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ARCTIC OCEAN CHRONOLOGY CONFIRMED BY ACCELERATOR ^{14}C DATING

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Abstract. The role of the Arctic Ocean in Earth's climatic and oceanographic development is significant but has become controversial because of disagreements concerning a reliable Arctic chronology. The first Arctic Ocean chronology based on U-Th and ^{14}C data was in agreement with magnetostratigraphy developed later but these data have been challenged by recent amino acid diagenesis dates. New accelerator ^{14}C data support the earlier U-Th-magnetostratigraphic dates and confirm the reliability of the established Arctic Ocean chronology.

Introduction

Sedimentation rates in the ice-covered central Arctic Ocean have been interpreted to be among the lowest of any of the oceans. U-Th and ^{14}C dates determined 20 years ago were in agreement and yielded sedimentation rates of 0.2 to 0.3 cm/10^3 yrs for the central Arctic Ocean [Olsen and Broecker, 1961; Hunkins and Kutschale, 1967; Ku and Broecker, 1967]. These radioisotope dates proved to be consistent with paleomagnetic measurements made in four different laboratories [Lin̂ Kova, 1965; Steuerwald et al., 1968; Clark, 1970; Hunkins et al., 1971; Aksu, 1985] and all the data formed the foundation of a chronostratigraphy that has functioned for paleoceanographic interpretations of the Arctic Ocean [Clark et al., 1980]. The validity of the low sedimentation rates is supported by both spectral analysis relating Arctic Ocean sedimentary parameters to Earth orbital variations [Boyd et al., 1984] and observations concerning mechanics of ice transport of sediment in an ice-covered ocean [Clark and Hanson, 1983].

In view of this large set of concordant observations, the report of very different age interpretations based on amino acid diagenesis of Arctic Ocean foraminifera is a matter of concern.

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According to Sejrup et al. (1984) the isoleucine epimerization measured in planktonic foraminifera from the Arctic Ocean "---cannot be reconciled with the proposed paleomagnetic time scale." Amino acid studies suggested that the oldest part of one Arctic core (T3-67-11) (Fig. 1), magnetically interpreted to be several million years old, is less than 0.2 million years and perhaps "not older than oxygen-isotope stage 4 (~72 kyr)."

The amino acid interpretations were challenged, in turn, by the results of the Canadian CESAR project [Jackson et al., 1985; Aksu and Mudie, 1985]. New sediment cores taken from the central Arctic Ocean by the CESAR group provided a new and independent magnetostratigraphy, a new dinoflagellate biostratigraphy and two approximate ^{14}C dates that were consistent and affirmed the established Arctic Ocean chronology that was brought into question by the amino acid dating [Aksu, 1985a:b; Mudie, 1985; Aksu and Mudie, 1985].

^{14}C Data

In order to reevaluate this controversial Arctic chronology, our group used radioisotope dating with the recently developed ETHZ-EN tandem accelerator in Zurich. Four approximately 8 mg samples of left coiling *Neogloboquadrina pachyderma* representing 1 cm intervals from core Fl-124 in the central Arctic Ocean (Figure 1) were studied. The results are shown as Figure 2 and suggest a sedimentation rate of 0.12 cm/10^3 yrs for the 2-3 to 4-5 cm interval and 0.32 cm/10^3 yrs for the 1-2 to 2-3 cm interval. These rates average 0.22 cm/10^3 yrs. These figures are consistent with the ages determined from the older ^{14}C, U-Th, and paleomagnetic studies. The uppermost sample (0-1 cm) gives an age of 9130±120 indicating either that the upper cm or so of the core top was lost during piston coring activity or that there has been homogenization of 9000 yrs of sediment by bioturbation. The progression of ages in the older samples is apparent (Fig. 2). In core Fl-124, from which the ^{14}C dates were obtained, the approximate 100 cm interval has been inter-

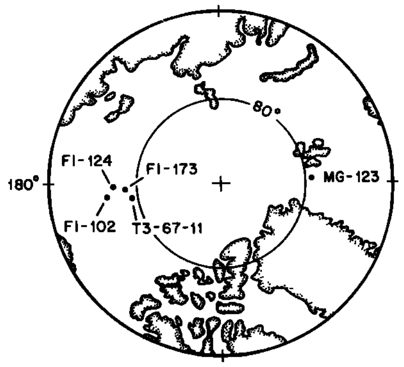

Fig. 1. Location and depth of sediment cores referred to in this report. T3-67-11 is core with amino acid dates, and MG-123 is high sedimentation rate core that has been correlated with Fl-124.
1. Fl-102 77°37.53' N, 173°58.23' W, 1938 m
2. Fl-124 78°13.50' N, 174°42.17' W, 1517 m
3. Fl-173 78°48.04' N, 175°16.73' W, 1731 m
4. T3-67-11 79°34.9' N, 172°30' W, 2810 m
5. MG-123 79° N, 0°48' E, 3050 m
First 4 cores taken from ice island T-3, 5 from YMER-80 cruise (Boström and Thiede, 1981).

preted to be ~400 kyr [Boyd et al., 1984]. This age was based on lithostratigraphic correlations with nearby cores with a well defined magnetostratigraphy. Although it may not be valid to project the ^{14}C sedimentation rate for all of the different textural units in the upper 100 cm of Fl-124, such a projection would yield an age of approximately 454 kyr (using the average ^{14}C sedimentation rate) compared to the approximate 400 kyr calculated for the 100 cm level from magnetostratigraphy.

