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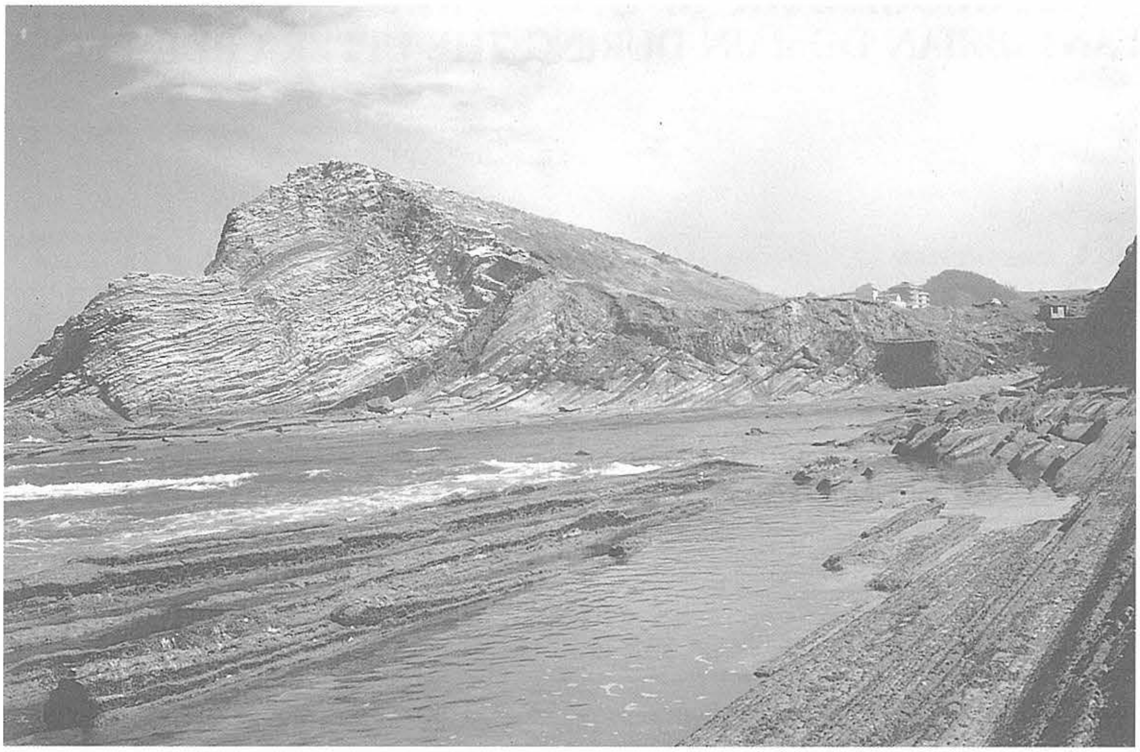

The Upper Maastrichtian - Lower Paleocene section at Punta de San Telmo (Zumaya, Northern Spain).

FIELD-GUIDE EXCURSION TO THE CRETACEOUS-TERTIARY BOUNDARY SECTION AT ZUMAYA (NORTHERN SPAIN)

Marcos A. LAMOLDA

Área de Paleontología. Facultad de Ciencias. Universidad del País Vasco.
48940 LEIOA, Spain

Bernard MATHEY

Centre des Sciences de la Terre de l'Université de Bourgogne, and U.A. CNRS-157,
Bd. Gabriel, 21100 Dijon, France

Jost WIEDMANN

Institut für Geologie und Paläontologie, Universität Tübingen.
Sigwartstr. 10. D-7400 Tübingen 1, F.R.G.

B. Mathey. Paleogeographical evolution of the Basco-Cantabrian Domein during the Upper Cretaceous.

J. Wiedmann. The K/T boundary section of Zumaya. Guipúzcoa.

M.A. Lamolda. Micropaleontology of the K/T boundary at Zumaya.

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PALEOGEOGRAPHICAL EVOLUTION OF THE BASCO-CANTABRIAN DOMAIN DURING THE UPPER CRETACEOUS

Bernard MATHEY

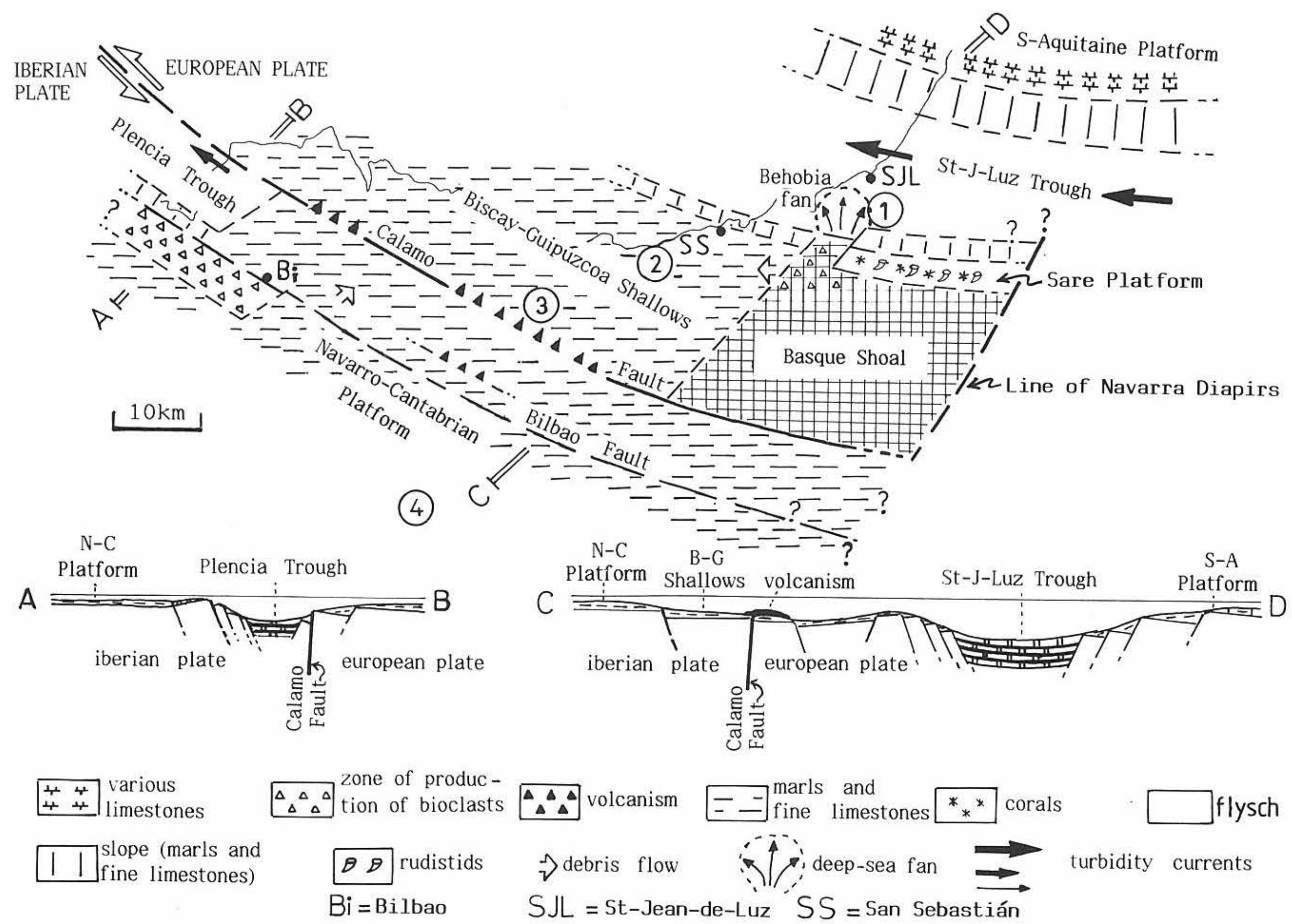

Figure 1. Paleogeography and facies of the Basco-Cantabrian Domain at the end of the Cenomanian. Vertical scale of the A-B and B-C cross-sections is exaggerated. Numbers 1 to 4 indicate the location of the stratigraphic sections of Fig. 2.

