130	-680	0.31	-	+
48	Migdal	1970/2490	-600	-120	50	170	-730	0.39	-	+
49	Huqoq	1980/2528	-600	-80	50	130	-730	0.28	-	+
50	Ammud stream	1975/2525	-450	-100	50	150	-600	0.50	-	+
51	Ammud stream	1980/2544	-350	50	50	0	-350	0.05	-	+
52	Ammud stream	1980/2567	-400	130	50	80	-480	0.25	-	+

Table 3: Direction and amount of vertical movements of the different tectonic phases

(end)

No.	Site/Borehole	Coordinates	Elevation Top Judea Gr. relative to MSL (m)	Elevation Top cgl. relative to MSL (m)	Initial elevation of top Cgl. relative to MSL (m)	Vertical Displacement of top cgl. (m)	Ratio between pre-cgl. displacement of top Judea Gr. (m)	Ratio between pre- and post cgl. displacements	Direction of movements	
			A	B	C	D = B - C	E = A + D	D/E	pre cgl.	post cgl.
	Boreholes									
53	Sites	1900/2506	150	100	40	60	90	0.66	+	+
54	Mimlah	1915/2510	150	100	40	60	90	0.66	+	+
55	Zomet Zalmon	1933/2521	-20	0	40	-40	20	2	+	-
56	K.Ha-Maccabi 354	16055/24293	-500	-152	10	-162	-338	0.48	-	-
57	Usha 7	16095/24373	-500	-54	10	-64	-436	0.15	-	-
58	Usha 12	16110/24522	-300	-2	10	-12	-288	0.04	-	-
59	Afeq 3	16186/24880	-150	-2	10	-12	-138	0.09	-	-
60	Shefar'am	1624/2428	-500	0	10	-10	-490	0.02	-	-
61	Afeq 2	16285/24998	-100	-6	10	-16	-84	0.19	-	-
62	Allonim	16315/23515	-500	-60	10	-70	-430	0.16	-	-
63	W. Malik 42	16410/24165	-400	0	10	-10	-390	0.03	-	-
64	Akko T/5	16436/25651	-180	-40	10	-50	-130	0.38	-	-
65	Akko T/3	16832/25566	-100	-26	10	-36	-64	0.56	-	-
66	Yasur 2	168343/253468	-114	23	10	13	-127	0.1	-	+
67	Yasur 3	168605/252741	-50	44	10	34	-84	0.4	-	+
68	Eshkol 2	173376/242417	-50	135	10	125	-175	0.71	-	+
69	Eshkol 1	173750/242806	-50	131	10	121	-171	0.71	-	+
70	Eshkol 3	174101/242558	-50	136	10	126	-176	0.72	-	+
71	Netofa 2	174029/245768	-50	106	10	96	-96	1	-	+
72	Sejera 16	1873/2418	50	127	30	97	-47	2	-	+
73	Hitim	1970/2447	-500	-70	40	-110	-390	0.28	-	-
74	Arbel AB 1	19790/24704	-400	102	50	52	-452	0.11	-	+

3) **Coastal Plain**. This region is typified by subsidence both in the older and younger tectonic phases. All 16 sites show that most of the displacement took place in the older phase.

MORPHOLOGICAL FEATURES

Several "suspicious" morphological features are found in the study area which do not coincide with the present drainage systems, but rather reflect part of the older drainage systems.

The features, shown on Figure 20 and detailed in Table 4 include:

(1) Wide, short valleys whose small catchment area does not justify their width (e.g., the Megged Valley) (Fig. 21). These seem to represent residual segments of previously longer drainage systems whose upper reaches no longer drain to the present system, following its capture due to subsequent tectonic movements.

(2) Wide "hanging" morphological saddles or windgaps, situated on divides between the older systems and the newly formed and captured segments (e.g., the Megged Valley, Kefar Manda). Such a saddle, which is at present topographically above the present drainage system, is actually a cross-section of the older (at present, hanging) valley.

The important characteristics of these morphological features are as follows:

a) Some (Table 4) are covered by the Bet Nir or Hordos conglomerates which represent the deposits of the old streams. The absence of conglomerates in the other sites might be due to later erosion.

b) They are usually around 200 m, and mostly between 200-230 m above m.s.l., similar to the elevations of the conglomerate exposures in the study area, adjacent to them.

c) They are not randomly distributed. They are found aligned in between conglomerate exposures (Fig. 20) and the combination and relationship between both enables the reconstruction of the alignment of the palaeodrainage systems.

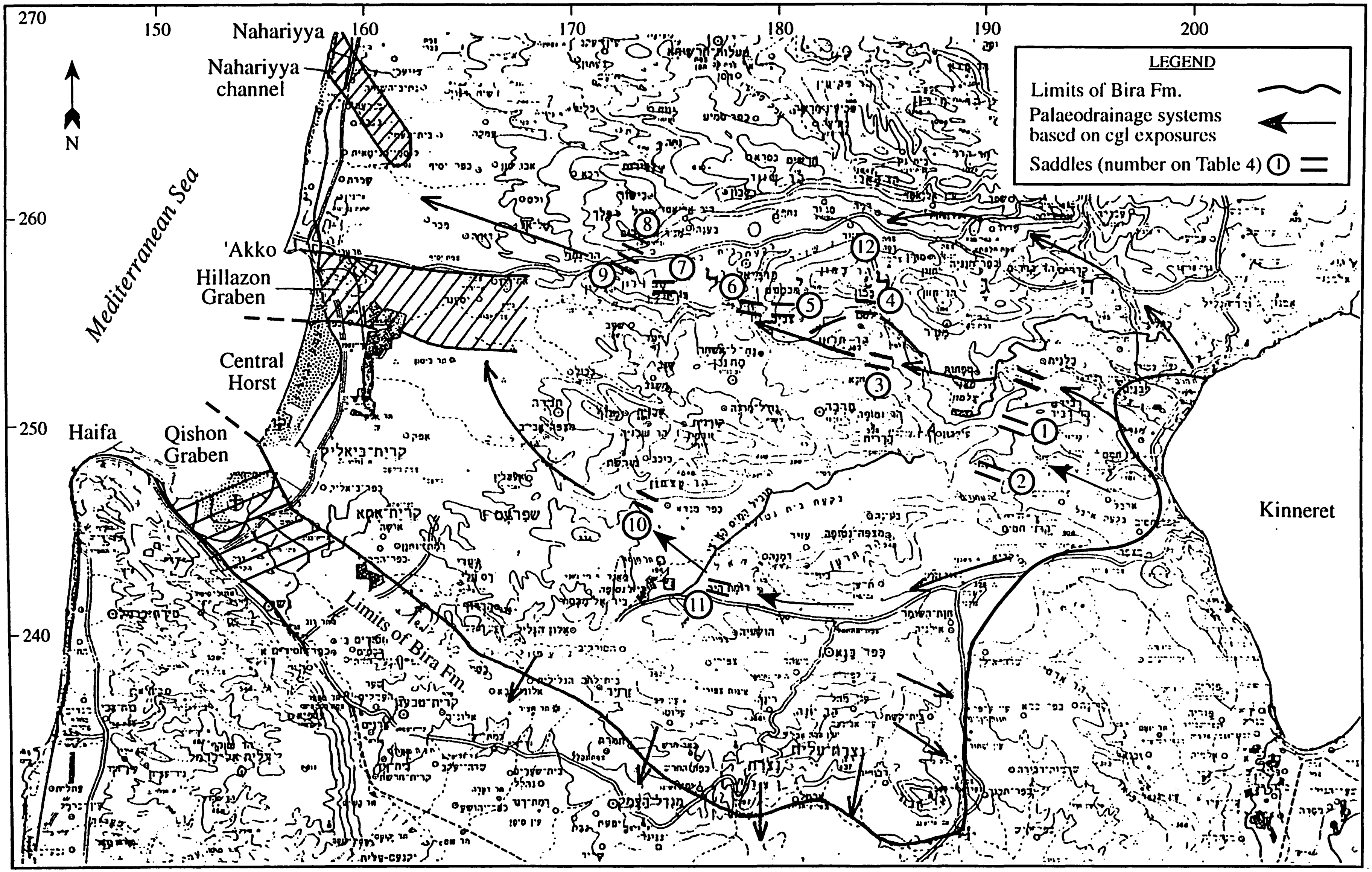


Figure 20: Map showing the palaeodrainage systems and the morphological features.

