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Climate Changes during the Holocene and their Impact on Hydrological Systems

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At a rather early stage of the research to be reported in this book, it was decided to use the connections between climate changes, hydrological and socio-economic systems in the Levant in order to establish a basic reference sequence of climate changes during the Holocene. Once this had been accomplished, this sequence would be correlated with other regions over the globe. This decision was based on the following observations.

1. This region is a transition zone between two climate belts: the westerlies system and the sub-tropical or intertropical convergence zone (ITCZ) overlying the Arabian–Sahara desert belt. The rate of movement of these two belts north and south affects the mean annual quantity of rain, as well as its variability from year to year. Consequently, the positions in the past of these belts that affect the Mediterranean region's climatic regime and hydrological cycle may provide information reflecting global climate changes.
2. The Nile, which reflects the easterlies and the tropical climate regime over eastern Africa, reaches the Mediterranean and its sediments reflect the history of the climate changes over its watershed.
3. The relatively moderate size of the Mediterranean region, causing climate changes to be rather synchronous (although not absolute) over most of the area, enables establishment of a regional climate change chronology.
4. The long history of human societies in this region, the abundance of documents and archaeological excavations, all facilitate investigation of the impact of climate changes on past socio-economic systems.

1.1 CONTEMPORARY CLIMATE

The Levant is affected by two climate systems. During winter, the westerlies bring in cyclonic low barometric pressures, causing cold air masses to arrive from the Atlantic and the North Sea. These travel over the relatively warm Mediterranean and become saturated by moisture, which is discharged as rain and snow. The rate of movement of the belts southwestward and, therefore, the number, intensity and duration of the rainstorms reaching the region, varies from year to year. When a belt of high pressure remains over the area, rainstorms are less abundant and the year is dry. Because of the configuration of the coastline of the southeastern edge of the Mediterranean Sea, the deserts of northern Egypt, Sinai, the Negev and southern Jordan lie outside the main path of rainstorms approaching from the west.

As can be seen from the multi-annual precipitation map (Fig. 1.1), precipitation usually declines to the south and the east. Yet the topography also has an influence. For example, the rift valleys are in the shadow of the rain coming from the sea and, therefore, are relatively arid, while the mountains receive more rain and snow in winter. The scarcity of rains and the high variance in rainfall from year to year become increasingly great as one goes farther into the desert. Rains in the desert, therefore, are characterized by scarcity and randomness.

Precipitation takes place during the winter months, from November to March. This is an advantage over other regions where rain falls in the summer. The temperatures during the winter are relatively low, which means that evaporation is also low. Consequently, the relative effect of the winter rains is rather high. The development of high-pressure systems often follows the low-pressure systems and causes clear and cold weather conditions. Many of the rainstorms, affected by a barometric low in the northern and central part of this region, enter the desert areas as smaller eddies on the margins of the bigger cone of low barometric pressure. They form small convective cells, a few to tens of kilometers in diameter. This causes rain to fall on a limited area around the center of the cell – other more peripheral areas may remain dry. Such a rainstorm may be of high intensity and last for only a few minutes, or it may continue for up to a few hours. Sometimes precipitation descends as hail, and it may snow at the higher elevations during a cold winter. Rainstorms may be preceded by a barometric high over the desert area. In this case, a flow of dry, hot air from the desert blows dust, which flows in the direction of the barometric low. In the autumn and spring, when dust storms are most abundant, the hot,

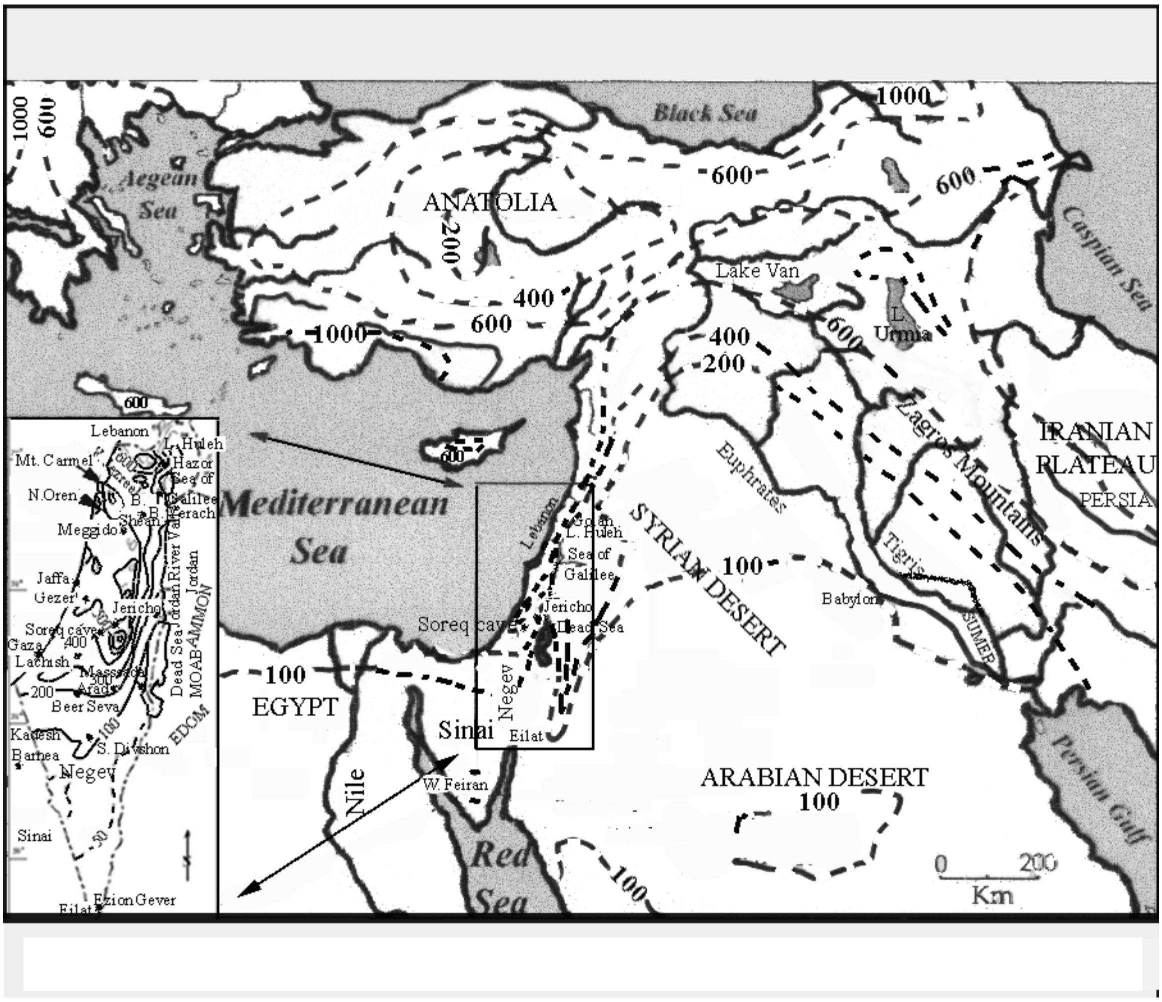

Fig. 1.1. Map of the Middle East showing the multi-annual precipitation (mm per year).

dry periods (known locally as *khamsin*) can come to an abrupt end with a heavy rainstorm. Most dust storms are connected with a barometric high over the continent and lows approaching from the sea.

The Mediterranean Sea acts as a gigantic temperature regulator, because of the high heat capacity of the water. As distance from the sea increases, the regulatory effect decreases. As a result, the temperature differences between day and night, as well as seasonal temperatures, are high. The influence of the Red Sea, the Dead Sea and the Persian Gulf, which are enclosed in narrow depressions, is limited to their very close vicinities. Thus, in the desert areas, the differences between day and night temperatures may reach 15 °C and in some extremes even 20 °C. In summer, the temperature can reach 40 °C during the day, while during the night it drops to about 25 °C. On a winter night, the temperature may fall below 0 °C, while during the day it may reach 20 °C. Ambient air temperature increases in a directional pattern, similar to that of regional precipitation. (In northern Syria, the average temperature is 5 °C in January and 24 °C in August; in Beirut, it is 13 °C in January and 27 °C in August.)

For inhabitants of these areas, the severity of the high and low temperatures is compensated for by the dryness of the weather during most of the year. This relieves heat stress, since perspiration can evaporate. Humans will feel comparatively comfortable if not exposed to direct sun radiation. However, the dryness causes high evaporation rates from the surface of water bodies and high transpiration rates from vegetation.

During the summer, the weather is less variable, being affected by the semi-permanent surface heat trough centered over Iran and Iraq. This surface trough is coupled with an upper air high-pressure system, producing stable, hot and dry weather. During the autumn (mainly October to November), cool and moist air masses occasionally penetrate the region from the north and produce rainfall. Spring (mainly March to April) is characterized by frequent occurrences of *khamsins* and dust storms, although some rainfall may occur.

Overall, six main air masses, originating over the following areas, affect the weather over the Levant:

1. The Arctic Ocean;
2. The Atlantic Ocean, south and west of Iceland;
3. Northern Russia and Siberia;
4. Northern Russia, being modified while passing over the Volga–Ural basins;
5. The Atlantic Ocean south of the Azores;
6. The North African and Syrian–Arabian desert.

Air masses of the first four areas originate at high latitudes and are characterized by low temperatures and dryness. The masses acquire moisture as they pass over the Mediterranean Sea. The last two air masses originate at low latitudes and are characterized by high temperatures, and dryness, which they maintain.

Rainfall in the Middle East, on the whole, has an inverse correlation with temperature, except in areas under the influence of the summer rainfall regime (Crown, 1972). A synoptic analysis of excessive rainfalls in Israel (Amiran and Gilead, 1954) shows that they are the result of an influx of deep, moist and cold polar air into the eastern Mediterranean along meridian trajectories, which makes contact with the warm surface air in a Cyprus low. With the build-up of the Siberian anticyclone as winter progresses, this situation becomes less probable. There is less chance of a strong jet stream forming over central Europe and the Mediterranean that would feed sufficient air into such a rainfall-causing circulation system. Such excessive rains are, therefore, restricted to the beginning of the season, i.e., November or December.

Aridity in the Levant has three general causes (Otterman, 1974):

- separation of the region from oceanic moisture sources owing to distance or topography (rain shadow);
- the existence of dry stable air masses that resist convective currents;
- the absence of a course of events that cause convergence to create unstable air masses and provide the lifting necessary for precipitation.

Zangvil (1979) investigated the temporal fluctuations of seasonal precipitation in Jerusalem during the period 1946/47 to 1953/54. He employed time spectrum analysis and filtering techniques. A prominent peak appeared in the spectrum at a period of 3.0–3.3 years. (Rainfall oscillations in California also show a peak around 3 years.) The most prominent peak in the spectra occurred at 3.3 years at most of the East African stations. A more than average rainfall in east Africa during the main rain period of January to April is probably associated with a more intense Hadley circulation. This circulation causes strong westerlies in the same longitude, resulting in reduced rainfall in the eastern Mediterranean. Zangvil (1979) suggests that there is, perhaps, a connection between the El Niño southern oscillation (ENSO) and the rainfall in Jerusalem. The ENSO is a world-wide phenomenon, having a dominant period of 3 to 6 years, which corresponds to Jerusalem rainfall oscillations, the first peak at 3.0–3.3 years and the secondary one at 5 years. A similar observation for the eastern part of the Iberian peninsula was found by Rodó *et al.* (1997).

Analyses of the multi-annual trends of variation of precipitation (Alpert *et al.*, 2002; Ben-Gai *et al.*, 1998) have shown that, while there is a general decrease in the overall quantities of precipitation over the Mediterranean region, there is a trend for an increase in the number of rainstorms of high intensity and for either rainier or drier years within the average rainstorms and years.

