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MAASTRICHTIAN AMMONITE AND INOCERAMID RANGES FROM BAY OF BISCAY CRETACEOUS-TERTIARY BOUNDARY SECTIONS

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ABSTRACT

New collecting of ammonites and inoceramid bivalves from Cretaceous-Tertiary boundary sections exposed at Sopelana and Zumaya, Spain, and Hendaye and Bidart (Biarritz), France, has led to better understanding of molluscan biostratigraphy in each of these coastal exposures. All of these sections can be lithologically correlated. At all of the sections, ammonites have now been found within the last meter of the Cretaceous. Also, in all of the sections, inoceramid bivalves disappear near the base *A. mayaronensis* planktonic foram zone, the only exception being the small, enigmatic bivalve genus *Tenuipteria*, which ranges up to the Cretaceous-Tertiary boundary.

Keywords: Ammonites, Inoceramids, Cretaceous-Tertiary boundary, Biostratigraphy, Spain, France.

RESUMEN

Nuevas recogidas de ammonites e inocerámidos de las secciones del límite Cretácico-Terciario (K/T) de Sopelana y Zumaya (España) y de Hendaya y Bidart (Biarritz, Francia) han permitido comprender mejor la bioestratigrafía de cada una de dichas secciones. Todas ellas pueden ser correlacionadas litológicamente y, asimismo, contienen ammonites hasta el último metro bajo el límite K/T. También en todas las secciones los inocerámidos desaparecen cerca de la base de la Zona Mayaroensis de los foraminíferos planctónicos, salvo el enigmático bivalvo *Tenuipteria* que se extiende hasta el límite K/T.

Palabras clave: Ammonites, Inocerámidos, Límite Cretácico-Terciarie, Bioestratigrafía, España, Francia.

INTRODUCTION

The Cretaceous-Tertiary boundary sections exposed in the vicinity of the Spanish-French border in the Bay of Biscay region are potentially of great use in testing hypotheses of Cretaceous-Tertiary transition extinctions. The reasons for this are several. First, these sections are judged by micropaleontologists to be relatively complete (Smit, *et al.*, 1987). Secondly, the sections showed high sedimentation rates, thus increasing resolution of stratigraphy. Finally, their virtually continous exposure along coastlines allows ready access for collecting.

The purpose of this brief contribution is to report progress in biostratigraphic collecting of ammonites and inoceramid bivalves from five of the well-exposed coastal exposures found on the Bay of Biscay: Zumaya, two sections at Sopelana, Hendaye, and Bidart (Fig. 1). Although species names have in most cases been assigned, they must remain provisional pending a fuller taxonomic treatment now in progress.

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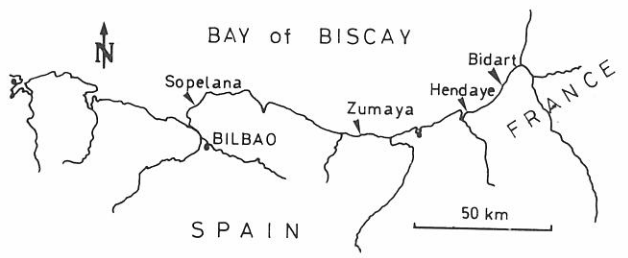

Figure 1. Locality map of Bay of Biscay sections.

MATERIAL AND METHODS

Each of these sections was measured using tape and staff; measurements in 10 m increments were written on the rocks to allow more precision in fossil location. The Cretaceous-Tertiary boundary served as the datum surface; fossil ranges are thus recorded in distances below this boundary. Fossils were collected from the exposures following measurement of the sections. All fossil ranges referred to in this paper are derived from fossils collected by the author or the author's field assistants. They do not include information from any other collections or collectors.