Table 4: Morphological saddles and divides

No.	Location	Coordinates	Elevation above MSL	Width (km) approx.	Divide	On top of Group	topped by a conglomerate	Remarks
1	Mimlah ridge	190/250	170	0.25	Between the Zalmon and the Arbel valleys	Judea	No	On the line connecting the conglomerates found in the Zalmon and Arbel valleys
2	Bet Netofa east	188/247	200	1.0	A wide divide between the Arbel and Bet Netofa valleys	Judea	No	On the Mediterranean-Rift divide
3	Deir Hanna	185/252	220	0.4	Between the Hillazon and Zalmon streams	Judea	No	On the Mediterranean-Rift divide. On the line connecting the Hillazon and Zalmon conglomerate exposures
4	Salame	184/255	180	0.5	- " -	Judea	Yes	- " -
5	Hillazon meander east	179/255	220	0.3		Judea	No	On the line connecting the Hillazon and Har Hagamal conglomerates
6	Hillazon meander	178/255	210	0.3	Between the limbs of the meander	Judea	No	- " -
7	Megged Valley	175/256	230	0.1	Between the Shagor and the Hillazon streams	Judea	No	- " -
8	Har Hagamal	171/258	230	0.1	Between the Shagor and the Izhar streams	Judea	Yes	Covered by the Izhar stream conglomerate
9	Bet Kerem windgap	171/257	200	0.3		Judea	Yes	Covered by the Shagor stream conglomerate
10	Kefar Manda	172/246	200	0.4	Between the Yiftahel (Bet Netofa) and Evlayim streams	Mt. Scopus	Yes	Underlying the conglomerates which are part of the Bet Netofa-Evlayim line
11	Rumet Heib	179/241	190	0.4	Between the Tur'an and Netofa valleys	Judea	No	Nearby conglomerate at the same elevation
12	Rama	185/259	340-380	1.0	Between the eastern and the western Bet Kerem Valley	Judea	No	The NE-SW divide coincides with the structural axis of Galilee. Forces the Zalmon stream to turn to the south

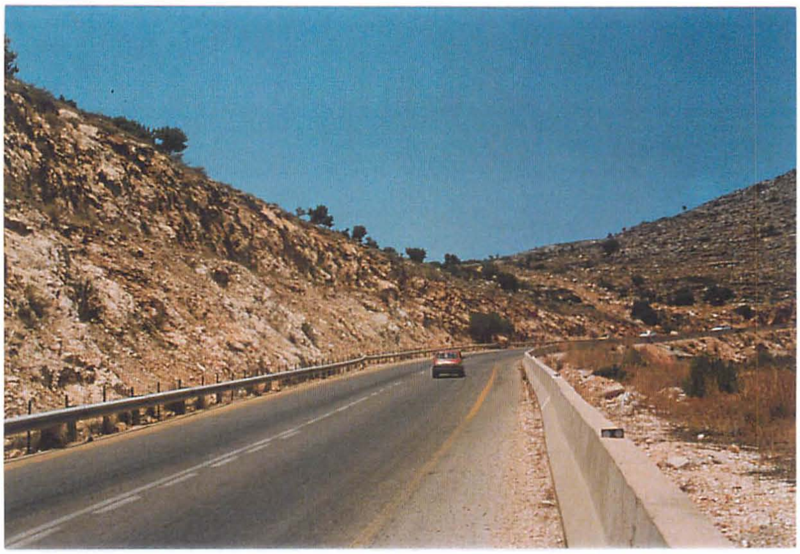


Figure 21: View to the NW on a windgap on top of a divide between the Megged Valley and the Hillazon stream. coord. 1753/2563.

Figure 23: View to the W, on a wide windgap in western Bet Kerem Valley, near Har Hagamal. coord. 171/258.

Figure 24: View to the W on a wide windgap between the Hananya and Bet Kerem valleys. coord. 187/259.

THE PALAEODRAINAGE SYSTEMS

(Fig. 20)

Based on the distribution of the different conglomerate exposures and their elevation coupled with the different morphological features, one can reconstruct the main palaeodrainage systems that drained the study area from the present Rift area to the Mediterranean in the west. The fact that the eastern part of the study area drained to the west in the past seems to be reasonable in spite of the fact that it currently drains to the eastern Rift base level which formed later due to subsequent capture of the system.

The configuration of the systems and their alignment were controlled by the structural elements and by the configuration of the base levels existing at that time, as shown schematically in Figure 22. The configuration of the western (Mediterranean) base level in Late Miocene-Early Pliocene times consists of the following elements (Kafri and Ecker, 1964; Issar and Kafri, 1972):

The Zevulun Plain is subdivided into the Qishon Graben in the south, the Hillazon Graben in the north and a central elevated horst in-between (Kafri and Ecker, 1964). Along both grabens the sea shore migrated inland, to a lesser extent in the Hillazon Graben in the north and considerably more along the Qishon Graben, where the sea penetrated through the Yizre'el Valley to the east forming a large "fjord."

The W-E directed central horst extends at least to the foothills but seems to be connected with the Shefar'am horst, forming a long E-W directed high during the time span discussed (see below).

Two Neogene channels north of the Haifa Bay, were identified by Issar and Kafri (1972). Both southern Nahariyya and northern Akhziv channels have a SE-NW direction, and similar to the former Zevulun Plain grabens, existed in Late Miocene (Tortonian) times (Issar and Kafri, 1972).

It is logical to assume that major drainage systems utilized the above elements and naturally drained into the Neogene grabens and channels as in other parts of the country. The major drainage systems, from south to north are, as follows:

(a) The northern margins of the Yizre'el Valley

Conglomerates, mostly of the Bet Nir type are exposed and were penetrated by boreholes along the northern margins of the Yizre'el Valley. In places where they overlie the Lower Basalt, they contain basaltic pebbles, but elsewhere they are devoid of any volcanic components. Where well exposed, their slope southward to the

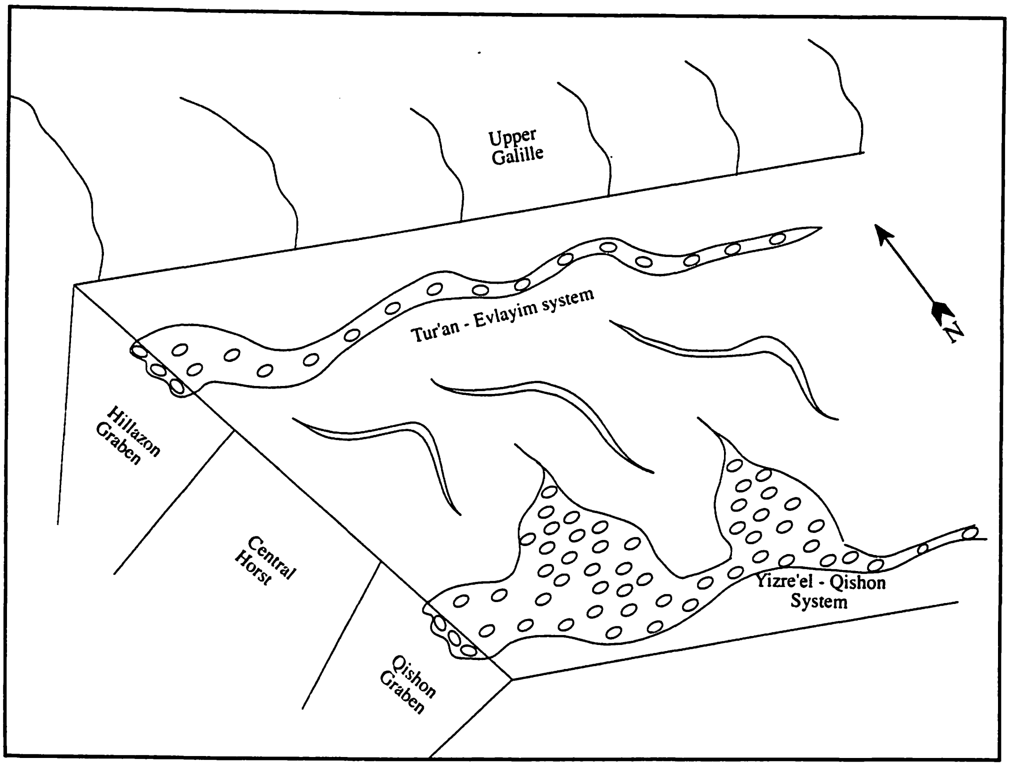


Figure 22: Schematic block diagram showing the base levels and the palaeodrainage systems.

