molecules attached to A subunits (muscle type) but not those attached to B subunits (heart type). At a concentration of 0.005*M* β-mercaptoethanol, the coenzyme presumably is partially removed from the A units so that in the case of band 1 the five possible combinations of the enzymes and the four coenzymes result, in the case of band 2 the four possible combinations result, and so forth. In this manner the 15 bands can be explained within the framework of the theory that the enzyme molecule consists of two dissimilar monomers (*2, 3*). On the other hand, if NAD is assumed to be completely removed from the B monomer, rather than not being removed at all, the same electrophoretic pattern would be expected (*9*).

The explanation offered for the appearance of the 15 bands of LDH leads to the prediction that a higher concentration of β-mercaptoethanol would completely dissociate the coenzymes from the enzyme, and that the latter would then migrate electrophoretically as a single band. When 0.01*M* β-mercaptoethanol was added to the gel, the multiple bands were no longer visible; each major band of LDH migrated as a compact band.

Furthermore, the presence of a sufficiently high concentration of NAD during electrophoresis should keep a full complement of coenzymes on the enzyme and again result in single bands. Indeed, when 0.01*M* NAD was presented during electrophoresis this was the case, but only in that fewer bands appeared rather than a single band. Since enzymes that degrade NAD occur in muscle homogenates, and could be expected to interfere, further experiments on the purified enzymes will be necessary to elucidate the effect of the presence of NAD on the electrophoretic behavior of LDH.

Two preparations of rabbit muscle LDH (Worthington Biochemical Corp.), recrystallized twice, have been examined, and each shows multiple bands in each of the four slowest major bands and in contrast to the mouse preparation the fastest band, number 5, is also split. The distribution of the sub-bands was the same in both a crude rabbit muscle homogenate and in crystalline preparations, but it was different from the distribution in mouse muscle (*10*).

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1. The following abbreviations are used: LDH, lactic dehydrogenase; NAD, nicotinamide adenine dinucleotide, previously known as DPN.
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Preliminary Pollen Studies at Lake Zeribar, Zagros Mountains, Southwestern Iran

Abstract. *A late Pleistocene* Artemisia *steppe, implying a cool, dry climate, changed about 13,000 years ago to an oak-pistachio savanna, as the climate became warmer. About 5500 years ago the savanna thickened to an oak forest, presumably reflecting an increase in precipitation or decrease in temperature to modern levels.*

As part of a continuing program (*1*) for the study of prehistoric environmental and climatic change in the Zagros Mountains of Iraq and Iran, sediment cores were obtained in 1960 at several lakes and marshes for pollen analysis and other paleontologic and chemical studies. This long mountain arc separates the Mesopotamian piedmont from the Iranian Plateau. Some believe it to be a principal locus for the domestication of plants and animals about 11,000 to 9000 years ago (*2*). The range consists of a series of fold ridges that are 2000 to 3000 m in elevation and separated by long valleys. It receives moisture in the winter from storms traveling from the Mediterranean Sea (*3*), and it bears a forest cover dominantly of oak between elevations of about 700 and 2000 m (*4*). The Iranian Plateau in this region has an elevation of about 1500 m. Because it lies in the precipitation shadow of the Zagros Mountains it is largely barren of trees.

The site chosen for detailed study is Lake Zeribar near the large village of Merivan, Iran, close to the Iraq border and about 160 km northwest of Kermanshah, Iran. It occupies what is probably a structural basin in the inner portion of the Zagros Mountains. The nearby ridges consist primarily of metamorphic rock. The lake basin has an elevation of about 1300 m above sea level. A few small intermittent streams enter the basin, and the lake occasionally overflows to the southeast over an alluvial divide into the headwaters of the Diyala River. The estimated annual precipitation in the region is 600 to 800 mm, and the estimated mean January and July temperatures are respectively 2° and 28°C (*3*).

The lake measures about 3 by 5 km, is almost completely surrounded by a sedge mat, the outer part of which is floating, and is only a few meters deep (*5*). The valley itself is extensively planted in wheat or barley or is used for grazing. The hills bounding the valley are covered largely with oak (*Quercus persica*), which has been reduced to a low tree by wood-cutting and grazing.