INTRODUCTION

The Basco-Cantabrian Domain (Basco-Cantabrian Basin of some authors) represents the eastern part of the southern side of the Bay of Biscay. In Late Cenomanian, as a result of previous environmental and morphological modifications, it was composed of two approximately E-W oriented elements, which are, from north to south (Fig. 1):

a) A deep marine area.

b) A marine shelf: the Navarro-Cantabrian Platform (i.e. the former "Bassin Navarro-Cantabre" of Ciry, 1940 and Feuillée, 1967). This is the outer part of a broader shelf: the North-Iberian Platform, whose inner part, south of the outer one, is named the North-Castillan Platform (Floquet, 1987).

The deep marine area comprised two major elements that were, from north to south:

a) An E-W oriented and westward open depression: the Saint-Jean-de-Luz Trough. Its northern limit was a slope that connects it with an other outer shelf: the South-Aquitaine Platform.

b) A topographically higher region: the Biscay-Guipúzcoa Shallows. It connected at north, through a northward dipping slope, with the St-J-Luz Trough. At south, it rose up to the Navarro-Cantabrian Platform and its limit might correspond to a great structural element: the Bilbao Fault (Amiot, Floquet, Mathey, 1982; Engeser et al., 1984). The southeastern part of the B-C Shallows was a small, always E-W trending despression: the Plencia Trough. On the contrary, its eastern part was a shoal: the Basque Shoal, whose some sectors are small platforms of inner type, whereas some other are emerged.

The eastern limit of the whole deep marine area could correspond with an alignment of diapirs: the. Line of Navarra Diapirs (Rat, 1983). During the Cretaceous, that line separated an Occidental and Navarro-Cantabrian domain from an Oriental and Pyrenean one.

From a more general point of view, the South-Aquitaine Platform belongs to the European plate, whereas the Navarro-Cantabrian Platform belongs to the Iberian one, so that the deep marine area lies astride both plates.

NATURE OF THE DEPOSITS AND PALEOGEOGRAPHICAL EVOLUTION FROM THE MIDDLE CENOMANIAN TO THE END OF THE SANTONIAN

NATURE OF THE DEPOSITS

The Saint-Jean-de-Luz Trough

Longitudinal, and, most of the time, low-density turbidity currents, flowing from east, carry calcareous particles (mainly bioclasts and peloids) into the trough. The resulting deposit is a calcareous flysch of basin plain type: monotonous and several hundred metres thick interbedding of thin and fine calcarenites or calcisiltites and of marls or calcareous shales (Fig. 2, section 1). Bouma sequences of the calcarenites and calcisiltites are, most of the time, base-absent (i.e. Ta division) and begin with Tb, Tc or even Td division. On the southern side of the trough, transversal, high - or low-density turbidity currents give rise to a small deep-sea fan: the Behobia Fan. They come from south and are fed by materials from the Basque Shoal. Due to the composite nature of that shoal (small platforms producing bioclasts and emerged sectors made of various siliciclastic rocks) the load of the turbidity currents is a mixture of calcareous and siliciclastic particles.

On the slopes of the trough, sedimentation is fine and hemipelagic, and deposits are planktonic foraminifera-bearing marls.

The Biscay - Guipúzcoa Shallows

The sedimentation style is the same as that of the trough's slopes and leads to the accumulation of several hundred metres of planktonic foraminifera - bearing marls (Fig. 2, base of section 2).

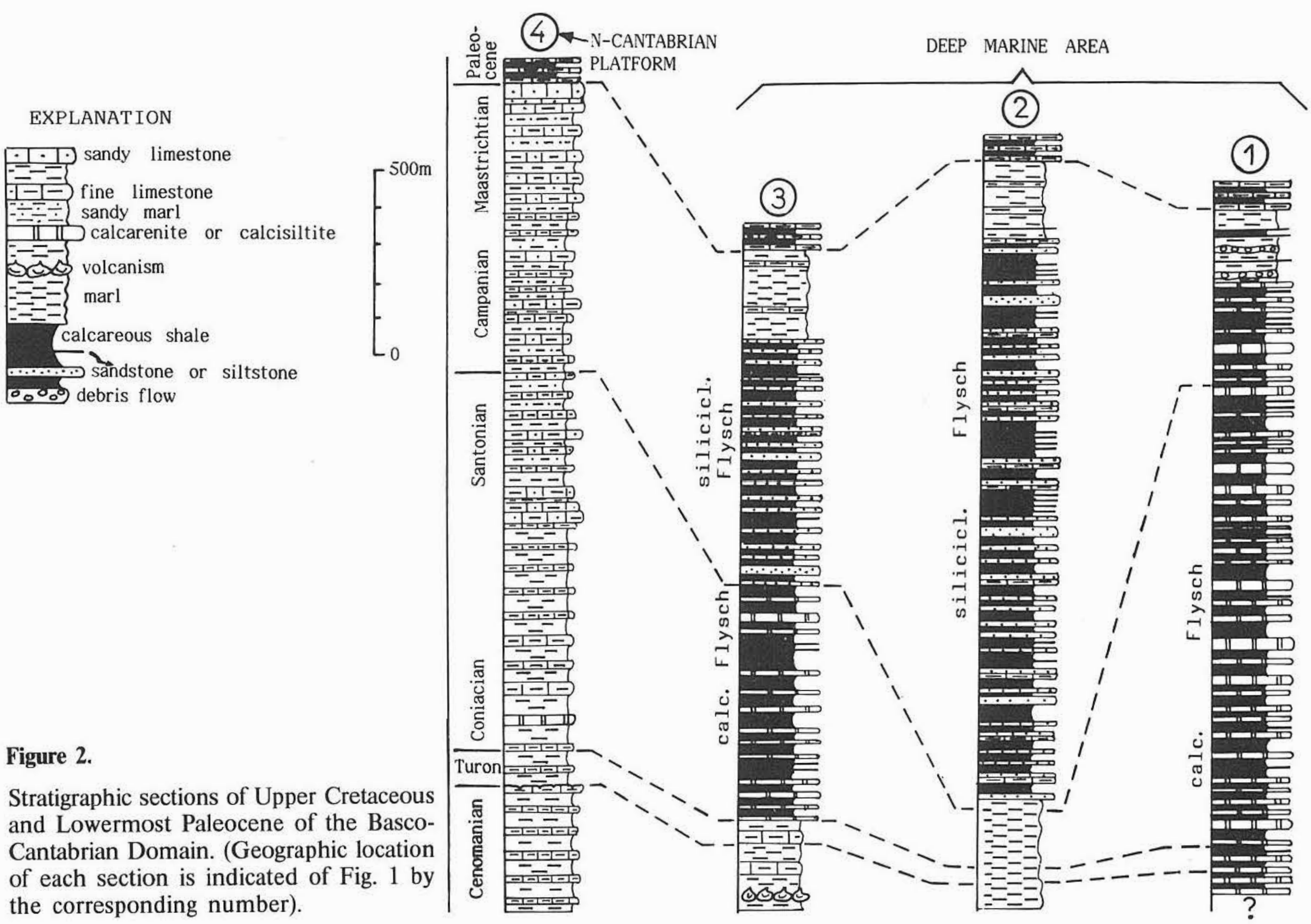

Figure 2.

Stratigraphic sections of Upper Cretaceous and Lowermost Paleocene of the Basco-Cantabrian Domain. (Geographic location of each section is indicated of Fig. 1 by the corresponding number).

Locally, some volcanic layers (tuffs, breccias, lavas) are interbedded with the marls. Their individual thickness ranges from few centimetres to several metres or tens of metres and their alkaline composition is related to a continental crust origin (Rossy, 1974; Meshede, 1985). Moreover, most of the volcanic occurrences are geographically aligned and restricted to a narrow and elongate area which is parallel to the regional trend (Fig. 1). For that reason, they are interpreted as staking out a distensional fracture, along which the volcanic products can rise up to the sea-bottom. This fracture has been named the Calamo Fault ("Accident profond du Calamo" of Amiot *et al.*, 1982) and regarded as the possible boundary between the European plate and the Iberian one. (Floquet and Mathey, 1984). In such an hypothesis, the St-J-Luz Trough, the Basque Shoal and the northern part of the B-C Shallows belong to the European plate, whereas the southern part of the B-C Shallows and the Plencia Trough belong to the Iberian one.

