^{14}C AGES OF TERRESTRIAL MACROFOSSILS FROM LAGO GRANDE DI MONTICCHIO (ITALY)

IRKA HAJDAS, GEORGES BONANI

Institut für Teilchenphysik, ETH-Hönggerberg, CH-8093 Zürich, Switzerland

BERND ZOLITSCHKA, ACHIM BRAUER and JÖRG NEGENDANK

GeoForschungsZentrum Potsdam, Telegrafenberg A26, D-14473 Potsdam, Germany

ABSTRACT. Lago Grande di Monticchio (Italy) contains long sedimentary records of >75 ka (Zolitschka and Negendank 1996). In a joint European project (Creer and Thouveny 1996), vegetation history and climatic changes for this part of the Mediterranean have been reconstructed (Watts, Allen and Huntley 1996; Watts *et al.* 1996). In addition to the time scale based on annual laminations and sedimentation rate, tephra layers and pollen spectra, radiocarbon dating was applied for the last 40 ka. Previous studies have shown that the age of bulk sediment from Lago Grande di Monticchio, which is a maar lake at the flanks of Mt. Vulture, was influenced by "dead carbon" of volcanic origin dissolved in the lake water. Thus, ^{14}C dating of the record is problematic and must be limited to dating macrofossils of terrestrial origin.

From a set of sediment samples, macrofossils were selected and dated using accelerator mass spectrometry (AMS). A ^{14}C time scale based on seven data points between 9000 and 24,000 BP is compared with other dating of the record based on varve counting and tephrochronology (Zolitschka 1996).

INTRODUCTION

Lago Grande di Monticchio, a maar lake in Italy, has been the subject of intensive paleoclimatic studies. Sediment cores recovered from the bottom of the lake contained up to 52 m of sediment. The record appeared to be partially laminated. This allowed Zolitschka (1996) to built a time scale based on varve counting and interpolation using sedimentation rates for intervals that are not laminated. The varve chronology is a basis for time series of pollen spectra (Watts, Allen and Huntley 1996; Watts *et al.* 1996) and paleomagnetic studies (Creer and Morris 1996). In their detailed studies, Watts, Allen and Huntley (1996) were able to reconstruct the history of vegetation and climate in the region of Monticchio. They concluded that the climate of the southeastern Mediterranean responded to the changes in the North Atlantic sea surface temperature (SST). Warmer and moister conditions succeeded Heinrich Events (HEs) of massive iceberg discharges into the North Atlantic and contributed to the expansion of woodland in the region of Monticchio. Zolitschka (1996), on the other hand, identified characteristic variations in sedimentation rate. His interpretation was that a high sedimentation rate corresponds to periods of increased input of minerogenic material. Such periods coincide with low total organic carbon (TOC) and were thought to have occurred at the time of HEs in the North Atlantic.

Some disagreement exists between timing of the events in the pollen and sedimentation rate records, even though a common time scale of varve chronology was applied. Attempts were made to validate the varve chronology of Monticchio. One of them was identification of the plentiful ash layers and dating them using tephrochronology. So far, 15 layers have been identified as useful for tephrochronology (Narcisi 1996) and three were dated using the Ar/Ar method (Watts, Allen and Huntley 1996). These results corroborate the varve chronology within the range of their errors, but their precision is very low. Another method of dating is ^{14}C chronology, which in the case of sediments from Lago Grande di Monticchio appears to be problematic. Already in 1985 Watts reported ages much older than expected from pollen stratigraphy (Watts 1985). Since these were ages obtained on bulk sediments, one suspected that remains of aquatic plants in the bulk were contaminated with "old" CO_2, a product of volcanic activity. Results of ^{14}C dating summarized by Zolitschka (1996) show many outliers, and *ca.* 70% of the data was rejected. Therefore, it is important to construct as

Proceedings of the 16th International ^{14}C Conference, edited by W. G. Mook and J. van der Plicht
RADIOCARBON, Vol. 40, No. 2, 1998, P. 803–807

detailed as possible a ^{14}C chronology of Lago Grande di Monticchio. The material for dating is sparse because it is limited to terrestrial macrofossils. However, our ^{14}C dating of terrestrial plants shows that prospects for a consistent ^{14}C chronology of the Monticchio record are quite good.

