MODERN POLLEN RAIN IN WESTERN IRAN, AND ITS RELATION TO PLANT GEOGRAPHY AND QUATERNARY VEGETATIONAL HISTORY*

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INTRODUCTION

Reconstruction of vegetational history through pollen analysis involves ecologic and floristic interpretation of pollen diagrams prepared from lake sediments or other continuous records. Because we lack knowledge of the relative pollen production and dispersal of the various plant taxa involved, the ecological interpretation of a particular pollen-assemblage zone is often unsure. The task is simplified if the modern pollen rain is known and can be compared with extant vegetation.

Historical studies through pollen analysis therefore require two supplementary programmes in addition to the collection of sediment cores and the actual preparation of the pollen diagram, especially in new areas. First the phytogeography of the area must be surveyed, with some attention to the climatic, microclimatic, edaphic and human factors where appropriate or possible. Then samples of moss or surface soil must be taken from representative localities over a wide area to determine by pollen analysis the relation between the modern pollen rain and the modern vegetation. If these pollen spectra match any spectra in the sediment core, then we have a basis for reconstructing past vegetation and, by extension, climatic conditions. If no match can be made, then we must either look elsewhere for modern analogues or conclude that the past vegetation of a particular time interval near the site has no modern counterpart.

An investigation of the vegetational and climatic history of south-western Iran was initiated in 1960 in connection with archeological studies in the area by Professor R. J. Braidwood of the Oriental Institute, University of Chicago. Several lake sites were cored, and a preliminary pollen diagram for one of the sites, Lake Zeribar, has been published (van Zeist & Wright 1963). The results were sufficiently interesting to justify the comprehensive supporting studies outlined above.

It was necessary for us to make extensive collections of the flora in order to provide a set of pollen-reference slides vital for aid in the identification of the unknown pollen types encountered in the analyses. Accordingly a collection of about 750 plants was made in 1961 by Wright and Anne M. Bent with the assistance of R. A. Watson and R. F. Wright, and in 1963 a collection of about 850 plant species was made by Marius Jacobs of the Rijksherbarium of Leiden. A set from both collections is deposited in the herbarium of the Museum of Natural History at Vienna, where identifications were made by Dr K. H. Rechinger and collaborators. Pollen samples from these specimens, supplemented by samples from the herbaria at Vienna, Kew, Minnesota, and Groningen, have provided a reference collection of about 1400 slides from western Iran, which,

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when supplemented by reference material from adjacent areas, provides a proper base for the identification of unknown pollen types.

The plant collecting was supplemented by reconnaissance in the field to check the zonation delineated by plant geographers. At the same time, surface samples were acquired along transects across the several vegetational zones from the Mesopotamian Lowland on the south to the interior plateau in Iran. The present report presents the results of the pollen analysis of the surface samples, and it then applies the results to refine the interpretation of the Lake Zeribar pollen diagram, which was initially presented without the benefit of these supporting studies.

The field work and collections of the samples were made by Wright in 1960 and by Wright and van Zeist in 1963. The pollen analyses were completed by McAndrews with the collaboration of van Zeist at the University of Groningen in 1964. More detailed pollen diagrams for Lake Zeribar and other lake sites in south-western Iran are now in preparation. The present report provides the information on the modern pollen rain that can be utilized for interpretation of all of the sites.

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**GEOGRAPHIC SETTING**

*Physiography*

The three great physiographic provinces of western Iran are the Mesopotamian Lowland, the Zagros Mountains, and the Iranian Plateau (Fig. 1).

Most of the Mesopotamian Lowland has been an area of tectonic subsidence since the Alpine orogeny began in the Tertiary, although isolated linear folds interrupt the structure in places. Many of these folds have the proper structure and stratigraphy to provide vast petroleum reservoirs. The superficial strata are largely Tertiary red beds and gravels, and only locally are the structures high enough to bring the hard, early-Tertiary limestones to the surface to interrupt the rolling terrain of the piedmont, which is eroded on relatively soft Tertiary beds. The land therefore rises gradually from the Tigris River across slightly dissected pediments and low hills to the first tree-covered foothills, and this is the area of intensive dry-farming—at least intensive by Near Eastern standards. Minor irrigation schemes are developed where major transverse streams debouch from the mountains, or where limestone springs sustain a steady summer source of water.

The most impressive debouchment of mountain streams in the entire area is the great composite fan of Khuzestan (Fig. 2). It was constructed between the Kebir Kuh and the Persian Gulf by the Karkheh, Karun and Diz Rivers, which have spread their yield of sediments over the piedmont in anatomosing channels. The fan protrudes so far into Mesopotamia that it constricts the lowland, essentially cutting off the Persian Gulf from the great marshlands of lower Iraq, and forcing the Tigris westward to join the Euphrates just above the gulf. Khuzestan has been a locus of intensive habitation both before and since the ascendance of Susa, the great capital city of Darius and the Persian Empire of the sixth century B.C., for the plain is at the main road and gateway from the Persian Gulf to the interior plateau and the other great Persian capitals of historic time. The vast fan is criss-crossed with irrigation canals and quanta (underground
Fig. 1. Vegetation map of western Iran, slightly generalized from Zohary (1963), who used the term steppe forest instead of savanna. Numbers show location of pollen surface samples in the four transects marked by ovoid areas.
canals for village water supply), which record millenia of water manipulation (Adams 1962).

The great Taurus–Zagros mountain arc extends unbroken from south-western Turkey to Afghanistan as part of the Alpine–Himalayan Mountain System; it presents a striking series of long ridges and valleys controlled by the unfaulted folds of Cretaceous and early Tertiary limestones. The ridges increase in height toward the interior; longitudinally there are two great culminations, one in the Cilo Dagh–Algurd Dagh area in the south-eastern corner of Turkey and in adjacent Iraq (Wright 1961), the other in the Zardeh Kuh, 650 km south-east along the range.

On the inner side of the Taurus–Zagros fold ridges lies the high, dry Iranian and Anatolian plateaus, which are great steppelands interrupted at random by low mountains. They grade eastward to the severe desert basins of eastern Iran. The intermontane areas show long, terraced piedmont slopes with gravelly fans, sparsely dotted with villages supported by small, ephemeral streams and land cultivated with difficulty. Some of the intermontane basins contain permanent lakes. These are in structural basins not yet filled with sediment, or they are in lowlands dammed by volcanic deposits. The largest lake of this type is Urmia, which has salt water and little life; to the east in the lower, hotter part of the plateau the lakes are just as large but are ephemeral or entirely dry, like the Dasht-e-Lut (Bobek 1959).
The dominating factors in the climate are the regime of summer drought and the influence of orography. Winter storms reach the areas from the Mediterranean Sea and veer along the mountain arc. The plateau is largely in the shadow, the more so where the mountains are high, as in the area extending from the Cilo Dagh–Algurd Dagh area of the Turkish corner. Farther south-east, where few of the ridges exceed 2000 m in elevation, the isohyets protrude inward (Wright 1961).

The orographic effect is shown even by the crude records of temperature and precipitation that are available (Wright 1961). Plots along two transects from the lowlands across the mountains to the plateau show a mean annual temperature lapse rate for ground stations of 0.7°C/100 m, along with a much less precise precipitation curve that likewise changes with elevation, at least on the outer flank of the mountains. The stations on the plateau, however, are more affected by distance from the rain source and by the shadow effect of the Cilo Dagh section than they are by local elevation.

Plant geography

The flora of western Iran is relatively well known. The Flora Orientalis of Boissier (1867–88) was the only reference work for a long time. In Parsa's Flore de l'Iran (1943–59) additions to the flora of Iran are included. A new flora of Iran (Flora Iranica) has been started by Rechinger (1963+) and collaborators.

The vegetation is known in its broad outlines by the studies of Bobek (1951, 1954), Pabot (1960) and Zohary (1963), of which the last-named considers both the floristic and ecologic aspects of plant geography. A section of the map of Zohary provides a satisfactory base for consideration of the plant-geographic regions pertinent to the present problem (Fig. 1).

Four major vegetation formations may be recognized: steppe of the Mesopotamian piedmont, savanna ('steppe forest') of the Zagros foothills and of the mountains of the interior plateau, oak woodland of the Zagros Mountains, and steppe of the interior plateau. The oak woodland on the Mesopotamian side (its lower or outer side) and particularly on its plateau side (inner side) is marked by areas in which human disturbance has left only groves or individual trees. The extent of the natural woodland must have been much greater in these areas before the times of disturbance, and accordingly they are here called respectively the outer and inner deforested areas, following Zohary. The map of Zohary (Fig. 1) shows that the inferred breadth of the natural woodland (250 km wide, reaching to Hamadan) was greatest in the Marivan–Khorramabad segment of the mountains. The relatively low height of the ridges in this segment permits the deeper invasion of storms from the Mesopotamian side (Wright 1961). The adjacent segments along the Zagros chain are so high that they block the penetration of storms into the plateau.

This factor, along with a greater number of separate mountains on the plateau northeast of Hamadan, accounts for the broad protrusion of the map unit designated by Zohary as originally steppe forest—a protrusion that reaches in fingers entirely across the plateau to the Elburz Mountains and breaks the Artemisia steppe into two areas, that around Tabriz and that extending eastward from Iraq (Fig. 1). The steppe forest (savanna) is now represented only by isolated trees or patches of Pistacia or Amygdalus, the rest of the area having been modified by cutting or other disturbance.

The savanna on the outer flank of the Zagros Mountains covers a narrower belt close
to the oak woodland and has a somewhat different composition. Besides *Pistacia* and *Amygdalus*, it contains *Ziziphus* and other plants that are dominant at still lower altitudes.

