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FLUCTUATIONS IN HIGH MOLECULAR FATTY ACID AS AN INDICATOR OF PALEOCLIMATIC CHANGE IN A TURKISH LAKE SEDIMENT CORE

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A 5 m sediment core taken from Lake Kestel in southwestern Anatolia, Turkey, was analysed for high molecular saturated fatty acids ($\geqq C_{20}$ FA_s) as a paleoclimatic indicator.

In the present paper, we discussed the correlation between the fluctuations in $\geqq C_{20}$ FA concentrations and precipitation in Anatolia over the last 2,000 years based on previous pollen records. The discussion led to the following conclusion:

1) The amounts of precipitation about 1,800 to 1,300 years ago were extremely low leading to very dry climatic conditions.
2) From 1,300 to 600 years ago, the precipitation increased gradually to a level similar to that of the present with some fluctuations into very low precipitation. From about 600 years ago to the recent past, a wet climate had prevailed.
3) From 200 to 40 years ago, the precipitation temporarily increased to about 1.5 times its previous level. Thereafter, it tended to decrease considerably.

Key words: HIGH MOLECULAR FATTY ACIDS, PALEOCLIMATIC INDICATOR, PRECIPITATION, CORE SEDIMENT, SOUTHWESTERN ANATOLIA.

INTRODUCTION

For the potential use of biological markers as paleoclimatic indicators, the following two factors are required. One is a biologically specific compound indicating an origin from particular organisms. The other is the survival of their diagnostic signal over a period of geological time. This is the case for high molecular saturated fatty acids ($\geqq C_{20}$ FA_s) found in lacustrine environments, which derive from higher terrestrial plants.

A previous study of a 100 m sediment core from Lake Mikata in Japan strongly suggested that the concentrations of $\geqq C_{20}$ FA_s in core sediments can provide information on precipitation levels for paleoclimatic reconstructions. To investigate the possibility that this is also true for core sediments deposited under quite different lacustrine envrionments from those of Lake Mikata, we obtained a 5 m sediment core from Lake Kestel in southwestern Anatolia, Turkey, a region with very low precipitation and poor vegetation, and analysed it for $\geqq C_{20}$ FA_s in the ^{14}C-dated sediment samples.

MATERIALS AND METHODS

Samples

Lake Kestel is located in the southwestern part of the Anatolian plateau (Fig. 1). The annual precipitation in the area is less than 600 mm. Thus, the climatic conditions around the lake are characterized by dry, hot summers and wet, cold winters, and the vegetation is very poor.

The present lake basin almost dries up, having some areas open for cultivation. A 5 m sediment core was taken from a location near the center of the basin and divided into sections at 5 or 10 cm intervals.

Plant Residues

Each sediment sample was separated into two size fractions before chemical analysis. Fractions of >250 μm were obtained by wet-sieving bulk samples (80-100 g dry weight) through stainless steel sieves. Land plant residues were collected from the mineral fraction by exploting the difference in specific gravity between plant and mineral materials. The residues thus obtained provide information for tracing the historical changes in the water area of a lake basin, as discussed previously (Nishimura and Mitamura, 1995).

