

PALYNOLOGICAL INVESTIGATIONS IN WESTERN IRAN

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1. INTRODUCTION

In this paper the final results of the palynological investigation of sediment cores from Lake Zeribar and Lake Mirabad, both situated in the Zagros Mountains of western Iran, will be discussed. The investigation of the vegetational and climatic history of western Iran started in 1960, when H. E. Wright (Limnological Research Center, University of Minnesota, Minneapolis, U.S.A.) cored several lake sites. A preliminary diagram of the most promising site, Lake Zeribar, was published by van Zeist & Wright (1963). A chemical examination of the Zeribar core was carried out by Hutchinson & Cowgill (1963).

In 1963, new cores extending to greater depths were acquired at Zeribar. Furthermore, borings were carried out at Lake Mirabad, Lalabad Springs, and Lake Nilofar (see fig. 1). Simplified pollen diagrams obtained for the 1963 cores from Zeribar and Mirabad were published by van Zeist (1967); Wasylikowa (1967) presented some results of the plant macrofossil analyses of the Zeribar cores. The Cladocera in the Lake Zeribar sediments were studied by Megard (1967).

During the field work in 1960 collections of plants were made by H. E. Wright & Anne M. Bent, and in 1963 by M. Jacobs. At the same time modern pollen samples were collected for the pollen reference collection. In addition to the plant collecting, vegetational surveys were carried out; in 1960 by H. E. Wright, 1963 by W. van Zeist. Furthermore, in 1963 surface samples were obtained from the various vegetation zones to be distinguished in western Iran (see 2.3.). The surface samples provide information on the relationship between pollen precipitation and vegetation, which is necessary for the interpretation of the fossil pollen record. The analyses of the surface samples were completed by J. H. McAndrews (Wright *et al.* 1967).

In 1970, H. E. Wright returned to Lake Zeribar and he succeeded in extending the 1963 cores by up to 15 m, *i.e.* to a total depth of about 40 m. The plant macrofossil analyses of the 1970 cores are being carried out by K. Wasylikowa. K. Wasylik is examining the diatoms in the Lake Zeribar cores obtained in 1963 and 1970.

The palynological examination of the 1963 cores

from Zeribar and Mirabad was started by W. van Zeist. S. Bottema completed the analyses of these cores, and he carried out the investigation of the cores acquired in 1970.

It should be mentioned here that Lake Zeribar (or Lake Zariver) has recently been renamed to Lake Aryamehr (personal communication of Dr. M. H. Nabavi, Geological Survey of Iran). As the site is known in the palynological literature as Lake Zeribar, this name is maintained in this paper. Moreover, a possible renaming would have caused much inconvenience because the manuscript and the drawings had been completed when the new name came to notice of the authors.

At the request of the authors, Professor H. Freitag (formerly Systematisch-Geobotanisches Institut, Universität Göttingen; at present Arbeitsgruppe Morphologie und Systematik der Pflanzen, Gesamthochschule Kassel) gave some comments on the interpretation of the pollen diagrams in terms of former vegetations. His remarks are presented as a separate contribution (Freitag 1977).

Much trouble has been taken to identify a great number of pollen types (*cf.* chapter 4). It was hoped that these efforts would result in more detailed information on the vegetation in former times. It can safely be stated that this aim was achieved, so that the investment of time and effort turned out to have been worthwhile. On the other hand, it remained unsatisfactory that by visual inspection many interesting pollen types occurring in low frequencies (one or a few grains per sample and present in only a small number of spectra) did not show more or less clear affinities to certain pollen assemblage zones. The authors wondered whether the application of computerized numerical methods, such as factor analysis and cluster analysis, could result in meaningful conclusions concerning possible correlations between these rare types and pollen types which greatly contribute to the zonation of the pollen diagrams. Mr. D. Stapert (Biologisch-Archaeologisch Instituut) undertook the statistical analysis of the Zeribar pollen diagrams. Unfortunately, he arrived at a negative answer as for the question mentioned above. Stapert's study will be published in the near future.

The field work was made possible through financial support from the National Science Foundation (grants GS-50 and GS-30365 to

Professor R. J. Braidwood of the University of Chicago).

This investigation and its publication were only possible thank to the cooperation of various people. Professor Herbert E. Wright Jr. (Minneapolis) provided much valuable information and critically read the manuscript. Without his interest in the Late Quaternary vegetational and climatic history of western Iran and without his improvisation talents in coring under difficult conditions this study would never have taken place.

The palynological examination of western Iran was greatly encouraged by Professor Robert J. Braidwood who also provided financial support for the field work.

The radiocarbon determinations were carried out by Professor M. Stuiver (then Yale University), Dr. W. G. Mook (Groningen), Dr. R. Stuckenrath (Smithsonian Institution, Washington D.C.), and Dr. W. S. Broecker (Lamont Geological Observatory).

Professor H. Freitag (Kassel) commented upon the interpretation of the pollen diagrams. A statistical analysis of the pollen data was carried out by Mr. D. Stapert. The English text was improved by Mr. C. van der Meulen and Mrs. B. M. van der Meulen-Melrose (Roden).

The majority of the pollen photographs published in this study were taken by Mr. H. Woldring, while Mrs. R. M. Palfenier-Vegter made the prints. The neat drawings were executed by Mr. H. R. Roelink, Mr. W. J. Dijkema and Mr. J. M. Smit. Mr. Jac. Klein prepared the illustrations for publication. Mrs. G. Entjes-Nieborg typed the successive drafts of the manuscript.

2. TOPOGRAPHY, CLIMATE AND VEGETATION OF WESTERN IRAN

In this chapter the physical setting and the vegetation of western Iran will briefly be reviewed. This discussion will generally be confined to those aspects which are of importance for the interpretation of the palynological data (chapters 6 and 7).

2.1. Topography

In western Iran three physiographic provinces can

be distinguished, *viz.* the Mesopotamian lowland, the Zagros Mountains, and the interior high plateaus.

2.1.1. *Mesopotamian lowland*

Only a relatively narrow zone of western Iran forms part of the Mesopotamian lowland, most of which has been an area of subsidence since the early Tertiary. The superficial strata are largely late-Tertiary redbeds and gravels (Wright *et al.* 1967). The Khuzestan plain is formed essentially of coalescing alluvial fans deposited by the Karkheh, Karun, and Diz Rivers (Pabot 1960).

2.1.2. *Zagros Mountains*

The Zagros Mountains form part of the great Taurus-Zagros mountain arc, which extends from southwest Turkey through southeast Turkey and northern Iraq to southwest Iran. The Zagros Mountains are built up of long parallel ridges and deep intermontane valleys. The ridges increase in height towards the interior. The alternate ridges and valleys consist mainly of Cretaceous and Tertiary limestones and marls; metamorphic rocks are found in the highest parts of the mountains. The area is drained by the Khabur, Greater Zab, Lesser Zab, and Diyala Rivers, which cut transversely across the mountain ranges to join the Tigris River (Wright 1961, Wright *et al.* 1967).

2.1.3. *The interior plateaus*

On the inner side of the Taurus-Zagros ridges lie the high Iranian and Anatolian plateaus, interrupted by low mountains. The Central Plateau of Iran is marked by many saline soils, for large masses of soluble salts are carried in from the surrounding mountains by intermittent streams (Zohary 1973, p. 15).

2.2. Climate

A fairly extensive discussion of the climate of the Taurus-Zagros arc was published by Wright (1961). The concise climatic information presented below is taken from Wright's paper.

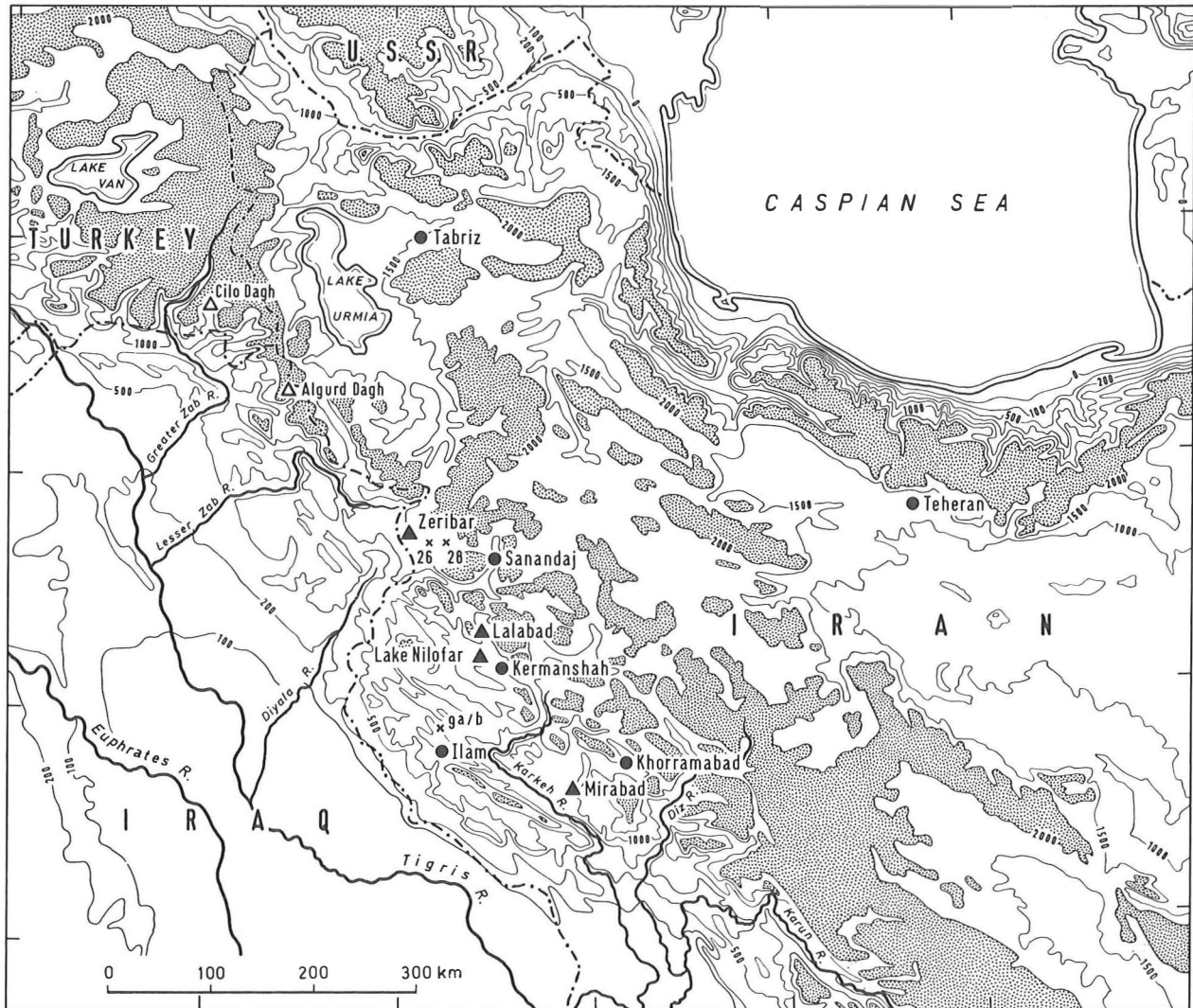


Fig. 1. Map of western Iran and adjacent regions, showing the location of pollen-diagram sites (black triangles) and surface-sample sites (indicated with a cross) mentioned in this paper. Contour lines are given for 0, 100, 200, 500, 1,000, 1,500, and 2,000 metres. Areas above 2,000 m are stippled. Redrawn from Bartholomew world travel map Middle East, scale 1:4,000,000 (1970).

The climate of western Iran is typically Mediterranean, with practically all precipitation in the fall, winter, and spring. The summers are dry, with high temperatures, particularly at lower elevations. Of major importance for the distribution of the rainfall are the Zagros mountain ridges, which form an effective barrier to the moisture-bearing

storm tracks from the Mediterranean area. Consequently, in the Central Plateau of Iran, which lies in the shadow of the Zagros Mountains, precipitation is low. The orographic effect on precipitation is clearly demonstrated by the rainfall map of fig. 3. The total precipitation rises abruptly on the western flank of the Zagros Mountains. A mean annual temperature lapse rate of $0.7^{\circ}\text{C}/100\text{ m}$ could be established along two transects from the lowland across the mountains to the plateau.

2.3. Vegetation

The vegetation of western Iran is relatively well known by the studies of Bobek (1951), Pabot

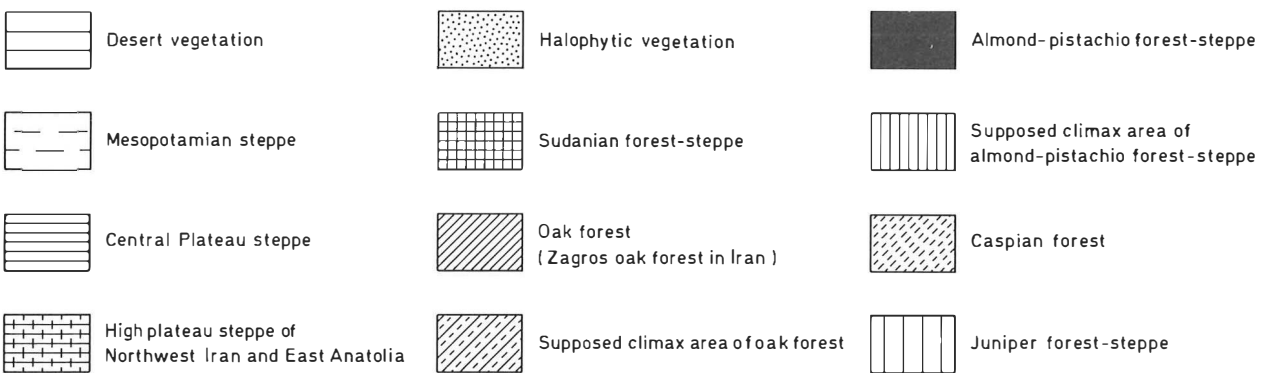
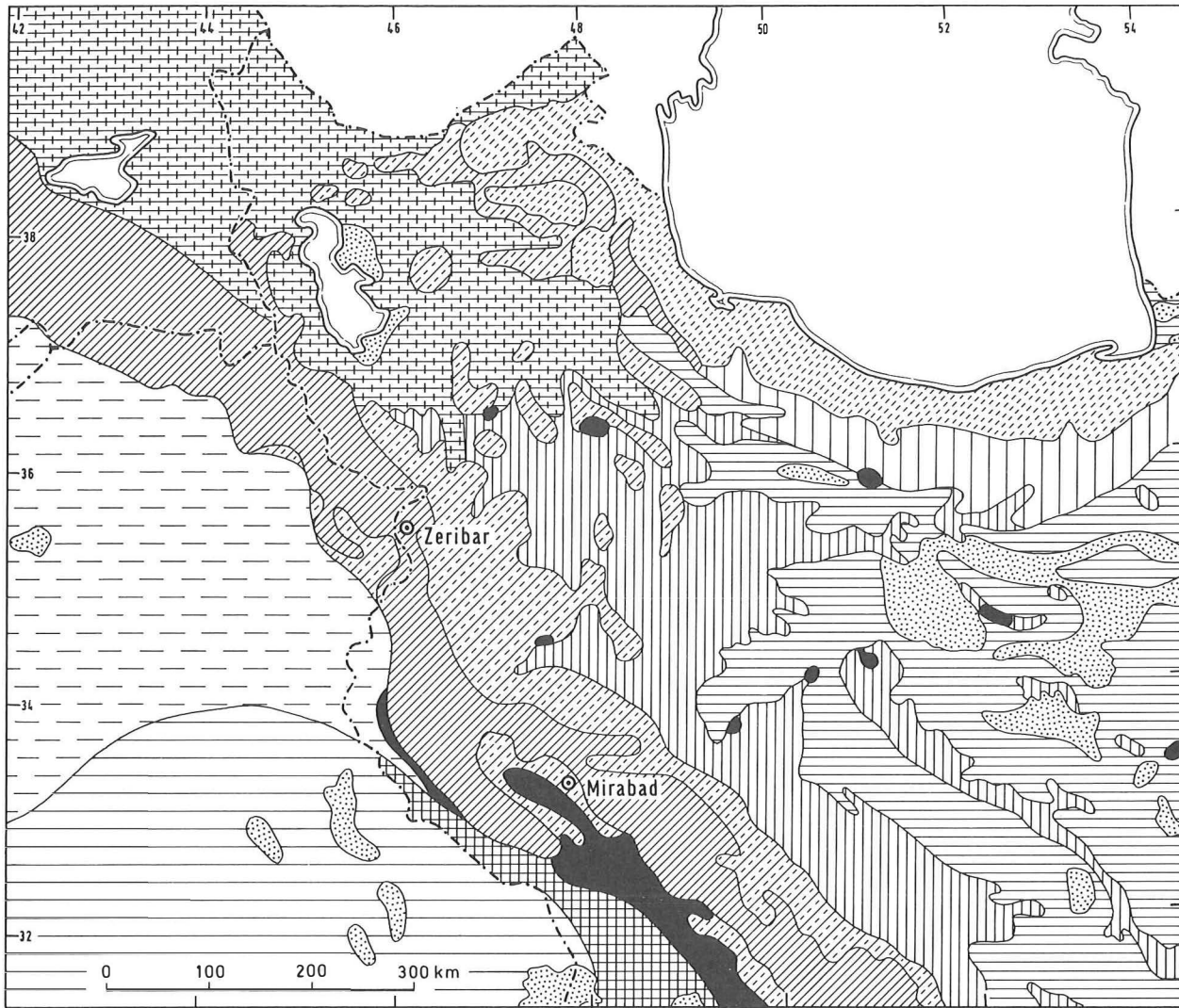


Fig. 2. Vegetation map of western Iran and adjacent regions.
Adapted from Zohary (1963, 1973).

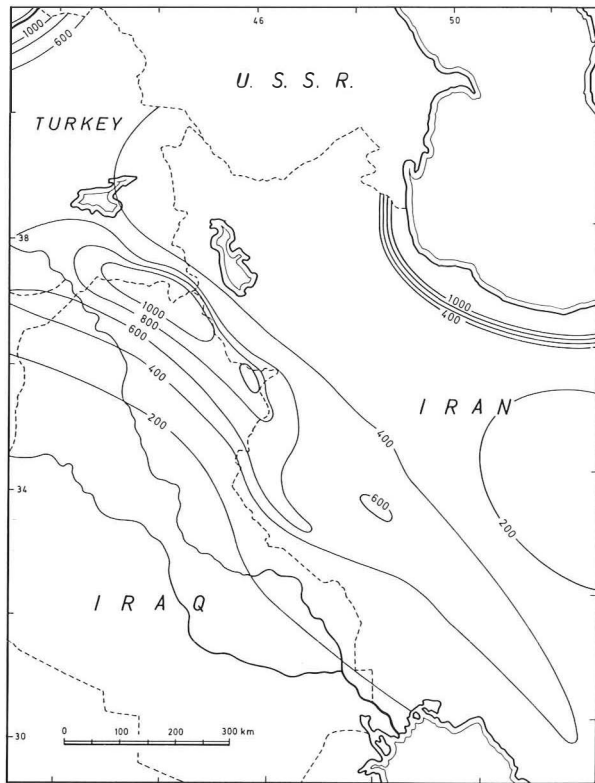


Fig. 3. Precipitation map of western Iran. The isohyets are largely redrawn from Wright (1961).

(1960), and Zohary (1963, 1973). The vegetation map of fig. 2 is a slightly simplified copy of the section concerned, taken from Zohary's (1963, 1973) geobotanical outline maps.

2.3.1. Lowland vegetations

In the lowland of the extreme west of Iran, with an annual precipitation of 150-300 mm, two vegetation zones are distinguished by Zohary (1963, 1973). The natural plant cover of the northern sector of the lowland belt belongs to the Artemisietea herbae-albae mesopotamica, which class comprises the lowland steppe vegetation of Syria, Iraq, Jordan, and Turkey. No description of the lowland *Artemisia* steppe of western Iran has been published so far.

Acacietaea flava iranica vegetation (Zohary 1973, pp. 596-598) occupies a broad strip of land in southern Iran and extends into the west of the country.

Various trees and shrubs occur in this vegetation (Bobek's (1951) *Baum- und Strauchfluren des südlichen Garmsir*). For the section represented in fig. 2 *Ziziphus spina-christi*, *Ziziphus nummularia*, *Punica granatum*, *Capparis spinosa*, *Calotropis procera*, and *Periploca aphylla* may be mentioned.

2.3.2. Pistachio-almond forest-steppe region

Between the lowland vegetation (2.3.1.) and the Zagros oak-forest zone (2.3.3.) a forest-steppe belt (that is, a steppe with more or less widely scattered trees and shrubs) is distinguished. Precipitation in this *Amygdalus-Pistacia* forest-steppe zone is 300-500 mm per year. Isolated trees and shrubs of *Pistacia kbinjuk*, *Pistacia atlantica*, *Amygdalus scoparia*, and *Ziziphus spina-christi* constitute the remnants of this vegetation type, which has virtually disappeared as a result of human interference. On the inner side of the Zagros Mountains a broad almond-pistachio forest-steppe zone is postulated between the forest belt and the steppe and desert-steppe of the high plateaus (2.3.4., 2.3.5.).

2.3.3. Zagros oak forest

The Zagros oak forest or the Kurdo-Zagrosian oak steppe-forest of Zohary (1973, pp. 582-583) is found at elevations of 700-800 m up to over 2,000 m, with annual precipitation exceeding 500 mm. The dominant tree is *Quercus brantii* (*Q. persica*). Other arboreal constituents of the Zagros oak forest include *Quercus infectoria*, *Pistacia kbinjuk*, *Pistacia atlantica*, *Acer cinerascens*, *Pyrus syriaca*, *Crataegus azarolus*, *Lonicera nummularifolia*, *Fraxinus rotundifolia*, *Amygdalus scoparia*, *Amygdalus lycioides*, *Rubus anatolicus*, *Berberis integerrima*, *Cerasus microcarpa*, and *Daphne mucronata*. A conspicuous parasite on various tree species is *Loranthus grewinkii*. Along streams *Platanus orientalis*, *Populus euphratica*, *Juglans regia* (planted?), *Salix* spp., and *Tamarix* spp. occur.

The Zagros oak forest is an open forest type (fig. 4). The ground flora usually shows a high degree of cover (up to 100%) and is also rich in species. The densest forest observed by W. van Zeist in the Zagros Mountains was that in a blind valley, c. 7 km northwest of Ilam, at an elevation of c. 1,700 m (April 1963). A tree cover (*Quercus*, *Pistacia*, *Acer*)

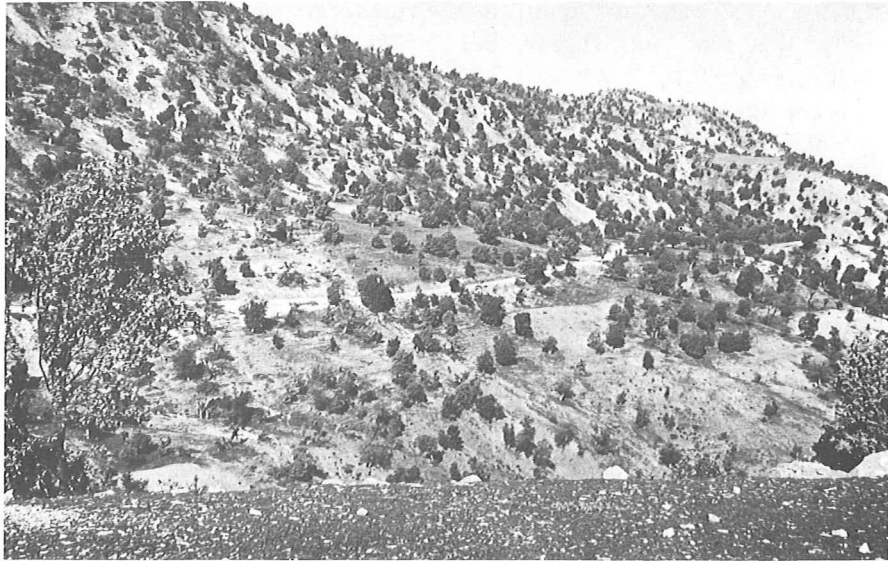


Fig. 4. Typical open Zagros oak forest, south of Ilam.



Fig. 5. Zagros oak forest, northwest of Ilam. This is the densest forest observed in the Zagros Mountains (2.3.3.).

of c. 50% was measured here (fig. 5). This forest had at that time only slightly been affected by wood-cutting.

As for the upper limit of the Zagros oak forest, the following can be remarked. Bobek (1951, p. 31) reports that on Manisht Kuh, forest has been observed up to 2,200-2,300 m (see also below) and on Bala Ghariveh, east of Khorramabad, up to 2,500 m. The area of Manisht Kuh, 9 km north of Ilam, was also studied by Dr. M. Jacobs (Rijksherbarium of Leiden) who joined the 1963 expedition to Iran (Wright *et al.* 1967, p. 427). "Here the *Quercus* at about 2300 m is reduced in size and number and gives way upward to a fringe of dominant *Acer* and this to *Lonicera* (which is not common in the *Quercus* woodland below), with two *Amygdalus* species and *Daphne* as large shrubs. *Lonicera* persists as the only tree up to almost 2400 m, where it is 2.5 m tall, with a globose crown and a gnarled but distinct trunk. Both *Amygdalus* species reach the top of the ridge, where cushions of *Acantholimon* sp. and *Astragalus* sp. are conspicuous." Pabot (1960) reports that in the high mountains of Khuzestan, *Quercus brantii* is locally abundant in the belt between the altitudes of 2,000 and 2,500 m. Other trees in this zone include *Pistacia atlantica*, *Pyrus syriaca*, *Acer cinerascens*, and *Lonicera nummularifolia*. Above 2,500 m *Quercus* is not found in Khuzestan.

From the above it seems justified to conclude that, depending on geographical or local factors (or both), the upper limit of the Zagros oak forest must be placed between 2,300 and 2,500 m. In the upper reaches of the Zagros oak-forest belt, disturbance of the original vegetation has led to the expansion of thorny, cushion-shaped species of *Astragalus*, *Acantholimon*, and *Acanthophyllum* (tragacanthic vegetations).

The inner (plateau) limit of the Zagros oak-forest belt, just like its outer (lower) limit, is determined by the degree of humidity. Where on the lee side of the high mountain ridges the annual precipitation decreases, the oak-forest belt gives way to the pistachio-almond forest-steppe belt. In large areas on the outer and particularly on the inner side of the oak-forest belt, the vegetation has suffered so much from human disturbance that at best some scattered trees or some shrub have been left, especially at cemeteries and other holy places. Following Zohary, these deforested areas are, in

fig. 2, indicated as supposedly Zagros oak-forest climax vegetation.

Almost no records of vegetation from above 2,500 m in the Zagros Mountains have been published. Pabot (1960) postulates a juniper steppe-forest (with some *Lonicera*, *Amygdalus*, and *Daphne* in addition to *Juniperus excelsa*) for elevations of between 2,500 and 3,000 m. Above 3,000 m treeless, alpine vegetations would constitute the natural plant cover.

2.3.4. Central Plateau

Information on vegetation and climate of the Central Plateau of Iran is provided by Zohary (1963, pp. 44-51; 1973, pp. 486-491). Climatic conditions are not favourable for plant growth. Rainfall generally does not exceed 200 mm, and in half of the area it is less than 100 mm. Only the mountain ridges, for which an almond-pistachio forest-steppe is assumed to be the natural vegetation, receive more precipitation. The high summer temperatures cause a high evaporation rate.

The poorly drained flats with saline soils are inhabited by halophytic vegetation. Steppe and desert-steppe vegetations, characterized by *Artemisia herba-alba* (Zohary's *Artemisietea herbae-albae iranica*), are found on well-drained soils. In addition, areas occur that are almost or completely devoid of plant growth.

Dependent on differences in soil and topography various plant associations are distinguished among the *Artemisietea herbae-albae* of the Central Plateau. In addition to *Artemisia herba-alba*, a great variety of species play a part in these vegetation types. According to Zohary's sample records plant cover may be as low as 5%.

2.3.5. High plateau steppe of NW Iran

The high steppe vegetation types of northwestern Iran are assigned by Zohary to the class of the *Artemisietea fragrantis*. No data on the steppes of NW Iran have been published so far, but one may assume that they show much resemblance to the steppes of adjacent eastern Anatolia, which are briefly described by Zohary (1973, pp. 485-486). The latter vegetation types are classified in the order of the *Artemisietalia fragrantis armeno-*

anatolica. They differ essentially from the *Artemisia* steppes and desert-steppes of the Central Plateau. The steppes of northwestern Iran and eastern Anatolia are usually dominated by *Artemisia fragrans*, but other *Artemisia* species may likewise be dominant. The sample records given by Zohary suggest a high plant cover (90-100%).