1.2 THE CLIMATE DURING THE LATE PLEISTOCENE

In general, the climates during glacial periods of the Quaternary, evidenced in the Mediterranean region by sea regressions, were cold, while interglacial and post-glacial periods, evidenced by transgressions, were warm and dry (Horowitz, 1989). In the coastal plains this resulted in the accumulation of black and brown clayey soils in the marshy areas and red loamy soils on the sandstone outcrops. In the mountain areas on the limestone rocks, terra rosa type soils developed. During the interglacial periods, the deposits of sands and the formation of coastal dunes along the coastal plain indicate a warmer and drier climate, as well as an increased supply of sands. These were brought from the delta of the Nile by the Mediterranean counter-clockwise currents (Emery and Neev, 1960; Issar, 1968, 1979; Rohrlich and Goldsmith, 1984). However, during a short period at the climax of the glacial periods, it seems that the climate became dry (Bar-Matthews *et al.*, 1997), possibly because it fell under the influence of the continental high-pressure zone of eastern Europe. The climate during the Last Glacial Period was not different, namely generally cold and humid, except during its climax. During this glacial period, the water found under the Negev and Sinai deserts in the Nubian sandstone layers was recharged. This is evidenced by its carbon-14 (^{14}C) age (which ranges between 30,000 and 20,000 (30 ka and 20 ka) while the oxygen-18 (^{18}O) to deuterium ratios show an Atlantic, rather than a Mediterranean, pattern (Gat and Issar, 1974). By comparing these ratios with the isotopic composition of contemporary rains and their relation to the trajectories of the rainstorms (Leguy *et al.*, 1983), Issar and Bruins (1983) have suggested that during the Last Glacial Period, a west to southwest trajectory of cyclonic lows was dominant. These came over the Mediterranean to reach the Sinai and the Negev, after entering and crossing the Libyan desert and Egypt. These lows intensified dust storm activity, to be followed by torrential rains. This caused the deposition of a loess layer some tens of meters thick (Issar, 1990). In the southern Sinai, shallow lakes extended all along the drainage basin of Wadi Feiran; the ^{14}C dates of the sediments were 24 ka BP (Issar and Eckstein, 1969). At the end of the glacial periods, at *c*. 15 ka BP, the deposition of loess became considerably less and, instead, the activity of sand dunes was extended. In the sand layers overlying the loess, epi-Paleolithic type tools were found (Goring-Morris and Goldberg, 1990; Issar and Tsoar, 1987; Issar *et al.*, 1989). Geyh (1994), on the basis of isotopic oxygen and carbon in the paleo-water under the deserts of the eastern Mediterranean, came also to the conclusion that the movement southward of the ITCZ can explain the pronounced climatic variations that characterized the transition from the Late Pleistocene Epoch to the Holocene Epoch. When warmer conditions prevailed, the regions governed by the westerlies became drier while the monsoonal regions became more humid (Geyh, 1994).

A calcareous layer is found in the upper part of the loess section all over the northern Negev (Bruins, 1976; Bruins and Yaalon, 1979). It was deposited *c*. 13 ka BP, according to radiocarbon dating by Goodfriend and Magaritz (1988). Whether this calcareous horizon is synchronous with the deposition of the loess or was formed later needs further investigation. In my opinion, it is epigenetic and the result of flushing of carbonates and sulfates from overlying layers and their deposition at a certain depth during a period of higher summer rains. This is inferred from the composition of the heavy oxygen and carbon isotopes in the stalagmites of Soreq Cave, which rose abruptly from 13.5 ka to *c*. 11.5 ka BP (Bar-Matthews *et al.*, 1997). The higher ^{13}C/^{14}C ratio points to the increase of C4 type vegetation, while the higher ^{18}O/^{16}O ratio suggests a warmer climate. These two indicators together would indicate a savanna landscape. In such a landscape, the topsoil becomes enriched in salts during the dry period as a result of evapo-transpiration, while during the rain season these salts are partially leached downwards because of the general decrease in precipitation caused by the warmer climate. The fact that the summer rains coming from the Indian Ocean system were abundant during this period is indicated by the freshwater lake deposits in the erosion cirque of Djebel Maghara in northern Sinai (Goldberg, 1977). Abundant arboreal pollen from this period, which was found in the central Negev, is additional evidence for a savanna habitat in a region that at present holds only a few trees along the riverbeds.

During the Last Glacial Period, the paleo Dead Sea, which at that time extended over most of the Jordan Valley and was known as Lake Lisan (Picard, 1943), clearly had a humid period during the Late Pleistocene, resulting in Lisan-type greenish-gray and laminated clay sediments (Neev and Emery, 1967). Lake Lisan proper was first formed *c*. 70 ka BP and after a few fluctuations it reached its maximum level of approximately 164 m below MSL at *c*. 25 ka BP. It stayed at this level for about 2000 years and then the level started to fall until, at *c*. 10 ka it was approximately 325 m below mean sea level (MSL) (Bartov *et al.*, 2002), or even 350 m below MSL (Begin *et al.*, 1985).

Stiller and Hutchinson (1980), investigating the stable isotopic composition of carbonates of a 54 m core in Lake Huleh, northern Israel, found ^{18}O data which suggested that no very drastic climatic changes occurred.

Based on palynological data, Van Zeist (1980) claims that from 24 ka to 14 ka BP it was colder and markedly drier than today and from 14 ka to 10 ka BP, there was an increase in temperatures. Many sites suggest a distinct rise in humidity around 14 ka BP.

Pollen diagrams from Lake Zeribar, Kurdistan, Zagros Mountains (El-Moslimany, 1986) show the absence of trees during the last glacial period and the migration of forest into the region between 10 and 5.5 ka BP. This has been interpreted as indicating aridity during the Pleistocene, with gradually increasing precipitation during its late glacial phase and the Holocene. However, the sensitivity of these species (*Quercus aegitops* and the associated *Pistacia atlantica* var. *mutica* and *Pistacia khinjuk*) to snow and their tolerance of low overall precipitation indicate that higher snowfall, rather than low precipitation, was the reason they did not thrive during the Pleistocene.

Stevens *et al*. (2001) investigated a core from the same lake and argue that low ^{18}O values would suggest a relative increase in winter rains rather than overall changes in effective moisture, and vice versa. Also Griffiths *et al*. (2001) argue for changes in the seasonality of the rains as an important factor in determining the nature of the sediments at Lake Mirabad, which is situated in the same region.

Based on continuous pollen diagrams from boreholes that penetrated the entire Quaternary sequences of the Hula (Huleh) and Dead Sea lakes, Horowitz (1979, 1989) concludes that the Dead Sea served as a continental base level throughout this period. According to Horowitz, the glacial phases in Israel were manifested by periods of somewhat lower temperatures and higher rainfall, some of it in the summer. The interglacials were hot and dry, with Saharan conditions prevailing. The interstadials had the character of a present-day short, rainy winter and a long, dry, hot summer. It is possible that short dry phases might have occurred in Israel at peaks in the glacial phases, but in general, the periods recorded by low sea levels had a wet climate.

Leroi-Gourhan (1974, 1980, 1981), investigating pollen spectra in the Middle East, found that there were fluctuations of wet and dry phases as well as of temperature during the Lower and Middle Würm. The cold–wet maximum seems to be dated around 45 ka BP, while drought conditions characterized the coldest Würmian phase. This probably explains the scarcity of archaeological evidence of occupation between 23 and 19 ka BP. The Late Glacial Period showed some improvements in climate, dated to 17 ka, 13.5 ka and 12 ka BP. Thereafter, a richer and more diversified flora marked the beginning of the Holocene. Leroi-Gourhan maintains that the increase in pastoral and agricultural population densities since 10 ka BP influenced the soils and vegetation. There is enough evidence to allow us to conclude that it became more humid at about 10 ka BP.

Data from the pollen time series from epi-Paleolithic and Neolithic sites in the Jordan valley, including the regions of Fazael and Mallaha, led Darmon (1988) and Leroi-Gourhan (Leroi-Gourhan and Darmon, 1987) to suggest the following climate changes for the transition period from the Pleistocene to the Holocene:

1. Kebaran (*c*. 19 ka–14.5 ka BP): slightly humid;
2. Geometric Kebaran (*c*. 14.5 ka–12.5 ka BP): a humid period;
3. Natufian (*c*. 12.5 ka–10.3 ka BP): a humid period in the Early Natufian, but the climate progressively becoming drier through the end of the Natufian period;
4. Pre-pottery Neolithic ((PPN) A: *c*. 10 ka to 9.5 ka BP): wetter, marked development of trees, *c*. 10 ka BP; relatively forested conditions between 10.25 ka and 7.9 ka BP.

Weinstein (1976) investigated the late Quaternary vegetation of the northern Golan, manifested by the pollen assemblage of samples from borehole P/8, drilled at the center of the lake of Birket Ram. This is a rather small, elliptical volcanic crater lake, 900 m × 600 m, bordered by very steep slopes. The present average annual precipitation is 1000 mm. The fluctuations in pollen samples seen in this section are significant, and a more intensive dating effort should be carried out since dates are rather scarce. A gradual change from a more forested landscape to a Mediterranean one can be seen in the upper part of the section, from 39 to 30 m (at 36 m, ^{14}C age is 28,400 ± 3000 BP). The assemblage is 80% arboreal pollen, of which conifers constitute 88%. From 30 to 22.5 m, the arboreal assemblage is reduced to 33%, consisting of 75–80% *Quercus* sp. and 40% Irano-Turanian types. From 22.5 to 11.5 m, there is an increase in the arboreal assemblage to 60%, of which 89% is *Quercus* sp. and only 20% Irano-Turanian types. One can conclude that towards the upper part of the profile, presumably uppermost Pleistocene, the climate became more humid.

A geomorphological study was carried out by Sakaguchi (1987) in the district of Palmyra in the eastern arid part of Syria (present mean annual precipitation is 125 mm). This survey provided the evidence for the existence of a pluvial lake, which went through periods of high and low levels since at least 100 ka BP. A wet period of the lake ended *c*. 19–18 ka BP; later it became brackish to saline and totally dried up, leaving behind a sabkha. At 10 ka BP, it rejuvenated and existed until 8 ka BP.

A study by Klein *et al.* (1990), of fossil and modern *Porites* corals from reef terraces in the southeastern Sinai along the Red Sea, indicates that the sea level was higher and a wetter climate prevailed in Sinai during the Late Quaternary, possibly with a summer rainfall regime. Most fossil corals showed degrees of fluorescent banding after irradiation with long-wave ultraviolet light, while living *Porites* corals did not exhibit distinct fluorescent banding. The source of fluorescence is humic acid of terrestrial origin, as was found in corals from the Great Barrier Reef of Australia (Isdale and Kotwicki, 1987). The distinct fluorescent banding in the fossil Sinai corals is understood to be a function of periodic terrestrial runoff floods during the lifetime of the corals, irrespective of later events. Modern corals show skeletal banding patterns: low-density bands being deposited in summer and narrow high-density bands in winter. Fossil corals have a similar density-banding pattern. An important finding is that the fluorescent bands related to humic acid from runoff floods are superimposed on the low-density portions of the skeleton bands, which implies summer rainfall (Klein *et al.*, 1990). This is in accord with the conclusion, already mentioned, that during warmer periods the climate of Sinai was influenced by summer rains.

According to Herman (1989), surface water temperatures of the Mediterranean, during glacial temperature minima, were *c*. 3 °C lower than the present in summer and *c*. 3–4 °C lower in winter. Salinities were highest during the peak of the glacial period when climates were more arid than today. The sea level was very low (130–140 m below MSL); the discharge of the Nile was greatly reduced and the connection between the Mediterranean Sea and the Black Sea (Bosphorus sill at 36 m below BSL), which is a major supplier of low-salinity water, was reversed.

Thunell and Williams (1983, 1989) investigated the paleo-temperature and paleo-salinity history of the Eastern Mediterranean during the Late Quaternary. They maintain that the Mediterranean isotopic signal is a complex record of regional temperature and salinity changes superimposed on compositional changes caused by the global ice volume effect. Hydrographic conditions in the Mediterranean at 8 ka BP must have been considerably different from those at 18 ka BP as well as from those of today. The water balance at 8 ka BP became positive as precipitation and runoff exceeded evaporation. Salinities were considerably lower at 8 ka BP and the west–east (increasing) salinity gradient was reversed to an east–west gradient. This is supported by east African climate records, which indicate the onset of very humid conditions at *c*. 12.5 ka BP, with wettest conditions occurring between 10 ka and 8 ka BP. This was also a time of intensified African monsoons and increased Nile discharge.

Larsen and Evans (1978) reported on findings from layers of the Hammar Formation in the subsurface of the present delta of the Shat-el-Arab. These contained recent marine fauna. They consider these findings as evidence for a transgression phase starting *c*. 10 ka BP. The fresh and brackish water deposits with marine lenses overlying the Hammar Formation are interpreted as layers laid down in a deltaic environment, caused by the progradation of the delta to the southeast. This has advanced *c*. 180 km during the last 5000 years

Sanlaville (1992) carried out geomorphological investigations of the paleo-climate of the Arabian Peninsula and found that these four humid phases occurred during the Quaternary. The two earliest stages, between *c*. 128 ka and 105 ka BP (isotopic stage 5e) and between 85 ka and 70 ka BP (isotopic stage 5a), as well as the last one, which took place during the earlier part of the Holocene, could be correlated with northward movement of the monsoon rains. He attributed the wet inbetween phase, which occurred during isotope stage 2, to a southward migration of the westerlies belt.