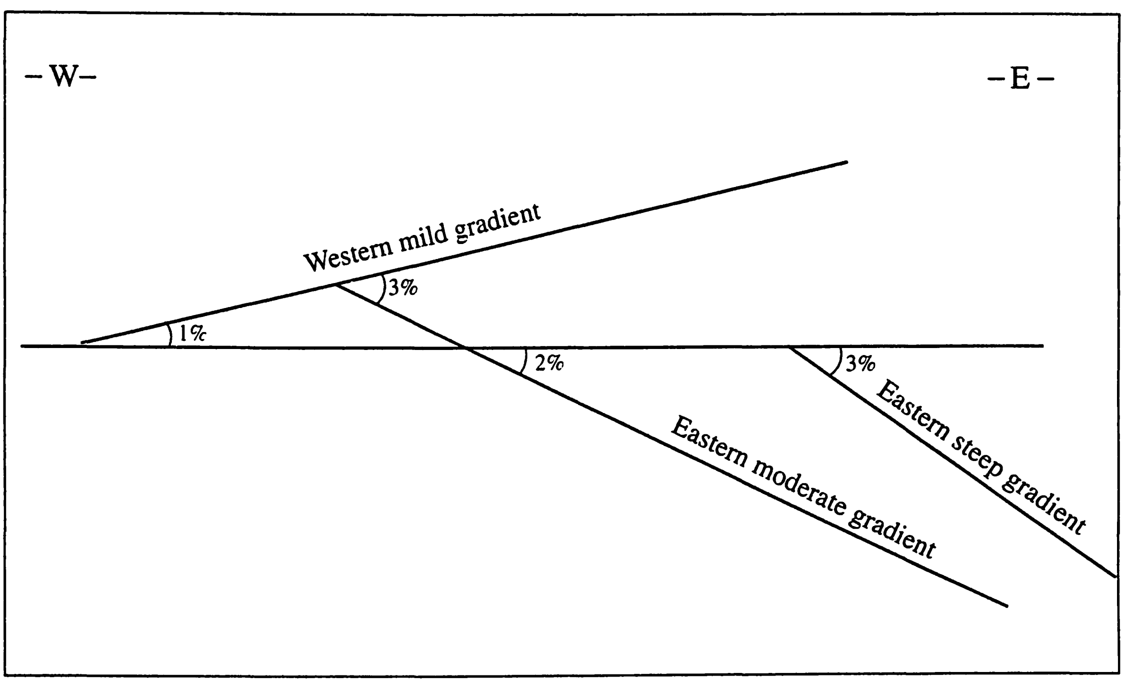


Figure 25: Scheme showing a moderate eastern gradient, the resultant of the "captured" western mild gradient to the east.

Yizre'el Valley is clear; in some places they interfinger with the Bira Marl (Fig. 12). These same conglomerates were defined as the Umm Sabune conglomerates which pass into the "Clay Series" in the subsurface of the Yizre'el Valley (Shaliv, 1991). The conglomerates are abundant along a WNW line, from Allone Abba via Migdal Ha'emeq to Biq'at Kesulot, along the northern margins of the above-noted "fjord" or Qishon Graben. A parallel zone, immediately north of it, between Shefar'am and Zippori is almost devoid of any conglomerate. This zone approximately coincides with the central horst-Shefar'am high (discussed above). This configuration allows interpreting this part of the study area as an intermediate marine-lacustrine and fluviatile base level which occupied the internal Yizre'el morphotectonic valley that terminated in the Mediterranean in the west. A series of streams drained the area between the nearby central horst-Shefar'am divide in the north southward to this base level, and from there westward to the Qishon Graben.

(b) The Tur'an-Netofa - Evlayim System

Conglomerate exposures extend along a E-W, SE-NW directed palaeodrainage system, from Lavi in the east to the Hillazon Graben in the NW. As mentioned above, this system is separated from the southern one by the Shefar'am-Zippori palaeo-divide. The exposures are found along the Tur'an Valley and the Yiftahel stream. In the Zomet Golani exposure (coord. 188/242) the conglomerate is overlain by Cover Basalt and intruded by the Mt. Tur'an dykes of Cover Basalt age (Table 2), accompanied by "baking phenomena". The Yiftahel stream turns north into the Bet Netofa Valley and then bends south to the Zippori stream, whereas the palaeo-drainage system keeps the NW direction through the Rumet Heib saddle and exposures leading to the Kefar Manda saddle (Fig. 16) and the exposures along Nahal Evlayim stream towards the Hillazon Graben. Elevations along this system (Table 1) are around 200 m above m.s.l., except for the western foothills (close to the Hillazon Graben) and the Bet Netofa area, where the exposures are found at lower elevations due to subsequent tectonic tilting and uplift, as mentioned before. North of this system, the elongated WNW directed high of the Kavul-Azmon-Netofa ridge is devoid of conglomerates and is interpreted herein as another palaeo-divide separating this system from the one north of it.

(c) The Zalmon-Hillazon system

A series of conglomerates and morphological saddles delineate this WNW system which extends from the Arbel-Migdal area in the east through the Mimlah ridge saddle to the Zalmon exposures (Peltz and Kafri, 1992; Kafri and Sass, 1996) and the Deir Hanna saddle. From there the system extends westward, through the Hillazon exposures and morphological saddles, crossing the Bet Kerem Valley and saddle (Fig. 23) and via the Izhar Valley to the Nahariyya channel, where conglomerates are found interbedded within Tortonian sediments (Issar and Kafri, 1972). Along this system the passage from the eastern (Hordos) to the western (Bet Nir) facies is recognized.

Elevations of the system in most of the central area are around 200 m above m.s.l., whereas toward the east (Rift) and west (western foothills) they decrease due to subsequent tilting, faulting and subsidence. In the Mt. Gilon area exposures are found even at higher elevations (330-360 m above m.s.l.) due to local tectonic uplift or, alternatively, they represent an older conglomerate (hinted at above).

North of this system another elongated W-E directed high, the Kamon-Hazon-Livnim ridge, is devoid of any conglomerates, forming a divide between the above system and the one to the north and northeast of it.

(d) The 'Ammud system

This system was described in detail by Kafri and Heimann (1994). An elongated NW directed strip of conglomerates extends from Lake Kinneret, close to the 'Ammud Valley toward the Hananya and Bet Kerem valleys (Fig. 24). Two generations of the system were identified, of pre-Cover Basalt age and post 2 m.y. age, draining to the northwest.

This system joined, the eastern Bet Kerem Valley roughly along the present E-W directed, upper reaches of the Zalmon stream. Subsequent uplift of the NE-SW structural axis is presently evidenced by a topographic divide between the eastern and western Bet Kerem Valley, east of Rama (Table 4, Fig. 20). This, in turn, obstructed the westward flow of the system and coupled with the formation of the Rift base level, captured the younger Zalmon stream to the south and east.

PALAEO-FLOW AND FLOW GRADIENTS

A flow gradient is obtained by drawing a longitudinal profile of a system from the watershed to the base level. In this particular case of palaeodrainage systems, some of the factors are not precisely known and have to be assumed:

(1) The locations and elevations of the respective base level of Late Miocene to Early Pliocene. to be used as reference points are obtained both from surface and subsurface data.

In the south, along the margins of the Yizre'el Valley, the conglomerates interfinger with the Bira Formation which represents the base level, and occurrences of which are found close to, or a few tens of meters above sea level. The Bira Formation is found only in the center of the valley at greater depths, due to subsequent tectonic subsidence.

In the west, in the Zevelun Plain, the base level is represented either by the shallow marine Kurdane Formation or the Bira Formation (in Nesher), found both at elevations close to,or a few tens of meters above, sea level, whereas in the Qishon and the Hillazon grabens Tortonian or Messinian marine sediments attain depths of -150 m and -110 m respectively, due to subsequent tectonic subsidence (Kafri and Ecker, 1964).

In the Western Galilee coastal plain, in the Nahariyya and Akhziv Neogene channels, Tortonian marine sediments are found, close to sea level and upto a depth of -45 m (Issar and Kafri, 1972.

(2) Elevation of exposures, in most of the central part of the study area, are around 200 m above M.S.L., except for those particular places where they subsided or were uplifted due to subsequent tectonic movements, as described before. Elevations close to the watershed, east of the Rift Valley, reach up to 350 m above M.S.L..

(3) The exact course and length of the palaeodrainage systems is unknown, and the profiles which connect the occurrences of the conglomerates between the base level and the watershed (Figs. 17, 18) represent the shortest way between both. Thus the gradients obtained are in fact maximal, due to the expected longer longitudinal profiles.

It can be seen that in most of the central area the gradients are very mild characteristic of a very flat morphology of migrating streams and floodplains (Kafri and Sass, 1996). Furthermore, the calculated maximal average gradient from the base level to the watershed (Figs. 17, 18) is between 0.4-0.5%, typical of a very mature morphology.

The present, as well as the palaeo-western flow gradients, are mature and mild, usually not exceeding 1%. The eastern drainage system, which is related to the young formations of the Rift Valley base level and its continuous deepening, shows rather steeper gradients which often exceed 3%.