The Plencia Trough

Low-density turbidity currents accumulate fine calcareous particles (mainly bioclasts and peloids). The resulting facies is a calcareous flysch of basin plain type which is fairly similar to that of the St-J-Luz Trough. The origin of the turbiditic supplies remains hypothetic because of lack of field data. They might come from south and derive from sectors of the edge of the Navarro-Cantabrian Platform where, because of a lower bathymetry invertebrates could proliferate and thence provide abundant calcareous skeletal and non skeletal particles.

The Basque Shoal

As is has been exposed before, the Basque Shoal is a composite area. Some parts are probably emerged and undergo erosion. Some other are small and very shallow platforms of inner type, upon which lenticular bioconstructions can be developped (e.g. the Sare Platform on Fig. 1).

The Navarro-Cantabrian Platform

Sediments are mainly fine to very fine, both calcareous and siliciclastic, and of hemipelagic origin. They consist of quartz - and planktonic foraminifera-bearing marls (Amiot, 1982) (Fig. 2, section 4).

PALEOGEOGRAPHICAL EVOLUTION

General remarks

Because the deep marine area is astride both European and Iberian plates, its paleogeographical modifications depend upon the plate motion. According to Grimaud *et al.* (1982) and Boillot *et al.* (1984), the relative movements of the Iberian plate, during Cretaceous time, are the following:

a) Phase 1, from? to Late Aptian (i.e. to −100 MY): southwestward movement leading to plate divergence and to the creation of a 130 km wide gap between the plates.

b) Phase 2, from end of Aptian to Early or Middle Campanian (i.e. from −100 to −80 MY): southwestward movement along a sinistral strike-slip fault which might be the Calamo Fault. Estimation of the total displacement is about 400 km.

c) Phase 3, from Late Campanian or from Late Maastrichtian - Early Paleocene (i.e. from −75 or −65 MY): northwestward movement. It induces convergence of the plates and disappearence of the formerly created gap (phase 1). It will culminate in the Eocene collision.

The Upper Cretaceous evolution of the Basco-Cantabrian Domain corresponds to a part of the second phase and to the beginning of the third one. Hence, in Middle Cenomanian, the just created Plencia Trough, wich is regarded as belonging to the Iberian plate, must be located probably several hundred kilometres west or northwest of its present position.

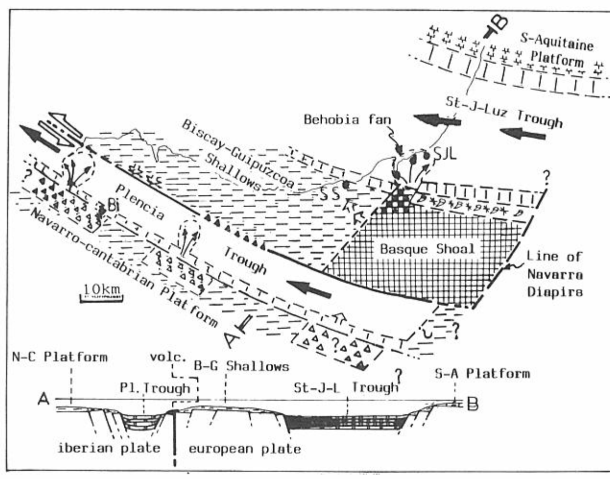

Figure 3. Paleogeography and facies of the Basco-Cantabrian Domain during the Lower Coniacian. Vertical scale of the A-B cross-section is exaggerated. (Same explanation as that of Fig. 1).

Paleogeographical modifications

The most important affecting the deep marine area:

a) In Late Turonian - Early Coniacian, the Plencia Trough extended east-ward (Fig. 3). The calcareous flysch continued to be of basin plain type, except along the southern side where it locally formed several deepsea fans. As it has been exposed, turbiditic supplies might have come from sectors of the top of the edge of the Navarro-Cantabrian Platform where environmental conditions would have been those of an inner shelf, because bathymetry would have been lower than that of the rest of the Platform. Such environmental conditions favoured life and, accordingly, the production of abundant calcareous biological particles (Figs. 3 and 4, and Mathey, Floquet and Amiot, 1983).

b) The volcanic activity, along the Calamo Fault, started in Upper Albian. It culminated in Upper Cenomanian and Turonian and ended during Coniacian (Lamolda *et al.*, 1983).

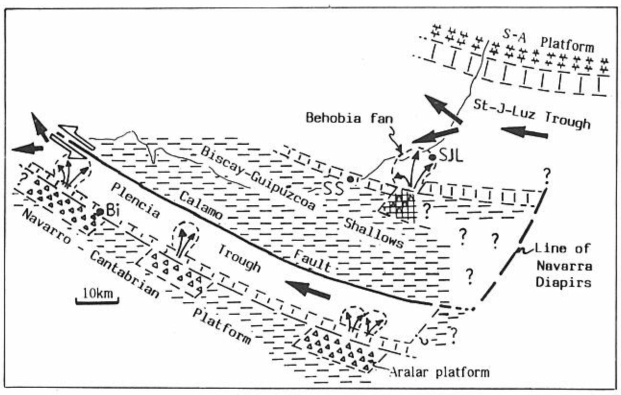

Figure 4. Paleogeography and facies of the B-C Domain during the Upper Santonian. (Same explanation as that of Fig. 1).

c) During Lower Senonian and mainly Santonian, the Basque Shoal sagged progressively and nearly entirely. As a consequence, the Biscay-Guipúzcoa Shallows extended eastward and the sedimentation, between the flysch troughs, becames hemipelagic throughout, except at the close south of the St-J-Luz Trough. There, a relict shoal continued to exist and to feed the Behobia Fan (Fig. 4). On the Navarro-Cantabrian Platform, no significant modification of the general style of sedimentation is observable, although some local and/or temporary bathymetric fluctuations occurred (Amiot, 1982).

THE LOWER AND MIDDLE CAMPANIAN TRANSFORMATIONS

Important changes affected the deep marine area during Lower Campanian:

a) The northern slope of the St-J-Luz Trough widened southward and the Trough grew accordingly narrow.

b) The southern part of the Biscay-Guipúzcoa Shallows sagged and the Plencia Trough widened northward in the same proportion.

Owing to that enlargement, the flysch overlaps the last southerly marls of the B-G Shallows. Moreover, because of a complete change in the nature of the turbiditic supplies, it becomes siliciclastic. Later, in Lower or Middle Campanian, the calcareous turbiditic supplies of the St-J-Luz Trough ended and the rest of the B-G Shallows sagged entirely. As a consequence, from Middle Campanian, the deep marine area displayed a new and more simple aspect. It was composed only of a single broad, E-W oriented and westward open flysch trough: the Orio Trough. This occupie the Plencia Trough's site, the Biscay - Guipúzcoa Shallows one and the southern part of the St-J-Luz Trough one (Fig. 5).

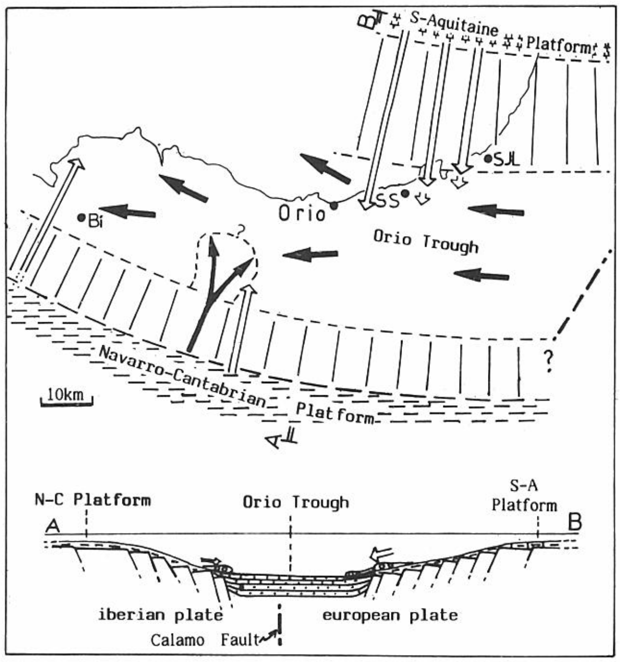

Figure 5. Paleogeography and facies of the Basco-Cantabrian Domain from the Middle Campanian to the Middle Maastrichtian. Vertical scale of the A-B cross-section is exaggerated. (Same explanation as that of Fig. 1).