It can be concluded that the transition period from the Pleistocene to the Holocene was one of general warming up, but with considerable fluctuations. In general, the frequency and intensity of the typical heavy dust and rainstorms, causing the deposition of the loess, decreased and, instead, the supply of sand and mobility of the sand dunes of the Sinai and Negev increased. This increase in the supply of sand resulted from the higher levels of the Nile and the strengthening of the rainstorm system over eastern Africa, The sand supply to the eastern Mediterranean was, probably, reinforced by the erosion of the Nile delta caused by the rise in the sea level. A warm period characterized by summer rains may be distinguished between 13 ka and 11 ka BP. This may have been followed by a cold humid spell, which more accurate dating may correlate with the Younger Dryas. This was followed by a warmer period, which continued until about 10.5 ka BP.

1.3 CLIMATE CHANGES DURING THE HOLOCENE IN THE LEVANT

The initial procedure adopted by the author to establish the sequence of climate changes during the Holocene was based on a chrono-stratigraphical cross section derived mainly from the sequence of ratios of $^{18}O/^{16}O$, with the ratios of $^{13}C/^{12}C$ as auxiliary data (Fig. 1.2). These isotopic data came from a core from the bottom of Lake Van in Turkey (Lemcke and Sturm, 1997), from a core at the bottom of the Sea of Galilee (Stiller *et al.*, 1983–84), from speleothemes of caves in upper Galilee (Issar (1990) based on M. A. Geyh *et al.*, unpublished data) and from the Soreq Cave in the Judean hills in the central part of Israel (Bar-Matthews *et al.*, 1998a,b) and from cores at the bottom of the eastern most part of the Mediterranean Sea (Luz, 1979; Schilman *et al.*, 2002). Needless to say, each time series has its advantages as well as constraints, especially when it comes to the dating of the various layers. Consequently, the time boundaries suggested in this cross section (Fig. 1.2) should be taken as a synthesis and a marker zone, which may fluctuate on the time dimension either because of the natural environment or because of the different methods of sampling and dating.

The reason for choosing sequences of ratios of $\delta^{18}O/^{16}O$ (the relative proportion of ^{18}O to ^{16}O in the sampled water compared with the isotopic composition of standard mean ocean water (SMOW)) as the most significant time series was because these ratios are strongly influenced by the ambient temperatures and climate regimes in general (Ferronsky and Polyakov, 1982; Fritz and Fontes, 1980; Gat, 1981) but are not influenced by anthropogenic activities. It was also assumed that, in the Middle East, the influence of climate changes on the $\delta^{18}O/^{16}O$ ratio could have been rather pronounced, based on the observation that the isotopic composition of contemporary rainwater is influenced by the trajectories of the rainstorms (Leguy *et al.*, 1983). There is no reason to suggest that such changes in the global climate regime would not have equally influenced these trajectories, and thus the $\delta^{18}O/^{16}O$, in the past. Therefore, interpretation of the stable isotope data as climate and humidity indicators follows the basic assumption that the $\delta^{18}O$ values of precipitation are interrelated with temperature (Geyh and Franke, 1970) and with other meteorological factors (such as changes in the storm trajectories, in the seasonal distribution of precipitation and humidity (Gat, 1981; Leguy *et al.*, 1983) and higher or lower rates of evaporation). This assumption was indeed justified by the interrelations that could be shown between the isotope time series and other proxy-data time series, as will be shown below.

As already mentioned, when correlation lines are drawn, small discrepancies caused by the dating and time scales used in the different data sources must be taken into consideration. These apply to the different amplitudes of the $\delta^{18}O$ records of the lake and sea sediments and of the speleothemes. For example, the water balance of the Sea of Galilee is also determined by an inflow of groundwater from the flanks of the rift valley. Spring water collected along the shore yielded ^{14}C dates of more than 10 ka BP. This would “dampen” the corresponding isotope variations. A certain retardation factor should be taken into consideration for the isotopic composition of the sediments of Lake Van, where part of its inflow comes from springs. In contrast, changes in $\delta^{18}O$ values of speleothemes reflect the fluctuations of isotope composition of the meteoric water over decades. The samples of 1 mm thickness analyzed represent age ranges of about 10 years.

In addition to the problems involved in the ^{14}C dates in relation to the isochrones, some other elements must be taken into consideration. First, the curves presented in the cross sections are modified by the running average method, in order to reduce the impact of noise created by short-term but intense fluctuations. Second, there are differences caused by the reservoir effect of the non-saturated and saturated zones in the subsurface of speleothemes, which is similar to the effect of groundwater storage for springs. Yet even with all these uncertainties, an apparent general

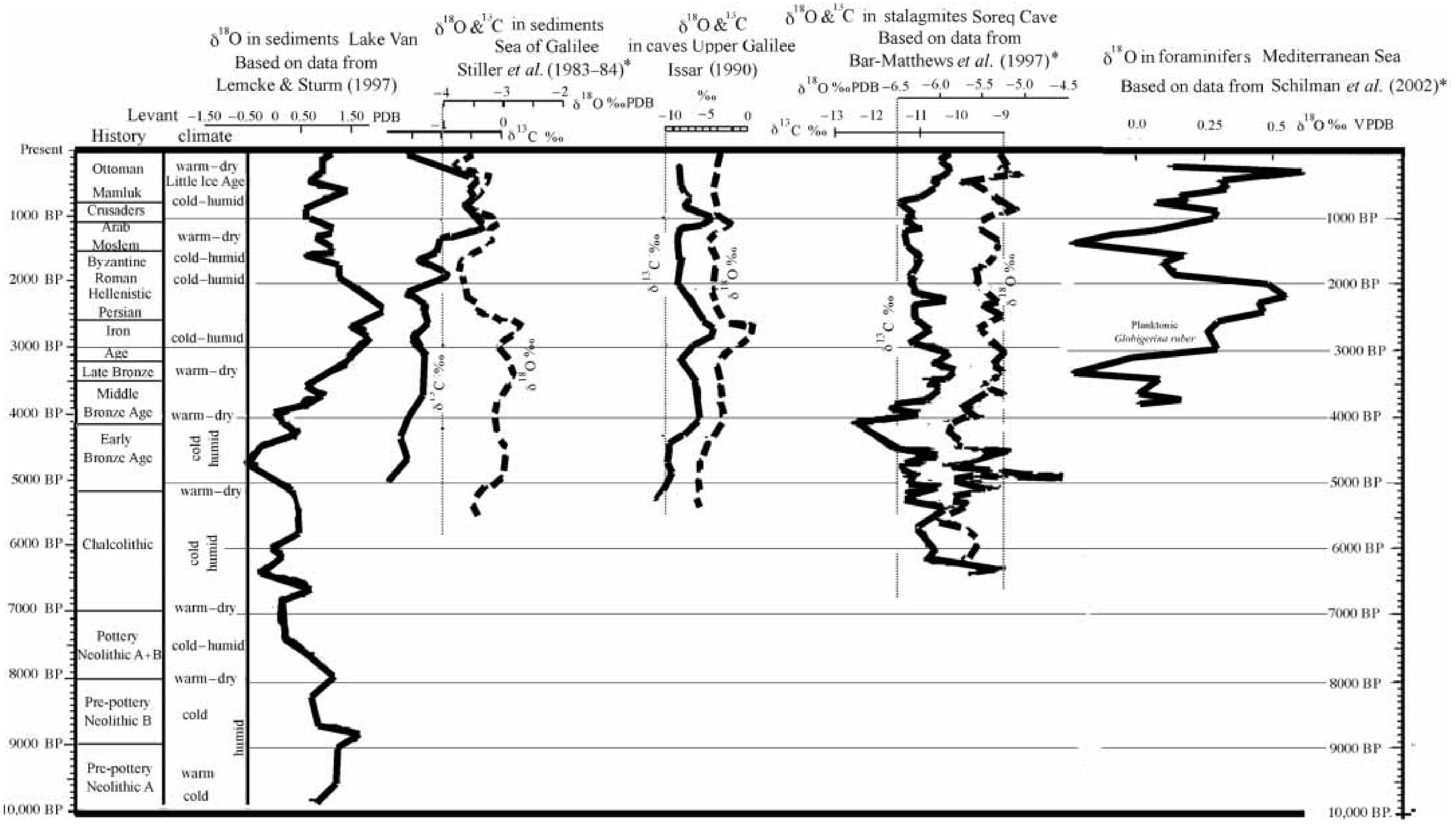

Fig. 1.2. Time series for environmental isotopes in the Middle East. *Adjusted to scale and streamlined (3–5) points by the running average method.

correlation of covariations can be observed. However, because of the problems outlined above, it is suggested that conclusions should also take into consideration other time series of natural proxy-data that are available for this region. These include the paleo-levels of the Mediterranean Sea, the ratios of planktonic foraminifers in the sediments of the eastern Mediterranean, and the Dead Sea lake levels (Fig. 1.3).

As presented in Fig. 1.2, the cross section starts with the δ^{18}O and δ^{13}C time series obtained from lacustrine carbonate cores drilled in Lake Van in Eastern Turkey (Lemcke and Sturm, 1997; Schoell, 1978), which is a closed lake at an altitude of 1720 m above MSL. The precipitation on the drainage basin of the lake is influenced by the Mediterranean climate system. The isotopic investigation is part of a general study that has been carried out by a multidisciplinary group (Degens *et al.*, 1984.) The lake has a volume of 607 km^3 and a maximum depth of 451 m and is in a tectonically active zone in eastern Anatolia. The lake level was at its highest at the height of the Last Ice Age, about 18 ka BP when it was 72 m above the present level. According to the pollen analysis, the vegetation was of a steppe type from 10 ka to 6.5 ka BP; from 6.5 ka to 3.4 ka BP, it was forest vegetation and from 3.4 ka BP to the top of the section, the vegetation is contemporary and shows the impact of agriculture. The drop in the level of the lake and the increase in the salinity of the water between 10 and 9 ka BP were interpreted as a change to a warmer and dryer climate. This can be observed in a trend towards a heavier composition of the ^{18}O/^{16}O ratios in the isotope curve. Around 7 ka BP, there was a rise in the level of the lake, a decrease in its salinity and a marked increase in the percentage of arboreal pollen. This is interpreted as a change to a more humid climate. One can observe a simultaneous decrease in the ^{18}O/^{16}O ratios. At *c.* 3.5 ka BP there is again a sharp decrease in the ^{18}O/^{16}O ratio, which reaches its lowest level at 2.7 ka BP and marks another cold period. Because of the increase in agricultural activities since then, the pollen and sedimentological records may present the impact of anthropogenic processes, and the author prefers to rely mainly on the isotope curve, which shows relatively low ratios from 1.8 ka to *c.* 0.8 ka BP, a heavier composition between 0.8 ka and 0.5 ka BP and an increase in the ratio at the top of the column.

Another isotopic composition time series, presented in Fig. 1.2, is that from a core taken from the Sea of Galilee (Stiller *et al.*, 1983–84). This lake is fed by the Jordan River, and by the floods and springs from Galilee and the Golan Heights. Thermal springs also flow into the lake. The base flow of the Jordan is maintained by the outflow of springs emerging from the aquiferous Jurassic limestone rocks of Mount Hermon, in the eastern part of the Anti-Lebanon. These rocks are highly permeable and the water from the rain falling on the mountain and from the melting snow, which covers the higher stretches of the mountain each winter, quickly infiltrates the subsurface to enrich the aquifer from which these springs arise. The average annual precipitation on the mountains may reach 1200 mm. The two main springs feeding the upper Jordan are the Dan and the Banias (comes from Pan, the Greek god patron of springs). Because of high permeability and the high rate of precipitation, the water flow of these two major springs is fairly regular. The difference between summer and winter is regulated by the large underground storage of Mount Hermon. A long spell of dry years and low snowfall on the drainage basin may cause a decrease in the total quantity of water in the springs, leading to a reduction in the flow of the Jordan and a low water level in the Sea of Galilee. This is intensified by a decrease in the volume of the floods and by higher evaporation rates from the lake, causing the levels of the lake to drop. One may assume that the ratio of ^{18}O/^{16}O in the carbonate sediments will be higher in such years. While the precipitation on the catchment area of the springs emerging from the southern tip of Mount Hermon is high, the precipitation on eastern Galilee and the Golan Heights, which form the catchment area of the floods and springs, is less abundant, and the rates of flow are strongly influenced by the average annual rainfall.

