CLIMATIC CHARACTERISTICS OF THE LATE PLEISTOCENE AND HOLOCENE CONTINENTAL DEPOSITS FROM SOUTHWESTERN SYRIA BASED ON PALYNOLOGICAL DATA

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Abstract. Hussein, K. M. 2006. Climatic characteristics of the late Pleistocene and Holocene continental desposits from sowthwestern Syria based on palynological data. *Darwiniana* 44(2): 329-340.

The goal of this research was to reconstruct the vegetational and climatic changes that took place during the late Pleisocene and Holocene in southwestern Syria. This reconstruction was based on palynological data obtained from the analysis of 27 sediments and surface samples (with a total thickness of 4.55 m) collected from Al-Hijaneh Lake basin (late Pleistocene) and from Al-Aouaj River valley (Holocene). Three pollen zones were established. The oldest one (zone A) corresponds to the late Pleistocene lacustrine deposits of Lake Al-Hijaneh. Zones B and C were defined in the Holocene fluvial-lacustrine deposits of the Al-Aouaj River valley. These three pollen assemblage zones are correlated to synchronic and similar C14 dated pollen zones from Syria, Turkey, Iran and Greece. This allows a more definite age determination for the deposits of this study. The region's past climates and vegetation are discussed.

Keywords. Flora, Holocene, late Pleistocene, paleoclimates, palynology, Syria.

Resumen. Hussein, K. M. 2006. Características climaticas de los depósitos continentales del Pleistoceno tardío y Holoceno del suroeste de Siria sobre la base de datos palinológicos. *Darwiniana* 44(2): 329-340.

El objetivo de esta investigación fue reconstruir la vegetación, el clima y los cambios que han tenido lugar durante el Pleistoceno tardío y el Holoceno, en el suroeste de Siria. Esta reconstrucción se basó en datos palinológicos obtenidos del análisis de 27 sedimentos y muestras de superficie (con un espesor total de 4,55 m) coleccionadas durante el verano de 1998 en el lago Al-Hijaneh (Pleistoceno tardío) y en el valle del rio Al-Aouaj (Holoceno), y analizadas en 1999. Se establecieron tres zonas de alemacenamiento de polen. La más antigua (zona A) corresponde al Pleistoceno tardío en los depósitos lacustres del lago Al-Hijaneh. Las zonas B y C quedaron definidas en los depósitos lacustres del Holoceno del valle del rio Al-Aouaj. Las tres zonas polínicas son correlativas con zonas de polen similar en territorios del Mediterráneo del este. Los climas presentes y pasados de la región, y su vegetación son tema de discusión.

Palabras clave. Flora, Holoceno, Paleoclimas, Palinología, Pleistoceno tardío, Siria.

INTRODUCTION

Damascus Basin, with its vast accumulation of sediments, forms the northern part of the Jabal Al-Arab graben of southwestern Syria. The southern part of the graben contains about 1200 m of Neogene and Quaternary volcanic rocks. The geology of Damascus basin has been studied by Van Liere (1961), Razvalyaev (1966), Ponikarov (1967), Bogdanov (1969) and Kaiser et al. (1973). Palynological methods have been used successfully for the stratigraphic subdivision of sediments in the Damascus basin, and the surrounding regions, since the early 1960's (Razvalyaev, 1966: 64), Niklewski & Van Zeist (1970), Hussein (1973, 1998), Hussein & Ribakova (1973), Kaiser et al., (1973), Leroi-Gourhan (1973a, 1973b, 1974), Bottema (1975, 1976, 1977, 1986).

East Mediterranean Quaternary vegetation and climates were studied by Bottema & Barkuda (1979), Bottema & Van Zeist (1981), and Van Zeist & Bottema (1982).

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This research discusses the palynological data consisting of 27 late Quaternary lacustrine and fluvial-lacustrine sediments and surface samples that were collected by the author from southwest Syria. The samples (Fig. 1) were obtained from the following (dated by fauna deposits from Al-Hijaneh Lake as Late Pleistocene) from Al-Otaibah Lake (one surface sample), and from Al-Aouaj River valley as Holocene. The task was to study and to discuss the changes in vegetation and climate that occurred during these time intervals.

GEOLOGICAL OUTLINE

Damascus Basin is separated from the Palmyrid folded zone by a Strike-slip fault system (Ponikarov, 1967, Milanovskii, 1987). Two lake basins are situated in the eastern part of Damascus basin: Al-Otaibah in the north and Al-Hijaneh in the south. Two short eastward-flowing rivers drain into these basins: the Barada River flows to Al-Otaibah Lake, and Al-Aouaj River flows to Al-Hijaneh Lake (Fig. 1). The two lakes are considered remnants of the Paleo-Damascus Pluvial lake of the early Quaternary period (Kaiser et al., 1973). The Palmyrid range is composed of Mesozoic and Cenozoic rocks that are mainly limestone, dolomite, and conglomerate sequences, with subordinate quantities of phosphorite deposits and flint. To the south and southwest of the Palmyrids, Damascus basin contains a basal sequence of middle Miocene (Helvetian age) volcanic extrusive rocks, which are unconformably overlain by sedimentary sequences of Pliocene and Quaternary ages. The Late Pleistocene lacustrine deposits are well known mostly in the lake basins of Al-Hijaneh and Al-Otaibah. At Al-Otaibah, the deposits form a vast undulating plain of salty carbonates, which pass northward into the surface of alluvial fans at the base of the mountains. In the central part of the basin, compact white marl intercalates with sandy and lumpy loam. From the stratigraphic and paleontologic point of view, in some places the sediments, which were studied by a group of geologists from the USSR in the mid 1970's, contain numerous shells of freshwater mollusks including *Lymnaea stagnalis* L. typ., *L. stagnalis* var. *subulata*, *Radix ovata* Draparnaud forma typ. Ex var., *Bithynia* aff. *leachi* Sheppard, and *Valvata pulchella* Studer (Razvalyaev, 1966: 72). These species are typical of the Late Pleistocene. The following similar mollusk assemblage was described from the Late Pleistocene deposits in boreholes to the northeast of Al-Otaibah Lake: *Valvata saulcyi* Bourguigant, *Hydrobia longislata* Bourguirgnat, *Bithynia badiella badiella* Küster, *B. badiella saulcyi* Bourguignat, *Radex peregra tenera* Mousson, *Lymnaea stagnalis chantrei* Locard, *Planorbis planorbis antiochianus* Locard, *Gyraulus picinarum picinarum* Bourguinat, *Armiger crista* L. and others. Also, Late Pleistocene ostracods from Dmer and Sahl Adra include; *Candona neglecta* Sars, *C. lartwigi* Müller, *Candonopsis kingsleii* Brady & Robertson, *Ilyocypris dentifera* Sars, *I. Monstrifica* Norman, *Cyclocypris ovum* Jurine, *C. laevis* Müller, *Cyprinotus salinus* Brady (Kaiser et al., 1973). Late Pleistocene deposits in Al-Hijaneh Lake are composed of gray and white beds of silty calcareous clay with a total thickness of 20 m. Some levels are rich in shells of freshwater gastropods. Holocene fluvial-lacustrine deposits in the lower course of the Al-Aouaj River consist of a few meters of sediment on the modern flood plain and the first river terrace. The deposits consist of silty clays with calcareous and basaltic pebbles and boulders. Freshwater gastropod shells are common in some levels.