3. THE POLLEN-DIAGRAM SITES

3.1. Lake Zeribar

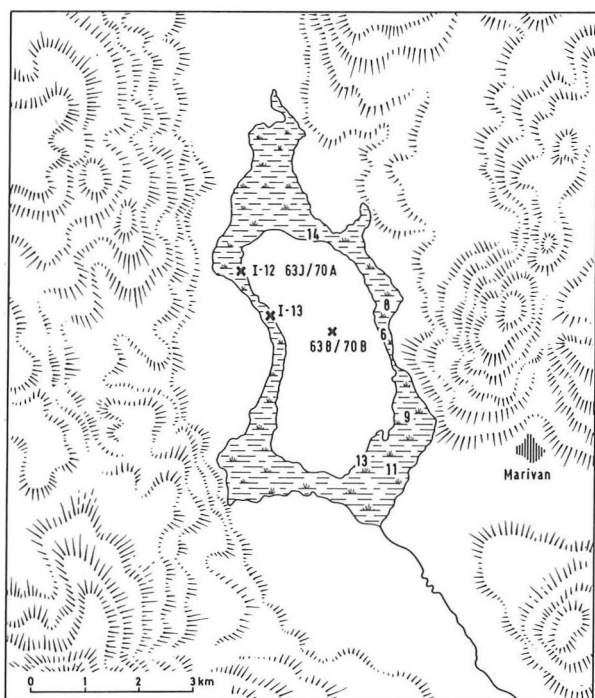


Fig. 6. Map of the Lake Zeribar area, showing the location of coring sites (indicated with a cross) and surface-sample sites (7.1.3.2.). The lake is drained by the river to the south.

3.1.1. *The geographical situation*

Lake Zeribar (35°32'N, 46°07'E) is situated in an intermontane valley in the inner portion of the Zagros Mountains, near the town of Marivan, c. 160 km northwest of Kermanshah. The valley has an elevation of c. 1,300 m above sea-level. The ridges to the east and the west of the valley are up to 2,100 m high. At a somewhat greater distance

mountain peaks reach elevations of nearly 3,000 m. Small intermittent streams from the surrounding slopes enter the basin and have deposited broad alluvial fans. The ridges around the basin are largely covered by oak shrub, which forms the seriously degraded remnant of the original Zagros oak forest.

The lake is c. 4.5 km long and has a maximum

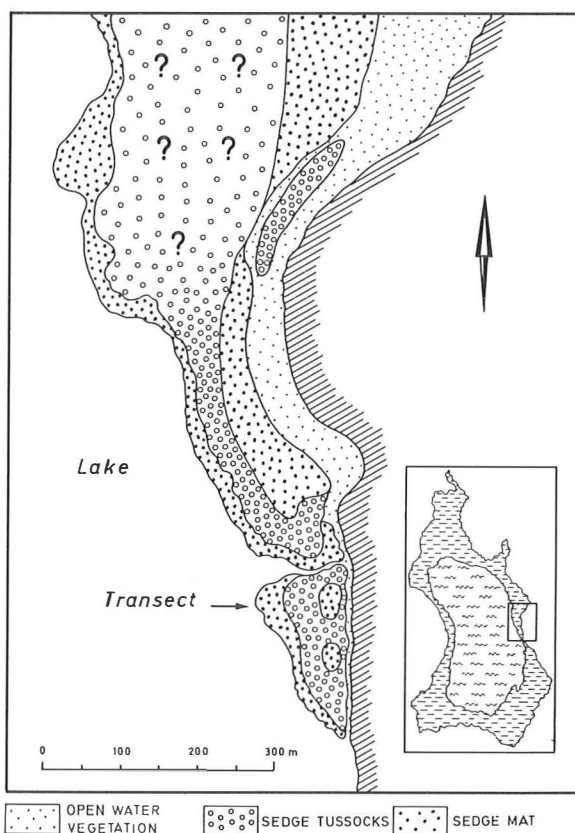


Fig. 7. Map of the marsh vegetation on the east side of Lake Zeribar.

width of c. 2 km, not including the marsh vegetation belt (3.1.2.). The lake drains to the south-east, but only at high water does the lake overflow. As for the origin of the lake, it was initially assumed that it occupied a structural basin (van Zeist & Wright 1963). Subsequent studies of the geomorphology of the area convinced H. E. Wright that we are dealing with a stream-cut valley here (*cf.* Megard 1967). After the headwaters of the main

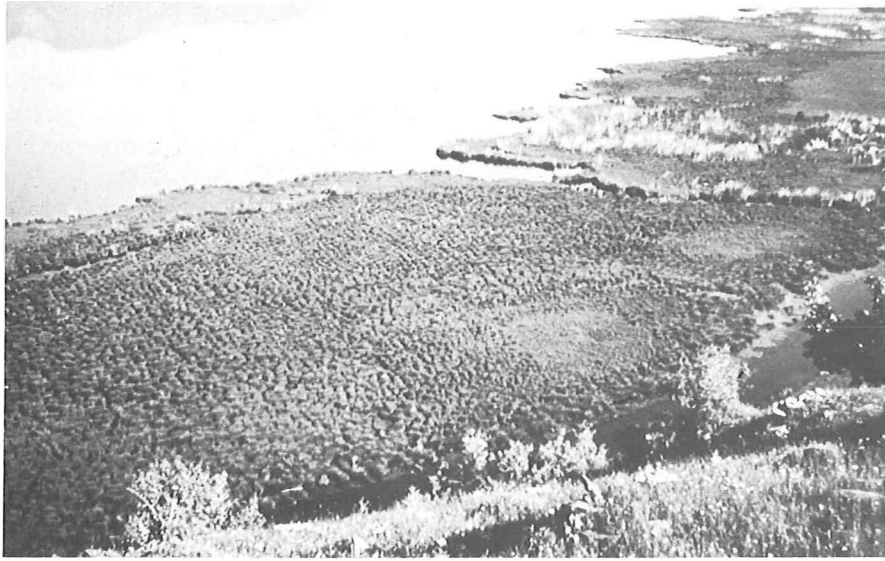


Fig. 8. Marsh vegetation on the east side of Lake Zeribar. The tussocky nature of the greater part of the marsh vegetation belt shows up clearly.

stream through the valley had been pirated by a westward flowing river about 5 km north of the present lake, the remaining stream was not large enough to remove the alluvial fan deposits to the south of the lake. This caused a damming-up of the main stream, in consequence of which the lake came into existence. The shape and the depth of the lake were therefore determined by the alluvial fan deposits on the south side of the basin.

3.1.2. The marsh vegetation belt

The marsh vegetation belt around the lake has a varying width (fig. 6). At one place on the east side of the lake the marsh vegetation was studied by W. van Zeist. This study was greatly handicapped by the high water and by the fact that the marsh vegetation was not yet well developed in the first half of May. The extremely wet spring of 1963 may have caused an extra delay.

The vegetation survey consisted of the examination of the plant growth along a transect c. 125 m long, oriented east-west. This study was supplemented by observations on the vegetation in a few other places. In addition, a vegetation map was sketched for an area extending over c. 1,000 m along the lake shore. The map (fig. 7) is partly based upon an air photograph, that is to say the inner and outer limits of the marsh vegetation belt

and the delineation of some vegetation zones are taken from the photograph. The area covered by the upper part of the map could not be surveyed satisfactorily, hence the question marks.

Three vegetation types are indicated on the map by different symbols. The inner edge of the marsh vegetation bounding the upland had open water up to a depth of c. 1 m. In this zone were observed: *Ranunculus peltatus* ssp. *sphaerospermus*, *Rorippa amphibia*, *Nasturtium officinale*, *Eleocharis palustris*, *Scirpus lacustris*, *Sparganium* sp., *Polygonum* cf. *amphibium*, *Phragmites australis*, *Myosotis* cf. *scorpioides*, *Hippuris vulgaris*, *Nymphaea alba*, *Carex* sp., and *Chara* sp. The distribution of the species within this zone is not uniform, and several vegetation units can be distinguished. It should be remarked that during periods of a lower lake level, e.g. in the summer, this zone may have no open water.

A greater part of the marsh vegetation belt consists of tussocks at short distances from each other (fig. 8). The tussocks are formed by *Carex budsonii*. Also observed on the tussocks were *Scirpus lacustris*, *Sparganium* sp., *Lycopus* sp., *Convolvulus* sp., *Polygonum* cf. *amphibium*, *Lytbrum* sp., and Malvaceae.

The third vegetation type consists of a dense mat. This vegetation type is found along the water as well as inside the marsh vegetation belt. A fairly great number of species could be determined: *Carex budsonii*, *C. otrubae*, *C. distans*, *C. divisa*, *C.*

pseudocyperus, *Eleocharis* sp., *Scirpus lacustris*, *Cladium mariscus*, *Phragmites australis*, *Sium erectum*, *Mentha* cf. *aquatica*, *Potentilla* cf. *reptans*, *Lytbrum* sp., *Poa* sp., *Taraxacum* sp., *Sonchus* sp., *Convolvulus* sp., *Galium* sp., *Lysimachia* sp., *Lycopus* sp., *Ranunculus* sp., *Trifolium repens*, Malvaceae, *Gentiana* sp., *Juncus* cf. *subuliflorus*, *Juncus* aff. *compressus*, cf. *Epipactis*, *Orchis* cf. *persica*, *Dryopteris palustris*, and *Drepanocladus* and other mosses. *Phragmites* and *Cladium* are particularly common along the outer edge of the marsh vegetation.

Through a rise in water level the edge of the vegetation mat may be lifted from the lake bottom, and through wave action parts of it will be torn away to become floating islands. These islands drift across the lake until they are blown against the shore, where they may become fused with the extant vegetation mat.

3.1.3. *The climate*

There are no rainfall and temperature data for the Marivan area. The estimated annual precipitation is 600-800 mm, and the mean January and July temperatures would be about 2° and 28°C respectively (cf. van Zeist & Wright 1963). According to Löffler (1961), in hard winters the lake may be ice-covered for 40-50 days.

3.1.4. *Lithology*

The description of the sediment cores sampled in 1963 was made by H. E. Wright, that of the 1970 cores by K. Wasylkowa. A somewhat simplified lithology of the cores is given below.

3.1.4.1. *Cores 63-J and 70-A*

These cores were taken close to each other on the west side of the lake (fig. 6). The borings were carried out at the outer edge of the floating sedge mat. The datum is the mat surface.

Zeribar 63-J

- 0- 4.00 m coarse undecomposed peat underlain by water (not sampled)
- 4.00- 7.10 m dark-brown peat
- 7.10- 8.90 m grey-blue clay gyttja with bands of plant detritus

- 8.90- 9.65 m grey-brown clay gyttja with bands of plant detritus
- 9.65-11.35 m marl with bands of plant detritus
- 11.35-13.80 m grey-blue to grey-brown clay gyttja with bands of plant detritus
- 13.80-15.45 m grey clay gyttja with layers of brown gyttja
- 15.45-15.90 m grey clay gyttja
- 15.90-16.50 m banded grey-brown clay gyttja with shells and grey-blue clay
- 16.50-17.15 m grey clay with shells
- 17.15-21.00 m banded grey clay and brown gyttja
- 21.00-22.00 m light-brown clay gyttja with shells
- 22.00-22.55 m banded grey-brown gyttja and clay gyttja with shells
- 22.55-23.60 m grey marly clay with shells
- 23.60-24.70 m banded yellow-grey clay and marl
- 24.70-25.20 m banded yellow-grey marly clay and clay gyttja
- 25.20-25.40 m grey clay with shells

Zeribar 70-A

- 16.10-16.50 m light-grey calcareous clay gyttja
- 16.50-17.50 m dark-grey calcareous clay with shells and some plant detritus
- 17.50-18.80 m grey-brown calcareous gyttja with clay
- 18.80-23.50 m banded grey to grey-brown clayey lake marl with plant detritus and shells
- 23.50-27.75 m banded grey clayey lake marl with shells and some plant detritus
- 27.75-30.85 m dark-grey calcareous clay with some plant detritus
- 30.85-32.90 m grey clayey lake marl with shells and dark bands of plant detritus
- 32.90-40.35 m grey to light-grey clayey lake marl with abundant shells and some bands of plant detritus

3.1.4.2. *Cores 63-B and 70-B*

These cores were taken near the centre of the lake (fig. 6). One should take into consideration that the distance between both mid-lake coring localities may have been several hundred metres. The datum is the water surface.

Zeribar 63-B

- 0- 4.30 m water

4.30- 8.15 m	white to grey marly clay gyttja with plant detritus
8.15-10.15 m	grey clay with bands of marly clay gyttja
Zeribar 70-B	
0- 4.00 m	water
4.00- 7.70 m	grey calcareous gyttja with bands of plant detritus
7.70- 8.70 m	grey calcareous clay with bands of plant detritus
8.70-10.00 m	grey calcareous gyttja with much plant detritus
10.00-12.40 m	grey calcareous clay gyttja with bands of plant detritus
12.40-13.20 m	grey calcareous clay gyttja
13.20-13.85 m	grey calcareous clay gyttja with shells
13.85-15.10 m	light-grey to grey lake marl with clay and shells
15.10-15.40 m	grey to dark-grey calcareous clay with shells
15.40-16.50 m	black clayey non-calcareous organic sediment
16.50-16.60 m	black clayey gyttja

3.1.5. Radiocarbon dates

Samples from the Lake Zeribar sediment cores discussed in this paper were dated by the Radiocarbon Laboratories of Yale University (Stuiver 1969), Smithsonian Institution, Lamont Geological Observatory, and Groningen University.

63-B	7.00- 7.10 m: 2,240 ± 150 B.P. (L-845B)
63-J	14.10-14.20 m: 8,100 ± 160 B.P. (Y-1432)
	17.10-17.20 m: 11,480 ± 160 B.P. (Y-1687)
	18.90-19.00 m: 13,650 ± 160 B.P. (Y-1686)
	25.35-25.45 m: 22,000 ± 500 B.P. (Y-1431)
70-A	34.15-34.30 m: 37,350 ± 1250 B.P. (GrN-7627)
	40.15-40.27 m: 29,780 ± 1400 B.P. (SI-732)
70-A-2	40.15-40.30 m: 42,600 ⁺³⁶⁰⁰ ₋₂₅₀₀ B.P. (GrN-7950)

70-B	9.78- 9.93 m: 5,640 ± 70 B.P. (GrN-7628)
	11.00-11.15 m: 6,890 ± 80 B.P. (GrN-7629)
	13.60-13.75 m: 10,600 ± 100 B.P. (GrN-7630)

The Smithsonian date for the bottom of the 70-A core cannot be reconciled with both Groningen dates for samples from the lower part of the core. No reasonable explanation can be given for this discrepancy. As the Groningen dates are in accordance with each other, the Smithsonian date will be left out of consideration in this paper.

For cores I-12 and I-13, also from the west side of the lake, sampled in 1960, two carbon-14 dates were determined at Yale (Stuiver & Deevey 1962; Stuiver *et al.* 1963). Generalized pollen diagrams for these cores were published by van Zeist & Wright (1963).

I-13	9.90-10.10 m (calcareous gyttja): 5,460 ± 120 B.P. (Y-934)
I-12	16.25 m (calcareous clay-gyttja): 14,800 ± 300 B.P. (Y-1160)

On the ground of pollen-floristic features these dates could be transferred to the Zer. Ib diagram (dates between brackets).

3.1.6. Pollen diagrams

The diagram prepared for core Zeribar 1970-A is shown in fig. 22 (Zeribar Ia), that for core Zeribar 1963-J in fig. 23 (Zeribar Ib). A preliminary diagram for the Zer. 63-J core was published by van Zeist (1967, fig. 3). The Zeribar II diagram (fig. 24) was prepared for cores Zeribar 1963-B and 1970-B, both from the centre of the lake.

The Zeribar Ia and Ib diagrams are constructed in such a way that they link up with each other. The Zer. Ib diagram can be placed above the Zer. Ia diagram to form one continuous diagram, although the overlap between the two diagrams must be taken into account. Thus, for instance, in the Zer. Ia diagram the columns for *Quercus* and *Salix* are much broader than is required for the pollen curves, and in some columns the pollen type concerned is not represented, e.g. *Juglans*, *Platanus*, and *Sanguisorba minor*-type in Zer. Ia, and *Bongardia* in Zer. Ib.



Fig. 9. Lake Mirabad. The coring platform can be seen. The large boulders are from the landslide debris (3.2.1.).

3.2. Lake Mirabad

3.2.1. *Geographical situation and climate*

Lake Mirabad is situated in the Saidmarreh valley, in the Zagros Mountains, c. 75 km southwest of Khorramabad (33°05'N, 47°43'E). The lake, which measures about 100 by 200 m, has an elevation of c. 800 m above sea-level. It lies in an area that is covered with landslide debris (fig. 9). A slab of Tertiary limestone 15 km long slid off the northern flank of Kabir Kuh, c. 15 km to the southwest of Lake Mirabad. The landslide, which must have been triggered by an earthquake, crossed two valleys and an intervening ridge and extended 20 km from its source (Watson & Wright 1969). Lake Mirabad owes its origin to the landslide, and the age of the bottom sediments gives a *terminus post quem* for this geological catastrophe.

Lake Mirabad lies near the lower border of the Zagros oak-forest belt (fig. 2). At present, the forest has disappeared completely from the area as a result of cutting and grazing.

There are no climatological data for the Mirabad area. The estimated annual precipitation for Mirabad is 500-600 mm. The mean January and July temperatures would be about 7° and 32°C respectively.

In April 1963, *Phragmites* was observed around the lake, while at the west side *Cladium mariscus*

occurred. The other plants of the marsh vegetation bordering the lake were still too poorly developed for proper identification.

3.2.2. *Lithology*

The sediment was cored near the west end of the lake, c. 20 m off the reed fringe. At the coring site the water was 1.60 m deep. The boring took place from a platform. The datum is the sediment surface.

Mirabad 63-B

0-0.65 m	white shelly marl
0.65-0.95 m	dark shelly marl
0.95-1.10 m	grey marl
1.10-3.15 m	white shelly marl
3.15-3.30 m	light-brown shelly marl
3.30-3.80 m	white shelly marl
3.80-4.30 m	grey to dark shelly marl
4.30-7.20 m	white shelly marl
7.20-7.23 m	dark peaty sediment
7.23-7.90 m	grey shelly marl (lost)
7.90-8.15 m	grey silty clay with stones

3.2.3. *Radiocarbon dates*

Two radiocarbon dates were obtained for the Mirabad core (Stuiver 1969):

4.75-4.83 m, white shelly marl: 10,790 ± 200 B.P. (Y-1758)

7.20-7.23 m, dark peaty sediment: $10,370 \pm 120$ B.P. (Y-1759)

It is likely that the date for the sample at 4.75-4.83 m is too old because of ^{14}C -depleted carbonates dissolved from the surrounding rock (limestone). This date will not be taken into consideration in the discussion of the palynological results, and it is consequently not indicated in the Mirabad pollen diagram.

3.2.4. Pollen diagram

The Mirabad pollen diagram is shown in fig. 26. A preliminary version of this diagram was published by van Zeist (1967, fig. 2).

4. POLLEN TYPES

4.1. Introduction

In this chapter some remarks will be made on pollen types distinguished in the examination of the Iranian sediment cores. Descriptions of pollen types well-known by readers familiar with the literature on the Late-Quaternary vegetational history of Europe have generally been omitted. Usually only features that are of importance for the identification of the grains are mentioned. Unless otherwise stated the terminology used in the descriptions of the pollen types is according to Faegri & Iversen (1964). The shape classes are according to Erdtman (1943): see table 1.

As for the distinction between pollen types, it should be taken into consideration that the pollen grains were studied under a transmitted light microscope, at magnifications of 400 and 1000 times. Enumerations of species included in a certain pollen type are necessarily confined to the species represented in the pollen reference collection in the Biologisch-Archaeologisch Instituut. The dimensions given in the descriptions refer to pollen grains mounted in silicone oil.

4.2. Anacardiaceae

4.2.1. *Pistacia*

Two *Pistacia* species are common in western Iran,

Table 1. Shape classes of pollen grains (after Erdtman 1943, table 5, p. 45).

Shape class	polar axis (Lg)/ equatorial diameter (Lt)
perprolate	> 2
prolate	1.33-2
subprolate	1.14-1.33
spheroidal	0.88-1.14
suboblate	0.75-0.88
oblate	0.50-0.75
peroblate	< 0.5

viz. *P. kbinjuk* and *P. mutica* (*P. atlantica* subsp. *mutica*). Both *Pistacia* species have suboblate to spheroidal pollen grains.

P. kbinjuk pollen is stephanoporate (P_4 - P_5) with an intectate, reticulate wall structure. The lumina are small, less than 1μ in diameter, and only visible at magnifications of 1000 \times . The size is 20-25 μ .

P. mutica pollen has 4 to 8 pores and can be stephanoporate as well as periporate. In some specimens one should rather speak of short colpi than of pores. The wall structure is the same as in *P. kbinjuk* pollen. Size 23-35 μ .

The subfossil grains are usually periporate, sometimes tending to pericolpate. In a poorly preserved state they are difficult to identify.

4.3. Berberidaceae

4.3.1. *Bongardia* (fig. 10: 1-5)

Prolate, tricolpate pollen; at the poles slightly pointed. Very long furrows. In some grains the wall is tectate perforate, in others the columellae seem to fuse into a reticulum. Size 50-60 μ .

4.3.2. *Leontice* (fig. 10: 6, 7)

Prolate, tricolpate pollen grains. Long colpi. Intectate reticulate, heterobrochate. Larger lumina up to 2 μ . Along the colpi only small lumina. Granulae distinct, sometimes forming double rows. Size 40-52 μ .

4.4. Boraginaceae

4.4.1. *Anchusa*-type

Subprolate to prolate, stephanocolporate (C_4P_4) pollen grains, sometimes with slightly constricted equatorial area. In polar view square. Short, narrow furrows. The transversal furrows are often united into a colpus equatorialis. Finely reticulate surface pattern. Size 35-45 μ . This type includes

Anchusa and *Lycopsis*.

4.4.2. *Echium*-type

Pear-shaped, tricolporate pollen grains. In polar view circular to rounded triangular. Long furrows with costae. Covered, meridionally elongated pores. Micro-reticulate surface pattern, sometimes scabrate. Size 15-20 μ .

This type includes *Echium*, *Onosma*, and *Podonosma*.

4.4.3. *Heliotropium*-type (fig. 10: 8, 9)

Subprolate to prolate pollen grains, heterocolpate (C_6P_3). Long furrows; round pores which in some species are difficult to observe. Psilate, tectate. Columellae < 0.5 μ . Size 25-32 μ .

4.5. Campanulaceae

4.5.1. *Legousia*-type

Spheroidal pollen grains with 3 to 5 pores (stephanoporate). Size 25-33 μ . Pores with distinct costae. Tectate (no columellae visible). The tectum is crowded with small spines.

4.5.2. *Phyteuma*-type

Triporate, spheroidal grains, 20-30 μ in diameter. Pores with costae. The wall is tectate perforate with tiny columellae. No projections on the tectum (psilate).

4.6. Caryophyllaceae

4.6.1. *Spargularia*

Spheroidal, tricolpate grains. Rather long furrows;

polar area index < 0.25. The edge of the furrows is not sharply delimited. Tectate, perforate wall; columellae small but distinct (diameter c. 0.3 μ). Size 14-22 μ .

4.7. Chenopodiaceae

4.7.1. *Aellenia*-type (fig. 11: 3, 4, 6, 7)

Circular to slightly angular in outline; size 20-30 μ . 12-20 isodiametric pores; the diameter of the pore is 1/3 to 1/5 of that of the pollen grain. The pore delimitation is clear. Columellae distinct, c. 0.5 μ thick. This type shows some resemblance to caryophyllaceous pollen. In addition to *Aellenia*, *Beta lomatogona* and *Halogeton* produce this pollen type.

4.7.2. *Atriplex*-type (fig. 11: 1, 2, 12)

Medium-sized pollen grains. Columellae in general distinct. Pores with a narrow but distinct annulus. This type includes the majority of the chenopodiaceous genera, such as *Atriplex*, *Chenopodium*, *Suaeda*, *Salsola*, *Bassia*, *Halimione*, *Kochia*, *Krascheninnikovia*, and *Petrosimonia*.

4.7.3. *Chenopodiaceae* < 20 pores (fig. 11: 13)

In the examination of the sediment samples a small chenopod pollen type with less than 20 pores was observed. In the pollen reference collection of the Biologisch-Archaeologisch Instituut this type is not present, so that its possible taxonomic affinity is uncertain. The closest match is *Salicornia*, with slightly over 20 pores.

4.7.4. *Noaea*-type (fig. 11: 5, 8-11)

Penta- to hexagonal in outline; size 13-23 μ . 10-20 relatively large pores: pore diameter is about $\frac{1}{4}$ of the diameter of the pollen grain. The delimitation of the pores is not clear. Small (diameter < 0.5 μ), but distinct columellae. This type includes representatives of the genera *Cornulaca*, *Girgensohnia*, *Noaea*, and *Seidlitzia*.

4.7.5. *Spinacia*-type

Pollen grains with c. 100 pores. Size 32-45 μ , distinct columellae. This type was not distinguished until at a later stage in the examination. For that reason it is not shown as a separate type in the pollen diagrams.

4.8. Liguliflorae Compositae

Two types of liguliflorous pollen grains are distinguished, *viz.* *Scorzonera*-type and *Crepis*-type. For the terminology etc. the reader is referred to Wodehouse (1959, pp. 457-472).

4.8.1. *Crepis*-type

Size about 25-35 μ . There are no equatorial lacunae, but equatorial ridges. The polar area consists of a thickening of varying extension and with a varying number of central spines; this depends upon the species. In the *Crepis*-type the ridges are generally broader than in the *Scorzonera*-type, and they often bear a double row of spines. The *Crepis*-type includes the majority of the Liguliflorae Compositae.

4.8.2. *Scorzonera*-type

Size about 45-50 μ . There are 6 equatorial lacunae. In some *Scorzonera* species each of the poles shows a lacuna, in other species there are no polar lacunae. The high ridges between the lacunae are narrow and bear one row of sharp spines. The ridges consist of fine, rod-like elements forming a vertically striate pattern.

As the *Scorzonera*- and *Crepis*-types were not distinguished consistently during the examination of the sediment samples and as moreover, in case of poor preservation, a distinction was not possible, Liguliflorae Compositae are presented as one group in the pollen diagrams.

4.9. Tubuliflorae Compositae

Among the Tubuliflorae a great number of pollen types is distinguished. All tubuliflorous grains are tricolporate and tectate.

4.9.1. *Artemisia herba-alba*-type and *A. vulgaris*-type

Spheroidal pollen grains, 18-25 μ in diameter. Two types of *Artemisia* pollen are distinguished:

A. vulgaris-type (fig. 12: 4-6). This type has relatively large spines that are visible at 400 \times magnification. The diameter of the spines is equal to or larger than that of the columellae. The *A. vulgaris*-type includes *A. vulgaris* and *A. tournefortii*.

A. herba-alba-type (fig. 12: 1-3, 7). In this type the spines are not visible at 400 \times magnification. Small spines can generally be observed under oil immersion (1000 \times), but some pollen grains of this type show no spines at all. The *A. herba-alba*-type includes *A. austriaca*, *A. herba-alba*, *A. scoparia*, *A. persica*, *A. maritima*, and *A. fragrans*.

4.9.2. *Carduus*-type

Spheroidal grains, diameter c. 40 μ (without spines). Ektexine c. 2 μ . Diameter columellae < 0.5 μ . Spines: diameter 5-6 μ , height 2.5-3 μ , contents granular, rather blunt.

4.9.3. *Carthamus*

Spheroidal to subprolate grains. Largest diameter 45 to 60 μ (without spines). Ektexine 2-3 μ thick; columellae 0.5-1.5 μ in diameter. Spines up to 2.5 μ high and 5 μ broad. Characteristic of this type is the fact that the spines are mutually connected by low ridges, which form a kind of reticulate pattern.

4.9.4. *Centaurea cyanus*-type

This type includes *Centaurea depressa*.

4.9.5. *Centaurea scabiosa*-type

This type differs from the *Centaurea solstitialis*-type mainly by its apiculate shape (slightly protuberant poles) and by the distinct, but small hyaline spines (diameter < 1 μ). Size 40-50 μ .

4.9.6. *Centaurea solstitialis*-type (fig. 12: 8-13)

Spheroidal to subprolate pollen grains. In some grains colpi and costae transversales or equatoriales can be observed, whereas in other grains these are

not visible. The size varies from 25 to 40 μ . The wall is 2-3 μ thick. The fine columellae can only be observed under oil immersion. The blunt, hyaline projections (c. 1 μ in diameter) on the tectum are clearly visible at 400 \times magnification.