NATURE OF THE DEPOSITS BETWEEN MIDDLE CAMPANIAN AND MIDDLE MAASTRICHTIAN

The Orio Trough

Sedimentation, in the Orio Trough, was turbiditic and siliciclastic. It was an extension, through a northward onlap, of that of the Plencia Trough's final state. Turbidity currents were always longitudinal and came from the east. They were of low-density type and gave rise to a quartz - and mica-rich flysch filling which displays characteristics of basin plain deposits: thick and monotonous alternation of thin-layered and fine sandstones or siltstones and of more or less calcareous shales.

Some thin structureless micritic layers occur within the flysch. Each of them caps regularly a turbidite and results from the hemipelagic sedimentation, thus indicating that the trough's bottom was above the CCD.

On the southern side of the trough, the flysch presents characteristics of a deep-sea fan: thinning - or thickening-upward sequences, radial dispersion of the current directions. These directions indicate also that turbiditic supplies originated from south (Fig. 5). Total thickness of the flysch varies considerably accross the trough: a few tens of metres near the northern slope's foot (Fig. 2, section 1), about 1,500 m along the axis (Fig. 2, section 2), and about 800 m near the southern slope (Fig. 2, section 3).

Slope deposits are planktonic foraminifera-bearing marls of hemipelagic origin. Near the slope's foot, the flysch and the marls contain lenticular and sometimes coarse conglomeratic intercalations (olistostromes) resulting from debris flows. These originated from the platform-slope edge, travelled downslope and carried clasts which are fragments from autochtonous platform deposits and from the slope itself.

The Navarro-Cantabrian Platform

Campanian sediments were more siliciclastic than the previous ones: quartz - and mica-rich marls, sandy limestones bearing echinoids, planktonic foraminifera and few ammonites.

During Maastrichtian, deposits were always siliciclastic marls but also contained bioclastic limestones and sandstones, both rich in benthic foraminifera (mainly orbitoids). Such coarse-grained facies suggest some northward and temporary advances of the nearshore - inner shelf environments (i.e. of the North-Castillan Platform((Floquet, 1987).

THE LATE CRETACEOUS UNIFORMITY

The deep marine area

The Orio Trough narrowed considerably during Middle Maastrichtian and disappeared during Upper Maastrichtian, while the turbiditic supplies got progressively scarce and weak.

The whole deep marine are became a broad and flat-bottomed depression that always connects by slopes with the adjacent platforms (Fig. 6). According to Delacotte (1982), that depression is about 1,500 m deep.

Sedimentation style was uniform as well, both on the slopes and into the depression. Deposits are marls and fine limestones bearing abundant planktonic foraminifera, some echinoids and ammonites, and common *Zoophycos* traces. The same uniformity of both the environmental conditions and the sedimentation style features the Lower Paleocene (Danian). Deposits, however, are less homogenous

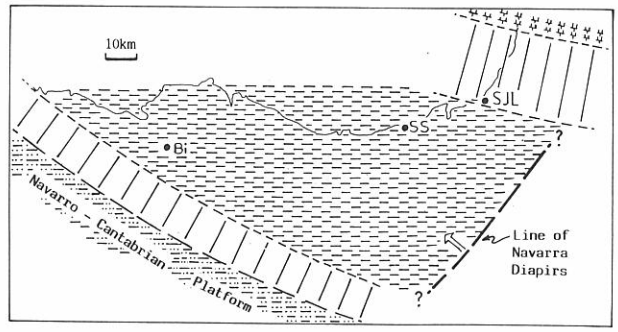

Figure 6. Paleogeography and facies of the B-C Domain during the Uppermost Maastrichtian. (Same explanation as that of Fig. 1).

and more calcareous then the previous ones. They consist of a monotonous alternation of pinkish, micritic and planktonic foraminifera - bearing limestones and of red calcareous shales. In the litterature, they are known as "Calcaires rosés du Danien" or "Calizas del Danés".

The Navarro-Cantabrian Platform

As it has been exposed previously, the Maastrichtian deposits are siliciclastic marls, bioclastic limestones and benthic foraminifera - rich sandstones that suggest northward advances of the environmental conditions of the North-Castillan Platform.

CONCLUSIONS

General evolution of the Basco-Cantabrian Domain

During Upper Cretaceous the evolution of the Basco - Cantabrian Domain is different according to whether the Navarro-Cantabrian Platform or the deep marine area is considered.

In spite of local and/or temporary fluctuations, the Navarro-Cantabrian Platform remains globally an outer shelf environment where deposits are mainly fine and of hemipelagic origin.

The deep marine area undergoes much more important transformations that trend toward a simplification and an uniformity of both the environment and the sedimentation. We observe successively:

a) From Middle Cenomanian to Lower Campanian, two flysch troughs and various other deposits: hemipelagic sediments, calcareous bioconstructions and even volcanic series.

b) From Middle Campanian to Middle Maastrichtian, a single flysch trough and lateral slope deposits: hemipelagic sediments associated with olistostromes.

c) During Upper Maastrichtian, a broad and uniform depression where sediments, including those of the lateral slopes, were hemipelagic throughout.

Origin of the sedimentary supplies

During the two troughs period, turbiditic sediments were calcareous and come from platforms where life can develop and produce abundant biological skeletal and non skeletal particles. According to the paleocurrent directions, those platforms were located mainly east but also south of the thoughs. During the one trough period, turbiditic supplies were siliciclastic but their geographical origin was the same as previously. One must therefore consider that drastic changes affected the source area. The platforms were transformed into emerged areas where crystalline and/or metamorphic rocks as well as sedimentary siliciclastic ones can be strongly eroded.

During Upper Maastrichtian, sediments of the deep-marine area were very fine and hemipelagic only. They were a mixture of calcareous and siliciclastic particles. The first of them were of (bio) chemical origin whereas the latter ones could originate from the quartz- and mica-rich source area which provided previously materials of the siliciclastic turbidites. If so, that source area must have been strongly eroded and flattened, because erosion provided only very fine particles.

The Basco-Cantabrian domain and the plate movements

The Upper Cretaceous evolution of the Basco-Cantabrian Domain was influenced by movements of the Iberian and European plates. The most sensitive area was the deep marine one, because of its particular position, astride both plates. The Navarro-Cantabrian Platform, which is entirely located onto the Iberian plate, is less influenced by plate motion but undergoes eustatic variations (Floquet, 1987).

A comparative examination of plate motion and of concomitant evolution of the deep marine area leads to the following remarks:

a) The phase 2 (i.e. sinistral strike-slip relative movement of the Iberian plate) corresponds to a transtensile regime that fits in with the evolution of the deep marine area: volcanic activity, birth and then size increase of flysch troughs (St-J-Luz and Plencia) separated by more or less shallow zones (Biscay-Guipúzcoa Shallows, Basque Shoal). Such an evolution can be assimilated to that of pull-apart basins.

b) The phase 3 (convergence of the plates) corresponds to a transpressive regime that can explain transformation, through a compressional uplift, of the calcareous source area of the flysch into an emerged and siliciclastic one. That regime fits in less with other observations:

– Lower and Middle Campanian general sagging of the Biscay-Guipúzcoa Shallows leading to the formation of a broad flysch trough.

– Late Cretaceous and Early Paleocene important decrease of both the grain size and the amount of the siliciclastic supplies. Owing to the compression, the oppositive evolution should be expected:

- The flysch trough should get narrow.
- The source area should undergo a continuous uplift and thence a continuous and active erosion, so that siliciclastic supplies should remain coarse and abundant as late as the end of the Cretaceous.

There is no satisfactory explanation of the above mentioned contradictions and their solution requires futher investigations, on land and in the sea.

