Japan Review, 1997, **8**: 229-234

RADIOCARBON DATING OF PLANT REMAINS AND LIPIDS IN CORE SEDIMENTS FROM LAKE KESTEL, TURKEY

KITAGAWA, Hiroyuki and YASUDA, Yoshinori
International Research Center for Japanese Studies, Kyoto, Japan
NISHIMURA, Mitsugu
Marine and Science Technology, Tokai University, Japan
NAKAMURA, Toshio
Dating and Materials Research Center, Nagoya University, Aichi, Japan

In 1992, a 5 m core was recovered from Lake Kestel, which is located on the southern Mediterranean coast of Turkey. Accelerator Mass Spectrometry (AMS) radiocarbon dating and stable carbon isotope ($^{13}C/^{12}C$) analysis were made on both plant remains and lipids from the core sediments.

AMS radiocarbon dates of plant remains showed that the sediment was deposited at a relatively constant rate (0.21 cm/year), suggesting a record of the environmental changes during the last 2000 years. The initial radiocarbon contents (A_0) in lipids were in the range of 30-90 percent modern carbon (pMC) and tend to vary inversely as $^{13}C/^{12}C$ change in lipids. Such a low content of A_0 in lipids was introduced by an influx of lipids with less ^{14}C contents from the surrounding soil. Therefore, the A_0 in lipids may be an indicator to assess the tranportion process of the organic materials from the surrounding soil to the lake sediment in the past, possibly relating to hydrological and environmental changes such as precipitation and evaporation.

Key words: ^{14}C, LIPIDS, LAKE KESTEL, TURKEY

INTRODUCTION

One of the tasks of archaeology is to explore the relationship between human and their environment at different stages of human evolution. Such a task could be performed by precise dating of both archeological and paleoenvironmental events. A detailed chronological study might make it possible to establish whether or not the synchronization of archaeological and paleoenvironmental events is possible.

Lacustrine sediments provide excellent records of past variations in climate, vegetation and human activities over a well-defined geographical area. Lake Kestel is located near Antalya (Attaleia) on the southern Mediterranean coast of Turkey where ancient settlements such as Attaleia, Perge, Silyon, Aspendos, Side, etc., are nearby. To reconstruct paleo-environmental changes in relation to human history around the southern Mediterranean coast area, a 5-m continuous sediment core (Lab. No., KGII) was collected from Lake Kestel in 1992.

Eight pairs of plant remains and lipids from selected depths of the KGII core have sellected for AMS radiocarbon dating. The aim of the present study is to obtain a precise chronology of the KGII core. The detailed chronology that forms the bases of the analysis is discussed here. Furthermore, there is discussion of a possibily method of assessing the past hydrological changes by means of the ^{14}C and stable carbon isotopic analyses in lipids.

CORING SITE AND MATERIALS

At present, the climate of the southern Mediterranean coast area of Turkey is characterized by hot, dry summers and cold, wet winters. The mean temperature in July at Antalya is about 28 °C; the daily mean highest and lowest temperatures in July are 34 °C and 22 °C, respectively. The daily temperature for January is about 11 °C on the average. Most of the precipitation at Antalya occurs during the winter (November -February). The annual precipitation is about 1000 mm (Meteorological Office, 1966).

A 5-m continuous sediment core, KGII, was collected from Lake Kestel near Antalya in 1992. The core sediment was divided every *ca.*, 10-cm interval. The lithology of the core is dominated by carbonate-rich clay and silt, indicating that the sediment was preferentially deposited in lake environments.

Eight strata in the 5 m sediment were selected for AMS radiocarbon and stable carbon isotope analysis for both plant remains and lipids at 45-50cm , 60-70cm, 130-140cm, 182-190cm, 280-290, 320-330, 424-432 and 480-490 below the top of the KGII core.