This pollen type includes a great number of *Centaurea* species, such as *C. ammocyanus*, *C. beben*, *C. brugnieriana*, *C. hyalolepis*, *C. intricata*, *C. rigida*, *C. solstitialis*, *C. squarrosa*, and *C. ustulata*.

4.9.7. *Cirsium*-type

Spheroidal grains, size 40-50 μ (without spines). Ektexine c. 4 μ thick. Columellae of irregular shape, the larger ones up to 3 μ in diameter. The tectum consists of small, rod-like elements (diameter <0.5 μ). Fairly sharp spines, up to 4 μ high and 5 μ broad; contents granular.

4.9.8. *Cousinia*-type (fig. 13: 1-5)

Prolate to subprolate pollen grains, 40-60 μ large. The columellae, 2-4 μ in diameter, are branched. In the intercolpia of the equatorial area the wall is about twice as thick as in the polar area. Tectum smooth (no spines).

In addition to *Cousinia* species, *Centaurea xeranthemoides* shows this pollen type.

4.9.9. *Doronicum*-type

Spheroidal pollen grains, 22-25 μ in diameter (without spines). Fine columellae. Thickness of the wall c. 2 μ . Sharp and large spines, 4-5 μ high and broad. In some specimens the upper part of the spines is hyaline, in others rod-like elements fill the whole of the spines.

This type includes *Doronicum*, *Carpesium*, and *Plucea* species.

4.9.10. *Echinops* (fig. 13: 8, 9)

Subprolate pollen grains, size 70-80 μ . In the equatorial area the ektexine is 13-15 μ thick, in the polar area up to 8 μ . The columellae, with a diameter of 0.5-1 μ , are 1.5 μ (in polar area) to 3 μ (in equatorial area) high. Tectum up to 12 μ thick, consisting of fine, granular, rod-like elements (*cf.* Stix 1959). Blunt hyaline spines (c. 1 μ high and c. 1.5 μ broad)

at great mutual distances. Conspicuous costae equatoriales.

4.9.11. *Filago*-type (fig. 13: 6, 7)

Spheroidal pollen grains, size 17-20 μ (without spines). Ektexine c. 1.5 μ thick. Columellae (<0.5 μ) only visible at 1000 \times magnification. The tectum is densely covered with sharp, hyaline spines, 1-1.5 μ high. This type includes *Filago*, *Micropus*, and *Evax* species.

4.9.12. *Gundelia*-type (fig. 14: 1)

Spheroidal pollen grains, size 32-38 μ (without spines). Fine columellae (< 0.5 μ in diameter). Thickness of the wall c. 3 μ . Spines 6-7 μ long, mutually connected by low ridges. *Gundelia tournefortii* is the only representative of this genus in Iran.

4.9.13. *Inula*-type

Spheroidal grains, diameter 20-25 μ (without spines). Ektexine 1.5 to 2 μ thick. Columellae (<0.5 μ) only visible under immersion objective. Relatively large spines with sharp to fairly sharp points. The spines, c. 2.5 μ high and 3.5-4 μ broad, have a granular contents. This type includes representatives of various genera: *Chrysophthalmum*, *Helicbrysum*, *Inula*, *Odontospermum*, *Pallensis*, *Zoegea*.

4.9.14. *Juvinea*-type (fig. 14: 2, 3)

Spheroidal to subprolate grains, 40-50 μ large. Ektexine 3-4 μ . Characteristic of this type are the large columellae of irregular shape, up to 4 μ in diameter. Between the large columellae smaller ones are present. The fairly blunt spines are 3 to 4 μ broad and 1.5 to 2 μ high; the contents of the spines is granular. In subfossil specimens the spines are often hardly visible.

4.9.15. *Matricaria*-type

Spheroidal pollen grains, 20-25 μ in diameter (without spines). Characteristic are the conspicuously thick wall (up to 5 μ thick) and the heavy columellae (1-2 μ in diameter). The sharp spines, with a height/width ratio of 2/3, are about 2.5 μ long. The type

includes representatives of the genera *Achillea*, *Anthemis*, *Chrysanthemum*, *Matricaria*, and *Tanacetum*.

4.9.16. *Onopordon-type*

This type is very similar to *Cirsium-type*. The diameter of the grains (without spines) is 55-60 μ .

4.9.17. *Senecio-type*

Spheroidal grains, size without spines 20-25 μ . Fine columellae, only visible at 1000 \times magnification. Characteristic of this type are the comparatively long (2.5-3 μ) and broad spines, the upper half of which is hyaline.

4.10. Convolvulaceae

4.10.1. *Calystegia*

Spheroidal, periporate pollen grains; c. 35 round to oval pores. Branched columellae 1-3 μ in diameter. Tectum with numerous perforations. Wall c. 4 μ thick. Size 68-75 μ .

4.10.2. *Convolvulus*

Tricolpate, spheroidal to subprolate grains. Long furrows, often with ektexine elements; polar area index 0.20-0.25. Columellae up to 3 μ in diameter in the intercolpia. Smaller towards the furrows. The larger columellae are branched. Tectum with numerous perforations. Wall up to 4 μ thick. Size 50-60 μ .

4.11. Cruciferae

4.11.1. *Brassica-type and Capsella-type*

Tricolpate, spheroidal, subprolate pollen grains with a reticulate ektexine. Small polar area. The wall shows its greatest thickness in the intercolpia, but no margo is present along the colpi. The separation of cruciferous pollen into two groups (apart from *Matthiola-type* pollen) is based upon the size of the columellae and the diameter of the lumina.

In the *Brassica-type* the lumina measure more than 1.5 μ , and the columellae are 0.3 μ or more thick. The pollen grains of this type are 18-25 μ .

In the *Capsella-type* the lumina are in general no more than 0.5 μ in diameter. The size is 15-20 μ . Transitional forms between both pollen types occur.

4.11.2. *Matthiola-type* (fig. 14: 4, 5)

Spheroidal grains; inaperturate or slight indications for three apertures in the form of pores or very short colpi. Reticulate wall structure with distinct columellae and 2-3 μ wide lumina. The wall is 2-3 μ thick. Size 20-30 μ .

4.12. Cucurbitaceae

4.12.1. *Bryonia* (fig. 14: 6, 7)

Tricolpate, spheroidal to subprolate grains. Long colpi with costae; polar area index c. 0.2. Meridionally elongated pore not sharply delimited. Intectate, reticulate with distinct granulae. Lumina up to 2 μ , smaller towards the colpi. Wall up to 2.5 μ thick. Size 40-45 μ .

4.13.1. *Cuscuta*

4.13. Cuscutaceae

Tricolpate, spheroidal to subprolate pollen. Rather long furrows with ektexine elements; polar area index c. 0.25. Distinct, regularly distributed columellae, up to 1 μ in diameter. Wall up to 2.5 μ thick, thinner along the colpi. Size 20-24 μ .

4.14. Cynocrambaceae

4.14.1. *Cynocrambe* (fig. 14: 8-10)

Spheroidal, stephanoporate pollen grains. Mostly 6, isodiametric, small pores. Tectate, perforate with distinct columellae (diameter c. 0.3 μ). Wall 2.5-3 μ thick. Size 34-38 μ .

4.15. Datisceae

4.15.1. *Datisca* (fig. 20: 10, 11)

Spheroidal, tricolpate, scabrate grains. Size c. 15 μ . *Datisca* pollen shows resemblance to small *Quercus*

grains. *Datisca* pollen occurs often in tetrads, but in addition to single grains, two or three are found adhering to each other. *Datisca cannabina* occurs in Iran (Rechinger 1966).

4.16. Dipsacaceae

4.16.1. *Cephalaria*

Suboblate pollen grains with 3 pores that are often meridionally elongated. Equatorial limb rounded triangular. Pores with a conspicuous annulus. Heavy columellae, with a diameter of c. 2μ . The tectum is densely set with spines. Larger spines, 2- 2.5μ long, form, as it were, the continuation of the columellae. A great number of small spines between the larger ones. Wall c. 5μ thick (without spines). Size of the grains $75-80\mu$.

4.16.2. *Dipsacus*

Tricolpate, spheroidal to subprolate pollen grains. Furrows relatively short with distinct costae colpi. Polar area index c. 0.7. Underneath the tectum relatively few large columellae, with a diameter of up to 4μ , and numerous small ones (c. 1μ in diameter). The tectum shows small but distinct perforations. The larger spines on the tectum (up to 3μ high) are supported by the large columellae. In addition to the large spines, a much greater number of small ones. Wall c. 6μ thick (without spines). Size $90-95\mu$.

4.16.3. *Scabiosa palaestina*-type

Triporate grains. Equatorial limb triangular. Wall 8μ thick. Densely crowded columellae, c. 1μ in diameter. On the tectum numerous small spines and a smaller number of hyaline gemmae, $1.5-2\mu$ high and $2-3\mu$ wide. Size of the grains $75-80\mu$.

4.17. Ephedraceae

4.17.1. *Ephedra*

Two types of *Ephedra* pollen grains were found, viz. *E. distachya*-type and *E. fragilis*-type.

Ephedra distachya pollen has branched grooves. This type includes for Iran: *E. intermedia*, *E. pachy-*

clada, and *E. procera*.

Ephedra fragilis pollen has more or less straight grooves. The Iranian *E. strobilacea* and *E. ciliata* show *E. fragilis*-type grains.

4.18. Euphorbiaceae

4.18.1. *Euphorbia*-type

Heavy, tricolpate, spheroidal pollen grains. Long furrows with distinct costae colpi. The protruding pore *c.g.* colpus transversalis is difficult to observe because it is covered by the ektexine. In subfossil specimens it is hardly present. The wall is up to 3μ thick. There is a considerable variation in the diameter of the columellae among the various species. In some *Euphorbia* species the columellae are more than 1μ thick, in others they are hardly 0.5μ . The size of the columellae diminishes towards the colpi (there is a margo). The tectum is perforate. Sometimes the columellae are arranged in a reticuloid pattern. The size of the grains varies from 20 to 45μ .

4.18.2. *Mercurialis annua*-type

Tricolpate, subprolate pollen. Long colpi with costae; polar area index c. 0.2. Vague, equatorially elongated pore to colpus transversalis. Numerous distinct, regularly distributed columellae below tectum. Wall $1-1.2\mu$ thick. Size $20-24\mu$.

4.19. Fagaceae

4.19.1. *Quercus*

The *Quercus* pollen grains in the Iranian sediment samples are identical to the *Quercus robur*-type from NW Europe and the *Q. cerris*-type from SE Europe. In this type the scabrae on top of the tectum are very conspicuous. *Q. brantii*, *Q. infectoria*, and the other Iranian oak species represented in the pollen reference collection in the Biologisch-Archaeologisch Instituut have *Q. robur*-type pollen.

4.20. Gramineae

4.20.1. *Cerealia*-type

Cerealia-type pollen is distinguished from other

gramineous pollen by its size (at least 40μ in silicone-oil-mounted slides), the thick wall, and the pronounced annulus. In addition to wild and cultivated cereals, various other Near Eastern grass species produce Cerealia-type pollen (*cf.* van Zeist *et al.* 1975). Consequently even fairly high Cerealia-type pollen values in Near Eastern pollen diagrams are not necessarily indicative of farming.

4.21. Guttiferae

4.21.1. *Hypericum assyriacum*-type (fig. 15: 1-3)

Spheroidal, pericorporate grains (C_5P_5 - C_6P_6), partly syncolpate. The pore can often not be observed; if visible mostly a colpus transversalis. Sometimes only an equatorial bridge is present. Intectate, micro-reticulate. Size 16 - 22μ . This type includes *H. assyriacum* and *H. scabrum*.

4.21.2. *Hypericum perforatum*-type

Tricolpate, subprolate pollen grains. Long colpi (polar area index c. 0.2). Instead of a protruding pore often only an equatorial constriction or equatorial bridge is visible. Intectate, micro-reticulate. Size 15 - 20μ .

4.22. Hippuridaceae

4.22.1. *Hippuris*

Spheroidal to suboblate, stephanocolpate grains (C_5 - C_6). In polar view somewhat angular. Rather short, not sharply delimited furrows, covered with a thin ektexine layer (the furrows are thinnings in the ektexine which can be ruptured). Tectate, perforate wall with tiny columellae. Size 22 - 28μ .

4.23. Iridaceae

4.23.1. *Sisyrinchium*-type (fig. 15: 4, 5)

Monocolpate grains. In equatorial view plano-convex; in polar view subrectangular with somewhat obliquely rounded or pointed ends. The furrow is about as long as half the greatest circumference of the grain. Characteristic is the fact that the colpus is narrow in the middle and broader at either

end. Psilate, tectate, perforate. Columellae $<0.5\mu$, sometimes arranged in a rugulate pattern. Size 35 - 48μ .

The genus *Sisyrinchium* is not recorded for Iran, and this pollen type is not represented in the Near Eastern pollen reference collection in the Biologisch-Archaeologisch Instituut.

4.24. Juglandaceae

4.24.1. *Pterocarya*

Stephanoporate grains (P_5 - P_6), angular in polar view. Pores with an annulus. Psilate wall, c. 1μ thick. Size 33 - 37μ .

4.25. Labiatae

4.25.1. *Nepeta*-type

Stephanocolpate (C_6). Suboblate, spheroidal, and subprolate pollen grains. Four very long and two slightly shorter colpi. In some species columellae are visible underneath the tectum, in others not. On the tectum a reticulate to striate surface pattern. Size 20 - 35μ .

This type includes *Nepeta* and *Prunella* species.

4.25.2. *Salvia spinosa*

Stephanocolpate (C_6) pollen. Most grains are suboblate, but spheroidal and subprolate specimens also occur. Four very long colpi and two slightly shorter ones. Intectate, reticulate. Largest lumina 2 - 2.5μ . Columellae are clearly visible at $1000\times$ magnification. Along the colpi a narrow margo. Size 30 - 40μ .

4.26. Leguminosae

4.26.1. *Ebenus*

Perprolate ($lg/lt > 2$), tricolpate pollen grains with rounded poles. Narrow, very long colpi. Syncolpate grains occur likewise. Supra-reticulate. Size 25 - 30μ .

4.26.2. *Prosopis*

Spheroidal to subprolate, tricolpate grains. Long and broad colpi with intruding edges. The round to longitudinally somewhat elongated pore is completely situated inside the furrow and has a distinct

costa. In the intercolpia the columellae are up to 1μ in diameter and the wall is up to 2.5μ thick. Towards the furrows the columellae become smaller. On the perforated tectum a vague reticulum is sometimes visible. Size $35-40\mu$.

4.27. Liliaceae

4.27.1. *Allium*-type

Monocolpate grains. In equatorial view plano-convex to biconvex. The furrow is longer than the greatest circumference of the pollen. Psilate. Very fine columellae visible underneath the tectum, sometimes forming a rugulate pattern. Size $28-50\mu$.

4.27.2. *Merendera*

Diporate grains. In equatorial view plano-convex to biconvex. Pores not sharply delimited. Intectate, reticulate, lumina c. 1μ wide. Wall c. 1μ thick. Size $40-48\mu$.

4.27.3. *Muscari*-type

Monocolpate grains. In equatorial view plano-convex to biconvex. The furrow is longer than half the greatest circumference of the pollen (it runs around the edge of the grain). Intectate, heterobrochate, reticulate. Sometimes the muri have a double row of columellae. Towards the colpus the reticulum becomes finer. Size $22-26\mu$.

This type includes *Muscari*, *Bellevalia*, and *Chionodoxa*.

4.28. Loranthaceae

4.28.1. *Loranthus* (fig. 15: 8-10)

Tricolporate to syncolporate, oblate (Lg/Lt c. 0.6) pollen grains. In polar view triangular to lobate. Sharply delimited, rectangular pore, meridionally elongated, $7-10\mu$. Wall c. 1.3μ thick, scabrate. Size $25-28\mu$.

4.29. Moraceae

4.29.1. *Morus*

Spheroidal to suboblate, diporate grains. Pores of

slightly irregular shape, without annulus or costa. Wall $1-1.3\mu$ thick, micro-scabrate. Size $16-20\mu$.

4.30. Oleaceae

4.30.1. *Fraxinus* (fig. 15: 6, 7)

The *Fraxinus* pollen in the Iranian sediment samples looks much like that of *Fraxinus excelsior* but is heavier; the columellae are always visible at a magnification of $400\times$. The grains show a variation in the size of the columellae and in the thickness of the wall. In Iran, *Fraxinus* is represented by *F. excelsior* and *F. rotundifolia*, the first occurring up to $2,335$ m, the second up to $2,600$ m (Murray 1968).

4.30.2. *Olea* and unidentified Oleaceae

Oleaceous pollen grains caused identification difficulties. Some of them are identical with *Olea* pollen, but others could not be attributed to a specific oleaceous genus. Of the latter grains some show affinities to the pollen of *Phillyrea*/*Fontanesia* (both genera not found in Iran nowadays) and some to those of *Ligustrum*.

Possibly wild *Olea europaea* is quite common in the Çoruh Valley, in the Euxinian sector of NE Anatolia (Zohary 1973, p. 372). The westernmost limit of *Olea ferruginea* lies in southern Iran, where it plays an unimportant part in the vegetation. *Olea aucheri* is observed in southern Iran. *Ligustrum vulgare* is reported for North and Northwest Iran (Murray 1968).

4.31. Papaveraceae

4.31.1. *Glaucium* (fig. 15: 11, 12)

Spheroidal to suboblate, tricolpate pollen grains with medium long furrows. In the broad colpi ektexine elements. Intectate. The distinct granulae fuse into a reticulum at a higher level. Size $25-45\mu$.

4.31.2. *Papaver*

Spheroidal to subprolate, tricolpate pollen grains. In the fairly long furrows ektexine elements are often present. A reticulate pattern can usually be

observed underneath the tectum (intra-reticulate). On the tectum regularly distributed micro-verrucae. Size 25-30 μ .

4.32. Plumbaginaceae

4.32.1. *Statice spicata*/*Psylliostachys* (fig. 11: 14-17)

Dimorphic pollen grains:

1. Spheroidal, tricolpate pollen, size c. 35 μ . Wall 2.5-4 μ thick; angular columellae, c. 1 μ in diameter. Tectum with large perforations and micro-spines.
2. Spheroidal, tricolpate pollen. Size 30-35 μ . Wall 4-5 μ thick. Granulae, c. 1.5 μ in diameter, fused into a reticulate pattern. Lumina c. 4 μ . Small spines on the muri.

4.33. Polygonaceae

4.33.1. *Atraphaxis* (fig. 16: 1-5)

Subprolate to prolate, tricolporate pollen grains. Long colpi with costae. The pore is not sharply delimited. Striate surface pattern (tectate perforate). Size 30-35 μ . The wall structure and the shape of the grain remind one of *Acer*, but the colpi are quite different.

4.33.2. *Calligonum*/*Pteropyrum* (fig. 16: 6-9)

Subprolate, tricolporate pollen. Very long colpi with costae. The distinct pore is round to meridionally elongated. Wall structure intectate reticulate, tectate perforate or tectate supra-reticulate. Size 30-40 μ .

4.33.3. *Fagopyrum tataricum*-type

Tricolporate, subprolate pollen grains. The pore is mostly difficult to observe. The furrows are narrow and long. Most characteristic is the wall structure. The coarse columellae, 1-1.5 μ in diameter, are branched. There is no margo. In some of the grains a vague reticulum can be observed on top of the tectum. Ektexine c. 2 μ thick. Size of the grains 35-45 μ .

4.33.4. *Polygonum aviculare*-type

Spheroidal to subprolate, tricolporate to pericorporate grains; the latter are less common. Distinct transversal furrows and costae transversales. Tectate, psilate with varying wall thickness over the grain. Size 20-27 μ .

Subfossil grains, which resemble *P. aviculare* pollen but which lack transversal furrows or even indications of pores (thus tricolpate grains), are included in this type.

4.33.5. *Rhenm* (fig. 16: 10, 11)

Spheroidal to subprolate, tricolporate pollen grains. Very long, narrow colpi with costae. Pore equatorially elongated. Wall c. 1.5 μ thick, tectate perforate, psilate. Size 30-37 μ .

4.33.6. *Rumex cyprinus*-type

This type is identical to the *Rumex acetosa*-type. Spheroidal grains, C₃P₃ to C₅P₅. Narrow furrows with a covered, small, round pore. Intectate reticulate with lumina < 1 μ . Size 20-28 μ .

4.33.7. *Rumex patientia*-type

Spheroidal pollen grains, C₃P₃ to C₄P₄. Narrow colpi. Furrows and pores with costae. Pore meridionally elongated, covered. Wall tectate perforate, psilate. Size 32-36 μ .

4.34. Ranunculaceae

4.34.1. *Anemone blanda*-type

Spheroidal, tricolpate grains. Long colpi: polar area index < 0.25. Tectate, perforate. Distinct columellae (c. 0.5 μ in diameter), more crowded than in *Ranunculus peltatus* (*Batrachium*)-type. Wall c. 1.5 μ thick. Size 21-24 μ .

4.34.2. *Anemone biflora*-type

Spheroidal, periporate grains. Isodiametric pores with ektexine elements. Pore delimitation vague. Wall 2-3 μ thick. Tectate, perforate. Larger (1-1.5 μ in diameter) as well as smaller columellae are pre-

sent. Micro-spines above the larger columellae. Size 30-40 μ .

4.34.3. *Delphinium-type*

Subprolate, tricolpate grains; largest diameter 15-30 μ . Long furrows with ektexine elements. The wall is thickest at the poles, suggesting an apiculate shape. In the equatorial area the columellae are <0.5 μ , whereas in the polar area they are up to 1 μ in diameter. The wall is smooth.

4.34.4. *Helleborus-type*

Spheroidal, tricolpate grains. Fairly long colpi; polar area index c. 0.25. Furrows with ektexine elements. Columellae c. 0.5 μ in diameter; sometimes 2 or 3 columellae united into rugulae. Tectate, perforate, sometimes reticulate to reticuloid. Wall generally c. 2.5 μ thick; at the poles somewhat thicker, but thinner along the colpi. Size 32-35 μ .

4.34.5. *Nigella*

Spheroidal, tricolpate grains. Rather long colpi; polar area index c. 0.30. Wall up to 4 μ thick in the intercolpia. Relatively few larger columellae (diameter c. 1 μ) and numerous small ones. Tectate, perforate. Small spines above the larger columellae. Size 40-45 μ .

4.34.6. *Ranunculus arvensis-type* (fig. 17: 1)

Spheroidal pollen grains, inaperturate (periporate according to Bot & van der Spoel-Walvius (1968)). Size 30-45 μ . Relatively few large columellae (diameter 1-2 μ) and numerous tiny ones. Characteristic are the conspicuous spines (up to 2.5 μ high), footing on shield-like bases (up to 5 μ broad) which are often fused into groups of two or more.

4.34.7. *Ranunculus asiaticus-type*

Periporate, spheroidal pollen grains, 20-28 μ in diameter. Pores isodiametric, with ektexine elements. The pore delimitation is not distinct. Larger (0.5-1 μ in diameter) as well as smaller columellae. Tectum slightly undulating. Spines more distinct than in the *Ranunculus repens-type*.

4.34.8. *Ranunculus peltatus-type*

This type is identical with the *Batrachium-type* (*Ranunculus aquatilis*, *R. circinatus*) of NW European pollen diagrams.

4.34.9. *Ranunculus repens-type*

Tricolpate to pericolpate, spheroidal grains, 20-30 μ in diameter. Larger as well as smaller columellae are present. The tectum is slightly undulating, its highest points being supported by the larger columellae. Micro-spines above the larger columellae. Ektexine elements in the furrows.

4.35. Rosaceae

4.35.1. *Amygdalus-type*

Tricolporate, spheroidal to prolate (Lg/Lt c. 1-1.5) pollen grains. Pore mostly strongly protruding; pore delimitation vague. Long colpi (polar area index c. 0.2). Tectate-perforate, striate wall structure. Size 30-50 μ .

4.36. Rubiaceae

4.36.1. *Asperula-type* (fig. 17: 2, 3)

Spheroidal, stephanocolpate pollen grains (C₇-C₈). The furrows are rather short. Fine but distinct reticulate wall structure. Size 20-25 μ .

4.37. Rutaceae

4.37.1. *Haplophyllum* (fig. 17: 4, 5)

Tricolporate pollen grains with strongly protruding pores. In equatorial view rhomboid to oval in outline. Triangular equatorial limb. Long colpi. Reticulate to striate surface pattern. Size 35-50 μ .

4.38. Santalaceae

4.38.1. *Thesium*

Heteropolar grain with triangular equatorial limb. At one pole the three colpi fuse together, forming a trilete pattern. The greater part of the grain shows

a heterobrochate reticulum; the diameter of the larger lumina is 4μ and more. The pole without colpi and the margo along the colpi have a psilate, perforate wall structure. Size $23-26\mu$.

4.39. Solanaceae

4.39.1. *Hyoscyamus*

Tricolporate, spheroidal to subprolate grains. Long furrows with intruding edges; polar area index c. 0.15. Protruding, vaguely delimited colpi transversales. Sometimes only an equatorial constriction is present. Some species show an intectate, reticulate wall structure, whereas in others the wall is tectate, perforate, striate (long striae running from pole to pole). Size $30-40\mu$.

4.40. Tamaricaceae

4.40.1. *Tamarix* (fig. 17: 6-8)

Tricolpate, spheroidal pollen grains. Long furrows. Size $15-18\mu$. Intectate, micro-reticulate wall structure. The reticulate pattern is finer along the colpi (margo is present). *Tamarix* pollen shows some resemblance to *Capsella*-type pollen (Cruciferae). In *Capsella*-type pollen there is no distinct margo, whereas in *Tamarix* pollen there is no gradual decrease in wall thickness towards the colpi as is the case in cruciferous pollen.

4.41. Umbelliferae

In the sections covered by pollen assemblage zones 1 to 4, umbelliferous pollen values are conspicuously high. Already during the initial stages of the investigation it became clear that various umbelliferous pollen types are present. The observed variety in subfossil umbelliferous pollen types encouraged, as it were, a more detailed study of the pollen of Near Eastern representatives of this family.

Extensive studies of umbelliferous pollen grains have been carried out by Cerceau-Larrival (1959, 1962, 1963, 1965). Although the descriptions and photographs in Cerceau-Larrival's publications were already of much help in connection with the umbelliferous pollen in the Iranian sediment cores,

the need for a special study of this group was felt. It was not possible to obtain pollen material from all umbelliferous species reported for Iran and adjacent areas. For genera with a small number of representatives in the area it has been attempted to obtain pollen of at least one species. For genera with a greater number of species in Iran and adjacent areas more species are represented in the pollen reference collection in the Biologisch-Archaeologisch Instituut. The main objective of this study was to examine to what extent the various genera could be identified pollen-analytically.

Unless otherwise stated the umbelliferous pollen types are tricolporate. The wall is tectate, psilate. The following types were distinguished in the sediment samples.

4.41.1. *Anisosciadium*-type (fig. 18: 1-6)

Most characteristic of this type is the fact that it is dicolporate. The colpi are rather short. Pores equatorially elongated. The endexine is constricted in the equatorial area and the poles are rounded. Lg/Lt c. 2. In equatorial view, with the colpi in central position, the grain has a distinctly inflated shape. The ectexine shows its greatest thickness in the intercolpia of the equatorial zone (2.5μ). The diameter of the columellae ranges from less than 0.5μ to c. 1μ (in the equatorial zone). Size $30-36\mu$.

This type includes *Anisosciadium*, *Dicyclophora*, *Echinophora*, and *Pycnocycla*.

4.41.2. *Bunium*-type (fig. 18: 13-17)

Subrectangular pollen grains with rounded poles. Lg/Lt >2 . The colpi are rather short. The protruding pores have a rectangular shape. The thickness of the ectexine does not vary markedly over the grain. Columellae $<0.5\mu$. Size $22-30\mu$.

This type is rather variable and includes species of *Bunium*, *Ammi*, *Anethum*, *Anthriscus*, and *Conopodium*.

4.41.3. *Bupleurum*-type (fig. 18: 7-12)

Oval-rhomboid in outline. Lg/Lt 1.2-1.5. In polar view triangular shape. Long colpi. Pore protruding, constricted. Columellae $<0.5\mu$, smooth wall. No variation in thickness of the ectexine. Size $16-23\mu$.

EXPLANATION OF FIGURES 10-20

Fig. 10.

- 1, 2, 3: *Bongardia chrysogonum* (modern)
- 4, 5: *Bongardia* (Zer. Ia, spectrum 15)
- 6, 7: *Leontice* (Zer. Ia, spectrum 15)
- 8, 9: *Heliotropium* (Zer. II, spectrum 36)
- 1250 ×

Fig. 11.