THE K/T BOUNDARY SECTION OF ZUMAYA, GUIPÚZCOA

Jost WIEDMANN

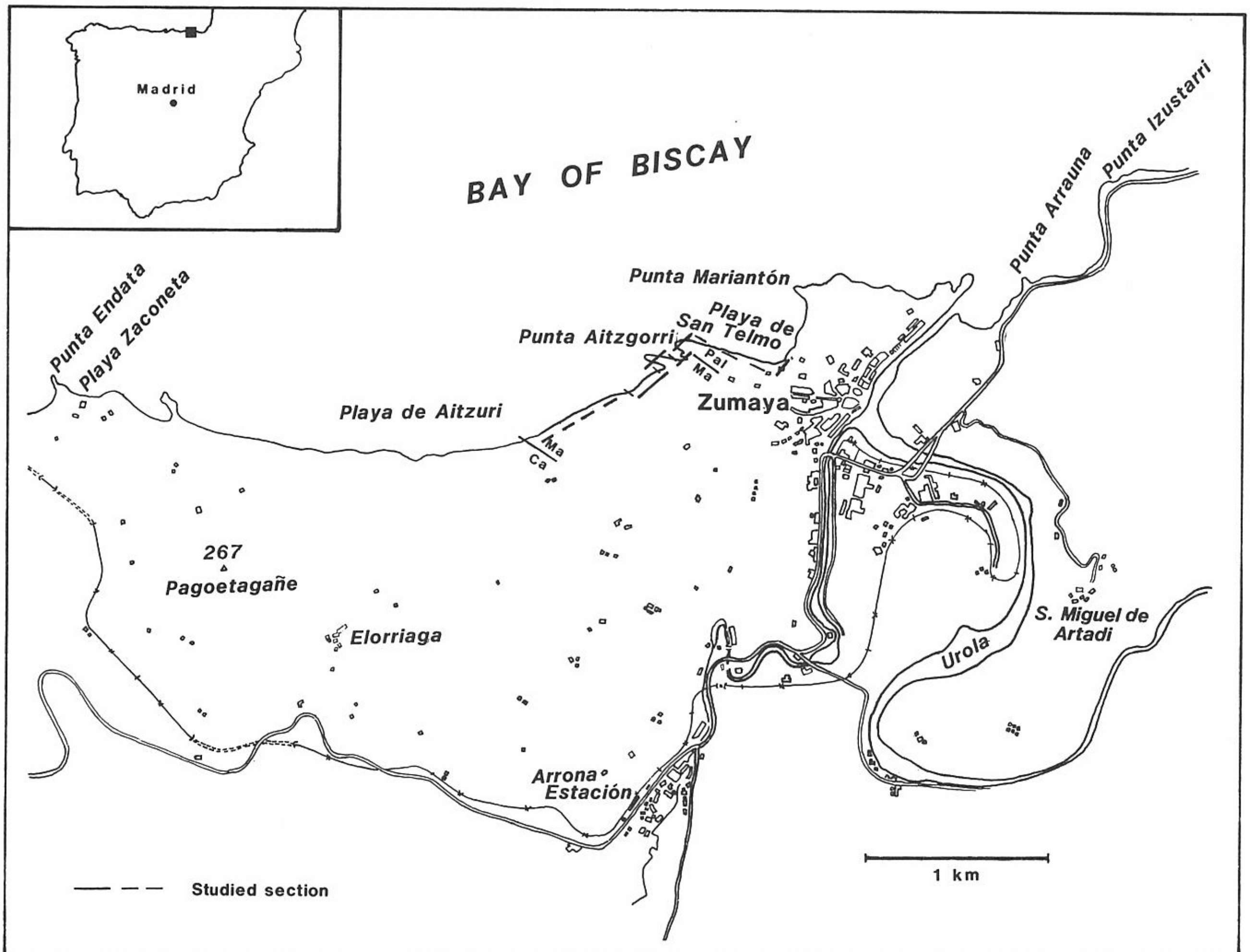

Figure 7. Site of K/T boundary section at Zumaya, Guipúzcoa. Ca: Campanian. Ma: Maastrichtian. Pal: Paleocene.

The famous coastal section at Zumaya, Guipúzcoa province (Fig. 7), was first described by Gómez de Llarena (1954, 1956). Herm (1965) and v.Hillebrandt (1965) studied the late Cretaceous-early Tertiary foraminifera of the Zumaya section, while Kapellos (1974) and Percival & Fischer (1977) worked on the calcareous nannoplankton. Wiedmann (1960) described *Pachydiscus llarenai* Wiedmann as a marker species of the Upper Maastrichtian in Zumaya; later (1962, 1969, 1981) more ammonite data were added. The 1969 paper deals with the decrease in diversity and in size of the late Maastrichtian Zumaya ammonites and the problem of ammonite decline. Ward & Wiedmann (1983) investigated much in detail the distribution of ammonites in the Zumaya Maastrichtian, and they made obvious that ammonites disappeared significantly below the K/T boundary and thus before the iridium event.

Kopp (1959) described Tertiary inoceramids from the nearby K/T boundary section at Sopelana beach, north of Bilbao, where a continuous K/T boundary transition was said to exist. Bijvank (1967), however, was able to show that a number of faults parallel to the bedding planes are concentrated at the boundary level, and that the "Tertiary" inoceramids in fact belong to Cretaceous fault sheets within the Tertiary. The section and its microfauna and nannoflora were recently described by Lamolda *et al.* (1983b).

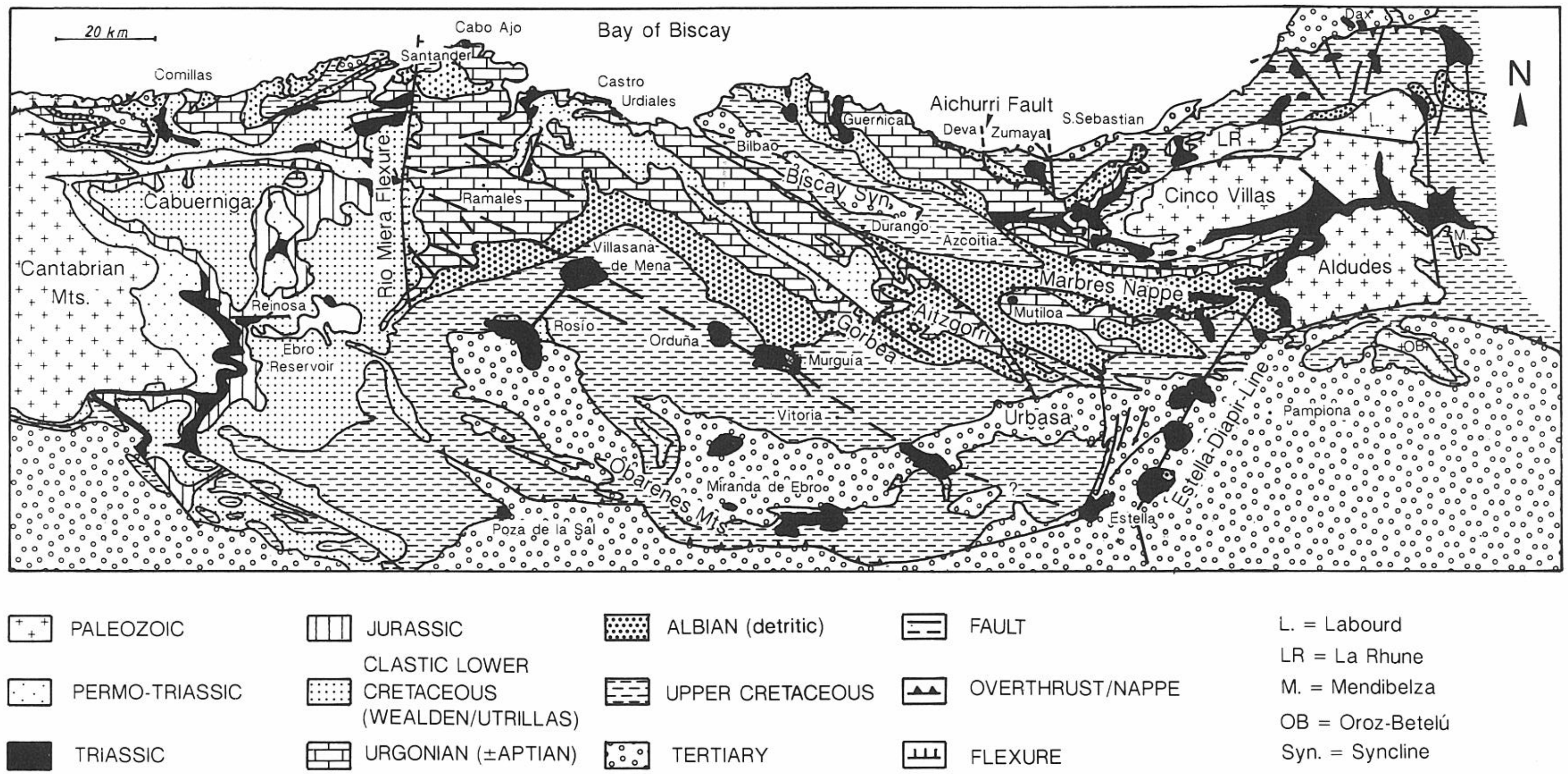

Figure 8. Geological map of the Basco-Cantabrian Basin and adjacent areas (from Engeser *et al.*, 1984).

