25. OCCURRENCE OF *INOCERAMUS* IN THE SOUTH ATLANTIC AND OXYGEN ISOTOPIC PALEOTEMPERATURES IN HOLE 530A[1]

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ABSTRACT

Inoceramus occurs in every DSDP hole that penetrated Cretaceous sediments in the South Atlantic Ocean, and specimen occurrence has been mapped in detail for each core. Oxygen and carbon isotope measurements were completed on 18 *Inoceramus* specimens from Hole 530A. Textural evidence of diagenesis is accompanied by depletion in ^{18}O. Paleotemperature results were obtained from 11 well-preserved specimens. Bottom water temperatures in the Angola Basin decreased from 23°C during the Coniacian to 13°C near the end of the Campanian.

INTRODUCTION

A major objective at Site 530 was to determine the paleoceanographic evolution of the Angola Basin, particularly during the Cretaceous episodes of black shale deposition. Determination of paleotemperatures is an integral part of reconstructing the paleoenvironmental history.

Most paleotemperature investigations have stressed isotopic analyses of foraminifers from deep-sea cores. Unfortunately, there is a notable lack of well-preserved foraminifers from Cretaceous sediments, despite the fact that many Deep Sea Drilling Project (DSDP) holes have penetrated Cretaceous sediments. As in sections elsewhere, there were no suitably preserved specimens of foraminifers found in the Cretaceous sediments in Hole 530A. However, there were abundant *Inoceramus* specimens, ranging in age from Maestrichtian to Coniacian, many of which were clearly well preserved.

The majority of quantitative paleotemperature estimates from the Cretaceous have been derived from oxygen isotopic analyses of belemnites and *Inoceramus* from outcrops of epicontinental sea deposits (e.g., Lowenstam and Epstein, 1954). The major advantage of analyses of these macrofossils is that the coarse crystalline structure is likely to preserve the isotopic signal. The major disadvantage is that the epicontinental-sea setting may be subject to more variable environmental conditions, such as fresh-water runoff, making the data difficult to interpret. Subaerial exposure may also result in substantial alteration. Because *Inoceramus* specimens preserved in deep sea cores do not have the same drawbacks as those in exposed continental sections, they have potential to expand greatly our knowledge of Cretaceous paleotemperatures.

We have mapped the distribution of *Inoceramus* fragments in all DSDP cores which penetrated Cretaceous sediments in the South Atlantic Ocean. Knowledge of the distribution of *Inoceramus* will aid in understanding their paleoecology as well as describe the potential source of isotopic data.

Oxygen and carbon isotope ratios were measured on *Inoceramus* fragments in various states of preservation in order to interpret diagenetic trends and establish textural criteria for selection of samples for paleotemperature analysis. This study resulted in paleotemperature data from 11 well-preserved *Inoceramus* fragments from Hole 530A, ranging in age from Coniacian to Campanian. These data confirm earlier studies of warm bottom water temperatures during the Cretaceous (see Savin, 1977 for view). Changes in bottom water sources during this time influenced the character of sedimentation in the Angola Basin. These changes were probably controlled by tectonic developments and eustatic sea level fluctuations in the early South Atlantic.

OCCURRENCE OF *INOCERAMUS* IN SOUTH ATLANTIC CORES

Inoceramus is an extinct epibenthic bivalve. The coarsely crystalline ostracum, which consists of vertically oriented calcite prisms, is preserved in deep-sea sediments (Fig. 1). *Inoceramus* is known to occur in a wide variety of paleoenvironments, within a large range of paleodepths and associated with a wide variety of sediment types (e.g., Thiede and Dinkelman, 1977). Studies of *Inoceramus* in the western interior seaway of North America (Kauffman, 1967) indicate that the organisms were adapted to soft mud bottoms.

Detailed mapping of the distribution of *Inoceramus* in DSDP cores will aid in understanding the paleoecology of this extinct organism. Rather than relying on descriptions of the occurrence of *Inoceramus* available in DSDP reports, which in some cases are rather general, all DSDP cores which penetrated Cretaceous sediments in the South Atlantic were examined specifically for *Inoceramus*. However, this does not insure a quantitative description of the organism's occurrence because visual examination is limited to the two faces of the split core.

[1] Hay, W. W., Sibuet, J.-C., et al., *Init. Repts. DSDP*, 75: Washington (U.S. Govt. Printing Office).

[2] Present address: National Center for Atmospheric Research, P.O. Box 3000, Boulder, CO 80307.

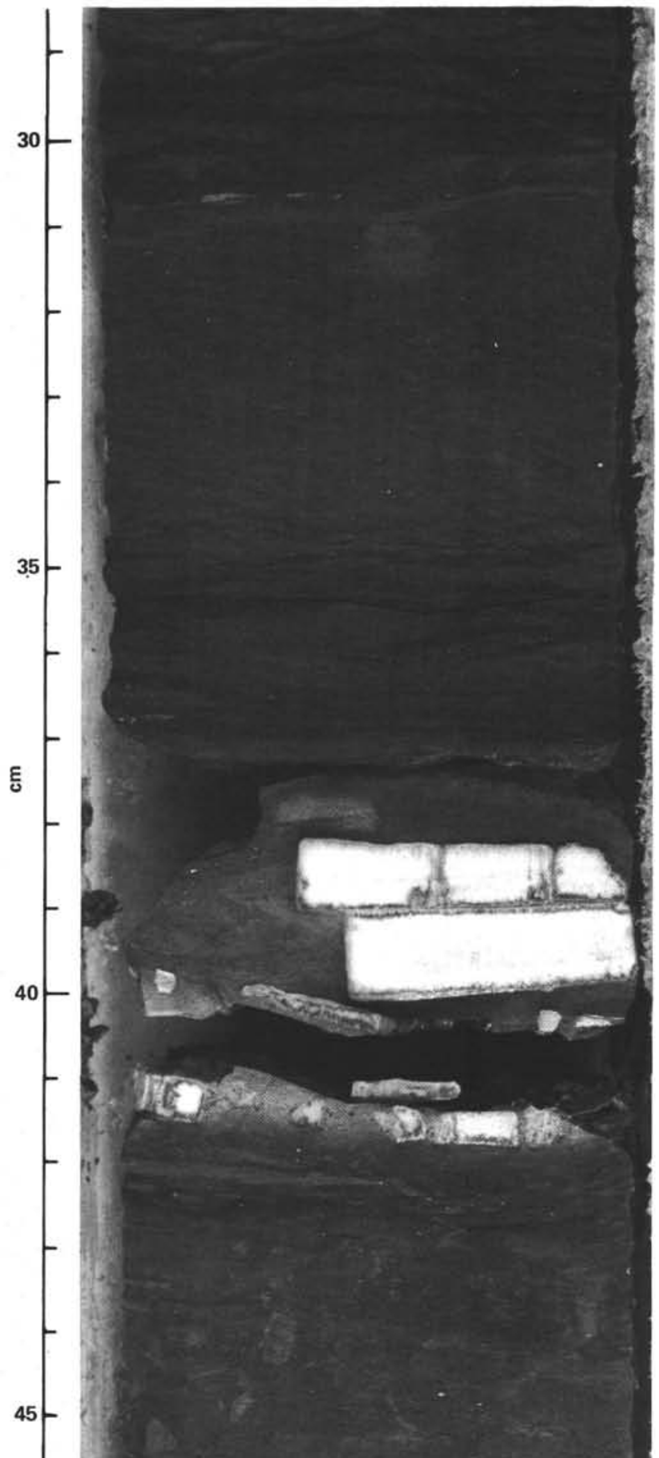

Figure 1. Example of preserved *Inoceramus* fragments at Samples 530A-63-1, 30–45 cm.