The reinterpretation, carried out by the present author, of the δ^{18}O/^{16}O sequence from this core was correlated with the δ^{13}C/^{12}C, data, assuming that depleted ratios signify more humid conditions, and thus abundant C3 types of vegetation, while a heavier composition indicates a drier climate and abundance of C4 type of vegetation.

Only four ^{14}C dates (at 5240 ± 520, 2955 ± 220, 2170 ± 125, 1020 ± 115 BP) were taken, the oldest one of which was near the bottom of the core hole at *c.* 5.0 m. Nevertheless, the spread of the dated samples along the column, and the body of other proxy-data available, in addition to δ^{18}O/^{16}O, ^{13}C/^{12}C ratios (i.e., percentage of $CaCO_3$) and the detailed pollen analysis (Baruch, 1986; Stiller *et al.*, 1983–84), enable this time series to be used to interpret climate changes in the region during the upper half of the Holocene.

These data have been used by the author in his argument against the prevailing paradigm which claims that no significant climate changes occurred during the upper part of the Holocene and attributes all environmental changes to human activity (Issar, 1990). This is also the case with the data from the Sea of Galilee (Stiller *et al.*, 1983–84), which were initially interpreted as reflections of anthropogenic factors rather than climate changes.

The examination of this core (Fig. 1.2) enables us to distinguish various zones. Zones of high δ^{18}O/^{16}O and δ^{13}C/^{12}C ratios are from *c.* 5.0 ka to 4.5 ka, from 2.8 ka to 2.3 ka, from *c.* 1.5 ka to *c.* 1.2 ka and, finally, at 0.4 ka BP. Zones with only high δ^{13}C/^{12}C ratios are from 4.2 ka to 3.5 ka and at 1.8 ka BP. Toward the uppermost part of the δ^{18}O/^{16}O curve, starting at *c.* 0.3 ka BP, there is a trend to heavier ratios.

The other δ^{18}O and δ^{13}C time series presented in Fig. 1.2 average the results of 41 stalagmites taken in 10 caves in Galilee,

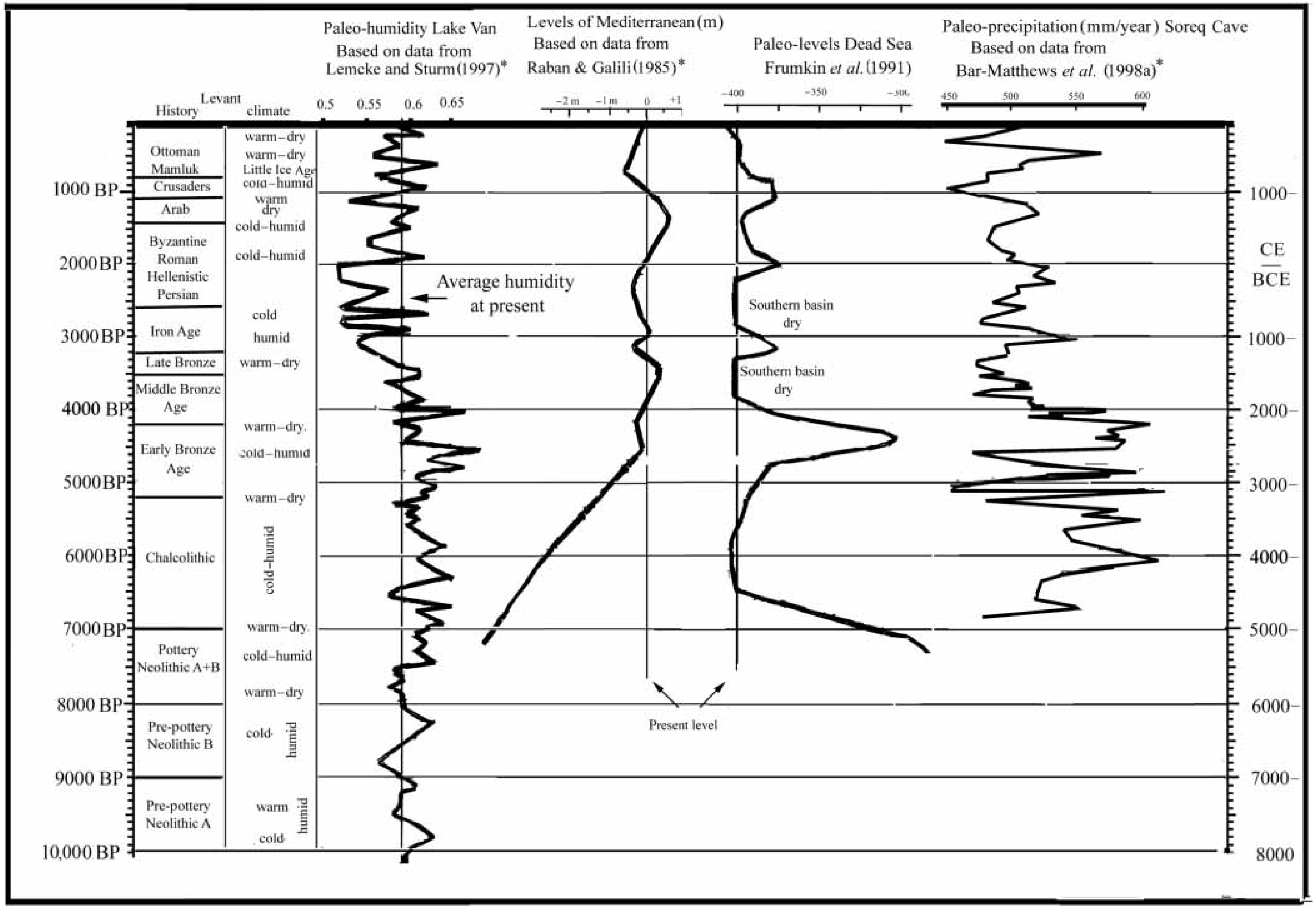

Fig. 1.3. Paleo-hydrology time series in the Middle East. *Adjusted to scale and streamlined (3–5) points by the running average method.

northern Israel. The age determination for all the sequence was from calibration of ^{14}C and uranium/thorium ($^{234}U/^{230}Th$) dates. Precisions of *c.* 300 years have been obtained, taking a reservoir effect of 900 years into account (Geyh *et al.*, unpublished data). Therefore, speleotheme ages are considered to be calibrated dates with a ± 300 years margin of error. That these dates, within this margin of error, are reliable can be deduced from the close similarity between this speleotheme curve and the one from the Sea of Galilee. Periods of heavy isotopic composition occurred *c.* 4 ka, 3.8 ka and 1.2 ka BP, while periods of light compositions occurred *c.* 4.8 ka, 3.3 ka, 2.0 ka and 1.0 ka BP.

Another sequence of $\delta^{18}O/^{16}O$, forming a time series of paleoclimatic significance, is of a speleotheme from a cave in the vicinity of Jerusalem, in the mountainous part of central Israel (Fig. 1.2; Ayalon *et al.*, 1998; Bar-Matthews *et al.*, 1991, 1993, 1996, 1997, 1998a,b). The age determinations were made by the $^{230}Th/^{234}U$ method (Kaufman *et al.*, 1998). The isotopic record, which is traceable for the last 58 ka, shows a pronounced difference between the values characterizing the speleothemes that were formed before 6.5 ka BP and those formed later, including the contemporary deposits. This, according to Bar-Matthews *et al.* (1998a,b), is probably because of altogether different climatic regimes.

This is an important observation with regard to the exact time dimension that is suitable to provide proxy-data for simulations using general circulation model (GCM) scenarios. Climate scenarios of the Pleistocene (glacials and interglacials) are not suitable whereas that starting *c.* 6 ka BP is. With regard to the climate changes during the last 6.5 ka, the team working on the speleothemes of Soreq Cave (Ayalon *et al.*, 1998; Bar Matthews *et al.*, 1998a,b) have calculated the paleo-rainfall values by correlating the paleo-$\delta^{18}O$ records with the contemporary ratios of $\delta^{18}O$/rainfall. Based on the $\delta^{18}O$ and $\delta^{13}C$ values and calculated paleo-rainfall, they divide the record into four stages. Stage 1 lasted from 6.5 ka to 5.4 ka BP and was very wet. During the period extending from 5.6 ka to *c.* 3.0 ka BP (stage 2), the climate was, in general, humid, interrupted by four short dry spells. One was between 5.2 ka and 5.0 ka and another was at *c.* 4.0 ka BP. Stage 3, lasting from *c.* 3.0 ka to *c.* 1.0 ka BP, was transitional to drier and more stable conditions. Stage 4, from *c.* 1.0 ka BP to the present, was characterized by fluctuations in rainfall. The high values between 0.4 ka and 0.5 ka BP may be connected with the Little Ice Age, while the increase in $\delta^{13}C$ values, which started *c.* 0.7 ka BP, may indicate a process of deforestation and increased grazing during the Turkish period.

The curve of $\delta^{18}O$ composition of pelagic and planktonic foraminifers (Luz, 1991) is not too conclusive. In general, changes in the $\delta^{18}O/^{16}O$ values reflect changes in oceanic temperatures and the water in which the animals lived. Such ratios in foraminifers' shells in deep-sea sediments enabled the establishment of the sequence of climate changes during the Quaternary (Emiliani, 1955). This, however, is mainly seen in planktonic assemblages. The isotopic record for the benthonic forms shows low fluctuation because of the relatively stable temperature of the water at the bottom of the sea. Shackleton and Opdyke (1973) have demonstrated that the changes in isotopic values reflect the changes in the continental volume of ice as melted glacier water causes the water of the oceans to become isotopically lighter. It is certain that the fluctuations in the isotopic composition between glacial and interglacial periods resulted from the glacial effects (Bowen, 1991). However, it seems that the isotopic composition of the Mediterranean Sea is more complicated as the isotopic record from cores taken from the Mediterranean Sea also seems to reflect local changes. Consequently the isotopic composition of the Mediterranean Sea reflects not only climatic parameters such as precipitation, evaporation and residence time of water mass within the basin but also the hydrological regimes of the Black Sea, the Nile and the Atlantic Ocean.

From the ratio of $\delta^{18}O/^{16}O$ of the epi-pelagic foraminifer *Globigerinoides rubes*, Rossignol-Strick *et al.* (1982) found that the oxygen isotopic composition ratio decreased through several large shifts to minimal values between 8 and 6 ka BP (see also Luz and Perelis-Grossowicz, 1980). The sharp depletion in $^{18}O/^{16}O$ ratio and the lowering in salinity from 8 ka to 7 ka BP may represent the heavy Nile floods during a mainly rainy period in Africa (Nicholson, 1980; Nicholson and Flohn, 1980), and it seems likely that the Nile was the major source of fresh water responsible for the low salinities in the Mediterranean Sea. However, the Nile water, coming from areas of low latitude, should be isotopically heavy. In a recent work, Luz (1991) suggested an alternative explanation for the isotopic depletion. He claimed that a high influx of low-salinity water entered the Mediterranean Sea from the Black Sea when the rising sea surface reached the level of the Bosphorus. This alternative explanation is not in agreement with the findings of Erinc (1978), who concluded that, even though the sea level rise in the Black Sea and in the Mediterranean Sea started simultaneously after the peak of the last glacial period, the Black Sea basin was disconnected from the Mediterranean. Moreover, the rise in sea levels caused the intrusion of the Mediterranean into the Black Sea. Cores obtained in the Black Sea (Degens, 1971; cited in Erinc, 1978) indicate, "that the main intrusion of saline water into the Black Sea started 7140 ± 180 years ago". In conclusion, it is clear that the reasons for the changes in oxygen isotope composition of the foraminifers of the Mediterranean have yet to be elucidated. In their book *Noah's Flood: The New Scientific Discoveries about the Event that Changed History*, the marine geologists William Ryan and Walter Pitman (1998) argue that this intrusion (around 7500 years ago) was caused by the breaching of the barrier at the Bosphorus, at the northeastern part of the Sea of Marmara, which filled up an ancient lake, the predecessor of the Black Sea, the level of which was 150 m lower than the present sea level. This caused a tremendous waterfall of seawater flooding the lowlands surrounding the ancient lake, a calamity for the people in the Neolithic agricultural communities that lived in this region. They further claim that this calamity lived on in the memory of the people who survived and migrated into Mesopotamia. The stories told were passed on from one generation to the next until they crystallized in the mythological texts found on ancient clay tablets of ancient Mesopotamia. At a later period, these stories were incorporated into the Hebrews' sacred scriptures and became part of the Judeo–Christian–Moslem heritage. Issar and Zohar (2003) maintain that the findings of an ancient flood filling up the Black Sea to its brim is, undoubtedly, of the greatest importance for the understanding of the prehistory of Europe and Central Asia during the Lower Holocene (i.e., 10 ka to 5 ka BP). And yet, this discovery should not be mixed up and confused with the Biblical Flood.