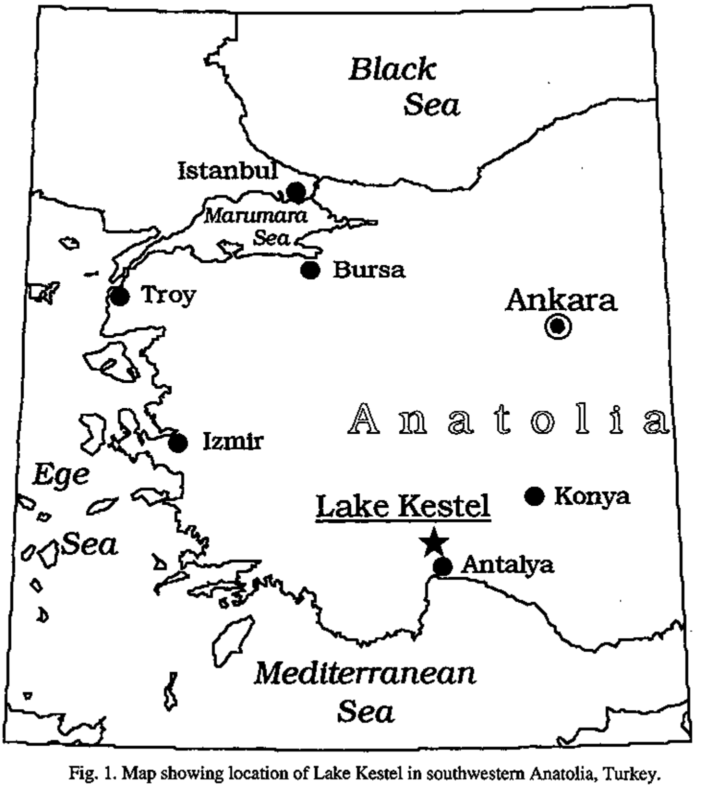

Fig. 1. Map showing location of Lake Kestel in southwestern Anatolia, Turkey.

Analytical Procedures

The analytical procedures from lipid extraction to quantification of fatty acids are described in detail elsewhere (Nishimura et al., in press). The methodology for some key procedures are briefly reiterated here.

Size fractions of <250 μm passing through the sieves with the wash water (500-1000 ml dist-water) were used for fatty acid analysis. Wet sediments were exhaustively extracted both with acetone only and with acetone-benzene (4 : 5). All extracts were combined as a solvent-extractable lipid fraction.

Each lipid extract was saponified with 0.5N KOH/methanol solution containing 5% water. Non-saponifiable lipids obtained were separated into a neutral fraction and an acid fraction using a KOH-impregnated SiO_2 column. The acid fraction was methylated by diazomethane in diethyl ether. The crude fatty acid methylesters were chromatographed on a column of 15% deactivated SiO_2. The hexane-benzene (9 : 5) fraction contained fatty acid methylesters.

GC/MS analysis was performed using a JMS-AX505H magnetic sector mass spectrometer (MS) coupled to a Hewlet Packard 5890 series Ⅱ capillary gas chromatograph (GC). Chromatographic separation was achieved with a DB-5, 0.25 mm i. d. × 30 m fused silica capillary column. Samples were injected at 30°C through an on-column injection system, and the column oven was then brought to 70°C. The oven temperature was programmed to 310°C at 6°C/min.

Quantitative analyses of fatty acid methylesters by GS were conducted on a Hitachi 163 gas choromatograph equipped with a cool on-column injector. All samples were analysed on a DB-5, 0.25 mm i.d. × 30 m fused silica capillary column using the same chromatographic conditions as above. The FID was operated at 350°C.

RESULTS

Vertical Profile of Plant Residues

Plant residues collected were observed under a microscope. Most of them consisted of various parts of terrestrial vascular plants. The vertical distribution was illustrated in Fig. 2. The amounts of plant residues in Lake Kestel sediments were extremely low as compared with those (usually, >several mg/g dry sed.) of various lakes in Japan. The highest value was only 0.75 mg/g dry sed.. This fact reflects very poor vegetation around the lake, due largely to the dry and hot climatic conditions in southwestern Anatolia. The distribution of the residues from 500 cm to 60 cm in depth was almost uniform, and there was no correspondence with the lithological classification based on differences in the distribution of four basic grain sizes (Fig. 2). On the contrary, the amounts of plant residues increased sharply from about 60 cm in depth to the surface, a tendency which corresponded to the change in the lithology from clay-silt to silt.

Distribution of $\geqq C_{20}$ FA_s

Fig. 3 is a typical gas chromatogram of fatty acids from Lake Kestel sediments. $\geqq C_{20}$ FA_s was mainly comprised of 17 components from C_{20} to C_{36}. The abundances of $\geqq C_{20}$ FA_s are compiled in Table 1. Like plant residues, fatty acid levels in Lake Kestel were very low, being two orders of magnitude below those in lakes in Japan, which refleced very poor vegetation around the lake. The concentrations varied in a relatively wide range from 0 to 7.6 μg/g dry sed..