A large amount of fossil material may be hidden (e.g., Kauffman, 1976). The specimens described in this chapter are typically fragments rather than whole shells, probably because of predation (E. Kauffman, pers. comm.). Individual prisms are not included as an occurrence.

Table 1 gives the occurrence of *Inoceramus* in South Atlantic DSDP cores, the number of fragments visible, the character of the preservation and a general designation of the sediment type. Samples collected for microscopic examination to determine their suitability for isotopic analysis are indicated by an asterisk. The stage designation is given from the respective site reports. Based on the stratigraphic zonation given in the site reports and the time scale of Obradovich and Cobban (1975) for the Late Cretaceous and van Hinte (1976a, b) for the Early Cretaceous and Jurassic, an estimated age in millions of years is calculated by assuming a constant sedimentation rate within paleontologic zones. This information is summarized in Table 2. The occurrence of *Inoceramus* is plotted in Figure 2.

All of the holes that penetrated Cretaceous sediments have at least one *Inoceramus* occurrence. Although *Inoceramus* are widely distributed in the South Atlantic, the factors controlling distribution are unclear. For instance Sites 21, 356, and 357 are located in close proximity on the Rio Grande Rise and the Sao Paulo Plateau. *Inoceramus* is common in Campanian strata in cores from Sites 21 and 356, but is not common in cores from the geographically intermediate Site 357. yet the geographically intermediate site, Site 357, is not characterized by abundant Campanian *Inoceramus* while Sites 21 and 356 have common occurrences. The Rio Grande Rise was also the site of abundant *Inoceramus* during the Santonian–Coniacian. Both of the basinal sites (355 and 530A) appear to have abundant *Inoceramus* in the late Campanian but not in the early Campanian. It is possible that there is a hiatus at the Maestrichtian-Campanian boundary at Site 355, but this is of unknown duration. With the exception of Site 361 on the South African margin, which has poor stratigraphic control, all South Atlantic DSDP sites contain *Inoceramus* in Santonian sediments. Five sites penetrated the middle Cretaceous, of which three have Albian *Inoceramus.* Of course, all of these comparisons are dependent on the recognition of any hiatuses. The oldest occurrence of *Inoceramus* is in Oxfordian strata from from Site 330 on the Falkland Plateau.

Preservation varies widely, involving silicification, recrystallization, overgrowth, and, rarely, dissolution. Many specimens appear completely unaltered. Table 1 also indicates the variety of associated sediment types, including euxinic sediments, olive clays and nannofossil foraminiferal oozes.

Occurrences in the South Atlantic also represent a wide range of paleodepths. The presence of shallow water indicators at Site 21 (Maxwell et al., 1970) suggests a paleodepth of 100 to 400 m in the early Campanian, and the paleodepth of *Inoceramus* was probably not much deeper. In contrast, the paleodepth in Hole 530A during the Late Cretaceous is in the range of 3500 to 4500 m, based on basement age and thermal subsidence history. Estimated paleodepths, derived from the respective DSDP reports, are given in Table 3.

It is important to note that the occurrence of *Inoceramus* in Hole 530A greatly extends the depth range as compared to Thiede and Dinkelman (1977). Careful examination of the distribution of turbidites (Stow, this

Table 1. *Inoceramus* occurrences and samples for microscopic examination and isotopic analysis.

