28. QUATERNARY DINOFLAGELLATE CYSTS FROM HOLES 548 AND 549A, GOBAN SPUR (DEEP SEA DRILLING PROJECT LEG 80)[1]

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ABSTRACT

Analysis of the dinoflagellate cysts from the Quaternary sediments cored in Holes 548 and 549A has indicated a series of five palynostratigraphic "events." These "events" are levels marking changes in the dinoflagellate cyst assemblages that can be interpreted as indicating significant alterations in water-mass environments. One of these "events" may serve to differentiate a middle/lower Pleistocene boundary, and corresponds roughly to the NN19/NN20 boundary. A second may serve to separate the upper and middle Pleistocene, and appears to correspond to the NN20/NN21 boundary. It is of particular interest that no "event" marks the Pliocene/Pleistocene boundary as identified by nannofossil analysis. The various environmental changes are discussed in relation to the little that is known about the distribution of the component dinoflagellate cyst species in modern sediments in the North Atlantic area. The relationships between these environmental changes and climate are surmised, where possible, but they are not as yet clearly understood.

INTRODUCTION

In 1981, during Leg 80 of the International Phase of Ocean Drilling (IPOD), four cored holes were drilled in a transect across the Goban Spur, to the north of the Bay of Biscay, about 250 km southwest of Ireland (Fig. 1). The purpose of Leg 80 was to document the structural and paleoenvironmental history of the northern part of the Bay of Biscay region. The results from Leg 80 should enable the geological history of the North Atlantic Ocean—before, during, and after the period of rifting that opened the ocean and separated Europe from North America—to be better understood. The Goban Spur area of the continental slope was selected for the drilling sites because it was believed that the sedimentary section at that location was fairly complete but thin enough to be accessible to drilling.

Two of the holes cored (548 and 549A) provided good sequences of Quaternary sediments, which were analyzed for dinoflagellate cysts. This effort augments other studies on the Quaternary environments of the area (Pujol et al., this volume), and supplements work on Leg 48 (Harland, 1979). The holes are situated as follows: (1) Hole 548: 48°54.95′N, 12°09.84′W, in 1256 m of water; (2) Hole 549A: 49°05.29′N, 13°05.89′W, in 2536 m of water.

Initial shipboard results showed that the Quaternary section at both sites consists of sometimes alternating calcareous and nannofossil oozes. The alternation is thought to be a result of climatic variations, with the more terrigenous layers having been deposited during the glacial periods (site chapter for Site 548, this volume).

The study of Quaternary dinoflagellate cysts is still very much in its infancy, but it is now becoming apparent that dinoflagellate cysts can be readily recovered from Quaternary marine sequences and used in the environmental interpretation of such sediments (Wall and Dale, 1968; Harland, 1977; Reid and Harland, 1977; Gregory and Harland, 1978). Work to date has tended to concentrate on shelf area sediments but, with increasing interest in the paleoceanography of the Atlantic Ocean and adjacent seas, some attention is being turned to outer neritic and oceanic sediments. In 1979, I looked at some Quaternary material, recovered on Leg 48 from an outer neritic/oceanic environment, and reported several distinctive dinoflagellate assemblages. The Leg 48 sequences were interpreted as indicating changing water-mass configurations in the Bay of Biscay, but no particular correlation with sequences was established, even though climate and oceanic circulation are inextricably linked.

The present study gives data for the Quaternary sequences recovered from Holes 548 and 549A. Coring in Hole 548 resulted in excellent recovery of a thick sequence that dated through nannofossil Zones NN19 to NN21. The sequence in Hole 549A is much thinner, but it is likewise dated through NN19 to NN21. These two sequences are potentially the most complete and most productive Quaternary sequences yet drilled on the continental slope and, as such, could possibly be used as a standard for dinoflagellate cyst interpretations in the eastern North Atlantic.

