Upper Cretaceous of the Barranca (Navarra, northern Spain); integrated litho-, bio- and event stratigraphy. Part II: Campanian and Maastrichtian

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ABSTRACT:


Campanian to Lower Maastrichtian strata of the eastern Barranca (Navarra, northern Spain), based on 11 exposures near Irurzun, were investigated in detail and correlated with coeval strata of the western Barranca and the Oroz-Betelu Massif (Navarra). The Sarasate Formation exposed in the Barranca is divided into ten members. Deposition was influenced by uplift of the Anoz-Ollo salt structure during the latest Santonian and Early Campanian. The Campanian – Maastrichtian of Navarra is characterised by thick and relatively complete successions containing biostratigraphically significant fossil groups (ammonites, inoceramids, echinoids). Detailed bed-by-bed collecting has enabled the establishment of an integrated zonal scheme with potential for interbasinal correlation. In addition to local peak, partial range and assemblage zones, based on echinoids and ammonite – echinoid assemblages, an ammonite zonation, based on an unnamed interval and the following 10 partial range (PRZ) and assemblage zones (AZ) of *Scaphites hippocrepis* III, *S. hippocrepis* III/*Menabites* spp., *Hoplitoplacenticeras marroti*, *Trachyxcaphites spiniger*, *Pseudoxybeloceras phalera-tum*, *Nostoceras* (Bostrychoceras) *polyplocum*, *Trachyxcaphites pulcherimus*, *N. (Didymoceras) archiacianum*, *N. (Nostoceras) hyatti*, and *Pachydiscus neubergicus/Pachydiscus epiplectus*, is presented. The ammonite zonation markedly refines both the existing regional and the so-called European standard zonal schemes. Correlation with other Spanish areas (Cantabria, Burgos and Guipuzcoa), the Aquitaine (France), Westphalia and Lower Saxony (Germany) and the Vistula valley (Poland) is discussed. Twelve of the recognised bio-events, characterised by mass-occurrences of irregular echinoids and of monospecific, or taxonomically more variable, mostly heteromorph ammonite assemblages, are significant for regional correlation. Three *Offaster* maxima are of interbasinal importance as they can be correlated to Germany, Great Britain and Northern Ireland. The origin of these bio-events is closely related to the transgressive and regressive pulses recognised in Navarra, of which the *pomeli* Transgression I and the *hippocrepis*, *subglobosa* and *polyplocum* regressions are the most pronounced. The tectonic phase at the Santonian/Campanian boundary is related to the Wernigerode Phase. The onset of the second phase is placed in the lower Campanian *marroti* Zone, the onset of a third phase (UCTE) in the upper Campanian *polyplocum* Zone.

**Key words:** Upper Cretaceous, Campanian, Maastrichtian, Integrated macrofossil biostratigraphy, Lithostratigraphy, Event Stratigraphy, Ammonites, Echinoids, Inoceramids, Correlation, Barranca, Navarra, Northern Spain
INTRODUCTION

This paper is the second part of the survey of the Upper Cretaceous of the Barranca in Navarra/northern Spain (see KÜCHLER 1998b). It describes the Campanian – Maastrichtian strata of this region and of an adjacent area, west of the Basque Oroz-Betelu Massif (Text-figs 1A, 1E) (see also KÜCHLER & KUTZ 1989, KUCHLER & al., in press; KUTZ 1995).

The investigations were mostly carried out in the area south of Irurzun (Text-fig. 1B), in the eastern Barranca, within a NNW-SSE zone north of the Sierra de Satrustegui. Here, relative good exposures existed at the time of the fieldwork (Pl. 1, Figs A, B), particularly along the A-15 motorway between Irurzun and Erice de Iza.

Area of Sarasate and Erice de Iza (Pl. 1, Fig. B, Text-fig. 1D). In the area of Sarasate, the exposures consist of small cuttings along tracks, erosional gullies and motorway exposures that are now mostly barely accessible or partly overgrown. The Lower Campanian in this area can be directly studied only at three localities: in the Sarasate I and II motorway-cuttings and, some km farther to the NW, in the motorway cutting at mount Astieso (Astieso section – KUCHLER, in prep.).

Temporary sections through the uppermost Upper Campanian and Lower Maastrichtian were previously available along tracks north of the village of Erice de Iza (Erice I and III sections – compare KUCHLER 1983) and on both sides of the N-240 national road, between the Sandaña hill and the easternmost part of the Sierra de Satrustegui, i.e. the Viscay range (Erice II section).

All these sections are situated on the southern and NE flank of the Sandaña-Sollaondi Anticline (KUCHLER 1983) the core of which, on the N-240 road, about 1 km SE of Sarasate, is composed of marls belonging to the Upper Campanian Trachyscaphites spiniger and Nostoceras (Bostrychoceras) polyplocum zones. The upper parts of the Campanian and the Maastrichtian are overturned and, on the northern flank of the Viscay as well as on the SW flank of the Mendi (Text-fig. 1D), in contact with Tertiary limestones. At the Sandaña and the Viscay, Lower Maastrichtian is locally absent and the Upper Maastrichtian is completely absent. The maximum thickness of the Campanian to Lower Maastrichtian strata in this area is about 360 – 400 m. The Campanian and Lower Maastrichtian are represented by the Sarasate Formation (KUCHLER & KUTZ 1989).

Area of Izurdiaga/Urriolza (Text-fig. 1C). The thickness of the Sarasate Formation is reduced to about 220 m by hiati in the Lower Campanian and by tectonic gaps at E–W faults in the area (Izurdiaga III, Urriolza S, Urriolza E I and II sections – see Text-fig. 1C). The Santonian Upper Izurdiaga Limestone Formation (KÜCHLER 1998b) between Izurdiaga and Urriolza is differentially eroded, resulting in a strong relief and a diachronous contact with the Campanian. Locally a 0.6 m thick conglomerate is developed. During the earliest and mid-Early Campanian, the area south of Irurzun represented a shallow-marine environment caused by the uplift of the nearby Anoz-Ollo salt-swell (compare Pl. 1, Fig. A, Text-figs 1A and 18). A belt of glauconitic marls and glauconite sands extends from Urriolza eastwards towards the N-240, in the vicinity of the village of Erice de Iza. Further thickness reductions of the Campanian – Maastrichtian succession to a maximum 150 m are caused by E–W faults at Urriolza, where higher Upper Campanian marls overlie Santonian limestones, and Lower Maastrichtian glauconitic sediments are in juxtaposition with Tertiary limestones.

