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PALYNOLOGICAL HISTORY OF THE LAST PLENIGLACIAL IN THE LEVANT

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Introduction

The last Pleniglacial, ca. 75000-15000 years ago, is a period of considerable cultural and environmental change in the Levant. Abundant data, mostly related to archaeological sites, have gathered in these two fields of research, resulting in long prehistoric and palaeoenvironmental sequences. However, none of the archaeological sites contains a continuous undisturbed depositional and/or cultural sequence. Therefore, cultural and palaeoecological correlations between the sites are difficult to make. The scarcity of absolute dates, especially for the early part of this period, makes the establishment of temporal relationships even more difficult.

The palynological data are, by their nature, more continuous. However, complete sequences for the period under discussion are rare. These are usually obtained from lakes, rather than from the archaeological sites themselves. Their dating is problematic, especially for the more ancient parts. Thus, correlations between these relatively continuous sequences and those established from archaeological sites remain debatable.

The aim of the present study is to draw a general picture of the climatological changes during the last Pleniglacial in the Levant, based on the palynological data. This would hopefully serve as a reference palaeoecological sequence for the correlation of palaeoenvironmental data obtained from archaeological sites.

Complete last Pleniglacial palynological sequences were studied in the Hula (northern Syria) basins, both within the Levantine Rift Valley (Fig.1). Other palynological curves are partial, including the last 40000 years of Lake Zeribar, Iran and a few, considerably shorter sequences in Turkey (Fig.1). Thus our discussion will concentrate on the Levantine data.

The Hula basin is situated at the northern end of the Jordan Rift Valley, at an elevation of approximately 70 m above sea level. This narrow and elongated shallow basin is flanked by the eastern Galilee mountains to the west and the Golan plateau to the east, both rising to about 800-1000 m. To the northeast the Hermon range reaches 2800 m. The Jordan River drains the basin southwards, toward the Dead Sea.

Climatic conditions in the Hula Basin itself are semi-arid, while the climate of the mountainous zones in the area is Mediterranean. Phytogeographically, the northern Jordan Valley, together with the surrounding mountains, be-

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longs to the Mediterranean vegetation belt. Pollen spectra of the area are also influenced by the Irano-Turanian steppe and desert vegetation of the east. A detailed outline of the climate and vegetation of the region is given by Weinstein-Evron (1983).

The Ghab Valley is situated in north-western Syria, about 300 km north of the Hula, and constitutes the northernmost extension of the Great Rift System. It is a narrow and elongated north/south oriented valley, through which the Orontes River flows, at an elevation of approximately 190 m above sea level. The valley is flanked by the Alaouite mountains to the west, reaching elevations of over 1300 m. The Zawiye mountains to the east are much lower, and rise to about 800 m above sea level. Climatic conditions in the area are Mediterranean; the climate east of the valley is semi-arid.

The geographical setting of the Hula and Ghab valleys is quite similar. Both are elongated shallow valleys, oriented north/south, flanked by mountains to the east and west, influenced by the semi-arid zone to the east and with a major river. However, the higher elevation of the mountains west of the Ghab valley creates relatively cooler and more humid conditions, so that deciduous oaks and cedars are abundant. Many more northern species also occur in the Ghab area. A detailed outline of the geography and vegetation of the region is given by Niklewski and van Zeist (1970).

The palynological sequences: characteristics and possible correlations

The Hula sequence, which is the longest in the area, is combined of two curves: the Hula L07 for the earlier part (Weinstein-Evron, 1983, 1988), and the 54 m core for the last 30 000 years (Tsukada, cited in Bottema and van Zeist 1981).

The Hula L07 core was drilled to a depth of 160 m, at the northwestern part of the recently drained lake. The uppermost 30 m of the core is missing and the section between 30-108 m has been studied to date. The palaeoclimatological reconstructions are summarized in Fig. 2. The generalized climatic curve (column A) is based on the arboreal pollen (AP) curve, and includes climatic characteristics defined by the interpretation of the pollen diagrams. The numbers indicate pollen zones. Trends in humidity, together with the limits of the main fluctuations, are shown in column B.

The lowest part of the curve, from a depth of 108 to 102 m. has been subject to a preliminary analysis only. High percentages of coniferous pollen, especially cedar and fir, indicate a period of humid and cold climate which is tentatively correlated with the end of oxygen isotope stage 6 (Emiliani, 1955; Shackleton, 1969).

The low AP levels in pollen zones 0-5 indicate relatively dry climatic conditions. Within these dry pollen zones more humid fluctuations occur. This section is correlated with isotope stage 5. Exact correlations with the different substages of isotope stage 5 are difficult because of the relatively small fluctuations in the pollen curves and a gap in the palynological sequence, at a depth of 83.5-77.5 m, probably the result of oxidation (Weinstein-Evron, 1983, 1987 a).

Pollen zones 6–18 include the last Pleniglacial (locally also termed the last "Pluvial" : Horowitz, 1979), with three main high AP and humid fluctuations, separated by two short drier ones. The humid fluctuations seem to become longer with time which is a result of a lower degree of compaction in the upper part of the sequence (Weinstein-Evron, 1987b). The Pleniglacial sequence, as a whole, indicates a more humid and cold climate than the preceding phase. Cold conditions are indicated by the relative abundance of cedar pollen. The beginning phase is the most humid and probably the coldest.

The onset of pluvial conditions is generally estimated to have occurred around 75 000 BP (Bar-Yosef, 1984; Tchernov, 1988), and is correlated with isotope stage 4, which exhibits cold conditions in the deep sea cores (Shackelton and Pisias, 1985). Pollen zones 6–18 are thus correlated with isotope stages 4 and 3, up to ca. 30 000 BP, based on a 14 C date of 42 590 ± 2010 BP (Pta 2538) from a depth of 40.9 m. (For further discussions of the palynological and chronological aspects of the research see Weinstein-Evron, 1983, 1987a, 1988).

The uppermost 30 m of the Hula L07 core is missing. However, a complete sequence can be drawn (Fig. 3) using an early study by Tsukada (cited in Bottema and van Zeist, 1981), which matches quite closely the diagram presented by Horowitz (1971) for the same period of time. Eleven 14 C dates are available for the upper part of the Hula sequence, between ca. 30 000 and the present day (Cowgill, 1969). The Pleniglacial sequence thus continues with a wet climate between ca. 30 000 – 22 000 BP, a very dry period between ca. 22 000 – 14 000 a wet Late-glacial to 10 000 BP and a drying Holocene. During the Holocene human interference probably masks the purely climatic influences on the vegetation (van Zeist and Woldring, 1980).