EXPERIMENTAL PROCEDURES

The sediments passing over a 60 mesh-size sieve were used for the extraction of lipids from the sediment. The lipids were extracted by the method reported in Nishimura *et al.* (this volume) and Nishimura and Becker (1987). The plant remains on the 60 mesh-size sieve were picked out by hand and then treated by acid (1 N-HCl), alkali (5 %-NaOH) and acid (1%-HCl) (AAA treatment) to remove possible contaminations (Olsson, 1986; Kitagawa,1997). The lipids and pretreated plant remains were combusted in an evacuated sealed Vycol tube with CuO as the oxygen source at 850 °C. The resulting CO_2 was purified cryogenically. The stable carbon isotope ratios ($\delta^{13}C$) were determined on a VG-OPTIMA isotope ratio mass spectrometer at the International Research Center for Japanese Studies. The stable carbon isotope datas are reported in the standard permil notation relative to the PDB standard calibrated by NBS19 international strandard (carbonate). For AMS ^{14}C measurements, a purified CO_2 was reduced catalytically to graphite with H_2 over Fe powder (Kitagawa *et al.*, 1993) and $^{14}C/^{13}C$ ratios of the resultant graphites were measured by a Tandetron Accelerator Mass Spectrometer at the Dating and Materials Research Center, Nagoya University (*e.g.*, Nakamura *et al.*, 1985). The procedure suggested by Stuiver and Polach (1977) was followed for the calculation of the radiocarbon ages, and the ^{14}C contents in dating materials are expressed as

$$\text{pMC(percent modern carbon)} = \text{Rsample}/\text{Rstandard} \times 100\ (\%) \qquad (1)$$

or

$$\Delta^{14}C = (\text{Rsample}/\text{Rstandard} - 1) \times 10^3\ (‰) \qquad (2)$$

where Rsample is the $^{14}C/^{12}C$ ratio in the sample normalized to $\delta^{13}C$=-25 ‰, and Rstandard is modern $^{14}C/^{12}C$ ratio calibrated by an international radiocarbon standard (NIST-HOxII). The errors are at the one sigma level and represent both the statistical errors of standard and sample.

RESULTS AND DISCUSSION

Chronology of KGII core

Table 1 shows the $\delta^{13}C$ and $\Delta^{14}C$ of plant remains and lipids from the KGII core sediments. The $\Delta^{14}C$ values of the plant remains from 60-65, 65-70 and 130-140 were higher than that in AD 1950 ($\Delta^{14}C$=0), indicating that the sediments were deposited after AD 1965 when many nuclear bomb experiments were carried out and the ^{14}C content in atmospheric CO_2 was significantly increased. The plant remains from 45-50 and 182-190 cm in depth contained visible (relatively large sized) charcoal fragments. It also showed a higher carbon content (Table 1). The charcoal is a possible contaminant with less ^{14}C content which was transferred from the surrounding soil over a long period of time. They were not used to calculate the age of the core

Table 1 $\Delta^{14}C$ and $\delta^{13}C$ of plant remains and Lipids of the KGII core from Lake Kestel, Turkey.

Depth (cm)	Plant remains: Carbon after AAA(mg)	(%)	$\Delta^{14}C$ (‰)	$\delta^{13}C$ (‰)	Lipids extracts: Carbon contents (mg)	wt (%)***	$\Delta^{14}C$ (‰)	$\delta^{13}C$ (‰)
45-50	13.42	46.3	-43.7±10.7**	-24.7	1.50	2.3	-198.8±9.6	-29.4
60-65	5.57	37.0	45.5±11.5	-24.4	n.m		-456.6±5.3*	-29.1
65-70	1.98	43.0	114.1±14.2	-25.2	n.m			-29.3
130-140	1.26	27.0	42.1±13.7	-25.3	0.76	1.3	-313.1±8.7	-29.1
182-190*	1.16	44.0	-271.6±8.6**	-25.3	1.33	2.4	-403.5±6.9	-29.1
280-290	2.78	37.7	-101.6±8.9	-24.3	1.13	1.6	-681.7±4.8	-27.7
320-330	0.98	37.0	-142.3±13.3	-24.7	n.m		-820.6±2.2	-28.0
424-432	1.99	29.6	-194.3±9.3	-24.5	0.20	0.3	-302.4±20.5	-27.0
480-490	1.12	37.5	-201.0±9.4	-24.3	0.92	1.7	-477.8±6.3	-27.1

* $\Delta^{14}C$ of Lipids was determined for the mixture of two layers (60-65 and 65-70 cm depth).
**The sample from 182-190 depth contains charcoal fragment.
*** The weight percentage of carbon to dry sediment.
n.m: not measured.