The process of capturing part of the western drainage basin to the east was often accompanied by eastern streams, which utilize segments of the former western palaeo-streams, although in an opposite direction. This phenomenon was reported previously from the 'Amud stream (Kafri and Heimann, 1994), showing that those "captured" segments exhibit moderate eastern gradients, namely a resultant between a western mild and eastern steep gradients, as shown schematically in Figure 25.

Figure 26 summarizes the above phenomena in the Ammud, Arbel and Raqqat streams, which presently drain to the east partially utilizing western palaeodrainage segments. The middle, SE-trending segment has a moderate 1.7% gradient, whereas the younger upper and lower segments have a gradient of 5.3% and 2.6%, respectively.

A similar configuration is seen along the Zalmon stream. The Zalmon stream flows from N to S in its upper reaches and then turns to the west. South of Bet Kerem Valley it is captured, as described above, to the south (along a narrow gorge between Mt. Kamon and Hazon) and then flows to the south east. North of Eilabun, it turns eastward to the Kinneret base level. It is easily recognized that the young, mostly N-S directed segments of the Zalmon stream are characterized by steep gradients of 3.2% and upto 10% in the upper reaches. The other, basically SE or WNW and ESE directed segments, are those that utilize the former NW and WNW directed palaeo-drainage ststems, although in an opposite direction, and therefore exhibit moderate eastern gradients of 1.6-1.7%, as shown before in the 'Amud stream. The bend of the Zalmon stream, from north of Eilabun to the Kinneret, parallels the uplift and tilt of the Migdal-Mimlah block (ridge) which obstructed the palaeoflow, from the Arbel area to the Zalmon, and forced the young Zalmon stream to bend to the north.

The above mentioned Mimlah uplift also effected the flow direction and gradient of the Arbel and Raqqat streams (Fig. 26). The middle segment of the Arbel stream and the upper one of the Raqqat stream have a E-SE direction on the palaeo SE extension of

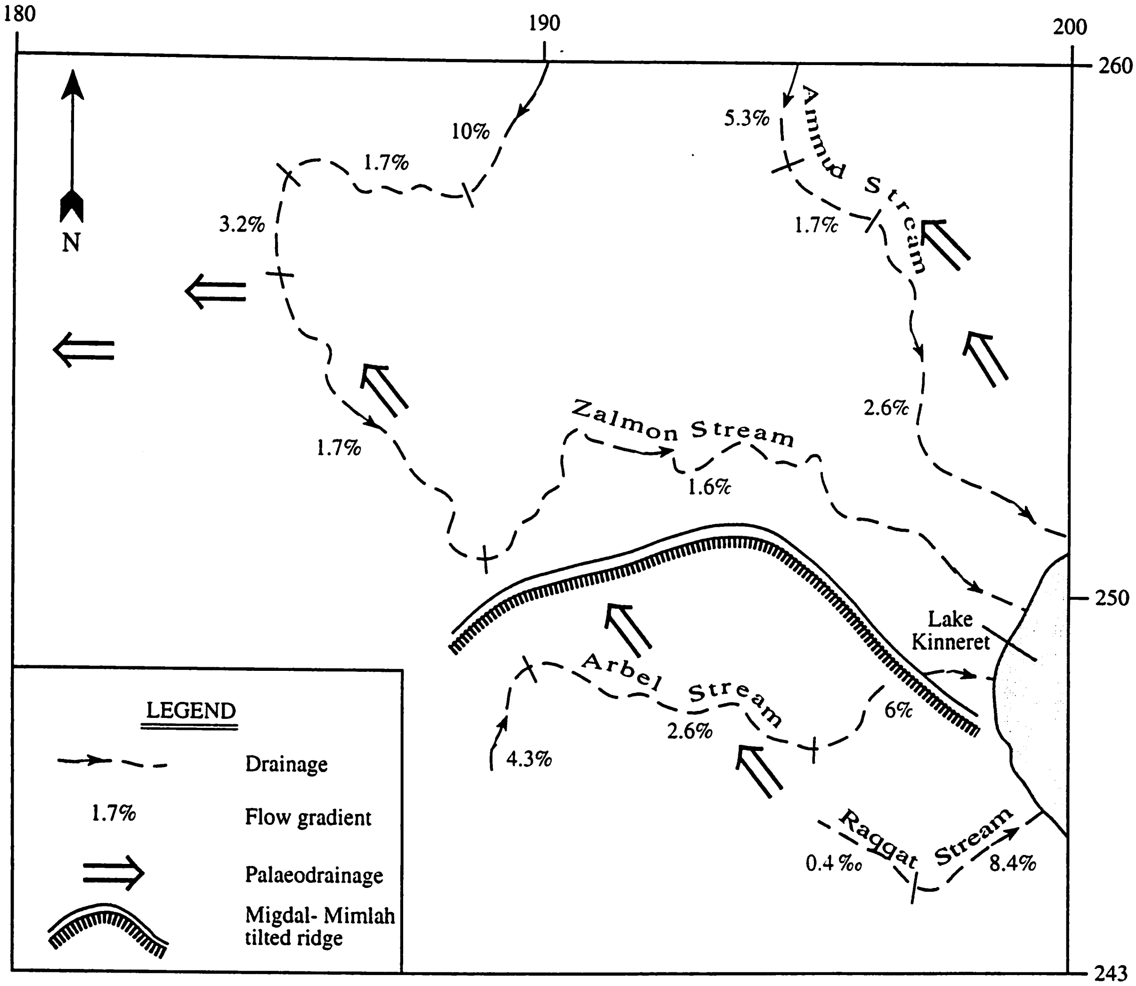


Figure 26: Map showing the present eastern drainage systems combined with palaeoflow directions and "inherited" gradients.

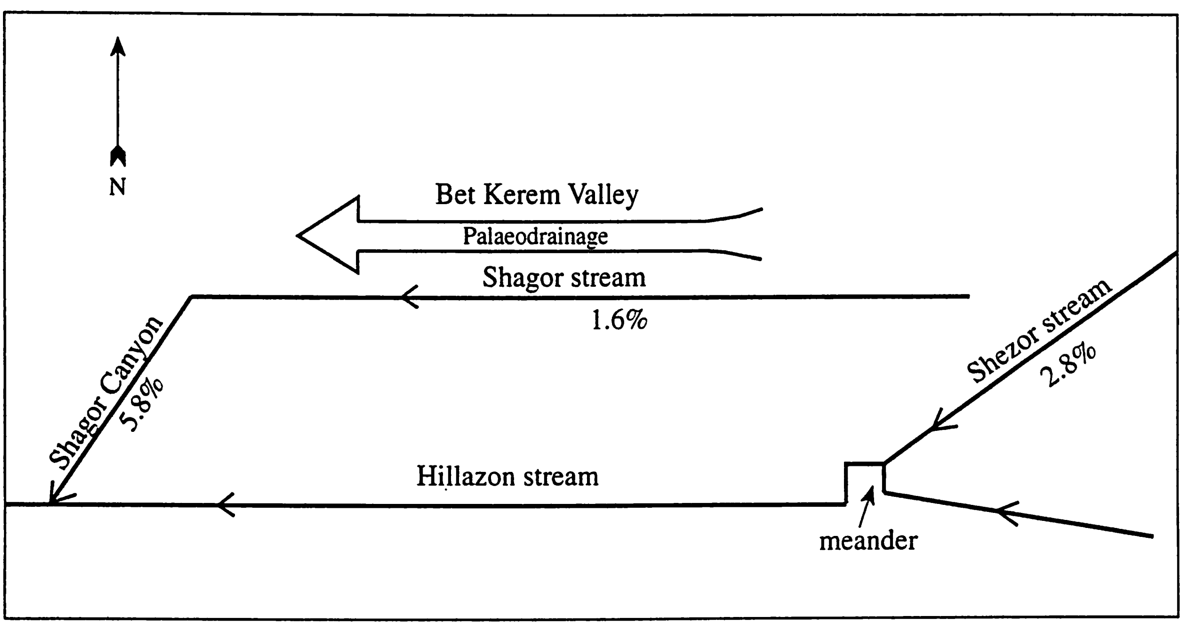


Figure 27: Scheme showing the capture of the Bet Kerem palaeo-system to the present Hillazon system and the respective gradients.

the palaeo-Zalmon stream at present separated by the Mimlah uplift. The respective gradients are 2.6% and even 0.4% in the wide Arbel Valley. Contrary to these, the young NE directed upper and lower segments of the Arbel stream and the lower Raqqat stream show steep gradients of 4.3% and 8.4% respectively.