Area of Ecay (Text-fig. 1C). The westernmost outcrops of the Sarasate Formation in the eastern Barranca are at Ecay (see Text-Fig. 1C), where the formation is reduced to about 350 m (basal hiati and tectonically induced gaps). However, the formation is only sporadically exposed (Ecay E and Ecay I sections). The boundary between the Sarasate and the Upper Izurdiaga formations is exposed at the south end of the village of Ecay, where the Campanian starts with strongly glauconitic beds that probably belong to the Lower Campanian Urriolza Member. The equivalents of these beds crop out east of Ecay (Ecay E section). Upper Lower and lower Upper Campanian strata lie under pasture at Ecay and are not exposed. The thickness of the Campanian succession from the top of the Upper Izurdiaga Formation to the base of the Ecay I section is about 150 m. In the Ecay I section (Text-fig. 12) the succession is about 86 m thick, comprising an interval from the Trachyscaphites spiniger to the Nostoceras hyatti Zone. Above an exposure gap of ca. 50 m, Upper Campanian strata are repeated due to a fault. These glauconitic beds (about 50 m in thickness) crop out in gullies, in a brook and in a track (Ecay II section). They belong to the T. spiniger to Nostoceras (B.) polyplocum zones.

DEFINITION OF THE STAGE AND SUBSTAGE BOUNDARIES

Santonian/Campanian boundary

The base of the Campanian is provisionally taken at the LAD (last appearance datum) of the pelagic crinoid Marsupites testudinarius (SCHLOTHEIM) (see HANCOCK & GALE 1996).
Fig. 1. Sketch-map of northern Spain, with location of the Barranca and other reference areas mentioned in the text (IA), the geographical location of the investigated sections in the western and eastern Barranca (IB-D), and location of investigated section west of the Oroz-Betelu Massif, eastern Navarra (IE).
Two other possible boundary markers proposed in Copenhagen 1981 (Birkelund & al. 1984, Schulz & al. 1984, Kennedy 1986, Hancock 1991), the FAD (first appearance datum) of the belemnite Goniotethis grunulataquadra (Stolley) and of the ammonite Placenticeras bidorsatum (Roemer), either correspond to or lie very close to the proposed standard marker. All three definitions are, however, unsuitable in Spain. G. grunulataquadra is limited to the Boreal Realm, *P. bidorsatum* is probably limited to north-western Europe (Germany, France, Austria) and the widely distributed crinoid *M. testudinarius* has been reported neither from Spain nor from Austria (Wagreich & al. 1998).

**Lower/Upper Campanian boundary**

During the Symposium “Cretaceous Stage boundaries” in Brussels ’1995, no formal proposals for Campanian substages boundaries were presented. However, it was agreed that the stage should be divided into three substages of equal duration, if possible.

In the generally accepted classic view of de Grossouvre (1901), the European Campanian is divided into two substages, with the base of the Upper Campanian taken at the FAD of the ammonite genus *Hoplitoplacenticeras* (see Birkelund 1965, Atabekian 1979, Blaszkiewicz 1980, Martinez 1982, Kennedy 1984, Küchler & Kutz 1989, Santamaria 1996). In Boreal Europe (east, central and northern parts of the continent), in the absence of stratigraphically significant ammonites, the Jeletzky (1958) concept, defining the base of the Upper Campanian at the LAD of the belemnite genus *Goniotethis* or at the FAD of the belemnite species *Belemnitella senior* Nowak (Schulz & al. 1984) is commonly followed. According to Schulz & al. (1984), the LAD of *Goniotethis* coincides with the FAD of *Hoplitoplacenticeras* in Germany. In Westphalia (Giers 1964) and in Lower Saxony, the LAD of *Goniotethis quadra* (Blainville) coincides with the appearance of *Hoplitoplacenticeras dolbergense* (Schlüter) (see Schmid & Ernst 1975, Ernst & al. 1979).

Following these classic concepts, a twofold subdivision of the Campanian, into Lower and Upper Campanian substages, is provisionally applied here. The base of the Upper Campanian is placed at the FAD of the ammonite *Hoplitoplacenticeras marroii* Coquand (compare also Küchler & Kutz 1989, Grafe & Wiedmann 1993).

In the Barranca the FAD of *H. marroii* is well fixed in an event stratigraphical framework, just below the level of a maximum-occurrence of the irregular echinoid *Offaster pilula* (Lamarck), an event that is traceable at least to southern England. Another index species, *Trachyscaphites spiniger* (Schlüter), has alternatively been used in some areas to define the base of the Upper Campanian (e.g. Wiedmann 1979, Blaszkiewicz 1979, 1980). It is, however, not particularly well suited because it appears stratigraphically higher than *H. marroii*, both in northern Spain and in northern Germany.

**Campanian/Maastrichtian boundary**

The base of the Maastrichtian should be placed at or close to the FAD of the ammonite species *Pachydiscus neubergicus* (von Hauer) (see Odin 1996a). This concept was already applied in Spain (Küchler & Kutz 1989), and the *Pachydiscus neubergicus/Pachydiscus epiplectus* Zone recognised here corresponds to the *Pachydiscus neubergicus/Echinocorys heberti* Zone of eastern Navarra. In contrast to this definition, Ward & Kennedy (1993) and Wiedmann (1987, 1988a, b) placed the boundary in the Zumaya section at the base of the *Pseudokossmaticeras tercense* Zone, which is partly equivalent to the Upper Campanian *Nostoceras hyatti* Zone (see discussion below). Hence the *Pachydiscus epiplectus* Zone of Ward & Kennedy (1993), their second Maastrichtian zone, equates with the basal Maastrichtian as understood here. The base of the *Pachydiscus epiplectus* Zone sensu Hancock & Kennedy (1993), recognised at Tercis, SW France, lies somewhat higher than that of the *epiplectus* Zone sensu Ward & Kennedy (1993). Consequently, it is proposed here to refer to the *epiplectus* Zone as the *Pachydiscus neubergicus/P. epiplectus* Zone.