MATERIALS AND METHODS

Thirty-five sediment and surface samples were subjected to pollen analysis (Figs. 2 and 3). Ten sediment and one surface samples were obtained from the outcropped Late Pleistocene deposits from the western side of the Al-Hijaneh Lake basin (Section VI, 33º 18' 38" N, 36º 35' 42" E, 615 m elevation) 200 m southeast of Omm-Dbeb village. The total sedimentary sequence has a 205 cm thickness. It consists of a basal 12-cm-thick calcareous silty clay with freshwater gastropod shells. The unit is overlain by 20-cm-thick silty clay with small calcareous and basaltic pebbles. The next younger unit consists of a 150-cm sequence of gray calcareous silty clay with laminae ranging between 0.5-3 cm. The uppermost unit consists of 23 cm of white calcareous silty clay (Fig. 2).

Eight sediment (Fig. 2) and one surface sample

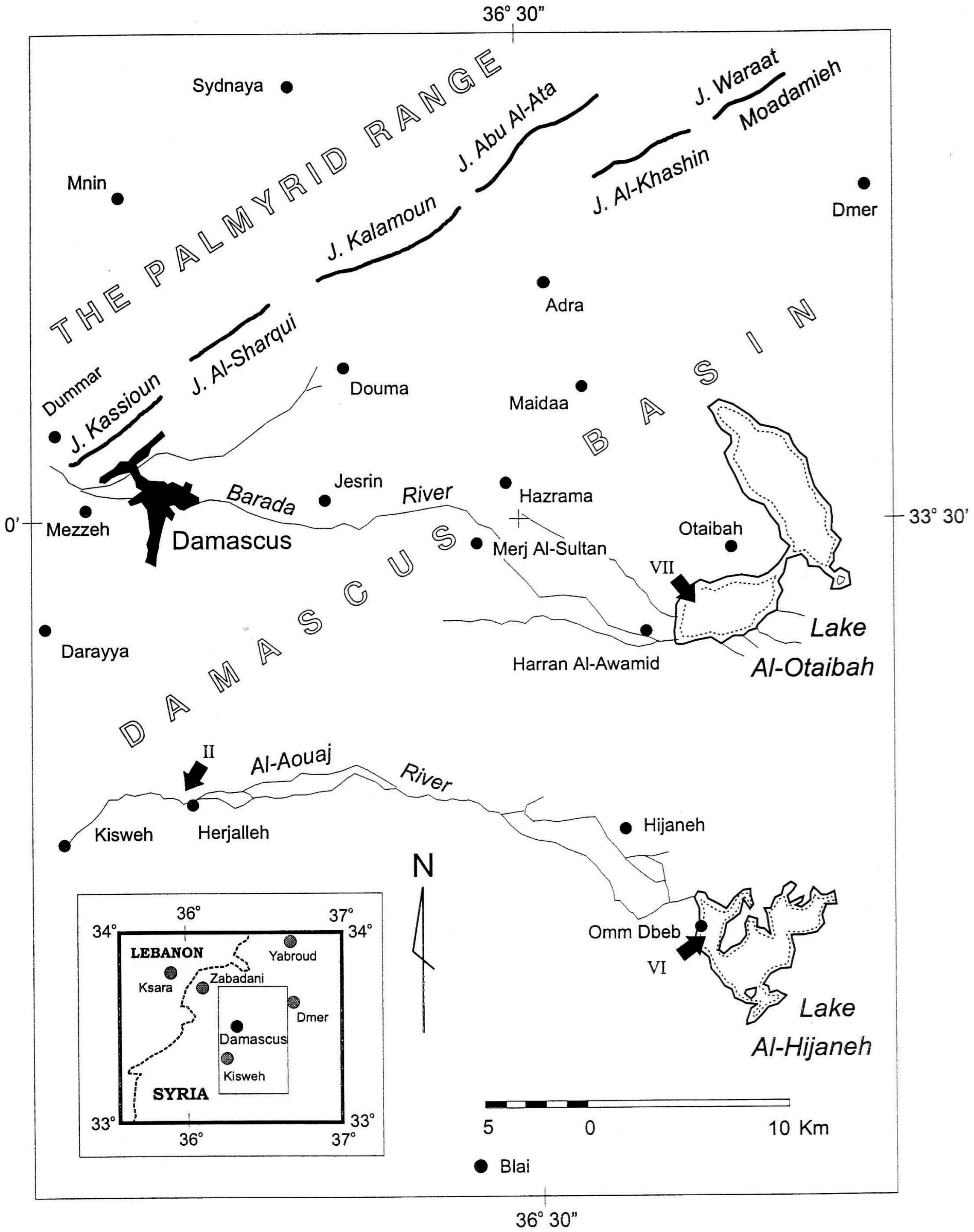

Fig. 1. Map of the Damascus basin and part of the Palmyrid Range of southwestern Syria. The arrows show the location of the three sections discussed in this paper.

