THE EFFECT OF DIFFUSION ON THE CONTENT OF RADIOCARBON IN PORE WATER OF DEEP MEDITERRANEAN SEDIMENTS

Sivan O.[1,2*], Lazar B.[1], Yechieli Y.[2] and Herut B.[3]

[1] Institute of Earth Sciences, The Hebrew University of Jerusalem, Jerusalem, Israel - sivan@vms.huji.ac.il, boazl@vms.huji.ac.il
[2] Geological Survey of Israel, Jerusalem, Israel - yechi@mail.gsi.gov.il
[3] Israel Oceanogrphic and Limnologic Research, Haifa, Israel - barak@ocean.org.il

Abstract

We present here field evidence from the deep SE Mediterranean sediments for significant ^{14}C excess in total dissolved inorganic carbon (DIC) of pore water down to depths of more than 2 meter. It is concluded that this enrichment is caused by diffusion of $^{14}CDIC$ across the water-sediment interface. The $^{14}CDIC$ flux distorts the ^{14}C ages of pore water, and may also severely interfere with age determination of small oceanic water masses. In addition, the ^{14}C excess can serve as a tool to identify the extant and duration of authigenic carbonate precipitation. We suggest a simple algorithm to correct for the effect of diffusion on the ^{14}C ages of pore water.

Keywords: ^{14}C; DIC ages; ^{14}C diffusion; Pore water; Deep SE Mediterranean.

Introduction

The activity of ^{14}C in the dissolved inorganic carbon in water ($^{14}CDIC$) is frequently used as a dating tool for groundwater (1), oceanic water masses (2) and marine pore water (3). It was recognized that 14CDIC activity is dependent not only on the decay of ^{14}C but also on diagenetic and transport processes (1,4-5). The effect of transport processes (diffusion, advection) was demonstrated only in theoretical studies (4-5).

Our study used field measurements to quantify the effect of the major biogeochemical processes, diffusion, advection and decay on the $^{14}CDIC$ activity in water. This was achieved by measurements of major ions and stable and radioactive carbon isotopes in SE Mediterranean deep-sea sediment and pore water. This area serves as an ideal natural laboratory to investigate ^{14}C processes due to its sole well-defined seawater end-member, relatively homogeneous sediment, steady state conditions and lack of significant advection.

Methods and Materials

Three cores, 25, 40 and 230 cm long were collected in June and September 1996, and in April 1999 at ca. 1500 m water depth in the SE Mediterranean. The cores were immediately sectioned and centrifuged under argon atmosphere to avoid contamination with atmospheric CO_2. Pore water was sampled for DIC, total alkalinity (A_T), $\delta^{13}C$ of DIC ($\delta^{13}C_{DIC}$), $^{14}C_{DIC}$ and major ion (Cl^-, Br^-, SO_4^{2-}, Na^+, Mg^{2+}, Ca^{2+}) analyses. Sediments were analyzed for stable and radioactive carbon isotopes in inorganic (SIC) and organic (SOC) fractions ($\delta^{13}C_{SIC}$, $\delta^{13}C_{SOC}$, $^{14}C_{SIC}$, $^{14}C_{SOC}$,) and also in foraminifera skeletons ($^{14}C_{SKT}$). Sediments from the long core were also sampled every 5 or less cm for $\delta^{18}O$ high-resolution chronostratigraphy.

Results and Discussion

The main results of this study are that the $^{14}C_{SOC}$, $^{14}C_{SIC}$ and $^{14}C_{SKT}$ apparent ages at each depth were similar to each other and to the independent «$\delta^{18}O_{GR}$ ages» and therefore represent the real age of the layer. The sediment ages varied from recent (top of the cores) to ca. 30 ky b.p. (bottom of the long core), covering most of the dynamic range of the ^{14}C method (ca. 5 half lives) (Fig. 1). These ages were markedly older than the apparent ages of the pore water DIC, calculated directly from the radioactive age equation (Fig. 1).