The steppe of the interior plateau, dominated by *Artemisia herba-alba* Asso, is confined to areas that are not only dry but have relatively cool winters. The northern area around Tabriz continues westward in intermontane valleys to central (but not moister western) Anatolia. The southern area extends eastward to Afghanistan, and in south-eastern Iran where the Zagros ridges are very low it almost comes into contact with the low-altitude desert steppe bordering the Persian Gulf.

**Land use**

Millenia of human activity have left their impress on the Zagros woodland through cutting of trees for charcoal, grazing of seedlings and sprouts by goats, and removal of trees for cultivation of grain. The degree of disturbance depends on the density and size of villages, on accessibility from treeless (and thus fuel-less) areas, and the movements of semi-nomads who travel annually from lowland to plateau and back. These factors in turn depend on the terrain, especially on the location of gaps that provide access through the ridges to the interior.

The travel routes are localized by two factors. First, the pattern of fold ridges provides structural gaps where plunging fold axes carry resistant strata underground. In places one can thread a zigzag lowland course across much of the fold belt by following around the noses of separate folds. Secondly, water gaps are provided by the great transverse rivers that lead from the plateau to the Tigris River in Mesopotamia. These include the upper Tigris, Greater Zab, Lesser Zab, Diyala, Karkheh and Karun. Some of these rivers have been localized in places by the plunges of the folds; here the rivers have cut modest canyons by autosuperposition onto a limestone bed. But most of the water gaps transect the higher parts of the folds, seemingly at random, and may either be antecedent or may be superimposed from the mass of Miocene and Pliocene alluvial sediments that once covered much of the present fold area to a thickness of thousands of metres, having been formed as the mountains were rising on the plateau side of the fold belt. At any rate, these impressive water gaps provide breaches through the imposing walls that otherwise rise 300–2000 m above the adjacent intermontane valleys. Although the travel routes through the water gaps may be difficult and hazardous (e.g. the Ruwandiz Gorge, as described by Hamilton 1937), their existence has been vital to the human economy of the region from prehistoric time to the present. Today many of the gorges provide ideal sites for multipurpose dams and are so being exploited by the governments of Turkey, Iraq and Iran.

In the area of the Taurus–Zagros Mountains under consideration in south-western Iran, two major traditional routes are apparent, one followed today by the highway from Baghdad through Khanaquin to Kermanshah and thence to Tehran on the Caspian Sea, the other by the highway from Khorramshahr (at the head of the Persian Gulf) through Khorramabad to Tehran (Fig. 1). They start at their lower ends by circumventing the opposite ends of the great doubly plunging fold system that makes the Kebir Kuh and related high ridges; then they transect gorges to enter intermontane valleys and plains. They thus thread their way through and around successive ridges of limestone and, as the plateau is approached, through the belt of metasedimentary rocks that represents the zone of maximum orogenesis. The natural vegetation along these major travel routes is vastly disturbed by human activity extending over many millenia.
POLLEN RAIN

Methods

Two complete transects (Dizful and Ilam) and one partial transect (Zeribar) of surface samples were made from the steppe of the Mesopotamian piedmont across the oak woodland of the Zagros Mountains to the interior savanna of the plateau. A single transect (Tabriz) extended far into the Artemisia steppe of the Tabriz area and adjacent Turkey (Fig. 1). In all, sixty samples were analysed from fifty-six sites.

Most of the samples were patches of moss taken from rock outcrops or large boulders. Sample size was 3–5 cm$^3$. The projecting plant parts serve as an excellent trap for dust. In the few localities where satisfactory moss could not be found (because no stones were present or because the climate was too dry), plant detritus or surface soil was collected in the lee of a post or shrub or other object. Preservation in most cases was good.

Three paired samples (Nos. 1a, b; 9a, b; 15a and b) showed no major differences in percentages of the main pollen types between the moss and detritus samples, although the latter tended to have a larger number of pollen grains of local plants.

The following procedure was used on each sample:

1. Gentle boiling in 10% KOH for several minutes.
2. Screening to remove sand and large organic detritus.
3. Decanting to remove sand.
4. Repeated centrifuging and decantation of a water suspension (in a 50-ml centrifuge tube) to remove colloidal mineral matter.
5. Treatment with 10% HCl if necessary to remove carbonate.
6. Gentle boiling with c. 40% HF to remove silicates. (If much mineral matter remained, residue was heated in plastic centrifuge tube in water bath.)
7. Washing 3–6 times with hot 10% HNO$_3$ to remove the precipitate usually formed in step 5. Sample was left in HNO$_3$ only momentarily before each centrifuging so that pollen was not be damaged.
8. Acetylation.
9. Washing 3 times with water.
10. Addition of 1–2 drops of safranin stain.
11. Dehydration.
12. Mounting in silicone oil.

The pollen counts (Fig. 3) are grouped according to the four transects that involve the six plant-geographic regions described above.

The pollen sum on which the percentages are calculated includes all pollen counted, except the unidentified grains. In regions that are sparsely forested such a sum can provide a crude picture of the proportion of tree cover to herb cover. Pollen of insect-pollinated types is included in the sum, contrary to the usual custom, because the persistent occurrences of certain Tubuliflorae, Cruciferae, Umbelliferae and Caryophyllaceae imply that these types are dispersed at least in part by the wind. Then if a taxon shows an anomalously high value in a certain spectrum this taxon can be excluded from the sum for that spectrum, and the percentage bars can be recalculated for the major taxa so that the effect of the offending anomaly can be evaluated (Wright & Patten 1963). In the present study Ziziphus, Centaurea solstitialis L. type, Tubuliflorae undifferentiated, Liguliflorae undifferentiated, Echinophorae undifferentiated, Cruciferae, Galium type, Astragalus type and Forskohlea were excluded from the sum for certain spectra from upland sites, and undifferentiated Cyperaceae and Dryopteris type were excluded for
seven samples from the sedge mat around Lake Zeribar. The resulting spectra can then be considered as a closer representation of the regional pollen rain.

Steppe of the Mesopotamian piedmont

In the lower part of the Mesopotamian piedmont, at elevations of about 200 m and with annual rainfall of about 300–400 mm, the vegetation is a desert steppe containing widely scattered shrubs of *Paliurus spina-christi* Miller as well as shrubs dependent on local conditions, including *Ziziphus nummularia* (Burm.) Walk. *Tamarix* spp., *Lycium* spp., *Calligonum* spp., *Capparis sicula* Duham., *Prosopis stephaniana* (Willd.) Spreng. and *Suaeda fruticosa* (L.) Forsk. Near canals and rivers *Populus euphratica* Oliv. is common. Pabot (1960) notes that the herbaceous cover is restricted almost entirely to those unpalatable annuals that have resisted the grazing pressure.

One sample (No. 14) was taken from under a *Ziziphus* shrub in this vegetation zone on the Dizful transect, at a point about 60 km south of Dizful on the Khuzestan Plain at an elevation of about 70 m above sea level. The site is at least 75 km from the nearest oak woodland. The pollen rain of this single sample has no representation of trees of the oak forest (Fig. 3). *Ziziphus* pollen, however, constitutes 21% of the total and *Forskohlea* 36%. These high values may represent a local condition, for *Ziziphus* pollen is not well represented in samples in the next vegetation zone (savanna), where the tree itself is more abundant than in the steppe, so it probably does not have a large pollen production or distant dispersal. If these two types are excluded from the pollen sum, the remainder consists largely of chenopods and *Plantago*.

Savanna

In the low foothills and rolling plains above Mesopotamia up to elevations of about 700–800 m, a steppe with trees even on exposed locations implies the existence of a former savanna (Pabot 1960), although throughout most of the area the trees are many kilometres apart. Among the trees and shrubs are *Ziziphus spina-christi* (L.) Willd., *Pistacia khenjuk* Stocks, *P. atlantica* Desf., *Amygdalus scoparia* Spach, *Ficus carica* L. var. *rupestris* Hausskn. and *F. carica* L. var. *johannis* Boiss. (Pabot 1960). This is the *Amygdalus–Pistacia* steppe forest of Bobek (1951) and Zohary (1963, p. 35), but the word forest hardly seems an appropriate term without evidence for closed-canopy structure, so savanna is here used instead. Because of the greater rainfall, more varied topography, and less intensive cultivation than at lower elevations, the herbaceous flora is richer in perennials; it has fewer chenopods, and it contains numerous species from the Mediterranean region (Pabot 1960). Farther south-east along the Zagros Mountains, where the hills are lower south of Kerman in Fars, the pistachio savanna is broader (Merton 1961, p. 10).

A double surface sample (Loc. 15) was taken from this vegetation area on the Dizful transect, from near the head of the Khuzestan plain north of Dizful at an elevation of about 325 m (Fig. 2). A few *Paliurus* shrubs occur in the vicinity, but otherwise the area is treeless. Grain fields and weed-filled fallow fields are scattered among grazed areas. *Plantago* is the dominant weed. The oak-covered ridges of the Zagros Mountains are about 15 km to the north. Sample 15a came from under a *Paliurus* shrub, and sample 15b from moss on a rock outcrop.