MATERIAL AND METHODS

A full list of the samples analyzed from Holes 548 and 549A is given in the Appendix. All the samples were given a standard palynological processing treatment. Care was taken, however, not to subject them to any of the more usual oxidation techniques, which might result in the loss of certain dinoflagellate cyst taxa—as, for example, peridiniacean cysts—that appear to be particularly sensitive to this kind of treatment (Dale, 1976). After digestion with hydrofluoric acid, the samples were handled using the sintered-glass funnel technique of Neves and Dale (1963). One slide from each sample was examined and its specimens counted until, in the case of rich assemblages, one species, at least, was represented by 120 specimens. The graphs of specimens per slide, as given in Figures 2 and 3, are therefore only a guide to dinoflagellate productivity, but they do indicate the number of speci-

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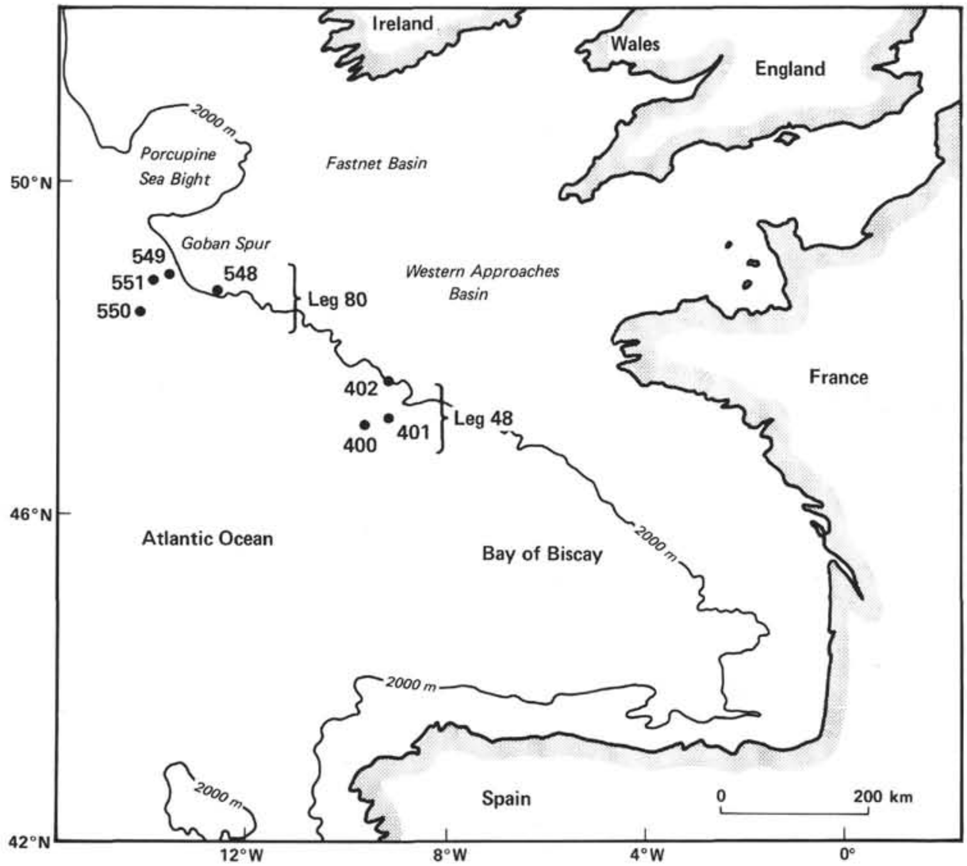

Figure 1. Sketch map of the Bay of Biscay region and Western Approaches Basin, showing locations of the Leg 80 holes.

mens on which the proportions were calculated, and they provide an indication of the richness of the samples. To maintain some internal consistency in the results, samples of similar size were used, and given the same palynological preparation. Insufficient time was available to complete full quantitative analysis, although such an analysis would have been most useful.

RESULTS

All the samples analyzed and reported upon here proved to contain well-preserved dinoflagellate cyst assemblages, although the apparent variability in productivity was quite marked (see Figs. 2 and 3). The results of the analyses given in Figures 2 and 3 portray the proportions of the various species or species groups recovered, as well as the numbers of specimens on which the proportions were calculated. The data for all the samples are held in the Palaeontology Unit, Institute of Geological Sciences (IGS), Keyworth. The results are given below for each of the two holes from which samples were analyzed.