Major ions and stable carbon isotope profiles proved that this marked apparent rejuvenation of the pore water was caused by a downward diffusive flux of ~90 atoms of $^{14}C_{DIC} \cdot m^{-2} \cdot s^{-1}$ from the overlying bottom water into the sediment. A simple algorithm is suggested to correct for the effect of diffusion (6). The $^{14}C_{DIC}$ flux is opposite in direction to the DIC flux out of the sediment.

It is suggested here that the $^{14}C_{DIC}$ flux may severely interefere with age determination of small submarine «brine lakes» formed in the deep Mediterranean. In addition, the ^{14}C excess should show up in authigenic carbonate phases precipitating within the sediment and hence, may serve as a tool to identify the extent and duration of authigenic carbonate precipitation.

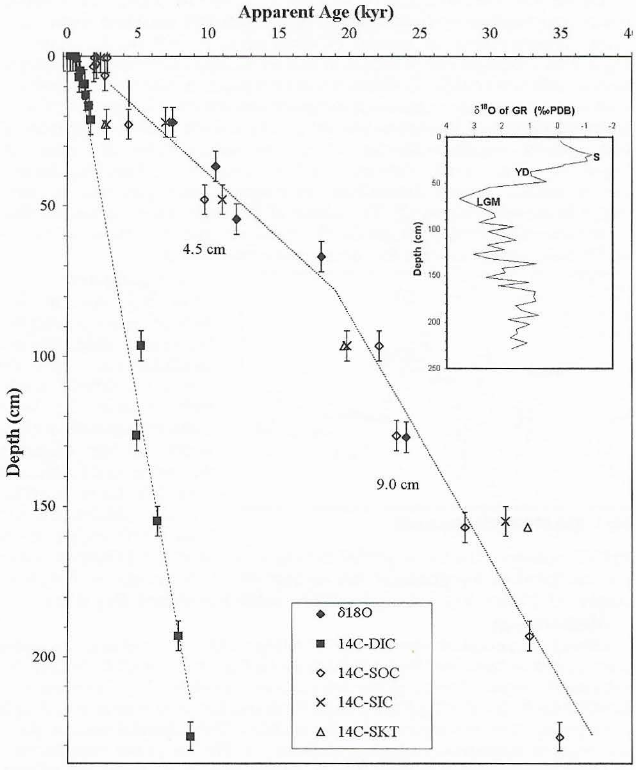

Fig. 1: Radiocarbon and $\delta^{18}O$ apparent ages as a function of depth in the long core.
$\delta^{18}O$ ages are based on the global events found in $\delta^{18}O$ depth profile of the planktonic Foraminifera Globigerinoides ruber (insert in the upper right). The identified horizons in this profile are marked as S – S1 sapropel, YD - Younger Dryas, LGM - Last Glacial Maximum. ^{14}C apparent ages were calculated for the DIC in pore water, for the inorganic and the organic sediment (SIC and SOC respectively), and for the carbonate skeletons (SKT). The ^{14}C sediment's ages of SIC, SOC and SKT and the $\delta^{18}O$ ages are similar to each other at each depth. Their profile shows a constancy down to ~5 cm due to bioturbation. A sedimentation rate of 4.5 cm kyr^{-1} (the slope of the best fit line) was calculated for the 5 to 75 cm depth interval and 9.0 cm kyr^{-1} below it.

References

1. Mook W.G., 1980. p. 49-74. *In* P. Frits and J. C. Fontes (eds.), Handbook of environmental isotope geochemistry I.
2. Broecker W.S. and Peng T.H., 1982. Traces in the Sea, Eldigio, New York.
3. Bauer J.E., Reimers C.E., Druffel E.R.M. and Williams P.M., 1995. Isotopic constraints on carbon exchange between deep ocean sediments and sea water. *Nature,* 373: 686-689.
4. Walker G.R. and Cook P.G., 1991. The importance of considering diffusion when using carbon-14 to estimate groundwater recharge to a confined aquifer. *J. Hydrology*, 128: 41-48.
5. Sanford W.E., 1997. Correction for diffusion in carbon-14 dating of groundwater. *Groundwater,* 35 (2): 357-361.
6. Sivan O., Herut B., Yechieli Y., and Lazar B., 2001. Radiocarbon Dating of porewater – correction for diffusion and diagenetic processes. *Radiocarbon,* Accepted.