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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24 December 1962

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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.

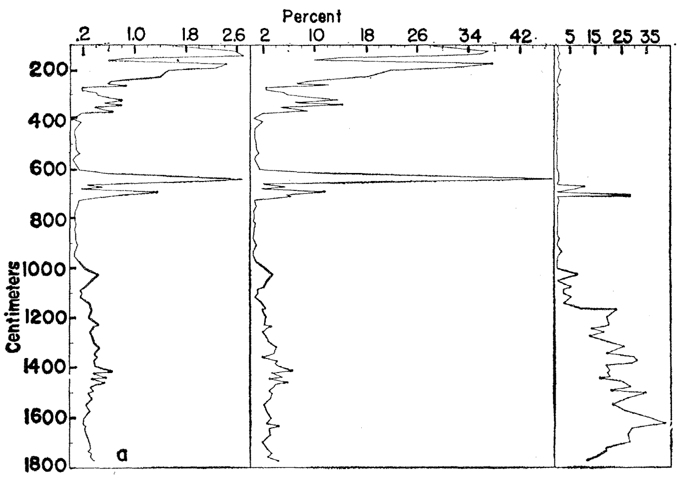
Analyses by emission spectrography

are given in Tables 1 and 2 (*2*) and the results of our wet analyses are presented in Figs. 1 to 4.

X-ray diffractometry indicates calcite in the deeper part (1777.5 cm), and the carbonate analyses show that considerable amounts of the mineral are present from 975 to 1785 cm. The other crystalline components throughout (107.5, 867.5, and 1777.5 cm) the core are quartz and a small amount of crystalline clay. The clay is composed partly of halloysite and a material tentatively identified as illite interstratified with montmorillonite. The peaks are very poorly developed and much of the aluminosilicate material is probably amorphous.

The carbonate content is maximal near the bottom and declines with decreasing depth. During this entire time there was evidently an appreciable deposition of organic carbon and nitrogen; the low percentage values are misleading because of a high rate of inorganic sedimentation. For the whole column from 120 cm to the bottom, the mean water content is 40 percent and the mean organic carbon content is 3.35 percent of the dry, or 2.4 percent of the wet sediment. Roughly this will correspond to 25 to 50 mg/cm^{-3}. The mean rate of sedimentation for the whole core appears to be about 1.2 m per thousand years, but since the littoral material may have been formed rather faster, a rough estimate of 1 m per thousand years would be reasonable for the deeper sediment. This would imply a carbon sedimentation of 2.5 to 5.0 mg/cm^{-2} yr^{-1}, which indicates a quite productive mesotrophic or eutrophic lake.

Chloride content in the dry sediment is high, but irregularly distributed at the bottom of the profile; it then decreases gradually from 1400 to 1000 cm. If, however, it be supposed that