We recognize that this is limited ^{14}C data but with such low Arctic Ocean sedimentation rates, only the upper 10 cm of sediment could be expected to give meaningful carbon dates. Additional tests of the validity of low sedimentation rates in Arctic cores have been made. Samples from different cores, but with ages determined from magnetostratigraphy or lithostratigraphic correlations with cores with magnetically determined ages, have been submitted to several labs. Samples from core Fl-173 (Fig. 1), estimated to be between 500 kyr and 1 my from magnetic boundary identifications were submitted to Dr. Takaharu Sato of Osaka University for Electron Spin Resonance analysis [Sato, 1982]. ESR dating yielded an age of 1.5 my. Samples from Fl-102 (Fig. 1) were submitted to Alpha Analytic Company for thermoluminescence dating. Results suggest that the samples have ages greater than 130 and 176 kyr, just slightly older than the ages extrapolated from magnetic boundaries. Oxygen and carbon isotope measurements of Arctic Ocean foraminifera are interpreted to correlate with lower latitude $\delta^{18}O$ stratigraphy and these correlations are also consistent [Aksu, 1985].

In summary, new accelerator ^{14}C analysis, ESR, thermoluminescence and oxygen isotope correlations are consistent with U-Th, ^{14}C and paleomagnetic dating of two decades ago. All of the data confirm extremely low sedimentation rates for the central Arctic Ocean and suggest that amino acid diagenesis dating of central Arctic Ocean sediment must be reevaluated. The ramification of this conclusion for all amino acid geochronology at high latitude sites deserves careful consideration.

Greenland Sea ^{18}O Stratigraphy

Short $\delta^{18}O$ stratigraphies for the Norwegian-Greenland Sea have been available since the publication of Kellogg et al. (1978). It is important to note that our confirmation of low rate of sediment accumulation in the central Arctic Ocean is not in conflict with higher sedimentation rates in the Greenland-Norwegian Sea area. Jansen et al. (1983) and Zahn et al. (1985) reported much higher sedimentation rates in cores from the Greenland-Norwegian sub-Arctic Ocean area and suggested that the central Arctic chronology should be reinterpreted using a high sedimentation rate model. Evidence at hand suggests that the two areas simply have different sedimentation rates and the central Arctic Ocean data are not constrained by the Greenland Sea data more than 1000 km away. The high sedimentation rates of the sub-Arctic Ocean are a function of several processes that are unrelated to activities in the central Arctic Ocean. For example, in the Greenland Sea, there is greater accumulation of glacial-marine sediment that is transported by the East Greenland current as well as accumulation of pelagic sediment deposited in ice-free conditions. Turbidites also are present in the Greenland Sea but absent in the area of most of the Arctic Ocean chronology studies. In addition, sedimentation rates of 1-2 cm/10^3 yrs have been calculated for core MG-123, from 79°N, 0°48' E, between Svalbard and Greenland (Fig. 1) and this high sedimentation rate core has been successfully correlated with our low sedimentation rate central Arctic Ocean cores [Marquard and Clark ms.]. The high sedimentation rates in this eastern Arctic Ocean area are real, but are controlled by different oceanographic conditions than those of the central Arctic Ocean.

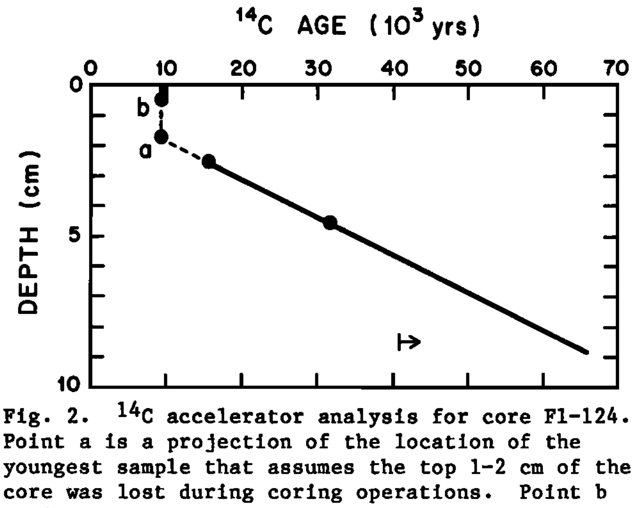

Fig. 2. ^{14}C accelerator analysis for core Fl-124. Point a is a projection of the location of the youngest sample that assumes the top 1-2 cm of the core was lost during coring operations. Point b is location of this same sample if it represents a homogenization of the top 1-2 cm of sediment and no sediment was lost during coring. Symbol indicates minimum age of deepest sample. Data are 0-1 cm, 9130 ± 120 yr; 2-3 cm, 15,310 ± 210 yr; 4-5 cm, 31,720 ± 1280 yr; 8-9 cm, > 41,100 yr.

Summary

The new ^{14}C ages are consistent with all ^{14}C, U-Th, and paleomagnetic interpretations of central Arctic Ocean sediment as well as with more recent dates interpreted from thermoluminescence, ESR and oxygen isotope correlation studies. The ages produced by all of these methods substantiate the chronostratigraphy that has formed the basis of a paleoceanographic framework for the central Arctic Ocean, and raise serious questions concerning recently published amino acid diagenesis dates.

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