The Hula L07 palynological sequence is the only continuous and detailed study in the area, which has so far reached isotope stage 5. In addition, detailed studies of the last Pleniglacial and Holocene periods in the Ghab valley are given by Niklewski and van Zeist (1970) and van Zeist and Woldring (1980). Only the Pleniglacial sequence will be dealt with here in detail. Similar to the Hula, the Ghab exhibits a strongly fluctuating curve (Fig. 4). The earlier part of the Ghab sequence, i.e. the period between ca. 75 000 and 30 000 BP, overlaps with that of the Hula L07 core. The dating of the Ghab sequence is based on 14 C dates of 10 080 BP for a depth of ca. 1.3 m and 45650 BP for a depth of 6.5 m (Niklewski and van Zeist 1970).

In the Ghab, a humid and cold phase (zones T1–T2) ends with a less humid but considerably colder period (zone U1), with the highest cedar percentages of the whole sequence. This is followed by three somewhat less humid fluctuations. The first is represented by the triple undulations of zones U2–U3, the second is found at zones W1–W2 and the third at zones X2–X3. Simplified diagrams for the two sites, showing the ratios between the total tree pollen, *Chenopodiaceae* and *Artemisia,* are given in Fig. 5. In this mode of representation, which is widely used in the analysis of other sequences in the Near East (van Zeist and Bottema, 1977; Bottema and van Zeist, 1981), the partly local plants (eg. *Gramineae*) are excluded. This facilitates comparisons between sequences from different localities.

The Hula L07 and Ghab sequences seem quite similar during the period under discussion. The predominance of oak pollen in both sequences and the lack of pollen type–fossils prevent comparisons beyond those based on the general form of the diagrams, especially when more local changes occur (i.e. the high *Carpinus/Ostrya* levels in Ghab zone Z1 and the high *Vitis* values in Hula zone 15). However, the proposed correlations are confirmed by the abundance of cedar pollen at the end of the first fluctuation, and by 14 C dates (Fig. 5). The last fluctuation in the Hula is relatively long, with a minor decrease in AP towards the upper part (pollen zone 17), which is correlated with the relatively minor climatological change interpreted in the Ghab for the same period of time (Niklewski and van Zeist, 1970). The occurrence of a peak in pine pollen in both curves, just below this dry phase, lends further support to this view.

It has been argued that the Ghab and Hula sequences exhibit opposite trends during the last 30 000 years (Bottema and van Zeist, 1981; van Zeist and Bottema, 1982). These dissimilarities are a result of comparisons based on 14 C dates, and not on the shape and composition of the diagrams. The dissimilarities seem surprising in view of the close correlations in the older parts of the sequences. When the Ghab curve is drawn against the composite Hula diagram (Fig. 6 column C), there is an "extra" fluctuation in the former, which cannot be fitted. This can be corrected by "squeezing" the Ghab diagram downwards and by adopting the more numerous Hula dates (11 dates for the last 30 000 years). The modified Ghab sequence, now quite similar to the Hula curve, is given in column B. Acceptance of the proposed correlations would necessarily result in the rejection of the 14 C date of 10 080 BP for a depth of 1.3 m in the Ghab.

This procedure results in similar palynological curves for these two Levantine basins, which seems quite logical given the similar geographical setting and the relatively short distance between the Hula and Ghab valleys. Similar climatic conditions in these two basins during the late Pleistocene can thus be proposed. If this reasoning is acceptable, it can be concluded that a typical Levantine sequence would be characterized by a relatively dry isotope stage 5, a humid and strongly fluctuating last Pleniglacial sequence, a dry and cold last glacial maximum, a wet Late-glacial and a generally dry Holocene.

When the composite Hula/Levantine curve is drawn against the European curves, i.e. the Grande Pile (Woillard 1978; Woillard and Mook, 1982), they exhibit quite clear opposing trends in humidity (Fig. 7). This can be traced not only when comparing major sections (isotope stage 5, isotope stages 4 to 2 and isotope stage 1), but probably also when tracing minor fluctuations within the early part of isotope stage 3. Curves from Greece (Wijmstra 1969), Turkey (van Zeist and Bottema, 1988) and Iran (van Zeist and Bottema, 1977) generally follow the European/northern shape (Weinstein-Evron, 1983). Reverse climatic conditions between the southern Levant on the one hand, and Turkey and western Iran on the other, were also suggested for the Holocene (van Zeist and Bottema 1988).

The Grande Pile diagram (Woillard, 1978) was chosen to represent the European sequences. Though differences in terminology and dating may occur (i.e. the identification of the Amersfoort, Brörup and Odderade interstadials, Fig. 7), the similarities between the different European curves are widely accepted when correlations are based on biostratigraphical criteria (de Beaulieu and Reille, 1984a). There is usually little argument about the identification of the major fluctuations of stages 5,4,2 and 1. Correlation of the more moderate fluctuations within isotope stage 3 seem more problematic (problems of dating, local influences, latitudinal changes, changes in rate of sedimentation, etc.; de Beaulieu and Reille, 1984a,b). Likewise, when additional deep sequences are studied in the Levant, we expect the relatively minor fluctuations of isotope stage 5 to be more difficult to identify and correlate than the relatively pronounced and better defined fluctuations of the last Pleniglacial.

Unlike the European curves which are relatively well dated as a result of cross correlations with deep sea cores (Woillard and Mook, 1982; Turon, 1984; Pujol and Turon, 1986; Duplessy *et al.*, 1986; Mangerud *et al.*, 1979; Ferry and de Beaulieu 1986), the dating of the Hula/Levantine curve is still problematic, especially in its early part. The proposed correlations (Fig. 7) are based on the assumed concurrence of changes in temperature. In the Hula sequence warm periods are palynologically undistinguishable, but cold periods are characterized by high ratios of cedar pollen. Especially relevant to this discussion are the generally low values of cedar pollen in the Hula proposed isotope stage 5 and the relatively high levels of cedars during isotope stages 4 to 2 and 6. In the latter fir pollen is also common. The relative abundance of *Utricularia* pollen in the Pleniglacial section oh the Hula should be mentioned here. These water plants, now extinct from the Hula, indicate cold climatic conditions (S. Bottema, personal communication). It is worth noting that, as in the Hula and Ghab sequences, the coldest phase of the Grande Pile curve is also at the end of isotope stage 4 (Woillard, 1978).