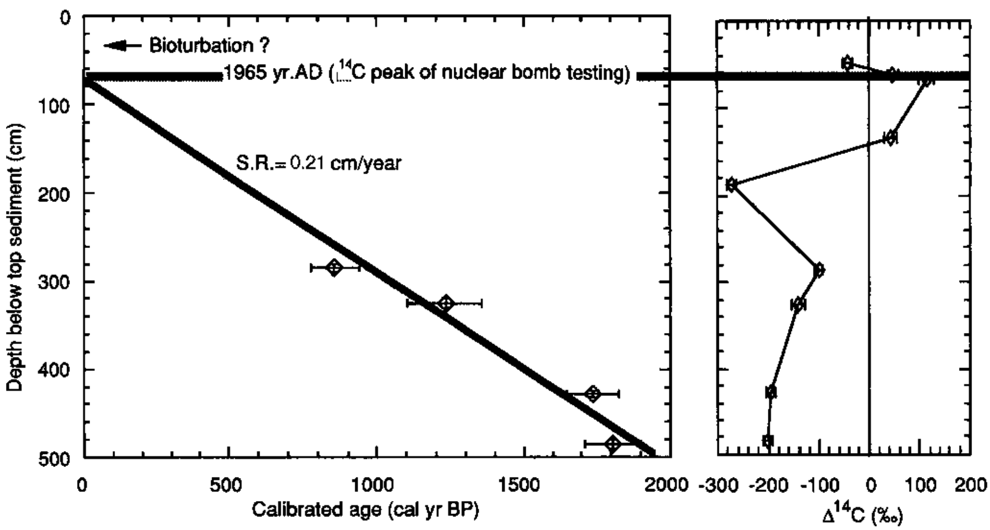

Fig. 1. Depth *vs.* calibrated radiocarbon age and ^{14}C content of the core sediments from Lake Kestel, Turkey. The black line shows the linear regression line between calibrated ages and depth. The regression coefficient is 0.8.

sediments. Figure 1 shows the calibrated radiocarbon ages of plant remains from the KGII core (Stuiver and Reimer, 1993). Assuming a constant sedimentation rate and using linear regression analysis between four radiocarbon dates and sample depths; 280-290 cm: AD 1145±80 yr, 320-330 cm: AD 805±120 yr, 424-432 cm: AD 285±110 yr and 480-490 cm: AD 220±110 year, it can be estimated that the annual sedimentation rate is 0.21 cm/year for KGII core. The sedimentation age is calculated using the following equation:

$$\text{Age (cal year BP)} = 4.68 \times \text{Depth(cm)} - 377.5 \qquad \text{(Eq.1)}$$

The estimated age of the 65-70 cm depth layer by Eq.1 is about AD 1965-70, in which the ^{14}C contents in atmospheric CO_2 were considerably increased. It confirmed that the age model is useful for the age calculation of the KGII core during the past 2000 years. Furthermore, the high linear regression coefficient between depth and age (r=0.8) indicates that the sediment was deposited at a relatively constant rate during the past 2000 years.