Hole 548

Hole 548 proved to have the thickest sequence of Quaternary sediments. In total, 75 samples were analyzed for dinoflagellate cysts. The results are discussed in terms of palynostratigraphic "events": identifiable horizons at which there was a significant change in the assemblages of dinoflagellate cysts (Fig. 2).

In the lower part of the sequence (below Section 7-6) the samples tend to record high productivity and to be reasonably stable in species composition, so it is extremely difficult to identify any "events" at all. Section 11-2, however, marks a change from a lower assemblage with *Bitectatodinium tepikiense* Wilson, *Spiniferites* spp., and an increased proportion of *Impagidinium* spp. in the upper part, to an upper assemblage characterized by *Operculodinium centrocarpum* (Deflandre and Cookson) Wall, *Spiniferites* spp. [especially *S. mirabilis* (Rossignol) Sarjeant, indicated by the inner line on Fig. 2], *Protoperidinium* spp., and *Nematosphaeropsis labyrinthea* (Ostenfeld) Reid. This change indicates the uphole establishment of an assemblage comparable to the East Atlantic Assemblage of Reid and Harland (1977). The reduction uphole of *Impagidinium* spp. and the increase of *O. israelianum* may indicate some shallowing.

The older sediments of the sequence, even across the Pliocene/Pleistocene boundary, show no marked floral variations, and are characterized by high percentages of *B. tepikiense*/*Tectatodinium pellitum* (see later discussion for an outline of some associated taxonomic difficulties) and *Spiniferites* spp. These assemblages, as presently known, indicate middle and outer neritic to oceanic conditions in a southern temperate to subtropical climate (Wall et al., 1977; Harland, in press). The fluctuations observed in the species proportions do not indicate any