THE ZUMAYA SECTION

This section is exposed at the coastal cliff west of the village of Zumaya, western part of Guipúzcoa province (Fig. 7). It thus belongs to the northernmost WNW-ESE striking syncline (Fig. 8) of the Basco-Cantabrian orogen, the so-called Zumaya Syncline (Engeser *et al.*, 1984). Most of these synclines (e.g. Deva, Biscaya, Vitoria synclines) correspond to sedimentary graben or half-graben structures, which were formed on tilted blocks during the opening of the Biscay Ocean (Engeser *et al.*, 1984). Separation of the Zumaya Syncline from its western prolongation, the Deva Syncline (Fig. 8), became necessary with recognizing both the nappe structure (Jerez Mir, 1971), and the importance of the Aichurri Overthrust, separating the two synclines (Engeser *et al.*, 1984). The Zumaya syncline originated on a tilted block situated further north than the Deva syncline. Both Zumaya and Deva Syncline comprise European paleomagnetic values (Vandenberg, 1980) while the Biscay Syncline further south exhibits Iberian ones. This means, that the Zumaya and Deva Sinclynes belonged to the southern slope of the so-called Bicay High (Voort, 1964) which formed the SW extension of the European Plate together with the Basque Massifs, and which subsided after the Albian. The Zumaya Syncline subsided during Upper Cretaceous and Paleogene (Coniacian-Eocene) to bathyal water depths documented by microfaunal assemblages and the dominance of distal turbiditic sedimentation (Wiedmann *et al.*, 1983).

The advantages of the Zumaya section are:

1) Continuity across the K/T boundary.

2) Relative abundance of fossil remains through the Maastrichtian.

3) Absence or nearly complete absence of turbidites in the purple marls and limestones of late Maastrichtian and early Paleocene ages.

4) Great thickness of the transitional beds.

5) Absence of tectonics within the transitional beds.

For the present purpose only the pelagic Maastrichtian to Paleocene part of the section will be treated in detail (Fig. 9).

Campanian:

More than 1100 m of flysch deposits (Herm, 1965) crop out on the E-W running coastline southwest of Zumaya (Ensenada de Achuri) or at the famous road cut section south of Zumaya ("Museo de las Pistas" of Gómez de Llarena, 1954). The Campanian ends with the Calcarata Zone (Herm, 1965: 311), which is situated at the eastern end of Ensenada de Achuri where the coastline curves into a NE-SW direction.

Maastrichtian:

Due to its great thickness and fossil content, the Maastrichtian at Zumaya can be subdivided into three parts, Lower, Middle and Upper Maastrichtian:

Lower Maastrichtian: About 400 m of turbiditic sandstones alternate with marls, grading into a limestone-marl alternation. Two limestone ridges, 100 meters thick each, are included in this substage which can be defined biostratigraphically by the presence of *Pseudokossmaticeras tercense* (Seunes) and *Globotruncana falsostuarti* Sigal.

Middle Maastrichtian: It comprises units 1 to 5 of Fig. 9 and shows a total thickness of 290 m. It starts with a turbiditic sequence about 200 m thick (Unit 1); within this part of the sequence macrofossils of any kind are rare. Higher up in the Middle Maastrichtian, *Pachydiscus neubergicus* (Hauer) appears, which can be used in combination with *Rugotruncana gansseri* (Bolli) as a marker species.

Unit 2: Consists of 40 m of grey marly limestone beds (0.10-0.20 m thick) alternating with grey marls (0.20-0.40 m); very thin, laminated arenaceous turbidites are occasionally intercalated (at intervals between 1 and 3 m). It is separeted from Unit 1 by a fault (waterfall), and from Unit 3 by two well-marked rippled sandstone layers. A central limestone member forms point n.º 5 *Pachydiscus neubergicus* (Hauer) first occurs in this Unit 2.

Unit 3: Is comprised of alternating pelagic grey limestones and marls of similar thickness (0.40-0.60 m). This unit is heavily covered by talus. Turbidite input decreases upsection.

Unit 4: Consists of 11 m of an alternation of grey limestones (0.40 m; resistant to weathering, and therefore forming point n.º 4, Fig. 9), and marls (0.40-1.00 m). These relatively thick marls produce a system of caves and mountain slides at the top of the unit. Large inoceramids, up to 0.50 m in diameter (*Inoceramus* ex gr. *balticus*), and *Zoophycos* are abundant on the upper surface. A peak in ammonite diversity exists in this part of the section (Wiedmann, this vol.). The unit is strongly burrowed. There are only a few laminated turbiditic arenaceous layers.

Unit 5: Is comprised of 16 m of grey marly limestones (0.50-2.00 m) alternating with marls (0.50-1.60 m) and a few laminated arenitic layers (0.01-0.10 m). The unit is strongly burrowed; ammonites, inoceramids, and echinoids are frequent.

Upper Maastrichtian: In Herm (1965) the Upper Maastrichtian is defined by the presence of *Abathomphalus mayaroensis* (Bolli) to which a series of pachydiscid species can now be added. It comprises Units 6 to 12, wich have a total thickness of 160 m.

Unit 6: Consists of 18 m of grey micritic limestones (0.20-0.30 m), strongly bioturbated (*Zoophycos* and others); marly and turbiditic interlayers are practically no existent.

Unit 7: Is composed of 30 m of purple marls with grey interbeds and a few thin (0.05 m) arenaceous turbidites.

Unit 8: Consists of 15 m of grey limestones (0.30-1.00 m) alternating with grey, partly red marls (0.20-0.80 m) and it forms point n.º 3 (Fig. 9). The upper portion is bioturbated (*Zoophycos* and many others).

Unit 9: Is comprised of 20 m of alternating well-bedded grey limestones (0.40-1.00 m) and grey and red marls (0.30-1.00 m); thin laminated and bioturbated sandstones overlie most of the limestone beds. Here it is the first mass occurrence of small-sized ammonites. The paved stairway descending from the Punta Aitzgorri to the coastline uses the upper surface of Unit 9.