The sediment was cored from the edge of the floating mat at two sites on the west side and one site at the south end. A modified Livingstone 1-inch piston corer was used to a depth of about 13 m and a Davis corer below (*6*). The sediment ranged from peat and gyttja in the upper part to clay and silt beneath to a total thickness of 18 m. The base of the sediment was not reached.

The abbreviated pollen diagrams in Fig. 1 are preliminary in nature. About 80 pollen taxa have been identified so far (*7*). This preliminary interpretation of the pollen diagrams is supported by the chemical studies on the same sediments as those reported in the accompanying paper (*8*), and the analyses of Cladocera contained in the cores give promise of providing more information.

The pollen sum used in the design of the diagram includes all trees, shrubs, and wind-pollinated herbs except *Salix* (willow), Gramineae (grasses), and Cyperaceae (sedges). On the basis of the abrupt fluctuations in their abundance, we believe that these three latter pollen types largely represent local lake-margin plants rather than the regional vegetation. The pollen sums counted at different levels range from 47 to 465.

Of the three cores available the longest core (I-12), that used for the chemical studies (*8*), contained poorly preserved pollen in its upper part, so the pollen diagram for this core is confined to the sediments from depths of 10 to 17 m. Analyses of the younger sediments were made instead on core I-13 from depths of 2 to 13 m, which was enough to overlap the other series.

Zone A represents treeless vegetation and is marked by relatively high percentages of *Artemisia*, along with dominance of Chenopodiineae. Although we have not as yet obtained surface samples to determine the modern pollen rain in different regions, this zone suggests a vegetation similar to that of the *Artemisia* steppe of eastern Anatolia (*9*). A carbon-14 date of 14,800 years ago was obtained at a depth of 16.25 m near the top of Zone A (*10*). The cool, dry climate implied by the high *Artemisia* percentages reflects conditions during the maximum of the last glaciation in the outer and higher parts of the Zagros Mountains (*3*). The very high percentages of Chenopodiineae throughout this zone as well as Zone B may reflect the abundance of these weedy plants growing in the shore zone of a fluctuating lake.

Zone B-1 shows consistently higher percentages for *Pistacia, Quercus, Plantago*, other Compositae, and Gramineae. The pollen of Chenopodiineae remains dominant, whereas that of *Artemisia* has decreased. An oak-pistachio savanna on the adjacent hills is suggested which is similar to that near the lower tree line on the outer slopes of the Zagros ridges. A warm, dry climate is thus implied.

Zone B-2 (core I-13) differs from Zone B-1 principally in the increased percentages of both pistachio and oak, which, however, are still minor compared to chenopods. It is further characterized by sharp fluctuations in the percentage of willow and other Compositae, which must represent plants around an intermittently exposed lake margin. The sharp peak of chenopods just above Zone B-2 may be attributed to the same local cause. Intermittently low lake levels and temporary exposure of sediments to the air is indicated by the fact that some samples contain only a few, badly preserved pollen grains whereas in adjacent samples the pollen grains are well preserved. The essentially complete absence of pollen grains from the upper part of core I-12 (that is, the missing Zone B-2 and most of Zone C in this core) may have resulted from such exposure; this site is located somewhat closer to an alluvial fan, which perhaps built up so rapidly that its surface was periodically above water level and thus subject to oxidation and destruction of the pollen grains.

Interpretation of low lake levels at the time of Zone B-2, presumably as a result of relatively dry or warm climate, is supported by studies in sediment chemistry (*8*).

Zone C shows the abrupt increase in oak at the expense of chenopods and pistachio. This assemblage remains uniform to the top of the core, which terminated at the base of the 2-m-thick sedge mat. It must represent the modern-type open oak forest of the surroundings. The climate may be characterized as temperate and moist relative to the preceding phases. The base of Zone C (depth 10 m) has been dated as 5460 years old (*10*).