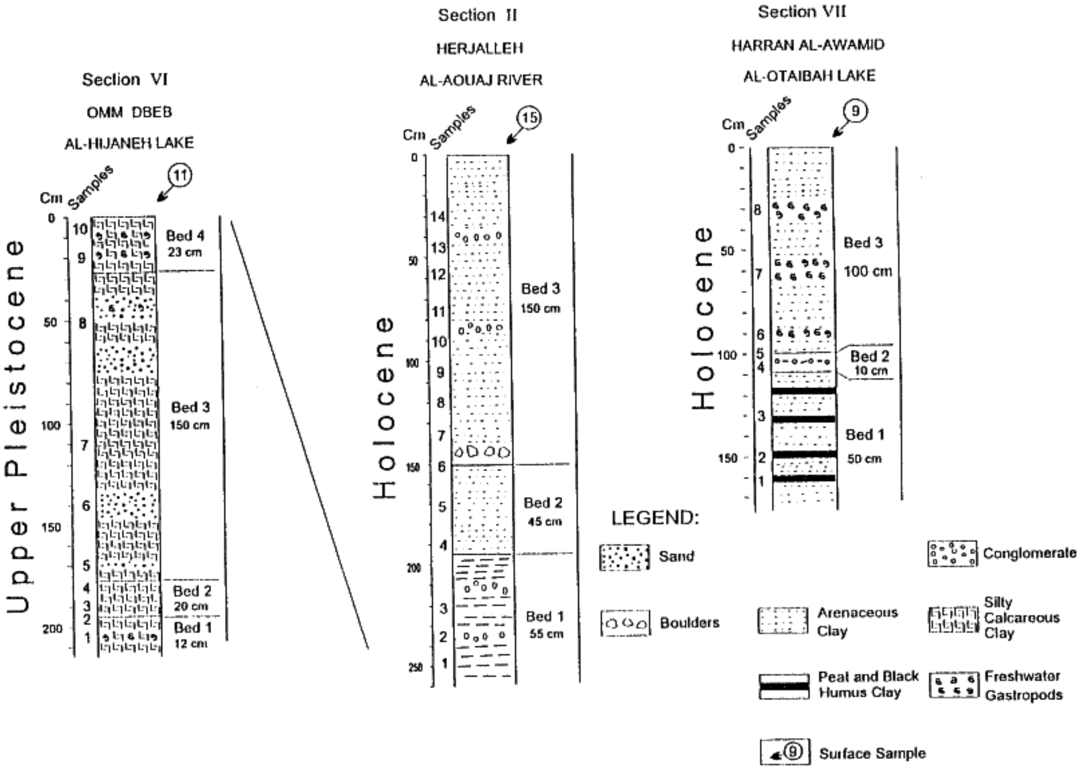

Fig. 2. Chrono-stratigraphy of the studied sections in the Damascus basin and the Palmyrid range, southwestern Syria.

(Fig. 3) were collected from a quarry at Al-Otaibah Lake, 3 km northeast of Harran Al-Awamid town (Section VII, 33º 31'04" N, 36º 37' 45" E, elev. 600 m). The total thickness of sediment is 160 cm. The lithology consists of clay and silty clay, with some calcareous and basaltic pebbles; the upper 100 cm contains unfossilized shells of freshwater gastropods. Unfortunately, the palynological analysis of the eight sediment samples showed them essentially barren. Only the surface sample was rich in pollen and spores.

In addition, fourteen sediment and one surface samples were obtained from the lower course of the Al-Aouaj River valley, to the west of Herjalleh village (Section II, 33º 23' 05" N, 36º 19' 25" E, elev. 720 m). The thickness of this section is 250 cm. The lower 100 cm consists of brown and gray clay with basaltic pebbles; this is overlain by 150 cm of sandy clay with basaltic pebbles and boulders. The sediment contains both lacustrine silt layers, with freshwater gastropod shells, and fluvial layers containing pebbles and boulders. The Total sediment thickness of the analyzed three sites is 6.15 m.

The reason for excluding the C^{14} dating for the research material was firstly because of the bad preservation of the faunal remains, as well as the contamination possibility of the site samples. Secondly, because the mollusk fauna shells of the studied deposits could easily pulverize and break when touched. Thirdly, due to the non fossilization of the shells themselves and the possibility of giving unreliable age indications. The geological time for the studied deposits was established based on the fossil record from the sites, as well as based on the geomorphologic characteristics of the sequences, mainly the succession of the deposits and the elevation of the strata (Razvalyaev, 1966; Bogdanov, 1969, Kaiser et al., 1973).

From 10 to 15 g (dry weight) of sample was crushed to a fine powder and treated with 10% HCl to remove carbonates and then with 10%

NaHO to soften organic matter. The residue was boiled in 48% HF in Teflon beakers for 5 minutes to reduce the volume of silicates. After acetolysis, a Zn Br2 heavy-liquid solution (Gray, 1965) of 2,15 s.g. was employed to separate the organic fraction from the residual silicates.

Routine study was done at 400-power magnification; 1000-power oil-immersion optics were used when required. Pollen and spores were identified using reference slides of the personal collection and the literature references as Erdtman (1952, 1957), Grichuk & Monaszon (1971), and Moore et al., (1991). The durable microscope slides are stored at the Department of Geology, Faculty of Sciences, Damascus University.

From an overall 27 studied samples, nine samples were found so poor in pollen and spores, that they were not considered to give any valuable information, however, eighteen samples were regarded to be fossiliferous with pollen and spores suitable for palynological study.