The Bet Kerem Valley is a palaeoodrainage system that drained to the west. At present, due to the young faulting and deepening of the Hillazon Graben, the Bet Kerem Valley is captured southward to the present Hillazon stream (as schematically shown in Fig. 27). The eastern margins of the Bet Kerem Valley is captured by the young Shezor stream trending WSW and then to the south to the Hillazon meander. The average gradient is 2.8%. Further to the west the Bet Kerem Valley is captured by the Shagor stream which flows in its upper reaches to the west, utilizing the old system, with a gradient of 1.6%. In the Shagor canyon it turns SW to the Hillazon stream with a steep gradient of 5.8%. As already shown in other basins the "captured" segments that utilize old ones show moderate (1.6%), whereas the young, newly formed segments show steep, gradients of 2.8% and 5.8%.

YOUNG CAPTURE OF PALAEODRAINAGE SYSTEMS

The palaeodrainage systems in the study area were affected, as stated above, by subsequent tectonic activity which changed, mainly through capturing, the drainage configuration to that of the present. Thus, the analysis of the present drainage pattern coupled with the geometry of the new structures, enables reconstruction of the palaeodrainage systems.

The scenario which resulted in the present drainage configuration can be summarized as follows:

The palaeodrainage system, which deposited the Hordos-Bet Nir conglomerates, drained in the study areato the one and only base level, the Mediterranean, in the west. In the south, the Yizre'el valley was an intermediate base level connected and leading to the Mediterranean in the west.

Subsequent tectonic activity resulted in:

(a) Formation and continuous deepening of the eastern base level along the Dead Sea transform.

(b) Deepening of the Yizre'el Valley-Qishon Graben morphotectonic feature in the south and the Hillazon Graben in the west.

(c) Uplift and tilting of regional, mostly E-W and NE-SW directed blocks, resulting in obstruction, diversion and capture of the old drainage systems to their present course.

Some examples of these processes in the study area are:

1. The Yiftahel-Zippori-Qishon drainage system (Figs. 28, 29)

The Yiftahel stream flows, at present, in a general E-W and SE-NW direction, draining the Tur'an and Bet Netofa valleys. In the western part of the latter it turns sharply to the SW and via a narrow young gorge enters the Zippori stream.

The Zippori stream flows in a general WNW direction. In the western margins of the Zevulun Plain, it turns sharply, to the SW and joins the Qishon stream, which drains the Yizre'el Valley, flowing in a general NW direction to the Mediterranean.

As mentioned above in the past, the Tur'an and Bet Netofa valleys drained through the Yiftahel-Evlayim drainage system to the Hillazon Graben in the NW, whereas at present, this huge basin drains to the south, via the Zippori stream, to the Qishon stream. This bending and capturing of a considerable part of the catchment area to the south (Figs. 28, 29), causing an asymmetry of the basin (see below), is a result of two tectonic processes:

(a) the deepening of the Yizre'el-Qishon base level, which drew and diverted the drainage to the SW, and

(b) the young uplift of the Netofa-Azmon-Tiv'on ridge, which disconnected the Bira ingression from the sea in its western portion (Rabinovitz, 1954; Kafri and Ecker, 1964; Rotstein *et al.*, 1993). This same uplift also obstructed the NW flow direction of the Yiftahel-Evlayim system, disconnecting the two segments and causing the diversion of the Yiftahel and Zippori streams to the SW parallel to the axis of uplift.

2. The Zalmon-Hillazon system (Fig. 26)

As already shown (Kafri, 1995) and discussed above, the Zalmon system drained in the past to the NW, via the Bet Kerem and Hillazon system. Due to the formation of the eastern base level and the uplift of the Migdal-Mimlah ridge, the NW flow was

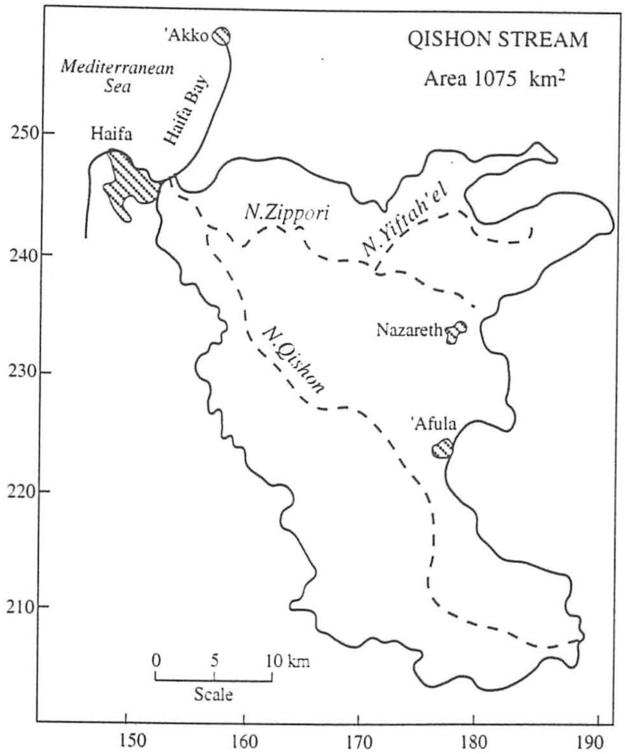


Figure 28: Generalized map of the Yiftahel-Zippori drainage system.

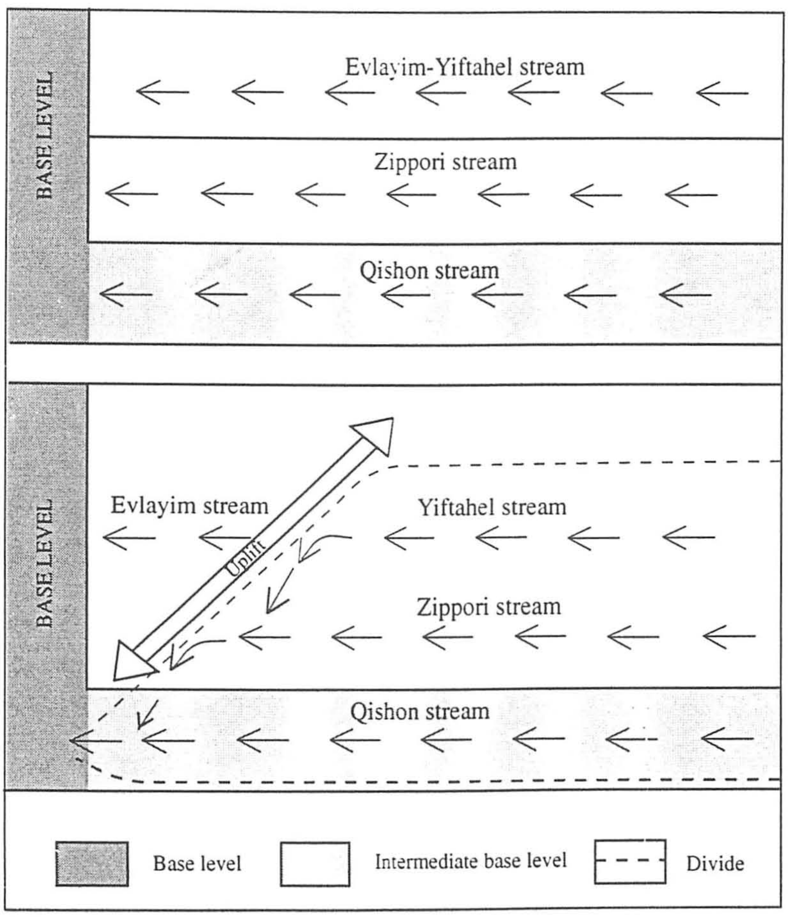


Figure 29: Scheme showing the capture of the Yiftahel-Zippori system toward the Qishon in the south.

obstructed by the uplift and the Zalmon system was captured to the east, some of its segments retaining a mature western fingerprint regarding direction and gradient.

Also, the lower reaches of the Zalmon stream were forced to make a big bend, from the NE to SE, parallel to the uplift of the Migdal-Mimlah ridge.

In the west, the palaeodrainage was through the Bet Kerem Valley and Izhar stream to the west. Due to the regional uplift of Upper Galilee and the deepening of the Hillazon Graben in the south, the Bet Kerem Valley was captured to the south and is presently drained by the Shagor and Shezor streams to the Hillazon stream, as shown schematically in Figure 27.

3. <u>The 'Ammud system</u> (Fig. 26)

As already described by Kafri and Heimann (1994), the palaeo-'Amud system drained in the past through the Bet Kerem Valley to the west. Following the formation of the eastern base level, it was captured to the east. One segment of the present system utilyzes the old system. This is concluded from its palaeo-direction and the rather mature gradients.

ASYMMETRY OF DRAINAGE BASINS

Assuming homegenous conditions throughout the entire drainage basin regarding topography, bedrock and climate, one would expect it to attain an ideal symmetrical pear shape. In this type of a basin, the surface areas of both sides of the main (1st order) stream are almost the same and the symmetry ratio, the one between the surface area of the right side to the left side (S=R/L), is approximately 1.