**AMMONITE ZONATION IN NORTHERN SPAIN; PREVIOUS RESEARCH**

Campanian ammonite faunas from northern Spain, mostly from the provinces of Alava and Navarra, were first mentioned by Wiedmann. However, he either merely listed assemblages (Wiedmann 1960, 1965; Wiedmann in Lamolda & al. 1981) or else described mainly Upper Campanian finds from various widely spaced localities (Wiedmann 1962), and a detailed stratigraphical succession could, therefore, not be established. On the other hand, Wiedmann (1979, Table. 5) suggested a generalised ammonite zonation that was inferred to be valid in Europe, including northern Spain. He recognised a lower Campanian *Scaphites hippocrepis* Zone, a Mid-Campanian *Delawarella delawarensis* Zone and a bipartite Upper Campanian comprising a lower *Trachyscaphites spiniger* Zone and a higher *Bostrychoceras polyplecticum* Zone.

Martinez (1982) used a three-fold division of the Campanian for Lleida (Catalonian) with a *Diplacnoceras*
woodsi woodsi

The following species: Anagaudryceras sp., and Didymoceras (KENNEDY 1986) and were also able to establish a twofold ammonite zones of the French Campanian type area plage zones. They recognised the four so-called standard scheme, based essentially on ammonite/echinoid assemblages measured sections. They presented an integrated zonal vertical distribution in the succession based on detailed (Barranca and Udiroz/Imiscoz area) and showed their Upper Campanian ammonite assemblages from Navarra navarrense regarded the Lower Campanian and Zone and a higher assemblage zone with the Lower Campanian into a lower Upper Campanian are found in the Lower Campanian up to the lower (Middle Campanian) and a higher assemblage. KÜCHLER & KUTZ (1989), and considered that the Neocrioceras riosi Zone as used in this work. KÜCHLER & KUTZ (1989) of the Barranca. It therefore corresponds not to the basal, but to the middle part of the H. marroii Standard Zone. The P. haldemsi assemblage from Puerto de Vitoria still yields H. marroii (C. CORRAL, pers. comm.) and is, otherwise comparable with the upper part of the marroii Zone [= E. subglobosa Zone to the Trachysphinctes spiniger Zone sensu KÜCHLER (1996, and the present paper)]. The N. (B.) polyplocum assemblage from Jauregui II contained, beside Baculites alavensis Santamaria, mostly Nostoceras (E.) eukadiense II KÜCHLER, several Nostoceras (E.) unituberculatum (BLASZKIEWICZ), a single fragment of N. (B.) polyplocum polyplocum and Pseudoxbeloceras interruptum (SCHULTER). The occurrence of N. (E.) eukadiense II in the Jauregui II fauna indicates a slightly younger age than the polyplocum Zone, as it falls into the base of the Didymoceras [sp.]/E. conoidea-Zone sensu KÜCHLER & KUTZ (1989) or into the Trachysphinctes pulcherrimus Zone as used in this work.

LITHOSTRATIGRAPHY OF THE CAMPAÑIAN AND LOWER MAASTRICHTIAN IN THE EASTERN BARRANCA

Two facies belts, a northern and a southern one, can be distinguished in the Campanian – Maastrichtian succession of the Barranca. The boundary between them runs ca. 3 km north of the village of Sarasate in the direction of the villages of Izurdiaga and Echeverri (Text-fig. 1B).
Vitoria Formation (AMIOT 1982)

The northern belt is characterised by a marly to clay-rich marly facies termed the Vitoria Formation. AMIOT (1982) defined this formation as fine sandy, micaceous and clay-rich marls with intercalations of nodular clayey limestones. In the Vitoria plain and the Estella area (Text-fig. 1A), the base of the formation lies in the middle Upper Santonian (AMIOT 1982), but, as it is shown herein, at the top of the Santonian in the Barranca. The top of the formation according to AMIOT lies in the Campanian.

In the eastern Barranca, the facies is limited, contrary to the view of AMIOT (1982), to the northernmost part, where it ranges at least into the Lower Maastrichtian. To the south, it adjoins the more siliciclastic and glauconitic facies of the Sarasate Formation and concomitantly it grades into the turbidite facies of the Ulzama region, north of Gulina (see VOLTZ 1964, EWERT 1964, SCHWENK 1990, MATHEY & al. 1983) (Pl. 1, Fig. A).

An increase in marls, particularly at the base of the Upper Campanian, is found in the Lecumberri, Astieso VII, and Astieso VIII sections studied by DEGENHARDT (1983), which are situated between the Astieso and Arardi ranges (Text-fig. 1C). Further exposures exist along the Rio Araquil, west of Echeverri, at the entrance to the motorway, south of Echeverri, in the brook near the village of Aizcorbe, and in the depression (the so-called Zuberetta) south of Larumbe (see KÜCHLER 1983 and Text-fig. 1B). In the Barranca, the marly facies starts to dominate the succession west of Iturmendi and becomes more extensive toward the Vitoria plain (Text-fig. 1A, B).

Sarasate Formation (KÜCHLER & KUTZ 1989)

The Sarasate Formation is composed of alternations of silty to fine-sandy, partly glauconitic, marls/clayey marls and thin-beded marlstones, as well as marls. To the south, they grade into highly glauconitic marl/marlstone alternations and calcareous glauconite sands. The lower boundary of the formation, defined in the Sarasate I section (Text-fig. 2), is marked by a hardground associated with a slight angular unconformity (see Pl. 2, Figs 1 and 2). The light-coloured, massive limestones of the Upper Izurdiaga Formation sensu KÜCHLER (1998b) are capped by dark-blue, silty clay-rich marls.