LITHOSTRATIGRAPHY

The Bay of Biscay exposures exposed at Zumaya, Sopelana, Hendaye, and Bidart (Biarritz) turn out to be excellent reference sections both for documenting Late Cretaceous macrofossil stratigraphy as well as yielding valuable information about the patterns of extinction immediately prior to the K-T boundary. All are exposed along seacliffs, and all contain a conformable sequence of Upper Cretaceous and Lower Tertiary marine strata. These strata were deposited in the Flysch Trough of the Basque-cantabric Basin (Lamolda *et al.*, 1981). This basin was one of several forming along the boundary of the European-Iberian Plates during the Late Cretaceous. During Campanian and early Maastrichtian time, sediments deposited in this basin were mainly of turbidity current origin. During the late Maastrichtian there was a change in depositional patterns, caused by a reduction in siliciclastic material influx, as well as basin-wide shallowing and regression (Lamolda *et al.*, 1981). The result is that Lower Maastrichtian flysch is overlain by Upper Maastrichtian limestone-marl rhythmites (Mount and Ward, 1986). Sedimentation rates dropped, with Lower Maastrichtian accumulation rates at the thickest section, that exposed at Zumaya, Spain, estimated at 200 bubnoffs (m/m.y., compacted) compared to 60 to 80 bubnoffs (m/m.y., compacted) for the Upper Maastrichtian. Immediately following the K-T transition there was an even more dramatic reduction in siliciclastic influx into the basin, resulting in the deposition of pink coccolith limestones during the Danian.

Four principal lithofacies can be recognized in the Cretaceous sections exposed along the Bay of Biscay. These include: 1) Thinly bedded, reddish to purplish marls, 2) limestone- marl rhythmites, 3) massive limestones, and 4) thin, distal turbidites. The Danian parts of the section are composed of a different lithofacies, a thickly bedded, pink limestone.

The stratigraphic section at Zumaya has received more study than any of the other Bay of Biscay sections. Compared to the other sections, the Zumaya section is the thickest, best exposed, and shows the least amount of faulting; because of these attributes, the Zumaya section is here considered a reference section against which the other sections in the region can be compared. Measured sections for the Maastrichtian part of the Zumaya section are available in Herm (1965), Mount and Ward (1986), Ward *et al.*, (1986). In addition, a recent, useful lithostratigraphic differentiation has been proposed by Wiedmann (1987 and this volume), where 13 units (non-formalized members) have been assigned. This scheme is largely followed here, as these units (with some modification) can be recognized as well in other K-T sections along the Bay of Biscay. A detailed description of these units is found in Wiedmann (1988).

The observed lithostratigraphy of the Maastrichtian part of the Zumaya section is apparently related to several cycles of sedimentation (Mount and Ward, 1986). Following cessation of submarine fan deposition in the area, in the middle of the Maastrichtian, sedimentation patterns alternated between limestone –dominated (units 4-6, 8, 9, and 11 of Wiedmann) and marl– dominated (units 7, 10, and 13) intervals of deposition. The changeover from turbidite to the limestone and marl lithofacies occurs near the waterfall locality at Zumaya, and corresponds to the transition from unit 1 to unit 2 of Wiedmann.

The correlation fo the five stratigraphic sections which I have studied area shown in Fig. 2. Correlations are easiest in the upper parts of the Maastrichtian sections because of the alternation of limestone or limestone-marl rhythmites with marl units. Correlation of the lower units are more problematical, because of changes in lithofacies between sections, and complications due to cover or faulting. Nevertheless, a remarkable similarity in overall lithology exists between the measured sections of this study.

One of the key marker beds recognizable in each of the five measured sections is a thick micritic limestone (unit 6 of Wiedmann). This limestone differs from limestones above and below because of the virtual lack of marl interbeds. It lies beneath the first of the thick purple marls. Its base corresponds with the base of the *Abathomphalus mayaroensis* planktonic foraminiferal Zone. The top of this unit, which averages about 15m thick in all sectios marks the last occurrence of *Inoceramus* in each of the sections. The remarkable lateral persistence of this unit is illustrated by the presence of a single, meter-