To summarize, whilst changes in temperature seem to be in concordance, changes in humidity usually exhibit opposing trends. One exception appears to be the last glacial maximum, when dry conditions prevailed in both Europe and the Levant. Cold and/or dry climatic conditions for this period are indicated by the faunal and sedimentological data (Tchernov, 1979 a,b; Goldberg, 1981, 1986; Goldberg and Bar-Yosef; 1982; Goodfriend and Magaritz, 1988). The absence of cedar pollen from this part of the Hula and Ghab sequences (Tsukada, cited in Bottema and van Zeist, 1981; Niklewski and van Zeist, 1970) can be explained by the pronounced dryness. The survival of cedar seedlings largely depends on the presence of orographic summer rains in Lebanon (Zohary, 1974). Extreme dry conditions and especially no summer rains, would have resulted in a possible deterioration of the cedar forests in Lebanon. Recent observations (Shmida and Lev-Ari, 1982) have shown that not only do cedar seedlings have little chance of surviving through a dry (hot) summer, but also many of the adult cedar trees produce no fruits. High percentages *of Artemisia* and *Chenopodiaceae* pollen in this part of the Hula sequence support this view.

Climatic reconstructions

Based on the palynological data and the geographical setting, a schematic cyclic representation of the onset of climatic events in the Levantine Rift Valley can be attempted (Fig. 8). High AP levels, especially *Quercus,* represent a dense Mediterranean maquis or forest with a probable shift of the Mediterranean vegetational belt eastward towards the semi–arid regions, in humid periods. High NAP levels are a result of increased values of Artemisia and Chenopodiaceae pollen, caused by a shift of the Irano–Turanian steppe and desert vegetation westward, towards the Rift Valley, in dry periods. Intermediate periods are characterized by more mixed AP and NAP spectra, with varied values of *Cedrus* (in relatively humid phases) or *Olea* and *Pistacia* pollen (in dry periods) within the AP and grasses and open field plants within the NAP. Worth noting is the fact that high cedar values never occur in peaks of humidity but rather on the "slopes" of a specific fluctuation . Moreover, cedar peaks always follow peaks in oak pollen. In other words, increases in humidity seem to always precede cold conditions in the area. This trend was also observed in the pollen analysis of Birket–Ram in the Golan (Weinstein, 1976), where local variations related to changes in elevation were also identified. The intensity and/or duration of a certain climatic fluctuation would determine the extent to which the vegetational/palynological sequence would reach a certain peak in AP or NAP. In the last 10 000 years human interference should be taken into consideration. Thus, in the northern Rift Valley area, climatic and vegetational changes generally seem to be more pronounced along a west/east axis, following the present day configuration of the semi–arid/humid boundaries.

It is worth noting, however, that this more local mechanism discussed above is triggered by global events and is, in turn, influenced by the rate and intensity of polar air influx into the area. Thus, even though these reconstructions are probably valid for most of the period under discussion, with variations related to different durations or intensities of the various climatic events, the last glacial maximum seems to be an exception. Isotope stage 2 was colder than the preceding isotope stages, including stage 4 (Shackleton and Pisias, 1985; N.J. Shackleton, personal communication) and thus was probably a more intense period of polar influx into the area (Fig. 9). The pronounced coldness and dryness thus masked the more local factors.

These reconstructions support the climatic model proposed by Horowitz (1987), which suggests Atlantic origin for the rains in the area during glacial/pluvial periods. These are postulated for the Levant on the basis of the north/south gradients in humidity, as seen from palynological, sedimentological and isotopic data (Horowitz, 1979; Horowitz and Gat, 1984; Begin et al., 1974; Goodfriend and Magaritz, 1988).

It is worth stressing that the proposed reconstructions and correlations relate to the northern Rift Valley and do not necessarily apply to the more arid southern regions of the Levant, where other mechanisms (i.e. monsoonal rains) may have prevailed during certain periods (Issar and Bruins, 1983; Goldberg and Rosen, 1987; Gat and Carmi, 1987). The acceptance of a specific model largely depends on the identification of rainfall gradients. This, in turn, depends on a detailed and precise chronological framework for the Levant, which, unfortunately, has yet to be established.