The activity of prehistoric man has not been recorded with certainty at any

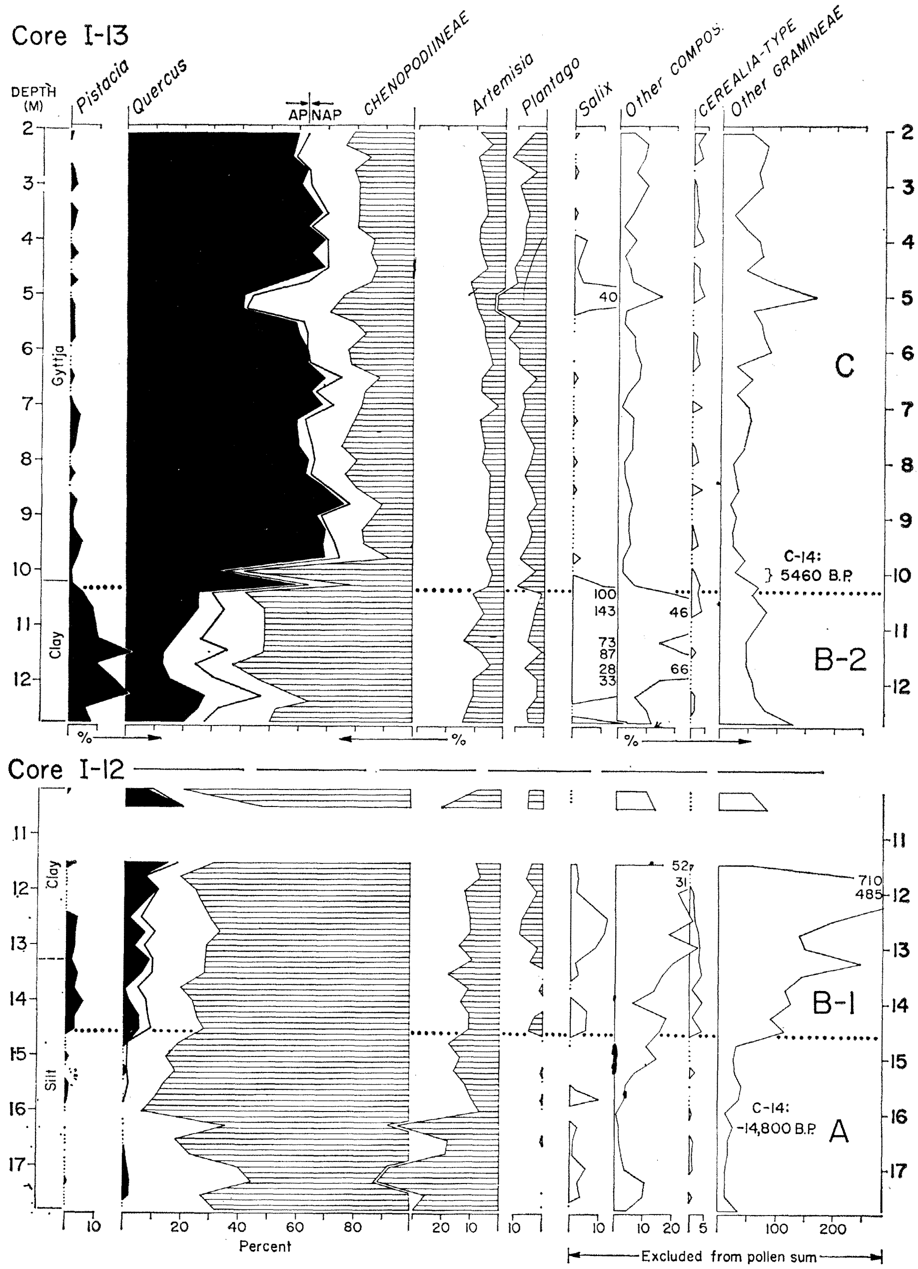

Fig. 1. Generalized pollen diagrams for sediments of Lake Zeribar, Iran. The two cores may overlap slightly. Percentage base includes arboreal pollen (AP, especially oak and pistachio) plus certain nonarboreal pollen (NAP, especially Chenopodiineae, *Artemisia*, and *Plantago*). Pollen types excluded from the pollen sum represent plants believed to grow primarily around the lake margin rather than on the upland. Carbon-14 dates in years before the present (B.P.).

level in the diagrams. As for cereal pollen, incompleteness of reference material has so far prevented the clear separation of the cultivated grasses, assuming that this will be possible at all. In Fig. 1 *Triticum*-type and *Hordeum*-type have been categorized together as Cerealia-type, but it has to be taken into account that this curve may include wild as well as cultivated grasses.

The increase in *Plantago* and Cerealia-type at the base of Zone B-1 probably records climatic change rather than the interference of prehistoric man. On the other hand, the sharp minimum of oak at a depth of 5 m along with the peak in *Plantago* and grasses may point to temporarily more intensive human activity in the area.