- 1, 2: *Atriplex tatarica* (modern)
- 3: *Aellenia glauca* (modern)
- 4: *Aellenia cinerascens* (modern)
- 5: *Noaea mucronata* (modern)
- 6, 7: *Aellenia*-type (Zer. Ia, spectrum 24)
- 8, 9: *Noaea*-type (Zer. Ia, spectrum 43)
- 10, 11: *Noaea*-type (Zer. II, spectrum 17)
- 12: *Atriplex*-type (Zer. II, spectrum 17)
- 13: Chenopodiaceae < 20 pores (Zer. II, spectrum 17)
- 14, 15: *Psylliostachys/Statice spicata* (Zer. II, spectrum 17)
- 16: *Psylliostachys/Statice spicata* (Zer. II, spectrum 36)
- 17: *Psylliostachys/Statice spicata* (Zer. Ia, spectrum 27)
- 1-5, 7, 12, 13: 1000 ×; 6, 8-11, 14-17: 1250 ×

Fig. 12.

- 1: *Artemisia herba-alba* (modern)
- 2, 3: *Artemisia austriaca* (modern)
- 4, 5, 6: *Artemisia tournefortii* (modern)
- 7: *Artemisia herba-alba*-type (Zer. Ia, spectrum 43)
- 8, 9, 10, 11: *Centaurea solstitialis* (modern)
- 12, 13: *Centaurea solstitialis*-type (Zer. II, spectrum 17)
- 1250 ×

Fig. 13.

- 1: *Cousinia compacta* (modern)
- 2: *Cousinia cylindrica* (modern)
- 3, 4: *Cousinia* (Zer. Ia, spectrum 54)
- 5: *Cousinia* (Zer. Ia, spectrum 43)
- 6, 7: *Filago*-type (Zer. II, spectrum 32)
- 8, 9: *Echinops* (Zer. II, spectrum 17)
- 1250 ×

Fig. 14.

- 1: *Gundelia* (Zer. II, spectrum 52)
- 2: *Jurinea*-type (Zer. Ia, spectrum 50)
- 3: *Jurinea*-type (Zer. Ia, spectrum 31)
- 4, 5: *Matthiola* (Zer. II, spectrum 17)
- 6, 7: *Byronia* (Zer. II, spectrum 3)
- 8, 9, 10: *Cynocranbe* (Zer. II, spectrum 23)
- 1250 ×

Fig. 15.

- 1, 2, 3: *Hypericum assyriacum* (modern)
- 4, 5: *Sisyrinchium montanum* (modern)
- 6, 7: *Fraxinus* (Zer. Ia, spectrum 25)

- 8: *Loranthus* (Zer. II, spectrum 58)
- 9, 10: *Loranthus*, pore (Zer. II, spectrum 58)
- 11, 12: *Glaucium* (Zer. II, spectrum 3)
- 1250 ×

Fig. 16.

- 1, 2, 3: *Atraphaxis spinosa* var. *glauca* (modern)
- 4: *Atraphaxis*-type (Zer. Ib, spectrum 74)
- 5: *Atraphaxis*-type (Zer. Ia, spectrum 24)
- 6, 7: *Calligonum comosum* (modern)
- 8: *Calligonum*-type (Zer. Ia, spectrum 24)
- 9: *Calligonum*-type (Zer. II, spectrum 52)
- 10, 11: *Rheum* (Zer. II, spectrum 17)
- 1250 ×

Fig. 17.

- 1: *Ranunculus arvensis* (Zer. II, spectrum 40)
- 2: *Asperula odorata* (modern)
- 3: *Asperula taurina* (modern)
- 4, 5: *Haplophyllum* (Zer. II, spectrum 32)
- 6, 7, 8: *Tamarix* (Zer. Ia, spectrum 43)
- 9, 10, 11: Unidentified type (Zer. II, spectrum 17)
- 12: Unidentified type (Zer. Ia, spectrum 31)
- 1250 ×

Fig. 18.

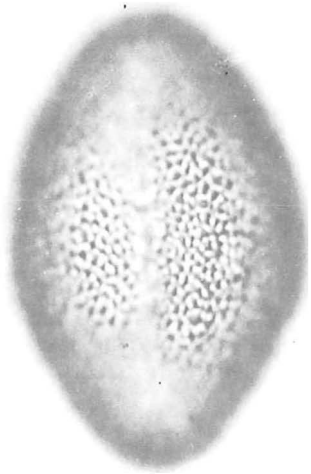
- 1, 2: *Anisosciadium orientale* (modern)
- 3, 4, 5: *Echinophora spinosa* (modern)
- 6: *Anisosciadium*-type (Zer. Ia, spectrum 43)
- 7, 8: *Bupleurum croceum* (modern)
- 9: *Bupleurum* cf. *semicompositum* (modern)
- 10, 11: *Astoma bakhtiaricum* (modern)
- 12: *Bupleurum*-type (Zer. Ia, spectrum 25)
- 13, 14, 15: *Bunium rectangulum* (modern)
- 16: *Bunium*-type (Zer. Ia, spectrum 25)
- 17: *Bunium*-type (Zer. Ia, spectrum 28)
- 1-5, 7-11: 1000 ×; 6, 12-17: 1250 ×

Fig. 19.

- 1, 2: *Eryngium campestre* (modern)
- 3, 4: *Eryngium*-type (Zer. Ia, spectrum 25)
- 5, 6: *Ferula ovina* (modern)
- 7, 8: *Ferula*-type (Zer. Ia, spectrum 43)
- 9: *Ferula*-type (Zer. II, spectrum 17)
- 10: *Malabaila kotschyi* (modern)
- 11: *Malabaila sekakul* (modern)
- 12: *Malabaila*-type (Zer. Ia, spectrum 1)
- 1250 ×

Fig. 20.

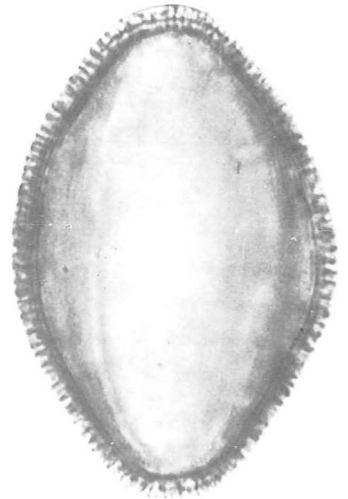
- 1, 2: *Pimpinella barbata* (modern)
- 3: *Psammogeton crinitum* (modern)
- 4: *Pimpinella*-type (Zer. Ia, spectrum 27)
- 5, 6: *Sium erectum* (modern)
- 7, 8, 9: *Turgenia latifolia* (modern)
- 10, 11: *Datisca* (Zer. II, spectrum 42)
- 1-3, 7-9: 1000 ×; 4-6, 10, 11: 1250 ×



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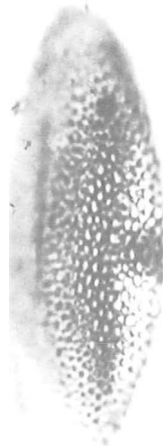
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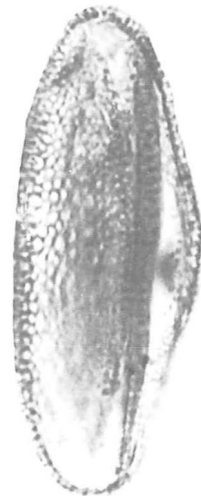
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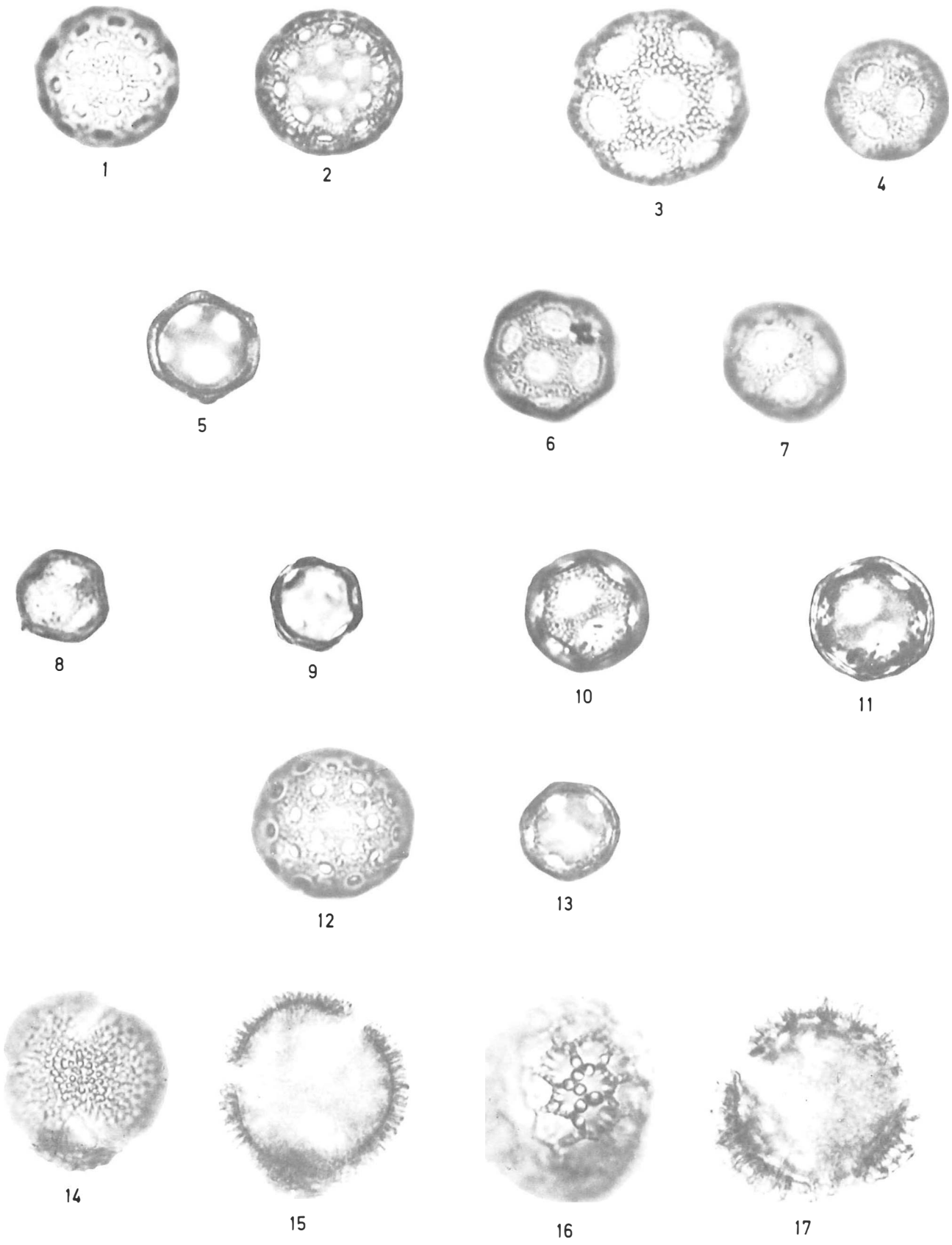


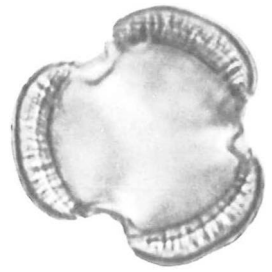
Fig. 11



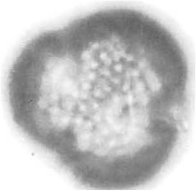
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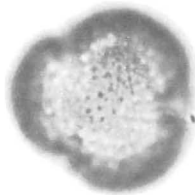
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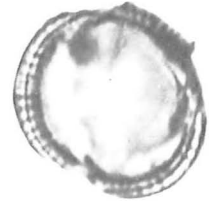
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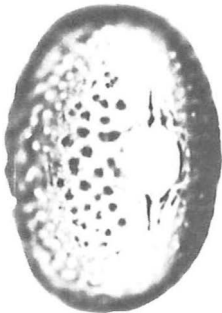
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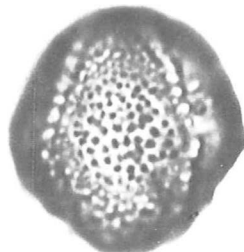
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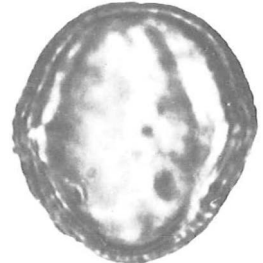
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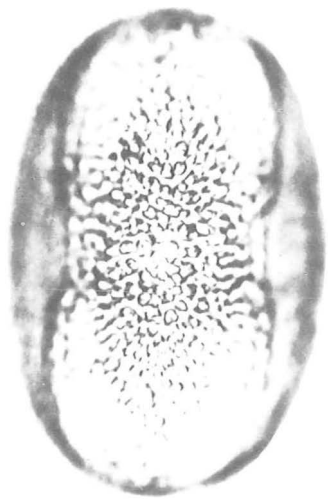
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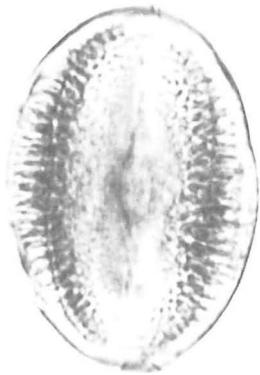
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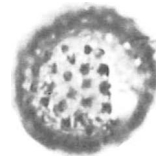
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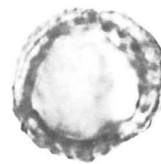
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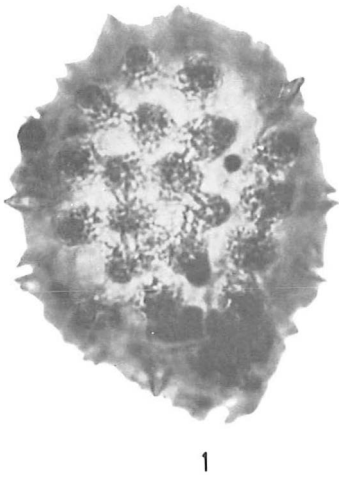
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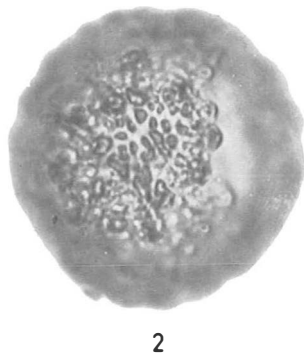
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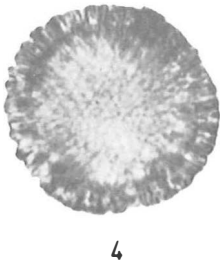
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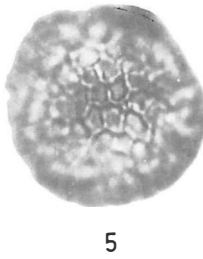
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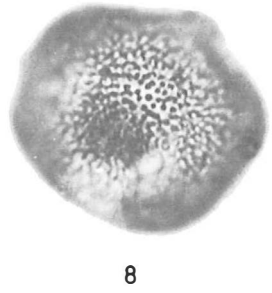
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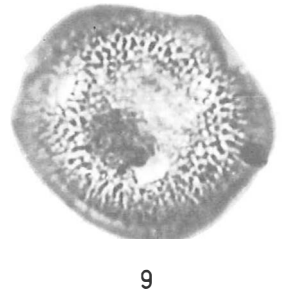
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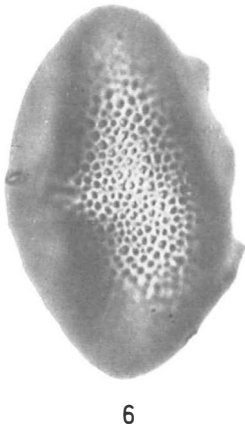
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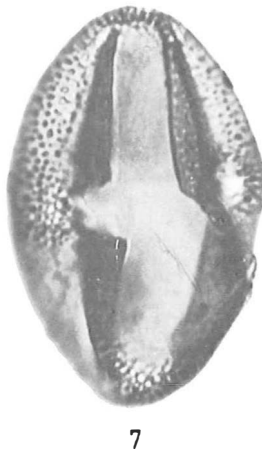
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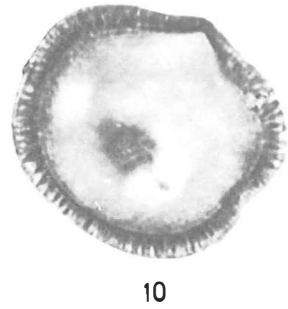
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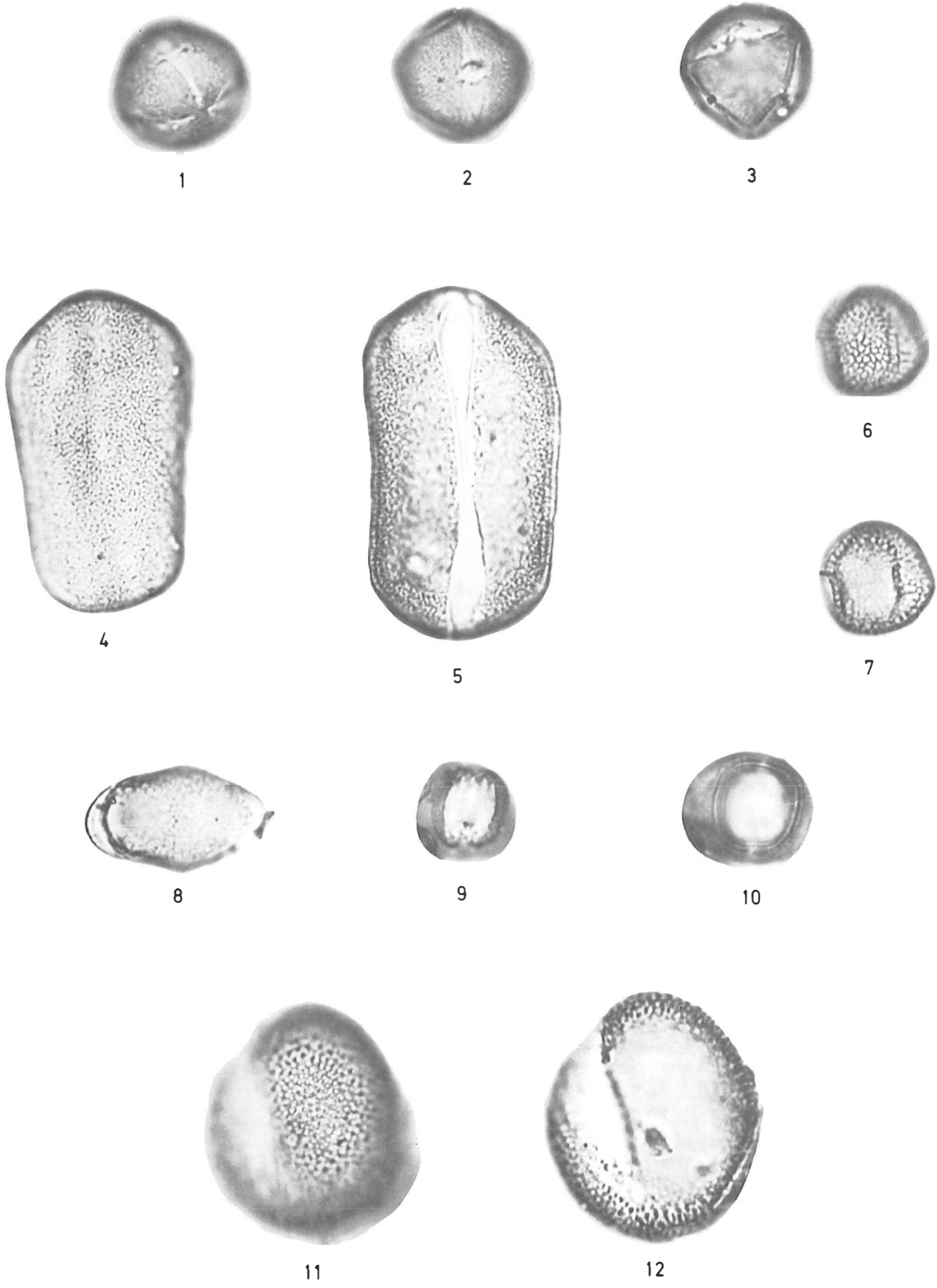
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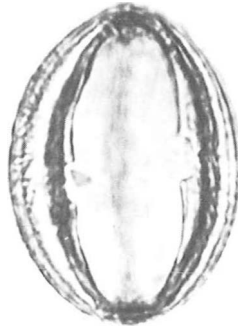


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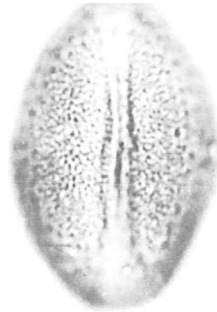
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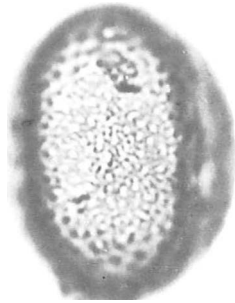
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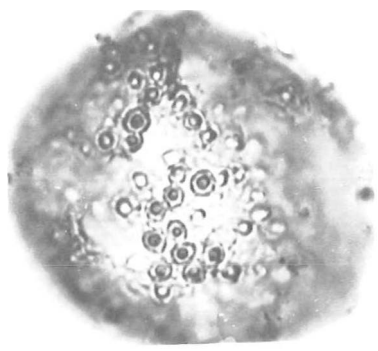
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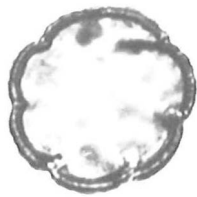
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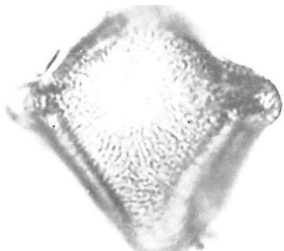
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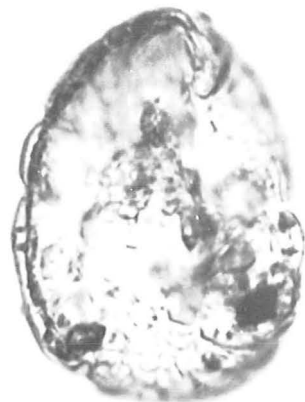
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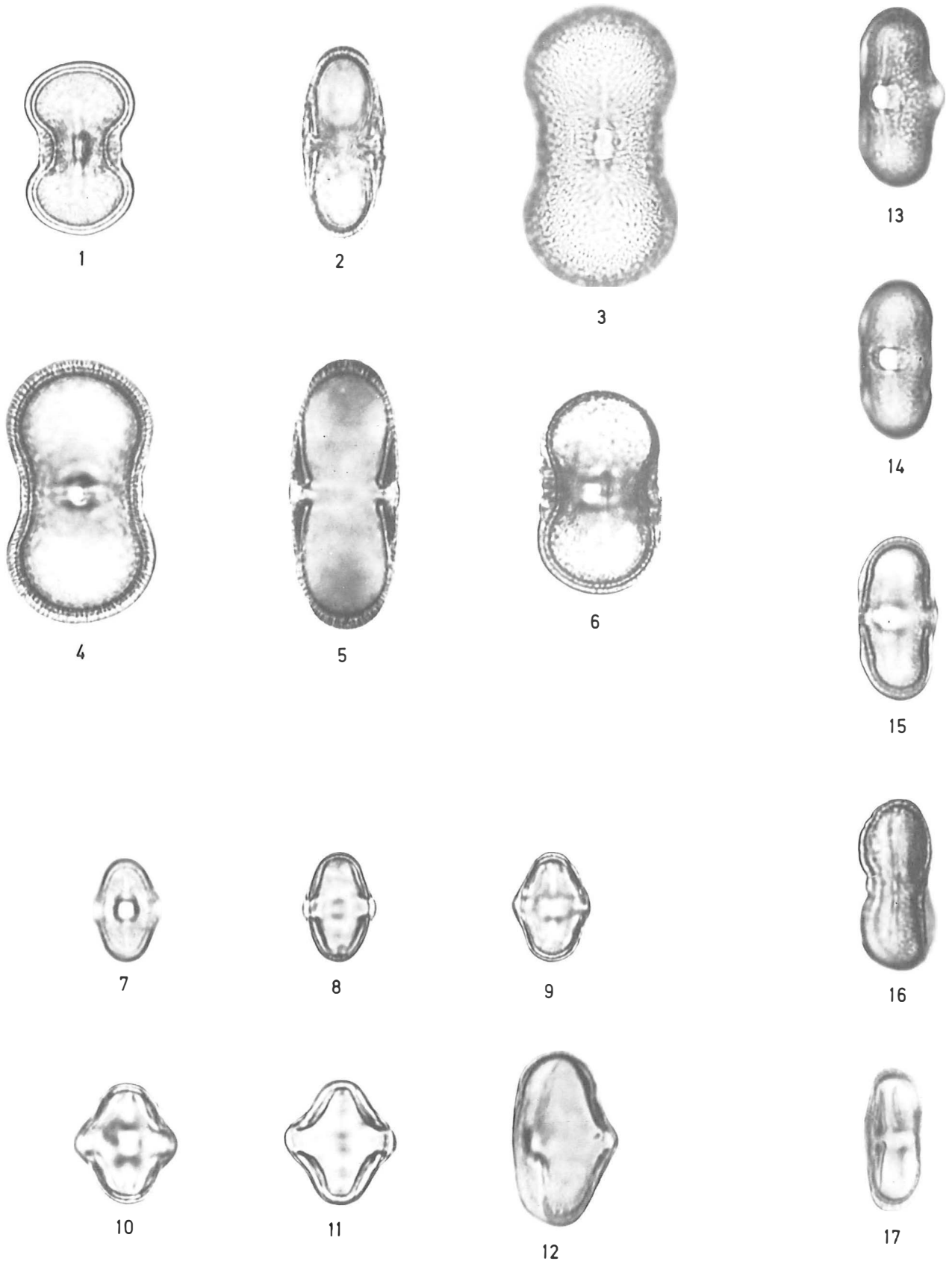
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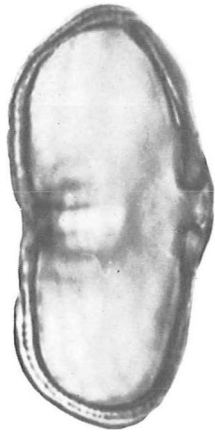


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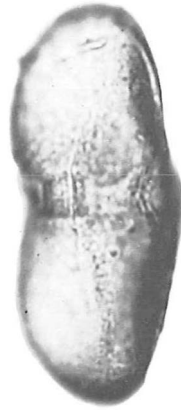




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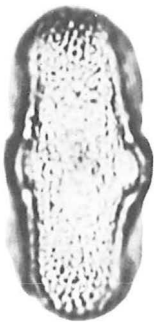
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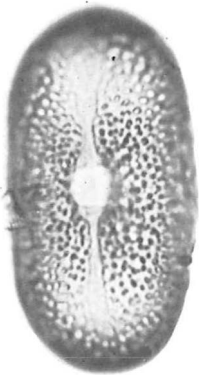
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Fig. 19



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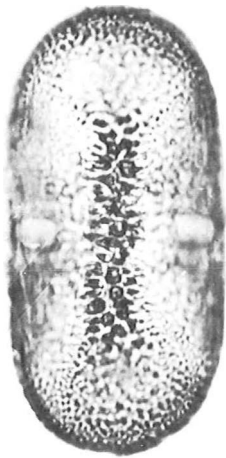
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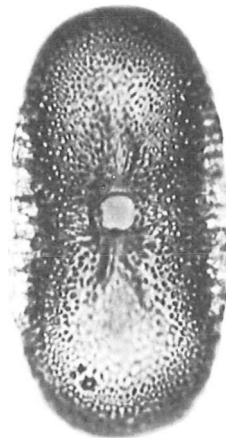
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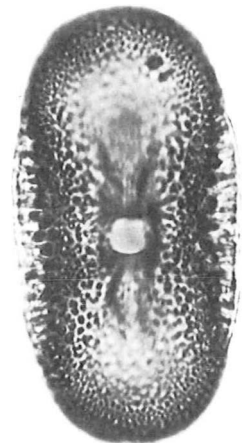
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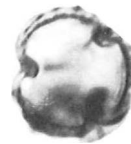
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Astoma, *Bupleurum*, *Physospermum*, *Smirniium*, and *Trachydium* species show this pollen type.

4.41.4. *Eryngium*-type (fig. 19: 1-4)

Subrectangular grains with mostly somewhat pointed poles. Lg/Lt c. 2. Fairly long, narrow colpi. Conspicuous, rectangular pores or transversal furrows. Smooth wall, columellae $< 0.5\mu$. The ektexine, c. 1μ thick, hardly shows differences in thickness in the various parts of the grain. Size 40-48 μ .