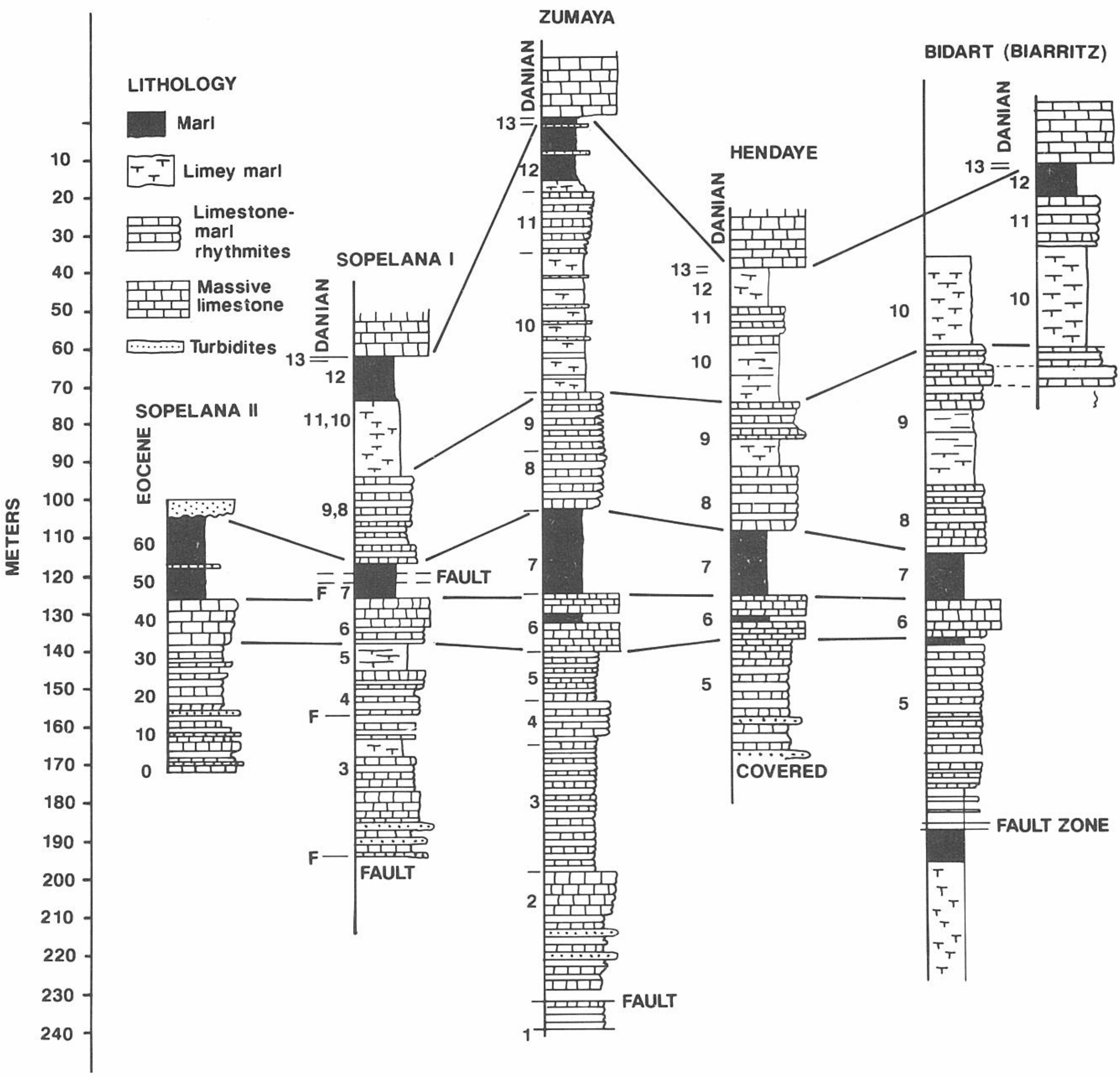

Figure 2 Lithostratigraphic correlations for Bay of Biscay sections described in this paper.

thick marl, intercalated between two massive limestones; this marl can be recognized in Zumaya, Hendaye, and Bidart.

In some respects the Bidart section has been the most difficult to correlate with the other sections, probably because of differences in post-depositional history. The Bidart section shows common faulting and separation of sections; no single section can be measured. The sections shown in the far right of Fig. 2 represent tw composites reconstructed from the outcrops. Also, the rocks at Bidart have apparently undergone less compaction and lithification than those at Hendaye, Zumaya, and Sopelana, resulting in differences in stratal color and induration. Nevertheless, the reconstructed sections at Bidart show great similarities in their upper parts to the other Bay of Biscay sections. Especially noteworthy is the presence at Bidart of inoceramid-rich, limestone- marl facies, succeeded by a thick limestone with rare inoceramids, and then a marl in which inoceramids cannot be found. This same succession exists at the other Bay of Biscay sections in precisely this order.

BIOSTRATIGRAPHIC PATTERNS

Macrofossils are scattered throughout the Bay of Biscay sections. Inoceramids are the most abundant macrofossils in units 2-6, but disappear at the top of unit 6. Ammonites and echinoids can be found throughout the section, but never in great abundances, and only rarely in bedding plane concentrations. The preservation of the ammonites is poor; they rarely have shell material or sutures preserved, and are invariably compressed to some degree.