The correlation of the pollen zones with other paleoclimatic events is not as yet fully clear; it is preliminary, in any case. Evidence from Pleistocene glaciation in the Zagros and Taurus Mountains implies a depression of the snow line and tree line of 1200 to 1800 m, some of which may be attributed to an increase in snowfall (*3*). The extensive glaciation in these mountains, however, was restricted to the outer (southwestern) portion, which intercepted the storms from the Mediterranean Sea. The steep inland rise of the Pleistocene snow line across the Zagros and Taurus Mountains indicates sharp inland reduction in precipitation then as now, so that the Lake Zeribar region, which is in the inner portion of the range bordering the Iranian Plateau, would have been relatively cold and dry. Such a climate is compatible with Zone A of the pollen diagram, which suggests a cool *Artemisia* steppe.

As already mentioned, Zone B of the pollen diagram reflects an oak-pistachio savanna of a warm dry climate. The carbon-14 date of 14,800 years for a level at 1.65 m below the base of Zone B indicates that in this region the manifestation of a climatic change from cool to warm occurred 13,000 years ago, at about the same time as in western Europe, where the beginning of the Late-glacial Bölling zone of the pollen sequence is dated at about 12,-500 years ago (*11*). The dry climate inferred for Zone B (early Holocene) is consistent with the ideas of Bobek (*12*). He suggested such a relation for Iran on the basis of stratigraphy and distribution of loess on the Caspian coast and on the adjacent Elburz Mountains. The striking change from warm savanna (represented by Zone B) to forest (Zone C) at about 5500 years ago must reflect a distinct increase in precipitation, or a decrease in temperature.

The preliminary studies of the pollen content of the Lake Zeribar sediments have provided enough stratigraphy to encourage further work. New cores extending to greater depths will be acquired for more detailed work on the pollen, Cladocera, and other fossil materials as well as on the chemical components of the sediments. At the same time ecological and floristic reconnaissance combined with the collection of pollen surface samples in a transect across the Iranian Plateau, Zagros Mountains, and Mesopotamian piedmont will provide a picture of the relations between the modern vegetation and the modern pollen rain and will provide a firmer basis for understanding the vegetation and climatic history through pollen analysis.

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References and Notes

1. Field studies in 1960 were conducted by one of us (H.E.W.) with the assistance of R. A. Watson, A. M. Bent, and R. F. Wright in connection with the Iranian Prehistoric Project of the Oriental Institute, University of Chicago, and with the aid of a National Science Foundation grant to R. J. Braidwood, director of the project. Laboratory work was pursued at the Pollen Laboratory of the University of Minnesota geology department by one of us (W.V.Z.) under the terms of a contract with the Office of Naval Research. Previous studies on the paleoecology and climatic history of the region are reported in (*2*) and (*3*).
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Chemical Examination of a Core from Lake Zeribar, Iran

Abstract. *Chemical studies indicate that during the first half of the history of Lake Zeribar, since about 14,800 years ago, the outlet ran very intermittently, thus resulting in a carbonate deposition and a moderate chloride content of the water. The later sediments are largely littoral and cannot easily be interpreted. A fall in exchangeable potassium at the top is probably correlated with the development of extensive beds of aquatic macrophytes. The data appear to be in harmony with those derived from pollen analysis.*

A chemical analysis was performed on a core (*1*) which had been collected from a swampy littoral flood plain located on the western side of Lake Zeribar. The top meter was not preserved; it was evidently not lacustrine. The methods employed in the examination were for the most part conventional.

The core material consisted of a series of sections which had been wrapped in foil. It had been opened once for the purpose of obtaining pollen samples, and in spite of the care exercised in rewrapping, the samples probably suffered water loss.

The material in general consists of a gray clay. The color varies considerably and these variations are partly correlated with the organic carbon content. At 607 to 718 cm there is a band of peaty organic sediment interrupted by a layer of clay; above 400 cm the material becomes progressively but irregularly more peaty. These variations show clearly in the organic carbon content and need not be described in detail. Shell fragments, mainly planorbid, occur at 1204 cm and throughout most of the core from 1371 cm downward. There are dark particles of discrete organic detritus throughout most of the same region as the shell. It is probable that throughout the entire history represented by the core there was littoral vegetation. In the earlier period this would have been to the west of the core site, a region now filled with sediment.

Analyses by emission spectrography