The pollen and spore diagrams (Figs. 3, 4 & 5) show the percentage a taxon represents in the pollen and spore sum for each level. The diagrams include all the taxa in the counts arranged alphabetically within the subgroups; Arboreal Pollen- AP (Gymnospermae), Arboreal Pollen- AP (Angiospermae), None Arboreal Pollen- NAP (Angiospermae), and Spores. The totals for these four groups are shown in the summary plot at the left of the diagram. The diagrams were constructed using Tilia and Tilia-Graph (Grimm, 1990) and Corel DRAW8(TM).

RESULTS

Results of the palynological analysis of Late Quaternary sediments were examined at three sites. The deposits in these sites belong to Late Pleistocene (Al-Hijaneh Lake samples) and Holocene (Al-Otaibah Lake & Al-Aouaj River valley samples), based on fauna and morphology as noted before.

Palynology of Al-Hijaneh Lake

One pollen and spore assemblage zone A was determined from the samples from Lake Al-

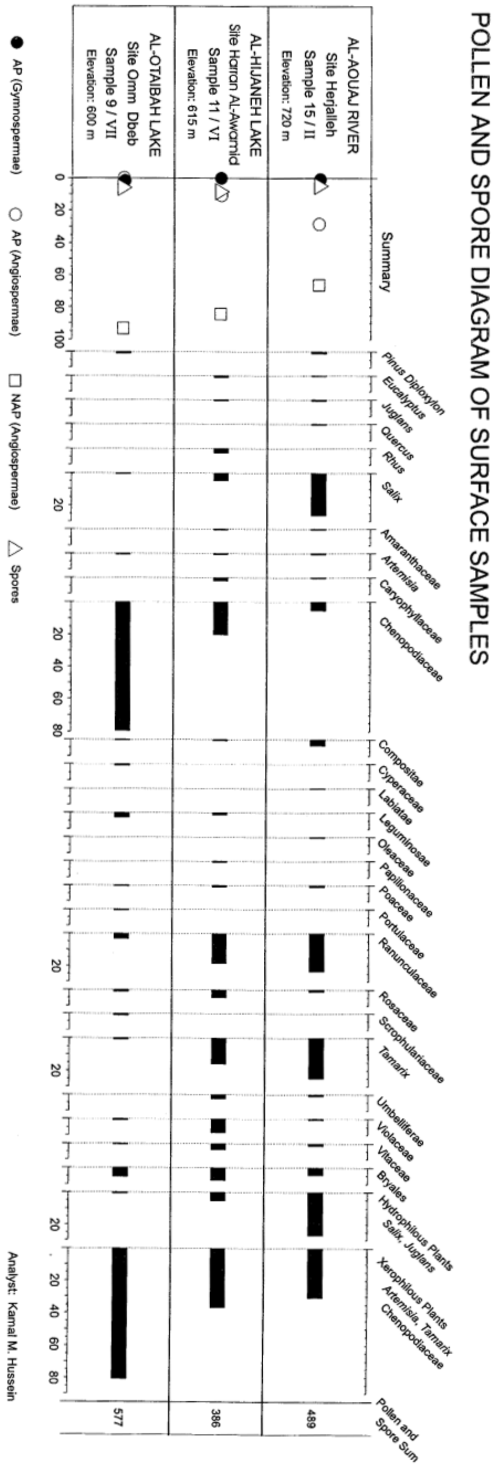

Fig. 3. Pollen and spore diagrams of three surface samples. The abundance values are percentages of the total pollen and spore sum.

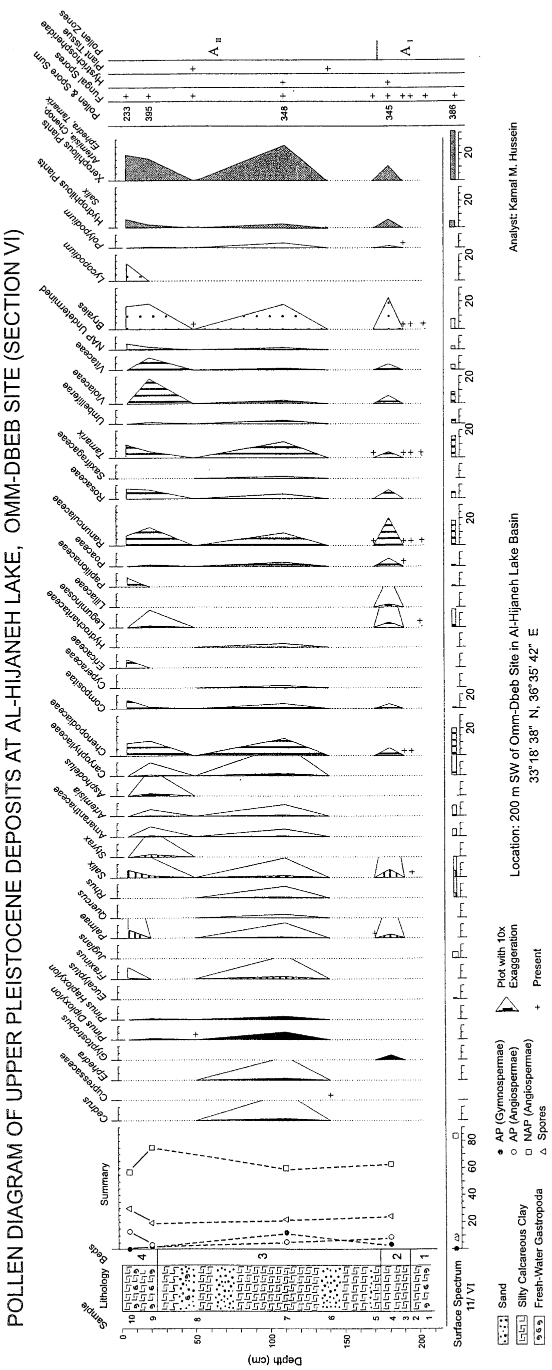

Fig. 4. Pollen diagram of the Late Pleistocene deposits at Al-Hijaneh Lake, Omm-Dbeb Site (Section VI).