The topmost part of the formation in the Sarasate area, between the Mendi range and Sandaña hill, consists of white to yellowish, calcareous marls belonging to the lower Upper Maastrichtian. These are overlain by reddish, clay-rich marls of the Cia Formation (AMIOT 1982) which, in the Larumbe area, have been assigned using planktonic foraminifer to the Upper Maastrichtian *Abathomphalus mayaroensis* Zone (KÜCHLER 1983, p. 66). In the Urrizola/Izurdiaga area, the Cia Formation directly overlies the glauconitic sediments of the Sarasate Formation. The Sarasate Formation thus spans an interval from the Lower Campanian to the Lower Maastrichtian.

The type area of the formation is the area around the village of Sarasate, ca. 4.5 km south-east of Iruzun (see Text-fig. 1D, see also KÜCHLER 1983). To the north, the formation is bounded by the Sarasate Overthrust, to the east it is limited by the Mendi range, and to the south-east and south by the Sandaña Overthrust (compare KÜCHLER 1983).

In the eastern Barranca, the formation additionally occurs in a narrow SSE – NNW zone, to the north of the Viscay range and the Sierra de Satrustegui, where it crops out between the villages of Erico de Iza and Ecy. In the west, near Ecy, the formation is cut by a N – S fault. To the south, there is a tectonic contact with Tertiary limestones of the Viscay and Lintañeta ranges. Isolated occurrences of the Upper Maastrichtian (red marls) overlying the Sarasate Formation, are only locally preserved.

In the area between Sarasate and Erico de Iza, the estimated thickness of the formation is about 400 m. In the area between Urrizola and Izurdiaga, this is reduced to 220 m due to hiatus in the Lower Campanian and tectonic gaps in the Campanian-Maastrichtian boundary interval.

The formation is divided into ten members. The individual members are characterised in the descriptions of the corresponding type localities.

**SELECTED SECTIONS IN THE AREA OF SARASATE AND ERICE DE IZA**

**Sarasate I (Upper Santonian – lowermost Upper Campanian)**

The Sarasate I section (Pl. 1, Fig. B, Pl. 2, Text-fig. 2) is located in the A-15 (Autopista de Navarra) motorway-cutting, about 1.5 km west of the village of Sarasate (Topographical map Gulina, sheet 115-9, 1: 10 000, R=598,600, H=4,750,900).

South-east of Iruzun, Campanian sediments, mainly greyish blue silty, clayey marls with marlstone intercalations, overlie the Santonian limestones unconformably, locally with angular discordance. The basal part of the succession is highly glauconitic. Sedimentary gaps at the Santonian/Campanian boundary are found over a wide area and, in Navarra, can extend into the Upper Campanian.

The Santonian/Campanian boundary hiatus is relatively small in the Sarasate I section in comparison with other Spanish localities. The comparatively complete stratigraphical record, coupled with the common occurrence of biostratigraphically significant faunas, makes this
a key section for the Lower Campanian in northern Spain. The 120 metres of Lower Campanian strata here represent the greatest recorded thickness for this sub-stage in the eastern Barranca. The high accumulation rates at Sarasate are due to the palaeogeographical position of the section in the northern rim-syncline of the uprising Anoz salt-structure. Towards the salt-structure, the Lower Campanian successions become progressively less complete as a result of erosion (Text-fig. 18).

The Sarasate I section is composite, comprising the Sarasate Ia and Sarasate Ib exposures (Text-figs 2-3). Sarasate Ia exposes the Santonian/Campanian boundary

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<table>
<thead>
<tr>
<th>Lower Campanian</th>
<th>Santonian</th>
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<tr>
<td>Scaphites hippocrepis III/M. membraniformis</td>
<td>M. hippocrepis</td>
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<tr>
<td>Lower Sarasate Marly Member</td>
<td>Lower Sarasate Glaucolithic Member</td>
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Fig. 2. Sarasate Ia section, 1.5 km west of Sarasate; Santonian limestones overlain discordantly by middle Lower Campanian glauconitic marl/marlstone alternations; integrated litho-, bio- and event stratigraphy
and extends up into the middle Lower Campanian (Echinocyris brevis – humilis Zone), while Sarasate Ib extends from the Echinocyris aff. turrita Zone up to the basal 5 m of the Upper Campanian (Hoplitoplacenticeras marroti Zone). The latter section is located at km 104 of the A-15 motorway. The Upper Campanian in the latter section is extraordinarily rich in ammonites in comparison to the Lower Campanian.

**Lithostratigraphy**

In the Sarasate I section, the conspicuous facies change from carbonates to siliciclastic deposits, which is traceable as a sequence boundary throughout the Navarro-Cantabrian region, is very well exposed (see Text-fig. 2, Pl. 1, Fig. B; Pl. 2, Figs 1 and 2) and is clearly visible from the N-240 national road, on the other side of the motorway. This sequence boundary (SB 3.3/3.4 sensu HAQ & al. 1987) is marked in the Barranca by the boundary between the Upper Izurdiaga Formation and the Sarasate Formation.

**Upper Izurdiaga Formation (KÜCHLER 1998b):** Near Sarasate, the formation is composed of thick-beded, pale grey subtidal to intertidal limestones. The upper 5 to 6 m consist of a silty calcarenite with erosional pockets and broken cavities, suggesting submarine limestone dissolution and (?subaerial) karstification. The calcarenite is a grainstone with poorly rounded echinoid fragments, micritized bioclasts, miliolid foraminifer, intraclasts and more than 15% of silt-sized quartz, as well as allochthonous components (coralline red algae, encrusting foraminifer and bryozoans). It is penetrated by large Thalassinoides burrows with glauconitized walls.