The ranges of Maastrichtian macrofossils have only been documented for the Zumaya section (Ward and Wiedmann, 1983; Ward *et al.*, 1986; Wiedmann, 1987, and this volume). New macrofossil collections made during 1987 now permit documentation of ranges in the other Bay of Biscay sections as well. It must be emphasized that the new range documentation is preliminary in both the species-level identification of the specimens, and in the number of specimens used to document local species ranges. Further collection will undoubtedly increase the ranges of many of the species described below. Also, revisions in taxonomy (currently in progress) workers may result in certain name changes. Nevertheless, enough new information is now available to justify the following progress report. The ranges and new results from each of the target sections are reported below.

1. Zumaya, Spain

The ranges of macrofossils from Zumaya have been reported on by Ward, Wiedmann, and Mount (1986), and in several papers by Wiedmann (1986, 1988, and this volume). Wiedmann (1986, 1988) has recently used these results to propose a tentative zonation composed of seven zones, from stratigraphically lowest to highest:

Pseudokossmaticeras tercense Zone, ranging through much of the lower Maastrichtian turbidite sequence to an unknown position below unit 1, corresponding with the Lower Maastrichtian.

Pachydiscus neubergicus Zone, ranging from beneath unit 1 to the top of unit 5, a range equivalent to the range of the planktonic foram *Rugotruncana gansseri*. Wiedmann equates this unit with the "Middle Maastrichtian".

Anapachydiscus fresvillensis Zone, ranging from the base of unit 6 to somewhere near the middle of unit 7. The base of this zone coincides with the base of the Upper Maastrichtian, (marked by the base of the *A. mayaroensis* planktonic foram Zone, which extends upward from this level to the Cretaceous-Tertiary boundary).

Pachydiscus gollevillensis Zone, extending from somewhere in the middle of unit 7 to the top of unit 8.

Pachydiscus llarenai Zone, extending from the base to the top of unit 9.

Pachydiscus jacquoti Zone, extending from the base to the middle of unit 10.

Pachydiscus epiplectus Zone, extending from the middle of unit 10 to the base of unit 12.

No zonation was provided for unit 12 and 13, which together encompass the last 12 m of Cretaceous section.

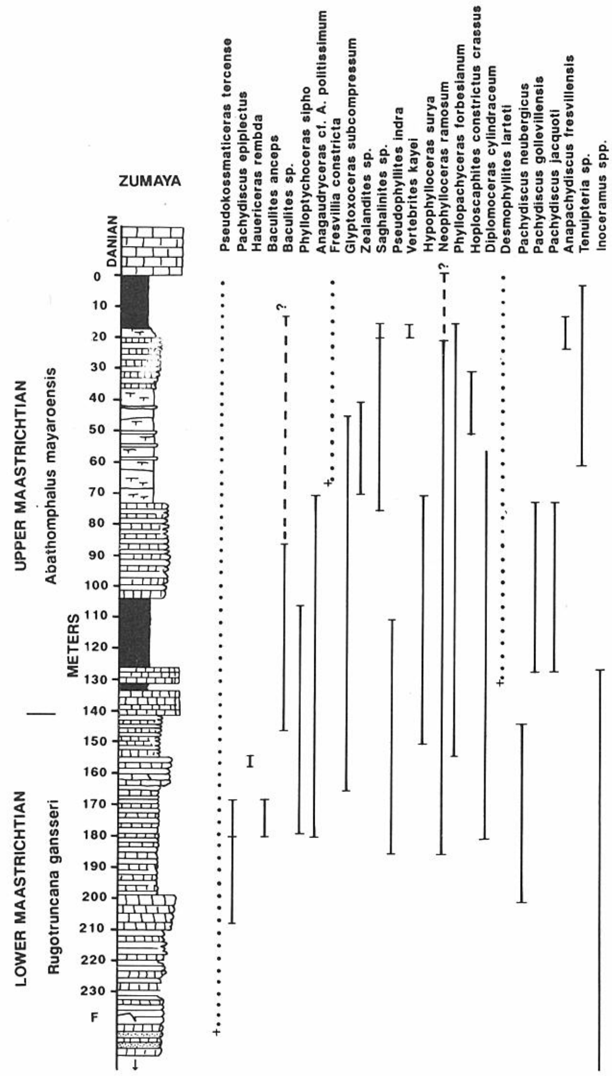

Figure 3. Measured section and ranges of ammonites for Zumaya.