In addition, two double samples were taken on the Ilam transect. One pair (1a from
### Vegetation Area

#### Transect
- **D**
- **I**
- **Z**

#### Elevation (meters)

#### Sample No
- **Outer Coss**
- **Artemisia**
- **Pistacia**
- **Acer**
- **Betula**
- **Alnus**
- **Ulmus**
- **Juglans**
- **Daphne**
- **Pinus**
- **Juniperus**
- **Salix**
- **Ziziphus**
- **Pollen**
- **Small**

#### Key
- **D** - Dizful
- **I** - Ilam
- **Z** - Zeribar
- **T** - Tabriz

- Percent of total pollen
- Percent of total pollen, excluding pollen type marked by X
- d Sample of detritus; other samples of moss

*(Facing p. 422)*
Fig. 3. Pollen diagram for surface samples. For location of sample sites and transects see Figs.
detritus under an _Astragalus_ shrub, 1b from moss on a rock) came from about 300 m elevation, the other (2a from dirt under a rock pile in a fallow field, 2b from detritus under a _Ziziphus_ shrub) from about 600 m. A lone _Pistacia_ tree occurred near each site, but shrubs of _Ziziphus_ and _Astragalus_ were more common. Grain fields and fallow fields were common around Loc. 2, but Loc. 1 is apparently beyond the limit of dry farming. These localities are respectively about 8 and 20 km in front of the oak-covered ridges of the Zagros Mountains.

The pollen rain for the six samples at these three localities in the savanna (Loc. 1, 2 and 15) is dominated by _Plantago_, which exceeds 40% in three of the samples after selected exclusions from the pollen sum (Fig. 3). _Artemisia_ accounts for less than 9% of the same total; the genus occurs in the Mesopotamian steppe (Pabot 1960, Zone B; Zohary 1963, p. 58), but it is not so abundant as on the Iranian Plateau. Tree pollen totals only a few per cent, and _Pistacia_ is present as well as _Quercus_. The anomalously high count for _Astragalus_ in sample 1a is explained by the fact that the sample consisted of detritus from under an _Astragalus_ shrub.

The samples from the savanna region allow a comparison between pollen rain and local vegetation. The surface samples have been taken in or near vegetation survey plots (relevés I, II and V of Table 1). The floristic composition of the vegetation has been analysed by the method of Braun-Blanquet (1951). In the table only the so-called cover/abundance has been given; the sociability has been omitted. The scale of values for cover/abundance as far as is pertinent to the relevés is as follows:

1. Sparse and covering only very little of the area.
2. Numerous, but covering only a little of the area, or fairly sparse but with greater cover value (up to 5%).
3. Very numerous, but covering only a little of the area, or with any number of individuals covering 5–25%.
4. Covering 25–50% of the area.

In order to facilitate the comparison between the relevés and the pollen spectra the sequence of the families in the table is the same as in the pollen diagram.

It should be emphasized that the relevés do not provide a complete picture of the vegetation. Various plants could not be identified, even to the family, because they had not yet developed flowers or flower buds. Moreover, the relevés show the situation at a certain time, and changes in the vegetation in the course of the year could not be recorded. For example, Marius Jacobs, who collected our plants in 1963, mentions that in June at a second visit to the Mirabad area _Centaurea brugiueriana_ (DC.) Hand.-Mzt. appeared to be a very common plant, whereas we did not observe this species in the same area in April. This example must be a warning of caution in relating vegetation to pollen rain from our data.

A comparison between relevés (I, II and V) and surface sample pollen spectra (1a, 1b, 2a, 2b, 15a and 15b) from the savanna region suggests that _Plantago_, _Artemisia_, and Chenopodiaceae are overrepresented in the pollen rain. This might be expected of wind-pollinated plants. It is possible that a part of the chenopodiaceous pollen is derived from the desert of south-western Iran, where, according to Pabot (1960), halophilous chenopods are the most abundant species. The pollen percentages of _Gramineae_, likewise wind-pollinated, are smaller than the share of grasses in the vegetation would suggest. On the other hand, pollen of insect-pollinated _Umbelliferae_, _Compositae_ and _Cruciferae_ is quite common in the surface samples.

Somewhat surprising is the occurrence of _Sparganium_-type pollen in various samples
Table 1. Relevés at four localities in Savanna and outer deforested area (see text under Savanna for explanation of symbols)

Relevé I at Loc. 1, 18 April 1963. Semi-desert, 5 km SSW of Amirabad, near Kunjan River 33° 17' N, 46° 15' E. Elevation about 300 m. Plot size 400 m². Near the survey plot are a few scattered small trees of *Pistacia* on virtually bare rocks. Plants outside the relevé include *Periplaca aphylla* Decne, *Prosopis* sp., *Amygdalus* sp., *Ephedra* sp., *Rumex cyprius* Murb., *Glaucium* sp., *Adonis dentatus* Del. ssp. *persicus* (Boiss.) Riedl., and *Plantago lagopus* L.

**Shrub layer**: very scarce

**Capparidaceae**
- *Capparis spinosa* L.

**Rhamnaceae**
- *Ziziphus spina-christi* (L.) Willd.

**Herb layer**: cover c. 5%

**Gramineae**
- *Stipa capensis* Thunb.
- *Aegilops* sp.
- *Heteranthemum piliferum* (Banks et Sol.) Hochst.
- *Leptochloa phleoides* (Vill.) Richt.
- *Aristida plumosa* L.

**Plantaginaceae**
- *P. bellardii* All. ssp.
- *P. coronopus* L.
- *P. ovata* Forsk.

**Chenopodiaceae**
- *Noaea* sp.

**Compositae tubuliflorae**
- *Artemisia* sp.
- *Achillea* sp.
- *Calendula cf. persica* C. A. Mey.
- *Evax* sp.

**Compositae liguliflorae**
- *Crepis* cf. *kotschyanana* Boiss.
- *Koelpinia* sp.

**Umbelliferae** (Echinophorae)
- *Anisociadium orientale* DC.

**Cruciferae**
- *Matthiola chenopodifolia* Fisch. et Mey.

**Caryophyllaceae**
- *Pteranthus dichotomus* Forsk.

**Rubiaceae**
- *Callipeltis microgemma* Boiss.
- *Galium* sp.

**Leguminosae**
- *Astragalus* sp.
- *Hippocrepis* sp.
- *Onobrychis* sp.

**Boraginaceae**

**Labiatae**
- *Salvia compressa* Vahl

**Liliaceae**
- *Liliaceae* indet.

**Geraniaceae**
- *Erodium glaucophyllum* Ait.
- *E. bryonifolium* Boiss.

**Cistaceae**
- *Helianthemum lippii* (L.) Pers.

**Thymelaeaceae**
- *Thymelaea* sp.

**Dipsacaceae**
- *Scabiosa* sp.

**Linaceae**
- *Linum strictum* L.
  - *var. scipicatum* (Lam.) Reichb.

**Primulaceae**
- *Anagallis arvensis* L.

Relevé II at Loc. 2, 18 April 1963. 20 km N of relevé I, c. 5 km NNW of Gulan. 33° 28' N, 46° 15' E Elevation about 600 m. Plot size 400 m². Grain fields in hilly landscape. Many stones.

**Herb layer**: cover 30–40%

**Gramineae**
- *Triticum* sp.
- *Crithopsis delileana* (Schult.) Roshed.
- *Lolium* sp.

**Plantaginaceae**
- *Plantago cf. psyllium* L.

**Compositae tubuliflorae**
- *Anthemis* sp.
- *Filago* sp.
- *Calendula cf. persica* C. A. Mey.
- *Gundelia tournefortii* L.

**Compositae liguliflorae**
- *Garhadiolus* sp.
- *Koelpinia* sp.

**Umbelliferae**
- *Bupleurum cf. semicompositum* Biel.
- *B. lancifolium* Hornem.
- *Torilis* sp.

**Cruciferae**
- *Brassica* sp.
CARYOPHYLLACEAE
1 Vaccaria cf. pyramidata Med.
+ Silene conoidea L.

Rubiaceae
2 Galium tricornutum Dandy
+ Callipeltis cucullaria L.

Leguminosae
+ Medicago hispida Gaertn.
  var. denticulata (Willd.) Urban
+ Trifolium campesatre Schreb.
+ Medicago orbicularis All.
+ cf. Onobrychis

BORAGINACEAE
+ Anchusa strigosa Labill.

Liliaceae
+ Ixiolirion sp.
+ Muscari sp.
+ Allium sp.

Ranunculaceae
+ Adonis dentatus Del.
  ssp. persicus (Boiss.) Riedl
+ Ranunculus asiaticus L.

Primulaceae
1 Anagallis arvensis L.

Malvaceae
+ Malva sp.

Valerianaceae
+ Valerianella cf. vesicaria (L.) Moench

Convolvulaceae
+ Convulvulus stachydifolius Choisy


Herb layer: cover c. 30%

Gramineae
1 Bromus sp.
1 Stipa capensis Thunb.
1 Poa sp.
+ Bromus fasciculatus Presl
+ Avena sp.
+ Alopecurus sp.
+ Dichanthium annulatum (Forsk.) Stapf
+ Heterantherium piliferum (Bank et Sol.) Hochst.

Plantaginaceae
2 Plantago ovata Forsk.
+ P. bellardii All.
  ssp. deflexa (Pilger) Rech. f.
+ P. lagopus L.

Compositae Tubuliflorae
+ Centaurea bruguieriana (DC.) Hand.-Mzt.
1 Calendula cf. persica C. A. Mey.
+ Filago sp.
+ cf. Echinops
+ Atractylis cancellata L.

Compositae Liguliflorae
1 Garadiolus sp.
1 Crepis cf. kotschyana Boiss.
+ Cichorium sp.
1 Crepis cf. thomsonii Babc.
+ Koelpinia sp.

Umbelliferae
1 Anisoscladium orientale DC.
1 Pimpinella sp.
1 cf. Oliveria

Cruciferae
1 cf. Erucaaria grandiflora Boiss.

Rubiaceae
+ Galium setaceum Lam.
  ssp. decaisnei (Boiss.) Ehrendf.