The top of the calcarenite is a mineralized hardground (HgSal) (Pl. 2, Fig. 3). Its wavy upper surface, well exposed over an area of several square metres, is both glauconitized and phos-
phatised, and exhibits cracks and solution cavities. It is encrusted by serpulids and exogyrine oysters and penetrated by borings which, like the Thalassinoideas burrows, are erosionally truncated.

The upper part of the limestones at Sarasate I is dated as Santonian. In the absence of ammonites and other biostratigraphically significant macrofossils, this age is inferred indirectly by a comparison with the type locality at Izurdiaga. Near there, the upper 100 m of the Izurdiaga Limestones were dated as Santonian by CARRANO & al. (1978, p. 27), and based on the foraminifer cited, most probably *Dicarinella concava* at Platoform foraminifer Zone.

**Sarasate Formation**: The boundary hardground (HgSaI) is unconformably overlain by silty, glauconite-rich marls to clayey marls (packstones to grainstones), which are interpreted as unconformably overlain by silty, glauconite-rich marls to clayey marls (packstones to grainstones), which are interpreted as allochthonites from the shallower subtidal. These marls fill the depressions within the hardground and are piped down in the Thalassinoides burrows and the erosional pockets. A basal conglomerate is not developed, but poorly rounded and superficially Thalassinoides depressions within the hardground and are piped down in the

**Siliceous Sponge Rhythmite (Member E)** [section height 113-125 m]: The rhythmically bedded, ca. 12 m thick unit is composed of 0.4 to 1.0 m thick marls and harder, ca. 0.1 m thick, marlstones that appear nodular on weathering. The marls are likewise strongly bioturbated, slightly glauconitic, and contain siliceous sponges.

**Clayey Marl Member (Member F)** [from section height 125 m upward]: Directly above the marroti/pilula Event the rhythmically bedded unit grades into a clayey marl facies with harder, m-thick intercalations. This member was too poorly exposed (incomplete sections in gullies) for detailed study.

**Integrated biostratigraphy**

The Sarasate I section is designated as reference section for the following five local peak, partial range and assemblage zones, based on echinoids and/or ammonites. Definition of zones in this paper follows the **INTERNATIONAL SUBCOMMISSION ON STRATIGRAPHIC CLASSIFICATION (1972) “Summary of an International Guide to Stratigraphic Classification, Terminology, and Usage”**.

(v) *Hoplitoplacenticeras marroti/Offaster pilula* Assemblage Zone
(iv) *Echinocorys aff. turrita* Partial Range Zone
(iii) *Echinocorys ex gr. brevis-humilis* Peak Zone (= Acme Zone)
(ii) Subzone of abundant *Scabphites hippocrepis*
(i) *Offaster pomeli/M. (Isomicraster)* sp. Assemblage Zone

The four lower zones enable a more refined subdivision of the widely occurring *Scabphites hippocrepis III* Total Range Zone and, consequently, a more precise dating of eustatic and tectonic events or sequence boundaries within this interval. The local marroti/pilula Assemblage Zone represents the basal part of the *Hoplitoplacenticeras marroti* Partial Range Zone in northern Spain.

**Offaster pomeli/Micraster (Isomicraster) sp. Assemblage Zone**: *Offaster pomeli Munier-Chalmas*, first appears just above the hardground (HgSaI) and has its acme-occurrence at the 13.5 m level (Text-fig. 2). Locally, *Micraster (Isomicraster)* sp., the second index taxon, enters slightly higher, ca. 6 m above the hardground and has its acme-occurrence in the overlying 21 m. According to G. EINSTEI (pers. comm.) the latter species, due to its diffuse fasciole and asymmetrical plastron shows affinities with *Micraster* (Gibbaster) sp., from the Gibbaster/Isomicraster lineage (sensu
Echinocorys LAMBERT, as the index taxon of the Subzone of abundant Scaphites hippocrepis, ranges from the base of Member C to the lower part of Member D at Sarasate I. At Sarasate I, the event lies ca. 13.5 m above the erosion surface (HgSa1) of the pomeli Transgression (Text-fig. 2). It consists of a thin (0.4 m) unit of glauconitic, clayey marls that has yielded more than 20 specimens of O. pomeli (see Pl. 5, Figs 10-18). On the southern slope of the Astieso, the pomeli Event is expressed by a conglomerate containing common occurrences of the index taxon (RADIO 1973, p. 60), and located directly above the transgression surface. The different stratigraphical positions of the pomeli Event in the two sections indicate the diachronous nature of the pomeli Transgression, and an hiatus comprising about 13 m of the Sarasate I succession is suggested to occur in the Astieso section. Generally, O. pomeli is very rare and, except for the pomeli Event, no other interval with common occurrences of the species was found in the Lower Campanian of the studied region. In the Izurdiaga/Urrizola area, the pomeli Event was either not developed or was eroded due to the position of the sections at the margin of a submarine swell (see Text-fig. 18).

**Echinocorys ex gr. brevis-humilis Peak Zone:** The zone is defined by the abundant occurrence of E. ex gr. brevis-humilis between the 96 and 103 m levels. At Sarasate I, the event lies ca. 13.5 m above the erosion surface (HgSa1) of the pomeli Transgression (Text-fig. 2). It consists of a thin (0.4 m) unit of glauconitic, clayey marls that has yielded more than 20 specimens of O. pomeli (see Pl. 5, Figs 10-18). On the southern slope of the Astieso, the pomeli Event is expressed by a conglomerate containing common occurrences of the index taxon (RADIO 1973, p. 60), and located directly above the transgression surface. The different stratigraphical positions of the pomeli Event in the two sections indicate the diachronous nature of the pomeli Transgression, and an hiatus comprising about 13 m of the Sarasate I succession is suggested to occur in the Astieso section. Generally, O. pomeli is very rare and, except for the pomeli Event, no other interval with common occurrences of the species was found in the Lower Campanian of the studied region. In the Izurdiaga/Urrizola area, the pomeli Event was either not developed or was eroded due to the position of the sections at the margin of a submarine swell (see Text-fig. 18).