Wiedmann (1986) admits that this zonation is tentative. My own collections from the Zumaya do not allow recognition of all of Wiedmann's zones, partly because of differences in taxonomic identification, and partly because of the extension of certain ranges. It should be stressed that ammonite identifications have proven difficult. Most of the various species of *Pachydiscus* are differentiated on shape of cross section. Because all of the Zumaya and other Bay of Biscay ammonites are laterally compressed, this key information is lost.

The ranges of ammonites that I have collected from the Zumaya section are shown in Fig. 3. I have followed the taxonomy of Kennedy (1986) for the pachydiscids. Kennedy has shown that elsewhere in Europe, *Pachydiscus epiplectus* appears to be restricted to the Lower Maastrichtian, while *Anapachydiscus fresvillensis* is restricted to the Upper

Maastrichtian. These two species are separated on the presence (*A. fresvillensis*) or absence (*P. epiplectus*) of umbilical tubercles. In my collections from Zumaya, the tuberculate form here assigned to *A. fresvillensis* is restricted to part of units 11 and 12. This species was identified as *Pachydiscus colligatus* by Ward *et al.* (1986).

A second problem stems from the identification of *Pachydiscus llarenai*. Only a single specimen of this species has ever been illustrated (Wiedmann, 1960). I have been unable to differentiate this species from *P. jacquoti*.

I have made two new ammonite discoveries from the Zumaya section during 1987 collecting that increase resolution of biostratigraphic correlation between Bay of Biscay sections and sections elsewhere in Europe. The first was the recovery of a single *Pseudokossmaticeras tercense* from the Zumaya waterfall locality of Zumaya (the very top of Wiedmann's unit 1). This well-preserved specimen has extended the range of this species in the Zumaya section by 200 m, and shows that the ranges of *P. tercense* and *Pachydiscus neubergicus* overlap. Secondly, I have discovered two well –preserved specimens of *Hoploscaphites constrictus* in unit 10 and the lower part of unit 11 of Wiedmann. These specimens suggest that the numerous, fragmentary, ornamented ammonites from this part of the section (identified as "kossmaticerids" in Ward *et al.*, 1986), may actually be examples of *Hoploscaphites.* This taxon, of great biostratigraphic use, has previously not been found in the Zumaya section.

Two additional findings from the Zumaya section merit discussion. First, Ward *et al.* (1986) found that the ubiquitous Cretaceous bivalve *Inoceramus* disappears at the just above top of the Lower Maastrichtian, at the top of the thick limestone (unit 6 of Wiedmann). Wiedmann (1988) has recently indicated that he found at least one specimen assigned to *Inoceramus* in his unit 9. I have not been able to duplicate Wiedmann's discovery of *Inoceramus* so high in the Zumaya section in spite of vigorous searching. Although an inoceramid-like bivalve (*Tenuipteria*) is found in the uppermost part of the Zumaya Maastrichtian section, true inoceramids (*Inoceramus, Endocostea, Platyceramus*) in my collections range only into the basal beds of the *A. mayaroensis* Zone. Inoceramids are common in the upper part of the Lower Maastrichtian at Zumaya: they virtually form pavements along bedding planes. Specimens up to a meter in length are common. Their disappearance coincides with a lithological change, and their disappearance is quite sudden. At least three species are common in the Lower Maastrichtian part of the section at Zumaya; all then disappear over a stratigraphic distance of 40 m. If step-wise extinctions (see Kauffman, this volume) are eventually accepted for the K-T extinctions, this may be the first, and perhaps most important "step".

One of the most interesting findings of the Zumaya work to date has been the 12 m gap in ammonite occurrences at the top of the Cretaceous section. A great deal of effort has gone into collecting this upper part of the section. I have been able to recover only a single fragment of cephalopod from this interval, found within a meter of the K-T boundary. This specimen is tiny (about 1cm diameter), incomplete, and is so poorly preserved that it is impossible to determine whether it is an ammonite or nautiloid. Other macrofossils can be recovered (echinoids, *Tenuipteria*). Wiedmann (1988) has recently reported the first find of an undoubted ammonite (*Neophylloceras ramosum*), also from within the last meter of Cretaceous at the Zumaya section. As ammonites are not rare from 20 to about 12 m below the boundary, the presence of the ammonite "gap" in most of Wiedmann's unit 12 remains enigmatic. Part of the problem relates to the nature of the beds. The final 15 to 20 m of Cretaceous section occurs in a strongly recessed bay. The strata are purple marls; their orientation is such that bedding planes cannot be observed. Jan Smit (pers. comm.) has argued that the absence of ammonites in this part of the section is due to collection failure only, because of the different mode of stratal exposure in this part of the section. This is certainly a possibility. It is harder to collect from this lithofacies, and ammonites are found much more easily on bedding planes than on exposures (such as the final 15 to 20 m of the Cretaceous section at Zumaya) striking perpendicular to coastline. It should be noted, however, that an identical lithofacies and regressive coastline lower in the section (unit 7 of Wiedmann) has yielded numerous ammonite specimens.