Core-Section (interval in cm)	No. of occurrences	Preservation (visual exam.)	Sediment type	Stage	Age (m.y. ago)
Leg 3, Hole 21					
4-4, 130–131[a]	1	Good	Nanno-foram ooze	l. Campanian	71.6
4-5, 105–107[a]	1	Good	Nanno-foram ooze	l. Campanian	72.1
4-6, 31–32[a]	1	Good	Nanno-foram ooze	l. Campanian	72.2
5-1, 21–22[a]	1	Moderate	Nanno-foram ooze	l. Campanian	73.5
5-2, 69–70[a]	Several	Moderate	Nanno-foram ooze	l. Campanian	74.1
5-2, 73–75[a]	1	Good	Nanno-foram ooze	l. Campanian	74.1
5-2, 76–82	1	Poor	Nanno-foram ooze	l. Campanian	74.1
5-2, 125–128[a]	1	Moderate	Nanno-foram ooze	l. Campanian	74.2
5-3, 53–58	1	Poor	Nanno-foram ooze	l. Campanian	74.5
5-3, 93–99[a]	1 layer	Disaggregated	Nanno-foram ooze	l. Campanian	74.7
5-5, 20–21[a]	1	Good	Nanno-foram ooze	l. Campanian	75.4
5-5, 39–41	1	Good	Nanno-foram ooze	l. Campanian	75.4
5-5, 69–71[a]	1	Reduction, disaggregated	Nanno-foram ooze	l. Campanian	75.4
5-5, 69–71[a]	1	Reduction, disaggregated	Nanno-foram ooze	l. Campanian	75.5
5-5, 83–84	1	Reduction, disaggregated	Nanno-foram ooze	l. Campanian	75.5
5-5, 90–91	1	Reduction, disaggregated	Nanno-foram ooze	l. Campanian	75.5
5-5, 95–97[a]	Several	Reduction, disaggregated	Nanno-foram ooze	l. Campanian	75.5
5-5, 121–122[a]	1	Good	Nanno-foram ooze	l. Campanian	75.7
5-6, 29–31[a]	1	Good to poor	Nanno-foram ooze	l. Campanian	75.8
5-6, 53–56[a]	Several	Disaggregated	Nanno-foram ooze	l. Campanian	76.0
5-6, 64–70	1	Poor	Nanno-foram ooze	l. Campanian	76.0
5-6, 90–91	1	Poor	Nanno-foram ooze	l. Campanian	76.1
5-6, 94–95	1	Poor	Nanno-foram ooze	l. Campanian	76.3
6-5, 147–148[a]	1	Moderate	Nanno-foram ooze	e. Campanian	78.0
6-6, 23–24	1	Poor	Nanno-foram ooze	e. Campanian	78.1
6-6, 26–27	1	Poor	Nanno-foram ooze	e. Campanian	78.1
6-6, 28–29	1	Poor	Olive nanno clay	e. Campanian	78.1
6-6, 30–34[a]	1	Good	Olive nanno clay	e. Campanian	78.1
6-6, 36–39[a]	1 layer	Good	Olive nanno clay	e. Campanian	78.1
6-6, 45–47[a]	1	Moderate	Nanno-foram ooze	e. Campanian	78.1
6-6, 58–61[a]	2 layers	Moderate	Nanno-foram ooze	e. Campanian	78.1
6-6, 71–72[a]	1	Good	Olive nanno clay	e. Campanian	78.1
6-6, 81–82	1	Poor	Olive nanno clay	e. Campanian	78.1
6-6, 106–107[a]	1	Moderate	Nanno-foram ooze	e. Campanian	78.3
6-6, 106–114[a]	Several	Moderate	Nanno-foram ooze	e. Campanian	78.3
6-6, 114–116[a]	1	Moderate disaggregated	Nanno-foram ooze	e. Campanian	78.3
6-6, 146–147	1	Poor	Nanno-foram ooze	e. Campanian	78.4
7-1, 83–84	1	Reduction	Nanno-foram ooze	e. Campanian	78.7
7-2, 97–99[a]	?	Pelecypod?	Nanno-foram ooze	e. Campanian	79.1
7-2, 101–102	Several	Poor	Nanno-foram ooze	e. Campanian	79.1
7-2, 108–109	Several	Poor	Nanno-foram ooze	e. Campanian	79.1
7-2, 123–125[a]	1	Moderate	Nanno-foram ooze	e. Campanian	79.1
7-2, 142–147[a]	1	Good	Nanno-foram ooze	e. Campanian	79.1
7-3, 45–46	1	Poor	Nanno-foram ooze	e. Campanian	79.4
7-4, 84–85	1	Poor	Nanno-foram ooze	e. Campanian	79.9
7-6, 75–76[a]	1	Moderate	Nanno-foram ooze	e. Campanian	80.4
8-2, 65–66[a]	1	Good	Nanno-foram ooze	e. Campanian	81.0
8-3, 120–122[a]	1	Moderate	Nanno-foram ooze	e. Campanian	81.6
Leg 36, Hole 327A					
12-3, 64–74	?	Poor	Olive gray clay	Maestrichtian	≈67.0
14-4, 134–135	1	Poor	Red brown clay	Cenomanian	92.0
14-4, 136–137[a]	1	Good	Red brown clay	Cenomanian	92.0
14-4, 139–140	1	Poor	Red brown clay	Cenomanian	92.0
14-4, 140–141	1	Poor	Red brown clay	Cenomanian	92.0
14-4, 151–152[a]	1	Good	Red brown clay	Cenomanian	92.0
14-5, 3–4	1	Poor	Red brown clay	Cenomanian	92.0
14-5, 4–5[a]	1	Moderate	Red brown clay	Cenomanian	92.0
14-5, 5–6[a]	1	Poor to moderate	Red brown clay	Cenomanian	92.0
14-5, 12–13[a]	1	Poor to moderate	Red brown clay	Cenomanian	92.0
14-5, 15–16	1	Poor	Red brown clay	Cenomanian	92.0
14-5, 31–32[a]	1	Moderate	Red brown clay	Cenomanian	92.0
14-5, 45–46	1	Poor	Red brown clay	Cenomanian	92.0
14-5, 61–62[a]	1	Moderate	Red brown clay	Cenomanian	92.0
14-5, 82–83[a]	1	Moderate	Red brown clay	Cenomanian	92.1
14-5, 86–87	1	Poor	Red brown clay	Cenomanian	92.1
14-5, 94–95[a]	Several	Moderate	Red brown clay	Cenomanian	92.1
14-5, 102–103[a]	1	Moderate	Red brown clay	Cenomanian	92.1
14-5, 135–136[a]	1	Poor to moderate	Red brown clay	Cenomanian	92.1
14-5, 142–143	1	Poor	Red brown clay	Cenomanian	92.1
15-2, 130–137[a]	1	Moderate	Light brown clay	l. Albian	95.8
15-2, 141–142	1	Poor	Light brown clay	l. Albian	95.8
15-2, 145–146[a]	1	Poor to moderate	Light brown clay	l. Albian	95.8
Leg 36, Hole 330					
1-1, 50–51[a]	1	Moderate	Euxinic	e.-m. Albian	100.0
5-2, 137–138[a]	2 layers	Poor	Euxinic	Oxfordian	143.2
6-1, 129–130[a]	1	Moderate	Euxinic	Oxfordian	143.9
6-2, 30–32[a]	1	Moderate	Euxinic	Oxfordian	144.0
6-2, 34–35	1	Moderate	Euxinic	Oxfordian	144.0
6-2, 58–59[a]	1	Moderate	Euxinic	Oxfordian	144.0
6-3, 126–127	1	Poor	Euxinic	Oxfordian	144.2
6-5, 104–105[a]	1	Good	Euxinic	Oxfordian	144.4
7-2, 20–21[a]	1	Good	Euxinic	Oxfordian	144.7
7-3, 10–11	1	Poor	Euxinic	Oxfordian	144.8
7-3, 14–15	1	Poor	Euxinic	Oxfordian	144.8
7-3, 21–22	1	Poor	Euxinic	Oxfordian	144.8
7-3, 47–48[a]	1	Good, disaggregated	Euxinic	Oxfordian	144.9
7-3, 51–52[a]	1	Good	Euxinic	Oxfordian	144.9

Table 1. (Continued.)