Schilman *et al.* (2001, 2002) examined two cores drilled at the sea bottom in the southeastern part of the Mediterranean near the shores of Israel for oxygen and carbon isotope composition as well as for physical and geochemical properties of the sediments. The date of the lowest layer of the sequence is *c*. 3.6 ka BP. According to Schilman *et al*. (2001, 2002), the δ^{18}O values of the planktonic foraminifer *G. ruber* suggest that humid phases took place between 3.5 ka and 3.0 ka and between 1.7 ka and 1.0 ka BP, while arid conditions prevailed between 3.0 ka and 1.7 ka BP. At *c*. 0.8 ka BP, a warm period, the Medieval Warm Period, took place and at 0.27 ka BP, a cold period, the Little Ice Age, occurred. Schilman *et al*. (2001, 2002) also suggest a long-term trend of aridization that started *c*. 7.0 ka BP in the mid–low-latitude desert belt and has continued until the present. They base their suggestion on the long-term slight increase in δ^{18}O values of planktonic foraminifers, which corresponds with a gradual decrease in the δ^{13}C values of both *G. ruber* and the benthos foraminifers *Uvigerina mediterranea*. This trend is concurrent with an increase in sedimentation rates, the titanium/aluminum (Ti/Al) ratio, magnetic susceptibility and color index of the sediments. Schilman *et al.*, suggest that this general long-term warming up, and thus aridization, reflects a gradual change in the δ^{13}C of the dissolved CO_2 of the entire southeastern Mediterranean water column, which parallels the global rise of atmospheric CO_2 observed for the late Holocene. They suggest that this is a result of terrestrial biomass destruction during the aridization process and the gradual reduction of the vegetation cover in east Africa, which led "to an increased erratic flood-related sediment flux via the Nile River. This is reflected by the general change in the local sediment composition. At 3.6 ka ago, the Saharan eolian input reached 65% whereas at about 0.3 ka ago 70% of the SE Mediterranean sediment was composed of Nile particulate-matter." I prefer to put more emphasis on the relative fluctuations of the isotopic composition and sedimentary sequence rather than on the general trend. As can be seen from Fig. 1.2, the two peaks of light oxygen isotopes (*c*. 3.40 ka and 1.4 ka BP), which suggest an influx of melted glacial water (i.e., a warm climate), correspond to two major warm periods: the Late Bronze and the Arab period. A secondary light oxygen period occurred at *c*. 0.7 ka BP, which corresponds to the Mamluk–Ottoman warm phase. The two peaks of heavy oxygen isotopes (*c*. 2.30 ka and 0.3 ka BP) correspond to two cold periods: the Roman and the Little Ice Age. A secondary cold period occurred at *c*. 1.0 ka BP, which corresponded to the Crusader period. I would also interpret the change in the sediment characteristics differently. The higher loess load at *c*. 3.60 ka BP could be the result of the inflow of loess from the higher rate of dust storms and floods in northern Egypt, Sinai and Negev during the Middle Bronze Age (MB), which was relatively (to the Intermediary and Late Bronze periods) cold and humid. The higher sand supply at *c*. 0.3 ka BP would be a function of the general warming up that started at *c*. 1.4 ka BP, which brought higher rates of easterly rainstorms over northeastern Africa and higher supplies of sand from the Nile. This corresponds with the post-Byzantine invasion of sand dunes into the coastal plain of Israel.

The curve reconstructing the sea-level changes along the coastline of central Israel, presented in Fig. 1.3, is by Raban and Galili (1985). It is based on a survey of archaeological sites along the Israeli coastline, with submarine as well as surface structures. It incorporates the results of the work of Galili *et al.* (1988), who reconstructed ancient sea levels between 8 ka and 1.5 ka BP along the coast line of Mount Carmel, and the conclusions of the survey of Bloch (1976), who based his observations on the altitude of ancient salt production basins. The curve of Raban and Galili (1985) shows that, since the lower Holocene, the sea level has risen to reach that of the present day. Between 8 ka and 6 ka BP, the sea level rose at a mean annual rate of 5.2 mm. According to these authors, no tectonic movements have occurred in the area during the last 8000 years. The most pronounced recessions of sea levels shown on this curve are between 4.5 ka and 4.0 ka BP, between 3.5 ka and 3 ka BP, between 2.5 ka and 2 ka BP and *c*. 0.7 ka AD. The periods of high sea level are around 5 ka BP, between 4 ka and 3.5 ka BP, from 3 ka to 2.5 ka BP and *c*. 1.4 ka BP. A trend toward a higher sea level can be seen after 0.5 ka BP. It is suggested that the periods of low sea levels correlate with periods of cold climate, that is, periods of expansion of polar glaciers, while during periods of high sea level the climate was warm and the glaciers melted.

While high levels of the Mediterranean indicate periods of warm climate and vice versa, high levels of the Dead Sea during the Holocene indicate cold and humid periods. This is because the Dead Sea is located at the lower end of the Jordan catchment basin, and its levels are determined by the amount of precipitation on this basin and the rate of evaporation from its surface. The curves of the levels of the lake presented in Fig. 1.3 are based on a survey of ancient shorelines and erosion channels inside the salt caves of Mount Sodom (Frumkin *et al.,* 1991). The results are in agreement with a prior survey that was based on ancient shorelines (Klein, 1982). The periods of high lake levels were found to have occurred *c.* 8 ka, 4.5 ka, 3 ka, 2 ka and 1 ka BP, while periods of very low levels, which most probably caused the drying up of the southern part of the Dead Sea, occurred *c.* 6.5 ka and 2.5 ka BP. In assessing the evidence from these curves, we have to take into consideration the fact that higher and younger lake levels may obliterate the evidence of older but lower levels.

A rather similar pattern of climate changes could be deducted from the carbon and oxygen isotope values investigated in a speleotheme in Nahal Qanah Cave, central Israel (Frumkin *et al.,* 1999).

1.4 CORRELATION BETWEEN CLIMATE CHANGES AND HISTORICAL EVENTS IN THE LEVANT

The climate changes derived from the curves presented in Figs. 1.2 and 1.3 were correlated with archaeological-cultural chrono-stratigraphy, especially as it relates to the history of the settlements in the desert regions (Issar *et al.,* 1989, 1992; Issar, 1990, 1995a,b; Issar and Makover-Levin, 1995). As will be shown presently, a rather good correlation was found. Consequently, it is suggested that the archaeological chrono-stratigraphy should be used as the paleo-climate stratigraphy of the Holocene for the Eastern Mediterranean region. One must be aware that the dating of the environmental time scale is mainly by ^{14}C methods whereas archaeological dates are also based on the history of civilizations, particularly those that left written documents. In the present work, dating is based also on data presented as non-calibrated ^{14}C ages. The reason for this is that the order of magnitude of correction in the first half of the Holocene is a few hundred years, which is the order of magnitude of the accuracy of the time series of the proxy-data presented in these sections. This lack of accuracy is mainly because the dating intervals in a certain section are rather sparse yet, in order to get a general sequence of climatic changes, the intervals between the dated intervals are assumed to represent periods of uniform deposition. Although it is accepted that this may reduce the accuracy of the chrono-stratigraphical division, it is still argued that it does not change the interpretation of the general pattern of climate changes during the lower part of the Holocene.

In the upper part of the Holocene, namely after *c.* 4 ka BP, the difference between the relative and absolute time scales diminishes as one progresses along the time dimension, and this, too, is within the boundaries of accuracy attainable for fixing the incidences of the climate changes based on proxy-data time series. We must also take into consideration the fact that the correlation lines of iso-impact of climate change between various regions will cut iso-chronological lines, because of the difference in the pace of response of different systems and different regions. The correlation between climate changes and historical events should be considered as giving the general framework of concurrencies rather than that of the particular events. These general lines will be discussed in the following sections from the climatological, hydrological, archaeological and socio-economical aspects. When correlations between the proxy-data curve and archaeological events are given, the calibrated dates will be given, while the archaeological dates will refer to the BCE–CE calendar (see Table 1.1 for correlation of archaeological periods in the Levant).

1.4.1 The Neolithic period, *c.* 10 ka to *c.* 7 ka BP

During the Neolithic period, human society achieved some remarkable progress in its struggle for survival. In the first place, certain societies in the Middle East adopted agriculture and domesticated animals as the dominant strategy in their struggle for survival. This agriculture, as will be discussed below, was based on irrigation. By using irrigation human society became less dependent on the natural environment, where productiveness is dependent on the randomness of climate changes, especially in regions bordering the arid belts of the world. In the second place, pottery was invented. This enabled the storage and cooking of agricultural products and of those that were gathered or hunted. The third achievement was the creation of urban centers, which enabled the efforts of a large community of individuals to be concentrated for cooperative projects, such as a defensive wall against artificial or natural hazards, such as floods. In due time, such communal effect enabled diversion canals to be dug for the irrigation of land at a distance from the riverbed.

Were these achievements interconnected with climate change? I believe there is such an interconnection, though climate change acted more as an encouraging agent rather than the main basic cause. This basic driving force is the general evolution of intelligence of the bio-world in general, and of the human species in particular (Issar, 1995a,b). In this conceptual model (Issar, 1990), the interconnection lies in the fact that the change of climate in the Middle East, resulting from its location on the border of the desert, forced humans to develop modes of life that would enable survival under natural conditions that would have precluded survival without such changes. The most eminent support for this conceptual model can be found in the archeological excavations of Jericho in the Jordan Valley (Kenyon, 1957). In the period around 11 ka BP, the climate was more humid as a result of the Young Dryas, a colder climate, and one would expect human societies to expand into regions that had previously been deserts. When the climate at a later stage became warm and dry again, these

Table 1.1. *General archaeological time table*

Date	Egypt	Syria-Palestine	Mesopotamia	Anatolia
CE				
2000	Mamluk–Ottoman	Mamluk–Ottoman	Seljuk–Ottoman	Seljuk–Ottoman
1000	Early Arab period · · · · · · · · ·	Early Arab period · · · · · · · · ·	Early Arab period · · · · · · · · · · · · · · ·	· · · · · · · · · · · · · · · · · · · ·
	Roman–Byzantine	Roman–Byzantine	Parthian–Sassanian	Roman–Byzantine
BCE	Ptolemaic · · · · · · · · · · · · · · ·	Persian–Hellenistic · · · · · · · · ·	Persian–Hellenistic · · · · · · · · · · · · · · ·	Persian–Hellenistic
	Late period	Iron Age II	Assyrian–Neo-Babylon	Iron Age
1000	· ·	Iron Age I · · · · · · · · · · · · · · ·	· ·	· · · · · · · · · · · · · · · · · · · ·
	New Kingdom	Middle–Late Bronze Age	Old–Middle Babylonian	Middle–Late Bronze
2000	Middle Kingdom· · · · · · · · ·	Intermediate Bronze Age · · ·	Akkad–Ur III/Isin · · · · · · · · · · · · · · ·	· · · · · · · · · · · · · · · · · · · ·
	Old Kingdom	Early Bronze Age II/II	Early Dynastic I–III	Early Bronze Age
3000	· ·	Early Bronze Age I · · · · · · ·	Jemdet Nasr · · · · · · · · · · · · · · · · · ·	· · · · · · · · · · · · · · · · · · · ·
	Archaic period	Mature Chalcolithic	Gawra (N)–Uruk (S)	Late Chalcolithic
4000	Pre-Dynastic period · · · · · · ·	· ·	· ·	· · · · · · · · · · · · · · · · · · · ·
		Early Chalcolithic	Ubaid (N & S)	Middle Chacolithic
5000	· ·	· ·	· ·	Early Chalcolithic · · · · ·
	Neolithic period	Pottery Neolithic A + B	Halaf (N)–Ubaid (S)	Ceramic Neolithic
6000	· ·	· ·	· ·	Early Ceramic
	Various	Pre-pottery Neolithic B	Hassuna–Samarra (north only)	Neolithic
7000	epi-Paleolithic cultures · · · ·	· ·	· ·	· · · · · · · · · · · · · · · · · · ·
		Pre-pottery Neolithic A	Pre-pottery Neolithic (north only)	Aceramic Neolithic
	· ·	Natufian · · · · · · · · · · · · · · ·	· ·	Epi-Paleolithic period
		Epi-Paleolithic: Kebaran		

From: Issar and Zohar, 2003.

societies concentrated near perennial rivers and springs, where they could put into more intensive practice the already existing rudimentary methods of planting and herding. The establishment of settlements near the perennial water sources enabled these societies to survive during drier periods and to develop and thrive during wetter periods, which later occurred.

