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26. ^{10}Be CONTENTS OF LATE CENOZOIC SEDIMENTS FROM SITES 720, 722, AND 728 IN THE WESTERN ARABIAN SEA[1]

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ABSTRACT

This paper is a comparative study of the variation in ^{10}Be content of different late Cenozoic sedimentary environments recovered during ODP Leg 117. The Oman Margin site, Hole 728A, with overlying high-productivity cells, the pelagic Owen Ridge site, Hole 722A, and the Indus Fan site, Hole 720A, each display a specific ^{10}Be distribution with time. Differences in scavenging intensity and upwelling in the water column, must account for the variations in the initial ^{10}Be input into the sediments from Holes 728A and 722A, whereas differences in sediment character and sedimentation rate can explain the variances between Holes 722A, 728A, and 720A.

INTRODUCTION

The cosmogenic radionuclide ^{10}Be (half-life 1.5 m.y.) is produced by spallation caused by cosmic rays in the Earth's atmosphere. It has been used for several purposes, among others: measuring accumulation rates and dating of deep-sea sediments (Arnold, 1956; Goel et al., 1957; Amin et al., 1966; Tanaka et al., 1977), determination of variations in production of ^{10}Be because of changes in the cosmic-ray flux and the Earth's magnetic field (Somayajulu, 1977; Southon et al., 1987; Beer et al., 1988), as a tracer of erosion and sediment transport (Brown, 1987), and as an indicator of sediment incorporation in island-arc magmas (Tera et al., 1986).

The abundance of ^{10}Be in sediment is controlled by several factors (Faure, 1986): the production rate of ^{10}Be in the atmosphere, the magnetic latitude of the site, the pathway and mixing during its transport into the sediment, sediment accumulation rate, and the amount of time elapsed since deposition. Processes in the ocean, such as scavenging by particles and organisms, and upwelling control the residence time of ^{10}Be in the surface layer, which eventually determines the ^{10}Be content in deep-sea sediments.

ODP Leg 117 in the western Arabian Sea drilled the Oman margin with the overlying upwelling cells and oxygen minimum zone, the Owen Ridge with mainly pelagic carbonates, and the Indus Fan with terrigenous sediments (Prell, Niitsuma, et al., 1989) (Fig. 1). We sampled Hole 728A (1427.8 m water depth), Hole 722A (2027.8 m water depth), and Hole 720A (4037.5 m water depth) at large intervals.

The goals of this study were to determine how the different (paleo-)oceanographical and sedimentary settings of the three investigated holes would influence their ^{10}Be content and distribution, and how the ages inferred from the ^{10}Be content compared with the dates derived from the biostratigraphy and the magnetostratigraphy (Prell, Niitsuma, et al., 1989).

MATERIAL AND METHODS

Table 1 lists the samples from Holes 720A, 722A, and 728A, which were analyzed for ^{10}Be content using the Utrecht tandem accelerator. Sample preparation and experimental methods are as described in Van der Borg et al. (1987). The 12% uncertainty in the absolute value is not included, 2σ analytical errors are listed in Table 1.

The $CaCO_3$ content was determined with a coulometric CO_2 analyzer at the Free University.

The samples were chosen at large depth intervals, using the ages and sedimentation rates published in Prell, Niitsuma, et al. (1989). The sediments range from foraminiferal/nannofossil oozes to muddy sands.

RESULTS

The ^{10}Be abundance (at/g) of the sediments is plotted vs. the depth below seafloor in the Holes 720A, 722A, and 728A (Fig. 2A). The highest ^{10}Be concentration is found in the two topmost samples of the Indus Fan Site, Hole 720A. The topmost sample of Hole 722A has a higher ^{10}Be content than that of Hole 728A, but the downcore trends in both holes are virtually the same. The distribution of ^{10}Be in Hole 720A shows a much steeper negative gradient than those of Holes 722A and 728A.

Since ^{10}Be enters the ocean mainly in ionic form, and clay particles have been suggested to be the most effective scavengers of ^{10}Be (Southon et al., 1987) it seems fit to consider $CaCO_3$ as a dilutant. Hence the ^{10}Be abundance on a $CaCO_3$-free base gives a better approximation of its initial contents (Fig. 2B). Still the initial ^{10}Be content of Hole 722A is somewhat higher than that of Hole 728A, and decreases faster downcore than that of Hole 728A. The ^{10}Be distribution in Hole 720A shows a 10 times faster decrease compared to Holes 722A and 728A.