Leguminosae
+ Astragalus sp.
+ Prosopis sp.
1 Medicago coronata Lam.
Table 1 (Continued)

Relevé VII at Loc. 17, 27 April 1963. Landslide area near Mirabad. 33° 06' N, 47° 43' E. Elevation about 750 m. Plot size 400 m². Dense herbaceous vegetation between large boulders. *Ephedra* in crevice; a few small *Ficus* shrubs in the vicinity. Not far from survey plot are *Plantago cf. bellardi* All., *Plantago psyllium* L. and *Gentiana olivieri* Griseb.

*Herb layer: cover 90–100%*

**GRAMINEAE**

1. *Bromus sp.*
2. *Stipa capensis* Thunb.
3. *Bromus sterilis* L.
5. *Lophochloa philoides* (Vill.) Reichb.
7. *Avena sp.*
8. *Aegilops sp.*
9. *Bromus rubens* L.
10. *Poa sp.*
11. *Gramineae indet.*

**COMPOSITAE TUBULIFLORA**

1. *Silybum marianum* L.
2. *Notosyris syriaca* L.
3. *Atractylis cancellata* L.
4. *Anthemis sp.*
5. *Gundelia tournefortii* L.

**COMPOSITAE LIGULIFLORA**

1. *Crepis cf. pulchra* L.
2. *turkestanica* Babc.
4. *Garadhiolus sp.*
5. *Urospermum picroides* (L.) Schmidt

**UMBELLIFERAE**

1. *Oliveria sp.*
3. *Pimpinella sp.*
4. *Umbelliferae indet.*

**CRUCIFERAE**

3. *Cruciferae indet.*

**CARYOPHYLLACEAE**

1. *Silene sp.*
2. *Arenaria leptoclados* Reichb.

**RUBIACEAE**

1. *Callipeltis cucchalaria* L.
2. *Galium setaceum* Lam.
4. *G. tricornutum* Dandy
5. *cf. Asperula arvensis* L.

**LEGUMINOSAE**


2. *Trifolium sp.*
4. *T. stellatum* L.
5. *T. formosum* UVV.
6. *T. resupinatum* L.
7. *Hippocrepis sp.*
9. *cf. Medicago*

**BORAGINACEAE**

1. *Boraginaceae indet.*

**URTICACEAE**

1. *Urtica pilulifera* L.

**LABIATAE**

2. *S. cf. multicaulis* Vahl

**LILIACEAE**

1. *Muscari sp.*

**SCROPHULARIACEAE**

1. *Celsia orientalis* L.

**RANUNCULACEAE**

1. *Delphinium sp.*

**GERANIACEAE**

2. *Geranium sp.*
3. *G. lucidum* L.

**CISTACEAE**

1. *Helianthemum salicifolium* (L.) Mill.

**LINACEAE**

1. *Linum strictum* L.
2. *var. spicatum* (Lam.) Reichb.

**PAPAVERACEAE**

1. *Papaver sp.*

**PRIMULACEAE**

1. *Anagallis arvensis* L.

**MALVACEAE**

1. *cf. Althaea*

**VALERIANACEAE**


**CAMPANULACEAE**

1. *Campanulaceae indet.*

**CUCURBITACEAE**

1. *Cucurbita*

**CRASSULACEAE**

1. *Sedum cf. rubens* L.

from the savanna region, for suitable habitats for such shallow water reeds as *Sparganium* spp. or *Typha angustifolia* L. are not present in the area.

**Zagros oak woodland**

**Vegetation**

*Quercus persica* Jaub. et Spach (also called *Q. brantii* Lindl. ssp. *persica* (Jaub. et Spach) Schwarz) is clearly dominant in the Zagros oak woodland, which occurs at
H. E. Wright, Jr, J. H. McAndrews and Willem van Zeist


Closer toward the upper tree-line *Lonicera nummularifolia* Jaub. & Spach, *Crataegus ambiguca* Becker, *Amygdalus elaeagnifolia* Spach and *Juniperus excelsa* Bieb. may be found on the slopes in addition to most of the species previously listed, and *Elaeagnus angustifolia* L., *Crataegus monogna* Jacq., and *Ulmus* sp. occur in the valleys. The woodland is less degraded than below, and perennial herbs are more common (Pabot 1960). The degradation is more severe on the south-facing slopes, where the initially more open tree cover provides easier accessibility to wood cutter and goatherd. The upper treeline may be disturbed by cutting and grazing through activities of the Kurdish nomads, who came to the high mountain ridges for the summer. An almost undisturbed treeline area was studied by M. Jacobs on Manisht Kuh, a flat-topped limestone ridge at the nose of a fold (Loc. MK) 8 km north of Ilam. 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.

Near the lower forest line (700–900 m), the trees are largely confined to north-facing slopes, and the forest cover has been severely depleted by cutting and grazing. The shrub and herb flora is not rich; annuals dominate the herbs because of overgrazing on perennial grasses and other forage species (Pabot 1960). Zohary's map (Fig. 1), following Bobek (1951), makes a distinction between the areas of present oak forest or woodland and the de-forested areas, the latter being delineated by the occurrence of surviving groves of trees near cemeteries and relatively inaccessible localities.

The extant oak woodland was measured at seven localities by the point-centred quarter method (Cottam & Curtis 1956). One tree in each quadrant at ten stations on a line was measured, and the following calculations were made: relative density (percentage of each species among the forty trees counted), relative dominance (percentage for each species according to basal area of trunk at breast height), and relative frequency (percentage of the ten stations at which each tree occurred). In addition, percentage tree cover and percentage shrub cover were determined along a separate 20 m line extending through each of the stations; relative cover, and density of saplings per hectare were calculated for the same line. Some of the measurements caused trouble because of the sprouting of suckers of cropped oaks. Basal areas were therefore not calculated in some cases; also, saplings could not be easily distinguished from suckers. Shrubs were arbitrarily considered as woody plants with stem diameter less than 15 cm at breast height; but in some cases the oak cover was so scruffy that no real distinction could be made between trees and shrubs, so cover values were grouped together. The importance value (Curtis & McIntosh 1951) averages three measures of relative importance of the different trees; it is the most useful quantity in comparing woodland composition with pollen rain (McAndrews 1966).

The results of the tree counts are shown in Table 2. In the summary at the base of
Table 2. Tree counts at seven localities in Zagros Mountains, according to point-centred quarter method (Cottam & Curtis 1956)

<table>
<thead>
<tr>
<th>Locality</th>
<th>Relative density (%)</th>
<th>Relative dominance (%)</th>
<th>Relative frequency (%)</th>
<th>% cover</th>
<th>Saplings per hectare</th>
<th>IV/3*</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MILAVI</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loc. 18 (950 m)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Quercus persica</em> Jaub. et Spach</td>
<td>29</td>
<td>72</td>
<td>78</td>
<td>50</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><em>Pistacia cf. khinjuk</em> Stocks</td>
<td>4</td>
<td>10</td>
<td>12</td>
<td>15</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><em>P. mutica</em> Fisch. et Mey.</td>
<td>3</td>
<td>8</td>
<td>5</td>
<td>15</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td><em>Acer cinerascens</em> Boiss.</td>
<td>3</td>
<td>8</td>
<td>4</td>
<td>15</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td><em>Amygdalus</em> sp.</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>5</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>SHARAZUL N</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loc. S. (1400 m)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Quercus brantii</em></td>
<td>39</td>
<td>98</td>
<td>100</td>
<td>91</td>
<td>25</td>
<td>2</td>
</tr>
<tr>
<td><em>Crataegus</em> sp.</td>
<td>1</td>
<td>2</td>
<td>9</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><em>Prunus</em> sp.</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>+</td>
</tr>
<tr>
<td><strong>SHARAZUL S</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loc. 9 (1600 m)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Quercus persica</em></td>
<td>24</td>
<td>60</td>
<td>38</td>
<td>48</td>
<td>32</td>
<td>0</td>
</tr>
<tr>
<td><em>Acer cinerascens</em></td>
<td>9</td>
<td>23</td>
<td>24</td>
<td>29</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td><em>Pistacia khinjuk</em></td>
<td>6</td>
<td>15</td>
<td>38</td>
<td>19</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td><em>Loniceria</em> sp.</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>+</td>
</tr>
<tr>
<td><em>Daphne angustifolia</em> C. Koch</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>+</td>
</tr>
<tr>
<td><strong>WARDALAN N</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loc. W (1700 m)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Quercus persica</em></td>
<td>37</td>
<td>94</td>
<td>76</td>
<td>12</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><em>Crataegus</em> sp.</td>
<td>1</td>
<td>2</td>
<td>8</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><em>Amygdalus</em> sp.</td>
<td>1</td>
<td>2</td>
<td>8</td>
<td>1</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td><em>Amygdalus</em> sp.</td>
<td>1</td>
<td>2</td>
<td>8</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
### Wardalan S

Loc. 11 (1700 m)

<table>
<thead>
<tr>
<th>Species</th>
<th>Mean distance (m)</th>
<th>Mean area per tree (m²)</th>
<th>No. trees per hectare</th>
<th>No. saplings per hectare</th>
<th>Basal area per tree (cm²)</th>
<th>Tree Cover (%)</th>
<th>Shrub Cover (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Quercus persica</em></td>
<td>13</td>
<td>33</td>
<td>28</td>
<td>36</td>
<td>2</td>
<td>0</td>
<td>28</td>
</tr>
<tr>
<td><em>Pistacia khinjuk</em></td>
<td>18</td>
<td>45</td>
<td>69</td>
<td>41</td>
<td>4</td>
<td>0</td>
<td>57</td>
</tr>
<tr>
<td><em>Amygdalus sp.</em></td>
<td>7</td>
<td>18</td>
<td>2</td>
<td>13</td>
<td>1</td>
<td>0</td>
<td>15</td>
</tr>
<tr>
<td><em>Astragalus sp.</em></td>
<td>1</td>
<td>2</td>
<td>+</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><em>Crataegus sp.</em></td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