This type includes *Eryngium* species and *Sanicula europaea*. In sediment samples, *Eryngium*-type grains appear often somewhat bow-shaped.

4.41.5. *Ferula*-type (fig. 19: 5-9)

This pollen type, which was often found in the Iranian sediment samples, is not very characteristic and, moreover, rather variable. Consequently, a description of this type must remain unsatisfactory.

Subrectangular grains with rounded poles or with one rounded and one somewhat pointed pole. This pollen type has usually an asymmetrical appearance. Lg/Lt c. 2. Long colpi. Colpi transversales are often constricted. Columellae distinct, c. 0.5μ in diameter, often showing a striate pattern. The ektexine is thinnest in the equatorial zone. Size 30-35 μ .

This type includes only *Ferula* species.

4.41.6. *Malabaila*-type (fig. 19: 10-12)

Subrectangular to slightly oval pollen grains with rounded poles. Lg/Lt c. 2. Fairly long colpi. Transversal furrow oval-rectangular. Distinct columellae, 0.5 to 0.8μ in diameter. Slight variations in the wall thickness over the grain; wall up to 2μ thick. Size 35-40 μ .

This type includes: *Malabaila sekakul*, *M. kotschyi*, *Orlaya grandiflora*, *Heracleum maximum*, *H. lasiopetalum*, *H. persicum*, *Ormoscadium aucheri*, *Scandix iberica*, *Stenotaenia nudicaulis*, and *Turgeniopsis foeniculacea*.

4.41.7. *Pimpinella*-type (fig. 20: 1-4)

Subrectangular pollen grains with rounded poles.

Lg/Lt > 2 . Fairly short colpi. Pore square to rectangular (equatorially elongated). Columellae c. 0.5μ . Characteristic of this pollen type are the ridges in the intercolpia. These ridges are particularly pronounced in the interzone (the zone between equatorial and polar zone). In the equatorial zone the ridges are much lower, and in the polar zone they are absent. In polar view rounded-triangular with conspicuous knobs on the edges. Not in all *Pimpinella* species are the ridges equally well pronounced. Size 25-30 μ .

Pimpinella barbata and *Psammogeton crinitum* show this pollen type. In the pollen of *Pimpinella aurea*, *P. eriocarpa*, *P. kotschyana*, *Rentera aurea*, *Daucus persica*, *Falcaria vulgaris*, *Fernago nudiflora*, and *Seseli libanotis* the ridges are less pronounced.

4.41.8. *Sium erectum*-type (fig. 20: 5-6)

Subrectangular to slightly oval pollen grains with rounded or somewhat pointed poles. Lg/Lt 1.8-2.0. Long colpi. Equatorially elongated pore to colpus transversalis. Wall up to 2μ thick. The endexine is thickest in the equatorial area of the intercolpia. The ektexine shows no noticeable variation in thickness. Columellae c. 0.5μ . Size 21-24 μ .

In addition to *Sium erectum*, this pollen type includes various other species, such as *Rhabdosciadium aucheri*, *Sison annuum*, *Trinia glauca*, *Froriepia nuda*, *Apium graveolens*, and *Oliveria decumbens*.

4.41.9. *Turgenia*-type (fig. 20: 7-9)

Subrectangular grains with rounded poles. Lg/Lt 1.8-2. The endexine is constricted in the equatorial area. The colpi are rather short. The pores are rectangular. Characteristic of this type is the extremely thick ektexine, up to 6μ thick, in the intercolpia of the equatorial area, with branched columellae. Columellae in equatorial zone up to 2μ in diameter. At the poles the ektexine is 1-1.5 μ thick. Size 55-65 μ .

In addition to *Turgenia* species, *Lisaea heterocarpa* produces this pollen type.

4.42. Urticaceae

4.42.1. *Urtica pilulifera*

Spheroidal, periporate (6-8 pores) grains. Pores

protruding (suggesting the presence of an annulus). Psilate, tectate; columellae only visible at 1000 X. Size 20-25 μ .

4.43. Valerianaceae

4.43.1. *Valerianella*

Spheroidal, tricolpate grains. Rather short colpi: polar area index c. 0.40. Tectate, perforate. Wall up to 4 μ thick in the intercolpia. Columellae usually c. 0.5 μ in diameter, but some are up to 1 μ broad. *Valerianella* pollen is usually micro-echinate, but in *V. kotschyi* no spines can be observed. Size 35-44 μ .

4.44. Verbenaceae

4.44.1. *Verbena*

Spheroidal to suboblate, heterocolpate grains. Three groups of 3 colpi; the middle colpus of each group with a protruding, equatorially elongated pore or transversal furrow. The edge of the colpi is rather vague. Psilate, tectate wall, c. 2 μ thick. Size 22-30 μ .

4.45. Unidentified type (fig. 17: 9-12)

Pear-shaped grains with three large apertures. Distinct fissures radiate from the apertures, the edge of which is irregular. The tectate, psilate wall resembles that of cyperaceous pollen, but it is coarser. The grains are often ruptured. Size c. 35 μ . This type, which was regularly found in the Zeribar samples, is shown in the diagrams as a separate curve.

5. POLLEN ASSEMBLAGE ZONES

The pollen diagrams are subdivided into a number of zones and subzones. The zoning is based upon changes in the Σ AP/NAP ratios and upon the behaviour of individual curves. The zoning which has been established for the Lake Zeribar diagrams could, to some extent, also be applied to the Mirabad pollen diagram. It will be superfluous to mention that the pollen-diagram zonation presented in this paper is only relevant to the Zeribar and Mirabad diagrams and perhaps to some future diagrams from the Zagros Mountains. It is unlikely

that it will ever be possible to establish a pollen-diagram zonation that is applicable to the Late Quaternary in the whole of the Near East. The development of the vegetation in the various parts of the Near East displays too many differences and too few comparable features (see chapter 8).

5.1. Lake Zeribar diagrams (figs. 22, 23, 24)

5.1.1. *Pollen assemblage zones 1-4*

In zones 1 to 4 the share of trees and shrubs in the pollen record is so low that changes in the Σ AP/NAP ratios can hardly be used in distinguishing between zones. Consequently, the distinction between zones 1 to 4 is based mainly upon changes in the percentages of individual pollen types. The quantitatively most important pollen types in zones 1-4 are *Artemisia*, Chenopodiaceae, Umbelliferae (in particular *Ferula*-type), and Gramineae. The other herbaceous pollen types, which occur in low percentages and often discontinuously, do not play a part in defining pollen zones 1 to 4. This does not, of course, imply that these types are of no importance for the reconstruction of the former vegetation.

5.1.1.1. *Zone 1 (Zer. Ia, spectra 1-13)*

From the bottom to the top of the zone *Quercus* decreases gradually from c. 5 to c. 1%. *Atriplex*-type, on the other hand, increases from c. 20 to c. 38%. *Pistacia* and *Acer* are discontinuously represented. For the bottom of the zone a radiocarbon date of 42,600 \pm $\frac{3600}{-2500}$ B.P. was obtained (3.1.5.).

5.1.1.2. *Zone 2 (Zer. Ia, spectra 14-26)*

This zone shows fluctuating *Quercus* pollen values. It is striking that the low *Quercus* maxima coincide with minima in the curve for *Atriplex*-type. *Pistacia* pollen was found in the majority of the samples of this zone, with values of up to 1%. *Acer* is comparatively well represented (in 9 of the 13 spectra). On the basis of the *Quercus* values this zone is subdivided into three subzones; in subzone 2b *Quercus* pollen values are on the average lower than in subzones 2a and 2c. It must be admitted that one could wonder whether the *Quercus* fluctuations are enough to justify a subdivision of zone 2. The level at a depth 34.15-34.30 m is radiocarbon

dated to $37,350 \pm 1250$ B.P. For the lower and upper zone boundaries dates of c. 39,300 and 33,500 B.P., respectively, were calculated.

5.1.1.3. *Zone 3 (Zer. Ia, spectra 27-58; Zer. Ib, spectra 61-87; Zer. II, spectra 1-8)*

This zone is characterized by extremely low tree pollen percentages. Of the whole diagram, *Hippophaë* is best represented in zone 3, although in very low percentages and discontinuously. For the level just under the zone 3/4 boundary a radiocarbon date of 13,650 B.P. was obtained (18.90-19.00 m). The corresponding level in the Zeribar I-12 diagram (van Zeist & Wright 1963) was dated to 14,800 B.P. Consequently, a date of c. 14,000 B.P. may be assumed for the zone 3/4 transition. The lower boundary of zone 3 has an interpolated date of c. 33,500 B.P. (5.1.1.2).

In the Zer. Ib diagram, the zone 3/4 boundary is placed at a depth of c. 18.80 m. In the Zer. Ia diagram, a marked decrease in *Artemisia* values takes place between spectra 58 and 59, that is between 19.00 and 18.45 m. This implies that in both diagrams the zone 3/4 transition is found at approximately the same depth. As the 1970-A core was taken close to the 1963-J core this good correspondence is not surprising. It should be mentioned here that the fairly large sample distance in the upper part of the Zer. Ia diagram is due to the fact that this section was examined only to establish the correlation between both Zer. I diagrams.

Zone 3 in the Zer. Ib diagram corresponds with zone A-1 in the Zeribar 63-J diagram of van Zeist (1967).

Attempts to subdivide zone 3, which embraces a period of c. 19,500 years, on the basis of the herb pollen failed because no consistent changes in the curves for herbaceous pollen types can be observed. Thus, the course of the *Ferula* curve in the Zer. Ib diagram, with comparatively high values in spectra 70-80, is not matched by the *Ferula* curve in the Zer. Ia diagram.

5.1.1.4. *Zone 4 (Zer. Ia, spectra 59-59b; Zer. Ib, spectra 88-97; Zer. II, spectra 9-13)*

Quercus percentages are not significantly higher than in zone 3, but *Pistacia* is again somewhat better represented. At the base of the zone a conspicuous decline in *Artemisia* is observed, but the

chenopodiaceous pollen values remain at the same level as in zone 3. This zone corresponds with zone A-2 in the Zeribar 63-J diagram (van Zeist 1967).

In the Zer. II diagram, the level of 13.60-13.75 m, just below the zone 4/5 contact at c. 13,60 m, is radiocarbon dated to $10,600 \pm 100$ B.P. In the Zer. Ib diagram, this zone boundary (at c. 16.25 m) has an interpolated date of c. 10,480 B.P. Consequently, a date of c. 10,500 B.P. may be assumed for the zone 4/5 boundary.

5.1.2. *Pollen assemblage zone 5 (Zer. Ib, spectra 98-111; Zer. II, spectra 14-29)*

In pollen zone 5, Σ AP percentages show a gradual increase, in which *Quercus* as well as *Pistacia* take part. In the upper spectra of the zone *Fraxinus* shows the highest percentages of the whole diagram. The high *Salix* pollen values in spectra 110 and 111 of the Zer. Ib diagram are due to a local expansion of willow (in these spectra *Salix* is left out of the pollen sum). In the corresponding spectra of the Zer. II diagram the *Salix* percentages remain fairly low.

The beginning of zone 5 is marked by a drastic decline in Chenopodiaceae and by a further decrease in *Artemisia*. On the other hand, the graminaceous pollen percentages increase strongly at the zone 4/5 transition. From the base of the zone on, *Plantago maritima*-type pollen has relatively high percentages. Pollen assemblage zone 5 is further characterized by the fairly frequent occurrence of *Rheum* and *Anisosciadium*-type pollen; only in this zone do these pollen types have continuous curves.

In the Zer. II diagram, the *Quercus* curve shows a small but distinct maximum in spectra 26 and 27. A similar maximum cannot be observed in the Zer. Ib diagram. It may be thought that spectra 108-110 in Zer. Ib correspond with spectra 26 and 27 in Zer. II, but this assumption is not supported by the *Fraxinus* curve. The *Fraxinus*-pollen maxima in both diagrams suggest a synchronicity of spectrum 29 in Zer. II and spectrum 110 in Zer. Ib. Unlike willow, ash cannot have found suitable habitats on the lake shore, so that the *Fraxinus* pollen must have originated from trees at some distance from the lake. The *Fraxinus*-pollen curve is not the reflection of strictly local conditions, and, consequently, it seems justified to synchronize the ash

pollen maxima in spectra 29 and 110 of Zer. II and Zer. Ib respectively. From the above one must arrive at the conclusion that the *Quercus* maximum in spectra 26 and 27 of Zer. II is absent in Zer. Ib, which is possibly the result of a hiatus in the Zer. Ib core. It should be remembered that the Zer. II diagram is less likely to reflect local changes in the vegetation than the Zer. I diagram.

On the basis of the *Quercus* curve, pollen assemblage zone 5 of the Zer. II diagram is subdivided into 3 subzones: 5a (spectra 14-25), 5b (spectra 26 and 27), and 5c (spectra 28 and 29).

On account of the radiocarbon measurements carried out for the levels at 11.00-11.15 and 9.78-9.93 m of the Zer. II core, the end of zone 5 (at 10.40 m) must be dated to c. 6,200 B.P. Zone 5 corresponds with zone B in the Zeribar 63-J diagram (van Zeist 1967).

5.1.3. Pollen assemblage zone 6 (Zer. Ib, spectra 112-115; Zer. II, spectra 30-34. 38-39)

This zone is characterized by a strong increase in Σ AP percentages, which is completely brought about by *Quercus*. *Pistacia* values are still relatively high in the lower part of the zone, but they decrease thereafter. *Fraxinus* shows a continuous curve in this zone. The decrease in herbaceous percentages involves Gramineae as well as Chenopodiaceae and *Artemisia*.

After the Zer. II diagram had been completed and drawn, some uncertainty concerning the correlation between the upper (1963-B core) and lower (1970-B core) part of the diagram arose. In an attempt to elucidate this difficulty, a few more samples above the level of sample 37 were examined for the 1970-B core. In fig. 25 the main diagrams are shown for the upper part of the 1970-B core, including the additional spectra 37a and 37b, and for the lower part of the 1963-B core. From this figure it is clear that the *Quercus* maximum in spectra 35-37 must correspond with the high oak pollen values in spectra 40 and 41. The subsequent decline in the *Quercus* curve is also present in both diagram sections. The increase in oak pollen values in the lower part of the 1963-B core should correspond with the upper part of zone 6 in the 1970-B core. The above implies that the diagrams obtained for the 1970-B and 1963-B cores show a slight over-

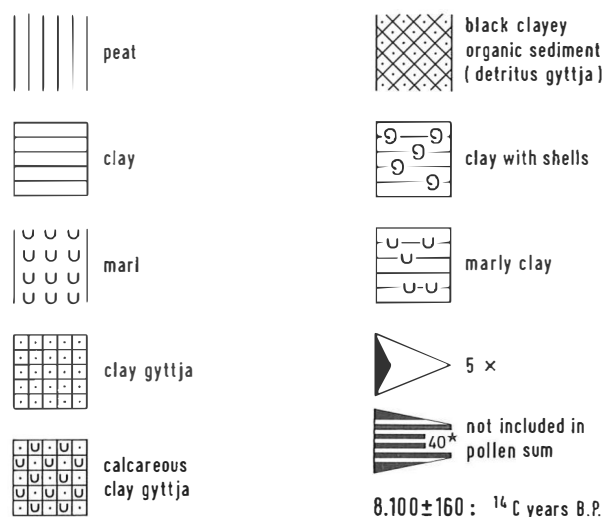


Fig. 21. Key to the pollen diagrams.

lap. As for the differences in the *Quercus* percentages, one should take into consideration that these cores were taken at some distance from each other (cf. 3.1.4.2.).

Extrapolation of the radiocarbon dates of 6,890 and 5,640 B.P. obtained for the levels at 11.00-11.15 m and 9.78-9.93 m respectively in the 1970-B core results in a date of c. 5,400 B.P. for the zone 6/7 boundary at c. 9.60 m. This inferred date is corroborated by the radiocarbon date of $5,460 \pm 120$ B.P. obtained for the approximately corresponding level in the Zeribar I-13 diagram (van Zeist & Wright 1963).

5.1.4. Pollen assemblage zone 7 (Zer. Ib, spectra 116-139; Zer. II, spectra 35-37, 40-61)

Pollen zone 7 is characterized by high *Quercus* percentages, whereas the values for Chenopodiaceae and *Artemisia* remain relatively low. *Pistacia* has a nearly continuous curve with values of up to 2.5%. This zone is subdivided into three subzones:

Subzone 7a (Zer. Ib, spectra 116-120; Zer. II, spectra 35-37, 40-41). In this subzone *Quercus* shows the highest percentages of the whole diagram, at least in Zer. Ib. In the Zer. II diagram the situation is less clear (see 5.1.3.).

Subzone 7b (Zer. Ib, spectra 121-129; Zer. II, spectra 42-48). *Quercus* values are somewhat lower than in subzone 7a. In the Zer. II diagram the oak pollen

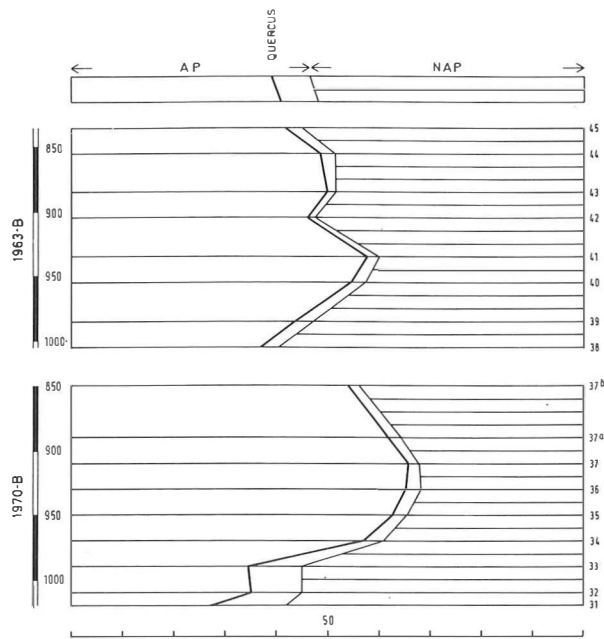


Fig. 25. Main diagrams for the upper part of the 1970-B core and the lower part of the 1963-B core (see 5.1.3.).

percentages do not fluctuate markedly. For that reason the conspicuous *Quercus* minimum in subzone 7b of the Zer. Ib diagram and the accompanying maximum in "other herbs" must probably be ascribed to local conditions.

Subzone 7c (Zer. Ib, spectra 130-139; Zer. II, spectra 49-61). This subzone is distinguished from subzone 7b by the continuous curve for *Plantago lanceolata*-type pollen, with values of up to 4%, and by the presence of *Juglans*. The lower *Quercus* values in the lower part of subzone 7c of the Zer. Ib diagram are caused by the high gramineous percentages in this section. The latter are due to a local expansion of grasses (peat!). In the Zer. II diagram a similar oak pollen minimum is not present. On the basis of the ¹⁴C date of 2,240 B.P. for the level at 7.00-7.10 m in the Zer. II diagram (63-B) and of the inferred date of c. 5,400 B.P. for the zone 6/7 boundary, a date of c. 2,700 B.P. was calculated for the subzone 7b/7c transition.

It should be mentioned that the top of the Zer. Ib core is not present-day; the floating vegetation mat, from which the coring was carried out (3.1.4.1.), was not sampled. The top of the Zer. II diagram, on the other hand, approaches more the present time, although it should be taken into con-

sideration that the very watery sediment above the more solid marly clay gyttja could not be cored.

5.2. Lake Mirabad diagram (fig. 26)

5.2.1. Pollen assemblage zone 5 (spectra 1-10)

The lower part of the Mirabad diagram compares well with zone 5 of the Zeribar diagrams, although there are differences, mainly of a quantitative nature. Oak pollen percentages gradually increase from the bottom upwards. *Pistacia* values show some fluctuations, but remain at about the same level. Chenopodiaceous pollen values (c. 50%) are distinctly higher than those in the corresponding zone of the Zeribar diagrams (20-25%), but *Artemisia* percentages are somewhat lower.

As at Zeribar, *Plantago maritima*-type pollen shows relatively high percentages in zone 5. The same is true for the *Anisosciadium*-type pollen, but, on the other hand, *Rhenm* is hardly represented in the Mirabad diagram. Gramineae, which are not included in the pollen sum, show high percentages in the lower part of the Mirabad diagram. Similarly high grass pollen values were obtained for zone 5 at Zeribar. The extremely large numbers of grass pollen counted in samples 1, 3, and 4 must in part have been of local origin (see 7.2.1.).

The bottom of zone 5 is radiocarbon dated to 10,370 ± 200 B.P. (3.2.3.).

5.2.2. Pollen assemblage zone 6 (spectra 11 and 12)

At Zeribar, zone 5 shows a gradual increase in tree pollen values, whereas a strong rise in the *Quercus* curve is characteristic of zone 6. At Mirabad, a similar strong rise in the oak pollen curve cannot be observed, but this is mainly due to the greater vertical (depth) scale in the latter diagram. The final rise in the oak pollen curve takes place between spectra 10 and 13, and consequently the lower and upper limits of zone 6 are laid between spectra 10 and 11 and 12 and 13 respectively. The zone 6/7 limit is further characterized by a marked decline in Chenopodiaceae.

5.2.3. Pollen assemblage zone 7 (spectra 13-39)

Pollen zone 7 is characterized by high *Quercus* pol-

len percentages. *Pistacia* shows relatively high values. This zone is subdivided into three subzones:

Subzone 7a (spectra 13-18). This subzone shows the highest oak pollen percentages of the whole diagram. The conspicuous minimum in the *Quercus* curve at spectrum 16 is caused by high pollen values for various Compositae taxa which must have expanded on the dried-out lake bottom (see 7.2.2.1.). Because of the near-absence of pollen in the section between spectra 16 and 17 no intermediate samples could be analysed.

Subzone 7b (spectra 19-31). *Quercus* is somewhat lower than in subzone 7a. In subzone 7b, *Plantago maritima*-type reaches the highest values of the Mirabad diagram. *Artemisia herba-alba*-type, too, shows relatively high percentages in this subzone.

Subzone 7c (spectra 32-39). This subzone is characterized by high *Plantago lanceolata*-type percentages (up to 18%) and by lower *Quercus* pollen values. Gramineae show high pollen values in this subzone, but the majority of the grass pollen is probably of local origin (cf. 7.2.2.3.).

In the section between spectra 31 and 32 hardly any pollen was preserved, very probably as a result of a drying out of the lake.

5.2.4. Correlation of Mirabad and Zeribar diagrams

The ¹⁴C date of 10,370 B.P. obtained for the bottom of zone 5 at Mirabad is in agreement with the date of c. 10,500 B.P. established for the zone 4/5 boundary at Zeribar. The further correlation between the diagrams of both sites is entirely based upon pollen-floristic features. One should consider the possibility that corresponding pollen assemblage zones in the Mirabad and Zeribar diagrams may not be wholly synchronous.

6. PLENIGLACIAL AND LATE-GLACIAL

6.1. The nature of the steppe and desert-steppe vegetations

Pollen assemblage zones 1 to 4 reflect vegetation patterns in which trees either played only an insignificant part or did not occur at all. Quantitatively important pollen taxa in zones 1-4 are *Artemisia*, Chenopodiaceae, and Umbelliferae. One would assume that these taxa played an impor-

tant part in the vegetation of the Zeribar area in Pleniglacial and Late-glacial times. In addition to *Artemisia*, Chenopodiaceae, and Umbelliferae, various other plant taxa must have been present in the Pleniglacial and Late-glacial vegetation. These taxa will shortly be reviewed after the discussion of *Artemisia*, Chenopodiaceae, and Umbelliferae.

6.1.1. *Artemisia*

The high *Artemisia* pollen percentages were to be expected. The great majority of the *Artemisia* pollen is of the *herba-alba*-type. *A. herba-alba* is a common, often a dominant species in the steppe and desert-steppe vegetation of the interior plateau of Iran (Zohary 1963). This species is also widespread in the open vegetation of the mountains of Central Asia. *A. fragrans*, which has pollen of the *herba-alba*-type, is the most common *Artemisia* species in the high plateau steppes of northwestern Iran (Azerbeidjan) and Anatolia. Of the latter vegetation *A. austriaca* also seems to be a common constituent. For the desert-steppe vegetation of Afghanistan, *A. scoparia* is reported in addition to *A. cf. herba-alba* (Freitag 1971). Both *A. scoparia* and *A. austriaca* have pollen of the *herba-alba*-type.

6.1.2. Umbelliferae

A conspicuous feature of the Lake Zeribar pollen record are the high umbelliferous percentages. In the Pleniglacial section of other pollen diagrams from the Eastern Mediterranean area, umbelliferous pollen occurs only in low percentages. The high umbelliferous pollen percentages are unique for Zeribar.

Common among the umbelliferous pollen in the Zeribar cores is the *Ferula*-type, which is produced by representatives of the genus *Ferula*. The *Turgenia*-type includes species of *Turgenia* and *Lisaea heterocarpa*. *Eryngium*-type pollen is not only produced by species of *Eryngium* but also by *Sanicula europaea*. *Bupleurum*-type pollen can have originated from *Bupleurum* species, *Smyrniium* species, *Physospermum aquilegifolium*, *tiaricum*. *Bunium*-type pollen is not particularly characteristic and is found in a greater number of genera. For that reason this pollen type is of little value for a more detailed analysis of the former

vegetation. Moreover, *Bunium*-like pollen was often classified among unidentified Umbelliferae. In addition to species of *Pimpinella*, the *Pimpinella*-type includes *Psammogeton crinitum*, *Renteria aurea*, *Daucus persica*, *Seseli libanotis*, and a few more species in the pollen reference collection of the Biologisch-Archaeologisch Instituut. From the above it is clear that umbelliferous pollen in the Zeribar cores cannot be identified to the species level, but that at least the presence of various genera, such as *Ferula*, *Turgenia*, *Eryngium*, *Bupleurum*, *Pimpinella*, *Malabaila* and *Anisosciadium* | *Echinophora*, is likely in the Würmglacial vegetation of the Zeribar area.

From the umbelliferous pollen study one may conclude that most of the pollen of this family counted in the Zeribar cores originated from upland vegetation. In the present-day marsh vegetation around the lake one umbelliferous species, *Sium erectum*, has been observed by W. van Zeist (3.1.2.). Pollen that could have been produced by *Sium erectum* was only counted in samples 1-4 and 7 of the Zeribar II core.

The conclusion that nearly all umbelliferous pollen in the Zeribar cores must have been of upland origin constitutes a problem. Umbelliferae are insect-pollinated and consequently under-represented in the pollen precipitation. It is unlikely that the large numbers of umbelliferous pollen in the Pleniglacial section of the Lake Zeribar cores were brought in through the air, in other words that these grains formed part of the pollen precipitation on the lake. One must assume that the majority of the umbelliferous pollen was washed in from the slopes. In this connection it must be borne in mind that withered flowers dropping on the surface may result in locally large quantities of pollen. Consequently, pollen of insect-pollinated species, only small numbers of which are released in the air, may be very common on the soil surface in the immediate vicinity of the plants concerned. The same applies to self-pollinated species. As a matter of fact, also in wind-pollinated species a considerable proportion of the pollen may never be released from the anthers and may eventually drop on the surface with the withered flowers (*cf.* Rempe 1937).

Most of the silt in the Lake Zeribar sediment must have been washed in from the surrounding slopes. To the present day, intermittent streams car-

ry sediment into the valley, forming alluvial fans. The erosion of the slopes caused a downward transport not only of topsoil but also of the pollen on the soil surface. In this way the large quantities of umbelliferous pollen could have been carried into the lake. It is clear that not only umbelliferous pollen, but also the pollen of other plants from the slope vegetation may have been carried into the lake by the water.

6.1.3. *Chenopodiaceae*

The high chenopodiaceous pollen values in the Pleniglacial and Late-glacial sections of the Zeribar diagrams give rise to the question as to how much of this pollen was of local and how much of regional origin. In this connection it should be mentioned that not only the Zeribar diagrams but also other pollen diagrams from the Eastern Mediterranean area show high chenopod pollen percentages in Pleniglacial and Late-glacial sections (*cf.* fig. 29). It is difficult to imagine that in all these sites *Chenopodiaceae* expanded only locally in the vicinity of the lakes and marshes concerned. One may safely assume that *Chenopodiaceae* played a rather important part in the Würm-glacial upland vegetation of the Eastern Mediterranean area.