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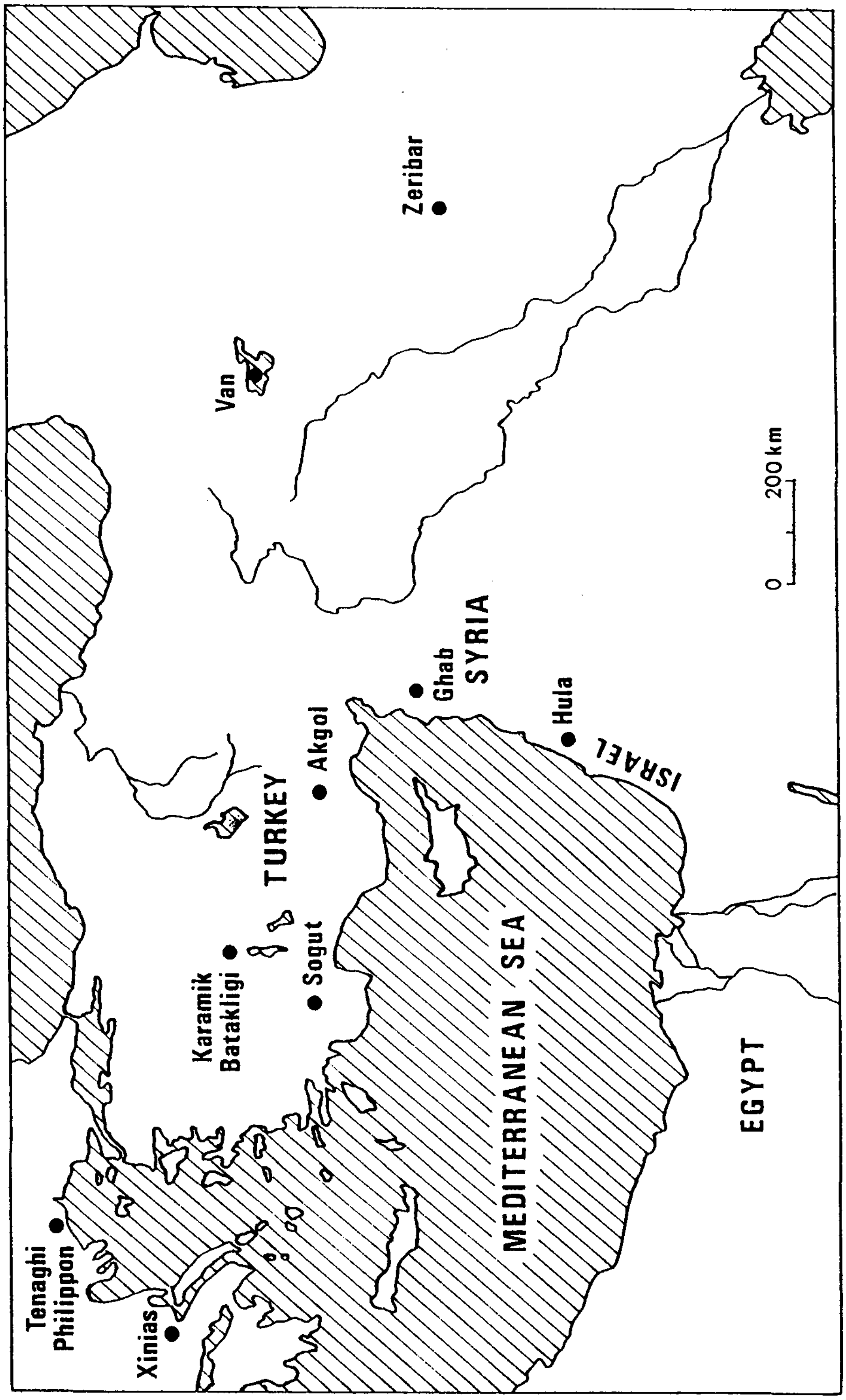

Fig. 1. Location map. Only sites with Pleniglacial and Late-glacial sequences are shown.

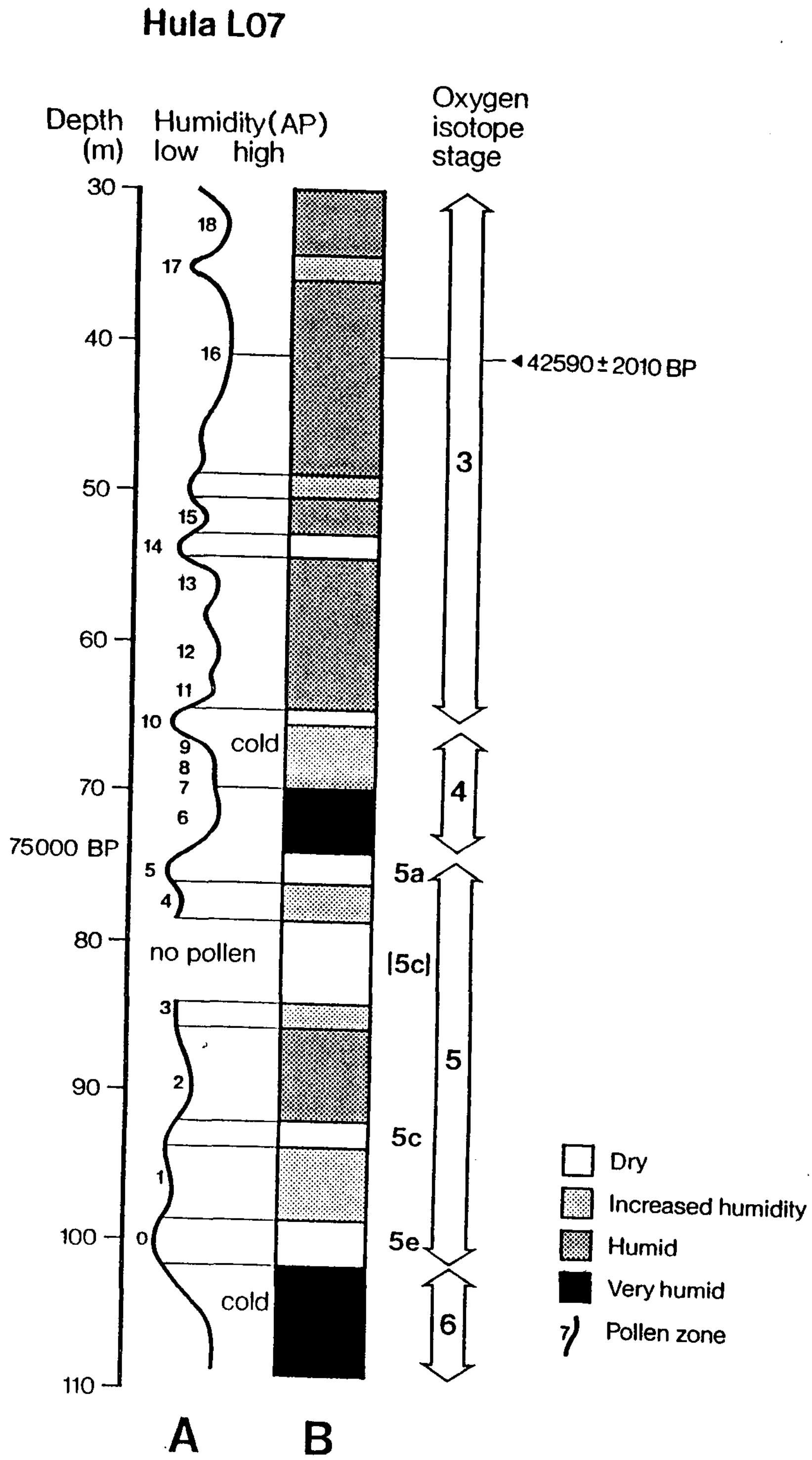

Fig. 2. Palaeoclimatological reconstruction of the Hula L07 core.