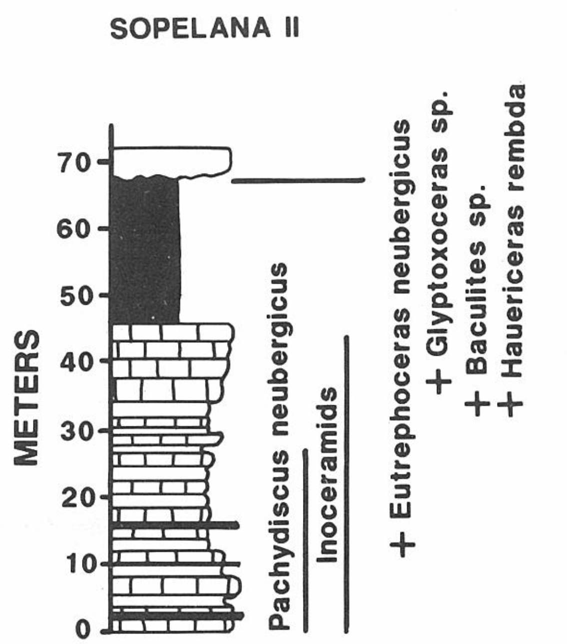

Figure 4. Measured section and ranges of ammonites for Sopelana, section II.

2. Sopelana, Spain

Two stratigraphic sections are exposed west of the town of Sopelana, near Bilbao. The first, and more complete of these is exposed along the bathing beach. The second is located immediately at the south of the first. Only the first of these sections (called Sopelana 1 herein) contains a Cretaceous-Tertiary boundary; the second (Sopelana 2) is unconformably overlain by Tertiary tubidites. Both sections are cut by faults and are more poorly exposed than the Zumaya section. Both also appear to be thinner. The Sopelana 1 section has been discussed by Bijvank (1967), and Lamolda *et al.*, 1983. The stratigraphic section at Sopelana is lithologically similar to Zumaya, but of lesser stratigraphic thickness; for instance, the *A. mayaroensis* Zone is approximately 50 m thick at Sopelana, compared to 100 m thick at Zumaya. Lamolda *et al.* (1983) showed a reduction in numbers of planktonic forams beginning at levels approximately 2 m below the Sopelana K-T boundary. The Sopelana section was considered by these authors to be more complete at the boundary than the Biarritz section, but equivalent to Zumaya.

The ranges of macrofossils in the Sopelana sections are shown in Fig. 4. Ammonites are not as common in the Sopelana sections, and much less time has been spent collecting them compared to the effort put into the Zumaya section. The main biostratigraphic interest to come from the Sopelana section relates to the ranges of inoceramids. The same species of *Inoceramus (Platyceramus) spp.* and *I. (Endocostea) sp.* recovered to date from Zumaya are also found at the two Sopelana sections. The disappearance of these species in the Sopelana sections occurs (in terms of order of disappearance and abundance patterns prior to extinction) in a manner similar to that found at Zumaya. At both Sopelana 1 and 2, the last true inoceramids (but not *Tenuipteria*) are found at the top of the massive limestones underlying the first thick purple marls of the Mayaroensis Zone.

3. Hendaye (Baie de Loya), France

The Hendaye section is exposed along the coastline east of the town of Hendaye, France. Shoreline exposures have been cut by multiple faults, deforming some of the strata. The Cretaceous-Tertiary boundary is repeated several times by faulting. The orientation fo the boundary beds is such that bedding plane exposures in the uppermost 20 m of Cretaceous are exposed, and can be collected. Hendaye beds, therefore, allow better collecting possibilities in the uppermost beds than do the Zumaya exposures. Perhaps because of this, far more ammonites have been collected in the uppermost beds at Hendaye than from correlative beds at Zumaya. This new information revises ammonite ranges in the Upper Maastrichtian in the Bay of Biscay region.