Core-Section (interval in cm)	No. of occurrences	Preservation (visual exam.)	Sediment type	Stage	Age (m.y. ago)
Leg 36, Hole 330 Cont.					
7-3, 54-55[a]	1	Good	Euxinic	Oxfordian	144.9
7-3, 55-56[a]	1	Moderate	Euxinic	Oxfordian	144.9
7-3, 105-106	1	Poor	Euxinic	Oxfordian	144.9
7-3, 132-133	1	Poor	Euxinic	Oxfordian	144.9
7-5, 108-109[a]	1	Good, disaggregated	Euxinic	Oxfordian	145.2
7-6, 18-19	1	Good	Euxinic	Oxfordian	145.2
7-6, 21-22[a]	1	Good	Euxinic	Oxfordian	145.2
7-6, 43-45[a]	1	Good	Euxinic	Oxfordian	145.2
7-6, 61-62[a]	1	Good	Euxinic	Oxfordian	145.3
7-6, 75-76	1	Poor	Euxinic	Oxfordian	145.3
8-1, 126-127	1	Poor	Euxinic	Oxfordian	147.2
8-3, 27-28[a]	1 layer	Good	Euxinic	Oxfordian	147.4
8-3, 33-34	1	Poor	Euxinic	Oxfordian	147.4
8-3, 45-46	1	Poor	Euxinic	Oxfordian	147.4
8-3, 54-55	1	Poor	Euxinic	Oxfordian	147.4
8-3, 88-89	1	Poor	Euxinic	Oxfordian	147.4
Leg 39 Site 355					
17-2, 137-138[a]	1	Good	Brown clay	e. Maes.-l. Camp.	69.7
17-2, 139-140[a]	1	Good	Brown clay	e. Maes.-l. Camp.	69.7
17-3, 8-9	1	Poor	Brown clay	e. Maes.-l. Camp.	69.7
17-3, 10-11	1	Poor	Brown clay	e. Maes.-l. Camp.	69.7
17-4, 95-96	1	Poor	Cemented clast	e. Maes.-l. Camp.	70.1
17-4, 96*	1 layer	Good	Brown clay	e. Maes.-l. Camp.	70.1
17-4, 96-98	Several	Poor	Brown clay	e. Maes.-l. Camp.	70.1
17-4, 104-105[a]	1	Moderate	Brown clay	e. Maes.-l. Camp.	70.1
17-4, 113-114[a]	1	Moderate	Brown clay	e. Maes.-l. Camp.	70.1
17-4, 120-121	Several	Poor	Brown clay	e. Maes.-l. Camp.	70.1
18-1, 87-92[a]	1-7 cm	Good	Brown clay	e. Maes.-l. Camp.	70.6
18-1, 104-105[a]	1	Good	Brown clay	e. Maes.-l. Camp.	70.6
18-2, 118-119[a]	1 layer	Good	Brown clay	e. Maes.-l. Camp.	70.9
18-3, 17-19[a]	1	Moderate	Brown clay	e. Maes.-l. Camp.	70.9
18-3, 53-54[a]	1	Moderate	Brown clay	e. Maes.-l. Camp.	71.1
18-3, 61-62	1	Poor	Brown clay	e. Maes.-l. Camp.	71.1
18-3, 81-84[a]	1	Moderate to good	Brown clay	e. Maes.-l. Camp.	71.2
19-2, 75-83	Several	Poor	Brown clay	Campanian	72.8
19-2, 85-87[a]	Several	Good	Brown clay	Campanian	72.8
19-2, 100-101	1	Poor	Brown clay	Campanian	72.9
19-2, 107-109[a]	1	Marginal	Brown clay	Campanian	72.9
19-2, 116-117[a]	1	Marginal	Brown clay	Campanian	72.9
Leg 39, Hole 356					
34-1, 56-57	1	Silicified	Olive marl	Campanian	76.4
34-1, 57-58	1	Silicified	Olive marl	Campanian	76.4
34-1, 71-72	1	Silicified	Olive marl	Campanian	76.5
34-1, 73-74	1	Silicified	Olive marl	Campanian	76.5
34-2, 70-71	1	Silicified	Olive marl	Campanian	77.0
34-2, 124-126	Several	Silicified	Olive marl	Campanian	77.1
34-3, 39-40[a]	1	Poor to moderate	Olive marl	Campanian	77.3
34-3, 42-43[a]	1	Poor to moderate	Olive marl	Campanian	77.3
34-3, 54-55[a]	1	Poor to moderate	Olive marl	Campanian	77.3
34-4, 31-33	Several	Silicified	Olive marl	Campanian	77.7
34-4, 42-43	1	Silicified	Olive marl	Campanian	77.7
34-4, 67-68	1	Silicified	Olive marl	Campanian	77.8
34-6, 129-130	1 layer	Moderate	Olive marl	Campanian	79.0
34-6, 135-136	1	Poor	Olive marl	Campanian	79.0
35-4, 49-50	1	Poor	Olive marl	l. Santonian	82.1
36-4, 11-12	2	Poor	Olive marl	l. Santonian	83.0
37-1, 144-148	Several	Poor	Olive marl	l. Santonian	83.7
38-2, 9-12[a]	Several	Poor	Tan marl	e. Sant.-l. Coniac.	84.1
38-3, 46-47	Several	Poor	Tan marl	e. Sant.-l. Coniac	84.3
38-3, 71-73	Several	Poor	Tan marl	e. Sant.-l. Coniac	84.3
38-3, 75-76[a]	Several	Moderate to poor	Tan marl	e. Sant.-l. Coniac.	84.3
38-3, 111-112[a]	Several	Moderate to poor	Tan marl	e. Sant.-l. Coniac.	84.3
38-3, 132-133	1	Moderate to poor	Tan marl	e. Sant.-l. Coniac.	84.3
39-2, 78-79	1	Clast	Tan marl	e. Sant.-l. Coniac.	86.1
40-3, 85-87	1	Clast	Tan marl	e. Sant.-l. Coniac.	86.5
Leg 39, Hole 357					
36-4, 36-44	Missing[b]	?	Green-gray marly chalks and limestones	Campanian	70.6
44-2, 38-39	1	Poor	Green-gray marly chalks and limestone	l. Santonian	82.9
44-2, 103-104	1	Poor	Green-gray marly chalks and limestone	l. Santonian	82.9
44-2, 110-111	1	Poor	Green-gray marly chalks and limestone	l. Santonian	82.9

Table 1. (Continued.)

Core-Section (interval in cm)	No. of occurrences	Preservation (visual exam.)	Sediment type	Stage	Age (m.y. ago)
Leg 39, Hole 357 Cont.					
44-3, 24–25[a]	2	Moderate	Green-gray marly chalks and limestone	l. Santonian	82.9
45-2, 97–99	1	Poor	Green-gray marly chalks and limestones	l. Santonian	83.3
45-2, 111–112	2	Poor	Green-gray marly chalks and limestones	l. Santonian	83.3
46-1, 125–126	1	Poor	Green-gray marly chalks and limestones	l. Santonian	83.3
46-1, 133–134	1	Poor	Green-gray marly chalks and limestones	l. Santonian	83.3
46-2, 92–96	Several	Poor	Green-gray marly chalks and limestones	l. Santonian	83.4
46-2, 139–140[a]	1	Moderate	Green-gray marly chalks and limestones	l. Santonian	83.4
46-3, 3–4	1	Poor	Green-gray marly chalks and limestones	l. Santonian	83.4
47-1, 143–144	1	Poor	Green-gray marly chalks and limestones	l. Santonian	83.7
47-2, 2–3	1	Poor	Green-gray marly chalks and limestones	l. Santonian	83.7
47-2, 11–12	1	Poor	Green-gray marly chalks and limestones	l. Santonian	83.7
47-2, 137–138	1	Poor	Green-gray marly chalks and limestones	l. Santonian	83.7
47-3, 13–15	1	Poor	Green-gray marly chalks and limestones	l. Santonian	83.7
47-3, 48–49	1	Poor	Green-gray marly chalks and limestones	l. Santonian	83.7
47-3, 51–52	1	Poor	Green-gray marly chalks and limestones	l. Santonian	83.7
47-4, 41–42	1	Poor	Green-gray marly chalks and limestones	l. Santonian	83.8
47-4, 85–86	1	Poor	Green-gray marly chalks and limestones	l. Santonian	83.8
47-4, 106–107	1	Poor	Green-gray marly chalks and limestones	l. Santonian	83.8
47-4, 135–136	1	Poor	Green-gray marly chalks and limestones	l. Santonian	83.8
47-4, 140–142	1	Poor	Green-gray marly chalks and limestones	l. Santonian	83.8
47-4, 146–147	1	Poor	Green-gray marly chalks and limestones	l. Santonian	83.9
47-5, 60–61	Several	Poor	Green-gray marly chalks and limestones	l. Santonian	83.9
47-5, 66–67	1	Poor	Green-gray marly chalks and limestones	l. Santonian	83.9
47-5, 73–74	1	Poor	Green-gray marly chalks and limestones	l. Santonian	83.9
47-6, 10–11	1	Poor	Green-gray marly chalks and limestones	l. Santonian	83.9
47-6, 13–14	1	Poor	Green-gray marly chalks and limestones	l. Santonian	83.9
47-6, 60	1	Poor	Green-gray marly chalks and limestones	l. Santonian	83.9
47-6, 61	1	Poor	Green-gray marly chalks and limestones	l. Santonian	83.9
47-6, 62	1	Poor	Green-gray marly chalks and limestones	l. Santonian	83.9
47-6, 63–64[a]	1	Moderate	Green-gray marly chalks and limestones	l. Santonian	83.9

Table 1. (Continued.)