Hijaneh (Fig. 4) at the Omm-Dbeb section. Zone A is divided into two sub-zones, AI and AII, based on the difference in the basal spectrum from the others. The older sub-zone AI consists only of one sample (4); the younger sub-zone AII, includes the other three spectra (7, 9 and 10). Plus marks (+) on the diagram indicate the taxa noted during scans of essentially barren samples.

Assemblage zone A is characterized by a low AP content gymnosperm (AP-G) and angiosperm (AP-A) trees. Zone A is noted for the dominance of its NAP. In both AI and AII, NAP averages 63%. Spores make up the second dominant palynomorph in zone A.

Subzone AI has a poorer record of trees than AII. The only tree recorded in the older zone is *Glyptostrobus* (Taxodiaceae). The xerophilous pollen is less frequent in AI than in zone AII, and many NAP types in zone AII are not found in zone AI. The abundance of Chenopodiaceae and *Tamarix* are less frequent in zone AI than zone AII. Poaceae and *Salix* pollen, on the other hand, are higher in the AI subzone than in the upper subzone.

In zone A the NAP is represented by many types. The xerophytes (see especially the Chenopodiaceae and *Tamarix*) are well represented in sub-zone AII. The pollen of stream-bank trees (Salix) is well represented throughout the whole time when the Al-Hijaneh Lake section IV was deposited. Bryales and *Lycopodium* spores were abundant during the middle of zone AII and *Polypodium* spores appeared. *Cedrus* pollen was also relatively abundant in the middle of the zone (spectrum 7). Toward the end of zone A, the xerophytes gradually decreased.

On the basis of these observations, it is possible to characterize the vegetation and the climatic conditions that existed during the deposition of sediment in section VI. It seems likely that the landscape during the time of sub-zone AI contained three or four vegetation types. In the middle-elevation, mountains to the west of Damascus at an elevation about 1200 m, were occupied by a mixed conifer and deciduous forest stand. In this association, the pine trees grew side by side with trees of the deciduous Mediterranean Maquis: *Quercus*, *Fraxinus*, *Rhus*, and *Styrax*. *Cedrus libani* must have spread at higher elevations.

The slopes of the mountains were probably covered with a forest-steppe type of vegetation, including several different trees and herbs. At the lowest elevations (about 600-700 m), *Salix* trees were growing along the streams and on the banks around ponds of water. Based on the palynological data, the climate during this interval was most likely cold and arid, but with areas of adequate moisture.

Palynology of Al-Otaibah Lake

Eight sediment samples and one surface sample were studied from the western margin of Al-Otaibah Lake basin. The site is 3 km northeast of Harran Al-Awamid (Fig. 1). The sediment samples yielded little useful pollen information, although the surface sample (9) contains a rich assemblage of palynomorphs. The meager pollen content of the lower samples does not allow their use for biostratigraphic or paleontologic interpretations.

Deposits from Al-Otaibah and Al-Hijaneh basins were previously studied by Bottema and Van Zeist (in Bottema, 1975, 1976, 1977). Bottema mentions that the two sites were very poor in pollen.

Palynology of Al-Aouaj River valley

Two pollen and spore assemblage zones were identified from the fluvial-lacustrine sediments from the lower course of the Al-Auoaj River, section II, near Herjalleh town (Fig. 5). Zone B was identified from the lower part of section II, whereas, zone C from the upper part of the section. Zone B consists of four pollen spectra (1-4). The interval (samples 5-7) between samples 4 and 8 is essentially barren. Only a few pollen and spores were noted, and these taxa are indicated by plus marks on the diagram. Zone C consists of seven spectra (8-14). The boundary between the two pollen zones was drawn at the edge between bed 2 and bed 3, at a depth of 150 cm.

Assemblage zone B is characterized by very high NAP values, compared with the older zone A. The NAP percentage is more than 80% in most of the spectra of this zone. NAP is dominated by *Artemisia*, in spectra 3 and 4, it reaches 23% and