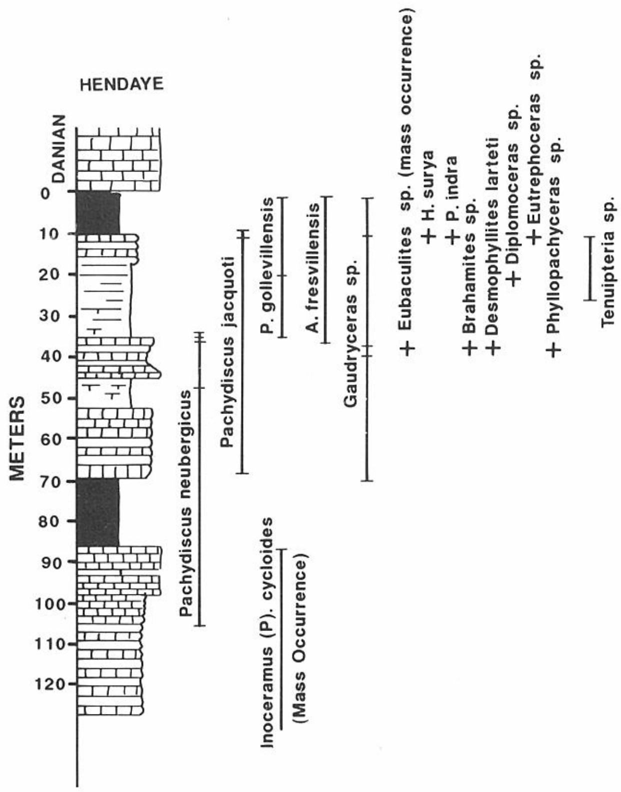

Figure 5. Measured section and ranges of ammonites for Hendaye.

Ammonite and inoceramid ranges from the Hendaye sections are shown in Fig. 5. Three species of ammonites, including the pachydiscids *P. gollevillensis* and *A. fressvillensis* have been collected from the last meter of the Cretaceous at Hendaye. Although it is not known at this time how complete the Hendaye section is compared to the Zumaya section, the two sections are nearly identical lithologically. Most importantly, both show very similar boundary clay layers at the top of the Cretaceous. Based on this lithological evidence, it is my guess that the Hendaye section has little missing at its uppermost Cretaceous exposures compared to the Zumaya section.

Although ammonites are common (more so than at Zumaya) in the Upper Maastrichtian part of the Hendaye section, they are less so in the lower parts of the section. One interesting finding from the Hendaye sections is the comparative ranges of the pachydiscids; *P. neubergicus* ranges higher at Hendaye than at Zumaya, overlapping the lower part of the *P. jacquoti* range. Also, the latter species ranges lower than *P. gollevillensis*; the opposite is true at Zumaya. A new occurrence of Hendaye not found at Zumaya is a mass occurrence of *Eubaculites sp.*, found in large numbers about 35 m below the K-T boundary. This species is common in other Upper Maastrichtian sections world-wide, but to date has not been found at Zumaya.

As at Sopelana and Zumaya, true inoceramids disappear in the Hendaye section at the top of the thick limestone correlative to unit 6 of Zumaya.