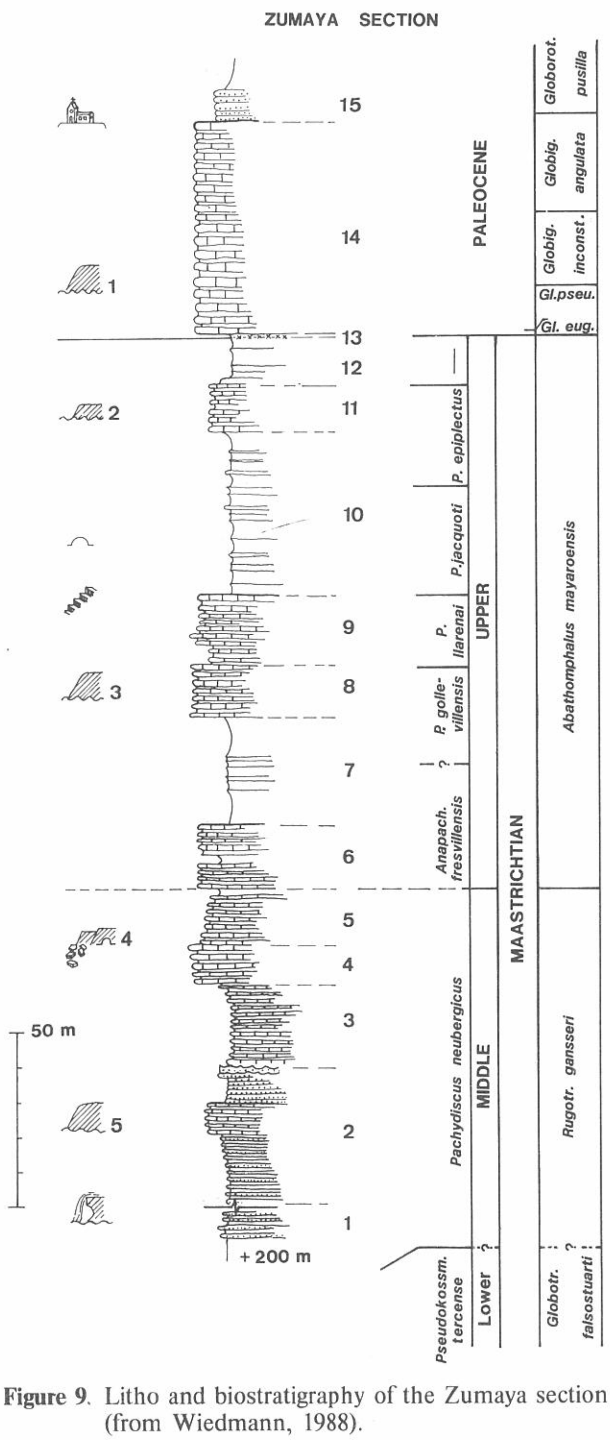

Figure 9. Litho and biostratigraphy of the Zumaya section (from Wiedmann, 1988).

Unit 10: Is composed of 47 m of purple marls with a few intercalated grey layers (turbidites). These grey layers are mostly bioturbated and coprolithic in nature and are marly or laminated sandstones (0.01-0.15 m). Often the grey layers form rhythms 0.40 m thick.

Unit 11: Consists of 13 m of purple marls with alternating layers of marly limestones; both have about the same thickness (0.50 m). A few fine grey arenitic layers (0.05 m) are intercalated. In Unit 11 the last (mostly small-sized) ammonites occur; the inoceramid (?) bivalve *Tenuipteria*, echinoids (*Stegaster*), and bioturbation (*Zoophycos* and others) are frequent. Unit 11 forms a small point (n.º 2, Fig. 9).

Unit 12: Is comprised of 13 m of purple marls with a few grey arenitic layers (0.30-0.10 m). No ammonites were found except one specimen of *Neophylloceras* 0.50 m below the boundary; echinoids (*Stegaster*) and *Tenuipteria* are the only macrofossils present in this unit, which forms the top of the Cretaceous.

Paleocene:

Unit 13, consists of 0.35 m of grey marls which proceed continuously from Unit 12; there is no marked clayey layer. Anomalous enrichment in As and Co and slight increases in Ni and Cr occur, iridium has recently be discovered (Smit *et al.*, 1987) from the rusty-pyritic boundary layer.

Herm (1965, Fig. 7) noticed the rapid decrease in planktonic foraminifera being replaced by an increasing number of calcareous and agglutinant benthics within this level; he still included it in the late Maastrichtian. This dating was corrected by Percival & Fischer (1977) and Smit & ten Kate (1982); Gómez de Llarena (1954) also placed the K/T boundary at a lower position, i.e., below Unit 12. Unit 13 form the lower part of the Globigerina eugubina Zone which continues into Unit 14.

Unit 14: Is comprised of about 60 m of red, micritic, well-bedded limestones (0.05-0.30 m) with minor marly intercalations (0-0.15 m). The base of the unit is formed by a thin turbiditic sandstones (0.05 m). This unit forms the Punta San Telmo (point No. 1, Fig. 9), which has a small chapel on its top.

The lower 0.50 m are still attributed to the Eugubina Zone which is followed by the Edita or Pseudobulloides Zone (v. Hillebrandt, 1965). A detailed Paleogene zonation was elaborated by v. Hillebrandt (1965). The whole unit can be referred to the Dano-Montian.

Unit 15: At Playa de San Telmo grey marls are exposed which become increasingly turbiditic upsection; they are of Landenian age.

CONCLUSIONS

It can be said that flysch deposits are present early and late in the Zumaya sequence, and that the grey and purple marls and limestones of late Maastrichtian age, as well as the red limestones of early Paleocene age, are mainly pelagic and non-turbiditic in nature.

The Upper Maastrichtian has a thickness of 160 m, and the complete Maastrichtian has about 850 m. If we admit a duration of 8 My for the whole stage (Harland *et al.*, 1982), an average sedimentation rate of 106 m/My can be calculated. This is even higher than what it was calculated by Percival & Fischer (1977) who estimated 40-80 m/My for the late Maastrichtian Mayaroensis Zone. This rate of sedimentation is considerable when compared to all other non-turbiditic K/T boundary sections. One of the advantages of the Zumaya section is the fact that the boundary itself is located within the uppermost portion of the purple and grey marls (Units 12 & 13), 35 cm below the base of the red limestone. This means that, in contrast to most other K/T boundary sections, there is no facies change at the boundary level. The faunal turnover, however, is as sharp as generally reported although restricted to the planktonic foraminifera (Herm, 1965; V. Hillebrandt, 1965) and the calcareous nannoplankton (Percival & Fischer, 1977). The zonation is complete and no signs of resedimentation at or above the boundary level have been recognized.

THE MICROPALEONTOLOGY OF THE ZUMAYA SECTION

Marcos A. LAMOLDA

The studied detailed section corresponds to the uppermost reddish marls, 13 m thick, below the K-T boundary. Partial results were presented at the Gwatt Conference (1st Working Session) and IInd Working Session (Beijing) of the IGCP project No. 199 Rare Events in Geology (Lamolda, 1985, 1987, respectively).

The section is composed of several thin levels of green marls, 1-5 cm thick, a sandy grey-brown levels and then purple marls (Fig. 10). *Zoophycos* and *Chondrites* are present throughout the section, but particularly well shown just below the K/T boundary; some *Zoophicos* specimens are apparently cut off by the surface boundary.

The K/T boundary is marked by a calcite vein (of supergenetic nature) 2-3 cm thick, single or multiple with grey dark shales intercalated. Above this calcite vein there are 7-8 cm of dark grey shales, and eventually 25 cm of grey marls; they constitute the so-called boundary marls. Several borrows have been found some cm above the K/T boundary. This basal part of the boundary marls are richer in pyrite and quartz grains than the supra- and infralaying materials.

Planktonic foraminifera

Most samples contain 40-45 planktonic forami-

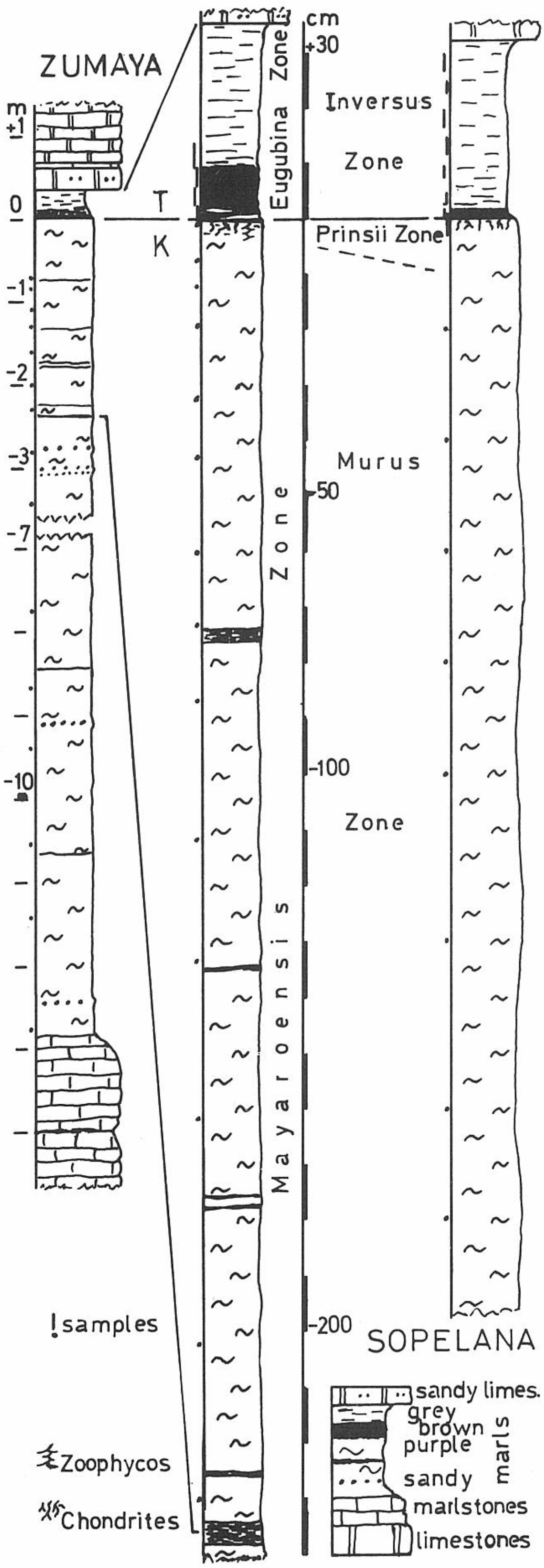

Figure 10. Lithostratigraphy and biostratigraphy of the Zumaya and Sopelana K/T boundaries.