On the other hand, one should consider the possibility that some of the chenopod pollen in the Zeribar cores was of local origin. Thus, anomalously high chenopodiaceous pollen values in sediment cores from southwestern Turkey are attributed to the expansion of representatives of this family on temporarily exposed lake bottoms (van Zeist *et al.* 1975). In this case the high chenopod pollen percentages are accompanied with high values for *Centaurea solstitialis*-type, *Liguliflorae* Compositae, and unidentified *Tubuliflorae* Compositae. These high Compositae pollen percentages point to a local expansion of the taxa concerned. In this connection it should be remembered that the species that produce these pollen types are insect-pollinated and are poorly represented in the regional pollen precipitation. The generally rather poor pollen preservation in sediment samples with high values for the Compositae pollen types mentioned above is considered as an indication of an intermittent drying out of the sediment.

In the Lake Zeribar cores, the high chenopod

pollen values are not accompanied with high percentages for Liguliflorae Compositae and Tubuliflorae Compositae other than *Artemisia*. Moreover, the pollen preservation in the sections with high chenopodiaceous percentages is generally good. There are no palynological indications that at Zeribar Chenopodiaceae and Compositae expanded on temporarily exposed lake bottoms.

The above does not imply that chenopods would never have played an important part in the local vegetation in the vicinity of the lake. The diatom analysis has demonstrated that under certain circumstances the salinity of the lake must have increased. K. Wasylik (*cf.* Wasylikowa 1967) the diatom species *Campylodiscus clypeus*, which is an indicator of brackish conditions, in the section between 19 and 16.50 m of the Zeribar Ib core. Below (down to 25 m) and above this section the diatoms point to fresh-water conditions. The above-mentioned increase in salinity of the lake water is ascribed to a lowering of the lake level. One can imagine that during periods of low water levels – as a result of less precipitation and/or higher evaporation – the outlet of the lake to the southeast (3.1.1., fig. 6) did not function, so that a closed basin came into existence. In the undrained lake the salinity increased because the salts were not discharged.

It should be noted that the section between c. 20 and 16.50 m in Zer. Ib, for which very high chenopodiaceous pollen percentages were established, coincides largely with the zone in which mesohalobious diatoms were found. Because of the salinity of the water, halophytic vegetation may have been present on or near the lake shore, resulting in a greater proportion of Chenopodiaceae in the pollen precipitation on the lake. In this connection it should also be mentioned that Wasylikowa (1967) found considerable numbers of chenopod seeds at c. 16.75 m and between 18.50 and 20 m, suggesting that Chenopodiaceae had spread on the lake shore. On the other hand, chenopod seeds were also abundant in the section 13–15.50 m, where chenopodiaceous pollen values are not conspicuously high.

The above indicates that at least some of the chenopodiaceous pollen in the Zeribar pollen diagrams may be of local origin. The majority of this pollen type, however, must have originated from

plants in the upland vegetation. For that reason some attention will be paid to the role of Chenopodiaceae in upland vegetation.

The question arises to what extent the high chenopodiaceous pollen percentages indicate brackish soil conditions in the uplands of the Zeribar area. According to Zohary (1963, p. 44), on the Iranian Central Plateau poorly drained flats are inhabited by halophytic vegetation, the well-drained areas by *Artemisia* steppe and desert-steppe (see 2.4.3.). Did a similar vegetation pattern perhaps also exist in the Zeribar area in Pleniglacial and Late-glacial times? In this connection it should be pointed out that Chenopodiaceae are not confined to saline habitats, but that various species of this family form part of the vegetation of non-saline environments. Thus, for the *Artemisia* steppe and desert-steppe of the Central Plateau of Iran the following chenopodiaceous species are reported by Zohary (1963, pp. 46–49; 1973, pp. 487–490): *Aellenia auricula*, *A. glauca*, *Cornulaca leucantha*, *C. monacantha*, *Haloxylon aphyllum*, *H. griffithii*, *Noaea mucronata*, *Salsola aurantiaca*, *S. incanescens*, and *S. vermiculata*. *Aellenia*-type pollen and *Noaea*-type pollen (which includes *Cornulaca*) can be distinguished (5.7.1., 5.7.4.) and they are shown as separate curves in the diagrams. H. Freitag informed the authors that according to his experience Chenopodiaceae play a very important part in the present-day desert-steppe of Iran.

6.1.4. Gramineae

It is difficult to estimate the possible role of grasses in the Pleniglacial and Late-glacial vegetation. Very probably, some of the gramineous pollen originated from grasses that formed part of the marsh vegetation belt along the lake. At least, the continuous curves for Cyperaceae and *Sparganium*-type suggest that marsh vegetations must always have been present at the edge of the lake. The high values for Cyperaceae, *Sparganium*-type, and *Dryopteris* in pollen zone 1 indicate that at that time marsh vegetation was not too far away from the locality of the Zeribar Ia core.

Cerealia-type pollen shows a nearly continuous curve in zones 1 to 4, with values of up to 5% (in zone 1). As has already been discussed elsewhere (van Zeist *et al.* 1975, p. 117) various Near Eastern

wild grasses produce Cerealia-type pollen. This pollen type is distinguished from that of other grasses by its size (at least 40μ in silicone-oil-mounted slides), the thickness of its wall, and the pronounced annulus.

In view of the comparatively low gramineous pollen values in zones 1 to 3 one must assume that grasses played a rather modest part in the Pleniglacial vegetation. The higher grass pollen percentages in zone 4 of the Zeribar Ib diagram are probably not due to an increase of grasses in the upland vegetation but to a local expansion. This must be concluded from the fact that the corresponding zone of the Zeribar II diagram does not show a rise in the gramineous pollen curve. Consequently, during zone 4 time, too, grasses would not have been very prominent in the upland vegetation.

6.1.5. *Other herbs*

In addition to *Artemisia*, various other Compositae taxa were present in the vegetation of zones 1-4. *Centaurea solstitialis*-type includes a great number of *Centaurea* species which are mostly found in disturbed habitats, such as fields and road-sides, but which originally must have formed part of steppe vegetation. *Matricaria*-type pollen includes *Achillea* and *Antbemis*, which are both common steppe plant genera. More than 350 *Cousinia* species are distinguished in Iran and adjacent areas by Rechinger (1972). Other Compositae genera represented in zones 1-4 include *Senecio*, *Jurinea*, and *Gundelia*. As for the evaluation of the possible role of Compositae other than *Artemisia* in the Pleniglacial and Late-glacial vegetation, one should take into consideration that these taxa are insect-pollinated. On the other hand, it has been suggested above (6.1.2.) that the majority of the umbelliferous pollen may have been washed into the lake. If this hypothesis is correct, a large proportion of the pollen of Compositae (and other taxa too) may in the same way have arrived in the lake, and subsequently in the sediment. Although nothing can be said on the proportion of insect-pollinated Compositae in the Pleniglacial and Late-glacial vegetation, one can safely state that a great variety of species of this family formed part of it.

As for the *Calligonum/Pteropryrum* pollen, the fol-

lowing should be remarked. *Calligonum comosum* is limited to sandy flats and sand dunes (Zohary 1973, p. 391). Other *Calligonum* species seem likewise to be bound to sandy habitats. It is not likely that at the time sand dunes or sandy flats were found in the Lake Zeribar area. *Pteropryrum aucheri* and *P. olivieri*, on the other hand, are reported for *Artemisia* steppe vegetation in Central Iran (Zohary 1973, pp. 487-489). For that reason it seems most likely that the *Calligonum/Pteropryrum* pollen in the Zeribar diagrams originates from *Pteropryrum*.

Ephedra species were likewise present in the Würm-glacial vegetation of the Zeribar area. *Ephedra* is particularly represented in steppe and desert-steppe vegetation. *E. ciliata*, *E. intermedia*, and *E. procera* are widespread in Iran and Afghanistan. Of these species, *E. ciliata* has pollen of the *fragilis*-type, whereas *E. intermedia* and *E. procera* pollen is of the *distachya*-type (5.17.1.).

Cruciferae, in particular *Brassica*-type, show rather high values. A great number of Cruciferae is found in steppe and desert-steppe vegetation. *Matthiola*, which is common in lowland steppes, is scarcely represented in the Zeribar diagrams.

Thalictrum (most probably *Th. isopyroides*) is rather well represented; Caryophyllaceae include various genera, such as *Arenaria*, *Dianthus*, and *Silene*, which are common in steppe vegetation. Of the other taxa that would have occurred in the Pleniglacial and Late-glacial vegetation, *Bongardia (chrysogonum)*, *Euphorbia*, *Linum*, *Leontice (leontopetalum)*, *Campanula*, *Asperula*, and *Papaver* should be mentioned.

Helianthemum pollen is conspicuously absent in the Zeribar cores. In the Pleniglacial section of the diagram of Karamik Batakliği in southwest Anatolia, this pollen type shows a continuous curve, with values of up to 1% (van Zeist *et al.* 1975). From the absence of *Helianthemum* pollen in Zeribar one must conclude that this genus was not found in the Pleniglacial and Late-glacial vegetation of western Iran.

The genus *Plantago* is scarcely represented in pollen zones 1-4. Of *Plantago major/media*, only in two samples one grain was found. The other *Plantago* pollen types distinguished in this study are somewhat better represented, but always in low percentages and discontinuously.

From the above it will be clear that the

Pleniglacial and Late-glacial vegetation that covered the uplands of the Lake Zeribar area must have been fairly rich in species. Most of these species must have been of minor importance from a quantitative point of view. *Artemisia*, Chenopodiaceae, and Umbelliferae must have constituted the predominant taxa.

6.1.6. *Modern analogues of the Pleniglacial vegetation*

In interpreting the results of the palynological examination one is inclined to look for modern vegetations which would match more or less closely the former vegetation. If it is possible to find the modern analogue of a past vegetation, more detailed conclusions on the former environmental conditions can be drawn than is possible on the basis of the individual plant taxa only. As long as one is dealing with vegetations from not too long ago, there is a fair chance that modern analogues exist. Where are vegetations which compare with the Pleniglacial vegetation of the Zeribar area to be found?

The fact that zones 1 to 3 date from the Pleniglacial implies that it was then considerably colder than nowadays. Consequently, the present-day lowland steppes of Mesopotamia do not come into consideration for a comparison with the Pleniglacial vegetation of the Zeribar area. The pollen record, too, resists such a comparison. The surface-sample spectra from western Iran (Wright *et al.* 1967) show high *Plantago* values for the warm lowland steppe. As has been mentioned above, *Plantago* pollen has very low values in the Pleniglacial section of the Zeribar diagrams. Because of the equally low *Plantago* percentages in the surface-sample spectra from the high plateau steppe in the Tabriz area of northwestern Iran, Wright *et al.* (1967) and van Zeist (1967) suggested that the latter vegetation could correspond with the Pleniglacial *Artemisia* steppe of the Zeribar area. However, in the steppe vegetation of the high plateaus in northwestern Iran and eastern Turkey, Umbelliferae do not play a quantitatively important part and Chenopodiaceae are only common in saline environments, such as on the shores of Lake Urmia. Because of the relatively small proportion of Umbelliferae the *Artemisia* steppe and desert-steppe of the high plateau of Central Iran are no

satisfactory match for the Pleniglacial vegetation either.

Present-day vegetation that may compare with the Pleniglacial vegetation of the Zeribar area, is found in Afghanistan. For Northwest Afghanistan, Freitag (1971) reports desert-steppe vegetation in which *Artemisia* as well as Umbelliferae (*Ferula asafoetida*, *F. badrakema*, *Dorema aitchisonii*) and Chenopodiaceae (*Salsola arbuscula*, *S. subaphylla*, *Eurotia ewersmanniana*) play an important part on non-saline soils. The annual precipitation amounts to 100-150 mm, and the winters are fairly long and cold. The Pleniglacial vegetation of the Zeribar area may have been somewhat less like desert-steppe than the present-day *Artemisia*-Chenopodiaceae-Umbelliferae vegetation of Afghanistan, the ground cover of which is at most 30%. It is doubtful whether, during zone 3 time, precipitation in the Zeribar area could have been as low as 100-150 mm, which is only 1/4 to 1/6 of the estimated present-day 600-800 mm. It should be mentioned here that Freitag (1977) arrives at a different conclusion concerning modern analogues of the Pleniglacial vegetation of the Zeribar area.

6.2. Pleniglacial and Late-glacial vegetations

6.2.1. *Pollen assemblage zone 1*

The relatively high *Quercus* pollen values in the lower part of zone 1, up to 5%, suggest that at that time oak was present in the Zeribar area. *Acer* and *Pistacia*, which are both under-represented in the pollen precipitation (*cf.* 7.1.3.2.), must likewise have been found there during zone 1 time. The pollen of the other trees represented in zone 1, namely *Pinus*, *Fraxinus*, *Cedrus*, *Ulmus*, *Ahns*, *Carpinus*, *Ostrya*|*Carpinus orientalis*, *Betula*, and *Fagus*, must have arrived from a great distance. Most of these trees probably formed part of forests on the north-facing slopes of the Elburz Mountains and in the mountains south of the Black Sea. It is likely that some tree pollen (*e.g.* *Cedrus*) was carried in from West Syria and Lebanon or Southwest and South-Central Turkey. On the other hand, one may assume that *Tamarix*, *Hippophaë*, and *Salix* did occur in the area. These shrubs would have found suitable habitats along (temporary) streams and, in the case of *Salix*, also along the lake.

During the lower part of zone 1, the upland vegetation of the Zeribar area must have consisted of steppe or desert-steppe interspersed with tree stands. These tree stands may particularly have been found in sheltered valleys with somewhat moister soil conditions because of the accumulation of water. *Quercus*, *Pistacia*, and *Acer* formed part of the tree stands, but it is not possible to estimate the relative proportions of these species.

In the course of zone 1 time, the tree stands must have diminished, whereas the proportion of Chenopodiaceae in the steppic vegetation increased. This was probably the result of an increase in dryness.

6.2.2. . *Pollen assemblage zone 2*

The courses of the curves for *Quercus*, *Pistacia*, and *Acer* in zone 2 suggest that tree stands were present, but that the numbers of trees may have fluctuated quite considerably. Particularly during subzone 2b time trees may have been very scarce and oak may even temporarily have been absent from the Zeribar area. In the course of zone 2 time, the share of trees diminished gradually. After each decline the subsequent recovery resulted in smaller numbers of trees than before.

6.2.3. *Pollen assemblage zone 3*

One may assume that during subzone 3a time, scattered tree stands were still present in the Zeribar area. In view of the serious under-representation of *Acer* in the pollen precipitation (cf. 7.1.3.2.) this species must have been the most important constituent of the tree stands. *Pistacia* would likewise have played a part, be it most probably a minor one. If oak was already found in the Zeribar area during subzone 3a time it must have been a very rare tree. Thus, the subzone 3a arboreal vegetation was dominated by *Acer*. Freitag (1977) has observed stands of *Acer* in ravines and along creeks and rivers in definitely dry parts of the Hindukush of eastern Afghanistan. This refers to *Acer semenovii*, but a comparable situation may have existed for *Acer cinerascens* in the Zeribar area during subzone 3a time.

There can be little doubt that during subzone 3b time the uplands of the Zeribar area were treeless.

Pollen of *Pistacia* and *Acer* was very sporadically found in the section concerned. *Quercus* pollen values of 1% and less may be ascribed to long-distance transport and do not indicate that oak was present in the area. On the other hand, *Tamarix*, *Hippophaë*, and *Salix* could maintain themselves in stream valleys and/or along the lake. It should be emphasized that *Hippophaë* is best represented in zone 3. In spite of the scarce representation in the pollen record *Hippophaë* may have been no rare shrub during zone 3 time. Surface-sample studies in Europe have shown that *Hippophaë* is seriously under-represented in the pollen rain. *Hippophaë* has a very wide distribution in Europe and Asia, where it is found from sea-level up to high in the mountains (Hegi 1926, pp. 732-741). The species is reported for elevations of up to 3,000 m in the mountains of Afghanistan (Murray 1968). Its occurrence in southern Siberia proves that *Hippophaë* can endure extreme continental conditions.

During subzone 3b time, not only the Zeribar area but very probably the whole or nearly the whole of the Zagros Mountains was treeless, except for some *Salix*, *Tamarix*, and *Hippophaë*. elevations dryness would have been the limiting factor for tree growth, whereas at higher elevations it was too cold for trees, in particular the growing season must have been too short (see further 7.3.). As for a possible glacial tree-refuge area in north-eastern Iraq, see 8.5.

Pollen zones 1-3, which are dated to c. 42,500-14,000 B.P., correspond with the Middle and Upper Pleniglacial of the European Würm-glacial chronology.

6.2.4. *Pollen assemblage zone 4*

The herbaceous vegetation of zone 4 differed from that of zone 3 in the much lower proportions of *Artemisia* and Umbelliferae. The rise in Gramineae pollen in zone 4 of the Zer. Ib diagram is not matched by a similar rise in the Zer. II diagram, so that most probably the proportion of grasses in the upland vegetation did not increase.

As for the high Chenopodiaceae pollen values in the upper spectra of zone 3 and in zone 4, it is possible that the rise in the *Atriplex*-type curve at the end of zone 3 was caused by a local expansion of chenopods. It has already been mentioned

(6.1.3.) that during the period concerned the water in the lake was brackish. This could have induced a salinization of the valley bottom, or at least of its poorly drained parts. In the period concerned, Chenopodiaceae may have expanded along the lake and locally on the valley floor. The conspicuous decrease in *Artemisia* at the zone 3/4 boundary and the further decline in Umbelliferae in zone 4 suggest that the share of these taxa in the upland vegetation had decreased.

In spite of the dry climatic conditions suggested by the low water levels (6.1.3.), trees must have reached the Lake Zeribar area again during zone 4 time. *Quercus* percentages are hardly higher than in zone 3, and the pollen grains concerned were most probably carried in from a great distance. On the other hand, *Pistacia* pollen, with values of up to 0.6%, is much more frequent than in the previous zone. In view of the rather poor pollen dispersal in *Pistacia*, one may assume that during zone 4 time this tree was present in the area. Below (6.3.4.) a possible Late-glacial vegetation zonation will be discussed.

Zone 4, which is dated to c. 14,000-10,500 B.P., corresponds largely with the Late-glacial of West and Central Europe. Consequently, one may assume that temperatures were considerably higher than in the previous zones. The climatic dryness of zone 4 must have been the result of the higher temperatures. Precipitation may also have been higher than in zone 3, but the effect of an increased precipitation was undone by the increase in evaporation. The assumed low water levels (6.1.3.) must also have been brought about by the high evaporation rate.

6.3. Hypothetical vegetation zonation

6.3.1. *Würm-glacial snowline depression*

During subzone 3b time, which period coincides with the second half of the Upper Pleniglacial of the European Würm-glacial chronology, the Zeribar area and the greater part of the Zagros Mountains were covered with treeless steppe and desert-steppe vegetation (6.2.3.). The absence of trees would to a great extent have been caused by the climatic dryness, *i.e.* it was too dry for tree growth. Besides, the question arises to what extent

it was too cold for trees. This leads to the problem of the temperature depression and subsequently of the upper treeline depression during the Upper Pleniglacial.

Conclusions on Würm-glacial temperatures in the Eastern Mediterranean area are particularly based upon snowline depressions. In his important publication on the Würm-glacial and present glaciation in the Mediterranean area, Messerli (1967) arrives at a maximum snowline depression of 1,000-1,200 m for Lebanon, West and Central Turkey. Assuming a lapse rate of 0.65°C/100 m, a snowline depression of 1,000-1,200 m would imply a temperature depression of 6-8°C. For eastern Turkey, he believes that the snowline depression was less, *viz.* 700 to 800 m. This does not imply, however, that there also the temperature depression was less than in more westerly areas. In eastern Turkey, a greater dryness could have been responsible for a less considerable expansion of the glaciated areas, and for this region a maximum temperature depression of 6-8°C may be assumed as well. It should be mentioned that Wright (1961) arrives at a much greater snowline depression for the Cilo Dagh area in southeastern Turkey. Instead of a depression of 700-800 m, Wright postulates one of c. 1,200 m. For the Algurd Dagh area, in northeastern Iraq, c. 180 km northwest of the Zeribar area, Wright found a Würm-glacial snowline depression of as much as 1,800 m. The great snowline depression in these areas may have been due to higher precipitations.

Messerli (1967) claims that the glaciation reached its greatest extension in the period of 40,000-18,000 B.P. Consequently, the maximum snowline and temperature depression must be dated to the same period.

6.3.2. *Hypothetical vegetation zones during subzone 3b time*

It seems justified to assume that in the Zagros Mountains the Upper Pleniglacial temperature depression must that have been in the range of 6-8°C. This implies that the upper treeline, which is determined by the temperature, must have been depressed by 1,000-1,200 m. The present-day upper treeline in the Zagros Mountains must be laid at 2,300-2,500 m (2.3.3.). A treeline depression of

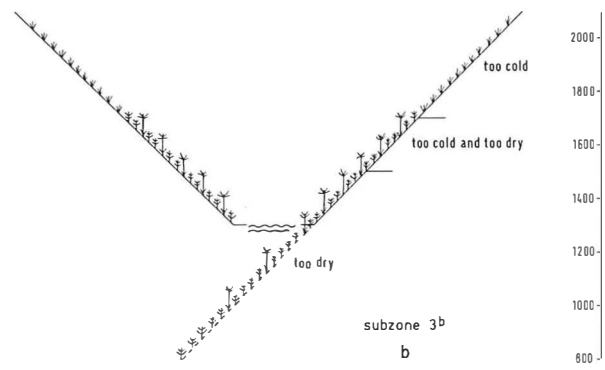
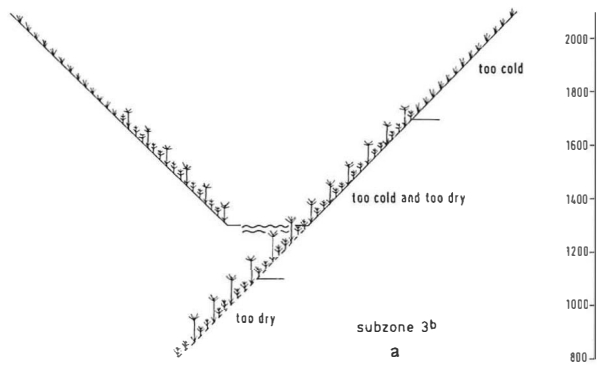


Fig. 27. Hypothetical vegetation zones in the Zeribar area during subzone 3b time. “too dry” etc. means “too dry for tree growth” etc. See 6.3.2.

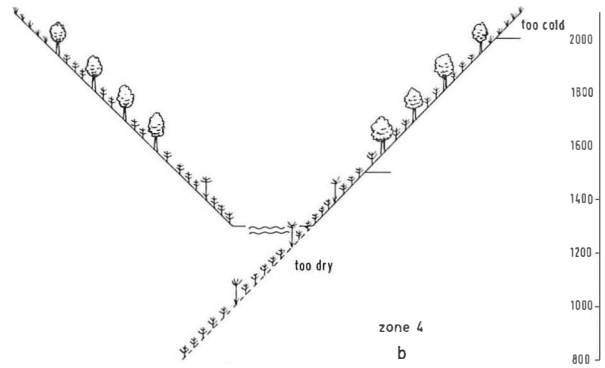
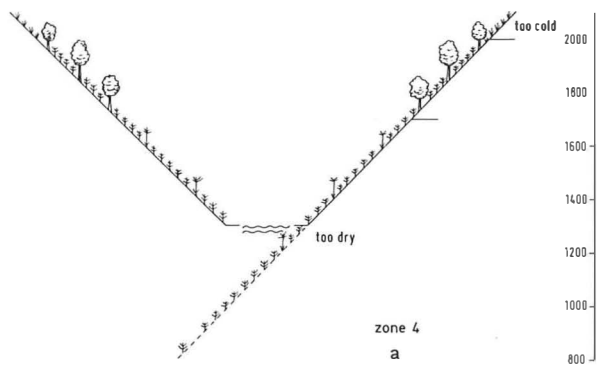
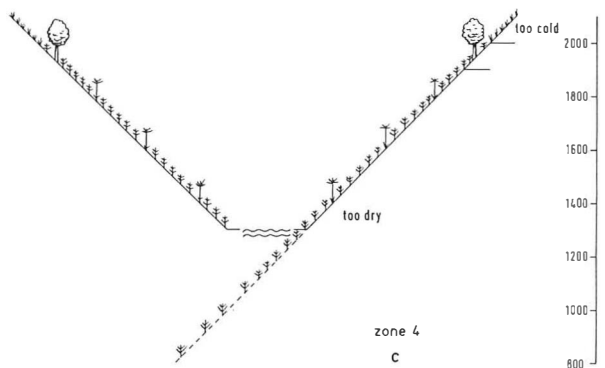


Fig. 28. Hypothetical vegetation zones in the Zeribar area during zone 4 time. See 6.3.3.



1,000-1,200 m would imply a theoretical, temperature-conditioned upper treeline at 1,100-1,500 m during the Upper Pleniglacial. This means that during subzone 3b time, either in the whole of the Zeribar area, at elevations between 1,300 and 2,100 m, it was too cold for tree growth (fig. 27a) or that only in a narrow zone between the valley bottom at 1,300 m and an altitude of at most 1,500 m temperature would not have been the limiting factor for tree growth (fig. 27b). The latter case does not imply that tree growth would have been possible in the narrow zone above the valley bottom; there dryness was the limiting factor, just as at elevations below 1,300 m. Above the belt where it was only too dry for tree growth, a zone was found in which it was too dry as well as too cold for trees. At higher altitudes, with increasing humidity, only temperatures, in particular the short growing season, must have been the limiting factor for tree growth. Thus, three (theoretical) belts can be distinguished for subzone 3b in the greater part of the Zagros Mountains: too dry, too dry and too cold, and too cold for tree growth.

As for the possible vegetation types in the inferred zones, the following may be speculated. The *Artemisia*-Chenopodiaceae-Umbelliferae vegetation may have been found in the zone in which it was too cold as well as too dry for tree growth, and probably also in the upper part of the zone in which only dryness was the limiting factor for trees. At lower elevations, the desert-steppe vegetation probably had a different composition. At higher elevations, where only temperatures were the limiting factor for tree growth, alpine vegetation prevailed.

6.3.3. Late-glacial vegetation zonation

The climate of zone 4 was probably as dry as that of subzone 3b, but temperatures must have been considerably higher. In spite of the dry climate, *Pistacia* was able to settle in the Zeribar area. Where could this tree possibly have found suitable habitats?

As a result of the higher temperatures, the lower limit of the belt in which during subzone 3b time it was too cold for trees (fig. 27a and b) must have moved upward quite considerably. This could have had the following effect on the vegetation zonation. In the lower part of the alpine belt of subzone 3b (too cold for trees) conditions had to some

extent become favourable for tree growth, because there temperature was no longer the limiting factor. It was in this belt that pistachio could establish itself during zone 4 time (fig. 28a). The above starts from the assumption that the climate of zone 4 was as dry as that of subzone 3b. If zone 4 had a somewhat moister climate, trees may also have expanded in the upper part of the former belt "too dry and too cold for trees", so that the forest-steppe belt was rather broad (fig. 28b). If the climate of zone 4 was even drier than that of subzone 3b, only a very narrow belt may have been suitable for tree growth (fig. 28c). In that case the steppe vegetation would also have encroached upon the lower part of the Upper Pleniglacial alpine belt. It should be stressed that the delimitation of the *Pistacia* vegetation belts in fig. 28 must not be taken too literally and that, moreover, within these belts pistachio would only locally have been found in favourable habitats.

It is self-evident that the zonation models presented in figs. 27 and 28 are very hypothetical. They only serve to stimulate the discussion on the Würm-glacial vegetation zonation in the Zagros Mountains.

7. POSTGLACIAL

7.1. Lake Zeribar

7.1.1. Pollen assemblage zone 5

7.1.1.1. Tree pollen

The upland vegetation of zone 5, which is dated from c. 10,500 to c. 6,200 B.P., must have consisted of a forest-steppe in which trees very slowly expanded. As has been reported in 2.3.2., a forest-steppe with *Pistacia kbinjuk*, *P. atlantica*, *Amygdalus scoparia*, and *Ziziphus spina-christi* would constitute the present-day natural vegetation in the foothills of the Zagros Mountains, at elevations between 300 and 800 m. An *Amygdalus-Pistacia* forest-steppe is also postulated between the Zagros oak-forest belt and the steppe vegetation of the interior high plateau of Central Iran. Was the vegetation of zone 5 time perhaps comparable to this *Amygdalus-Pistacia* forest-steppe?

Pistacia pollen values are comparatively high in zone 5. As for *Amygdalus*, the following should be

remarked. *Amygdalus* pollen is hard to distinguish from that of various other rosaceous trees and shrubs, such as *Pyrus*, *Rosa*, and *Crataegus*. For that reason the pollen of these rosaceous taxa is included in the curve for "other Rosaceae". The low percentages for "other Rosaceae" do not, however, imply that rosaceous trees and shrubs were of minor importance. Surface-sample studies have demonstrated that *Amygdalus*, *Crataegus*, *Rosa*, *Pyrus*, and other rosaceous shrubs are seriously under-represented in the pollen precipitation. From the above it is clear that *Amygdalus* may be represented in the pollen record of zone 5, but that there is no absolute proof for it.