The apparent ages of the sediments can be calculated with the Law of Radioactivity:

$$^{10}Be = {}^{10}Be_i\, e^{-l}\, t \qquad (1)$$

$$Ln^{10}Be = Ln^{10}Be_i - (l/a)\, h \qquad (2)$$

Where ^{10}Be is the measured abundance of ^{10}Be, $^{10}Be_i$ is the initial contents during deposition of the sediment, l is the ^{10}Be decay constant = $0.462 \times 10^{-6}\ y^{-1}$, t is the time elapsed since deposition, a is the sedimentation rate, and h is the depth in the core.

In Figures 3A and 3B linear fits were matched on the measured ^{10}Be concentrations, with which the apparent ages, using equation (2), were calculated (Table 2). Comparison with the ages of the sediments derived from biostratigraphy and magnetostratigraphy (Prell, Niitsuma, et al., 1989) shows that differences in the ages derived by the two methods are substantial;

[1] Prell, W. L., Niitsuma, N., et al., 1991. *Proc. ODP, Sci. Results,* 117: College Station, TX (Ocean Drilling Program).
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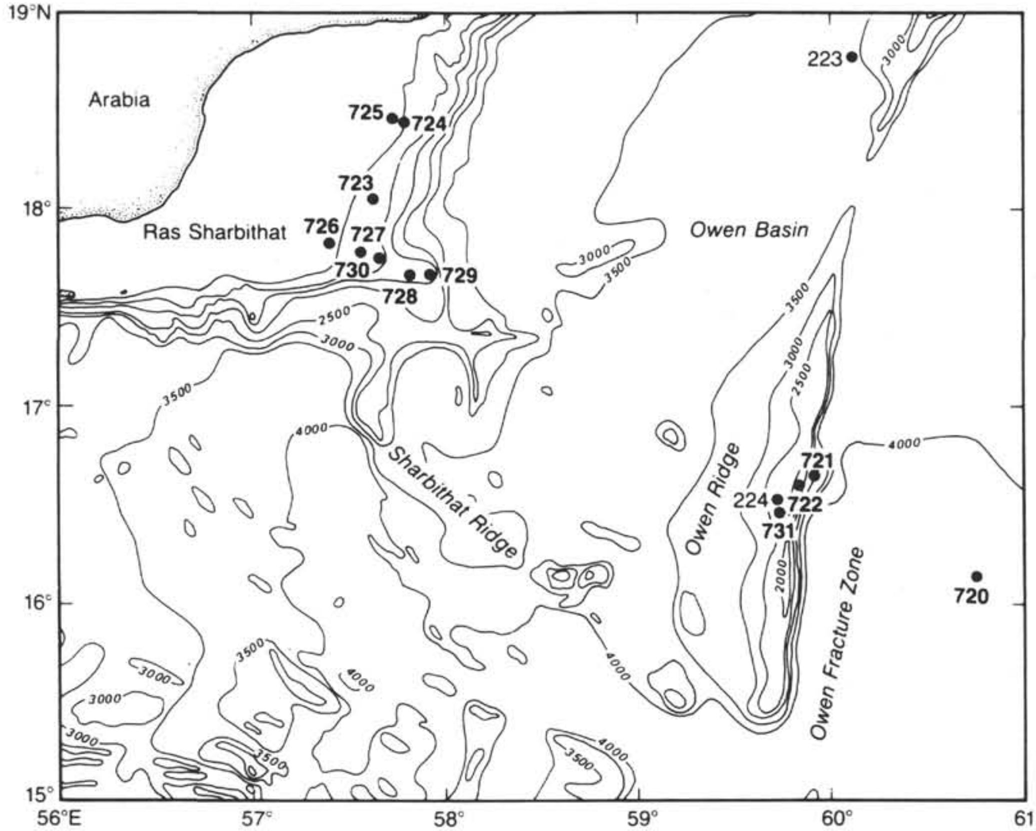

Figure 1. Leg 117 Sites in the western Arabian Sea.

Table 1. Sample numbers, depth below seafloor, ^{10}Be concentrations (10^8 at/g, 12% uncertainty not included), $CaCO_3$ wt%, and ^{10}Be on a $CaCo_3$-free basis (10^8 at/g).