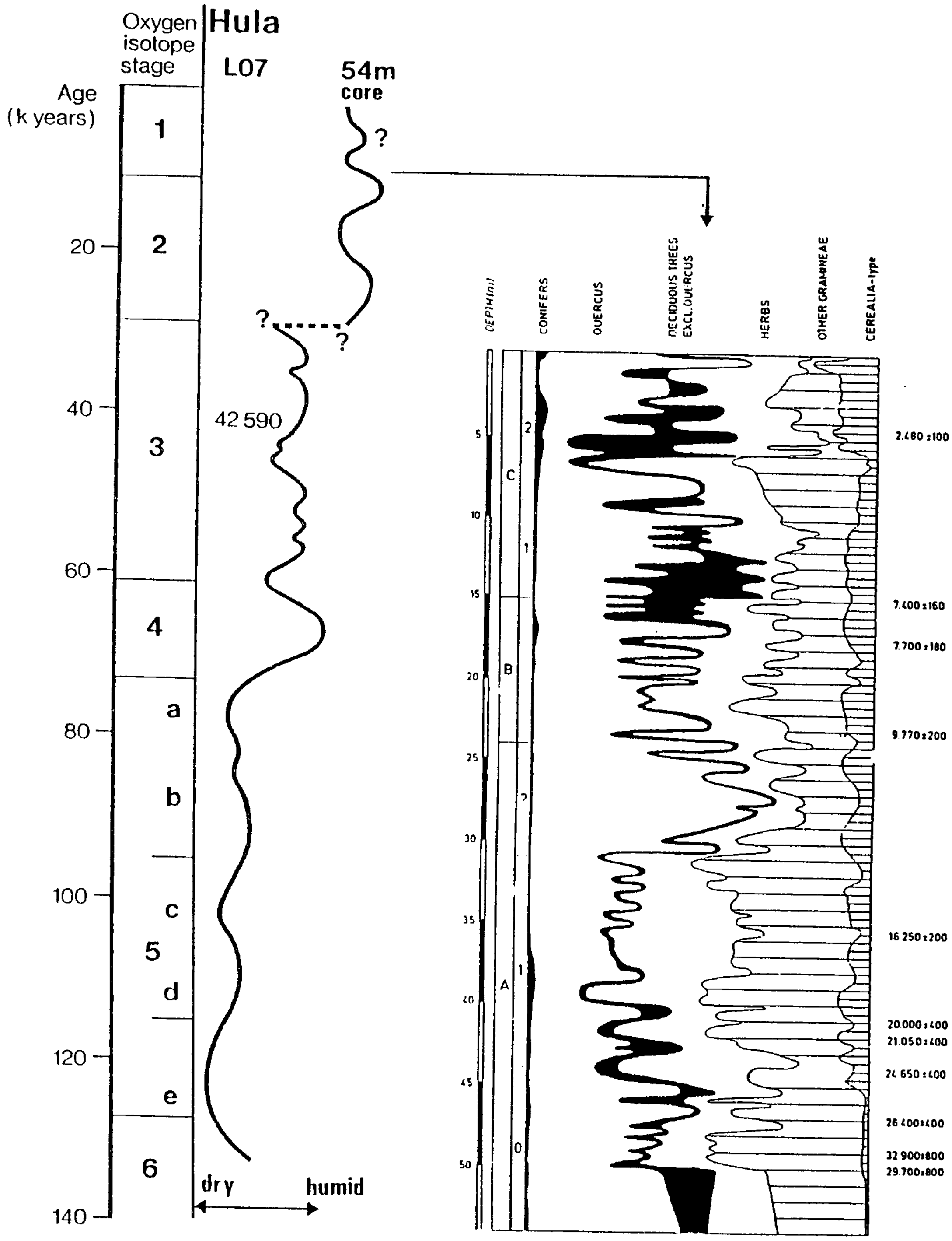

Fig. 3. A composite Hula curve for the last 130,000 years. The last 30,000 years are from Tsukada (cited in Bottema and van Zeist, 1981).

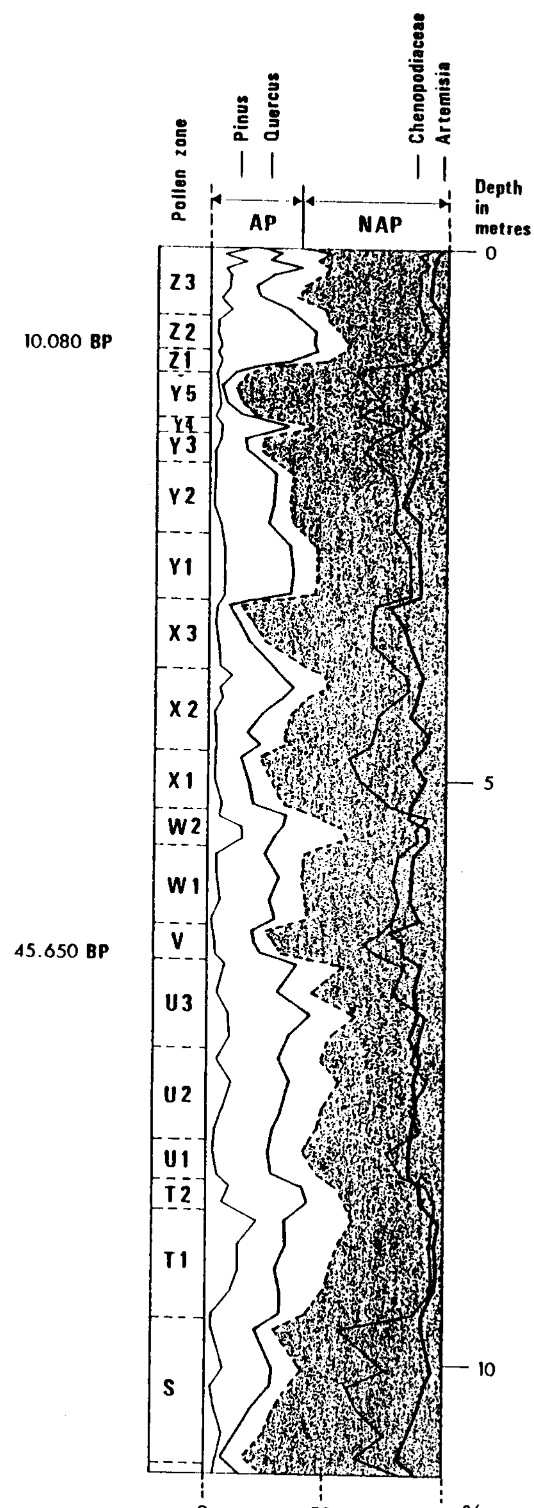

Fig. 4. The main diagram of the Ghab sequence, after Niklewski and van Zeist, 1970.