In addition to *Pistacia* and possibly *Amygdalus*, *Quercus* was a tree of increasing importance during zone 5 time. Further, *Acer* is represented in this zone. In view of the poor representation of *Acer* in the pollen precipitation (cf. 7.1.3.2.) one must assume that notwithstanding the low and irregular *Acer* pollen percentages this tree must have occurred in the Zeribar area during zone 5 time.

The pollen evidence suggests that the tree stands of zone 5 were made up of the same species that are the quantitatively most important constituents of the Zagros oak forest (see 7.1.3.2.). Consequently, the vegetation of zone 5 cannot have been comparable to the present-day almond-pistachio forest-steppe. The question arises whether at the time either a mosaic of steppe and Zagros oak-forest stands or a kind of Zagros oak forest-steppe was found in the Zeribar area. This was very probably not the case. The *Quercus/Pistacia* ratio in zone 5 (c. 3.5) is considerably lower than in zone 7, which reflects the Zagros oak forest (c. 46). In view of the rather poor pollen dispersal of *Pistacia* one must assume that at the time pistachio was considerably more common than oak. *Pistacia* was probably the dominant tree of the forest-steppe vegetation of zone 5 time.

7.1.1.2. *Rheum* and *Anisosciadium*-type pollen

Pollen assemblage zone 5 is characterized, among other things, by relatively high values for *Rheum* (*ribes*) and *Anisosciadium*-type. *Rheum ribes* is the most common wild *Rheum* species in Iran. This species from open vegetations is found in the mountains and high plateaus of Turkey, the southern Caucasus, Iran, Afghanistan, and Pakistan. As for

its moisture and temperature requirements, *Rheum ribes* seems to be fairly flexible. Rechanging & Schiman-Czeika (1968) report a lowest occurrence at 900 m (in Baluchistan) and a highest occurrence at 3,300 m (in eastern Iran). In Turkey, the species is found on rocky slopes, between 2,300 and 2,700 m (Davis 1967, p. 269). Zohary (1963, p. 49) mentions an association of *Artemisia herba-alba* and *Rheum ribes* in the area between Kerman and Saidabad in central Iran at an elevation of over 2,000 m and with an annual precipitation of 100-200 mm. In the Zagros Mountains, W. van Zeist observed much *Rheum ribes* on a west-northwest-facing limestone slope c. 25 km east of Lake Zeribar at an elevation of c. 1,850 m and with an estimated annual precipitation of 600-700 mm. After the cutting of the forest an open herbaceous vegetation with scattered coppice had developed there.

For the slope mentioned above a vegetation survey was carried out (Wright *et al.* 1967, p. 431). In addition to *Rheum ribes*, *Poa bulbosa* ssp. *vivipara*, *Achillea* sp., *Graminosciadium* sp., Umbelliferae indet., *Alyssum* sp., *Cruciata coronata* ssp. *persica*, *Astragalus* sp., *Geranium tuberosum*, and *Ranunculus* sp. were quantitatively important species (in early May 1963). The shrubs included *Quercus brantii*, *Pistacia atlantica*, *Acer cinerascens*, and *Pyrus syriaca*. A surface sample (nr. 28) from this locality was analysed by J. H. McAndrews (Wright *et al.* 1967, fig. 3). As the spectrum obtained by McAndrews does not show *Rheum*, a re-examination of the sample was carried out by S. Bottema. As is clear from table 2, Bottema found 3.7% *Rheum* pollen. This result suggests that the proportion of *Rheum* in the pollen rain is less than that in the vegetation. Consequently, *Rheum* values of up to 8.2% in pollen zone 5 (Zer. II) may point to a common occurrence of this species in the then vegetation on the slopes around Lake Zeribar.

The *Anisosciadium* pollen type includes *Anisosciadium* as well as *Echinophora*. Among the *Echinophora* species, *E. tenuifolia* seem to be widespread in Iran (Parsa 1948). Iranian *Echinophora* species are reported for steppe vegetation and fields. *E. anatolica* (*E. tournefortii*) is salt-tolerant. *Anisosciadium orientale* is reported for dry terrain; the species is also found on brackish soils.

It is not known to the authors whether at present

Table 2.

Surface-sample spectra from western Iran. For the location of the samples see fig. 1. Samples 9a and 9b are from a well-preserved forest near Ilam; sample 26 is from a forest remnant c. 15 km east of Lake Zeribar; sample 28 is from a deforested limestone slope c. 25 km east of Lake Zeribar.

Sample number	9a	9b	26	28
Pistacia	0.5	4.8	0.7	0.4
Quercus	83.5	81.7	41.1	26.2
cf. Morus	—	—	0.2	—
cf. Rhus	—	—	—	0.1
Juglans	0.2	—	0.9	—
cf. Platanus	—	—	—	0.1
Acer	0.2	0.2	0.2	—
Juniperus	—	—	—	0.1
Pyrus-type	—	0.2	0.5	—
Daphne	0.5	0.2	—	—
Crataegus-type	—	—	0.7	—
cf. Citrus	—	—	0.2	—
Salix	—	—	0.7	0.4
ΣAP	85.0	87.0	45.2	27.5
Artemisia vulgaris-type	0.2	—	0.5	0.7
Artemisia herba-alba-type	1.1	0.5	2.3	6.8
Chenopodiaceae < 20 pores	0.2	0.2	—	2.9
Noaea-type	0.4	0.5	2.3	2.5
Atriplex-type	1.3	0.5	3.4	4.6
Ephedra fragilis-type	0.2	0.2	—	0.1
Plantago lanceolata-type	0.5	0.7	0.7	1.5
Plantago maritima-type	0.5	0.9	0.7	2.8
Plantago ovata-type	—	—	0.5	—
Plantago sp.	0.5	0.7	1.1	2.9
Cerealia-type	0.2	—	1.4	—
Gramineae	5.0	3.1	19.7	13.2
Zea mais	—	—	0.2	—
Cyperaceae	—	—	0.9	0.3
Centaurea solstitialis-type	—	—	3.4	0.7
Datisca	0.2	—	—	—
Scabiosa	—	—	0.2	—
Matricaria-type	—	0.3	3.6	2.1
Cousinia	—	—	0.2	0.1
Senecio-type	—	—	—	0.6
Evax-type	—	—	—	0.9
Tubuliflorae indet.	—	0.2	3.2	2.8
Liguliflorae indet.	0.9	—	0.9	1.2
Bunium-type	0.4	2.9	0.5	3.8

Sample number	9a	9b	26	28
Pimpinella-type	—	0.2	—	0.7
Anisosciadium-type	—	—	—	0.4
Bupleurum-type	—	—	—	0.6
Ferula	—	—	—	0.3
Umbelliferae indet.	0.4	1.4	1.8	9.7
Sanguisorba minor-type	—	—	—	0.9
Rosaceae	1.3	0.2	—	0.6
Ranunculus acer-type	—	—	0.2	0.1
Anemone-type	—	0.2	—	0.4
Caltha	—	—	0.2	—
cf. Thalictrum	—	—	0.2	0.1
Leguminosae	0.2	—	0.2	0.4
Cruciferae	0.2	—	0.7	0.4
Mercurialis	—	—	0.2	—
Phyteuma	—	—	0.2	0.1
Caryophyllaceae	0.7	—	0.9	—
Rhinanthus-type	—	0.2	—	—
Mentha-type	—	—	0.2	—
Rumex acetosa-type	0.2	—	0.2	—
Rheum	—	—	—	3.7
Echium-type	—	—	0.9	—
Rindera-type	—	—	—	0.1
Heliotropium-type	—	—	—	0.1
Cyclamen-type	—	0.2	—	0.3
Papaver	—	—	0.2	—
Galium	—	0.2	0.9	1.3
Liliaceae	—	—	—	0.1
Sparganium-type	0.2	—	0.5	1.0
cf. Equisetum	—	—	0.2	—
Pteridium	—	—	—	0.1
Indeterminatae (not included in pollensum)	9.0	8.0	10.7	22.8
Pollen sum	557	585	439	679

vegetations exist in which both *Rheum ribes* and *Echinophora*/*Anisosciadium* play an important part. For the vegetation with *Rheum ribes* from which surface sample 28 originates, no *Echinophora* or *Anisosciadium* is reported, but at the time of surveying the species may not yet have been in flower and may consequently not have been collected (the species list includes Umbelliferae indet.). *Anisosciadium*-type pollen is hardly present in the surface sample concerned (0.4%).

One must assume that the climatic conditions of zone 5 time were favourable for an expansion of *Rheum* and *Anisosciadium* and/or *Echinophora* in the steppe vegetation of the Zeribar area.

7.1.1.3. Gramineae

As for the high Gramineae pollen percentages in zone 5, the following may be remarked. In the case of the Zer. Ib diagram, from the edge of the lake, it is doubtful whether the majority of the grass pollen

originated from the marsh vegetation around the lake. The type of sediment in the section concerned (clay gyttja) and the high *Myriophyllum* pollen percentages in the upper part of zone 5 point to open water at the locality of this core during zone 5 time. It is conceivable that during this period the marsh vegetation belt had approached the Zer. Ib coring locality, thus giving rise to a considerable increase in grass pollen. On the other hand, the similarly high grass pollen values in the Zer. II diagram from the middle of the lake rather point to an expansion of Gramineae in the upland vegetation. However, this is no solid evidence for a regional expansion of grasses. If at the beginning of zone 5 time the marsh vegetation belt had broadened considerably or/and the proportion of grasses in the marsh vegetation had increased markedly, this also could possibly have caused a strong increase of Gramineae in the pollen precipitation in the middle of the lake. Consequently, we are left with the problem that the high Gramineae pollen percentages in zone 5 could have been effected by a local (marsh vegetation) as well as by a regional (upland vegetation) expansion of grasses. Do the courses of the grass pollen curves in the upper sections of the diagrams perhaps provide a clue for solving this problem?

In both diagrams the high Gramineae pollen values of zone 5 are succeeded by a strong decline in the grass pollen curves. One could possibly imagine that this decrease was caused by a contraction of the marsh vegetation belt, e.g. as a result of a rise in the water level. In other words, the reduced production of grass pollen by the marsh vegetation would equally have affected the Gramineae pollen percentages in both sediment cores. However, in that case the strong increase in grass pollen percentages in the upper part of the Zer. Ib diagram (subzone 7c) should also have found expression in the Zer. II diagram. There can be no doubt that the majority of the grass pollen in the upper part of the Zer. Ib core is of local origin. The sediment in the core section concerned consists of peat. In addition to Gramineae, Cyperaceae and *Dryopteris* were important constituents of the peat-forming vegetation.

The deposition of peat at the locality of the Zer. Ib core implies an extension of the marsh vegetation belt lake inwards. If the decrease in grass

pollen values in zones 6 and 7 of both Zeribar diagrams was due to a contraction of the marsh vegetation belt, the subsequent broadening of this belt should have resulted in an increase in Gramineae pollen percentages not only in the Zer. Ib diagram but also in the Zer. II diagram. However, in the Zer. II diagram a corresponding increase in the grass pollen curve is not present. For that reason it seems unlikely that the increase in grass pollen values at the beginning of zone 5 and the subsequent decrease reflect changes in the local vegetation. Consequently, from the high Gramineae pollen percentages in zone 5 one may conclude that grasses played an important part in the upland vegetation of that time.

7.1.1.4. Other herbaceous pollen types

From the beginning of zone 5 on, *Plantago maritima*-type pollen shows relatively high percentages, indicating that plantain species played a rather important part in the Postglacial herbaceous vegetation of the Zeribar area. *Plantago maritima*-type includes *P. ovata* and *P. psyllium*, which are both widespread upland species. Percentages for *P. major/media*-type pollen, which includes common species such as *P. bellardii*, *P. gentianoides*, and *P. major*, remain rather low in zone 5 and succeeding zones.

Chenopodiaceae played a much more modest part in the steppic vegetation of zone 5 time than in the vegetation of zones 1 to 4. As will be discussed below (7.1.3.3.), *Artemisia* pollen values of up to 5% could have been due to long-distance transport. Be this as it may, *Artemisia* would at most have played a minor part in the steppic vegetation of zone 5 time.

7.1.1.5. Vegetation and climate

The slow increase in tree pollen percentages in zone 5 suggests that in the early Postglacial the climate was less favourable for tree growth than nowadays. It is unlikely that in Postglacial times temperature was the limiting factor for tree growth. Consequently, one must assume that dryness prevented a more rapid expansion of trees. In the early Postglacial, that is in the period c. 10,500-6,200 B.P., the climate of western Iran must have been relatively warm and dry, particularly the summer dryness may have been much more severe than

at present.

The composition of the steppic vegetation of zone 5 time must have differed considerably from that of the steppe and desert-steppe vegetation of zones 1 to 4. On the one hand, the role of Chenopodiaceae, *Artemisia*, and *Ferula* had diminished greatly, whereas Gramineae, *Rheum*, *Anisosciadium*/*Echinophora*, and *Plantago* were important constituents of the forest-steppes of zone 5. The early Postglacial climatic change not only caused a gradual expansion of trees, but it also resulted in a drastic change in the composition of the herbaceous vegetation cover.

7.1.2. Pollen assemblage zone 6

Pollen zone 6 represents the replacement of the forest-steppe by the Zagros oak forest. After a very slow expansion of trees in the preceding 4,000-4,500 years, zone 6 time witnessed the establishment of the forest within a period of c. 800 years.

The strong increase in tree pollen percentages is entirely accounted for by *Quercus*. On the other hand, *Pistacia* pollen values decrease. Of the herbs, Gramineae and Chenopodiaceae show the most marked decline.

Somewhat puzzling is the significance of the rather high pollen percentages for *Fraxinus* at the zone 5/6 transition. The low *Fraxinus* maximum is used for correlating both Zeribar diagrams (see 6.1.2.). For western Iran only one *Fraxinus* comes into consideration, viz. *F. rotundifolia* (Murray 1968). Bobek (1951, p. 57) mentions *F. oxyphylla* and *F. syriaca* for the Zagros oak forest, but according to Murray these are both synonyms of *F. rotundifolia*. Zohary (1973, p. 582) lists *F. rotundifolia* among the trees and higher shrubs of the class of the Quercetea brantii. According to Bobek (1951, p. 30), *Fraxinus* forms part of the Zagros oak forest itself as well as of the hydrophilous forests along streams. W. van Zeist observed *Fraxinus* along a stream c. 15 km east of Marivan, together with *Salix*, *Tamarix*, *Cornus*, *Rosa*, and *Crataegus*.

In the section with increased *Fraxinus* pollen values, *Salix* shows higher percentages too. The particularly high *Salix* percentages in the Zer. Ib diagram suggest that the expansion of willow was of local character, viz. on the lake shore. The marshy lake shore with stagnant water is no suitable habitat

for *Fraxinus*, so that this tree cannot have expanded there. It will be difficult if not impossible to establish whether the temporary expansion of *Fraxinus* in the zone 5/6 transitional period took place on the uplands or in stream valleys. One could imagine that in the period just before the rapid thickening of the forest *Fraxinus* spread to some extent on the upland. The subsequent expansion of *Quercus* would have superseded *Fraxinus*. H. Freitag commented that it is extremely unlikely that *Fraxinus excelsior* or *F. rotundifolia*, the only ash species reported for Iran, would have spread on the uplands, because in Southwest Asia these species are restricted to riverine habitats.

7.1.3. Pollen assemblage zone 7

7.1.3.1. Vegetation and climate

The upper zone of the Zeribar diagrams reflects predominantly forest vegetation. During the last 5,500 years the Zagros oak forest must have been present in the Lake Zeribar area and in the greater part of the Zagros Mountains. During zone 6 time, humidity must have reached modern levels, while the climate of zone 7 would largely have been the same as the present-day one. The latter, of course, does not exclude minor climatic alterations during zone 7 time, in consequence of which the composition of the forest may have changed somewhat or the distribution area of the Zagros oak forest may have expanded or contracted to some extent.

7.1.3.2. Tree pollen

The pollen record suggests that oak was by far the most important tree in the forests of zone 7 time, whereas the proportions of maple and pistachio were insignificant. This picture is not in conformity with the composition of the Zagros oak forest (see 2.3.3.). Although *Quercus* is indeed the predominant tree in the Zagros oak forest, other trees are present in considerable numbers. Thus in the fairly untouched forest c. 7 km northwest of Ilam (2.3.3.), the ratio between oak, pistachio, and maple was about 8:1:1. In a forest remnant on a north-facing slope, c. 15 km east of Marivan, *Quercus brantii*, *Pyrus syriaca*, and *Acer cinerascens* occurred in about equal numbers. Furthermore, *Pistacia atlantica*, *Crataegus* sp., *Lonicera nummularifolia*, *Amygdalus* sp., and *Daphne mucronata* were found in

this tree stand. It should be emphasized that the composition of the latter vegetation had been interfered with rather seriously by man, but one must assume that in addition to *Quercus* various other trees and shrubs formed part of the original forest in the Zeribar area. The low percentages or even the virtual absence of most of the constituents of the Zagros oak forest in zone 7 of the Zeribar diagrams must be ascribed to the poor pollen dispersal of these species.

The latter is already indicated by the surface samples from the sedge mat to the east and north of the lake (fig. 6). In surface samples Z 6, 8, 9, 11, 13, and 14 (Wright *et al.* 1967, fig. 3) *Quercus* has an average pollen value of 24.7% (excluding Cyperaceae and *Dryopteris* from the pollen sum) and *Pistacia* of 1.1%. *Acer*, *Lonicera*, and *Daphne* are not represented, and the group "other Rosaceae", which includes *Pyrus*, *Crataegus*, *Rosa*, *Amygdalus*, and *Prunus*, shows an average value of 0.2% (represented in only 2 of the 6 samples). One could object that the modern pollen rain in the Lake Zeribar valley does not reflect the Zagros oak forest, for, as has already been mentioned (3.1.1.), what is left of the forest cover on the slopes around the lake is mostly depauperate shrub vegetation.

The poor representation of *Pistacia* and particularly of *Acer* in the pollen rain as compared to *Quercus* is demonstrated by surface samples 9a and 9b from the well-preserved forest near Ilam, which were re-examined by S. Bottema (table 2). In case of an equal representation of *Quercus*, *Pistacia*, and *Acer* in the pollen rain, percentages of c. 68, 8.5, and 8.5%, respectively, were expected in the surface-sample spectra concerned, making a total tree pollen sum of 85%. However, for *Pistacia* and *Acer* average percentages of 2.6 and 0.2, respectively, were obtained, whereas the mean *Quercus* value amounts to 82.6%.

For surface sample 26 from the forest stand c. 15 km east of Marivan, a total tree pollen value of 45.2% was obtained (table 2). Although *Quercus*, *Acer*, and *Pyrus* occur in approximately equal numbers in the vegetation, *Acer* and *Pyrus*-type pollen scored only 0.2 and 0.5%, respectively, as against 41.4% *Quercus* pollen. The *Pistacia* pollen value of 0.7%, that is c. 1.5% of all tree pollen, is significantly lower than its share of c. 5% in the tree cover. Of *Lonicera* and *Daphne*, which were both

present in the vegetation, no pollen was counted in the surface sample, demonstrating the poor representation of these taxa in the pollen precipitation.

From the above it will be clear that the forests that covered the Zeribar uplands during zone 7 time were very probably less monotonous than is suggested by the pollen record. There can be little doubt that oak was the dominant tree, but other trees and shrubs, such as *Pistacia*, *Pyrus*, *Acer*, *Lonicera*, *Daphne*, and *Crataegus*, also formed part of these forests.

7.1.3.3. *Herbaceous pollen*

Although in pollen zone 7 tree pollen percentages reach by far the highest values of the whole diagram, this does not imply that herbaceous pollen was insignificant. On the contrary, the share of herbs in the pollen precipitation amounts to more than 50% in some spectra of zone 7. In this connection it should be remarked that the exceptionally high total herbaceous pollen percentages in spectra 130-134 of the Zer. Ib diagram are due to high Gramineae pollen values. As has been discussed above (7.1.1.3.), the increased Gramineae pollen values in these spectra, which are not paralleled by similarly high values in the Zer. II diagram, must be of local origin.

The high herbaceous pollen percentages in zone 7 indicate that the forest vegetation was rather open, permitting a luxuriant ground flora. In this connection it may be remembered that in the rather untouched forest vegetation near Ilam the crown cover was only 50%. The herbaceous flora of zone 7 time would have consisted largely of the same species as were found in the steppic vegetation of the early Postglacial, but, on the other hand, the pollen record suggests some differences. Thus, the share of *Anisosciadium*/*Echinophora* and *Rheum* was considerably smaller in zone 7 time. *Sanguisorba minor* must have played a fairly prominent part in the ground flora of the Zagros oak forest. At least, only in pollen assemblage zones 6 and 7 *Sanguisorba minor*-type pollen, which in all probability originated from *Sanguisorba minor* itself, is fairly well represented.

In the upper Postglacial part of the Zeribar diagrams (zones 6 and 7) *Artemisia* occurs in values of about 5%. In surface samples Z 6, 8, 9, 11, 13, and 14 from the sedge mat along Lake Zeribar (fig. 6),

the average *Artemisia* value amounts to 3.9% after correction for the anomalously high *Dryopteris* and Cyperaceae percentages (Wright *et al.* 1967, fig. 3). However, W. van Zeist did not observe *Artemisia* in the Lake Zeribar area in May 1963. It is possible that some plants were overlooked (continuous rainy weather was not favourable for vegetation surveying), but *Artemisia* cannot have been common in the area. Consequently, one wonders whether *Artemisia* pollen values of 4 to 5% could largely have been due to long-distance transport. *Artemisia* is the dominant species in the lowland steppe of Mesopotamia as well as in the high plateau steppe and desert-steppe of central Iran, and tremendous amounts of *Artemisia* pollen are released into the air there.

7.1.3.4. *Subzone 7a*

The high *Quercus* and relatively low herbaceous pollen percentages in subzone 7a suggest that during the period concerned the densest forests of the whole of zone 7 time occurred. It should be remembered that the present-day Zagros oak forest has no closed tree canopy. The greater density of the forest of subzone 7a suggests that at that time the humidity was higher than in the succeeding subzones. In particular the period of summer drought may have been shorter.

7.1.3.5. *Subzone 7b*

Subzone 7b differs from subzone 7a by the somewhat lower *Quercus* pollen values and from subzone 7c by the absence of distinct indications of human activity in the area. It is not unlikely that subzone 7b reflects the vegetation cover which at present would be found in the Zeribar area under natural conditions, that is without the influence of man.

7.1.3.6. *Subzone 7c*

Subzone 7c is characterized by the presence of *Juglans* and by the rather high *Plantago lanceolata*-type pollen percentages. The latter points to an increased grazing activity. *Plantago lanceolata*-type pollen includes *P. lanceolata* as well as *P. lagopus*. *Juglans* must have been introduced by the people who inhabited the Lake Zeribar area during subzone 7c time. This fruit tree occurs in a wild state in

the Euxinian forests to the south of the Black Sea and in the Hyrcanian forests to the south of the Caspian (Zohary 1973, p. 372).

The introduction and cultivation of walnut in the Zeribar area constitute no problem. To-day this tree thrives well in the area, often in a semi-wild state. More difficult to explain is the presence of pollen of *Olea* and unidentified Oleaceae in the Zeribar diagrams. The grains listed as unidentified Oleaceae partly resemble those of *Phillyrea*/*Fontanesia*, which genera are both absent in Iran, and partly those of *Ligustrum*, which is only represented in northern and northwestern Iran (4.30.2.). Of the *Olea* species, only *O. europaea* is cultivated. *O. ferruginea*, which is distributed in Afghanistan, Pakistan, and Kashmir, is reported for southern Iran. *O. aucheri*, another wild olive species, is also found in southern Iran (Murray 1968). For western Iran no wild *Olea* species are reported, and neither is olive cultivated in this region. According to Murray (1968), Bornmüller found *Olea europaea* in the Iraqi section of the Zagros Mountains, near Ruwandiz, up to 1,000 m. This would indicate that under the present-day climatic conditions cultivated or spontaneous olives could maintain themselves in the lower part of the Iraqi Zagros Mountains.

Surface-sample studies in northern Greece (Bottema 1974) and southwestern Turkey (van Zeist *et al.* 1975) have demonstrated that olive has a good pollen dispersal, so that *Olea* pollen grains may be found at a great distance from the nearest olive trees. For that reason, the small numbers of *Olea* pollen found in the Lake Zeribar cores may not be considered as evidence of olive cultivation in the Zeribar area. It is most likely that the *Olea* pollen grains in the Zeribar cores must be ascribed to long-distance transport, *e.g.* from the Eastern Mediterranean coastal areas.

It is striking that in subzone 7c, in which an increased human activity is suggested by the pollen record, no increase in *Sanguisorba minor*-type percentages can be observed. In the pollen diagrams of Beyşehir and Söğüt, in southwestern Turkey (van Zeist *et al.* 1975), *Sanguisorba minor*-type pollen shows fairly high values in sections reflecting a large-scale interference of man with the vegetation (land occupation phases). At Zeribar, no reaction of *Sanguisorba minor* to the increased activity of man is suggested by the pollen record.

The lower boundary of subzone 7c and consequently the start of the increased human activity is dated to c. 2,700 B.P. (5.1.4.).

7.2. Lake Mirabad

After the detailed discussion of the Lake Zeribar diagrams that of the Lake Mirabad diagram can be more concise.

7.2.1. Pollen assemblage zones 5 and 6

The lower part of the Mirabad diagram (spectra 1-12) reflects a vegetational development that in many respects seems to be identical with that suggested by zones 5 and 6 of the Zeribar diagrams (however, see below). As at Zeribar, in the lower part of zone 5 *Pistacia* pollen values are as high as or only slightly lower than those of *Quercus*. The very high herbaceous percentages in the lower part of the zone point to predominantly steppe vegetation. The vegetation reflected by spectra 1-10 must have consisted of a forest-steppe.

As for the vegetation pattern during zone 5 time, the following hypothesis may be brought forward. Under the present-day climatic conditions, Lake Mirabad, at c. 800 m above sea-level, lies near the lower limit of the Zagros oak-forest belt (fig. 2). During zone 5 time it was drier than nowadays. Consequently, one could imagine that at least during the lower part of zone 5 time the Mirabad area was situated in the *Amygdalus-Pistacia* forest-steppe belt, whereas *Quercus* was only found at higher elevations. In the course of zone 5, oak would have reached the Mirabad area, where it spread more rapidly during zone 6. If this hypothesis is correct, the early Postglacial development of the vegetation in the Mirabad area must have differed from that in the Zeribar area. In view of the different climatic conditions in both areas, any differences in the vegetational history are not illogical. It should be stressed, however, that the view presented above is highly speculative.

As for the nature of the steppe vegetation represented by zone 5 at Mirabad, the following can be remarked. At Mirabad, chenopod pollen values are much higher than in the corresponding section of the Zeribar diagrams. The considerably greater proportion of chenopods in the Mirabad steppe ve-

getation is probably due to drier conditions than at Zeribar. The estimated present-day precipitation at Mirabad is lower than at Zeribar, and temperatures are higher (3.1.3., 3.2.1.).

At Zeribar, grasses must have played an important part in the steppe vegetation of zone 5 time. At Mirabad, too, grass pollen values are high in zone 5. It is questionable, however, whether the majority of the grass pollen of zone 5 was of regional (upland) origin. At present, a marsh vegetation with *Phragmites* is found around the lake (3.2.1.). The very high Gramineae pollen values in spectra 20 and 32-36 must undoubtedly be ascribed to local grasses, probably *Phragmites*. The conspicuously high grass pollen values in spectra 1, 3, and 4 likewise point to a local production of Gramineae pollen. However, much of the grass pollen in other samples of zone 5 may also have been of local origin. The strong fluctuations in the grass pollen values, with minimum percentages in spectra 8 and 9, rather point to a predominantly local than to a predominantly upland origin of the Gramineae pollen. Although one may safely assume that in the steppe vegetation of zone 5 time grasses occurred, it is not likely that they played a prominent part.

Artemisia percentages are conspicuously low. Of the other genera in the early Postglacial vegetation in the Mirabad area, *Plantago*, *Anisosciadium*/*Echinophora*, *Pimpinella*, *Centaurea*, *Matricaria*/*Achillea*/*Anthemis*, and *Ephedra* may be mentioned. As has already been stated, *Rbenn* is scarcely represented at Mirabad. *Ferula*-type pollen, which still shows relatively high percentages in zone 5 at Zeribar, was hardly found in the Mirabad samples. Chenopodiaceae were most likely predominant in the steppic vegetation of zone 5 time.