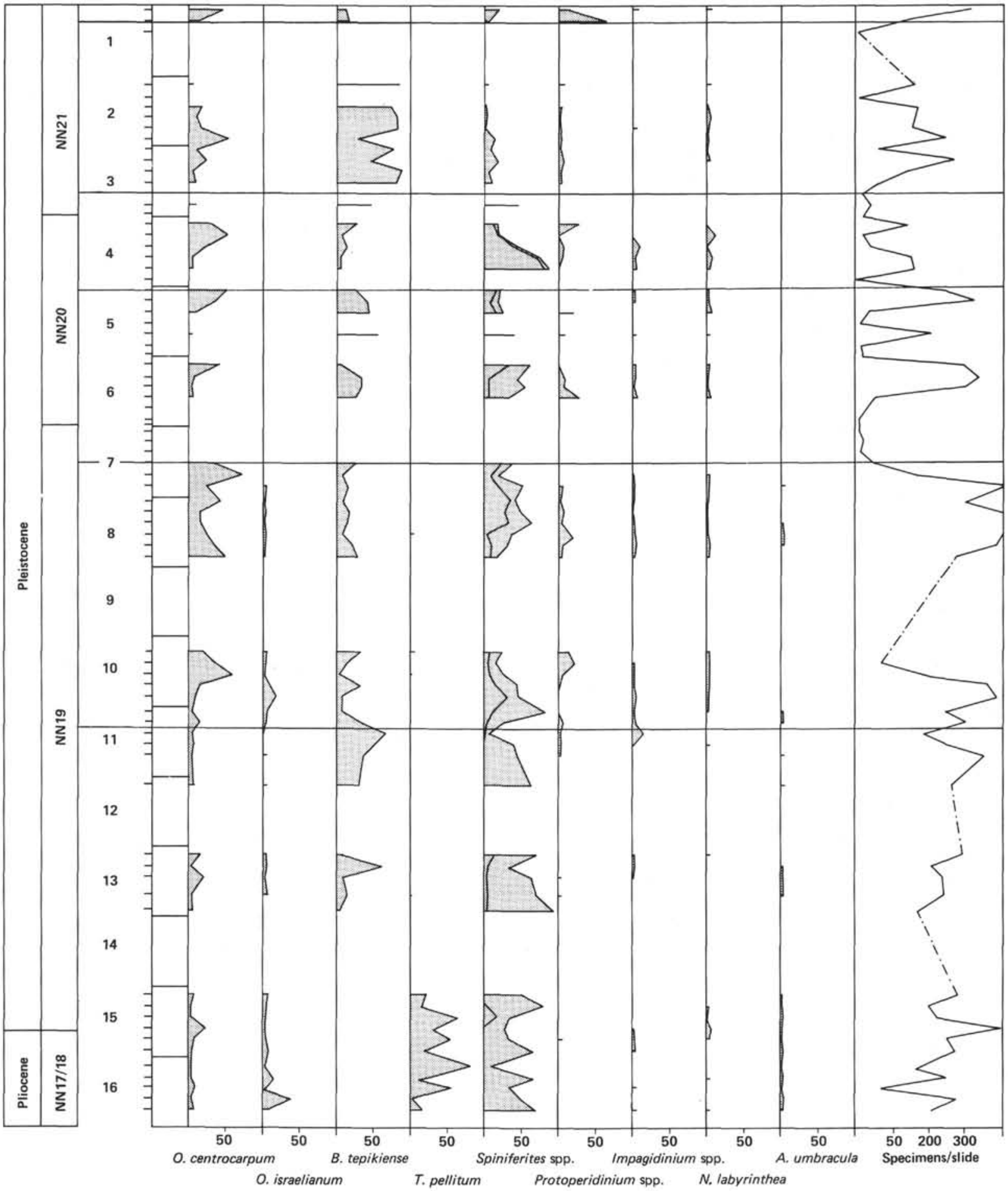

Figure 2. Dinoflagellate cyst biostratigraphy of the Pliocene/Pleistocene of Hole 548, showing the proportions (%) of various cyst species or groups and the number of specimens recorded per slide. NN designations indicate nannofossil zonation. Numbers 1–16 indicate the cores sampled and analyzed; the ticks show sample positions. Individual *Spiniferites* spp. noted in the text are indicated by the inner graph in the appropriate column. The long horizontal lines mark "events" described in the text.

marked change in climate or in the water-mass environment, and they probably reflect changes of short duration.

The dinoflagellate cysts from sediments above Section 11-2 and below Section 7-6 also seem to reflect a reasonably stable environment and one much like that of today, in terms of the East Atlantic Assemblage as presently known. They may, however, indicate somewhat warmer conditions (judging by the presence of *O. israelianum* and *T. pellitum*) and a slightly shallower environment than that prevailing during formation of the older sediments.

The most striking change, one that effectively divides the Quaternary sequence into two parts, occurs in Section 7-6, where the first downhole appearance, or local extinction level, of the species *Amiculosphaera umbracula* Harland and *Operculodinium israelianum* (Rossignol) Wall is to be found. *Tectatodinium pellitum* Wall, an associated species, has a local extinction level in Section 8-4. This level approximates fairly closely the NN19/NN20 boundary, and may be regarded as a lower/middle Pleistocene boundary, an analogy with the "classic" lower Pleistocene sediments of East Anglia, which also carry these particular species (Wall and Dale, 1968). In the East Anglian Ludham Borehole sequence (Wall and Dale, 1968), *A. umbracula* may have been identified as *Thalassiphora delicata* Williams and Downie, but since no illustrations were published it is not possible to be sure without investigating the original material.

After the time corresponding to the interpreted lower/middle Pleistocene boundary, the environmental conditions were certainly less stable than those prevailing when the sediments below it were laid down, as indicated both by the measure of productivity and by some of the fluctuations in cyst proportions (Fig. 2). Three "events" can be recognized.