Core-Section (interval in cm)	No. of occurrences	Preservation (visual exam.)	Sediment type	Stage	Age (m.y. ago)
Leg 39, Hole 357 Cont.					
48-1, 78–79	1	Poor	Green-gray marly chalks and limestones	e. Santonian	84.1
48-1, 79–80	1	Poor	Green-gray marly chalks and limestones	e. Santonian	84.1
48-1, 83–87	1	Poor	Green-gray marly chalks and limestones	e. Santonian	84.1
48-2, 136–137	Several	Poor	Green-gray marly chalks and limestones	e. Santonian	84.2
48-3, 35–36	Several	Poor	Green-gray marly chalks and limestones	e. Santonian	84.2
48-3, 114–117	1	Poor	Green-gray marly chalks and limestones	e. Santonian	84.3
48-4, 97–98	1	Poor	Green-gray marly chalks and limestones	e. Santonian	84.4
48-4, 104–105	1	Poor	Green-gray marly chalks and limestones	e. Santonian	84.4
48-6, 122–123	1	Poor	Green-gray marly chalks and limestones	e. Santonian	84.6
49-3, 25–26	1	Poor	Green-gray marly chalks and limestones	e. Santonian	84.9
49-6, 57–85[a]	1	Poor	Green-gray marly chalks and limestones	e. Santonian	85.3
50-1, 0–2[a]	Several	Poor	Green-gray marly chalks and limestones	e. Santonian	85.3
50-1, 25–26	1	Poor	Green-gray marly chalks and limestones	e. Santonian	85.3
50-1, 102–103	Several	Poor	Green-gray marly chalks and limestones	e. Santonian	85.4
50-2, 65–66	1	Poor	Green-gray marly chalks and limestones	e. Santonian	85.4
50-2, 108–109	1	Poor	Green-gray marly chalks and limestones	e. Santonian	85.5
50-2, 121–122	1	Silicified	Green-gray marly chalks and limestones	e. Santonian	85.5
50-4, 37–38	1	Poor	Olive marly limestones	e. Santonian	85.6
50-4, 116–117	1	Poor	Olive marly limestones	e. Santonian	85.7
50-4, 137–138	1	Poor	Olive marly limestones	e. Santonian	85.7
50-4, 139–140	1	Poor	Olive marly limestones	e. Santonian	85.7
50-6, 108–109	Several	Silicified	Olive marly limestones	e. Santonian	85.9
50-6, 113–114	Several	Silicified	Olive marly limestones	e. Santonian	85.9
Leg 40, Hole 361					
15,CC, —	1	Moderate	Euxinic	e. Maes.-l. Camp.	74.0
Leg 40, Hole 363					
21-3, 133–134[a]	1	Moderate	Foram-nanno chalk	e. Maestrichtian	69.3
21-6, 48–52[a]	1	Moderate	Foram-nanno chalk	e. Maestrichtian	70.2
21-6, 52[a]	1	Moderate	Foram-nanno chalk	e. Maestrichtian	70.2
21-6, 67–68[a]	1	Moderate	Foram-nanno chalk	e. Maestrichtian	70.2
Leg 40, Hole 364					
38-3, 24–25	1	Poor	Olive marly limestones	u. Aptian	110.2
38-3, 61–62	1	Poor	Olive marly limestones	u. Aptian	110.3
39-5, 20–22[a]	1	Good	Olive marly limestones	u. Aptian	111.8
Leg 75, Hole 530A					
55-1, 11–12	1	Silicified	Green mudstone	e. Maes.-l. Camp.	70.0
55-1, 34–36	3	Silicified	Green mudstone	e. Maes.-l. Camp.	70.0

Table 1. (Continued.)

Core-Section (interval in cm)	No. of occurrences	Preservation (visual exam.)	Sediment type	Stage	Age (m.y. ago)
Leg 75, Hole 530A Cont.					
55-1, 39–41	2	Silicified	Green mudstone	e. Maes.-l. Camp.	70.0
55-1, 67–68	1 layer	Silicified	Green mudstone	e. Maes.-l. Camp.	70.0
55-1, 141–143	3	Silicified	Green mudstone	e. Maes.-l. Camp.	70.0
55-2, 68–69	1	Silicified	Green mudstone	e. Maes.-l. Camp.	70.0
55-2, 105–106	1	Silicified	Green mudstone	e. Maes.-l. Camp.	70.2
55-3, 112–113	1	Silicified	Green mudstone	e. Maes.-l. Camp.	70.2
56-2, 44–45	2	Silicified	Green mudstone	e. Maes.-l. Camp.	70.6
56-2, 45–46	1	Silicified	Green mudstone	e. Maes.-l. Camp.	70.6
56-2, 48–49	1	Silicified	Green mudstone	e. Maes.-l. Camp.	70.6
56-2, 56–58	1	Silicified	Green mudstone	e. Maes.-l. Camp.	70.6
56-2, 62–63	1	Silicified	Green mudstone	e. Maes.-l. Camp.	70.6
56-2, 69–70	1-layer	Silicified	Green mudstone	e. Maes.-l. Camp.	70.6
56-2, 87–88	1	Silicified	Green mudstone	e. Maes.-l. Camp.	70.6
56,CC	1	Silicified	Green mudstone	e. Maes.-l. Camp.	70.6
60-1, 121–124[a]	Several	Good	Green mudstone	e. Maes.-l. Camp.	70.8
61-2, 53–54[a]	Several	Very good	Green mudstone/ marlstone	e. Maes.-l. Camp.	70.9
61-2, 56–57[a]	Several	Very good	Green mudstone/ marlstone	e. Maes.-l. Camp.	70.9
61-2, 65–66[a]	1 layer	Moderate	Green mudstone/ marlstone	e. Maes.-l. Camp.	70.9
61-2, 78–81[a]	2 layers	Very good	Green mudstone/ marlstone	e. Maes.-l. Camp.	70.9
61-3, 59–61	1	Poor	Green mudstone/ marlstone	e. Maes.-l. Camp.	71.5
63-1, 37–40[a]	2	Good	Green mudstone/ marlstone	e. Maes.-l. Camp.	72.5
63-2, 71–72[a]	1	Poor	Green mudstone/ marlstone	e. Maes.-l. Camp.	72.5
63-2, 79–80	1 layer	Poor	Green mudstone/ marlstone	e. Maes.-l. Camp.	72.5
63-3, 6–8		Poor	Green mudstone/ marlstone	e. Maes.-l. Camp.	72.7
63-3, 8–9		Poor	Green mudstone/ marlstone	e. Maes.-l. Camp.	72.7
63-3, 52–53	1 layer	Poor	Green mudstone/ marlstone	e. Maes.-l. Camp.	72.7
63-3, 104–105[a]	Several	Poor	Sandy layer	e. Maes.-l. Camp.	72.7
64-1, 113–114[a]	1	Poor	Olive mudstone/ marlstone	Campanian	73.1
64-2, 8–9[a]	Several	Good	Olive mudstone/ marlstone	Campanian	73.1
64-2, 10–11[a]	Several	Good	Olive mudstone/ marlstone	Campanian	73.1
79-5, 71–73[a]	1	Very good	Sandy layer	Campanian	81.2
79-5, 141–142[a]	Several	Good	Red and green claystone	Campanian	81.2
80-1, 1[a]	1 layer	Moderate	Red and green claystone	Campanian	81.9
83-1, 62–63[a]	1	Good	Fine sand	Santonian-Coniac.	83.6
83-1, 98–99	1	Poor	Red and green claystone	Santonian-Coniac.	83.6
83-1, 123–124	1 layer	Poor	Red and green claystone	Santonian-Coniac.	83.6
83-2, 118–119[a]	1	Moderate	Red and green claystone	Santonian-Coniac.	83.7
83-3, 50–51	1	Poor	Red and green claystone	Santonian-Coniac.	83.8
83-3, 112–114[a]	1	Moderate	Red and green claystone	Santonian-Coniac.	83.8
83-4, 5–6[a]	1 layer	Moderate	Sedimentary laminations	Santonian-Coniac.	83.8
83-4, 33–34	1	Poor	Red claystones	Santonian-Coniac.	83.9
85-2, 23–24[a]	1	Poor	Red-brown claystones	Santonian-Coniac.	84.9
85-2, 66–67[a]	2	Moderate	Red-brown claystones	Santonian-Coniac.	84.9
85-3, 4–5[a]	1	Moderate to poor	Red-brown claystones	Santonian-Coniac.	85.0
85-3, 30–31[a]	Several	Moderate	Red-brown claystone	Santonian-Coniac.	85.0
88-2, 94–95[a]	3	Cemented block	Red and green claystone	Santonian-Coniac.	86.1
89-1, 88–89[a]	2 layers	Good	Red and green claystone	Santonian-Coniac.	86.3

[a] A sample.
[b] See site summary, Leg 39.