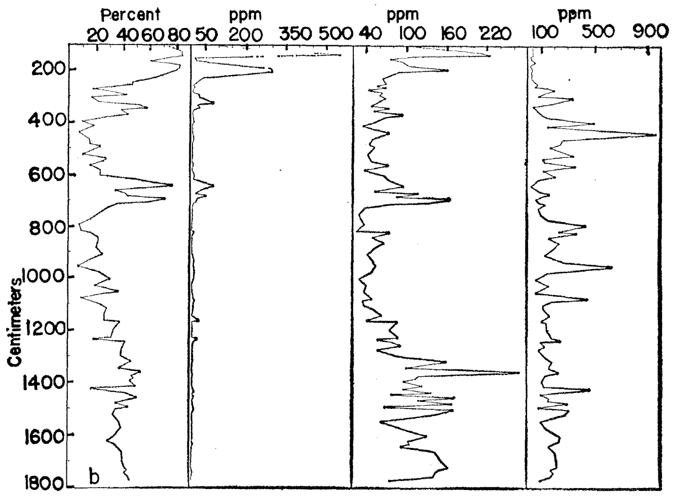
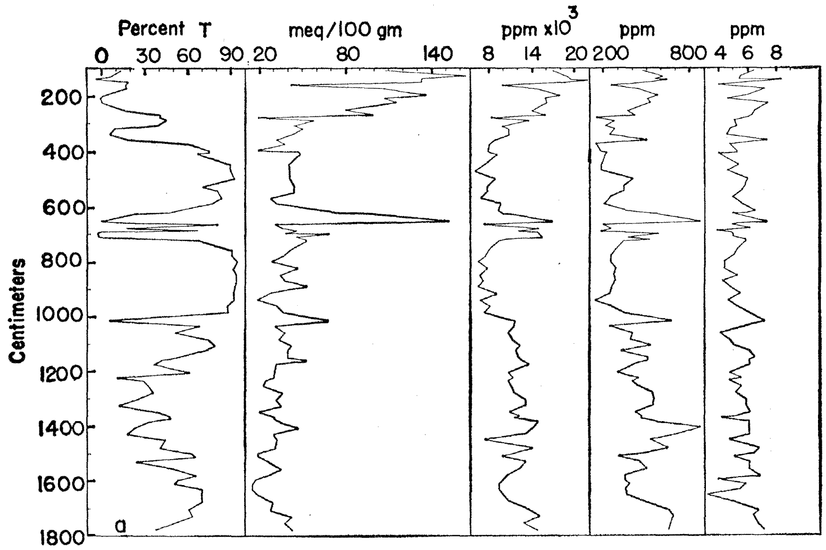


Fig. 1 (left). Results of wet analyses showing percentages of nitrogen (left column), organic carbon (middle column), and carbonate (right column) present in the core material. Fig. 2 (right). Percentage of water content (left column), parts per million of water-soluble phosphorus (left center column), chloride in dry sediment (right center column), and chloride in water (right column) of the core material.



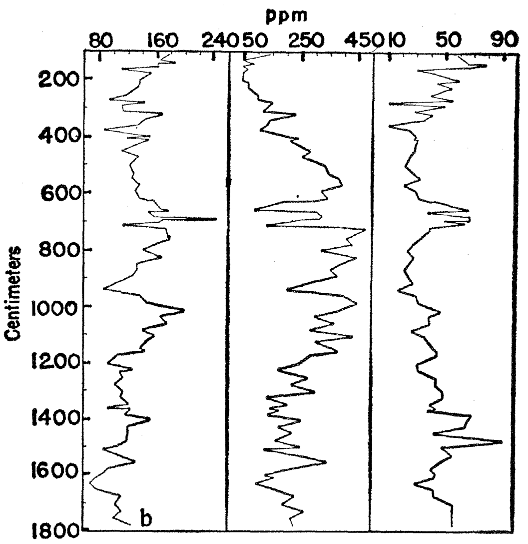


Fig. 3 (left). Organic color of ammonium acetate extract (arbitrary units decreasing with increasing color) (left column), cation exchange capacity (left center), exchangeable calcium (center), exchangeable magnesium (right center), and exchangeable lithium (right column). Fig. 4 (right). Exchangeable sodium, potassium, and strontium (left to right columns, respectively) present in the core material.

the chloride is in solution in pore water and that the loss of weight at 110°C gives a valid idea of the latter, we can recalculate the chloride relative to this water. It then appears that there is much less variation. Assuming that a few very low water contents are in part due to drying after collection and so are too low and result in excessive chloride values, we felt it reasonable to estimate the modal chloride content as between 150 and 200 parts per million present in the sediment water. This is considerably higher than the values below 50 parts per million from the top of the core and much higher than the modern chloride content of 3.4 parts per million (*3*) of the water of the lake.

We conclude that although the lake must have overflowed on occasions during the first half of its presently known history or the chloride in the water would have risen systematically, overflow occurred much less frequently than today. The lake in fact was behaving more as a closed than an open body of water. It has been pointed out that in Indian Tibet (*4*) all closed lakes deposit carbonate sediments and all open lakes do not. The carbonate sedimentation in the earlier part of the history of Lake Zeribar is thus in line with the chloride content and suggests a drier climate than today. The high boron contents in the two deeper layers (Table 2) may well be in accord with this hypothesis.