Drainage basins subjected to tectonic movements might obtain an asymmetric configuration, as a result of (a) asymmetric capturing of adjacent basins or (b) tectonic tilting; both examples are found in the study area. These types of asymmetry will result in symmetry ratios either below or above 1, depending on the side of asymmetry.

The symmetry ratios calculated for the main streams of Western Galilee, relevant to the present discussion are given in Table 5 and Figure 30.

The streams draining Lower Galilee, namely the Yiftahel-Zippori-Qishon system, exemplify asymmetry formed by capturing, due to the deepening of the southern base level, and obstruction of the palaeodrainage.

The symmetry ratios (Table 5, Fig. 30) exceed 1, namely a pronounced asymmetry of the right (northern) side of the basin.

Table 5: Symmetry ratios of western Galilee basins

Table 5: Symmetry ratios of some drainage basins Stream/system	**Surface area of drainage basin (km^2)**	**Surface area of right side of basin R (km^2)**	**Surface area of ledft side of basin L (km^2)**	**Symmetry ratio R/L**	**Remarks**
Qishon + Zippori + Iftahel	1075	676	399	1.9	
Zippori + Iftahel	284	224	60	3.3	
Iftahel	172	112	60	1.86	
Evlayim	50	25.5	24.5	1.04	
Hillazon	223.25	103.75	119.5	0.86	
Yasaf -west of coord. N-167 - east of coord. N-167	59.5 31.5 28	22.75 15.5 7.25	36.75 16 20.75	0.62 0.97 0.35	
Bet Ha'emeq -west of coord. N-167 - east of coord. N-167	78 21.75 56.25	53 8.5 44.5	25 13.25 11.75	2.1 0.64 3.8	Due to the uplift off Mt. Meron block in the NE
Ga'ton	42.5	16.25	25.25	0.62	
Sha'al	23.5	10	13.5	0.74	
Keziv	137.75	60.25	77.5	0.78	Values become lower from west to east
Bezet	122.25	40.25	82	0.49	Due to uplift of Mt. Meron in the SE, values become lower from W-E

The Evlayim and Hillazon streams are in the transition zone, between Lower and Upper Galilee, and in the latter the effect of tilting and uplift is more emphasized. Thus the symmetry ratios of the Evlayim and the Hillazon streams are close to 1 and somewhat above and below 1.

The drainage basins of upper Western Galilee are relatively young since their systems are incised into Upper Miocene morphology which reflects an ancient abrasion plain (Buchbinder, 1964). The young structure of upper Western Galilee is controlled by two factors: (a) uplift of the regional Mt. Meron region in the east, and (b) uplift and tilting to the N and NW of a series of approximately E-W directed blocks. The tilting and vertical displacement of these blocks are more emphasized in the east, gradually diminishing westward (Kafri, 1965, 1972b).

In this particular case of uplift or tilt the strike is closely parallel to the main stream and the latter is "shifted" downdip by backward incision updip in order to moderate the gradients which asymmetrically enlarged the uplifted side of the basin.

From the analysis of the streams of upper Western Galilee (Fig. 30, Tab. 5), the following is concluded:

1) The symmetry ratio in Upper Galilee (except for Bet Ha'Emeq stream) is below 1, *i.e.*, an asymmetry to the south as expected due to the N and NW tilting.

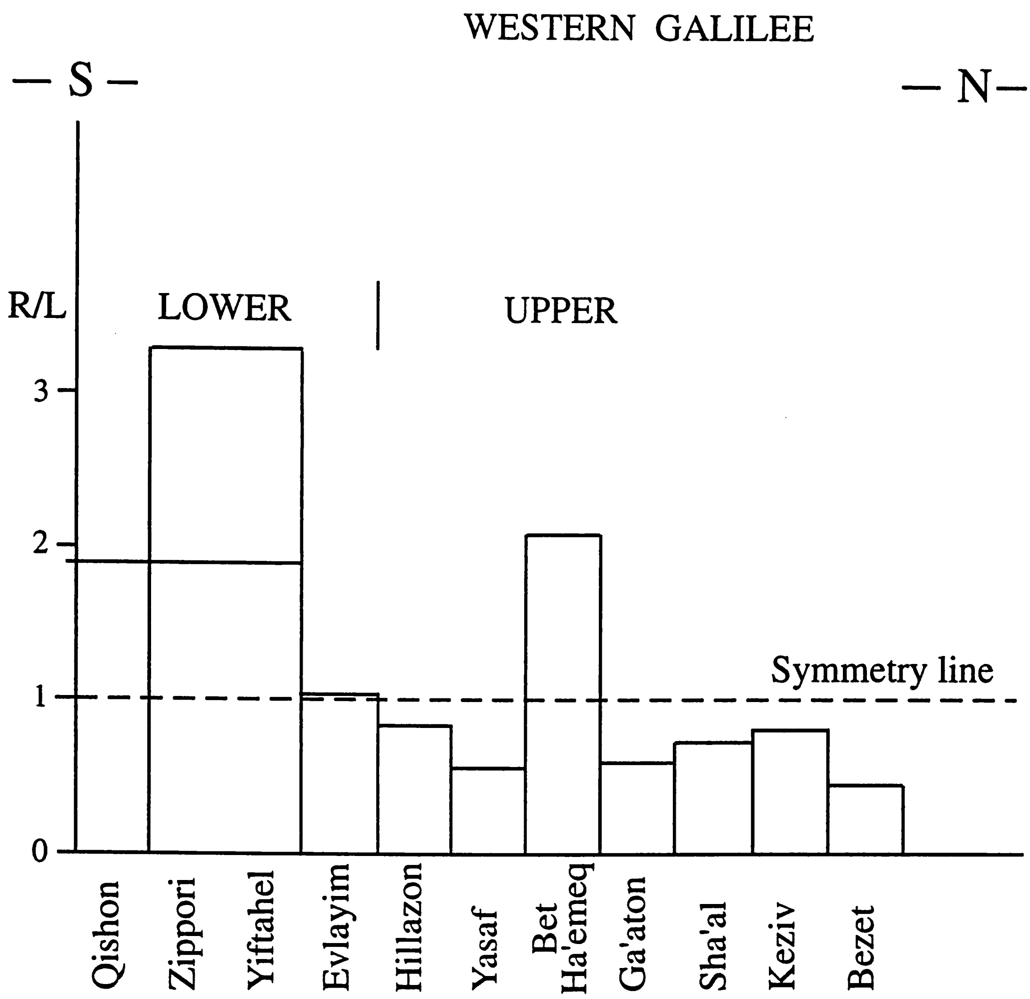


Figure 30: Bar diagram showing the change of symmetry ratios for the different Western Galilee streams.

2) Bet Ha'Emeq stream has an asymmetry to the north, due to the uplift of the Mt. Meron region, NE of it.

3) Symmetry ratios become smaller from W to E (e.g., the Yasaf and Bezet streams), due to greater tilting in the eastern part of the blocks.

As pointed out above, the symmetry within particular basins changes in different segments of the basin. Therefore a more detailed analysis is essential for the understanding of the relationship between young tectonics and basin symmetry.

A somewhat modified symmetry vector analysis method, described by Cox (1994), is thus adopted herein. Although this method was used for loose Quaternary substratum, the present study attempts to employ it for hard rock.

Following the procedure for the different basins, the basin midline and the divides were drawn, and the basins were segmented along their main courses into approximately 3 km segments. The symmetry vector obtained is: T = Da/Dd, where Da is the distance between the main stream and the basin midline, and Dd is the distance from the basin divide to the basin midline. The T value has a magnitude (between 0 along the stream line and 1 along the divides), and a bearing which shows the direction of the stream deflection from the midline.

The configuration of the above and the calculated data for the main western Galilee basins are shown and given in Figures 31, 32 and Table 6.

The conclusions obtained from the analysis of the above can be summarized as follows:

1) The Western Galilee drainage system is divided into two domains: the southern Zippori-Yiftahel system, which shows an emphasized northern symmetry (extension) of the basin and a northern domain from the Hillazon to the Bezet stream, which generally shows a southern symmetry, controlled by the tilted block system.

2) In most of the basins there is a reversal in the direction of the symmetry between the western and eastern segments (Figs. 31, 32). This happens mostly in the foothills region across longitude coordinates 171-172 in the north, and 164-167, more to the south.

In most cases the western segments show a northern symmetry and the eastern ones a southern asymmetry. In addition, the western segments, despite the northern asymmetry, are typical of small deviations of the streams from the basin midline, as compared to the east.