METHODS

Site, Cores and Sediment Samples

Lago Grande di Monticchio, located in southern Italy (45′N, 15′E, 120 km east of Naples), occupies a caldera on the west side of Monte Vulture. As a maar lake, Lago Grande di Monticchio (LGM) was a subject of studies of the EU-funded maar lake research project EUROMAARS (Creer and Thouveny 1996). Two of four piston sediment cores LGM-C (40 m) and LGM-D (52 m) were combined into one record with a composite sediment depth of 52 m. This profile has been studied for pollen, geochemistry, sedimentology, physical sediment properties, paleomagnetism, tephras and varve chronology. A set of 19 sediment samples was submitted to the ^{14}C lab at ETH-Hönggerberg. In order to increase the mass of material dated, subsamples from three correlated cores (LGM-B/C/D) were combined.

Sample Pretreatment and Dating

Sediment samples were treated with 10% HCl (6 h) and 10% KOH (24 h) in order to disperse sediment particles. Sediment was then sieved through a 500 μm sieve. Organic matter that remained on the sieve was examined using a microscope. A mixture of bark, leaf fragments and seeds of trees was picked out when only identification was possible. In one case, a sample made up of a mixture of unidentified fragments of plants was dated after terrestrial macrofossils were picked out (LGM5.2). From the total of 19 samples that were washed, only seven contained sufficient amounts of organic matter/terrestrial macrofossils for AMS dating.

Standard acid-base-acid treatment was applied in order to remove carbonates and humus contaminants. Solutions of 0.5 M HCl and 0.1M NaOH were used at 60°C. Each step lasted *ca.* 1 h and was followed by rinsing with distilled water to the normal pH. Samples were combusted in Vycor® tubes and CO_2 was converted to graphite in a reaction with H_2 over cobalt as a catalyst. More details on cleaning terrestrial macrofossils and graphitization are given by Hajdas (1993).

Measurements of $^{14}C/^{12}C$ and $^{13}C/^{12}C$ ratios were done at the Zurich AMS facility (Bonani *et al.* 1987). Conventional ^{14}C ages were calculated following Stuiver and Polach (1977).

RESULTS AND DISCUSSION

Our results are summarized in Table 1 and Figure 1. This chronology adds to the existing dating of Lago Grande di Monticchio and improves its resolution. The Holocene sediments are now dated by five samples. The Younger Dryas period (10–11 ka BP) has been identified in the new record but could not be seen in the first study of Watts (1985) because the resolution of pollen analysis was too low. Watts *et al.* (1996) classify a period of renewed dominance of herbs, with *Betula* and *Artemisia* prevailing, as the Younger Dryas cooling. The corresponding sediments from 775 to 857 cm are now dated by three points (Table 1). They all fall into to the range of the Younger Dryas ^{14}C ages and plot on the characteristic plateau (Fig. 2). Only one point dates the Late Glacial part of the pollen record. The age of 11,720 ± 120 for the sample at 838–840 cm (sample LGM5.2) is in stratigraphic agreement with the age of 12,540 ± 130 (1985) (900 cm correlated depth) for the onset of this period here at the depth of 872 cm (Watts *et al.* 1996). Attempts have been made to date the Late Glacial sediments (Zolitschka 1996), but all the ages have been rejected as too old. In fact, the age of 23,000 ±

https://doi.org/10.1017/S0033822200018750 Published online by Cambridge University Press

190 obtained on the remaining material, presumably of aquatic origin, of the sample LGM5.2 is close to the ages reported by Zolitschka (1996).