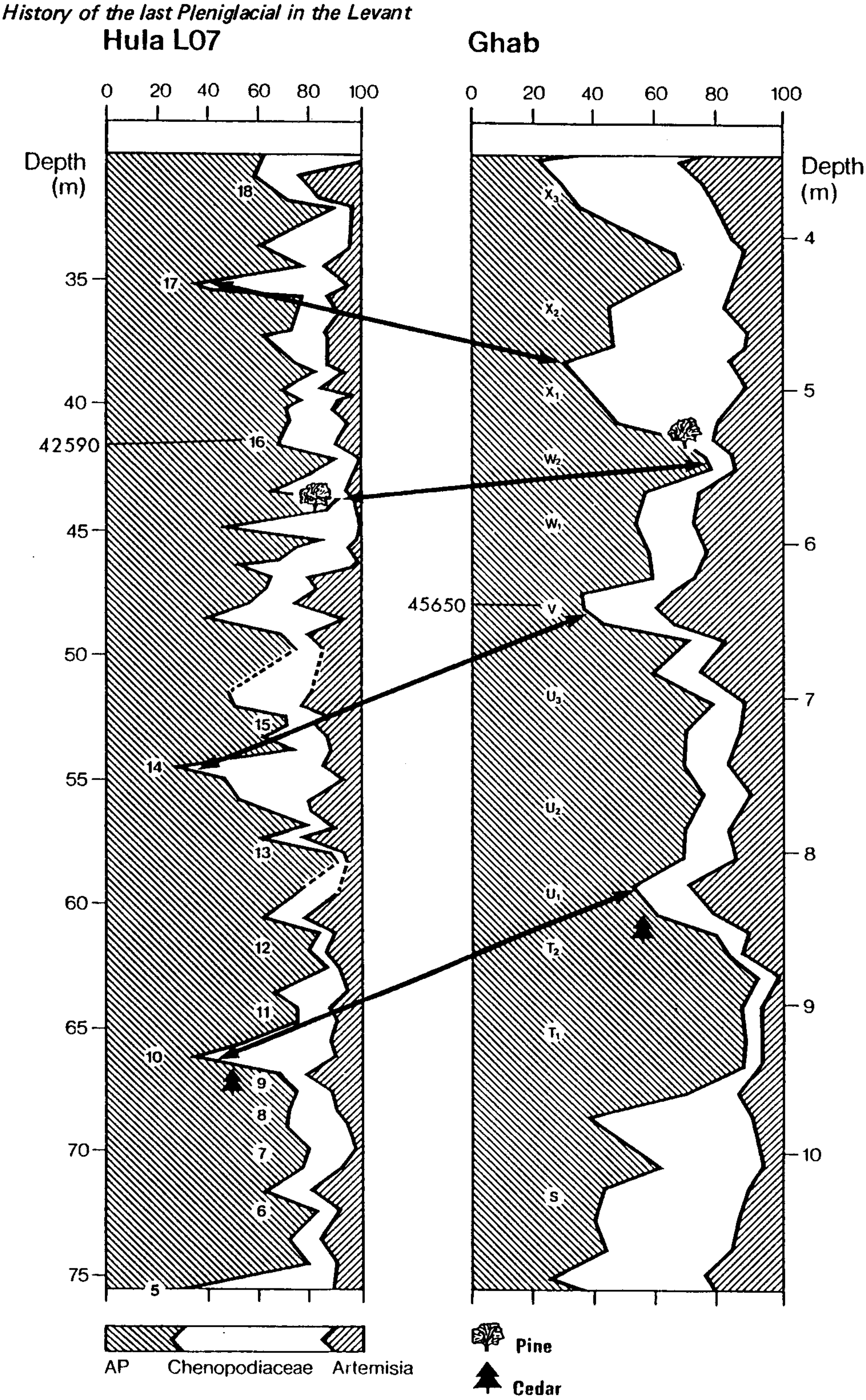

Fig. 5. Comparison between the last Pleniglacial sequences of the Hula and Ghab

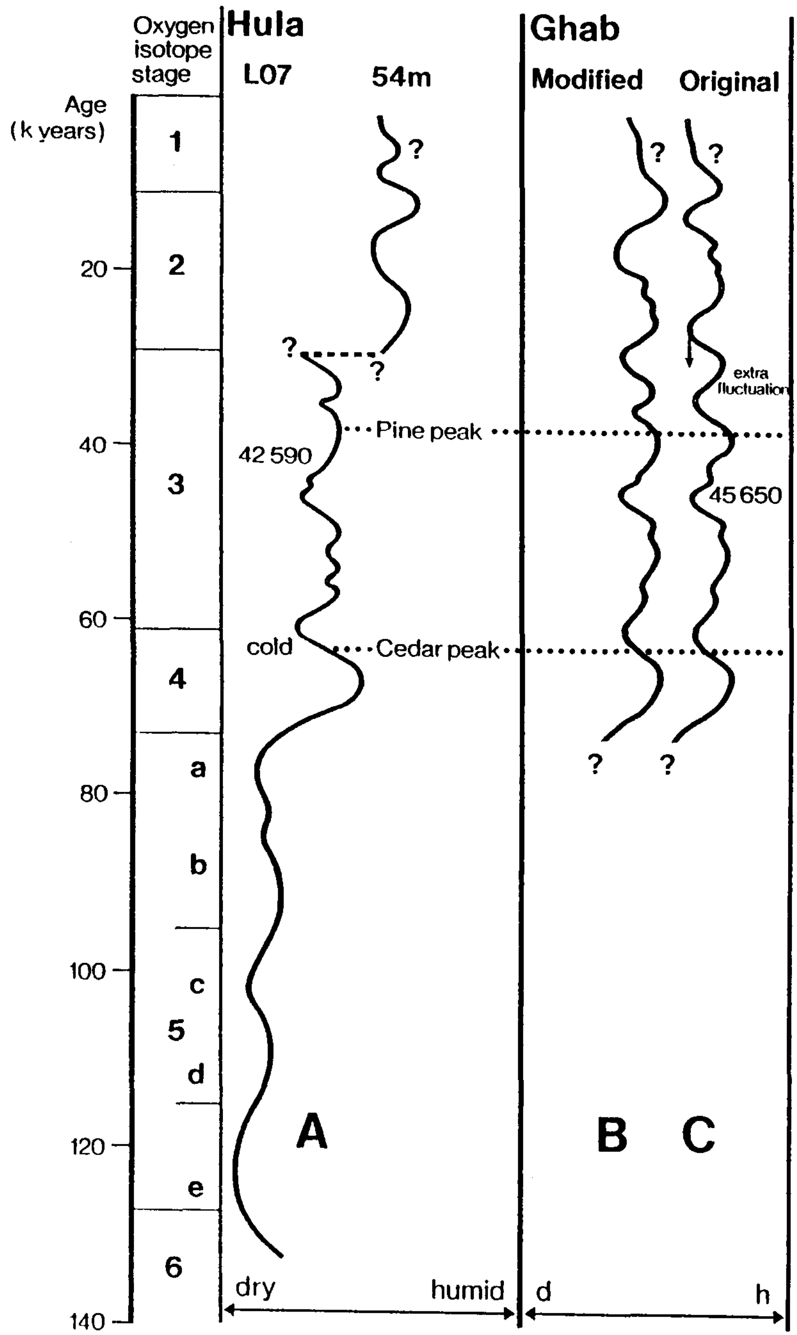