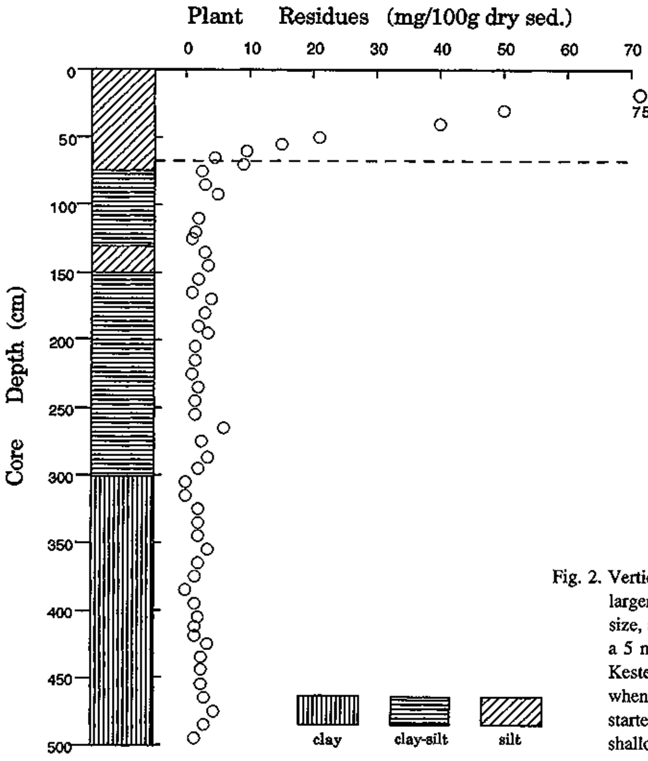

Fig. 2. Vertical profile of plant residues larger than 60 mesh (250 μm) in size, and the sedimental facies in a 5 m sediment core from Lake Kestel. Horizontal dashes show when the water area of the lake started to diminish and thus get shallower.

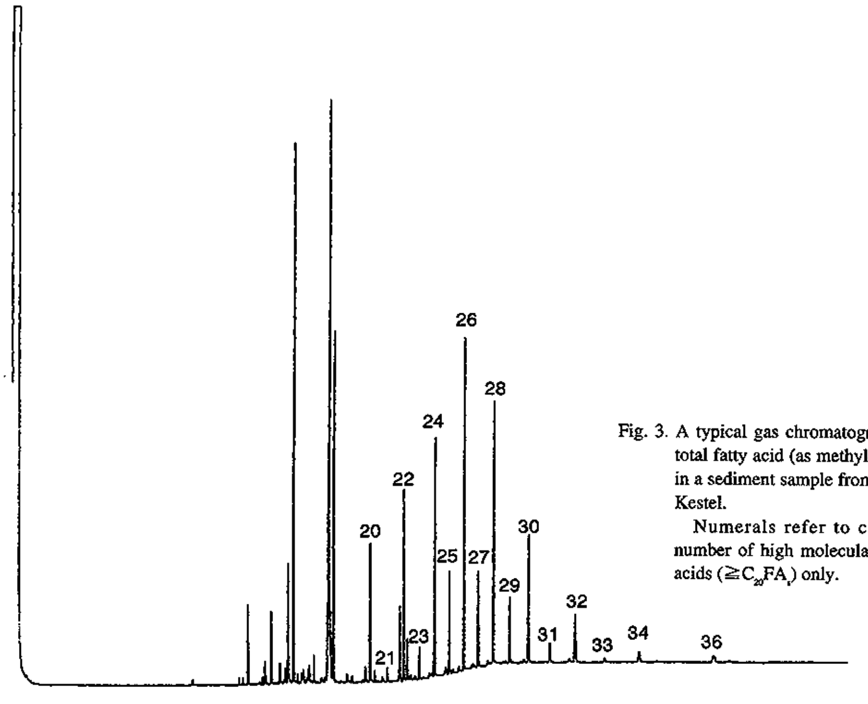

Fig. 3. A typical gas chromatogram of total fatty acid (as methylesters) in a sediment sample from Lake Kestel.

Numerals refer to carbon number of high molecular fatty acids ($\geqq C_{20}FA_t$) only.

Table 1. Total concentration of high molecular fatty acids ($\geqq C_{20}$ FA_s) in 5m core sediments from Lake Kestel.