1.4.1.a THE LOWER NEOLITHIC PERIOD, *c.* 10 ka TO 8 ka BP (PRE-POTTERY NEOLITHIC)

The lowest part of the isotope cross sections at Lake Van (Lemcke and Sturm, 1997) indicates that at *c.* 10 ka BP, the ratio of δ^{18}O/^{16}O was rather low, while the lower part of the oxygen composition of the marine curve (Luz, 1979) shows a heavy composition, which may suggest a rather cool and, therefore, humid climate. This may have facilitated the formation of sedentary communities organized in small villages during the beginning of the Neolithic period (Bar Yosef, 1986a; Clutton-Brock, 1978). Areas such as the Mediterranean zone, which were suitable for primitive agriculture, would rely upon cultivated plants and livestock. Semi-arid zones could provide hunting and grazing for domesticated animals. In any case, the transition from a hunter–gatherer to a farming society was not immediate. One can assume that the settling into communities only occurred after the acquisition of knowledge about food storage and the opportunities derived from cultivating plants.

On the basis of his own and other investigations in the Uvda Valley in the central part of Negev Desert of Israel, Avner (1998) concluded that agricultural settlements existed in this desert valley continuously from *c.* 10 ka to *c.* 4 ka BP. Bar Yosef (1986a,b) is of the opinion that, although communities of hunters and gatherers continued to exist in the arid regions such as the Negev mountains, the farming communities of the PPNA period expanded mainly towards the northern part of Israel and to the Jordan valley. During this period, the two main sites of settlements in Israel were Jericho and Nahal Oren.

Kenyon (1957), who excavated the site of ancient Jericho, maintained that the PPNA period was a period of floods, which again indicates a more humid climate. Jericho is situated in an arid region because it is shadowed from the rains by the Judean mountains. For this reason, I maintain that the development of agriculture at Jericho was based on irrigation (Issar, 1990). Such water could be derived from two sources: the floods coming from the mountains and the water from a big perennial spring, emerging from a regional aquifer, fed by the precipitation falling on the Judean mountains. It seems more logical that the farmers of ancient Jericho learnt to harness the water of the perennial spring before they found a way to use the water of the floods for irrigation. Moreover, the considerable storage of groundwater in the aquifer feeding the spring could mitigate the impact of a few years of drought. In any case, whether irrigation came from floods or from the spring, or from both sources, the fact that an agricultural society could survive in such arid conditions for about a thousand years suggests that the spring was perennial during this period and/or floods were abundant. Both suppositions lead to the conclusion that the climate was not too dry. Issar (1990) suggests that the floods became too strong towards the end of the period, and the disappearance of the PPNA people may have been caused by severe flooding, as evidenced by the nature of the layers of silt and gravel that cover that ruins of the PPNA culture.

Nahal Oren, by comparison, is situated in the more humid part of Israel, on the fringe of Mount Carmel near the Mediterranean coast, and enjoys ample rains during the winter season while, during the summer months, the natural forest of the Mount Carmel, and its fauna, could supply ample food during humid periods. Even so, a few years of continuous drought could have forced the settlers to abandon the place.

Therefore, one has to conclude that the climate was indeed rather cold and humid and it is difficult to agree with the conclusions of Horowitz (1973, 1980), who maintains that the pollen assemblage in Lake Hula (Huleh) indicates higher temperatures during this period of time and thus concludes that this period was drier than that of the PPNB. The same difficulty arises with the suggestion of Van Zeist (1969) that the Near East suffered from a rise of temperature during the PPNA, and that the climate during the PPNA was too dry to allow cultivation of barley and wheat; consequently the grains that have been found in the Near East must have been imported. Also Butzer (1978) concluded that temperatures rose during the PPNA and precipitation was less than that today. A marked improvement in precipitation only occurred towards the beginning of the PPNB. Wreschner (1977) found little material from the PPNA in the coastal region. The sites that were found lie high above present sea level. He explains this as a consequence of the Flandrian transgression of the sea, which forced the inhabitants to look for high ground for their living sites. Based on the evidence from Jericho, I would suggest that this period may have been characterized by severe storms, high groundwater tables and strong floods, which caused the people to seek higher ground for their settlements. Indeed Sakaguchi (1987) reports that a lake existed in the Palmyra district between 10 ka and *c*. 8 ka BP.

The disagreement between these assessments may be explained by changes in climate during this period, starting with a cold climate, continuing as warm and dry, and becaming again colder and more humid, reaching a maximum, towards the period’s end. As vegetation tends to change rather slowly, evidence based on pollen will indicate a dry climate, while evidence from isotopes, hydrological systems and human habitat, all of which respond rather quickly, will indicate that the period was cold and humid.

The later gradual enrichment of the deposits of Lake Van by heavy isotopes of oxygen and, at the same time, the depletion in the oxygen isotope ratios of the biomarine deposits suggest the warming up of the climate towards the end of the PPNA. There is also evidence that the desert areas were settled at this time, which suggests a climate warm enough to propel the monsoon-type rains northward, causing summer rains over the deserts of the Negev and Sinai.

Bar Yosef (1986b) suggests that the climate during the PPNB favored hunters and gatherers and attracted them to occupy more desert areas (the Negev and northern Sinai). The economy of the sites in the more humid areas was based on legumes and cereal cultivation, together with hunting and herding. In the more arid areas, the inhabitants probably lived in the sites during the winter, autumn and spring, with an economy based on hunting and gathering. A remarkable number of sites were found in the central part of the Negev (Gopher, 1981). According to the pollen spectrum found in one of these sites (Sede Divshon), Horowitz (1977) came to the conclusion that this period was more humid than today and enabled agriculture even in the more desert area. A pattern of dense PPNB settlement is found in the central Sharon and southern plain (Wreschner, 1977), which supports a climate during most of this period that was humid enough to sustain socio-economic systems based on agriculture.

Sanlaville (1989), who investigated the sediments of the Persian Gulf, observed a transgression from 9 ka to 6 ka BP, expressed by a rapid progress of the Persian Gulf shore towards the north, which also suggests a warm period.

Toward 8 ka BP, the oxygen isotope composition of the continental layers at the bottom of Lake Van became lighter and the isotopic composition of the planktonic foraminifers at the bottom of the eastern Mediterranean showed a heavier trend. At the same time, the level of the Dead Sea was rather high. These signals point towards a cooler period, and most probably a more humid climate. From palynological analysis, Erinc (1978) concludes that the climate in southwestern Anatolia was markedly cooler and moister at *c*. 8.5 ka BP than it is now. This stage of relatively more humid conditions was followed by an extremely dry phase at *c*. 7 ka BP.

1.4.1.b THE MIDDLE AND UPPER NEOLITHIC PERIOD, *c*. 8 ka TO *c*. 7 ka BP (POTTERY NEOLITHIC)

The heavier composition of oxygen isotopes in the continental environments, the lighter composition of oxygen isotopes in the marine environment and the lower level of the Dead Sea, all betoken a warmer and presumably drier climate during the Pottery Neolithic (PN) period.

The occurrence of deposits of greenish-gray laminated sediments led Neev and Emery (1967) to suggest a humid period from the beginning of the Holocene until 7 ka BP. Thereafter, the climate became drier, reaching a peak between 6.5 ka and 5.5 ka BP. Neev and Hall (1977) then revised their study of the depositional processes of the Dead Sea. The new study was based on new U/Th and ^{14}C dates and updated stratigraphical information. They concluded that the period when the paleo Dead Sea (Lake Lisan) extended over the Jordan Valley was followed by a pluvial period lasting 3000 years, from 10 ka until about 7 ka BP, while the dry period, evidenced by extensive rock salt deposition, occurred between 7 ka and 5 ka BP.

Very few PN sites were found in the northern part of the Negev and southern Sinai although six sites were discovered in the southern Negev. Most of the PN sites in Israel are found in the Jordan Valley and the coastal plain. Bar Yosef (1986b) explained the scarcity of sites, not as a consequence of climatic conditions but as a consequence of social and economic changes (an organization of "tribal kingdoms"). However, Horowitz (1973, 1980) uses palynological data to conclude that there was an increase in temperature. He also maintains that there was a rise in the sea level by 1–2 m as a result of melting ice sheets. There was an increase in precipitation even in the southern parts of Israel at about the same time. The herbaceous cover in the south, resulting from quite a heavy level of precipitation, changed the economic system and directed the emphasis towards agriculture and pastoralism. Crown (1972) and Issar *et al*. (1992) explained the increased humidity in this area as being caused by increased precipitation owing to the migration of the monsoon belt northward. It is suggested that from about 7.5 ka BP there was a reversal in the relationship between the anticyclones of the Azores and northeast Europe, which had an effect on the climate of the southern part of the Near East. Up to about 6.5 ka BP, the southern part of the Near East came under the influence of the trade winds and thus the summer monsoon rains. As a result, the PNB climate in the southern part appears to have been both warmer and moister than that today, while in the northern part, it was warmer and dryer.

In general, most of the PN sites (8 ka to 6.2 ka BP) are covered by alluvial deposits with large stones, indicating severe flooding. The Neolithic sites were located close to water resources and in low areas, which required a protective system against flood and mud flow damage. As Bar Yosef (1986b) noted, the response of the inhabitants of Jericho to the floods and sheet wash was "to build a wall and then, where necessary, dig a ditch". Knowing the Neolithic inhabitants as a peaceful society (lacking social aggression) before the eigth millennium BP, it is an alternative explanation for the Neolithic walls of Jericho.

There was an increase in oak and the appearance of pistacio in the vegetation in the regions bordering the eastern Mediterranean Sea after *c*. 10 ka BP (Post Glacial Period). This indicates both a rise in temperature and an increase in humidity as drought caused by a rise in temperature alone at lower elevations would have been a limiting factor for oaks (even though oak is more tolerant than conifers of dryness). The appearance of oak is an indication of an accompanying increase in precipitation. The climate change favored an extension of the forest, while steppe plants mostly disappeared. The eastern parts of the Near East zones, like the Ghab Valley in eastern Mesopotamia, seem to show a similar pattern of expansion of the forest (especially oaks) to that found in Greece and Italy. Information from more easterly zones like northwest Iran (Lake Zeribar) point to a change in climatic conditions, but the oak forest reached an optimum only at about 5.5 ka BP (Bottema, 1978).

Wright (1976) concluded from pollen records in lake sediments that steppe vegetation changed to open woodland or to forest at *c*. 11 ka BP. In some areas, like Lake Zeribar, the transition started as late as 6 ka ago whereas in others such as Tenagi Philippon, Macedonia, the transition started as early as 14 ka BP. Wright also claims that the vegetation change "perhaps reflects variable responses of local areas to increases in precipitation or temperature or both, as well as possible delays in the migration of trees from Pleistocene refuges". Van Zeist and Bottema (1982) came to the same conclusion concerning the heterogeneity of climate from one zone to another within the same climatic belt.

Depletion in ^{18}O values in the carbonate of land snail shells from 9 ka to 7.3 ka and from 6.5 ka to 6 ka BP (Chalcolithic period) was related by Goodfriend (1991) to changes that occurred in circulation patterns during more humid periods. During those periods, the rain entered the Negev area from northeastern Europe through the Mediterranean Sea to northeastern Africa. The depletion in ^{18}O values results from intensive evaporation over the Mediterranean Sea or from a continental effect along the northern coast of Africa. Goodfriend (1991) suggests that the changes in ^{18}O represent changes in the isotopic composition of rainfall in the Negev, rather than temperature fluctuations. The analysis of ^{13}C in organic matter in the early Holocene land snails also supports the above findings, by showing approximately twice the rainfall in the northern Negev during the early Holocene compared with that at present (Magaritz and Goodfriend, 1987). In another study, Goodfriend (1990) found that there was a shift of *c*. 20 km to the south of the transition zone of 150 mm isohyets during the period between 6.5 ka and 3 ka BP. On the basis of these data, the Negev zone would have had more rain until 3 ka BP. This time scale, based on the snail data, was of a longer humid period than is suggested by lake and sea sediments. I would suggest that these data are considered as a general indication of climate, and in some periods they may provide an alternative scenario to that suggested in this book.

On the whole, it can be concluded that the Neolithic period, extending from the PPN and PN periods, was characterized by climatic fluctuations. The general trend seems to have been humid during most of the period and dry towards its end.