**Event stratigraphy**

The following eight events (in ascending order) are recognised in the Sarasate I section (see Text-figs 2-3; see also Text-figs 18-19).
here than in the Izurdiaga III and Urrizola EI1 sections (Text-fig. 18), which are situated over swells.

brevis–humilis Event: The event is defined by the mass-occurrence of the index echinoid, in a 1 to 2 m thick interval, ca. 98 m above the basal hardground at Sarasate I.

antiquus/aturicus Event: This is an Upper Campanian interval with common Micraster aturicus and/or M. antiquus immediately below the marroti/pilula Event. At Sarasate Ib (Text-fig. 3). M. aturicus is common between beds SaI 92 and 94. The event is traceable through the Barranca up to the village of Iturmendi (see Text-fig 19).

Sarasate II (middle Lower Campanian)

This temporary exposure (Topographical map Gulina, sheet 115-9; 1: 10,000; R=599,400, H= 4,749,820) on the A-15 motorway, about 520 m SW from the centre of
Sarasate (see Text-fig. 1D, Plate 1, Fig. B), is now largely overgrown. The motorway here cuts through the NE flank of the Sandaña/Sollaondo Anticline (see KÜCHLER 1983) at 500 m altitude, exposing upper Lower Campanian strata dipping 20-25° NE. The succession (see Text-fig. 4) is complicated by numerous faults and is also, because the beds strike parallel to the road, affected by rockfalls and slips.

**Lithostratigraphy**

The exposed succession belongs to the Urrizola Member and Member D of the Sarasate Formation. The boundary with the underlying Upper Iruzuriaga Formation (Santonian) is not exposed here but it is situated, under forest cover, at an altitude of ca. 540-550 m.

**Urrizola Member**: 14 m of silty and well-bedded marlstones, separated by thin marl seams. It is characterised throughout by a high glauconite content and strong bioturbation.

**brevis – humilis Marls (=Member D): Ca. 21 m thick succession of soft, greyish-blue marls/clayey marls with only a low glauconite content.**

**Fauna and integrated biostratigraphy**

The Urrizola Mb. yielded a scarce ammonite fauna comprising *Scaphites hippocrepis* (see Pl. 8, Fig. 4) and *Menabites (Delawarella) campaniense* (DE GROSSOUVRE) (see Pl. 7, Fig. 3), the latter found loose. The small-sized early forms of *S. hippocrepis* III, were found at a single level, ca. 8-10 m below the *Micraster antiquus* Event.

The marls of Member D are rich in calciosponges (*Porosphaera nuciformis*). The eponymous *Echinocorys ex gr. brevis-humilis* (see Pl. 5, Figs 6-9) appears 18 m above the base of the member. The associated fauna comprises *Micraster antiquus, Conulus* sp., indeterminable inoceramids, *Baculites* sp. 1, and late forms of *S. hippocrepis* III. A single specimen of *Submortonicerus* sp. was found in the basal part of the section (Pl. 8, Fig. 2).

The entire Sarasate II section corresponds, in terms of the event stratigraphy and local echinoid zonation, to the *O. pomeli/M. (Isomicraster)* sp. AZ up to the E. ex gr. *brevis-humilis* Peak Zone.

The advanced forms of *S. hippocrepis III, M. (D.) campaniense* and *Submortonicerus* sp. date most of the section as *S. hippocrepis/Menabites* sp. AZ, which corresponds to the middle part of the local total range of *S. hippocrepis III* (compare Text-figs 14-16).

**Event stratigraphy**

Three marker horizons are recognised, in ascending order: the *Scaphites hippocrepis* Bed, the *Micraster antiquus* Event and the *Echinocorys ex gr. brevis-humilis* Event.

*Scaphites hippocrepis* Bed: In the Sarasate II section, which is distal in relation to the Anoz-Ollo salt-swell (see Text-fig. 18), a bed in the lower part of the Urrizola Member contains small-sized, early forms of *S. hippocrepis* III. Due to poor exposure and/or the presence of hiati, it has not been found in other sections.

*Micraster antiquus* Event: This widespread horizon with small-sized *M. antiquus* is here ca. 1 m thick. Beside the index taxon it contains *Offaster pomeli*. In the eastern Barranca, it was found at five other localities in the upper part of the glauconite sands of the Urrizola Member (see Text-fig. 18).

*Echinocorys brevis – humilis* Event: At Sarasate II, this event, a mass-occurrence of *Echinocorys ex gr. brevis-humilis*, is found in a 1.5 m thick interval. In the eastern Barranca, which is characterised by silty glauconitic marls, the echinoid fauna is dominated by depressed *E. brevis-humilis* types (Pl. 5, Figs 6-9). Elevated tests of the *E. conica* type (compare Pl. 10, Figs 4-5) occur only rarely, e.g. in the more distal Sarasate I and Astieso sections. It therefore appears that in more distal environments the depressed morphotypes are replaced by the elevated *conica* types. This observation fits observations from northern Germany, where *E. ex gr. brevis-humilis* occurs in the silty/sandy facies of the northern Münsterland, while *E. conica* is found preferentially in the distal white chalk and marl facies of Holstein and Lower Saxony (ERNST 1970b, 1972, p. 98).

**Sarasate IV (Lower/Upper Campanian boundary)**

This natural exposure consists of erosional gullies, ca. 500 m NW of Sarasate (Topographical map Gulina, sheet 115-9, 1: 10 000, R=599.200, H= 4,750.500) (Pl. 3, Text-fig. 5). Unfortunately, a temporary pit excavated near the exposures at the end of 1991 destroyed the section.

To the north of the track from Sarasate to Gulina, upper Lower Campanian to lower Upper Campanian successions were partially exposed in gullies. Because of the rich macrofauna (ammonites, irregular echinoids, inoceramids) and (the former) good exposures of the Lower/Upper Campanian boundary, this section represented one of the best and most complete successions of the boundary interval in northern Spain.