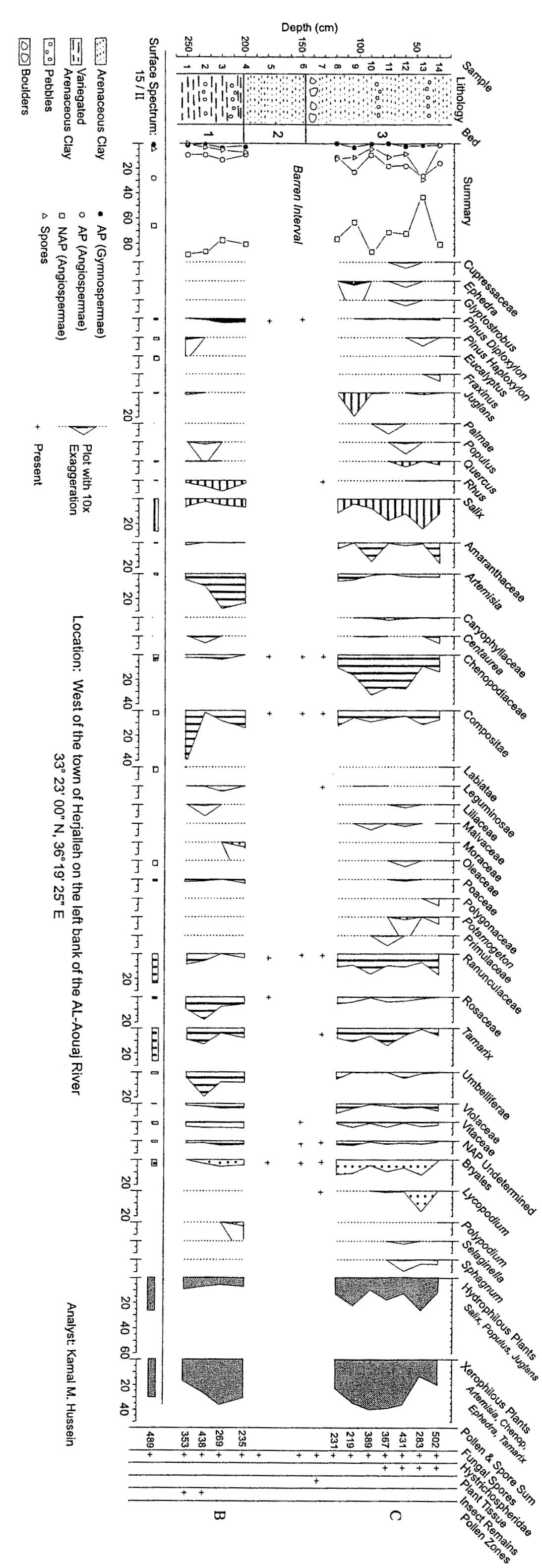

Fig. 5. Pollen diagram of the Holocene deposits at Al-Aouaj River valley, Herjalleh Site (Section II).

Table 1. Stages of vegetation development (and inferred climate) in southwest Syria based on the palynology of Late-Glacial and Holocene sediments.

Chronology	Lithology	Pollen Zones		Main Vegetation Elements	Vegetation Stages		Climate
Holocene	AL-AOUAJ Fluvial-lacustrine	C		None Arboreal Pollen (NAP) or Herbal Elements : 43-87% Xerophytes: Chenopodiaceae, Artemisia, Ephedra, Tamarix (10-40%) Arboreal Pollen (AP): Quercus, Pinus, Rhus, Fraxinus (15-30%) StreamBank Pollen (SBP): Salix, Juglans, Populus (10-30%) Spores: 10-20%	III	Forest - Steppe	Similar to Climate of today
		B		None Arboreal Pollen (NAP) or Herbal Elements: 80-85% Xerophytes: *Artemisia*, Chenopodiaceae, *Tamarix* (10-28%) Arboreal Pollen (AP): *Quercus, Pinus, Rhus*, (15%) StreamBank Pollen (SBP): *Salix* (8-10%) Spores:~5%	II	Steppe	Temperate-Arid
Late Pleistocene	AL-HIJANEH lacustrine	A	AII	None Arboreal Pollen (NAP) or Herbal Elements: 60-70% (average 63%) Xerophytes: Chenopodiaceae, *Artemisia*, *Ephedra* (20-30%)	I	Steppe + Tree Stands	Cold-Arid
			AI	Arboreal Pollen (AP): less than 20% StreamBank Pollen (SBP): *Salix* (5-10%) Spores: 20-25%			

28%, and to a lesser extent by *Centaurea* and other Compositae. Chenopodiaceae is less abundant. The AP percentage is low in this zone. AP is slightly lower than it was during the previous zone A, but its components differ. The AP (Angiosperm) dominates over the AP (Gymnosperm). The conifer pollen percentage, represented only by Pinus pollen types, is lower than that of the Mediterranean deciduous taxa. The AP (Angiosperm) includes pollen of *Quercus*, *Rhus*, *Populus*, *Salix* and *Juglans*. *Salix* pollen percentages fluctuate between 2% and 6%. Xerophilous pollen increases upward, maintaining a high percentage. Concomitantly, the relatively low percentage of the stream-bank pollen slightly decreases.

During the time represented by zone B, the pollen contents indicate that the vegetation was dominated by steppe associations with poor tree stands. The maximum NAP percent in spectrum 1 is 89%. The Compositae, *Artemisia*, *Tamarix*, and to less extent *Centaurea*, played an important role in the landscape. The Chenopods played a less important role than did *Artemisia* in the vegetation of zone B. In the medium elevation of the mountains, arboreal vegetation of *Pinus* and temperate deciduous types were scattered. *Cedrus* was present at higher elevations. The pollen data suggest that the climatic condition represented by zone B was more temperate and arid than it was during zone A time.

Zone C is different from the previous two zones. Although the dominant pollen in this zone belongs to herbaceous plants, show a much greater fluctuation compared to zones A and B. NAP in zone C, for instance, fluctuates between 43% and 87%. The NAP in zone C is characterized by a very high percentage of Chenopodiaceae (32% in sample 10). The NAP has a higher proportion of Amaranthaceae, and a much lower proportion of *Artemisia* than in the previous zone B. The AP (Angiosperm) abundance during zone C is higher than it was in zone B, and it fluctuates between 8 % and 26% within the zone. The percentage of the AP (Gymnosperm) is remarkably low.

Ephedra pollen also played a role in zone C, and the AP are slightly more diverse than in zone B. Zone C has a mixed character with more active participation of *Quercus*, *Salix*, *Juglans*, *Rhus*, and *Fraxinus*. *Pinus* decreases but Cupressaceae and Taxodiaceae are noted in sample 12. Spores of Bryales, *Lycopodium*, *Selaginella*, and *Sphagnum* are more diverse in this zone.

The sum of the xerophilous plants is very high with a maximum in the middle of the zone (40% in sample 10). There is also a high percentage of the stream-bank pollen types that are mainly represented by *Salix*, *Juglans*, and *Populus*. Generally, it is important to note the fluctuating character of the taxa through this zone, which may have had variable temperature and moisture conditions (Precipitation ratios).