1.4.2 The Chalcolithic period, *c*. 7 ka to *c*. 5 ka BP

The Neolithic period ended towards the end of the seventh millennium BP and was followed by a culture characterized by a new innovation, namely copper production. The Chalcolithic culture arrived in the Middle East at about 7 ka BP. The period between the Neolithic and Chalcolithic is demarcated by a gap in settlement that might have been caused by an extreme phase of the warmer and drier climate, which reached its maximum around 7 ka BP but might have extended later to influence the pattern of settlements a few centuries later.

A marked depletion of the ^{18}O composition of Lake Van can be observed in sediments from *c*. 6.5 ka BP (Lemcke and Sturm, 1997) and continued to about 6 ka BP. Degens *et al.* (1984) observed a strong rise in the level of Lake Van during this period. The low ^{18}O values of planktonic foraminifers from deep-sea cores in the eastern Mediterranean (Luz, 1979; Luz and Perelis-Grossowicz, 1980) suggest the inflow of heavier ocean water. Although no evidence was found in the caves of Mount Sodom to indicate that the level of the Dead Sea was high during this period, I believe that the still higher level of the lake during the lower Bronze Age, which followed, obliterated any such evidence. The evidence for a more humid climate will be discussed below.

An important settlement of the Chalcolithic period was excavated at Tel el-Ghasul in the eastern Jordan Valley near Jericho (Hennessy, 1982). The archaeological remains in this site show that it was inhabited by a society that reached a rather sophisticated cultural level, building a shrine and decorating its walls with mythological murals. This culture is referred to as Ghasulian, and it is believed to have started sometime during the third quarter of the sixth millennium BP (Ussishkin, 1986).

The origin of the people of the Chalcolithic period is still unclear. The main stream in Middle Eastern archaeology believes that part of the population of the Chalcolithic culture was local and it absorbed a new wave of people with their new culture. Some of the researchers note that there was a migration of people from the "north" (Mellaart, 1966; Govrin, 1991). Gophna (1983) also claimed that the Chalcolithic population entered the Levant from the north and brought with it a very developed and organized culture. Ussishkin (1986) suggested that, according to archaeological remains and skeletons' structure, the Chalcolithic cultural bearers originated in the Caucasian Mountains of East Anatolia or the mountainous areas of Armenia. Other archaeologists accept the idea that the new Chalcolithic immigrants came from an unidentified "east" (Elliot, 1978), which could be Mesopotamia. Yet, not all archaeologists agree with the "north or east theory"; for example, Gonen (1992) suggested that natural and internal processes were responsible for the change from the small isolated local communities of the Neolithic period to the new social and economic system of the Chalcolithic period. The change in culture was in a response to the need to find a solution for the changing condition of the society and to ensure its continuation and succession.

Whichever theory is correct, one still has to explain the reasons for the sudden rise, after several hundred years of decline, in the number of settlements, and the appearance of a new form of culture equipped with a new technology, for which there is no sign of a gradual evolution, as is the case in the invention of pottery. Issar (1990) favors the theory of the immigration of people from the north and explains it by a strong climatic change from warm and dry to cold and humid. This made the high plateaus of Anatolia, Iran and maybe even Central Asia less habitable, and it simultaneously caused the plains of the Middle East to flourish. This, as archaeological evidence shows, gave rise to an incredible increase in population density: a rise in the total numbers as well as an increase in community sizes and the range and rate of productivity in many economic areas. New activities included ceramic, metal, ivory and basalt industries. Levy (1986) suggested that the Chalcolithic economy indicated a development of production beyond the domestic circle and based on an increase in socio-economic complexity, which involved the development of social ranking and hierarchies. Another characteristic feature of the Chalcolithic culture was the emergence of distinct regional cultures, with a high level of adaptation to the local environment (Levy, 1986).

The population of the Chalcolithic period settled in Israel in planned farming communities in the Jordan valley, the coastal plain, the Judean desert and the northern and eastern Negev (Ussishkin, 1986). Sedentary village life was established during the Neolithic period, but the Chalcolithic cultural communities were larger and more advanced farming villages. These villages later became the pattern of the "modern" village in the Middle East.

These settlements expanded into the Negev. Their remains are found all over the Beer-Sheva plain, reaching the Arad area to the east and Nahal Besor to the west. They spread into the arid Arava valley, from Ein Yahav in its northern part to Timna in the south. Most of the settlements were located on the tops of low hills close to river valleys (Cohen, 1986, 1989). Archaeological remains show that many settlements also thrived in the valleys of the southern mountains, practicing agriculture in areas that today get less than 100 mm of rain per year (Avner, 1998). Cohen (1989) maintains that the settlements in the Negev mountains were temporary and semi-nomadic, based on pastoral grazing and transportation of copper from the Feiran area and the Timna valley.

The discovery of mining and smelting sites in the Feiran area, the Timna valley and Eilat area suggests the importance of mining and special production activities. Avner (1998) attributes this flourishing of the desert to a more humid climate. He further suggests that the source of the rain was monsoonal. Yet, this explanation makes it difficult for him to find a climatic reason for the fact that this valley continued to flourish during the Early Bronze Age (EB); he explains this anomaly anthropogenetically, by the adaptation of these societies to desert conditions. This explanation may not be necessary, however, if one considers the EB to have been cold and humid, as I suggest.

The settlers in the Beer-Sheva plain built their dwellings underground, digging into the loess soil in the escarpment overlooking the riverbed (Perrot, 1968). The people most probably received their water supply from shallow wells located in the riverbed. It is even possible that the river flowed during most of the year. There are many indications that the people cultivated fields along the riverbeds. Diversion dams were also used in order to bring water from the river to the fields (Alon, 1988).

Consequently, one cannot avoid the conclusion that, indeed, the Chalcolithic period was one of economic and cultural prosperity, and the most logical reason for this is a climatic change that brought more precipitation to the semi-arid Middle East and enabled agriculture to spread into the desert area. As noted, the isotopic evidence supports this conclusion.

The magnificent Chalcolithic culture, with its artistic tradition and technical knowledge, lasted for about 1300 years and suddenly disappeared towards 5 ka BP. All the sites were abandoned without any signs of violence. Archaeologists explain the disappearance of the Chalcolithic culture in various ways. Hennessy (1982) suggests that they had to leave their settlements because of a migration of a new wave of people – the ones who established the EB culture. But archaeological remains do not reveal any exchange of cultures in the same sites. Others looked for a circumstantial connection between the disappearance of the Chalcolithic population and the expansion of the first Egyptian Kingdom of Naarmer at about 5 ka BP. However, there are no indications of violence involved in the abandonment of the settlements. Levy (1998) suggests that a drier climate caused the collapse of this culture and I would support this explanation based, once more, on the isotopic data of Lake Van, the Sea of Galilee and Soreq Cave. Also, there appears to be an increase in the level of the Mediterranean Sea at this time. Yet there are some difficulties with this hypothesis, because it is known that the settlements in the area of Beer-Sheva and the Judean desert were the last to be abandoned (Gonen, 1992). Perhaps the type of settlement that was established in the south can explain this. The people of the south maintained either a pastoral way of life or agricultural settlements along the riverbeds (Govrin, 1991). Both societies experienced semi-arid conditions from time to time. Therefore, the conditions led them to develop a way of life involving desert agriculture irrigated by floodwater and the technology of shallow wells. This might have given them a sufficient water supply during less rainy years. It is reasonable to think that a severe crisis in the north caused the rapid collapse of the settlements in that area, while the impact of the crisis on the population of the more arid zone, who exploited their knowledge and life style, was less severe, at least in the beginning. A further explanation, with a similar basis, is that the warming up of the climate increased the incidence of monsoon-type rains and this helped to support vegetation suitable for forage.

In the general framework of these paleo-environmental and socio-economic scenarios, one can explain the observations made by Tsoar and Goodfriend (1994) of a dense population existing on the sand dunes of the northeastern Sinai bordering the Negev at *c.* 4100 cal. BC. According to these authors, the higher silt content of the sands indicates a higher rate of precipitation. They suggest that the activation of the dunes was a function of overgrazing and trampling. An examination of the precipitation curve from Soreq Cave (Fig. 1.3) shows that precipitation reached a peak during this periods, but soon afterwards the climate started to deteriorate. I would suggest that the activation of the dunes was more a function of overgrazing during the aridization phase, which immediately followed the peak (and which can be seen in the Lake Van humidity record in Fig. 1.3).

Sanlaville (1989) records a maximum level of the Persian Gulf at *c.* 5.5 ka BP. Yet, as Sanlaville states, the dates on which this curve is based (Sanlaville, 1989, p. 19) show the high sea level to be around 5 ka BP, which corresponds well with the upper Chalcolithic warm period.

1.4.3 The Early Bronze Age *c.* 5 ka to *c.* 4 ka BP

All environmental data show that a major change some time after 5 ka BP brought a cooler and more humid climate to the Middle East. The level of the Mediterranean Sea declined, while the level of the Dead Sea rose, and oxygen isotope composition in lake deposits and speleothemes became lighter (although the change observed in the sediments of the Sea of Galilee appears to come later and is believed to reflect rather the small number of dated samples and thus the imprecision of the timing of the changes). Rosen (1986), investigating the alluvial deposits of Nahal Lachish, concluded that the deposits of the Chalcolithic period and the EB indicated a climate that was moister than today. Massive alluviation, indicating a more humid climate, was observed in other riverbeds, such as Nahal Beer-Sheva, Nahal Shiqma and Nahal Adorayim, in the southern part of Israel (Goldberg and Rosen, 1987). Consequently, more or less parallel to the time during which indications of proxy-data show a more humid climate, the archaeologists place the beginning of the EB. This brought major developments in agricultural technology, together with an enlargement of international trade, contributing to the emergence of the walled city, which achieved a central role as a religious and economic center.

There are some questions concerning the beginning of the EB. It is not yet clear whether it started immediately after the end of the Chalcolithic period, if there was an overlap between those two cultures or if a gap in time existed between the end of the Chalcolithic period and the beginning of EB I. Until the middle 1970s, the transition from the Chalcolithic period to EB I was explained by intrusion of foreign societies (de Vaux, 1971; Kenyon, 1979; Lapp, 1970). At the end of the 1990s, there are more and more claims that the transition from the Chalcolithic period to EB I was a process of local evolution (Levy, 1986; Schaub, 1982).

The debate whether this culture developed locally or was brought in by immigrants from the north is important with regard to the question of whether this cold period was strong enough to drive people from areas becoming less habitable because of the cold climate, towards the more hospitable south, for example the people of the central plateau of Asia. Although this issue has not been decided, it is interesting to view the relevant evidence.

Archaeologists who entertain a foreign origin for the EB I culture have noted that the urban life style had the character of a new culture. Kenyon (1979) described a new culture brought in by the Proto Urban people. She suggested that three groups of people (A, B and C) entered Canaan from the north and brought with them different types of craft. These Proto Urban groups existed side by side in different areas in the Levant, and all of them were responsible for the development of urban life. Lapp (1970) and de Vaux (1971) suggest scenarios differing slightly from that of Kenyon but agree that the B culture peoples came from the north with a new tradition of architecture and an urban life style.

Some difficulties in accepting the migration theories arise from the fact that there are no parallels to the emerging EB culture outside Canaan (Ben Tor, 1992; Levy, 1986; Schaub, 1982). Also, there is no proof for a route of migration to this place during that period of time. Moreover, on-going archaeological research has shown a connection between the cultural material of the Chalcolithic period and that of EB I. Ben Tor (1992) noted that ceramics from the EB, especially those belonging to the first stage of the EB I, were not totally different from those of the Chalcolithic period. In fact, there seems to be a sequence in traditions, which might also support the possibility of a continuation in the population.

Considering new evidence collected since the early 1980s, there is a tendency to explain the social processes leading to urbanization as an evolutionary conceptual rather than an intrusion: diffusion model (Ben Tor, 1992; Amiran and Kochavi, 1985). The evolutionary theories emphasize the continuation of local elements rather than "importation" from the outside, and the adaptation of the local culture to changing environments. Amiran (1985) emphasized the emergence of walled cities, which seem to have been established by the same type of population as in the preceding periods. Amiran saw continuity in population throughout the early phases of the EB and concluded that there was an unbroken development from the village community to the urban society. But Amiran is cautious about concluding that urbanism was solely a local process. Hennessy (1982) also noted a mixture of foreign and local cultures in developing the so-called urban culture. Schaub (1982) concluded that the transition from the Chalcolithic period to EB I in Israel was locally oriented, as the new cultural material appears only gradually, rather than suddenly.