Table 2. Age–depth relationships used to calculate the age in millions of years for *Inoceramus*, using the time scale of Obradovich and Cobban (1975) for the Late Cretaceous and van Hinte (1976a, b) for the Early Cretaceous and Jurassic, and a constant sedimentation rate within paleontologic zones described in the respective site reports.

Core	Sub-bottom depth (m)	Age (Ma)
Leg 3, Hole 21		
3	76.3–85.4	65.0–67.5
4	85.4–87.7	67.5–69.4
4–5	87.7–105.9	70.5–75.8
6–8	105.9–130.6	75.8–82.0
Leg 36, Hole 327A (coring not continuous)		
10–12	90.0–118.0	65.0–
13	137.0–142.0	–68.3
13	142.0–146.5	68.3–75.8
14	146.5–151.0	85.0–86.0
14	151.0–156.0	91.7–92.5
15	175.0–184.5	94.0–100.0
Leg 36, Hole 330 (coring not continuous)		
1	129.0–138.5	100.0–
2	176.5–186.0	–106.5
3	224.0–233.5	112.0–
4	271.5–281.5	–115.0
5–7	300.0–328.5	143.0–
8	347.5–357.5	–148.0
Leg 39, Hole 355		
17–18	404.5–423.5	69.4–72.0
19–21	423.5–449.0	72.0–82.0
Leg 39, Hole 356		
34	513.0–522.5	75.8–82.0
35–37	541.5–608.0	82.0–84.0
38–40	646.5–700.0	84.0–86.5
40	700.0–703.0	87.8–88.6
Leg 39 Hole 357		
36–41	607.5–711.5	70.5–82.0
42–47	711.5–759.0	82.0–84.0
48–51	759.0–787.5	84.0–86.0
Leg 40, Hole 361		
12–20	297.5–620.0	65.0–87.0
Leg 40, Hole 363		
21	363.5–373.0	68.3–70.5
Leg 40, Hole 364		
38	948.0–947.5	110.0–
39	967.0–967.5	–112.0
Leg 75, Hole 530A		
50–59	590.5–685.5	65.0–70.5
59–80	685.5–885.0	70.5–82.0
80–94	885.0–1008.0	82.0–87.0

volume) indicates that specimens were not displaced from shallower regions except possibly in three cases (Samples 530A-63-3, 104 cm; 530A-79-5, 71 cm; and 530A-83-1, 62 cm are associated with fine-grained sandy layers). All the DSDP cores were examined carefully for any characteristic which might indicate downslope transport in order to reconstruct the occurrence of *Inoceramus* and interpret the paleotemperature data accurately. It does not appear that *Inoceramus* is indicative of any specific paleodepth.

STABLE ISOTOPE ANALYSES: OXYGEN AND CARBON

Analytical Techniques

Oxygen and carbon isotopic compositions were measured by analyzing CO_2 evolved by the reaction of samples and standards (B-1 and NBS-20) with 100% H_3PO_4 at 40°C. Analyses were performed on a Micromass 602 ratio mass spectrometer. The measurement technique has standard reproducibility of better than ±0.1 ‰. All analyses are reported relative to PDB (Pee Dee Belemnite).

Paleotemperatures are calculated using the equation of Craig (1965). The oxygen isotopic composition of mean ocean water is taken to be −1.0 ‰ relative to SMOW (Standard Mean Ocean Water), assuming polar ice volume to be negligible during the Cretaceous (Shackleton and Kennett, 1975).

Sample Preparation

All samples were taken from the calcitic prismatic layer of *Inoceramus* fragments either by simply breaking off pieces, prying free individual crystals, or by drilling small holes in the shell with a high-speed burr. No detectable isotope effects are associated with the drilling procedure.

DIAGENETIC TRENDS

Isotopic results from 25 *Inoceramus* fragments are listed in Table 4 and plotted in Figure 3. Eleven samples with no evidence of recrystallization, dissolution, overgrowths, or silicification are indicated as "well preserved" in Figure 3. These samples exhibit a range in $\delta^{18}O$ of +1.1 to −2.6 ‰ and a range of +1.9 to −1.25 in $\delta^{13}C$ and were considered suitable for paleotemperature analysis. Several of the moderately well-preserved samples also fall within these ranges. Poorly preserved samples tend to be lighter in both oxygen and carbon, reaching values of −6.75 ‰ in $\delta^{18}O$ and −3.2 in $\delta^{13}C$.

Depletion in ^{18}O with increasing textural alteration is a common diagenetic feature in deep sea sediments. This is further illustrated by analyses of bulk carbonate from a black shale (Sample 530A-88-3, 122 cm) of Coniacian age. The carbonate component of the black shale consisted largely of recrystallized foraminifers with calcitic overgrowths. The $\delta^{18}O$ of the sample is −7.57 ‰. The observed depletion in O^{18} of diagenetic carbonates may result from two effects: (1) increasing temperature with burial depth, and (2) pore water ^{18}O depletion resulting from formation of authigenic silicates.

The oxygen isotopic composition of the diagenetic carbonates (−4.5 to −7.5 ‰) yields a calculated temperature of 33–50°C. This agrees reasonably well with the 30–45°C estimated downhole temperature of these sediments (Site 530 summary chapter, this volume).

Lawrence et al. (1975) found a correlation of $\delta^{18}O$ gradients with changes in pore water cation composition and mineralogy at several DSDP sites. They demon-