nifera species, but only the following forms are common: *Globotruncana arca, Globotruncanita stuartiformis, Globotruncana falsostuarti, Globotruncanella havanensis, Rugoglobigerina rotundata, Rosita patelliformis, Globotruncana orientalis, Globotruncana rosetta, Racemiguembelina fructicosa, Planoglobulina brazoensis, Pseudotextularia elegans, P. deformis* and *Heterohelix planata*. The species *Abathomphalus mayaroensis*, although generally present, is not abundant and it has not been found in the last 2.75 m (except 1 specimen 12 cm below the K/T boundary). Around this level the species *Globotruncana contusa* is reduced in number by a factor of 10. The species *R. rotundata* is also greatly reduced. The number of planktonic foraminifera species decreases about 15-20 %, and the number of planktonic foraminifera specimens decreases from 92-95 % to 84 %. The percentage, in weight, of planktonic foraminifera undergoes a decrease in the last sample, just below the K/T boundary, e.g. 0.6 % against 1.5-2.2 in the previous ones (Fig. 11).

The grey marls of lowermost Paleocene age, contain a poor fauna of planktonic tertiary foraminifera of the Eugubina Zone, Smit & Ten Kate (1982).

Nannoflora

Percival & Fischer (1977) showed that the nannoflora species present are almost exclusively of Cretaceous age —"vanishing species"— throughout the purple marls and the lower part of the boundary marls; then drop abruptly and "persistent" species become dominant (*Thoracosphaera* spp., etc.). In their words: "... make sporadic and very rare appearances in the Purple marls, until thoracosphaeres appear in somewhat greater abundance, inmediately below the Boundary Shale, then they suddenly displace the vanishing species as the dominant floral elements...".

Proto-Decima (personal communication) has only found *Micula prinsii* in the last sample just below the K/T boundary. There by the Prinsii Zone is apparently very reduced, having only a few cm, as it happens in the Sopelana area.

Differences with other K/T sections

The upper Maastrichtian planktonic foraminifera show a faster decline here than in the Sopelana section, last 20 cm vs. 1-1.5 m. In addition, the number of species are also higher in Zumaya than in Sopelana (Fig. 11). Is it the case of a longer stratigraphical distribution, or erosion, or no deposition in the uppermost part of the Zumayan Maastrichtian? If we have in mind the different rate of deposition in both sections, the differences are even greater.

The nannoflora species in the Zumaya K/T boundary are similar to those in both the Sopelana and Biarritz sections, mainly due to the large number of specimens of *Thoracosphaera* spp. present

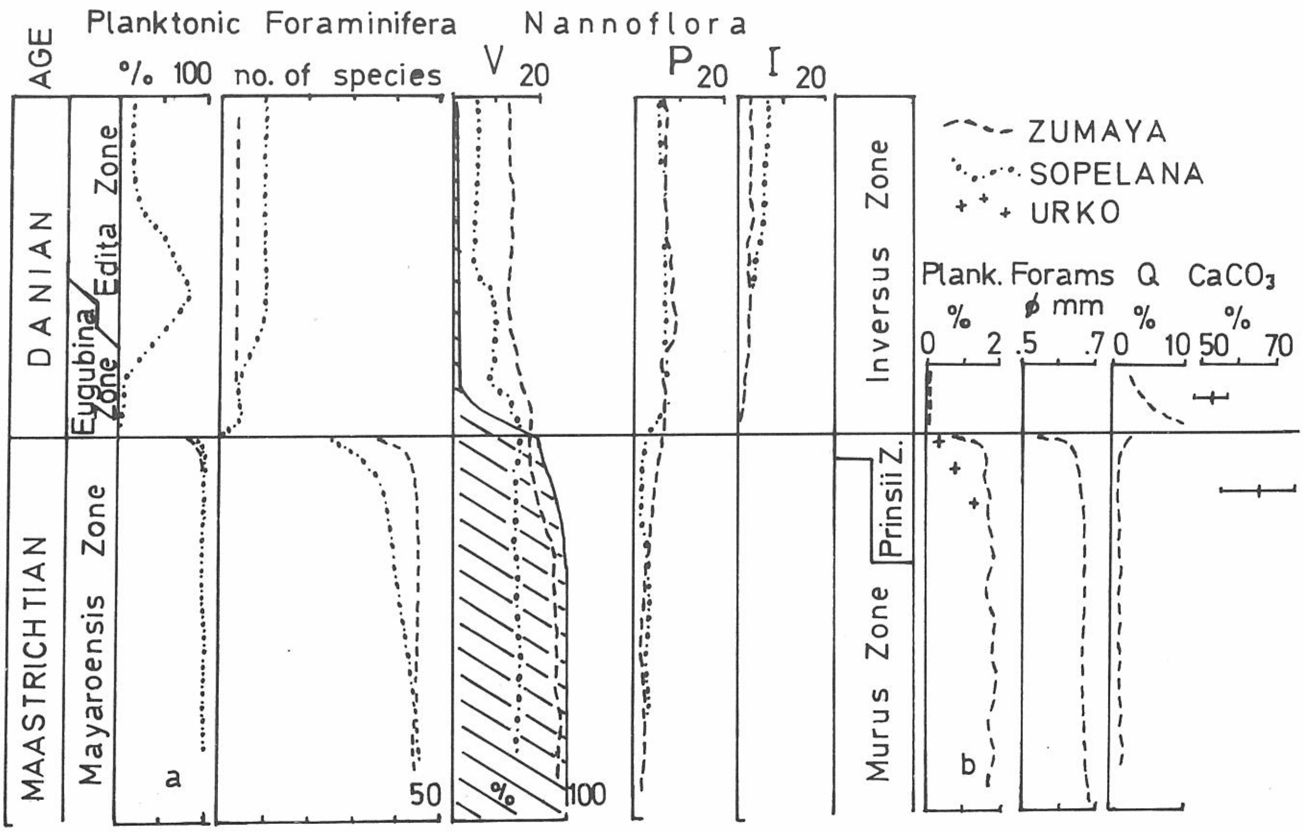

Figure 11. Planktonic foraminifera and nannoflora occurrences at the Zumaya and Sopelana boundary sections. a) % planktonic foraminifera/Foraminifera; b) % in weight of planktonic foraminifera (dry and whased samples). V, vanishing species. P, persistent species. I, incoming species.

following the planktonic foraminifera extinction. However, the thickness of the Prinsii Zone is different in Biarritz, 6-7 m, in opposition to a few cm in both Zumaya and Sopelana.

Apparently there is a poor development of the final Maastrichtian in the later sections; but it is not so simple, because the first known occurrences of *M. prinsii* in both the Zumaya and the Sopelana sections, are above the extinction of last occurrence of *Abathomphalus mayaroensis*. However, in the El Kef and the Caravaca sections it has place below the extinction. Then, there is not an easy correlation between the Basque K/T boundary sections, and other sections around the world.

On the other hand, some level, in the lowermost Paleocene are present at both Zumaya and Sopelana characterized by an association of *Thoracosphaera* spp. and Cretaceous coccolith species. This association has not been found in the Biarritz section, although it might be also a reworking sedimentary process.

In any case, these differences ilustrate the complex processes of sedimentation and/or biostratigraphy at small scale, in the three Basque sections.

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