### Zeribar W

Loc. M (1350 m)

<table>
<thead>
<tr>
<th>Species</th>
<th>Mean distance (m)</th>
<th>Mean area per tree (m²)</th>
<th>No. trees per hectare</th>
<th>No. saplings per hectare</th>
<th>Basal area per tree (cm²)</th>
<th>Tree Cover (%)</th>
<th>Shrub Cover (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Quercus persica</em></td>
<td>40</td>
<td>100</td>
<td>100</td>
<td>40</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><em>Prunus sp.</em></td>
<td>0</td>
<td>0</td>
<td>-</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>3</td>
</tr>
</tbody>
</table>

### Zeribar E

Loc. E (1300 m)

<table>
<thead>
<tr>
<th>Species</th>
<th>Mean distance (m)</th>
<th>Mean area per tree (m²)</th>
<th>No. trees per hectare</th>
<th>No. saplings per hectare</th>
<th>Basal area per tree (cm²)</th>
<th>Tree Cover (%)</th>
<th>Shrub Cover (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Quercus persica</em></td>
<td>39</td>
<td>98</td>
<td>-</td>
<td>91</td>
<td>21</td>
<td>0</td>
<td>96</td>
</tr>
<tr>
<td><em>Crataegus sp.</em></td>
<td>1</td>
<td>2</td>
<td>-</td>
<td>9</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><em>Prunus sp.</em></td>
<td>0</td>
<td>0</td>
<td>-</td>
<td>0</td>
<td>+</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td><em>Rosa sp.</em></td>
<td>0</td>
<td>0</td>
<td>-</td>
<td>0</td>
<td>+</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

### Summary

*IV/3 = Importance value divided by 3. Importance value is relative density + relative dominance + relative frequency.*
the table the sizes and spacing of the trees are expressed in different ways, and the sites are arranged according to decreasing density of trees.

On the Dizful transect a site (Loc. 18) was chosen on the side of the Karkheh River gorge on a north-facing slope 2 km east of the village of Milavi (Table 2). This gorge has long served as a principal travel route across the mountains, so that many of the oak trees have been cropped to non-flowering scrub. None the less, the composition of the woodland, if not the size or the crown coverage of the individual trees, is fairly characteristic of much of the Zagros area. The wide spacing of the trees may be accentuated by the disturbance and by the steep and rocky character of the slope, but more than that it reflects the low elevation of the site, close to the lower forest line.

On the Ilam transect the oak woodland was measured at four localities. A rare, fully developed, and essentially undisturbed oak woodland was measured at the east end of the valley south of Kuh-i-Sharazul, 7 km north-west of Ilam (Loc. 9) (Table 2). Handsome specimens of Quercus, Acer and Pistacia reach diameters of 1 m. The absence of cut limbs on the trees and the abundance of dead branches both on the trees and on the ground indicate that the woodland has not been used as a source area for fuel, although the virtual absence of seedlings and saplings may mean that the recent grazing of goats prevents regeneration of this magnificent woodland. The site is in a dry, blind valley bounded by high ridges; it has not been a route of travel until the recent construction of the new road from Shahabad to Ilam, which in fact crosses the sharp crest of the Kuh-i-Sharazul in a tunnel. Farming, grazing and wood-cutting on these ridges and isolated intermontane valleys has been minimal, not only because of their inaccessibility but also apparently because of inadequate water supply. The transition in disturbance between this site and Ilam is striking; just a few kilometres to the west down the valley towards Ilam the dead branches are gone from the trees, and many of the oaks are severely cropped. Still farther towards Ilam the woodland is more of a savanna, and the openings between trees are cultivated to grain. As Ilam itself is approached (Loc. 8) the oaks are widely scattered, and grain fields are everywhere.

Another tree count from near the north base of Kuh-i-Sharazul (Loc. S) shows that little but oak occurs in the woodland, here relatively undisturbed.

Two other counts were made high on opposite sides of Kuh-i-Wardalan, another principal limestone ridge in the Zagros Mountains. On the north-facing slope (Loc. W), the woodland is almost entirely oak, so badly converted to scrub by cutting and grazing that basal-area measurements and sapling density were not recorded. On the more xeric south-facing slope (Loc. 11) of the same ridge and at about the same elevation (1700 m), the composition is more diversified, and the structure is much more like a savanna, with only 8% tree cover. Large, isolated trees of oak and pistachio are widely scattered, with grasses and forbs below.

Two tree counts were made on the Zeribar transect, on the hills to the west (Loc. M) and east (Loc. E) of Lake Zeribar. In both cases the woodland was almost entirely oak, which had so many sucker shoots as a result of the severe cropping that basal measurements could not be made. These sites are only 25 km from the present inner edge of the oak woodland.

In the forests and forest remnants elsewhere near Lake Zeribar the following trees and shrubs were observed: Quercus persica Jaub. et Spach, Q. ibérica Stev Crataegus sp., Amygdalus sp., Pyrus cf. syriaca Boiss, Acer cinerascens Boiss, Lonicera nummulariifolia Jaub. et Spach, Pistacia mutica Fisch. et Mey., Berberis sp., Rosa sp., Daphne staphii Bornm. et Keissl., Fraxinus sp., Sorbus sp., Rubus sp., Populus sp., Salix sp., Prunus sp.,
Tamarix sp. and Cornus sp. Relevés made in the wooded hills east of Lake Zeribar (Loc. 26 and 28) are shown in Table 3.

Lake Zeribar itself is about $5 \times 3$ km in area and is surrounded by a floating sedge mat locally as much as 1 km wide (Fig. 4). Ranunculus cf. peltatus Schrank spp. sphaerospermus (Boiss. et Blanche) Meikle and Rorippa amphibia (L.) Bess. are common in the open water that locally occurs next to the shore. Carex hudsonii A. Benn. forms large tussocks on the mat. Of the other plants observed on the mat the following may be

Table 3. Relevés at two localities east of Marivan on Zeribar transect

Relevé VIII. at Loc. 26. 5 May 1963. North-facing slope on limestone, about 15 km E of Marivan. 35° 32' N, 46° 21' E. Elevation c. 1450 m. Plot size 600 m². Scattered coppice, grazing. Salix along rivulet at the foot of the slope.

Tree layer: cover 40–50%
Fagaceae
2 Quercus persica Jaub. et Spach.
Anacardiaceae
1 Pistacia mutica Fisch. et Mey.
Aceraceae
2 Acer cinnamomum Boiss.
Caprifoliaceae
1 Lonicera nummulariafolia Jaub. et Spach
Rosaceae
2 Pyrus cf. syriaca Boiss.
+ Crataegus sp.
拢 DRANThaceae
+ Loranthus grewinkii Boiss. et Buhse
Shrub layer: cover c. 10%
Fagaceae
1 Quercus persica Jaub. et Spach.
Aceraceae
+ Acer cinnamomum Boiss.
Caprifoliaceae
+ Lonicera nummulariafolia Jaub. et Spach
Rosaceae
1 Amygdalus sp.
1 Pyrus cf. syriaca Boiss.
Thymelaeaceae
1 Daphne staphylifolia Bornm. et Keissl.
Herb layer: cover 80–100%
Gramineae
1–2 Poa bulbosa L.
ssp. vivipara Koel.
Compositae Tubuliflorae
+ Achillea sp.
Umbelliferae
3 cf. Anthriscus
1–2 Pimpinella sp.
+ Smyrnium cordifolium Boiss.
1 Umbelliferae indet.
Cruciferae
+ Isatis sp.
+ Matthiola sp.
+ Capsella bursa-pastoris (L.) Med.
+ Parlottaria sp.
1 Cruciferae indet.
+ cf. Matthiola
Rubiaceae
1 Cruciata coronata (Sibth. et Sm.) Ehrendf.
ssp. persica (DC.) Ehrendf.
1 Galtum tricornutum Dandy
1 Galtum sp.
Rosaceae
+ Pyrus cf. syriaca Boiss.
Leguminosae
+ Astragalus sp.
+ Leguminosae indet.
Boraginaceae
+ Symphytum kurdicum Boiss.
Labiateae
+ Lamium sp.
+ cf. Lamium amplexicaule L.
Liliaceae
1–2 Gagea sp.
1 Ornithogalum sp.
+ Tulipa sp.
+ Allium sp.
Scrophulariaceae
+ Veronica sp.
Geraniaceae
1 Geranium tuberosum L.
Ranunculaceae
2 Ficaria sp.
1 Thalictrum sp.
+ Ranunculus sp.
+ Anemone sp.
Guttiferae
1–2 Hypericum sp.
Papaveraceae
+ Corydalis sp.
+ Fumaria sp.
Cucurbitaceae
+ Cucurbita sp.
Euphorbiaceae
1 Euphorbia condylocarpa Bieber.
+ E. cf. denticulata Lam.
Modern pollen rain in western Iran

Table 3 (Continued)

Relevé X at Loc. 28. 7 May 1963. West–north-west-facing slope on limestone, about 25 km E of Marivan. 35° 30' N, 46° 24' E. Elevation c. 1850 m. Plot size 600 m². Scattered coppice, grazing. Salix along rivulet at the foot of the slope.