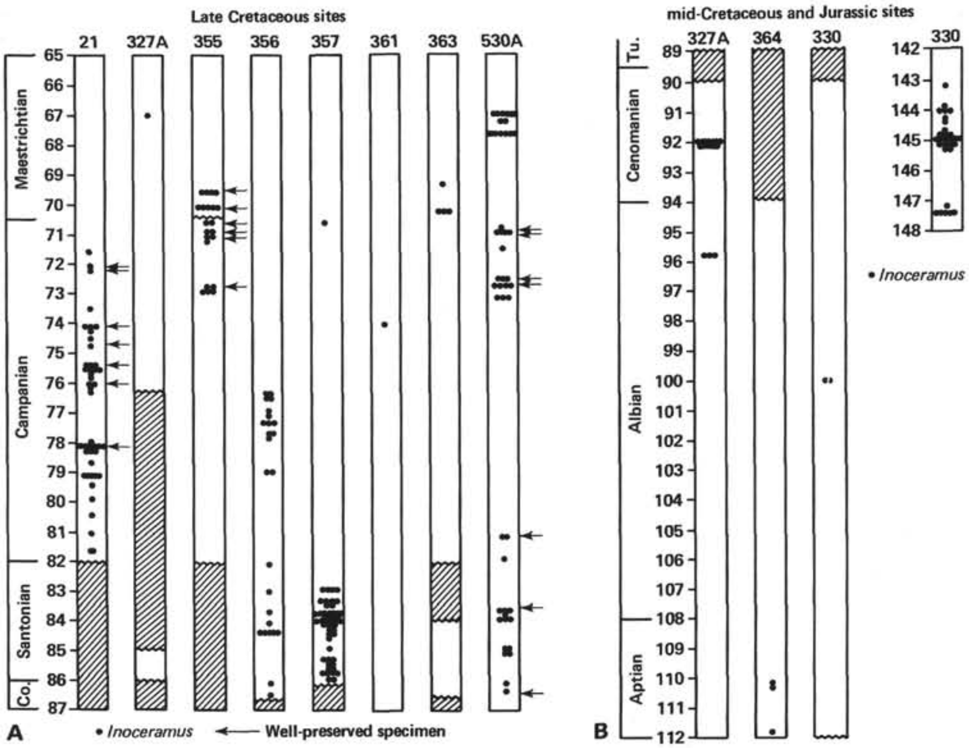

Figure 2. A. Occurrence of *Inoceramus* in Late Cretaceous sediments in South Atlantic DSDP cores, with age in million years. Each dot represents a single *Inoceramus* fragment. Site 364 has a Late Cretaceous section but is not plotted because there is no record of *Inoceramus* at this time. Site 361 has a record of the late Aptian to the Early Cretaceous and Site 356 has Turonian and late Albian sediments, but are not plotted because there is no record of *Inoceramus* at these times. Isolated calcite prisms are not included. The stratigraphy is given in Table 2. B. The occurrence of *Inoceramus* in Jurassic and middle Cretaceous sediments in South Atlantic DSDP cores. Each dot represents a single *Inoceramus* fragment. Isolated calcite prisms are not included. The stratigraphy is given in Table 2.

Table 3. Estimated paleodepths for South Atlantic DSDP sites with *Inoceramus*, based on the respective site reports. A range of paleodepth from oldest to youngest occurrence is given.

Hole	Stage	Water depth (m)
21	Campanian	≈500
327A	Albian–Maestrichtian	100–400 to 2000
330	Oxfordian–Albian	<1500
355	Campanian–E. Maestrichtian	2500 to 3000
356	Albian	1000
357	Santonian–Campanian	1000
361	Campanian–E. Maestrichtian	3000 to 4000
363	Maestrichtian	1000
364	Aptian–Albian	<2000
530A	Santonian–Maestrichtian	3500 to 4500

strated that alteration of volcanogenic sediments to more ^{18}O enriched authigenic phases is responsible for the pore water isotope shift. Volcanogenic turbidites of Campanian age are present in Unit 6 of Hole 530A and may have caused some pore water changes. Without pore water $\delta^{18}O$ measurements, it is not possible to distinguish between the effects of temperature and pore water alteration on the $\delta^{18}O$ of diagenetic carbonates.

PALEOTEMPERATURE RESULTS

Eleven well-preserved specimens were selected for paleotemperature analysis (Table 5). These specimens yield isotopic temperatures ranging from 11.3 to 23.9°C. Isotopic variability within single specimens is generally slightly greater than analytical error. For example, nine analyses of a Campanian fragment (79-5, 140 cm) give a $\delta^{18}O$ of -0.78 ± 0.24‰ (1σ) and a $\delta^{13}C$ of 1.21 ± 0.08 ‰ (1σ). The calculated paleotemperature for this specimen is 16 ± 1°C.

Three of the specimens were associated with sandy layers, raising the possibility of downslope transport. Shallow water indicators are notably absent from these sediments. Hence it is impossible to determine how far the fragments may have been transported. Two of these specimens (79-5, 72 cm and 83-1, 62–63 cm) yield isotopic temperatures which are slightly warmer than most in the core (23.9 and 19.2°C, respectively). However, Sample 530A-89-1, 88–89 cm of Coniacian age, which showed no evidence of transport, gave a similar temperature (23.1°C). The third fragment (63-3, 104–105 cm), associated with a sandy layer, yielded one of the coldest temperatures in the core (11.5°C) and was probably not transported from very far upslope. The remainder of the specimens in Table 5 are considered to be *in situ* and

Table 4. Oxygen and carbon isotopic results from *Inoceramus*, Hole 530A, Leg 75, all samples.

Core-Section (interval in cm)	$\delta^{18}O_{PDB}$	$\delta^{13}C_{PDB}$
60-1, 121–124	−0.40	0.78
	−0.27	0.74
61-2, 53–54	0.40	0.88
61-2, 56–57	−0.17	0.59
61-2, 65–66	−0.91	1.01
61-2, 78–81	−0.90	1.38
	−0.82	1.21
63-1, 37–40	−0.60	0.40
	−0.93	0.55
	0.20	1.01
	0.156	0.324
63-2, 71–72	—	—
63-3, 104–105	0.35	0.38
64-1, 113–114	−1.19	−0.89
64-2, 9–10	−1.13	−0.64
64-2, 10–11	−0.90	−0.22
	−1.36	−0.49
79-5, 72	−2.42	1.99
	−2.53	2.07
	−2.59	1.94
79-5, 140	−0.92	
	−0.58	1.16
	−1.01	1.30
	−0.83	1.35
	−1.01	1.19
	−0.80	1.19
	−0.62	1.21
	−0.53	1.15
	−0.47	1.07
	−1.14	1.25
79-5, 141–142	−2.03	0.94
80-1, 1	−2.82	1.10
83-1, 62–63	−1.53	0.84
	−1.66	0.79
	−1.53	−0.68
83-2, 122–123	−5.02	−0.18
	−4.61	−0.41
83-3, 113	−0.48	1.23
	−1.97	0.57
	−0.62	1.19
83-4, 5–6	−6.31	−0.01
	−6.02	−0.13
	−5.84	−0.42
85-2, 23	−6.77	−0.37
85-2, 66–67	−0.39	0.97
85-3, 4–5	−3.12	−1.36
85-3, 30–31	−1.43	−0.18
88-2, 94–95	−6.62	−1.66
89-1, 88–89	−2.28	−4.38
	−2.41	−1.27

suitable for interpretation of the paleotemperatures in the Angola Basin.

Estimated isotopic paleotemperatures from Table 5 are plotted as a function of time in Fig. 4. These results indicate that there was a general decrease in bottom water temperatures in the Angola Basin from the Coniacian to the late Campanian. Late Campanian samples show significant and apparently regular variability in a short section of core. These temperature variations appear to be real, though they are difficult to interpret in terms of physical processes.