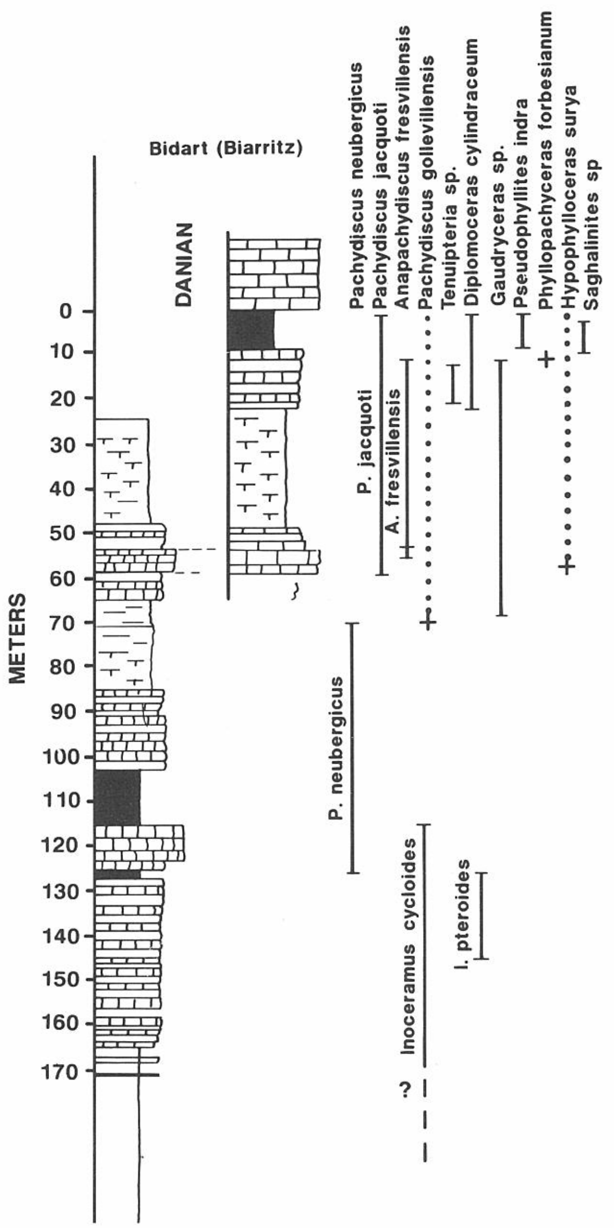

Figure 6. Measured section and ranges of ammonites for Bidart (Biarritz), France.

4. Bidart (Biarritz), France

The final section studied for its macrofossil ranges was the Bidart section, located on the coast near the city of Biarritz. This section shows a great deal of faulting, and was the most difficult to structurally reconstruct. No single section can be constructed. The Cretaceous-Tertiary boundary, however, is located at the top of a less complicated section of approximately 60 m thick. This section is itself correlated with the top of a much thicker section found to the west.

The ranges of ammonites are shown in Fig. 6. Four species of ammonites were found in the last meter of section. Inoceramids disappear in a manner similar to the other sections studied.

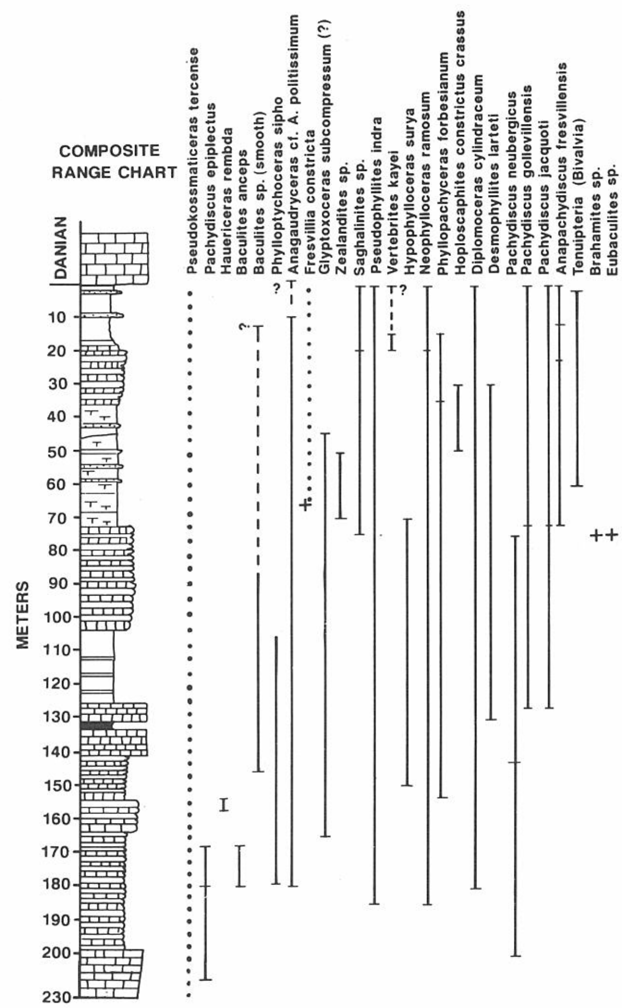

Figure 7. Composite fossil ranges projected onto Zumaya measured section.

SUMMARY AND CONCLUSIONS

The five sections studied here give some new information about the extinction of macrofossils at the end of the Cretaceous. The Zumaya section, thickest and best exposed, has yielded few ammonites in its uppermost parts, but gives the best information about the lower and middle parts of the Maastrichtian. With the addition of information about ranges of ammonites now recovered from the Bidart and Hendaye section, a composite picture of ammonite ranges, projected against the Zumaya section can be produced (Fig. 7). As many as seven species of ammonites were apparently present in this region during sedimentation of the final meter of Maastrichtian. Also, the composite ranges presented indicate that Wiedmann's proposed ammonite zonation for the Maastrichtian of this region is untenable as currently defined.

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