**Shrub layer**: cover c. 5%

**FAGACEAE**
+ *Quercus persica* Jaub. et Spach

**ANACARDIACEAE**
+ *Pistacia mutica* Fisch. et Mey.

**ACERACEAE**
+ *Acer cinnamomun* Boiss.

**CAPRIFOILIACEAE**
+ *Lonicerum nummulariformia* Jaub. et Spach

**ROSACEAE**
1 *Pyrus cf. syriaca* Boiss.
+ *Amygdalus* sp.
+ *Prunus* sp.
+ *Rosa* sp.

**Herb layer**: cover 60–70%

**GRAMINEAE**
2 *Poa bulbosa* L.
+ *Poa vivipara* Koe.
+ *Bromus* sp.

**COMPOSITAE TUBULIFLORAE**
1–2 *Achillea* sp.
+ *Senecio* sp.
+ *Gundelia tournefortii* L.
+ *Chardina* sp.

**COMPOSITAE LIGULIFLORAE**
1 *Sorzonera papposa* DC.

**UMBELLIFERAE**
1–2 *Graminosciadum* sp.
+ *Smyrnium cordifolium* Boiss.
1–2 Umbelliferae indet.

**CRUCIFERAE**
+ *Isatis* sp.
+ cf. *Matthiola*
+ *Lunaria* sp.
+ Capsella bursa-pastoris (L.) Med.
+ *Drabopis verna* C. Koch
1–2 *Alyssum* sp.
+ Cruciferae indet.

**CARYOPHYLLACEAE**
1 *Silene amplausta* Boiss.
1 *Cerasium* sp.

**RUBIACEAE**
1–2 *Cruciata coronata* (Sibth. et Sm.) Ehrendf.
+ *Sthrica persica* (DC.) Ehrendf.
+ *Galium tricornutum* Dandy
+ *Asperula arvensis* L.

**ROSACEAE**
+ *Sanguisorba* sp.

**LEGUMINOSAE**
1–2 *Astragalus* sp.
+ *A. agrobromus* Boiss. et Hoh.
+ *Astragalus* sp. sect. Proselius
+ *Trifolium* sp.
+ *Vicia* sp.

**LABIATAE**
+ *Lamium amplexicaule* L.
+ Labiatae indet.

**BORAGINACEAE**
+ *Rindera lanata* (Lam.) Bunge
+ *Symphytum kurdicum* Boiss.

**LILIACEAE**
+ *Tulipa* sp.
+ *Muscar* sp.
+ *Gagea* sp.
+ *Fritillaria* sp.
+ *Allium* sp.

**GERANIACEAE**
1–2 *Geranium tuberosum* L.

**POLYGONACEAE**
1–2 *Rheum ribes* L.
+ *Rumex* sp.

**CISTACEAE**
1 *Helianthemum lediulorum* (L.) Mill.

**RANUNCULACEAE**
1–2 *Ranunculus* sp.
1 *Ficaria* sp.
+ *Thalictrum* sp.

**PAVONIACEAE**
+ *Papaver* sp.

**MALVACEAE**
+ Malvaceae indet.

**GUTTIFERAE**
+ *Hypericum* sp.

**EUPHORBIACEAE**
+ *Euphorbia condylocarpa* Bieb.

**VIOLACEAE**
+ *Viola* sp.

**ORCHIDACEAE**
+ Orchidaceae indet.

Fig. 4. Map of Lake Zeribar area showing location of coring sites and the surface samples in the Z series.
Pollen rain

On the Dizful transect, the lower deforested zone (cf. Zohary; Fig. 1) was sampled at two localities. Loc. 16-C is at the base of the outermost south-facing limestone ridge, at least 80 m below the lowest extant tree. Loc. 17 is near the Saimarreh Landslide lakes, for which a long sediment core is being studied for pollen analysis. Not a tree now exists on the landslide debris in this broad valley, but the entire north-facing slope of the Kebir Kuh to the south has a severely cropped woodland, as do the slopes of the ridges to the north. Herbs at Loc. 17 are recorded in a relevé (Table 1).

The pollen count for these two samples (16-C, 17) shows about 10% oak, compared to the negligible percentages in the savanna and steppe of lower elevations (Fig. 3). The Quercus/Pistacia ratios are 26 and 9. Plantago exceeds 30%, as in most of the other lower-elevation samples. No Plantago was tallied in the relevé at Loc. 17, and although it was common near by it is clearly over-represented in the pollen rain. Gramineae, dominant in relevé, is apparently under-represented in the pollen rain. The other pollen types seem not to be diagnostic.

In the extant oak forest or woodland on the Dizful transect, samples were analysed from three localities. Loc. 16-A was from the south-facing slope of the outermost ridge of the mountains, 300 m higher than 16-C, in scattered Pistacia and Quercus. The pollen rain is dominated by oak (43%), but Pistacia exceeds 3%. The other two samples on the Dizful transect came from the Karkheh gorge. Locality 18 (the site of one of the tree counts, which showed a very sparse tree cover) had only 21% Quercus. Loc. 19, just west of Khorramabad, near the inner or plateau limit of the oak woodland, had 34% Quercus after exclusion of Centaurea solstitialis type from the sum.

On the Ilam transect, eleven surface samples were collected across the oak forest. The Quercus values were lowest at the lower limit of the forest (Loc. 3, elevation 750 m, 14% oak after exclusion of Centaurea solstitialis type and undifferentiated Cruciferae) and near the inner limit (16% at Loc. 12, in the open Shahabad Valley, where little but non-flowering oak scrub occurs on the ridge between there and the Kermanshah Valley).

Intermediate values for Quercus came from areas of sparse local trees: 30% at Loc. 7 on barren low ridges of marl near Ilam, 29% at Loc. 13 on the edge of the oak woodland east of Shahabad, 42% at Loc. 10 in a very broad treeless area of cultivated valleys and hills in the midst of the mountains and 41% in the Pistacia–Quercus savanna that was counted on the south-facing side of the Kuh-i-Wardalan (Table 1, Loc. 11). At the last-named locality Pistacia pollen reaches an impressive 4.5%, the highest encountered.

The highest percentages of Quercus (46–92%) are all within the heavily forested regions south (Loc. 4 and 5) and north (Loc. 8 and 9) of Ilam.

The Zeribar transect covers only the plateau side of the Zagros oak forest. Although in much of the region the tree cover is fairly dense (the tree counts at Loc. M and E in Table 2 are representative), the trees are severely cropped, and many of them do not flower. Consequently the oak-pollen percentages are in the low and intermediate category compared to those in the heart of the Ilam transect. Around Lake Zeribar itself, both on the sedge mat and the hills adjacent to the east, the oak values are 15–41% after exclusion of the locally derived Cyperaceae, Dryopteris and (from 1 sample) Liguliflorae. Similarly in the four localities in the extant woodland between Zeribar and Sanandaj (Loc. 26, 29, 28 and 47) the oak percentages are in the same range. The two samples with high values of Juglans (Loc. 47 and 29) were both close to springs with walnut trees.

Several surface samples were taken at localities where the shrub cover was studied, so the relation between the vegetation and the pollen rain can be examined (Table 4).
Localities 9, 11 and 18 were studied according to the point-centred quarter method, and at localities 9 and 26 the crown cover of the various trees was estimated as a part of the Braun-Blanquet relevés. As pollen of *Amygdalus* and *Pyrus*, if present in the surface samples, will have been noted as undifferentiated Rosaceae, this pollen type is shown in the table, although it may include other Rosaceae as well.

It is not surprising that in general insect-pollinated Rosaceae and *Acer* are under-represented in the pollen rain. The absence of *Acer* pollen in samples 9 and 26 is striking,

Table 4. *Comparison of pollen rain with tree and shrub cover at four localities*

<table>
<thead>
<tr>
<th>Locality</th>
<th>Pollen number</th>
<th>Pollen percentage</th>
<th>Importance percentage</th>
<th>Crown cover (%) (from relevé)</th>
<th>Relative crown cover (%) (from relevé)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td><em>Quercus</em></td>
<td>868</td>
<td>99·1</td>
<td>49</td>
<td>30–40</td>
</tr>
<tr>
<td></td>
<td><em>Pistacia</em></td>
<td>7</td>
<td>0·8</td>
<td>24</td>
<td>3–5</td>
</tr>
<tr>
<td></td>
<td><em>Juglans</em></td>
<td>1</td>
<td>0·1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td><em>Acer</em></td>
<td>0</td>
<td>0</td>
<td>25</td>
<td>3–5</td>
</tr>
<tr>
<td></td>
<td>Rosaceae</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>876</strong></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td><em>Quercus</em></td>
<td>122</td>
<td>87·7</td>
<td>32</td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>Pistacia</em></td>
<td>13</td>
<td>9·4</td>
<td>52</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rosaceae</td>
<td>4</td>
<td>2·9</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td><strong>139</strong></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td><em>Quercus</em></td>
<td>54</td>
<td>91·5</td>
<td>67</td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>Pistacia</em></td>
<td>1</td>
<td>1·7</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>Acer</em></td>
<td>2</td>
<td>3·4</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rosaceae</td>
<td>2</td>
<td>3·4</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td><strong>59</strong></td>
<td></td>
</tr>
<tr>
<td>26</td>
<td><em>Quercus</em></td>
<td>118</td>
<td>92·2</td>
<td>20</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td><em>Pistacia</em></td>
<td>5</td>
<td>3·9</td>
<td>3–5</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td><em>Juglans</em></td>
<td>4</td>
<td>3·1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td><em>Ulmus</em></td>
<td>1</td>
<td>0·8</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td><em>Acer</em></td>
<td></td>
<td></td>
<td></td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Rosaceae</td>
<td></td>
<td></td>
<td></td>
<td>10</td>
</tr>
<tr>
<td></td>
<td><em>Lonicera</em></td>
<td></td>
<td></td>
<td></td>
<td>3–5</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td><strong>128</strong></td>
<td></td>
</tr>
</tbody>
</table>

for these samples came from localities with numerous *Acer* trees. Very low *Acer* percentages in pollen spectra may therefore point to an appreciable share of this tree in the forest vegetation.