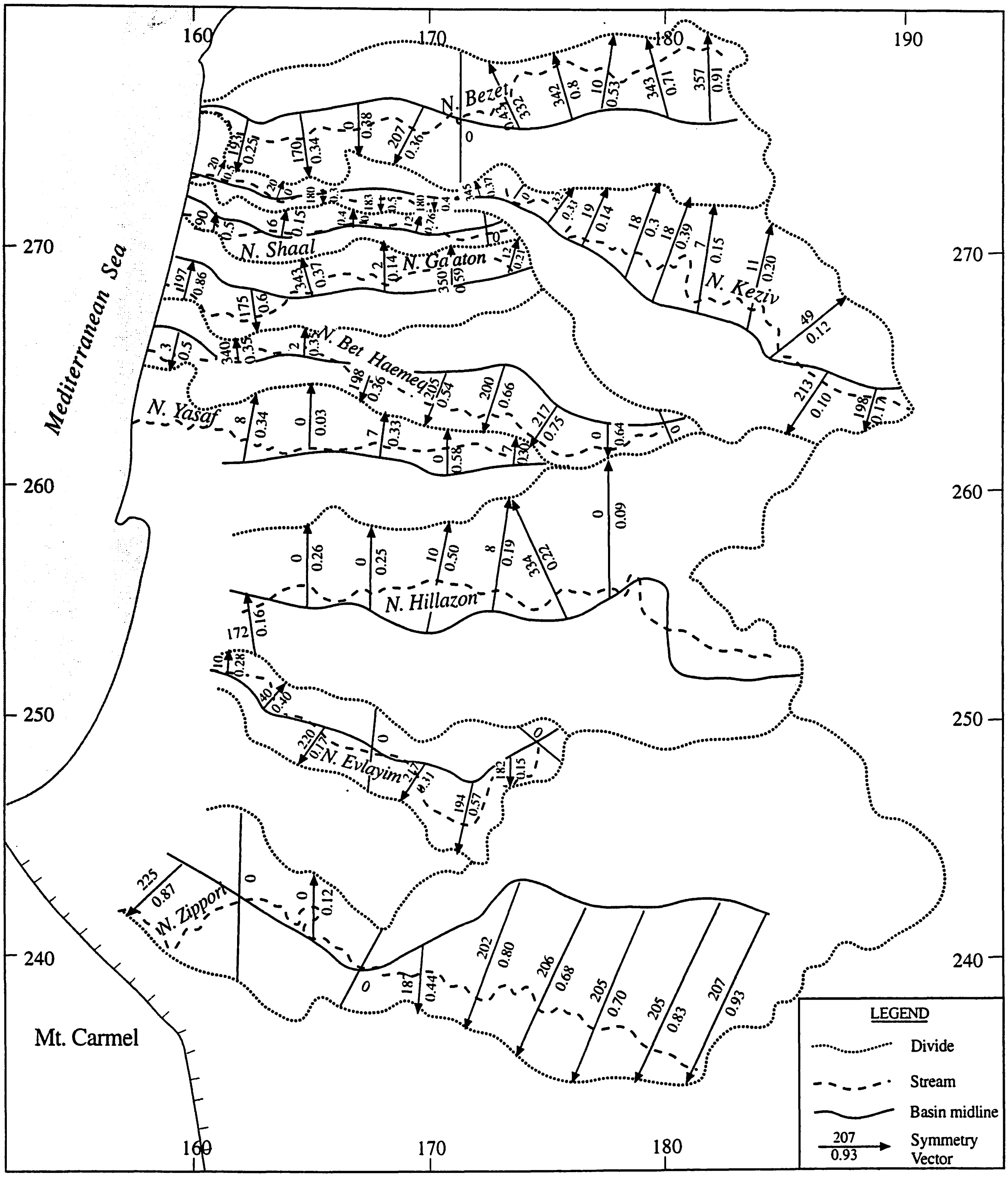
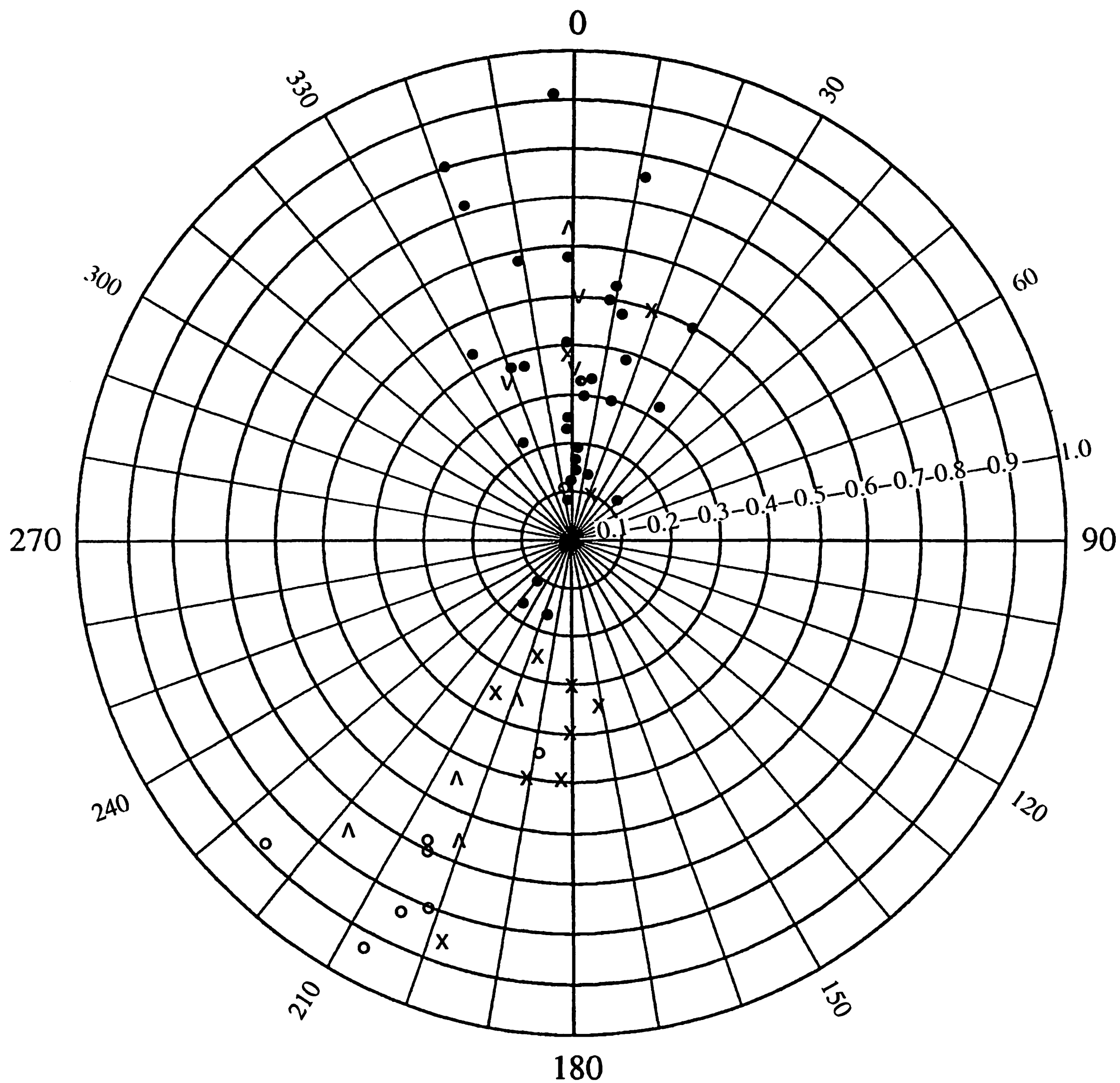


Figure 31: Map showing the Western Galilee basins and their symmetry vectors.



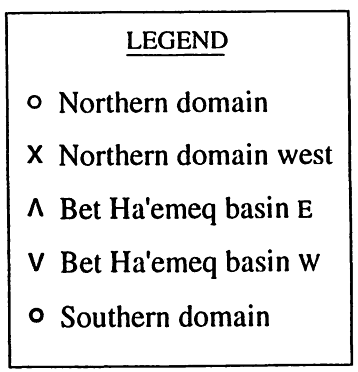


Figure 32: Polar plot of symmetry vectors of different segments of Western Galilee basins.

ACKNOWLEGEMENTS

Thanks are due to E. Zilberman and B. Katz for their constructive criticism, to C. Alafi for typing the manuscript and to B. Cohen and N. Shragai for drafting the figures.