The first (in Section 5-1) is a distinct change of assemblage, from one characterized by *O. centrocarpum, B. tepikiense,* and *Spiniferites* spp. in fairly equal proportions, below, to one dominated by *Spiniferites* spp., especially *Achomosphaera andalousiense* Jan du Chêne (as indicated by the inner line in the *Spiniferites* spp. column of Fig. 2), above. The older assemblage tends also to be characterized by higher productivity than the younger. The younger assemblage may indicate a deeper-water environment, since it contains increased proportions of both *Impagidinium* spp. and *N. labyrinthea*.

A second "event" occurs at about Section 3-6, where the younger assemblage (just described) is replaced by one dominated by *B. tepikiense* and including low percentages of both *O. centrocarpum* and *Spiniferites* spp. The number of specimens per slide, indicating productivity, is generally higher through Cores 2 and 3 than in the assemblages immediately below. This event appears to be particularly marked, and indicates a significant change in North Atlantic circulation. It occurs at the NN20/NN21 nannofossil zone boundary.

Finally, a third "event" marking the change to present-day conditions or conditions very similar to today's, is visible in Section 1-3. The assemblage dominated by *B. tepikiense* gives way to one with high proportions of *O. centrocarpum* and *Protoperidinium* spp., together with the notable presence of *S. mirabilis* (which accounts for most of the *Spiniferites* spp. column in Fig. 2) and *N. labyrinthea*. The Recent assemblage for the area (East Atlantic Assemblage of Reid and Harland, 1977; Harland, in press) is very similar, having the important species components *S. mirabilis, N. labyrinthea,* and *O. centrocarpum*.

The productivity curve shows, apart from the high present-day productivity, that two late Pleistocene periods of particularly high productivity in cysts are recorded from Section 2-3 to Section 3-4 and between Section 4-3 and Section 6-4. Although there are many inherent difficulties in using such a graph to interpret environments, the curve, together with the "event" stratigraphy, may indicate two periods of complex climatic amelioration, with attendant changes in water-mass configurations. The (more recent) amelioration (Section 2-2 to Section 3-4) was characterized by a north-temperate, outer neritic to continental slope water-mass environment that differed from the present-day situation at this locality and was more like that seen today to the south and southeast of Iceland (Harland, 1983). In contrast, the second amelioration (Section 4-3 to Section 6-4) was characterized by a north-temperate outer neritic to continental slope water-mass environment more akin to that found today much farther south and to the west of Ireland in the eastern Atlantic. It was, therefore, quite comparable to the present-day situation at this locality. This gives some indication of the complex changes that occurred in the eastern Atlantic during the middle and late Pleistocene (NN20 to NN21), as interpreted from the evidence of dinoflagellate cysts.

Hole 549A

Thirty-four samples were analyzed from the Quaternary sediments in Hole 549A. A similar method of interpretation was employed (Fig. 3), in an attempt to recognize "events" and to effect some sort of correlation. This correlation is by no means certain, but does give some indication of the possibilities.

The lower Pleistocene "event" that marked the significant change to an older assemblage characterized by *B. tepikiense/T. pellitum* in Hole 548 is here tentatively recognized in Section 3-3, and is marked also by a sudden increase in the measure of productivity. These two factors point to changes in the water-mass environment and hence, possibly, in climate.

I believe that the "event" reflecting the lower/middle Pleistocene boundary occurs at Section 3-2 in Hole 549A, defined on the first presence downhole of the species *O. israelianum* and *T. pellitum*. Specimens of *A. umbracula* were not seen. This "event," like that in Hole 548, occurs close to the NN19/NN20 boundary.

In the middle and upper Pleistocene part of the sequence, the "events" recognized in Hole 548 can all be recognized (in downhole order) in Sections 1-2, 1-5, and 2-1. The last is a little more difficult to recognize and define in this sequence, but it does again seem to occur approximately at the NN20/NN21 boundary.

Summary

The two holes, 548 and 549A, can be tentatively correlated, and they record similar environmental histories, even though interpretation is at the moment somewhat difficult. Clearly, the sequence in Hole 548 is a more expanded sequence than that in Hole 549A. Perhaps two major periods of amelioration are recorded, with their accompanying oceanic changes, for the middle and late Pleistocene. A generally warmer and more equable environment is recorded for the early Pleistocene. Finally, it would seem that there is no record across the Pliocene/Pleistocene boundary (as marked by the nannofossil zonation) of a major environmental change.