A fairly rapid thickening of the tree stands took place in zone 6. As at Zeribar, the increase in tree pollen percentages is entirely brought about by *Quercus*. By the end of zone 6, the Zagros oak forest had taken possession of the Mirabad area.

7.2.2. Pollen assemblage zone 7

The greater part of pollen zone 7 reflects a more or less continuous forest cover of the Mirabad area. In addition to *Quercus*, which was the predominant tree, *Pistacia*, *Acer*, and probably other arboreal species, such as *Pyrus syriaca*, *Daphne*, *Amygdalus*,

Crataegus, and *Prunus*, were found in these forests. The AP/NAP ratios suggest that the forests were more open than those in the Zeribar area. As for a comparison between the AP/NAP ratios, one must take into consideration that in contrast to the Zeribar diagrams, Gramineae are not included in the pollen sum of the Mirabad diagram. The rather open woodland in the Mirabad area is the reflection of comparatively dry climatic conditions.

7.2.2.1. *Subzone 7a*

This subzone shows the highest oak pollen values of the whole diagram, suggesting that at the time the natural forest cover was denser than afterwards. The same phenomenon was established for the Zeribar area. During subzone 7a time, the lake must have dried out intermittently. On the exposed lake bottom various Compositae species expanded: sample 16 scored high percentages for Compositae pollen types. The conspicuous *Quercus* minimum is not an indication of a drastic recession of the forest but is caused by a high local pollen production. The lower *Quercus* percentage in spectrum 15 is also due to an increased proportion of local pollen (*Carthamus*-type). Likewise indicative of intermittently exposed lake bottoms is the rather poor pollen preservation in sample 16. The sample at 4.00 m could not be counted because only a few badly damaged pollen grains were found.

7.2.2.2. *Subzone 7b*

Various herbaceous pollen types, such as *Artemisia*, *Plantago maritima*-type, *Rumex*, and *Ranunculus asiaticus*-type, show comparatively high values in subzone 7b (and 7c). One wonders to what extent the increase of these taxa could point to grazing in the upland forest vegetation. In this context it should also be mentioned that *Plantago lanceolata*-type pollen, too, is found in subzone 7b, be it in only 9 of the 13 samples. If grazing affected the ground flora, could the thinning of the tree stands also have been caused by man? This possibility cannot be excluded, but, as at Zeribar the decrease in trees at the subzone 7a/7b transition was very probably brought about by a change in climate, this might also have been the case for Mirabad. The same climatic change may partly or wholly have caused the expansion of the herbaceous taxa mentioned above.

7.2.2.3. *Subzone 7c*

This subzone is characterized by high *Plantago lanceolata*-type percentages, suggesting extensive grazing. *Plantago maritima*-type, on the other hand, shows somewhat lower percentages on the average. *Quercus* pollen values are also lower than in subzone 7b. In view of the increased grazing activities, it is not unlikely that the reduction in oak was the result of human interference. Either parts of the forest were cleared for agricultural purposes or the forest stands were thinned out. It should also be taken into account that grazing by itself may in the long run have caused a reduction in trees by preventing the natural regeneration of the forest.

The subzone 7b/7c transition represents another period in which the lake dried out regularly. In the section between spectra 31 and 32 hardly any pollen was preserved, and in spectra 31 and 32, Compositae pollen types again show higher values.

The high Gramineae percentages throughout subzone 7c suggest that reed vegetation had extended to near the coring locality. Although at present *Cladium* is quite common in the western end of the lake, where the coring was carried out, this marsh plant is scarcely represented in the upper part of the Mirabad core.

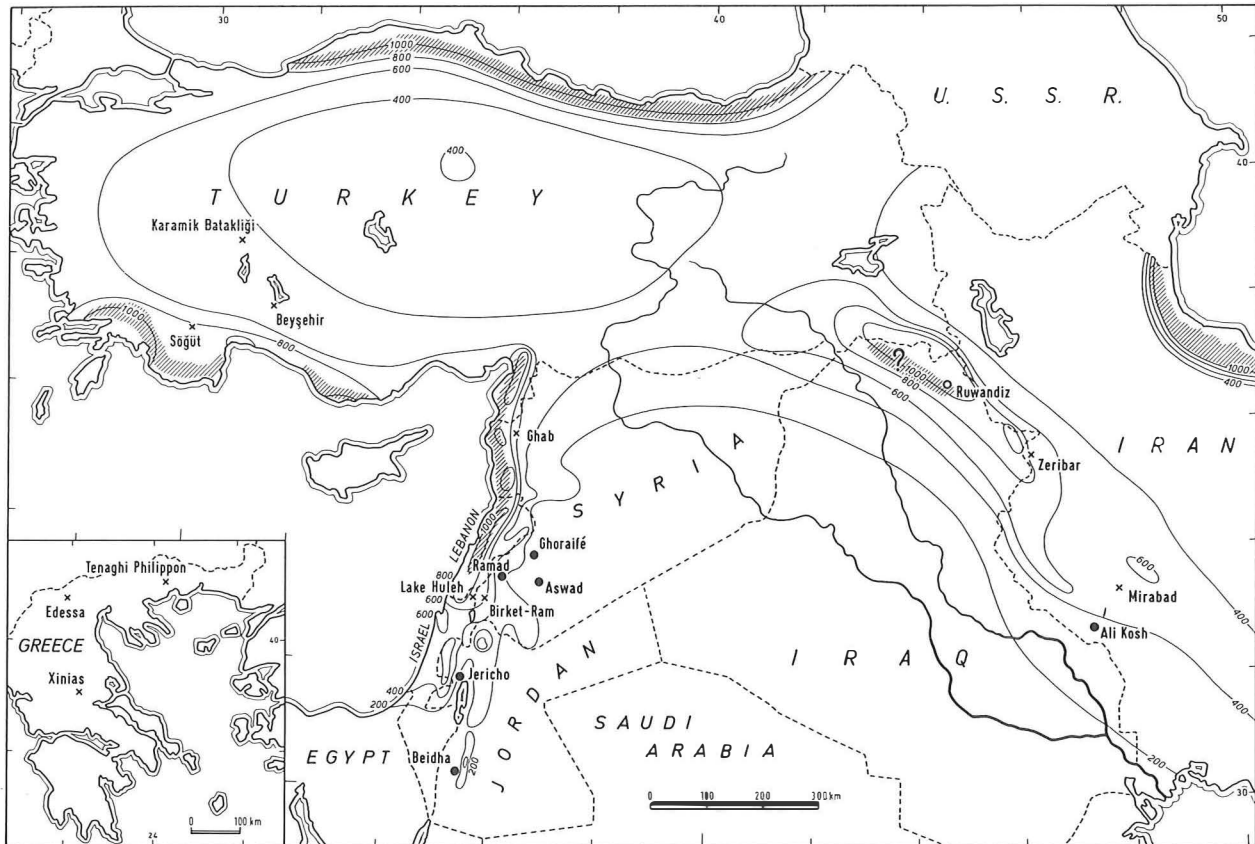
7.3. Conclusions

The pollen diagrams of Zeribar and Mirabad reflect a similar Postglacial vegetational development. These diagrams suggest that in the Zagros Mountains trees started to spread in the final phase of the Late-glacial, c. 10,500 years ago. In early Postglacial times, trees expanded slowly, most probably as a result of fairly dry climatic conditions. The establishment of the present-day Zagros oak forest belt must have taken place after 6,000 B.P.

8. THE LATE QUATERNARY VEGETATIONAL AND CLIMATIC HISTORY OF THE EASTERN MEDITERRANEAN AREA

8.1. Pleniglacial and Late-glacial pollen-diagram sites

As has been discussed above in chapters 6 and 7, the



Lake Zeribar pollen diagrams provide information on the vegetational and climatic history of the area during the last 40,000 years. In addition to those for Zeribar, pollen diagrams were prepared for various other Late Quaternary deposits in the Eastern Mediterranean area. Although these pollen diagrams are still too few in number to enable a satisfactory reconstruction of the development of the Late Quaternary vegetation in the whole of the Eastern Mediterranean area, some conclusions concerning vegetation and climate in the past can already be drawn. In fig. 29 generalized "main diagrams" (see 8.2.) are shown for a number of sites which cover a greater or lesser part of the last glacial period. The location of these pollen-diagram sites is indicated in fig. 30. Concerning the sites other than Zeribar the following can be remarked.

Tenaghi Philippon. The Tenaghi Philippon diagram was prepared for a core from the Drama basin in northeastern Greece, 40 m above sea-level. A section covering the whole of the last Glacial and

Fig. 30. On this map the location of pollen-diagram sites (indicated with a cross) and early Neolithic habitation sites (black dots) is indicated. Further, the isohyets are shown. The shaded areas are possible Würm-glacial tree refuges (see 8.5.).

the Postglacial was published by Wijmstra (1969). The lower part of the Würm-glacial is not shown in fig. 29.

Xinias. For a core from the centre of drained Lake Xinias, at an elevation of c. 500 m, c. 20 km northwest of Lamia in east-central Greece, a pollen diagram was prepared by Bottema (in press).

Ghab. The Ghab diagram was prepared for a core from the Orontes valley in northwestern Syria, at an elevation of c. 200 m. This diagram, which was published by Niklewski & van Zeist (1970), covers the greater part of the last Glacial and the Postglacial. The lower section of the diagram is not shown in fig. 29.

Sögüt. Recently drained Sögüt Gölü is situated in an intermontane valley in the Taurus Mountains of

southwestern Turkey, at an elevation of nearly 1,400 m. A diagram for the Söğüt core was published by van Zeist *et al.* (1975). The diagram covers the last 20,000 years or more.

The pollen diagram of Karamik Batakliği, in southwestern Anatolia (van Zeist *et al.* 1975), the base of which has been radiocarbon dated to 20,300 B.P., will not be included in the discussion. The correlation of the Karamik diagram with the diagrams presented in fig. 29 poses many difficulties, possibly due to a hiatus in the sedimentation at the Karamik site.

The pollen diagrams prepared for the long Lake Huleh core, in northern Israel (Horowitz 1968, 1971), and for a core from Birket-Ram, on the Golan Heights (Weinstein 1976), are not detailed enough for a proper comparison with other Late Quaternary pollen records from the Eastern Mediterranean area.

8.2. Construction and correlation of the pollen diagrams

The "main diagrams" in fig. 29 show the ratio between total tree pollen and the sum of *Artemisia* and Chenopodiaceae. The curves for some individual pollen types are also represented. Only Chenopodiaceae and *Artemisia* are included in the pollen sum because various other herbaceous pollen types, in particular Gramineae and Compositae, can show high percentages resulting from local conditions. On the other hand, *Artemisia* and Chenopodiaceae seem to be reliable indicators of the degree of openness of past vegetation, although Chenopodiaceae can also show anomalously high pollen values as a result of a local expansion of representatives of this family.

A comparison between diagrams involves an attempt at correlation. The lines that are drawn between the diagrams presented in fig. 29 are supposed to connect synchronous horizons. The correlations are based upon the courses of the curves, in particular of the AP/NAP curve, upon the radiocarbon dates, which are indicated in the diagrams, and upon inferred dates. As in all correlations of pollen diagrams from widely scattered areas, the assumed synchronicity of diagram sections and pollen-floristically defined horizons is subject to doubt and criticism as long as there are not enough

radiocarbon dates to provide a satisfactory time-stratigraphic framework. In our case sufficient radiocarbon dates are available only for the diagrams from Xinias, Tenaghi Philippon, and Zeribar. The type of sediment in the Ghab valley and at Söğüt is less suitable for radiocarbon dating because of the generally low organic content.

8.3. Pleniglacial

As the Zeribar diagrams cover the last 40,000 years, the discussion of Würm-Pleniglacial vegetation and climate will be confined to the period of 40,000-14,000 B.P. The diagrams of Tenaghi Philippon, Xinias, Ghab, and Zeribar all show higher tree pollen values in the section that is dated to around 40,000 B.P. In this connection it should be noted that the arboreal pollen percentages at Zeribar are much lower than in the other diagrams mentioned above. In the section covering the period from about 40,000 to 30,000 B.P., the diagrams of Tenaghi, Xinias, Ghab, and Zeribar show fluctuations in the AP/NAP ratios, although in the Zeribar diagram these fluctuations are of very minor importance.

The diagrams of Tenaghi, Xinias, and Ghab suggest an alternating increase and decrease of forest vegetation in the period of c. 30,000-16,000 B.P. In these diagrams three phases with higher tree pollen values separated by distinct Σ AP minima can be observed. On the other hand, the Zeribar diagram does not show fluctuations in the AP/NAP ratios in the section dated to c. 30,000-16,000 B.P.

Fairly strong fluctuations in the Upper Pleniglacial forest cover are also reflected in the Söğüt diagram. Concerning the lower part of the Söğüt diagram, the following should be noted. On the basis of the radiocarbon date of 9,255 B.P. for the upper part of subzone 3c at Söğüt, one may assume that the lower part of the Söğüt diagram, covering zones 1, 2, 3a, 3b, and the lower part of 3c, is of Pleniglacial and Late-glacial age. There is a striking resemblance to the Ghab diagram. The lower part of subzone 3c at Söğüt may be correlated with subzone Y₅ of the Ghab diagram. The course of the Σ AP curve below subzone 3c at Söğüt is nearly identical with that of subzones Y₁-Y₄ in the Ghab diagram. One should perhaps not attach too

much value to this close correspondence, but it will be clear that the Sögüt diagram shows considerable fluctuations of the AP/NAP ratio in the section that can be dated to c. 25,000-16,000 B.P.

The changes in climate, which in the period of c. 30,000-16,000 B.P. favoured the temporary expansion of trees in (parts of) Greece (Xinias, Tenaghi), southwestern Turkey (Sögüt), and western Syria (Ghab), had no similar effect in western Iran. In the period of c. 30,000-22,000 B.P. *Acer* and *Pistacia* could maintain themselves to some extent in the Zeribar area, but after c. 22,000 B.P. trees must have disappeared there completely (6.2.3.). The pollen evidence suggests that the Pleniglacial climate of the Zeribar area was much more adverse to tree growth than that of the areas from which the diagrams of Xinias, Tenaghi, Sögüt, and Ghab originate. A similarly conspicuous difference between the growing conditions for trees in the latter areas and those in the Zeribar area does not exist at present (see also the upper sections of the diagrams concerned). The diagrams of Xinias, Tenaghi, Ghab, and Sögüt are from areas not too far away from the Mediterranean coasts, whereas Lake Zeribar lies far inland. Consequently, one wonders whether it was the more continental climate of the Zeribar area which in one way or another was the limiting factor for tree growth during the Pleniglacial.

One might also speculate on the extent to which the distance of the Zeribar area from possible Würm-glacial tree-refuge areas (see 8.5 and fig. 30) played a part in the scarcity or absence of trees in the Pleniglacial of western Iran. Could periods of improved climatic conditions have been too short to permit tree species to reach the Zagros Mountains? This could possibly only apply to the incapacity of *Quercus* to return to the Zeribar area after c. 33,000 B.P. and of *Acer* and *Pistacia* after c. 22,000 B.P. However, the fact that in the period of c. 40,000-22,000 B.P., when trees were present in the Zeribar area, they never expanded markedly, demonstrates that the Pleniglacial climate never became reasonably favourable for tree growth, this in contrast to the coastal areas.

8.4. Late-glacial

At Tenaghi, Xinias, Ghab, and Sögüt, the pollen-

diagram section which in fig. 29 is dated to c. 16,000-11,000 B.P. is characterized by generally low Σ AP percentages, whereas chenopod pollen values are high. The upper and lower limits of this section are marked by a strong rise and decline in herbaceous percentages, respectively. At Tenaghi, the subzone X₄/X₅ transition, which coincides with the lower limit of the section under discussion, has an inferred date of c. 16,000 B.P. At Zeribar, there is no similarly marked decrease in tree pollen values. In this diagram the lower limit of the section concerned is put at the level for which a date of c. 16,000 B.P. has been calculated on the basis of the available radiocarbon dates.

The date of c. 11,000 B.P. for the upper limit of the section is based upon the radiocarbon dates of 10,080 and 10,750 B.P. for Ghab and Xinias, respectively, for levels just above the sections with high herbaceous pollen values. At Zeribar, the upper limit is placed at the level with an inferred date of c. 11,000 B.P. In contrast with the other diagrams, the Zeribar diagram does not show a conspicuous increase in herbaceous pollen values in the section under consideration, but chenopod percentages are higher than in the preceding sections.

The high herbaceous pollen values point to a dry climate during the end of the Pleniglacial and the greater part of the Late-glacial (which period is dated to c. 14,000-10,000 B.P.). One may assume that in the Late-glacial, temperatures rose markedly in the Eastern Mediterranean area. For western and central Europe it could be established that during the warmest phase of the Late-glacial, during the Allerød time, mean July temperatures were only 2°C lower than at present. It is likely that the precipitation increased, too. However, because of the higher evaporation rate the climate remained dry, in consequence of which trees did not expand (only at Zeribar slightly higher tree pollen values occur in zone 4). The expansion of trees started c. 11,000 B.P., that is, in the final phase of the Late-glacial, during Late Dryas time. In Late Dryas time, temperatures dropped again, as a result of which humidity may have increased, which in its turn favoured the spread of trees.

8.5. Possible Würm-glacial tree-refuge areas

In the period of c. 40,000 to 14,000 B.P. it must

have been colder as well as drier than nowadays. In the same period rather strong fluctuations in temperature and/or humidity must have taken place. Periods during which trees expanded were succeeded by periods with a climate that was very adverse to tree growth. The question arises where trees could have maintained themselves during periods with very unfavourable conditions for tree growth. The present-day distribution of precipitation may provide a clue for the location of potential Pleniglacial tree-refuge areas. Pleniglacial tree-refuge areas are to be found in regions that at present receive appreciable amounts of rain at lower elevations, that is to say 1,000 mm and more at elevations of between c. 500 and 1,200 m. It may be expected that in that altitudinal range it was not too cold for trees, and that at the same time, in spite of a considerable decrease in precipitation, humidity was still sufficient to allow tree growth. As is indicated in fig. 30 such areas could have been found in the mountains adjoining the Mediterranean in Lebanon, western Syria, and southwestern Turkey. Furthermore, in the mountains to the south of the Black Sea and the Caspian, forests could have maintained themselves. A problematical tree-refuge area is indicated in the Ruwandiz region, at the foot of a very high and massive section of the Zagros-Taurus Mountains, in northeastern Iraq. For Ruwandiz, at an elevation of about 1,000 m, a mean annual precipitation of c. 1,000 mm is reported. It should be emphasized that also outside the tree-refuge areas indicated in fig. 30 some tree species may have been able to survive unfavourable climatic periods.

The pollen evidence suggests that during the greater part of the Late-glacial, the climate was very unfavourable for tree growth. Late-glacial tree-refuge areas were probably in the same regions as the Pleniglacial tree stands. It is likely that because of the increase in temperature the Late-glacial forest stands were found at higher elevations.

At the end of the last glacial period trees started to spread from their refuge areas. One wonders whether the Würm-glacial forests adjoining the Black Sea and the Caspian contributed essentially to the reforestation of the Near East. The trees from these mesic forests are not adapted to the summer-dry climate in the greater part of Southwest Asia. Very probably, most trees spread

from the refuge areas in Lebanon, western Syria, and southwestern Turkey (van Zeist 1969).

8.6. Postglacial

The slow increase in trees at Zeribar and Mirabad during the lower Postglacial (c. 10,000-6,000 B.P.) suggests that at that time conditions for tree growth were less favourable than afterwards. The present-day natural vegetation pattern did not establish itself until c. 5,500 B.P. In the Postglacial, temperature cannot have been the limiting factor for tree growth in the Mirabad and Zeribar areas. Consequently, the most likely explanation for the slow expansion of trees is the assumption that during the lower Postglacial it was drier than at present. It was not until after 6,000 B.P. that humidity reached modern levels.

A drier lower part of the Postglacial is also suggested by the Söğüt diagram. The present-day natural vegetation in the Söğüt area is pine (*Pinus nigra*) forest. During the first half of the Postglacial (zone 4), in addition to pine, *Quercus* and *Juniperus* must have formed an important part of the forests in the Söğüt area (van Zeist *et al.* 1975). It was not until c. 3,000 B.P. that pine became the dominant tree in the area. The further development of the forest was interrupted by the large-scale interference of man with the vegetation (zone 6). The upper part of the diagram (zone 7) reflects the almost pure pine forest, which nowadays constitutes the climax vegetation in the Söğüt area. The development from oak-juniper-pine forests to pure pine forests would point to an increase in humidity in the course of the Postglacial.

The Beyşehir diagram (van Zeist *et al.* 1975) shows a strong increase in pine and decrease in cedar at the level dated to c. 5,850 B.P., indicating that by that time the present-day vegetation pattern became established. The replacement of cedar by pine could have been due to an increase in humidity, but this is not quite certain.

The pollen evidence from the Ghab does not provide unequivocal information on possible changes in climate in Postglacial times. Subzone Z₂ shows lower herb pollen values than subzone Z₃, suggesting that at first humidity was somewhat higher than afterwards. On the other hand, one could wonder whether the rise in pine in subzone

Z₃ indicates an increase in humidity. However, the possible effects of human interference with the vegetation should not be left out of consideration. Thus the increase in herbs in subzone Z₃ may be due to agricultural practices, whereas at present pine invades cleared areas in the mountains of western Syria. Be this as it may, it may be wise to refrain here from conclusions concerning changes in climate during the last 10,000 years.

Zones Y and Z₁₋₂ at Tenaghi Philippon show comparatively high percentages for *Pistacia* and *Sanguisorba (minor)*, while Gramineae pollen values are still high in this section. Bottema (1974) found the same in pollen diagrams from northern Greece, including the diagram from Edessa, c. 200 km west of the Tenaghi site. Bottema considers the presence of *Pistacia* and *Sanguisorba minor* and the rather high Gramineae percentages as evidence of open deciduous forests in the first stages of the Postglacial. On account of the radiocarbon date of 7,850 B.P. for subzone Z₁, the period representing more open vegetation would have lasted up to c. 6,500 B.P. Thus, the Tenaghi pollen record may point to relatively dry climatic conditions in the lower part of the Postglacial, from c. 11,000 to c. 6,500 B.P. Thereafter it would have become moister.

The Postglacial section of the Xinias diagram suggests a climatic history similar to that of Tenaghi and other pollen-diagram sites in northern Greece.

In summary, one may conclude that most pollen diagrams from the Eastern Mediterranean area suggest that the climate of the lower part of the Postglacial was drier than that of the later stages of this period. Two possible explanations can be brought forward for a drier early Postglacial. One can assume that the increase in humidity in the course of the Postglacial was at first brought about by a rise in precipitation, and that later a drop in temperature may also have contributed. This assumption implies that in early Postglacial times precipitation was less than nowadays. On the other hand, the greater dryness in the early Postglacial could also be explained by assuming that during that period the annual precipitation was not less than it is nowadays, but that as a result of higher temperatures, or of a longer rainless period, the summers were drier (van Zeist 1969).

8.7. Some archaeological implications

In 1960, the investigation of the vegetational history of western Iran was started as part of a program for the study of prehistoric environments in the Near East. The impetus to this study came from the side of the archaeologists who became very much interested in the Late Quaternary climatic history of Southwest Asia. It was in this area that the domestication of plants and animals took place 8,000 to 10,000 years ago, and the question has been posed to what extent changes in climate and vegetation had stimulated the beginning of food production. According to the then-existing theory, a moist Würm-glacial (pluvial) had been succeeded by a much drier Postglacial. It was assumed that the early Postglacial desiccation and the subsequent drastic decline in the area that could support food gatherers had induced prehistoric man to start food production. This archaeological theory is invalidated by the palynological results obtained for the Eastern Mediterranean area, which indicate that the area suitable for a food-collecting economy had increased after the last glacial period rather than decreased (*cf.* van Zeist 1969).

The assumption of a smaller amount of rainfall in the early stages of the Postglacial (8.6.) seems difficult to reconcile with the location of various early Neolithic sites. Early agricultural sites, such as Ali Kosh in Iranian Kuhzestan, Ramad, Ghoraifé, and Aswad near Damascus, and Beidha in western Jordan, are situated in areas where, under the present climatic conditions, dry farming is already marginal (fig. 30). It is difficult to imagine that in the sites mentioned above dry farming could have constituted an important base of subsistence if the precipitation was even lower than that of today. It was for that reason that van Zeist (1969) wondered whether the rainfall was perhaps not less than at present but that the summers were drier (see also 8.6.). A more severe summer dryness would not have affected cereal and leguminous plants because these annuals complete their vegetation cycle before it becomes really hot and dry. On the other hand, if in early Neolithic times rainfall was less than it is at present, the question arises whether perhaps at a very early stage in agriculture, prehistoric farmers managed to make up for insufficient precipitation.

There are, indeed, indications for an early exploitation of surface water. Helbaek (1969) suggests that the early inhabitants of Ali Kosh (Bus Mordeh phase) planted their crops at the edge of a lake that extended up to the site. Tell Aswad, which was inhabited from c. 7,800 to c. 6,600 B.C. (de Contenson 1973), is situated in an area with a mean annual precipitation of less than 200 mm. This is too low to rely on for dry farming, for which an average annual rainfall of at least 250 mm is required. At the time of the habitation of tell Aswad, Lake Ateibe, a fresh-water lake c. 30 km east of Damascus, may have extended up to the site. One wonders whether the Aswad farmers planted their crops on the shore of the lake, thus providing the plants with several weeks of extra moisture at the beginning of the dry season. This assumption is supported by the fairly numerous seeds of the marsh plant genera *Carex* and *Cyperus* recovered from the Aswad samples (J. A. H. Bakker-Heeres, in preparation). The inhabitants of Ghoraifé, dated to c. 6,750-6,200 B.C. (de Contenson 1976), with the same climatic conditions as at Aswad, could likewise have cultivated their cereal and leguminous crop plants on the shore of Lake Ateibe. An early utilisation of surface water for agricultural purposes also seems likely for Jericho, for which site a mean annual precipitation of c. 140 mm is reported. Here the powerful spring, to which Jericho owes its origin, could have provided the water.

It must be admitted that there is no proof for the exploitation of surface water in early Neolithic times. One could, for instance, imagine that at Aswad and Ghoraifé plant cultivation was only of minor importance, and that more or less regular crop failures did not threaten the survival of the sites. The inhabitants of early Neolithic Jericho could have obtained agricultural produce from farmers on the uplands adjoining the Jordan valley in exchange for salt, bitumen, and sulphur from the Dead Sea shore. On the other hand, one should seriously consider the possibility that the first efforts in exploiting surface water, which was ultimately to lead to highly sophisticated irrigation techniques, date back to the early stages of agriculture.

9. SUMMARY

In this paper the palynological examination of sediment cores from Lake Zeribar and Lake Mirabad in the Zagros Mountains of western Iran is discussed. Radiocarbon dates suggest that the Lake Zeribar pollen record covers the last 40,000 years, that of Lake Mirabad the last 10,000 years.

Topography, climate and natural vegetation of western Iran are briefly reviewed in chapter 2 (figs. 1-3). Information on the coring localities is presented in chapter 3. In chapter 4 short descriptions are given for a great number of pollen types distinguished in the Iranian sediment cores (figs. 10-20).

In the period of c. 40,000 to c. 10,500 B.P. open vegetations, in which Chenopodiaceae, *Artemisia*, and Umbelliferae played a predominant part, prevailed in the Zagros Mountains. The high percentages for umbelliferous pollen, among which a fairly large number of types could be distinguished, are a conspicuous feature of the Zeribar pollen diagrams.

Scattered tree stands were present in the Zeribar area in the period of c. 40,000-22,000 B.P., whereas between c. 22,000 and 14,000 B.P. trees had disappeared completely from the Zeribar area and probably from the greater part of the Zagros Mountains. Climatic dryness must have been a major limiting factor for tree growth in western Iran in Pleniglacial times.

After 14,000 B.P. pistachio was again present in the Zeribar area. Trees (*Pistacia*, *Quercus*, *Acer*, and others) expanded slowly in western Iran after 10,500 B.P., which resulted in forest-steppe vegetation. The nature of the herbaceous vegetation differed markedly from that in Pleniglacial times. It was not until c. 5,500 B.P. that the present-day natural forest cover had established itself. In the upper sections of the Zeribar and Mirabad diagrams distinct indications of human activity are recorded.

A comparison of the Zeribar pollen record with that of sites in Greece, southwestern Turkey, and western Syria indicates that the Pleniglacial climate of continental western Iran must have been more adverse to tree growth than that of areas near the Mediterranean coasts. Most pollen diagrams from the Eastern Mediterranean area suggest that the early Postglacial climate was drier than that of to-day.

Whether this was due to lower precipitation or to drier summers (higher temperatures, longer rainless period) is not yet clear. Finally some archaeological implications of the results of the palynological investigation are discussed.

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