Above the zone in which the amount of carbonate sedimentation is appreciable there are two layers of relatively sterile clay (718 to 975 cm and 430 to 607 cm) separated by a layer of organic sediment which is itself divided by a narrow clay band. The organic layer is preceded by a transitory renewal of carbonate sedimentation. We regard the clay layers as evidence of somewhat greater erosion in the basin and so of inorganic sedimentation in the lake which was possibly initiated by increasing rainfall. The intermediate organic band composed of coarse macrophytic detritus may represent the establishment of a carpet of water plants over the bottom of the lake. At the present time much of the floor of the lake is evidently covered (*3*) with *Myriophyllum* and *Naias* and their remains. Whether a similar condition existed for a time at a rather low lake level, when the sediment between 6 m and 7 m was deposited, could only be ascertained from more borings taken from an area well out from the present littoral. The variation in the chloride in these upper levels is too problematic to permit any conclusions.

Table 1. Major constituents of the core (percent of dry sediment).

Depth (cm)	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	CaO	MgO	Na_2O	K_2O
107.5	49	0.70	15	5.0	0.030	1.65	3.3	0.75	1.35
542.5	52	.80	20	7.7	.060	1.70	2.2	.60	2.35
622.5	32	.47	15	4.4	.080	30.0	1.8	.80	0.85
867.5	54	.90	17	8.1	.065	1.5	2.3	.70	2.57
1032.5	51	.82	20	6.4	.055	3.0	2.3	.92	2.10
1122.5	50	.82	16	7.1	.065	7.5	2.0	1.22	2.10
1477	30	.40	8	3.6	.075	25.0	3.2	0.97	1.15
1627.5	22	.30	3.8	2.0	.075	38.0	3.1	.75	0.70
1777.5	40	.65	14.0	4.9	.070	20.0	2.9	1.30	1.26

Table 2. Minor constituents of the core (parts per million).

Depth (cm)	B	Ba	Be	Co	Cr	Cu	La	Ni	Sc	Sr	V	Y	Zr
107.5	25	350	2.2	6	150	37	< 50	90	12	120	240	15	160
1032.5	40	330	2.0	12	160	35	< 50	130	18	120	230	20	190
1777.5	45	270	1.5	8.5	180	32	< 50	110	13	190	150	20	160

The upper layers of sedge peat, to some extent, interstratified with clay, clearly reflect littoral conditions similar to those of today. In general, water-soluble phosphate reflects the organic carbon and nitrogen and is clearly derived from the decomposition of sedimented organic matter.

In the inorganic layers the cation exchange capacity increases slightly and irregularly up the core. In the organic layers there is clearly a great increase in cation binding capacity, as has been recorded in other fresh-water peaty material (*5*). The exchangeable alkaline earths all decline slightly from the bottom until the lower organic layer is reached; a small solution of carbonate may be involved here. In the upper part of the core their distribution is clearly related to the increased exchange capacity of the organic layers.

Sodium and potassium vary in a way opposite to that of the alkaline earths in the lower part, possibly suggesting a slight concentration in the water during the early period of the history of the lake. At the top of the profile sodium behaves rather like the alkaline earths, whereas potassium declines steadily. This decline seems to be partly associated with the development of the littoral peaty deposits.

At present the potassium content of the water is below the limits of quantitative analysis available to Löffler (*3*). Much potassium is no doubt locked up in the extensive carpet of *Myriophyllum*. The exchangeable potassium appears at all levels to be but a small part of the total potassium. It is possible that in recent times much potassium taken up by water plants has been fixed in nonexchangeable form in the sediments after the decomposition of such plants. The fall in exchangeable potassium may therefore record the spread of macrophytes from the littoral over much of the lake bottom.

While much more information could be gained from cores taken well away from the littoral, we believe that our results, notably as to the probably drier climate in the early part of the lake history, provide confirmation of the rather surprising conclusions to be drawn from the pollen analyses discussed in the preceding report.

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References and Notes

1. The core upon which we based our present study was received from Herbert E. Wright. Results of his pollen analysis on the same core are described in the accompanying report [*Science* **140**, 65 (1963)].
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