The Upper Campanian *H. marroti* Zone, represented by a numerically rich ammonite fauna, has been recognised here for the first time in northern Spain (KUCHLER & KUTZ 1989). The FAD of *H. marroti* can be located precisely within an event stratigraphical framework and echinoid zonal scheme, thereby enabling correlation with boreal sections.

**Lithostratigraphy**

The graphic log (see Text-fig. 5) is based on the exposure conditions before 1990. The section starts with 1.3 m of rhyth-
mically bedded marlstones and marls (Sa IV-100) characterised by the common occurrence of the echinoid *Offaster pilula* (Pl. 10, Figs 7-12) in *pilula* Bed I. This part of the succession belongs unequivocally to the Lower Campanian. The basal Upper Campanian index ammonite, *H. marroti*, appears 4.5 m higher.

**Member E** (Siliceous Sponge Rhythmites): A ca. 8.0 m thick (from SaIV 100 to 116 – see Text-fig. 5) alternation of grey, silty, in part more indurated, marls and marlstones. In the basal 1.3 m the alternation is closely-spaced, with dm-thick rhythms. Above the *pilula* Bed I there is a change to a more marly lithofacies, with an increase in clay in the background sedimentation being expressed by an increase in thickness of the marl beds.

Some of the intercalations of harder marlstones (0.1 – 0.2 m on average) are attributable to horizons with siliceous sponges (demosponges). Between beds SaIV-104 and SaIV-106 calcareous sponges (*Poroplaena*) are common and solitary corals occur rarely.

**Member F** (Clayey Marl Member): The base of the Member is marked by the 0.2 m thick marlstone bed SaIV-116, which is overlain by a layer of clay pebbles. Above this bed, softer silty and clayey marls dominate, with sporadic intercalations of 0.1 – 0.2 m thick marlstones.

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![Diagram of Sarasate IV section](image-url)

**Fig. 5.** Sarasate IV section; boundary interval between Lower- and Upper Campanian; lithostratigraphic column, bio- and event stratigraphy and local ranges of ammonites, irregular echinoids and inoceramids.
Fauna and integrated biostratigraphy

Ammonites: The ammonite association is rich in individuals but is of low taxonomic diversity. It consists of heteromorphs (Scaphites, Glyptoceras and Bacinulites). Maximum occurrences are mostly restricted to distinct beds.

The FAD of Hoptilopecteniceras marroii (PL. 9, Figs 1-2, 3, 7-8), is in bed SaIV-104. It marks the base of the European basal Upper Campanian marroii Zone and the local marroii/pilula AZ respectively. The occurrence of the index species is limited here to the lower 3.7 m of the Upper Campanian part of the section.

Pachydiscus haldemensis (SCHLÜTER) (PL. 9, Fig. 4), appears at the same level as H. marroii. Throughout the local marroii/pilula AZ and in the lower part of the local Echinocorys subglobosa PRZ, Scaphites hippocrepis IV KÜCHLER (PL. 9, Figs 5-6), is common, indicating that S. hippocrepis is not limited to the Lower Campanian.

The Spanish forms of Glyptoceras retrorsum (SCHLÜTER) (PL. 9, Figs 9-10), are small variants of the species. In northern Spain, this species ranges at least up into the Lower Campanian (see Text-fig. 5). Baculites sp. 3, including both smooth and fine-ribbed variants, occurs commonly in the marroii/pilula Event and in the ammonite-bearing horizon SaIV-116, together with the coarse-ribbed Baculites sp.1.

Echinoids: Except for distinct horizons with a usually monospecific echinoid assemblage, this group is only poorly represented in the Sarasate IV section.

The Echinocorys subglobosa (GOLDFUSS) morphotype occurring in the Sarasate IV section represents a transitional form between Echinocorys aff. turrita (PL. 6, Figs 1-3) and the E. subglobosa that occurs in the Sarasate III section (PL. 10, Figs 1-3). E. subglobosa locally appears directly above the marroii/pilula Event. Its late first appearance in northern Spain in the Upper Campanian marroii Zone is remarkable, but is presumably controlled by facies and/or bathymetry. It may also be interpreted as representing a cold water incursion from the north. The FAD of E. subglobosa can be used to correlate the Sarasate IV section with the Iturmendi V/VI section in the western Barranca (compare KÜCHLER 2000a, Text-fig. 7, ZANDER 1988, and Text-fig. 19). However, this datum may only be used for correlation in northern Spain, since elsewhere, e.g. in Germany, the species occurs in the Lower Campanian (see ABU-MAARUF 1975; SCHULZ & al. 1984 and Text-fig. 15).

In the Sarasate IV section, E. subglobosa occurs mainly at two horizons (see Text-fig. 5). The lower one is ca. 17 m above the marroii/pilula Event; and the upper one, which marks its local LAD, is about 8.9 m higher. In the latter horizon, E. subglobosa is associated with Echinocorys ex gr. conica. This level is referred to as the subglobosa/conica Event. In the Urdiroz/Imiscoz area the latter event is strongly developed and located at the base of the Trachyscaphites spiniger Zone (= Pachydiscus haldemensis/Echinocorys conoidea Zone sensu KÜCHLER & KUTZ 1989). As in the case of the Urdiroz/Imiscoz area, large forms of E. subglobosa disappear at this stratigraphical level and are replaced, as a result of changing environmental parameters (lithofacies and bathymetric position), by small E. ex gr. conica. A similar pattern can be observed with respect to E. ex gr. conica and E. ex gr. conoida (see Text-fig. 19).

E. ex. gr. conica already occurs sporadically in the Lower Campanian but is restricted to the brevis-humilis Event. In the Upper Campanian it is possible to distinguish a thin acme-zone of E. ex gr. conica but only in the clayey marl facies of Sarasate, whereas in the more proximal sections, with a more silty and glauconitic facies (e.g. at Ecy II section, Text-fig. 19), morphotypes of the E. conoidea group occur in an equivalent stratigraphical position.