Hole, core, section	Depth (mbsf)	^{10}Be (10^8 at/g)	2σ (10^8)	$CaCO_3$% ($CaCO_3$-free)	^{10}Be (10^8 at/g)
720A-1H-CC	9.4	4.80	0.11	62.4	12.80
720A-2H-CC	19.0	4.79	0.04	13.4	5.53
720A-7K-CC	67.3	1.54	0.10	10.4	1.72
720A-16X-CC	154.4	0.78	0.19	12.4	0.89
720A-30X-CC	289.4	0.53	0.08	10.8	0.59
720A-40X-CC	385.2	0.17	0.03	8.8	0.19
722A-1H-CC	9.8	4.16	0.11	62.9	11.20
722A-11X-CC	105.9	0.68	0.04	82.5	3.89
722A-16X-CC	154.3	0.52	0.04	64.9	1.48
722A-26X-CC	251.0	0.24	0.03	52.9	0.51
728A-1H-CC	9.6	2.72	0.08	58.4	6.54
728A-4H-CC	38.0	2.14	0.06	55.4	4.80
728A-9H-CC	85.7	1.25	0.04	47.4	2.38
728A-17X-CC	162.8	0.54	0.04	65.3	1.56
728A-31X-CC	298.1	0.26	0.04	56.8	0.60

Hole 720A biostratigraphic and magnetostratigraphic ages show deviations from the ^{10}Be ages of 20% up to >300% throughout the core. Hole 722A biostratigraphic and magnetostratigraphic ages compare within 14%–21% with the ^{10}Be ages, and, when corrected for $CaCO_3$ dilution, even within 1%–7.5% (Table 2). Hole 728A ages show a larger spread in accuracy, from 0%–52%, and there is no improvement after correction for the $CaCO_3$ contribution to the sediments (Table 2 and Fig. 3B).

The initial content of ^{10}Be, corrected for radioactive decay, shown in Figure 4, fluctuates throughout the cores, except for Hole 720A which has an increasing ^{10}Be input toward the present.

DISCUSSION

The variations in the distribution of ^{10}Be in the sediments of the three holes are probably related to the different sedimentary environments. The initial ^{10}Be concentration in the sediments, corrected for radioactive decay vs. sediment accumulation rate illustrates this (Fig. 5). The sediments from the pelagic Owen Ridge Hole 722A, which are rich in biogenic $CaCO_3$ (Table 1: 52.9%–82.5%) show a positive correlation between sedimentation rate and ^{10}Be concentration (Fig. 5). The samples with the highest sediment accumulation rate have the lowest $CaCO_3$%, therefore, this correlation probably exists due to higher input of

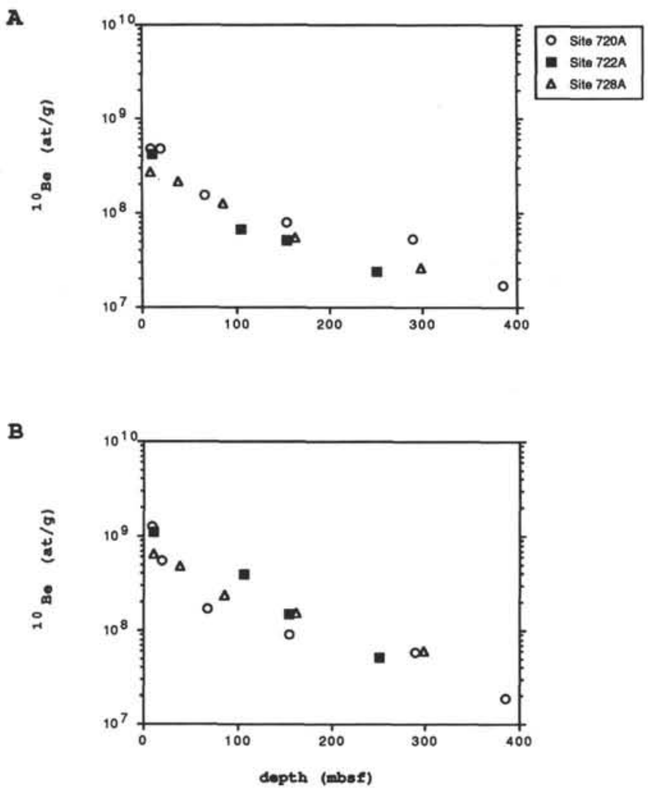

Figure 2. **A.** ^{10}Be content vs. depth in Holes 720A, 722A, and 728A. **B.** ^{10}Be content on a $CaCO_3$-free base vs. depth.