TABLE 1. ^{14}C Ages Obtained on Terrestrial Macrofossils (Seeds, Catkin Scales, Bark, Leaf Fragments) from Sediments of Lago Grande di Monticchio

Lab code	Sample number	Depth (cm)	Varve age (yr BP)	^{14}C age (yr BP)
ETH-12452	LGM1.1	694.5	10,320	9230 ± 120
ETH-12453	LGM1.2	699.5	10,440	9355 ± 85
ETH-12454	LGM2.1+2	752.5	11,670	10,250 ± 130
ETH-12357	LGM3.2	796.5	12,260	10,550 ± 150
ETH-12461*	LGM5.2AQ	839.5	13,440	23,000 ± 190
ETH-12461	LGM5.2	839.5	13,440	11,720 ± 120
ETH-12464	LGM7.1	1382.5	23,280	23,140 ± 360
ETH-12465	LGM7.2	1406.5	23,540	24,400 ± 460

*Sample composed of unidentified plant fragments.

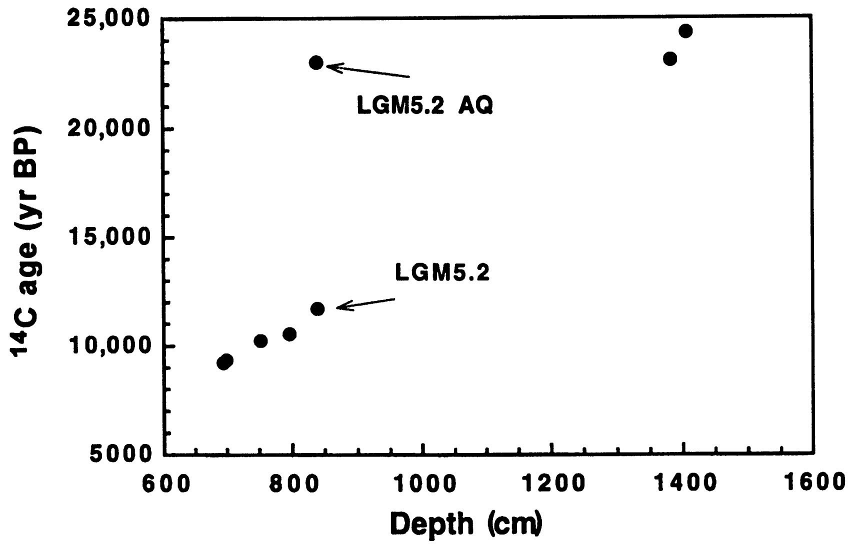

Fig. 1. ^{14}C ages plotted *vs.* composite depth in core LGM-B/C/D from Lago Grande di Monticchio. The arrows point to the ages obtained on mixed organic matter, possibly of aquatic origin, and terrestrial macrofossils. This illustrates a discrepancy between ages obtained on bulk samples and terrestrial macrofossils, which is typical for Monticchio record.

The older sediments contain few macrofossils. Pollen found in sediments down to 1650 cm depth suggests mainly herbaceous vegetation (Watts *et al.* 1996) but *Juniperus* and *Pinus* were also present. Therefore, improvement of the chronology between 13 ka and 23 ka BP seems possible. It is interesting to note that the two ^{14}C ages obtained on bulk sediments by Robinson (1994) are relatively close to the ages obtained on macrofossils (LGM7.1 and LGM7.2; see Fig. 2).

Improving the present chronology as well as extending the ^{14}C chronology beyond the age of the oldest sample (24,400 ± 460 BP) is essential for interpretation of the Lago Grande di Monticchio record. When the varve chronology is compared with the U/Th time scale of corals (Bard *et al.* 1993;

Bard *et al.* 1996), it agrees for the past 15 ka, but the varve ages beyond 22 ka BP appear to be too young (Fig. 3). Varve ages of sediment are equal to or younger than ^{14}C ages of macrofossils, which implies that the atmospheric ^{14}C content was low *ca.* 24 ka BP. This is in contradiction to the U/Th chronology; however, the resolution of the latter is rather poor and any dramatic variations in ^{14}C