Core Depth (cm)	$\geqq C_{20}$ FA (μg/g dry sed.)
30-45	7.6
55-60	1.0
70-75	1.3
80-90	2.2
100-110	1.7
120-130	1.4
140-150	1.6
158-166	1.5
174-182	1.7
190-200	0.3
210-220	1.6
230-240	1.5
250-260	n.d
270-280	1.0
290-300	0.2
310-320	0.5
340-350	0.1
360-370	n.d
380-390	n.d
400-408	n.d
416-424	n.d
432-440	n.d
450-460	n.d
470-480	3.1
490-500	1.0

DISCUSSION

Changes in Depositional Conditions

The vertical profile of plant residues, together with the lithology, (Fig. 2) provides information on the changes in water level in Lake Kestel based on a previous study of environmental factors controlling residue distribution in a lake (Nishimura and Mitamura, 1995). Residue distribution in the 60-500 cm layer implies that Lake Kestel had a widespread and stable water basin and thus deep water during that period of residue accumulation. Residues in the 0-60 cm layer indicate the steady decline toward a shallower, smaller basin which finally resulted in the dried-up condition seen today.

Environmental Factors Controlling the Concentrations of $\geqq C_{20}$ FA_s

The concentrations of $\geqq C_{20}$ FA_s down to 60 cm were about five times higher than those below that depth. Judging from the distribution of plant residues, this may be due to an increasing invasion of terrestrial vascular plants into the marshy area as Lake Kestel became shallower. Thus, the geochemical implications of $\geqq C_{20}$ FA concentrations in the 60-500 cm layers are quite different from those in the 0-60 cm layer. The former shows stable depositional conditions with deep water, whereas the latter is a series of transitional phases from deep lake to marsh to dry basin. Consequently, our discussion is focused on the distribution of $\geqq C_{20}$ FA_s from 500 to 60 cm in core depth.

The sedimentation rate of the core sediments was measured by Kitagawa et al. (this volume) with ^{14}C-dating. Using that rate, the age of each sediment layer was calculated (see vertical numbers in Fig. 4). The vertical distribution of $\geqq C_{20}$ FA_s in 60-500 cm core depths is characterized by the following:

1) Although a relatively high concentration of $\geqq C_{20}$ FA_s occurred around 1,900 years ago, almost no or extremely low $\geqq C_{20}$ FA_s was detected in the period from about 1,800 to 1,300 years ago.
2) From 1,300 to 600 years ago, the concentrations increased gradually from trace amounts to 150 μg/100 g dry sed. with some fluctuations. From about 600 years ago, the sediment layers retained a relatively high level of $\geqq C_{20}$ FA_s.
3) Fatty acid concentrations increased sharply to about 1.5 times during the period from 200 to 40 years ago, and then declined abruptly to half for about 20 years.

In our previous study, we concluded that a major factor controlling $\geqq C_{20}$ FA concentrations in lacustrine sediments was a natural phenomenon which transported terrigenous organic matter into lakes. We identified this as precipitation, rather than the kinds or amounts of vegetation surrounding lakes (Nishimura and Mitamura, 1995). Thus, the changes in $\geqq C_{20}$ FA

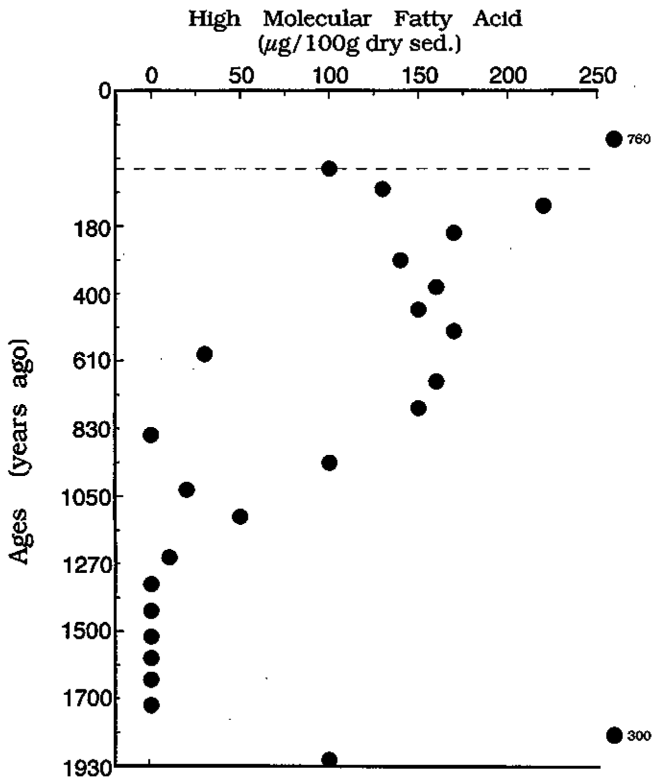

Fig. 4. Vertical distribution of $\geqq C_{20}$ FA_s in a 5 m sediment core sample from Lake Kestel.
Ages of each sediment were calculated using the sedimentation rate measured by Kitagawa et al. (in this volume) with ^{14}C-dating. Dashes show when the area of the lake started to diminish.