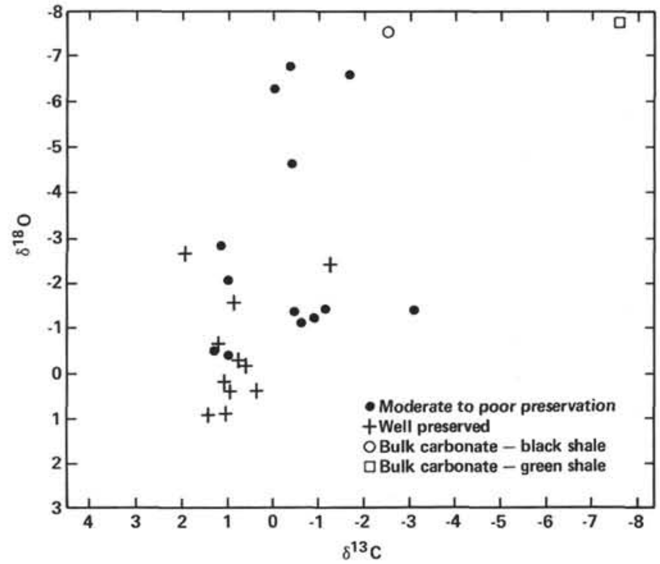

Figure 3. Carbon and oxygen isotopic results from all samples (indicated by footnote a in Table 1) at Hole 530A.

Table 5. Oxygen and carbon isotopic results from well-preserved *Inoceramus*, Hole 530A, Leg 75. Paleotemperatures are calculated using Craig's (1965) equation.

Core-Section (interval in cm)	$\delta^{18}O_{PDB}$	$\delta^{13}C_{PDB}$	T (°C)
60-1, 121–124	−0.27	0.74	13.9
61-2, 53–54	0.40	0.88	11.3
56–57	−0.17	0.59	13.5
65–66	−0.91	1.01	16.5
78–81	−0.82	1.21	16.1
63-1, 37–40	0.20	1.01	12.1
63-3, 104–105	0.35	0.38	11.5
79-5, 72	−2.59	1.94	23.9
140	−0.62	1.21	15.3
83-1, 62–63	−1.53	0.68	19.2
89-1, 88–89	−2.41	−1.27	23.1

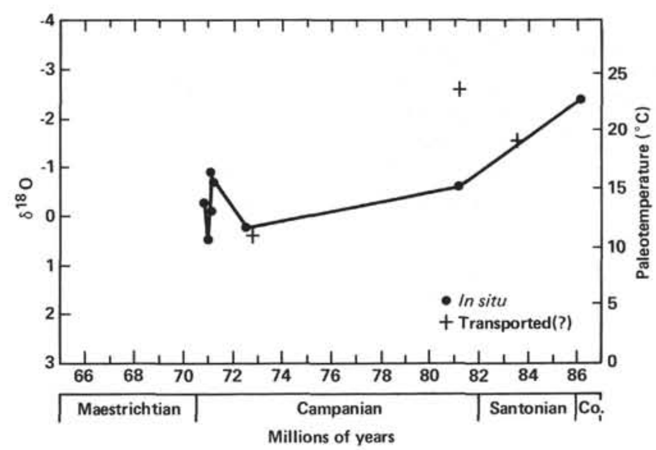

Figure 4. Oxygen isotopic paleotemperatures through time from all well-preserved specimens from Hole 530A.

DISCUSSION

The Angola Basin is bounded by Africa, the Romanche Fracture Zone, the Mid-Atlantic Ridge, and the Walvis Ridge. The evolution of these topographic barriers strongly influenced the paleoceanography of the early South Atlantic. At present the topographic barriers have a large influence on the bottom water circulation. The Walvis Ridge is a barrier to bottom water circulation and only rather deep passages in the Rio Grande Rise permit overflow of Antarctic Bottom Water (AABW) into the Brazil Basin. The northward flow of the AABW is also significantly influenced by the mid-ocean ridges in both the Atlantic and Indian oceans (e.g., Neumann and Pierson, 1966).

During much of the Cretaceous, the Angola Basin was considerably more restricted than at present. For instance, sections of the Walvis Ridge were above sea level in the mid-Cretaceous (Sibuet et al., this volume). At this time the Walvis Ridge was probably a barrier to all but the surface circulation. Because of the proximity of Africa and South America at the Romanche Fracture Zone (e.g., Sclater et al., 1977), the connection to the North Atlantic was also considerably more restricted than at present. Thus we expect that the paleocirculation in the middle and Late Cretaceous was controlled more strongly by topography than at present. A second factor is that the African margin of the Angola Basin was characterized by extensive epicontinental seas during much of the Cretaceous, in contrast to the present day (e.g., Barron et al., 1981). Finally, from 100 to 70 m.y. ago most of the Angola Basin was confined to the subtropical latitudes (e.g., Barron and Harrison, 1980) and thus probably experienced relatively high evaporation rates. These three factors are likely to be the major controls of the Cretaceous paleoceanographic setting.

Based on the thermal subsidence history of oceanic crust and a basement age of about 102 m.y. at Site 530, the Coniacian sediments, containing the oldest recovered *Inoceramus*, probably were deposited at a depth greater than 3500 m. The majority of the *Inoceramus* specimens from the Santonian and Campanian apparently lived at depths greater than 4000 m (exceptions to this were stated earlier). Thus, the paleotemperatures reflect paleoceanographic conditions in a deep restricted basin, bordered by epicontinental seas.

The measured isotopic temperatures are considerably warmer than those in present-day deep basins. The Coniacian value is extremely warm, implying a considerably reduced vertical temperature gradient in the basin. The basin is somewhat less restricted at the end of the Cretaceous, but the tectonic setting during the Coniacian and the Santonian–Campanian are similar. Since the paleolatitude of the basin had not changed, the difference in bottom temperature between the Coniacian and the Santonian–Campanian must reflect changes in the relative amount of colder and warmer bottom water sources during this time period.

The interpretation of the isotopic temperatures is further supported by Campanian isotopic measurements at Site 355 (Saltzman and Barron, 1982). Despite the fact that Site 355 has a shallower Campanian paleodepth than Site 530, the Brazil Basin is about 5°C cooler than the Angola Basin. First, this clearly demonstrates that the Mid-Ocean Ridge is acting as an oceanographic barrier and second, the source, or mixing between sources of bottom water, must be different for the two basins. The bottom water in the Angola Basin must represent a greater proportion of water from a low latitude source. We speculate that warm, dense (saline) water was formed from high evaporation in the shallow epicontinental seas of Africa, and we note that the South American margin adjacent to the Brazil Basin is not characterized by extensive marginal seas. This supports the hypothesized processes of bottom water formation in subtropical latitudes as discussed by Brass et al. (1982).

These conclusions are important because they imply a source of warm saline bottom water for the Angola Basin and also indicate that mixing of cool and warm sources has probably increased toward the end of the Cretaceous. It is also important to note that if the water is saline, the isotopic temperature may be somewhat cooler than the actual temperature.

These results also have important implications for the sedimentation history in the South Atlantic. The isotopic paleotemperature for the Coniacian is the first recorded value that is stratigraphically associated with the deposition of black shales and implies relatively high bottom water temperatures. Warm temperatures, high salinity, and hence low oxygen solubility (Weiss,1970) are likely to promote anoxia even without considering changes in productivity or mixing rates. Warmer temperatures in the Angola Basin, as compared to the Brazil Basin, are indicative of different bottom water sources and probably different oxygen contents.

The evolution of oceanic circulation in the South Atlantic was controlled by the tectonic setting, paleolatitude, and distribution of epicontinental seas. It is not surprising that anoxic sediments were not deposited synchronously in all the South Atlantic basins (see van Andel et al., 1977). Our data contribute to the picture of a dynamic, variable deep-water circulation in the Cretaceous South Atlantic.

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