It was not expected, however, that *Pistacia*, a wind-pollinated tree, also would be seriously under-represented in the pollen rain. The *Quercus–Pistacia* ratio in the pollen rain is 20–50 times higher than in the vegetation at the three sites (Loc. 9, 11 and 18) at which both pollen counts and importance values were determined. This discrepancy must be taken into consideration in interpreting pollen diagrams from this region.

It may be concluded that in general the proportion between tree pollen and non-tree pollen is in accordance with the vegetation in the surroundings of the samples in question. Exceptions are samples 16-A, 21 and 28, in which tree pollen percentages are considerably higher than one might expect from the vegetation. In sample 28 the tree-pollen percentage is out of sequence in the transect of samples 26–29–28–47 from the wooded Zeribar
region to the treeless plateau. The well-developed forest at the site of sample 26 (relevé VIII, Table 3) has a crown cover of 40–50%, whereas in the vicinity of sample 28 (relevé X, Table 3) only some brushwood was present and no fully grown trees were observed except for a few Salix along a rivulet. In spite of this great difference in tree growth locally at the two sites, the tree pollen percentage in sample 28 is still two-thirds of that in sample 26. This relation indicates that oak pollen in great quantities travels far from its source, blanketing unwooded areas with a regional pollen rain that obscures the less abundant pollen production from local sources.

**Inner defrosted area of the plateau margin**

North of the Zagros Mountains is a broad zone in which groves or isolated specimens of the Zagros oak woodland can be found (Fig. 1). Plant geographers have generally agreed that a woodland or savanna covered these areas before the epoch of human disturbance. Its detailed limits were drawn by Bobek (1951, in appendix and Fig. 2) largely on the basis of mountain elevation, as extrapolated from the few scattered occurrences of trees; they were adopted with essentially no modification by Zohary (1963, map). The elevation of this region is all above about 1300 m, so summers are relatively cool and winters cold; precipitation is about 400–600 mm (Wright 1961).

In place of the trees, especially at higher elevations, the important elements in the ground cover are bushy Astragalus and Acanthophyllium (tragacanth), as well as Prunus spp., Daphne angustifolia C. Koch, Amygdalus horrida Spach, and other shrubs (Pabot 1960). The conspicuous rosette-like dwarf shrubs that constitute the tragacanthic vegetation dominate the higher elevations, especially where overgrazing has prevailed, for these forms are generally spiny or otherwise unpalatable (Zohary 1963, pp. 51, 98).

One surface sample was taken from the inner deforested area at the northern end of the Diz transect (Loc. 21), near Dorud on a high ridge that had only Prunus and Astragalus as shrubs, with no trees. Scrubby oak trees occur on ridges 10 km to the south, however, and the relatively high content of Quercus pollen in the sample (38%) reflects proximity to the extant oak woodland (Fig. 3).

On the Ilam transect, three samples were taken from the Kermanshah Valley, which is a rich agricultural region of limestone soils, with hundreds of villages and almost an equal number of prehistoric sites, indicating intensive habitation for many millenia. A small but fine remnant of woodland, consisting of about twenty oak trees and one large pistachio, occurs about 40 km west of Kermanshah on an east-facing slope 10 km west of Lake Nilofar, from which a sediment core was taken for pollen analysis. The three samples from the Kermanshah Valley (Loc. 22, 34 and 60) showed 15–20% oak pollen. The one at Lalabad (Loc. 34) is next to a very large spring, which has a deposit 12 m thick which was cored for pollen analysis.

The Zeribar transect has five surface samples in the inner deforested area, two west of Sanandaj (Loc. A and 25, respectively about 20 and 30 km north-east of the edge of the extant oak woodland) and three to the north of Sanandaj (Loc. 61, 62 and 63, all about 65 km from the woodland). Oak pollen constitutes 4–12% of the total pollen. Of interest in the two northern samples (62 and 63) are the high values of Artemisia pollen (22–26%), reflecting proximity to the Artemisia steppe of the interior plateau. This compares with values generally less than 15% elsewhere in the inner deforested area of all transects.
Artemisia steppe

The interior of the Iranian plateau has elevations of 1400 m in the north-west around Lake Urmia, where the annual precipitation is about 300 mm and the summers are relatively cool and the winters cold. South-eastward the elevations and precipitation decrease steadily. The vegetation is dominantly an Artemisia steppe, interrupted by chenopods on poorly drained areas with saline soils. A. herba-alba Ass is the principal species, in combination with different other plants in varied edaphic conditions, for the area has a relatively rich flora (Zohary 1963). Towards the Turkish border A. fragrans Willd. is dominant (Zohary 1963). Among important wind-pollinated genera, Ephedra and several genera of chenopods are common. In areas of heavy grazing pressure, tragacanthic species of Astragalus have invaded the Artemisia steppe from higher elevations (Zohary, 1963).

The pollen rain for the Artemisia steppe was sampled on the Tabriz transect at nine localities (Loc. 30–31 and 66–62). Quercus pollen generally accounts for less than 5%; Pistacia is absent (Fig. 3). The dominant pollen types are chenopods and Artemisia. The chenopod percentages are variable, depending on proximity to Lake Urmia and other sites with saline shore areas. At localities 30 and 31, for example, a few kilometres south of Lake Urmia, chenopods reach 75%. Artemisia reaches 53% in the sample from the gravel-covered pediments south of Mount Ararat in easternmost Turkey. Ephedra is 5% in one sample taken from a spot where Ephedra plants were common, but it is virtually absent in the rest. Plantago is less than 5% in all samples.

Summary

The four surface-sample transects across the Mesopotamian steppe, the piedmont savanna, the Zagros oak woodland, and the Artemisia steppe of the Iranian plateau, with a total of sixty analyses, provide an adequate picture of the modern pollen rain in western Iran. Even though this pollen rain represents vegetation that has been highly disturbed by wood-cutting, grazing and cultivation, the main natural vegetation areas have certain characteristic pollen spectra that are probably valid for relatively undisturbed vegetation, and thus they may provide the basis for reconstructions of vegetational history through pollen analysis of lake-sediment cores. The summary of pollen percentages in Table 5 is based on pollen sums with selected exclusions.

The single sample (14) from the Mesopotamian steppe is characterized by the absence of pollen from trees of the Zagros oak woodland, and by the presence of pollen of local Ziziphus and Forskohlea. Both Plantago and chenopods have high percentages, but Artemisia is low.

The six samples (1a, 1b, 2a, 2b, 15a and 15b) from the much disturbed Amygdalus–Pistacia savanna of the Zagros piedmont have only 1–2% of Quercus and large amounts of Plantago. Artemisia is low (5%).

Two samples (16-C and 17) from the outer deforested area have greater values of Quercus (10%) and Pistacia (1%), being closer to the extant Zagros woodland, and the Plantago percentages are high, as in the savanna and steppe below.

The twenty-nine samples from the Zagros oak woodland are dominated by Quercus (35%), with Pistacia present in most samples. Grasses generally have higher percentages than in lower areas.
Table 5. Summary of pollen percentages of sixty surface samples from seven vegetation areas

<table>
<thead>
<tr>
<th>Transect</th>
<th>Locality-number</th>
<th>Quercus</th>
<th>Pistacia</th>
<th>Gramineae</th>
<th>Plantago</th>
<th>Chenopod-iaceae undiff.</th>
<th>Artemisia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mesopotamian desert-steppe</td>
<td>Diz</td>
<td>14</td>
<td>0</td>
<td>0</td>
<td>18</td>
<td>26</td>
<td>18</td>
</tr>
<tr>
<td>Piedmont savanna</td>
<td>Ilam</td>
<td>1, 2</td>
<td>t-2</td>
<td>t</td>
<td>5-25</td>
<td>15-55</td>
<td>5-20</td>
</tr>
<tr>
<td></td>
<td>Diz</td>
<td>15</td>
<td>1</td>
<td>t</td>
<td>15</td>
<td>35</td>
<td>10</td>
</tr>
<tr>
<td>Outer deforested area</td>
<td>Diz</td>
<td>16-C, 17</td>
<td>8-14</td>
<td>t-2</td>
<td>5-18</td>
<td>31-34</td>
<td>7-8</td>
</tr>
<tr>
<td>Zagros oak woodland</td>
<td>Diz</td>
<td>16-A, 18, 19</td>
<td>13-92</td>
<td>0-4</td>
<td>1-42</td>
<td>1-16</td>
<td>1-15</td>
</tr>
<tr>
<td></td>
<td>Ilam</td>
<td>3, 4, 5, 7, 8, 9, 10, 11, 12, 13</td>
<td>35</td>
<td>1</td>
<td>18</td>
<td>9</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Zeribar</td>
<td>Z-series, 63-J 26, 28, 29, 47</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inner deforested area</td>
<td>Diz</td>
<td>21</td>
<td>3-38</td>
<td>0-3</td>
<td>5-23</td>
<td>4-15</td>
<td>3-40</td>
</tr>
<tr>
<td></td>
<td>Ilam</td>
<td>22, 34, 60, 50, 53, 56</td>
<td>15</td>
<td>1</td>
<td>17</td>
<td>10</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>Zeribar</td>
<td>A, 25, 61, 62, 63</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Plateau steppe</td>
<td>Tebriz</td>
<td>30, 31</td>
<td>0-5</td>
<td>0</td>
<td>1-20</td>
<td>0-4</td>
<td>15-70</td>
</tr>
<tr>
<td></td>
<td></td>
<td>66, 67, 68, 69, 70, 71, 72</td>
<td>2</td>
<td>0</td>
<td>10</td>
<td>1</td>
<td>45</td>
</tr>
</tbody>
</table>

Upper figures are range of percentages, after selective exclusion; lower figure is mean percentage (t = <0.5%).
In the inner deforested area *Quercus* is moderate again (15%), and *Artemisia* higher than in previous areas (15%).