The lack of precision in these results is such that each of the two recorded ameliorations may have been extremely complex. Further samples are being studied to

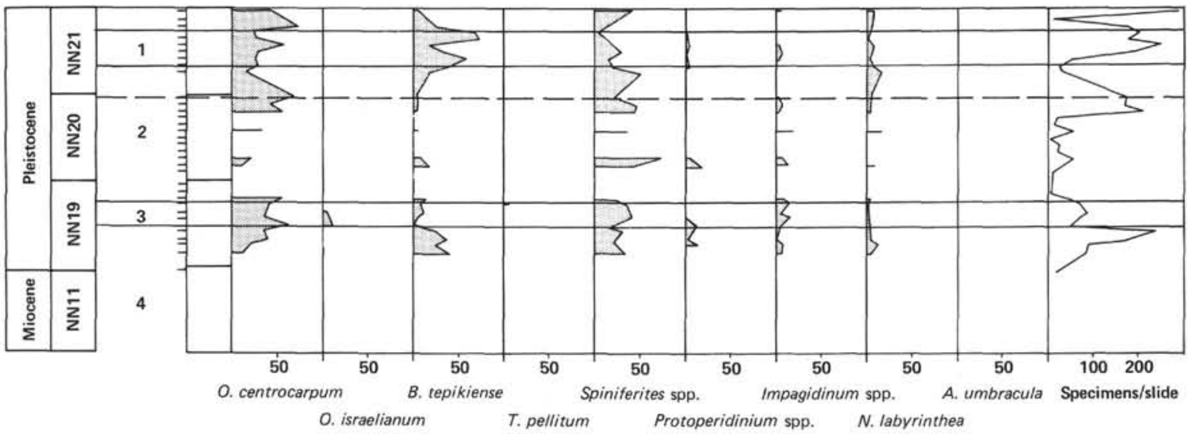

Figure 3. Dinoflagellate cyst biostratigraphy of the Pleistocene of Hole 549A, showing the proportions (%) of various cyst species or groups and the number of specimens recorded per slide. NN designations indicate nannofossil zonation. Numbers 1–4 indicate the cores sampled and analyzed; the ticks show sample positions. The long horizontal lines mark "events" described in the text.

supplement the present data, with the aim of better understanding these sequences and also of providing a standard with which other sequences, both on and off the shelf, can be compared. A full synthesis of all these results is in preparation.

COMPARISONS

Work at the Institute of Geological Sciences (IGS) on shelf sediments around the British Isles has already established that a series of favorable and unfavorable units, paleoenvironmental intervals, can be recognized from the dinoflagellate cyst record (Harland et al., 1978; Gregory and Harland, 1978). This series appears, in combination with the benthic foraminiferal record, to reflect water-mass/climatic change. Such a relationship is also apparent in the results presented here, except that, since coring on Leg 80 was undertaken much farther south and on the continental slope, the recovery and diversity of cysts is generally much better than that around the British Isles.

The "events" described here are not so clearly recorded, or so readily identifiable, in the inner-shelf sediments, particularly for times of major changes in environment and hence of changing sedimentary regimes. However, the nature of the youngest "event"—replacement of an assemblage in which *B. tepikiense* predominates by the modern assemblage in which *O. centrocarpum* is important—has also been recorded in such areas as the Sea of the Hebrides on the west Scottish coast, and in the North Sea (Harland, 1977). If the distribution of modern dinoflagellate cysts is influenced more by latitude than previously realized, the recording and correlation of these events may have rather more significance in understanding Quaternary oceanographic history.

The dinoflagellate cysts I studied (Harland, 1977) during Leg 48 in the Biscay area are not easy to compare with those from Leg 80. In Hole 400A, most of the sediments were lower Pleistocene. The only mid-lower Pleistocene "event" of the present account may be recognized in about Section 400A-2-2. The younger sediments from Holes 400 and 400A are even less easy to compare with those from the holes described here and in this volume, such that the younger assemblages of Holes 400 and 400A may provide a record of events not yet seen in Hole 548. Further work, now in progress, may clarify this point.