The vegetation during zone C suggests a relatively less dry climate, compared to zones B and A. Zone C is relatively cooler than zone B, but warmer than zone A. Also, the vegetation suggests a well-developed stream system in the area, with *Salix* and Ranunculaceae widespread along the banks. Other stream-bank trees and ferns must have been growing in damp places such as the lower levels of forest vegetation. An explanation of the high values of Chenopodiaceae pollen in this zone might be related to widespread saline soils in the Damascus basin, or at least in the vast semi-desert and arid territory to the east. That might be a result of the wide land territories outcropped by Damascus pluvial paleolake evaporation. That could explain the spread of Chenopodiaceae, Amaranthaceae, *Ephedra*, *Tamarix*, and other xerophytes and halophytes. The deciduous trees seem to be more widespread during this zone compared to the more arid zone B. Mediterranean moderate arboreal taxa seem to be spreading on the slopes of the mountains to the west of Damascus city. The pollen data of zone C suggest forest-steppe vegetation. The vegetation and climate conditions inferred from the three pollen zones A, B, and C are summarized in Table 1.

DISCUSSION

Three pollen and spore assemblage zones were established from the lacustrine and fluvial-lacustrine deposits of southwest Syria. Zone A is based on late Pleistocene lacustrine deposits of Al-Hijaneh Lake, which are characterized by freshwater assemblage of mollusks and ostracods. Zones B and C are defined from the Holocene fluvial-lacustrine deposits of the Al-Aouaj lower River valley. The last sediments are characterized by their geomorphologic position as the most recent deposits of the river valley and by their contents of unfossilified fresh-water mollusks, which as mentioned before, are known in the area for the Holocene age (Ponikarov, 1967). The two pollen diagrams with their pollen zones cover the sedimentation time interval of the studied deposits from Late Pleistocene to about late Middle Holocene. The pollen zones coincide with the vegetation development history that took place in southwestern Syria during that time.

As a basis for the pollen diagrams of this research correlation and comparison, with the synchronous pollen diagrams from Syria and from the surrounding countries of eastern and northeastern Mediterranean, the terminology and the climatic subdivisions of the Alpine and northwestern European regions has been used (Williams et al., 1993). Nevertheless, the Syrian pollen diagrams were correlated with C^{14} or varv dated pollen diagrams from the surrounding countries. Great importance was given to the detailed changes of the pollen-morphs.

The correlation suggests that Zone A (Subzones AI & AII) of this study is similar to the synchronous palynological data obtained from Syria: pollen zones Da 2a (C^{14} -aged, 22,010 yr B. P.) and Da 2b (Da 2b1 & Da 2b2) from Sahl Adra (Leroi-Gourhan in Kaiser et al., 1973, p. 303-318), and subzone Y2 with a calculated C^{14} age between 21,000 and 17,000 yr B. P. from Ghab I (Al-Ghab in our usage, Niklewski & Van Zeist, 1970). Also similar from Turkey is the pollen zone 1 from Karamik Batakligi marsh with, a C^{14} -dated lower limit at 20,130 yr B. P. In addition, similar also is pollen zone 1 from the drained Sogüt Golü site, which occur prior to 9,180 C^{14} yr B. P. They coincide with the pleniglacial (Bottema & Van Zeist, 1981). From Iran, the upper part of zone 3b from Zeribar Lake pollen diagram (Van Zeist, 1977) was C^{14}-dated between 22,000 to 14,000 yr B. P. Zone 3 coincides with late pleniglacial of the European Würm chronology (Bottema & Van Zeist, 1981). Zone A1 from another pollen diagram from Zeribar Lake was dated by C^{14} from 22,000 to 14,800-13,650 yr B. P. (Van Zeist, 1967). The two pollen zones from Zeribar suggest a similar vegetation but a more severe climatic pattern, compared to Late Pleistocene of southwest Syria. From Greece, similar to zone A from Syria are sub-zones X4b and X4c from the Tinagi Philippon II section. The calculated age based on C^{14} dates for the end of X4c is 16,600 yr B. P. Zone X, coincides with the late pleniglacial and with the local Philippi interstadial. This interstadial correlates with the Lascaux of northwest Europe (Wijmstra, 1969). Also similar is the pollen material from 13 to 5 m depth core from Tinagi Philippon in Macedonia, which was C^{14}-dated earlier than 12,600 yr B. P. (Van Der Hammen et al., 1965).

From Greece, similar to the Syrian zone A, is sub-zone V5 from Ioannina Lake (Bottema, 1974 in Van Zeist & Bottema, 1982), and zone X from the drained Xinias Lake, which was C^{14}-dated between 25,600 and 15,000 yr B. P. (Bottema, 1979 in Van Zeist & Bottema, 1982).

In addition, the two Holocene pollen zones B and C of this study are able to be correlated with the synchronous pollen data obtained from Syria. The Holocene pollen spectrum from Jabal Sis (Leroi-Gourhan, 1973a, 1974) is similar to pollen zone C of our study. The pollen spectrum from Dmer shows similar arid vegetation. The two pollen spectra from Jabal Sis and Dmer are similar to each other (Leroi-Gourhan, in Kaiser et al., 1973, p. 303-318).

The C^{14}-dated pollen diagram from Tell Mureybet on the Euphrates River was shown to be younger than 8,400 yr B. P. (Leroi-Gourhan, 1974). The lower part of the pollen diagram is similar to pollen zone B, whereas the upper part seems almost to be a northern variant of the pollen zone C from Herjalleh.

The palynology from Ghoraife site, 30 km to the east of Damascus, was C^{14}-dated between 6,760 and 5,630 yr B. P. (Leroi-Gourhan, 1974). It looks similar to zone C from the Al-Aouaj River valley.

The postglacial pollen zones B and C from the Al-Aouaj River valley are comparable, respectively, with pollen zones 5 and 6 from the Ghab II diagram, which was C^{14}-dated as younger than 10,080 yr B. P. (Van Zeist & Woldring in Bottema & Van Zeist, 1981, p. 111-132).

Similar pollen data from Turkey were obtained from the Van Lake core (Van Zeist & Woldring, 1978). The basis of the Van Lake pollen diagram was varv-dated to be 9,800 yr B. P. so, it covers nearly the whole postglacial time (Kemp & Degens in Van Zeist & Woldring, 1978). It's most likely that pollen zones 3 and 4 from Van lake are similar, respectively, to pollen zones B and C from the Al-Aouaj River valley. The lower part of the Sogüt Golü Pollen diagram from western Turkey shows a dominant aridity through the first half of the postglacial. The lower part of pollen zone 4 from (Sogüt Golü) matches pollen zone C from the Al-Aouaj River valley.