In the plateau steppe, *Quercus* is down to a few per cent, and chenopods (45%) and *Artemisia* (25%) are high.

Taken as a whole, *Quercus* percentages reflect proximity to the *Quercus* woodland. *Pistacia* percentages are low and erratic but are highest in the oak woodland and its periphery. High *Plantago* values are an index of lower elevations. High *Artemisia* values are found in the interior plateau, along with high chenopod values, which may relate to the occurrence of undrained depressions with saline soils. Gramineae pollen reaches somewhat higher percentages in the oak woodland than elsewhere.

**INTERPRETATION OF LAKE ZERIBAR POLLEN DIAGRAM**

A preliminary pollen diagram (Fig. 5) through 16 m of sediment at Lake Zeribar was made without benefit of any surface-sample analyses of the modern pollen rain in the important vegetation areas of western Iran (van Zeist & Wright 1963). Thus it was not possible to designate any modern areas as analogues of past vegetation in the Zeribar area.

With the survey of the modern pollen rain now available, interpretation of the diagram can be made with more confidence. The same pollen-rain data will eventually be used for the interpretation of the detailed pollen diagrams that are now under preparation for Lake Zeribar to a depth of 26 m and for other lake sites in western Iran.

The preliminary diagram for Lake Zeribar was calculated on a percentage base consisting only of *Quercus*, *Pistacia*, Chenopodiinae, *Artemisia* and *Plantago*. Other types were excluded from the sum because the large fluctuations in the pollen curves implied a local source—*Salix*, Gramineae, Compositae (other than *Artemisia*). Even though the sum is therefore different from that used for the surface-sample diagram, general comparisons may be made.

The lowest pollen zone (A) is characterized by high values of chenopods (70%) and *Artemisia* (30%) and a virtual absence of tree pollen. It therefore fits the modern pollen rain of the plateau steppe of the Tabriz area, which is drier than the present Zeribar area and cooler in both summer and winter (Ganjii 1960). A radiocarbon date of 14 800 years old near the base indicates that Zone A correlates with the full-glacial of Europe.

The lack of oak pollen at this time implies that the Zeribar area was at least 75 km north-east of the oak woodland, for such low percentages can be found in the modern pollen rain only where the site is this far from the woodland. Inasmuch as the Zagros woodland in this area is only 100 km broad, and Zeribar is 75 km from its present outer (lower) limit in the Mesopotamian piedmont, it is possible that during full-glacial time the entire woodland was obliterated from the Zagros Mountains in this area.

Zone B is marked by *Pistacia* pollen (up to 15%) along with an equal or greater per cent of *Quercus*, increasing upwards through the zone. *Artemisia* is much lower than in Zone A, about 10%, but the chenopod curve remains high (70%, decreasing upward to 50%). *Plantago*, which was essentially absent in Zone A, reaches 10% in Zone B. Gramineae, *Salix*, Compositae other than *Artemisia* and other types that are thus excluded from the pollen sum are uncommon in Zone A, but in Zone B they amount to much greater totals; they may represent the shore plants of a fluctuating lake.

The present surface-sample study revealed no area in which the *Quercus/Pistacia*
Fig. 5. Generalized pollen diagram for sediments of Lake Zeribar, Iran, showing principal arboreal (AP) and non-arboreal (NAP) types. Other non-arboreal pollen types (shown in white) are excluded from the pollen sum because they are believed to represent plants growing principally around the lake margin rather than on the upland. Carbon-14 dates, in years before the present (B.P.), were determined by Dr Minze Stuiver, Yale University: 5460 ± 120 (Y-943) and 14 800 ± 300 (Y-1160). The zone A/B boundary on another core has subsequently been dated as 11 480 ± 160 (Y-1687). Diagram reprinted with permission from Science (van Zeist & Wright 1963).
ratio was so low as in Zone B, so there seems to be no analogue in the area sampled. Bobek (1951; cf. Zohary 1963, p. 35) delineates a *Pistacia–Amygdalus* 'steppe forest' (? savanna) on the mountains of the Iranian plateau on the basis of scattered trees that he considers to be remnants of a broader cover in the past before the times of extensive human disturbance. On some of the higher ranges of the plateau this steppe forest is mapped by Bobek at intermediate elevations, with remnants of the *Quercus* (or *Quercus–Juniperus*) woodland above and the steppe below. Bobek also identifies a largely destroyed *Pistacia–Amygdalus* 'steppe forest' on the Mesopotamian below the *Quercus* woodland. Tree counts in woodland (Table 4) shows that *Pistacia* is poorly represented in the pollen rain even when the tree is common, and *Amygdalus*, a genus of Rosaceae, is insect-pollinated and thus also poorly represented. This factor of under-representation, plus the extensive destruction of the former savanna, means that an analogue for Zone B, if such could ever be identified, does not exist today in the area sampled. The closest approach may be the savanna measured on the south-facing slope of Kuh-i-Wardalan (Table 2, Loc. 11), where almost two-thirds of the trees are *Pistacia* and *Amygdalus*.

Choice between a plateau savanna or a piedmont savanna as a possible analogue might be decided on the basis of the *Plantago* percentages, which in Zone B are much higher than in Zone A and are thus more comparable to the high *Plantago* percentages found in surface samples in the lower, warmer localities of the piedmont savanna.

Farther south-east along the Zagros Mountains, beyond the Zarreh Keh culmination, the ridges are lower and more widely spaced and therefore present a broader area of intermediate precipitation and relatively warm temperatures. Here the *Pistacia–Amygdalus* type is more extensive (Merton 1961), or at least it was before the last few decades of intensive disturbance. The vegetation of this region might be the best available modern analogue to that of Zone B at Lake Zeribar, thus implying a climate warmer than that of Zone A and warmer and drier than that of Zone C.

Zone C is marked by *Quercus* values of about 60%, continuing up close to the surface of the sediment. Little doubt exists that the oak forest had invaded the hills around the lake by about 5500 years ago, presumably as a result of increased precipitation. *Pistacia* pollen falls at the same level to very low values, and *Artemisia* and *Plantago* are generally about 10%. The fluctuating shore types again have low representation, but Gramineae has higher values than in Zone A.

The climatic history for the Zagros Mountains of western Iran accordingly involves the following sequence. In late-Pleistocene time (full-glacial in northern Europe), the area was cool and dry, with a climatic regime like that of the higher (cooler) parts of the interior plateau. In early Holocene time, about 11 500 years ago, the climate became warmer, so that vegetation with abundant *Plantago* in the herb cover came closer to the Lake Zeribar area and the *Artemisia* type withdrew into the plateau. At the same time the precipitation increased slightly, permitting *Pistacia* and *Quercus* (and *Amygdalus?*) to invade the area in small numbers. Further increase in moisture converted the savanna to a *Quercus* woodland by about 5500 years ago, and since this time the forest composition in the region has had no major change.

The cutting and grazing in the oak woodland during the past few millenia have not had any appreciable effect on the pollen rain into Lake Zeribar. Although the valley in which the lake is located offers broad alluvial fans suitable for agriculture, it is quite isolated, and most of the surrounding country is mountainous and inaccessible. No archaeological site of importance has been discovered in the valley, so occupation and agriculture have apparently never been very intensive in the region. On the other
hand, the oak trees are cropped throughout the area for firewood, although relatively few trees have apparently been removed or reduced to non-flowering scrub.

The surface-sample study, along with additional phytogeographic surveys in the field, have provided a substantial basis for vegetational reconstruction and at the same time a reasonable climatic history. The detailed pollen diagrams now in preparation for Lake Zeribar and other sites in western Iran, when combined with other fossil and chemical studies of the sediments also in progress, will permit additional elaborations of the vegetational, limnological and climatic history of the area.

SUMMARY

Western Iran has diversified topography and a long history of land exploitation, but the basic geomorphic and climatic zones are reflected in vegetational belts. At lower elevations is the Mesopotamian steppe, grading up to a Pistacia–Amygdalus savanna that is now largely destroyed. Between about 800 and 2000 m elevation on the ridges of the Zagros Mountains is a Quercus woodland, which is in various stages of degradation as a result of cutting, grazing and clearing. North of the mountain belt on the Iranian plateau is a transitional zone that may once have been a Pistacia–Amygdalus savanna, but most of the plateau is characterized by a steppe dominated by Artemisia herba-alba, with chenopod species prominent especially on saline soils around lakes.

The modern pollen rain in the Mesopotamian steppe and piedmont savanna is marked by relatively high percentages of Plantago, the Zagros oak woodland by Quercus, and the plateau steppe by Artemisia and chenopods. Comparison of tree counts and herb plots with the pollen content at individual sample sites shows that Pistacia pollen is under-represented in the pollen rain, as are also Acer, Amygdalus, Pyrus and other insect-pollinated trees. Quercus pollen constitutes 10–20% of the pollen rain in the deforested areas marginal to the Quercus woodland, but less than 5% in the piedmont savanna and in both the Mesopotamian steppe and the plateau steppe.

Application of the pollen-rain data to an 18 m core from Lake Zeribar in the modern oak woodland implies that the Zagros Mountains were treeless during the late Pleistocene until about 11,500 years ago, with a relatively cool, dry climate such as is found today in the western part of the Iranian plateau. Slow invasion of Pistacia and Quercus during the next 6000 years record a climate warmer than before, with increasing moisture. The modern climatic regime was established about 5500 years ago.

REFERENCES


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