Fig. 6. Comparison of the composite Hula curve and that of the Ghab.

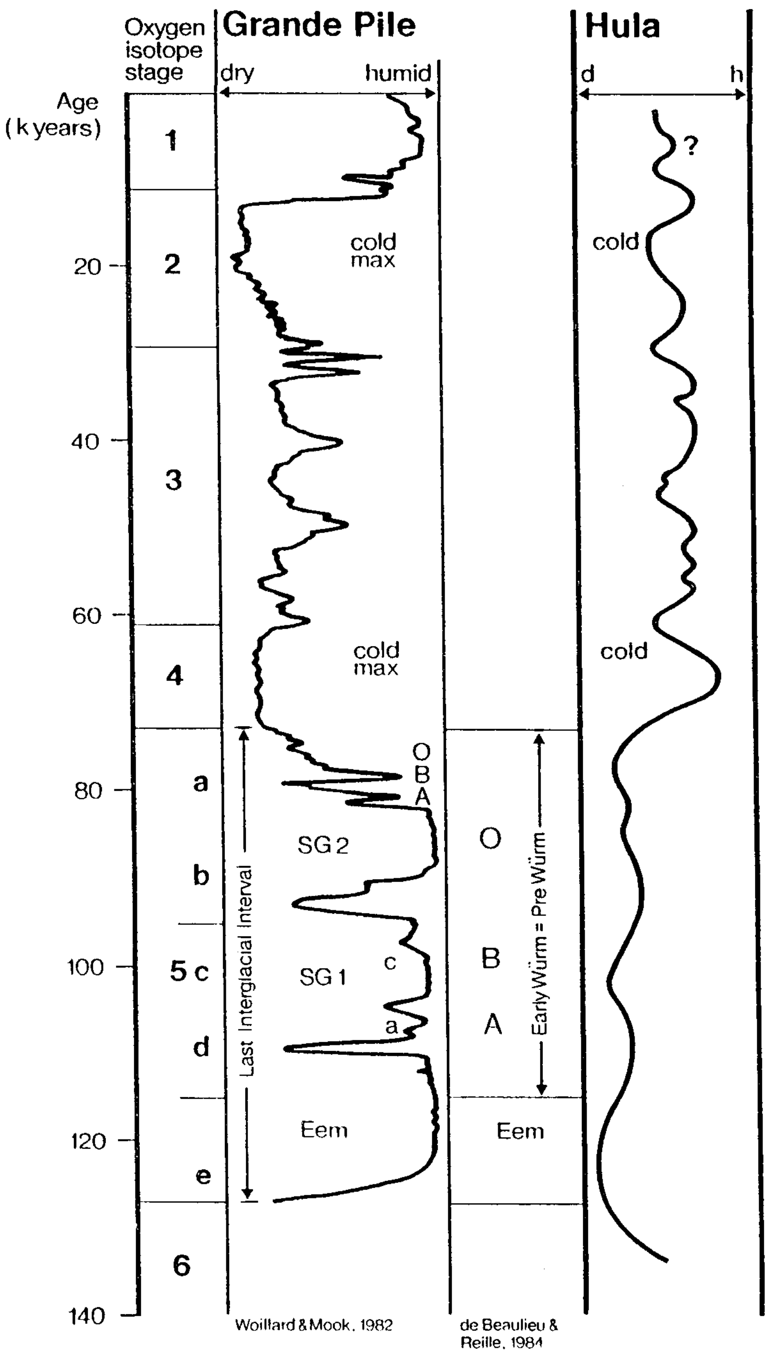

Fig. 7. Comparison of the general form of pollen curves from Europe and the Levant.