The radiocarbon contents in lipids

Figure 2 shows the change of initial radiocarbon contents (Ao) and $\delta^{13}C$ values in lipids and lipids contents (=lipids/dry sediments) as a function of the estimated age based on the radiocarbon age of the plant remains. The Ao value in lipids from the KGII core sediment is apparently older than that of the plant remains from the same depth. The Ao in lipids changes in the range of 30-90 pMC, indicating that the lipids with less ^{14}C content was added. It could be interpreted that 1) lipids from a deeper layer were diffused, possibly by bioturbation and chemical penetration towards the upper layer and 2) lipids produced in the surrounding soil were transported. The $\delta^{13}C$ value in lipids are in the range of -29.5 and -27.6 ‰, and tend to vary inversely as Ao change in lipids (Fig. 2). It could be concluded that the ^{13}C-rich and lower ^{14}C lipids were transported into the lake sediment. It may be interpreted that ^{13}C-rich lipids originated from C4 plants grown in grassland were transported to the lake sediment. If this interpretation is correct, Ao and $\delta^{13}C$ in lipids in the lake sediment were strongly influenced by the influx of organic matter from the surrounding soil.

In the Medieval Warm Period (about AD 1200), the influx of organic matters from the

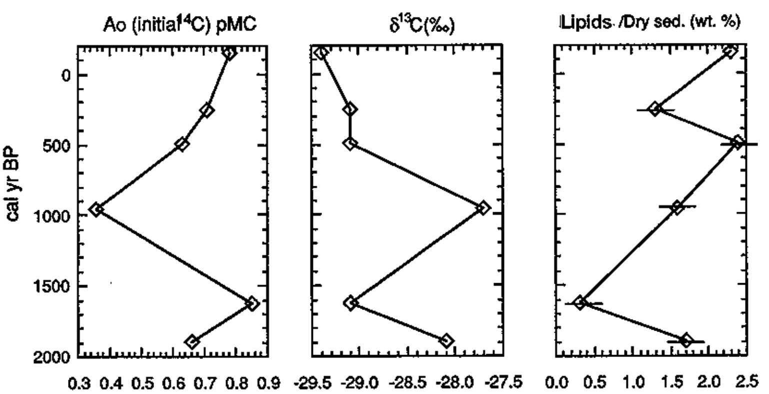

Fig. 2. Initial radiocarbon contents (Ao), $\delta^{13}C$ and contents of lipids in sediment from Lake Kestel as a function of calibarated ^{14}C age.

surrounding soil may have increased because of the small Ao and high $\delta^{13}C$ values. The lipids from decomposing C4 plant detritus with less ^{14}C content and high $\delta^{13}C$ values were transferred into the lake sediment. This may suggest increased precipitation or reduction of lake-size during the Medieval Warm Period as a global climatic change (Lamb, 1980).

CONCLUSION REMARKS

A chronology was constructed of the core sediment from Lake Kestel, near ancient settlements such as Attaleia, Perge, Silyon, Aspendos, Side etc. Using this chronological study, the studies of paleoenviromental reconstruction in relation to the human history around the southern Mediterranean coast of Turkey is in progress.

The stable-and radio-isotope changes of lipids in sediments were used as a possible indicator for past hydrogical changes. In the case of Lake Kestel, the isotope change of lipids is probably influenced by the additional lipids with less ^{14}C content and high $\delta^{13}C$ value, possibly from the surrounding landscope. Our approach may provide a new perspective on past changes of organic inflows from the surrounding soil to the lake sediment, possibly relating to the past hydrological processes around the lake.

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トルコ・ケステル湖から得られた柱状堆積物の植物性残在物と脂質の炭素14年代

北川浩之、西村亜弥、中村俊夫、安田喜憲

要旨：1992年、トルコ・ケステル湖（Lake Kestel）から採集した柱状堆積物の植物性残在物と脂質について炭素14年代測定と安定炭素同位体比（$^{13}C/^{12}C$）分析を実施した。

植物性残在物の炭素14年代測定の結果、トルコ・ケステル湖の堆積物は、過去2000年間にわたり比較的一定の堆積速度（4.6cm/year）で堆積してきたことが明らかとなった。堆積物から抽出した脂質の炭素14濃度は30-90%希釈され、またその希釈の程度は、$^{13}C/^{12}C$ 比と逆相関の関係にある。これは、堆積物中の脂質がケステル湖周辺の土壌から運搬されたと考えると解釈できる。したがって、堆積物中の脂質の炭素同位体分析は、過去の陸水環境の変動の一つの指標として有効である可能性がある。