Table 6: Symmetry vectors of western Galilee basins (Fig. 31)

No.	Basin	Data Point	Symmetry Vector Magnitude (T)	Bearing (o)
1	Bezet	W 1.1	0.25	193
		1.2	0.34	170
		1.3	0.38	0
		1.4	0.36	207
		1.5	0	
		1.6	0.43	332
		1.7	0.80	342
		1.8	0.53	10
		1.9	0.71	343
		E 1.10	0.91	357
2	Keziv	W 2.1	0.50	20
		2.2	0.10	20
		2.3	0.30	180
		2.4	0.50	183
		2.5	0.40	180
		2.6	0.37	345
		2.7	0	
		2.8	0.33	32
		2.9	0.14	19
		2.10	0.30	18
		2.11	0.39	18
		2.12	0.15	7
		2.13	0.20	11
		2.14	0.12	49
		2.15	0.10	213
		E 2.16	0.17	198
3	Sha'al	W 3.1	0.50	190
		3.2	0.15	6
		3.3	0.40	0
		3.4	0.76	12
		E 3.5	0	
4	Ga'aton	W 4.1	0.86	197
		4.2	0.60	175
		4.3	0.37	343
		4.4	0.14	2
		4.5	0.59	350
		E 4.6	0.21	12
5	Bet Ha'emeq	W 5.1	3	3
		5.2	340	340
		5.3	2	2
		5.4	198	198
		5.5	205	205
		5.6	200	200
		5.7	217	217
		5.8	0	0
		E 5.9		
6	Yasaf	W 6.1	0.34	8
		6.2	0.03	0
		6.3	0.33	7
		6.4	0.58	0
		E 6.5	0.30	7
7	Hillazon	W 7.1	0.26	0
		7.2	0.25	0
		7.3	0.50	10
		7.4	0.19	8
		7.5	0.22	334
		7.6	0.09	0
		7.7	0.17	213
		7.8	0.50	30
		E 7.9	0.48	13
8	Evlayim	W 8.1	0.28	10
		8.2	0.40	40
		8.3	0.17	220
		8.4	0	
		8.5	0.31	217
		8.6	0.57	194
		8.7	0.15	182
		E 8.8	0	
9	Zippori + Yiftahel	W 9.1	0.87	225
		9.2	0	
		9.3	0.12	0
		9.4	0	
		9.5	0.44	187
		9.6	0.80	202
		9.7	0.68	206
		9.8	0.70	205
		9.9	0.83	205
		E 9.10	0.93	207

REFERENCES

Bentor, Y.K. et al., 1960. Lexique Stratigraphique International. Vol. III- Asie. Fasc. 10c-2. Israel. CNRS Paris, 151 p.

Buchbinder, B., 1964. The geology of the Maalot Tarshiha Area. M.Sc. thesis, Hebrew Univ. Jerusalem, 37 p. (in Hebrew).

Buchbinder, B., Magaritz, M. and Buchbinder, L.G., 1983. Turonian to Neogene palaeokarst in Israel. Palaeogeogr., Palaeoclim., Palaeoecol., Vol. 43, pp. 329-350.

Cox, R.T., 1994. Analysis of drainage-basin symmetry as a rapid technique to identify areas of possible Quaternary tilt-block tectonics: An example from the Mississippi Embayment. Bull. Geol. Soc. America, vol. 106, pp. 571-581.

Folkman, Y., 1980. Magnetic and gravity investigations of the Dead Sea Rift and adjacent areas in northern Israel. J. Geophys., Vol. 48, pp. 34-39.

Freund, R., Zak, I. and Garfunkel, Z., 1968. Age and rate of the sinistral movement along the Dead Sea Rift. Nature, vol. 220, pp. 253-255.

Greenberg, Y., 1962. The geology of the Kefar Hahoresh Eilut region. M.Sc. thesis, Hebrew Univ. Jerusalem, 52 p. (in Hebrew).

Gvirtzman, G. and Buchbinder, B., 1969. Outcrops of the Neogene formations in the central and southern Coastal Plain, Hashephela and Be'er Sheva regions, Israel. Isr. Geol. Surv. Bull. 50, 54 p.

Hayati, G., 1964. The geology of the Shefar'am-Ahihud region. M.Sc. thesis, Hebrew Univ. Jerusalem, 36 p. (in Hebrew).

Heimann, A., 1990. The development of the Dead Sea Rift and its margins in northern Israel during the Pliocene and the Pleistocene. Ph.D. thesis, Hebrew Univ. Jerusalem, 83 p. (in Hebrew).

Horowitz, A., 1979. The Quaternary of Israel, Academic Press, London. 394 p.

Issar, A. and Kafri, U., 1972. Neogene and Pleistocene geology of the western Galilee Coastal Plain. Isr. Geol. Surv. Bull. 53, 14 p.

Kafri, U. and Ecker, A., 1964. Neogene and Quaternary subsurface geology and hydrogeology of the Zevulun Plain. Isr. Geol. Surv. Bull. 37, 13 p.

Kafri, U., 1965. The geology of the Segev area (western Galilee, Israel). Isr. J. Earth-Sci., vol. 14, pp. 67-75.

Kafri, U., 1972a. The lithostratigraphy of the Judea Group in central and western Galilee. . Isr. Geol. Surv. bull. 54, 56 p.

Kafri, U., 1972b. The geological map of Israel. 1:50,000, Sheet 1-IV: Nahariyya. Explanatory notes. Isr. Geol. Surv., 10 p. + maps.

Kafri, U., Kaufman, A. and Magaritz, M., 1983. The rate of Pleistocene subsidence and sedimentation in the Hula Basin as compared with those of other time spans in other Israeli tectonic regions. Earth-Sci. Planet.Lett., vol. 65, pp. 126-132.

Kafri, U. and Heimann, A., 1994. Reversal of the palaeodrainage system in the Sea of Galilee area as an indicator of the formation timing of the Dead Sea Rift Valley base level in northern Israel. Palaeogeogr., Palaeoclimat., Palaeoecol., Vol. 109, pp. 101-109.

Kafri, U., 1995. Neogene and Quaternary continental drainage systems in the lower Galilee between the Rift Valley and the Mediterranean. Isr. Geol. Soc., Ann. Meet., Field trip guidebook, pp. 1-11 (in Hebrew).

Kafri, U. and Sass, E., 1995. Hollow pebbles in Neogene conglomerates, Northern Israel. Isr. Geol. Soc., Ann. Meet., Abstr., 53 p.

Kafri, U., 1996. Sense and amount of vertical displacement related to the two main young tectonic phases in Lower Galilee. Isr. Geol. Surv. Curr. Res. 10, pp.81-83.

Kafri, U. and Sass, E., 1996. Hollow carbonate pebbles: a case study of selective secondary porosity generation, Neogene, Israel. Sediment. Geol. Vol. 103, pp. 161-174.

Levy, Y., 1983. The geological map of Israel. 1:50,000,. Sheet 3-II: Shefar'am. Isr. Geol. Surv.

Michelson, H., 1979. The geology and palaeogeography of the Golan Heights. Ph.D. thesis. Tel Aviv Univ., 163 p. (in Hebrew).

Michelson, H., Flexer, A. and Erez, Z., 1987. A comparison of the eastern and western sides of the Sea of Galilee and its implication on the tectonics of the northern Rift valley. Tectonophysics, vol 141, pp. 125-134.

Movshovitz, M., 1965. The geology of the Ein Mahil-Ilania area and the neighbourhood. M.Sc. thesis. Hebrew Univ. Jerusalem, 52 p. (in Hebrew).

Neev, D., 1979. The geology of the Kinneret. IN: The Kinneret (I. Gal., ed.). The Kinneret Authority, Zemah, pp. 15-26.

Peltz, S. and Kafri, U., 1992. Neogene pyroclastics containing peperites in the Zalmon Valley, central Galilee, Israel. Isr. J. Earth-Sci., Vol. 41, pp. 45-49.

Rabinovitz, D., 1954. The geology of the Shefar'am-Tiv'on-Bet Netofa area. M.Sc. thesis, Hebrew Univ. Jerusalem. (in Hebrew).

Rotstein, Y., Bruner, I. and Kafri, U., 1993. High resolution seismic imaging of the Carmel fault and its implications for the structure of Mt. Carmel. Isr. J. Earth-Sci., Vol. 42, pp. 55-69.

Saltzman, U., 1964. The geology of the Tabgha, Huquq and Migdal area. M.Sc. thesis, Hebrew Univ. Jerusalem, 55 p. (in Hebrew).

Shaliv, G., 1991. Stages in the tectonic and volcanic history of the Neogene basin in the Lower Galilee and the valleys. Ph.D. thesis, Hebrew Univ. Jerusalem, 94 p. (in Hebrew).

Vishkin, Y., 1973. The geological structure and the water geochemistry as the basis for understanding the hydrological regime of groundwater in the Yizre'el Valley. M.Sc. thesis, Hebrew Univ. Jerusalem, 56 p. (in Hebrew).

Weiler, Y., 1961. The geology of the Nazareth and Tabor Mts. M.Sc. thesis, Hebrew Univ. Jerusalem (in Hebrew).

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