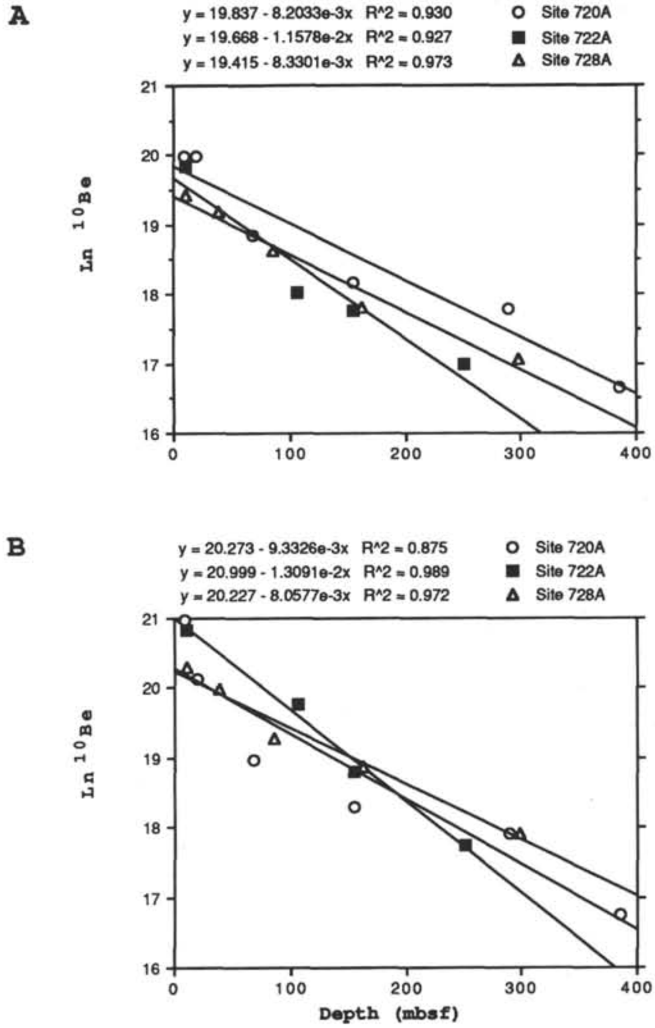

Figure 3. **A.** Ln of ^{10}Be content vs. depth; regression lines through the data points of each hole, and corresponding correlation coefficient. **B.** Ln of ^{10}Be content corrected for $CaCO_3$ wt%, vs. depth; regression lines through the data points of each hole, and corresponding correlation coefficient.

clay minerals which are more efficient carriers of ^{10}Be (Southon et al., 1987).

Hole 728A lacks any correlation between initial ^{10}Be contents and sediment accumulation rate, maybe because of redistribution of the ^{10}Be by the overlying upwelling cells (Faure, 1986) and delivering of ^{10}Be from several sources.

The abrupt decrease in ^{10}Be content, below 20 mbsf in Hole 720A can be explained by the change in sediment type; the upper 17.2 m consist of pelagic nannofossil ooze, Sample 720A-1H-CC and partially Sample 720A-2H-CC (Table 1), with a high initial ^{10}Be content. The underlying clastic sediments are all of turbiditic origin with very high sedimentation rates (up to 94.4 cm/k.y.) and of a mud to sandy composition, with a low initial ^{10}Be content.

The ages derived from the ^{10}Be content for pelagic Hole 722A agree well with those inferred from the biostratigraphy and magnetostratigraphy (Prell, Niitsuma, et al., 1989). This indicates that the original precipitated ^{10}Be atoms did not undergo important redistribution in the water column or in the sediments. On the other hand the ^{10}Be ages for the Holes 728A and 720A show large discrepancies with the magnetostratigraphic and biostratigraphic ages. In the case of the hemipelagic Hole 728A this can have several causes: as already indicated in the above, Site 728 is overlain by an zone of intensive upwelling and an oxygen minimum zone. Whether or not "boundary scavenging" (Anderson et al., 1990) plays a role in the ^{10}Be distribution is not clear. However, we do not find as distinct a difference between the margin site (728) and the more open ocean sites (722 and 720) as Anderson et al. (1990) did.