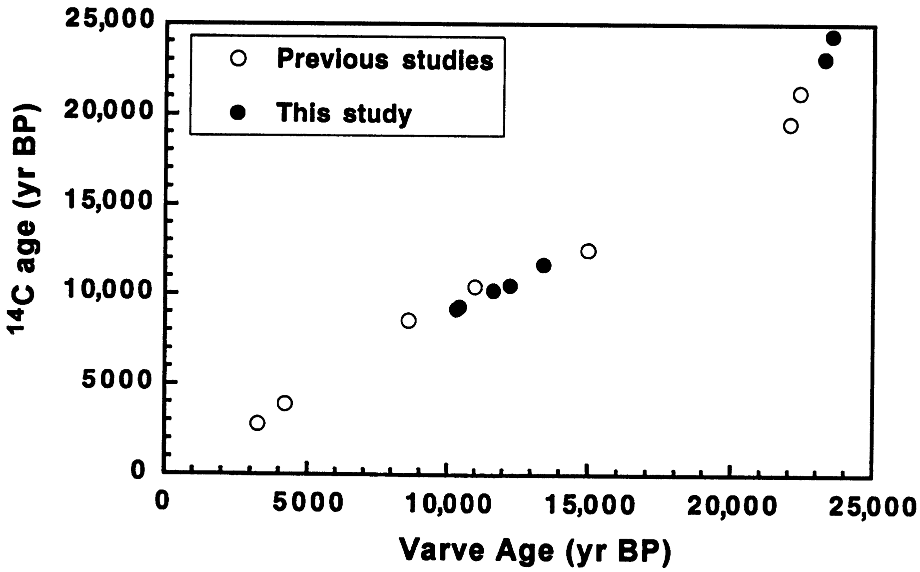

Fig. 2. ^{14}C-varve chronology of Lago Grande di Monticchio. ○ = results of previous dating that have been accepted as free of contamination from "old carbon" (Zolitschka 1996); ● = results from this study. Age of the sample LGM5.2 AQ has been excluded from this figure.

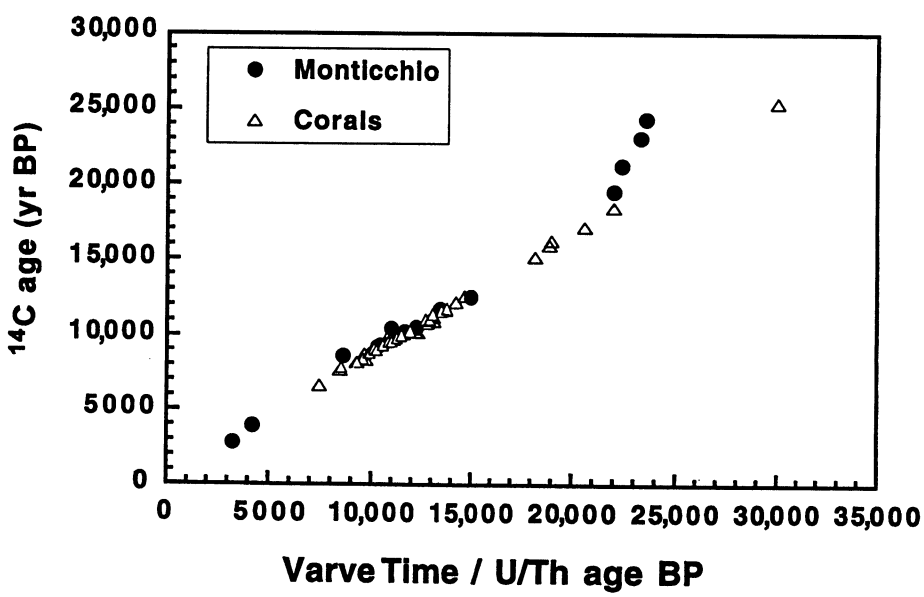

Fig. 3. Comparison between ^{14}C-varve chronology of Lago Grande di Monticchio (●) and results from U/Th dated corals (△) (Bard *et al.* 1993, 1996).

https://doi.org/10.1017/S0033822200018750 Published online by Cambridge University Press

cannot possibly be seen there. On the other hand, variability of the ^{14}C time scale (plateaus and steep changes), which can be seen in the newest results from laminated Lake Suigetsu, Japan (Kitagawa and van der Plicht 1998), do not show such a dramatic change at 24 ka BP as the one in the record of Monticchio. However, one must keep in mind that the record of Lago Grande di Monticchio is not free of dating problems caused by the noncontinuous character of the varves; underestimated varve age could be the reason for a dramatic excursion in ^{14}C ages at 23 ka BP. Nevertheless, efforts should be made to explore the potential of this record that contains important paleoclimatic information.