The size of the settlements of the EB I was almost the same as that of the settlements during the Chalcolithic period, but the density of inhabitants in most was increased. This is an indication of an increase in population (Ben Tor, 1992). However, not all the settlements during EB I are defined as cities. Some were "small cities", such as Megiddo, Lachish and Jericho. Others were considered "big cities", such as Yarmut, Gezer, Afek and Beit Yerach. Agricultural villages were located alongside the cities.

There is a transition of EB settlements to the mountainous areas, the foothills and the valleys of Jezreel. New locations for sites involved a transition to a Mediterranean method of agriculture. Ben Tor (1992) and Broshi and Gophna (1984) claimed that the people of the EB mainly preferred areas in which the annual amount of rainfall was more than 300 mm. More than 600 sites from EB I and II were discovered in the Negev highlands and Uvda valley (Avner, 1998), which would support the claim that it was a humid period.

Not all the EB settlements of the Negev were walled and most of them were located on hills, near valleys, that had permanent water resources (Cohen, 1989). Cohen claimed that the population growth of the Negev highlands was caused by the movement of settlers who could not adapt themselves to the growing urbanization of life style in the northern parts of Israel. The economy of the EB settlements in the Negev was based on agriculture, pastoralism and hunting.

The archaeologists divide the EB into three parts, namely EB I, EB II and EB III. However, there is not a major change in the basic cultural characteristics during these times. Most of the EB I settlements became more urbanized during the EB II and a type of a "planned city" appeared, parallel to a transition from settlements with no walls to fortified cities (Ben Tor, 1986, 1992; Broshi and Gophna, 1984). Thus, the seeds of urbanism, which were planted during EB I, flourished. Walled cities and agricultural villages were located side by side, and economic and social connections were developed between them.

At *c*. 4.6 ka BP, the city of Arad, located in the eastern part of the Beer-Sheva plain on the border of the desert, was deserted, most probably because of worsening climate (Amiran, 1986; Amiran *et al.*, 1980a,b). When I investigated the water supply system of ancient Arad, I found that the main supply of the EB Canaanite city was based on a deep well touching a perched local groundwater table. Its recharge area was limited to the area surrounding the city. Consequently, once the climate started to become drier, replenishment diminished and the well dried up, leaving the inhabitants of the city without a perennial water supply (A. Issar, unpublished report). Whether the desertion of Arad was the first sign of the major dry spell characterizing the end of the EB is difficult to say. A general trend towards drying up of the region is indicated by several pieces of evidence: the city was not resettled during the MB; the isotopic data shown in Fig. 1.2; the paleo-precipitation curve calculated for Jerusalem from isotope data in the speleothemes of Soreq Cave; and the decline of the level the Dead Sea, (Fig. 1.3). Samples of ancient tamarisk wood found along ancient shorelines of the Dead Sea, which penetrated the caves of the salt plug of Mount Sodom (Frumkin *et al.*, 1991), dated to 3780 years BC. These were analyzed for their ^{13}C content and gave values similar to that of present-day trees in this region, namely for trees growing in an arid environment, By comparison trees dating from the Roman period, *c.* 2 ka BP, showed a marked depletion of ^{13}C, indicating a cooler and more humid period. Additional areas of desertion were observed in other more arid parts of the Middle East (Richard, 1980, 1987). Most of these sites were dependent, like Arad, on local springs. In general, a survey of the archaeological reports shows a desertion of the settlements in the Negev and Sinai during EB III. One can conclude that a warming-up phase had started some time towards the end of the third millennium BC, and, as a result, a gradual decline in the average annual precipitation was first evidenced in the areas closer to the desert. Settlements that were in the vicinity of perennial springs, feeding from a regional aquifer (such as Jericho, Megiddo, Beit Shean), close to the Sea of Galilee (Beit Yerach) or in the more humid parts of the country like Ai and Lachish continued to prosper. It is possible that many of the inhabitants is of the abandoned settlements of the EB II in the drying-up regions resettled in the more humid areas or at sites that were located near big springs, such as Jericho.

As time went on, the trend towards warming strengthened and a general trend of decline of cities, with a transition to a nomadic and semi-nomadic society towards the end of EB IV, namely towards *c.* 2.3 BC (or *c.* 3.8 BP uncalibrated) is reported by all archaeologists. The exact time period of EB IV is a matter of debate between the archaeologists (Albright, 1962, 1965; Amiran and Kochavi, 1985; Ben Tor, 1992; Dever, 1973; Gophna, 1992; Lapp, 1970; Mazar, 1986; Wright, 1938). As this book centers on the general trends of climate change and their impact on the hydrological and socio-economical systems, and, of course, different water systems and various societies will react at a different pace to the worsening of the climatic conditions, the main conclusion that one can draw from the archaeological reports is that at the turn of the third to the second millennium, the desertion of cities reached a climax. At the end of this stage, urban centers, which had existed for several hundreds of years, had all disappeared, being abandoned without any sign of destruction. The demise of the cities has been observed in archaeological excavations all over the Middle East (Butzer, 1958; Harlan, 1982; Rosen, 1997; Weiss *et al.*, 1993).

In Canaan, EB IV is difficult to recognize, even in the cities located near perennial springs, like Hazor, Megiddo, Beit Shean, Jericho, Lachish, and Tel Beit Resisim (Dever, 1980, 1985a), most probably because of the growing poverty of the surrounding agricultural communities. With the collapse of the cities in the northern more humid part of Canaan, the center of settlement was shifted to the semi-arid and arid marginal areas such as Trans Jordan, the Jordan Valley, the Negev and Sinai. This is explained by the archaeologists as a result of changes in the socio-economic structure of the local population, as the demise of the cities of the north forced the people of these cities to move to the marginal areas and become pastoral nomads (Dever, 1985a; Richard, 1980, 1987). “Pastoral nomadism” according to Johnson (1969) is distinguished from a sedentary way of life by the high degree of mobility and the adjustment to seasonal availability of pasture and water for animal husbandry, which is the primary economic basis. Finkelstein and Prevolotsky (1989) recognized the cultural, political and social relations between nomads and urban populations. Neither group was totally independent. Therefore, the collapse of urban society caused pastoral society to look for a new way of supplying its needs for sustenance. The change in economy of the pastoral society towards one of grazing and agriculture gave rise to a sedentarizing process among the nomads in the marginal areas.

The reasons for this regional devastation are a matter of argument between the archaeologists, most of whom do not accept climate change as a reason. Some archaeologists connect the abandonment of cities with the migration of the Amorite, a semi-nomadic people who overran the EB III cities, causing de-urbanization (Albright, 1926; Kenyon *et al.*, 1971; Cohen, 1983). However, they fail to consider whether there was an environmental reason for the Amorite migration. The Amorite hypothesis is based on Sumerian texts dealing with the invasion of tribes from the east into Mesopotamia. Such an invasion should have left signs of destruction, but the archaeological remains indicate a continuation of the cultural material of the EB IV with the EB III tradition (Richard, 1980, 1987), which makes it more reasonable to attribute the cultural material to the same population rather than to a new wave of immigrants. The same argument applies to the rejection of the “invasion theory” of Trans-Caucasus tribes, who were supposed to have come from Central Asia (Kochavi, 1969; Lapp, 1970). Mazar (1968, 1986) suggested another explanation for the disappearance of the cities. He claimed that the Egyptian campaign caused a dislocation of people and ruined cities, and this was the cause for the decline of the political regime in Israel. This kind of disorder left the country open to the Amorites, who came with the Acadian troops and replaced the weakening Egyptian troops. However, archaeological remains do not support any destruction by military forces. Moreover, there is no textual evidence of Egyptian military activity. Ben Tor (1986) noted that one of the explanations for the de-urbanization could have been the competition between the cities themselves. This hypothesis does not have any archaeological evidence.

Richard (1980, 1987) was one of the few archaeologists who came to the conclusion that it was a climate change that had such a destructive impact on the socio-economic systems of the Middle East. He concluded that, although amalgamation of a complex array of socio-economic and political factors must have occurred to terminate the EB urban life, probably the major factor was a shift in climate to drier conditions. This ecologically significant shift caused, either by itself or combined with an already weakened economy, the abandonment of sites. Presumably, the climatic shift was substantial for otherwise one would expect cultural adaptation to the new condition rather than total abandonment of the sites (Richard, 1980, p. 25).

As already mentioned, the environmental proxy-data presented in Figs. 1.2 and 1.3 support this explanation. Moreover, in archaeological surveys where the archaeologists examined the nature of the deposits as well as the cultural remains, they found evidence that, indeed, the lower part of the EB was humid, while the upper part became dry. Ritter-Kaplan (1984), in her report on the excavation of the Exhibition Gardens in Tel-Aviv, described the different characteristics of the soil stratification at the site. She found that a black clayey layer laid down in a swamp and containing an abundance of oak pollen was deposited during the EB I–III age. Overlying this layer, she found a grayish sand layer, almost devoid of pollen, overlying the remains of the EB IV or MB I culture. She interpreted the change from clay to sand as an indication of a change to a drier climate and described this period as that of "the crisis of the aridity".

The sand, as already discussed, came from the Nile, and the increase in its supply was most probably a function of an increase of the precipitation on the Ethiopian highlands and possibly from the erosion of the delta through abrasion by the rising sea level. Sivan (1982), investigating the history of deposition in the Haifa Bay, found that this bay was dramatically filled in with sand, resulting in the shoreline advancing several kilometers since the MB, *c.* 4 ka BP; this is additional evidence for a major climate change.

The pollen assemblage in the sediments of the Sea of Galilee shows a remarkable reduction of the pollen of the Mediterranean natural forest, especially of oak and pistachio, and a parallel increase of olive pollen starting *c.* 5.5 ka BP, and the reversal of this trend starting *c.* 4.5 ka BP (Baruch, 1986; Stiller *et al.*, 1983–84). I interpret the first stage as a result of a more humid climate, which made it economic for the people of the semi-arid part of the drainage area of the Sea of Galilee to cut down the natural forest and plant olives. When climatic conditions started to become warmer and drier, the olive harvests declined to a stage when they had to be abandoned, and the natural vegetation rejuvenated. Afterwards, one finds a similar trend during the shift from the Roman to the Moslem period.

Quercus and *Pinus* species grew at Beer-Sheva and Arad (northern Negev) at 2.8 ka BP. Later, and to the present day, these trees completely disappeared and were replaced by *Acacia* sp. and by tamarisk, indicating an arid to semi-arid habitat (Liphschitz and Waisel, 1974).

As already mentioned, this climatic crisis affected the whole Middle East. Neuman and Parpola (1987) found documentary proof of aridization in a reduction of the water level of the Tigris–Euphrates and an increase in salinization (from *c.* 4.3 ka to 3.9 ka BP). Crown (1972) found indications that the climate in Iraq after 4.5 ka BP was drier than the markedly wet period of 5.5 ka to 4.5 ka BP. About 4.3 ka BP, the rise in temperature caused severe droughts and crop failures. Lakes in the Zagros mountains dried out between 4.5 ka and 4.0 ka BP (Wright, 1966) and a significant reduction in arboreal pollen was found in Lake Zeribar (Van Zeist and Bottema, 1977). Weiss *et al.* (1993) analyzed soil samples from Tel Lailan in northern Mesopotamia and also concluded that a deterioration in the climate had caused the geo-political crisis which led to the demise of the Acadian empire at the end of the third millennium BC. The same conclusion – that a severe climate change was the reason for the collapse of the socio-economic systems of the Levant – was reached by most of the participants in the NATO workshop in 1994 (Dalfes *et al.*, 1997).

All this evidence tends to refute the accusation that the ancient inhabitants of this region caused the salinization of their soils. This claim was based mainly on data from deciphered clay tablets from Sumerian archives (Jacobsen, 1957–58, 1960; Jacobsen and Adams, 1958). The data demonstrate that many long irrigation and (probably also) drainage channels were dug by the inhabitants of that area between 2300 and 1800 BC. In this same period, the ratio of barley to wheat was constantly rising in offerings and taxes delivered to the temples. As barley is more tolerant of soil salinity than wheat, the archaeologists incorrectly concluded that excessive irrigation had caused salinization. There was an attempt to refute these accusations by demonstrating, from similar archive texts, that the Sumerians were aware of the danger and had taken some preventative drainage measures (Pollock, 1999).

Sanlaville (1989) observed that the delta of the Mesopotamian rivers in the Persian Gulf rapidly developed at *c.* 4.5 ka BP. It is suggested that this could be correlated with the cold and humid climate of the EB.

To sum up, environmental and archaeological evidence indicates that the climate was wet during the lower part of the EB, presumably as the result of a cold climate phase. A dryer phase started in the middle part of the EB and reached its climax towards the end of the fifth millennium. The deterioration of climate caused the collapse of the urban socio-economic system of the Middle