CONCLUSIONS

In this study we find that in one of the holes, Hole 722A, the initial ^{10}Be content increases with increasing sediment accumulation rate due to higher input of clays. In Hole 728A no distinct relation between sediment accumulation rate and ^{10}Be content is visible. Hole 720A shows a negative correlation between the sediment accumulation rate and the ^{10}Be content because of a high input of terrigenous sediments. This confirms the influences of both the origin of the sediment and the sedimentation rate on the distribution of ^{10}Be in the sediments. In Holes 722A and 728A the ^{10}Be abundances were determined over a time interval of 7.5 m.y. and 6.5 m.y., respectively. The calculated ages differ from the biostratigraphic and magnetostratigraphic ages by 14%–21% in Hole 722A and by 0%–52% in Hole 728A.

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Table 2. Sample numbers, magnetostratigraphic/biostratigraphic ages, calculated ages, initial ^{10}Be content (corrected for decay), and sediment accumulation rates.

Hole, core, section	Age[a] (Ma)	Age[b] (Ma)	Age[c] (Ma)	$^{10}Be_i(10^8$ at/g)[d]	Sediment accumulation rate (m/m.y.)
720A-1H-CC	0.22	0.17	0.19	5.31	42.7
720A-2H-CC	0.29	0.34	0.39	5.48	137
720A-7X-CC	0.64	1.20	1.39	2.07	137
720A-16X-CC	0.86	2.74	3.19	1.16	512
720A-30X-CC	—	5.14	—	—	—
720A-40X-CC	—	6.84	—	—	—
722A-lH-CC	0.28	0.24	0.29	4.73	37.7
722A-llX-CC	3.37	2.65	3.12	3.23	27.7
722A-16X-CC	4.83	3.87	4.54	4.84	42.3
722A-26X-CC	7.29	6.29	7.38	6.96	48.2
728A-lH-CC	0.17	0.17	0.18	2.94	64.7
728A-4H-CC	0.93	0.69	0.70	3.29	35.0
728A-9H-CC	3.20	1.54	1.57	5.48	23.3
728A-17X-CC	4.35	2.93	2.98	4.03	87.6
728A-31X-CC	6.40	5.37	5.46	5.00	27.8

[a] Ages interpolated from the biostratigraphy and magnetostratigraphy of Holes 720A, 722A, and 728A.
[b] Ages calculated with equations (1) and (2) derived from the linear regressions in Figure 3A.
[c] Ages calculated with equations (1) and (2) derived from the linear regressions in Figure 3B, $CaCO_3$-free.
[d] $^{10}Be_i$ is the initial content of ^{10}Be, corrected for decay, using bio-/magnetostratigraphic age.

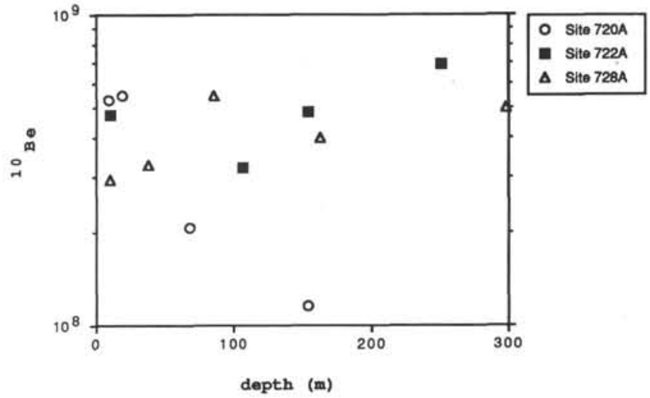

Figure 4. Initial, decay-corrected, ^{10}Be content vs. depth.

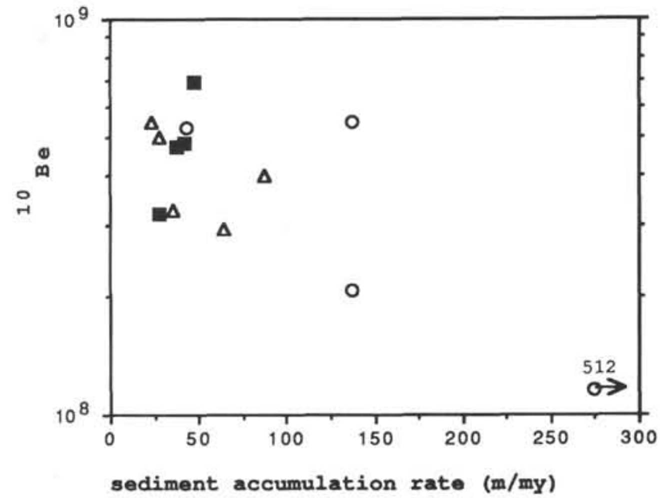

Figure 5. ^{10}Be content vs. sediment accumulation rate.