Akgol Lake pollen diagram (Konya Basin) was C^{14}-dated between 10,920 and 8,040 yr B. P. (Bottema, 1986). The comparison between sub-zone 2a with zone B and sub-zone 2b with zone C from Al-Aouaj River valley provides many similarities.

From Iran, the Zeribar Lake (Zagros M., about 160 km northwest from Kermenshah) pollen diagram (Van Zeist, 1967) is very similar to the Van Lake diagram (Bottema & Van Zeist, 1981). Pollen zone B from Zeribar 63-J pollen diagram is compared to the two pollen zones B and C from the Al-Aouaj River valley. The lower part of Zeribar Lake zone B seems to be more like zone B, whereas the upper part of Zeribar's zone is more similar to zone C from the Al-Aouaj River valley. The middle of Zeribar zone was C^{14}-dated at 8,100 yr B. P. The zone's vegetation is thought to have a savanna-like character.

Merabad Lake (Zagros M., 270 km southeast of Zeribar Lake) pollen diagram shows many similarities with that from Zeribar Lake, but there are local differences between them. Zone B in Merabad suggests a forest-steppe to savanna vegetation (Bottema & Van Zeist, 1981, p. 118). The description of the flora development looks somewhat similar to that which was reported in the Al-Aouaj River valley.

Zone Z (Cores 20 and 21) of the hypersaline Urmia Lake basin pollen diagram from northwestern Iran is similar to pollen zones B and C from the Al-Aouaj River valley. The base of sub-zone Z1 was C^{14}-dated to 9,540 yr B. P., and the lower part of sub-zone Z2 was dated to 7,505 yr B. P. (Bottema, 1986). The common taxa between the correlated pollen zones from Urmia Lake and from the Al-Aouaj River valley include many similar pollen and spore types.

From northern Greece, the two pollen diagrams, Tinagi Philippon, Macedonia (Van Der Hammen et al., 1965) and Tinagi Philippon II (Wijmstra, 1969) show the spread of a forest vegetation during most of the Holocene. The lowest of the three top spectra from Tinagi Philippon show high values of AP, and was C^{14}-dated to 5,850 yr B. P. (Van Der Hammen et al., 1965). The spread of tree vegetation through zone Z from Tinagi Philippon II pollen diagram is similar. The beginning of the zone was dated by the C^{14} method at 10,300 yr B. P. (Wijmstra, 1969). The vegetation and climate were quite different in northern Greece from that in southern Syria during the Holocene.

As a conclusion for the pollen data correlation of the East Mediterranean region, the sediments in Al-Hijaneh Lake must be assigned to the late Würm with an approximate age ranging between 20,000 and 14,000 yr B. P. The sediments from the Al-Aouaj River lower course are likely to be assigned to the early to middle Holocene, say between 8,000 to 6,000 yr B. P.

The pollen analysis of the surface samples shows that the present region of Al-Otaibah Lake is richer in xerophytic pollen than are the other two sites. Unfortunately, the Holocene lacustrine deposits from Lake Al-Otaibah were palynologically barren. The two sections from Al-Hijaneh Lake (Section VI, late Pleistocene) and from the Al-Aouaj River valley (Secton II, Holocene) of this study, can be considered as a single composite record of the vegetation and climate during the time interval from the late Pleistocene to the late middle Holocene (Table 1).

The vegetation in southwestern Syria during the time interval of this study shows the dominance of steppe vegetation with tree stands during the Late Pleistocene (Late Würm Glaciation), and steppe and then forest-steppe vegetation, during the middle Holocene. During the whole of this time interval, the herbaceous vegetation was dominated by xerophytes. The arboreal vegetation had less chance to spread in the mountainous regions; but during the Holocene, especially during zone C, its range expanded. During the time of pollen zone C, the vegetation development suggests fluctuating moisture conditions. During that stage, the vegetation began to approach its modern form in southwestern Syria.

Climatic conditions of southwestern Syria during the closing phase of the late Würm glacial interval, were colder and more arid than now. For two-thirds of the Holocene, the climate was temperate-arid and then temperate with a higher relative humidity. The humidity might be caused by a greater precipitation rate, less evaporation, or a combination of the two factors. The possibility of correlating the vegetation development using pollen diagrams from the vast Eastern Mediterranean region including Syria, Turkey, Iran and Greece, shows that there are many similarities in these diagrams (Bottema & Van Zeist, 1981, El-Moslimany, 1990). However, although the development was similar (the trend toward aridity and toward the contemporary climate of each region respectively) during the studied time episodes in the different areas, it does not necessarily mean that the changes were synchronous. In general, the consistent pattern of the vegetation development in this region shows that the climate fluctuations had the same major trends.

The main conclusiones can be summarized as follows:

1. Two pollen and spore diagrams were drawn based on the results of the palynological analysis of the lacutrine and fluvial deposits from three sites from southwest of Syria.
2. Three pollen and spore assemblage-zones were identified and described in detail from the studied fluvio-lacustrine dediments of southwest Syria: assemblage-zone A from late Pleistocene deposits Al-Hijaneh lake in Omm-Ddeb site, and zones B and C, from the Holocene deposits of the lower course of Al-Aouaj river.
3. The vegetation development during the studied time intervals could be divided into three main types.
4. Paleoclimatic changes that took place during the concerned time episodes were determined in three main phases.

5. The correlation of pollen and spore assemblages-zones of this study, with the sunchronous pollen zones from Syria, Turkey, Iran and Greece showed that the climatic changes that took place in the studied sites, had a general trend toward the contemporary climatic conditions in every site respectively. The changes were asynchronous in the different regions. Remarkably, the climatic events were earlier in some places than in others. The climate picture was clearly changeable during the studied time intervals.

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