concentrations in Lake Kestel core sediments (Fig. 4) may correspond to variations in amounts of precipitation in southwestern Anatolia over the last 2,000 years.

In order to investigate this possibility, we surveyed the literature regarding the 2,000 year history of precipitation in that region. Unfortunately, there is little information available except for studies by Yasuda (1988) and Bottema (1993). Their pollen analyses for core sediments from wetlands (Yasuda, 1988) and a lake (Bottema, 1993) relatively near Lake Kestel consistently revealed a climatic change from wet to dry conditions around 1,900 years ago. Based on the remarkable increase in the ratio of tree pollen to total pollen from about 1,000 years ago in southwestern Anatolia, it is thought that dry conditions ended *ca.* 1,000 years ago when the climate changed gradually to wet conditions relatively similar to those found today. These climatic changes appear to correspond fundamentally to the changes in $\geqq C_{20}$ FA concentrations, which were mentioned in 1) and 2), although more detailed information on climatic change is needed.

Climatic Changes Based on $\geqq C_{20}$ FA_s

The close correspondence between $\geqq C_{20}$ FA concentrations and pollen types over the last 2,000 years supports the previously suggested possibility that such concentrations in core sediments from lakes can provide information about precipitation (Nishimura and Mitamura, 1995). In conclusion, the $\geqq C_{20}$ FA concentrations in core sediments from Lake Kestel probably reveal the following climatic changes in southwestern Anatolia:

1) The amounts of precipitation in the period from about 1,800 to 1,300 years ago were extremely low; that is, climatic conditions were very dry.
2) From 1,300 to 600 years ago, precipitation increased gradually to a level relatively similar to that today with some fluctuations to very low levels. Since about 600 years ago, a wet climate had prevailed until recently.
3) During the period from 200 to 40 years ago, precipitation temporarily increased to about 1.5 times its previous level. Thereafter, it tended to decrease considerably.

The occurrence of such a clear contrast in climatic conditions between about 1,800-1,300 years ago and the last 600 years was also supported by stable carbon isotope data obtained by Kitagawa et al. (this volume). Mean $\delta\ ^{13}C$ values of lipids from sediment layers in both periods were significantly different from each other (27.4‰ and 29.1‰, respectively). This fact indicates that the input of terrigenous organic matter to the lake during the last 600 years was apparently greater than from 1,800 to 1,300 years ago due to a significant difference in precipitation levels.

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トルコの湖底柱状堆積物における、古気候変動の指標物質：高分子脂肪酸の変化

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要旨：湖沼堆積物に存在する炭素数が20コ以上からなる高分子脂肪酸は、降水量の変動についての情報をもたらしうる有機分子であることが、三方湖柱状堆積物の研究から示唆されている。このことが、三方湖とは全く違った環境下にある湖沼の堆積物についても同様に適用できるか否かについて検討を行った。

試料は、トルコの南西アナトリア高原にあるケステル湖から得られた５ｍの柱状堆積物（約2,000年前迄遡る。）を使用した。得られた高分子脂肪酸量の変動は、花粉分析によって示される湿潤・乾燥の古環境変化とかなりよい対応をしていることが解っ

た。その結果、最近の約2,000年間における、南西アナトリア高原の降水量の変動は、次の様であったと結論された。

1）1,800年前から1,300年前の間、降水量は極端に低く、たいへん乾燥した気候であった。
2）1,300年前から600年前にかけて、降水量は、いくつかの変動をしながらも、現在のそれに近いレベルにまで徐々に増大した。600年前以降から最近迄、湿潤な気候が支配的であった。
3）200年前から約40年前迄の間、降水量は、それ以前のレベルの約1.5倍まで一時的に上昇し、その後、大きく減少する傾向に あった。