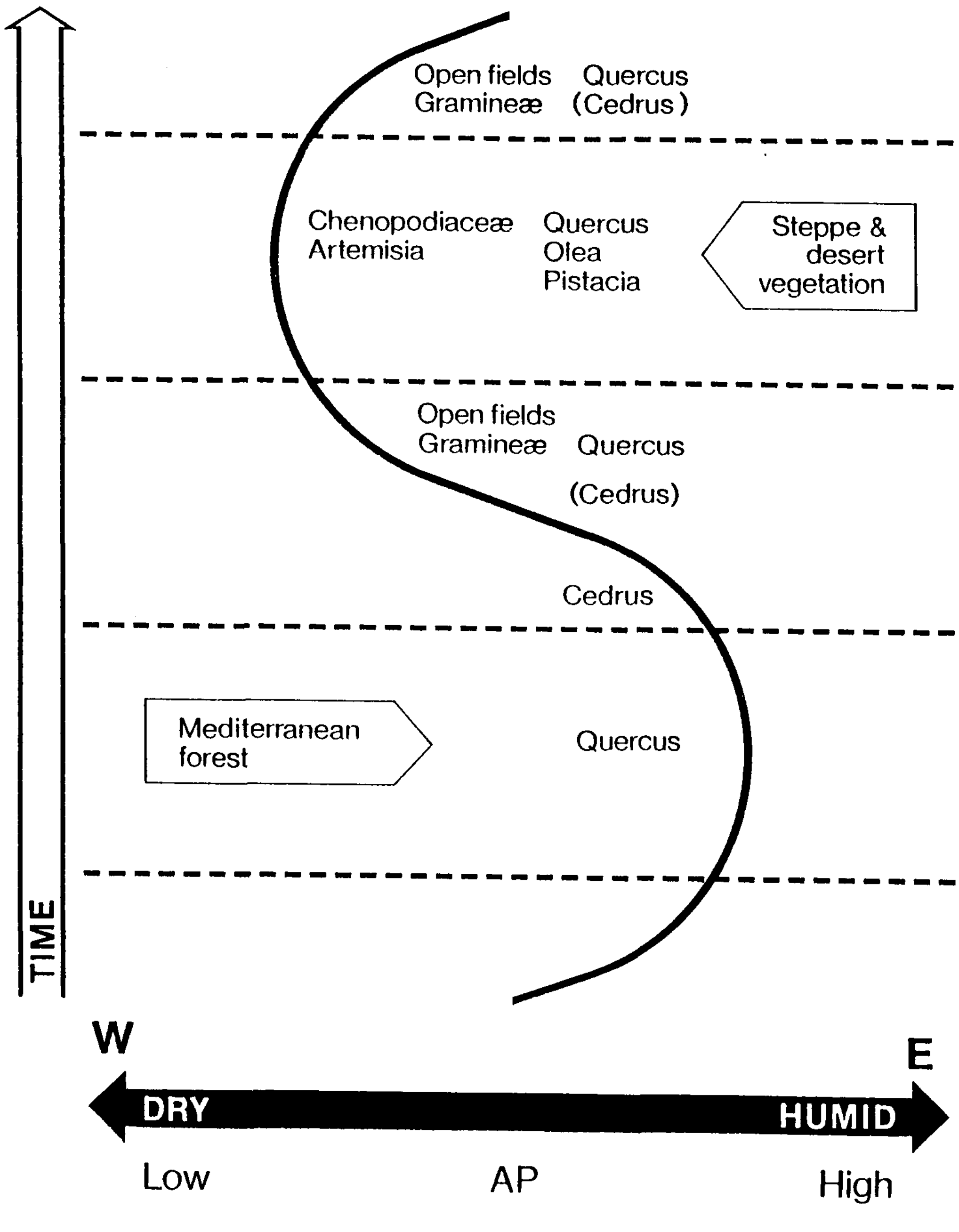

Fig. 8. Schematic representation of the main palaeoclimatological changes identified within the Hula/Levantine sequence.

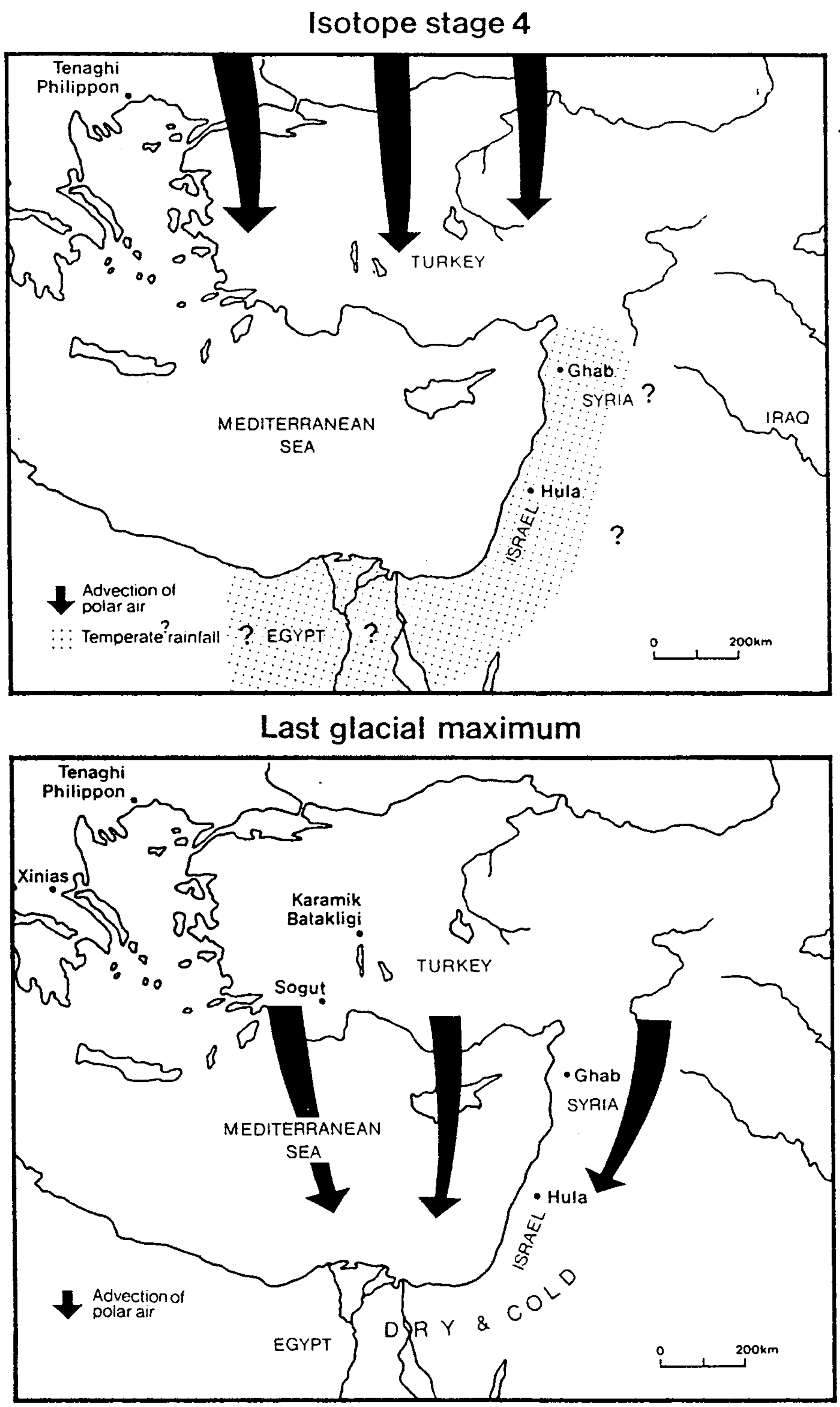

Fig. 9. Regional climatic conditions during isotope stages 4 and 2, with the relevant pollen sites.