TAXONOMIC COMMENT

Two comments worth making concern the taxonomy of the studied dinoflagellate cysts. The first concerns the relationship of the cyst species *Bitectatodinium tepikiense* Wilson and *Tectatodinium pellitum* Wall. These species are similar, in that they are basically spheroidal cysts having a comparable wall structure and lacking paratabulation or processes. They differ in archaeopyle structure, however; the first has a 2P archeopyle and the second a 1P archeopyle. *T. pellitum* also tends to have a thicker, more robust wall; P. C. Reid believes its structure to be different (pers. comm., 1982). In modern sediments the distribution of these two species is quite separate (Harland, 1983), but in the present study the lower Pleistocene assemblages contain cyst morphotypes with both kinds of archeopyle structure, making it somewhat difficult to understand the assemblage. Further investigation into the nature of these populations is needed, better evaluating the possibility of an evolutionary relationship, which could affect the environmental interpretations.

Second, it was noticed that a number of forms in the *Spiniferites* group of species need closer study. It is probable that many new species are present, although they may be only subtly different from extant species. Documentation of these forms may assist in the environmental evaluations, especially of lower Pleistocene and older sediments, and increase the precision of the dinoflagellate cyst biostratigraphy.

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APPENDIX
Samples Prepared and Examined for Quaternary Dinoflagellate Cysts[a]

Hole 548	Hole 548 (Cont.)
1-1, 38–39	11-5, 49–50
1-2, 38–39	12-1, 130–121
1-3, 38–39	13-1, 100–101
2-1, 139–140	13-2, 100–101
2-2, 139–140	13-3, 100–101
2-3, 139–140	13-5, 26–27
2-4, 100–101	13-6, 100–101
2-5, 100–101	15-1, 102–103
2-6, 100–101	15-2, 102–103
3-1, 19–20	15-3, 102–103
3-2, 19–20	15-4, 102–103
3-3, 19–20	15-5, 102–103
3-4, 19–20	15-6, 102–103
3-5, 19–20	16-1, 145–146
3-6, 19–20	16-2, 145–146
3-7, 19–20	16-3, 145–146
4-1, 108–109	16-4, 145–146
4-2, 108–109	16-5, 145–146
4-3, 108–109	
4-4, 108–109	Hole 549A
4-5, 108–109	
4-6, 119–120	1-1, 19–20
5-1, 50–51	1-1, 141–42
5-2, 30–31	1-2, 40–41
5-3, 30–31	1-2, 110–111
5-4, 30–31	1-3, 5–6
5-5, 30–31	1-3, 110–111
5-6, 30–31	1-4, 5–6
5-7, 10–11	1-4, 113–114
6-1, 131–132	1-5, 5–6
6-2, 121–122	1-5, 110–111
6-3, 118–119	2-1, 1–2
6-4, 118–119	2-1, 113–114
6-5, 118–119	2-2, 5–6
6-6, 123–124	2-2, 110–111
7-1, 71–72	2-3, 5–6
7-2, 10–12	2-3, 110–111
7-3, 28–29	2-4, 5–6
7-4, 30–31	2-4, 110–111
7-5, 42–43	2-5, 5–6
7-6, 15–16	2-5, 110–111
8-1, 56–57	2-6, 5–6
8-2, 56–57	2-6, 110–111
8-3, 56–57	3-1, 35–36
8-4, 56–57	3-1, 120–121
8-5, 56–57	3-2, 35–36
8-6, 56–57	3-2, 120–121
10-2, 47–48	3-3, 39–40
10-3, 47–48	3-3, 110–111
10-4, 47–48	3-4, 39–40
10-5, 47–48	3-4, 110–111
10-6, 47–48	3-5, 39–40
11-1, 49–50	3-5, 110–111
11-2, 49–50	3-6, 39–40
11-3, 49–50	4-1, 34–35
11-4, 49–50	

[a] Intervals in cm.