Conclusion

In this paper we have presented the results of ^{14}C dating of the Lago Grande di Monticchio record obtained on available material of Holocene, Late Glacial and Glacial age. Dating terrestrial macrofossils has great potential for resolving chronostratigraphic questions of this record and illuminating its implications for paleoclimatic reconstruction.

References

Bard, E., Arnold, M., Fairbanks, R. G. and Hamelin, B. 1993 ^{230}Th-^{234}U and ^{14}C ages obtained by mass spectrometry on corals. *In* Stuiver, M., Long, A. and Kra, R. S., eds., Calibration 1993. *Radiocarbon* 35(1): 191–199.

Bard, E., Hamelin, B., Arnold, M., Montaggioni, L., Cabioch, G., Faure, G. and Rougerie, F. 1996 Deglacial sea-level record from Tahiti corals and the timing of global meltwater discharge. *Nature* 382: 241–244.

Bonani, G., Beer, J., Hofmann, H., Synal, H. A., Suter, M., Wölfli, W., Pfleiderer, C., Junghans, C. and Münnich, K. O. 1987 Fractionation, precision and accuracy in ^{14}C and ^{13}C measurements. *Nuclear Instruments and Methods in Physics Research* B29: 87–90.

Creer, K. M. and Morris, A. 1996 Proxy climate and geomagnetic palaeointensity records extending back to ca. 75,000 bp derived from sediments cored from Lago Grande di Monticchio, Southern Italy. *Quaternary Science Reviews* 15: 167–188.

Creer, K. M. and Thouveny, N. 1996 The EUROMAARS Project. *Quaternary Science Reviews* 15: 99–245.

Hajdas, I. (ms.) 1993 Extension of the radiocarbon calibration curve by AMS dating of laminated sediments of lake Soppensee and lake Holzmaar. Ph.D. dissertation, Eidgenössische Technische Hochschule Zürich (Nr. 10157): 143 p.

Kitagawa, H. and van der Plicht, J. 1997 A 40,000-year varve chronology from Lake Suigetsu, Japan: Extension of the ^{14}C Calibration Curve. *Radiocarbon*, this issue.

Narcisi, B. 1996 Tephrochronology of a Late Quaternary lacustrine record from the Monticchio maar (Vulture volcano, Southern Italy). *Quaternary Science Reviews* 15: 155–165.

Robinson, C. 1994 Lago Grande di Monticchio, southern Italy: A long record of environmental change illustrated by sediment geochemistry. *Chemical Geology* 118: 235–254.

Stuiver, M. and Polach, H. A. 1977 Discussion: Reporting of ^{14}C data. *Radiocarbon* 19(3): 355–363.

Watts, W. A. 1985 A long pollen record from Laghi di Monticchio, Southern Italy: A preliminary account. *Journal of the Geological Society* 142: 491–499.

Watts, W. A., Allen, J. R. M. and Huntley, B. 1996 Vegetation history and palaeoclimate of the Last Glacial period at Lago Grande di Monticchio, Southern Italy. *Quaternary Science Reviews* 15: 133–153.

Watts, W. A., Allen, J. R. M., Huntley, B. and Fritz, S. C. 1996 Vegetation history and climate of the last 15,000 years at Laghi di Monticchio, Southern Italy. *Quaternary Science Reviews* 15: 113–132.

Zolitschka, B. 1996 *Palaoklimatische Bedeutung Laminirter Sedimente*. Potsdam, Habilitationschrift: 196 p.

Zolitschka, B. and Negendank, J. F. W. 1996 Sedimentology, dating and palaeoclimatic interpretation of a 76.3 ka record from Lago Grande di Monticchio, Southern Italy. *Quaternary Science Reviews* 15: 101–112.