Inoceramids: In the Barranca, inoceramids are comparatively rare. They first appear around the Lower/Upper Campanian boundary (compare the Sarasate I b section). Amongst poorly preserved specimens from the clayey marl facies of Sarasate, K.-A. TRÖGER identified Cataneceramus baliticus (BÖHM), C. baliticus cf. haldemensis (Giers), and Inoceramus cf. heberti FALLOT. Cataneceramus subsanunensis? cited by KÜCHLER & KUTZ (1989, Text-fig. 3) he referred to as Inoceramus sp.

Event stratigraphy

The Lower/Upper Campanian boundary interval is marked by a bundle of 8 bio-events, comprising horizons with abundant, but low-diversity heteromorph ammonite assemblages, and mass-occurrences of irregular echinoids (Offaster, Micraster and Echinocorys). The second, third and fourth of these, in ascending order, can be grouped as the marroii/pilula event-sequence.

Offaster pilula Bed I: This horizon of abundant Offaster pilula (SaIV-100) lies in the topmost part of the Lower Campanian, ca. 8 m below the second pilula maximum of the marroii/pilula Event. The former level marks the base of an acme-zone of O. pilula around the Lower/Upper Campanian boundary in northern Spain.

Glyptoceras retrorsum Bed I: It is a level at which the heteromorph ammonite G. retrorsum first occurs commonly, and it also marks the FAD of H. marroii. The ca. 1.0 m thick horizon abounds in calcareous sponges (Porosphaera sp.) and contains rare solitary corals and Micraster spp.

Micraster aturicus/Micraster antiquus Event: This marker is a strongly bioturbated horizon (SaIV-105), about 2.1 m thick, with abundant Micraster. It is traceable from the Sarasate I section (SaI-92 to SaI-101) to the western Barranca (Iturmendi V section, see ZANDER 1988; see Text-fig. 19). At Iturmendi, the horizon is characterised by the abundance of baculitids; in the Sarasate IV section these first occur slightly up-section, within the marroii/pilula Event.
marroti/pilula Event: The event, which is limited to a 0.9 m thick (SaIV-106 to SaIV-108) interval, is characterised by the common occurrence of *O. pilula* and related forms. It is the most spectacular horizon within the basal Upper Campanian. Beside *S. hippocrepis* IV, this event has yielded *H. marroti* and poorly preserved inoceramids.

Baculites Bed II: The Baculites II Bed is the second horizon that is dominated by smooth and ribbed baculitids. *Glyptoceras retrorsum* develops a second maximum, and *S. hippocrepis* IV, which is very rare, has its LAD at this level. The horizon is limited to a 0.2 m thick slightly glauconitic bed (SaIV-116), marked by mud pebbles and an inoceramid layer at its top. It is treated here as the erosional surface of the *subglobosa* Transgression I (Text-figs 5, 17, 19).

Echinocorys subglobosa Event: The *subglobosa* Event (SaIV-118 to SaIV-120) falls within a regressive unit and contains rare oysters and regular echinoids (*Temnocidaris* sp.). Bed SaIV-118, ca. 1 m thick, contains extraordinarily abundant *E. subglobosa* as well as fragmentary baculitids

subglobosa/conica Event: This event falls at the level SaIV-124, and it marks the local facies-controlled LAD of *E. subglobosa*, as well as the facies-controlled sudden re-appearance of *E. ex gr. conica*. It coincides with an acme-occurrence of *E. subglobosa* at Sarasate III (see Text-fig. 19).

Echinocorys conica Event: This is an horizon with abundant irregular echinoids, ca. 15-20 m above the base of the *E. ex gr. conica* Zone. The assemblage comprises equal proportions of *E. ex gr. conica* and *E. ex gr. brevis-humilis*. *Micraster aturicus* also occurs in numbers.

Sarasate III (lowermost Upper Campanian)

Section on the A15 motorway (Plate 1, Fig. B; Text-figs 1D, 6) ca. 700 m SE of Sarasate (Topographical map Gulina, sheet 115-9; 1:10000, R=599.900, H=4,749,500), at the hill (542 m altitude) south of the bridge over the national road N-240, opposite the petrol station.

It exposes a 15 m thick succession of the *E. subglobosa* Zone, dipping NE at 30°. The lithological and faunal characteristics reveal a lateral facies change compared to the Sarasate IV section, 1.3 km to the north-west. The Sarasate III section is characterised by the predominance of thickly bedded marlstones which, as the marl beds thicken, pinch out in the direction of Sarasate IV.

The co-occurrence of specific echinoids such as *Conulus haugi* and *Temnocidaris* sp., in distinct glauconite-rich beds, together with generally silty sediments, indicate a short-term shallowing and the proximity of a swell (diapir of Anoz-Ollo?).
Lithostratigraphy

The succession starts within the brevis – humilia Marls (Member D) (not figured). These marls are followed by the Siliceous Sponges Rhythmites, which are composed of a ca. 6 m thick alternation of greyish-blue, 0.2 – 0.3 m thick marlstones and 0.3 – 0.8 m thick platy marls.

At Sarasate III, the overlying Clayey Marl Member is composed of a 6 m thick interval of strongly bioturbated marls, which is overlain again by a thick-bedded marlstone/marl alternation (Upper Sarasate Glauconite Member), the upper part of which contains silty, highly glauconitic beds.

Fauna and integrated biostratigraphy

Elongated siliceous sponges and spherical calcareous sponges occur throughout the section. They are typical of the sponge facies that is developed in the Barranca from the lower Lower Campanian Echinocorys aff. turrita Zone up to the lower Upper Campanian E. subglobosa Zone.

Ammonites: Ammonites, mostly preserved as fragments or as external moulds, are extremely rare: Glyptoceras sp., Baculites sp., Scaphites sp. indet., Hoplitoplacenticeras sp. indet (loose) and Pachydiscus sp. (loose) (see also Text-fig. 6). The loose finds of Hoplitoplacenticeras sp. date the succession of Sarasate III as early Upper Campanian marroti Zone. The abundance horizon of E. subglobosa in the upper part of the section indicates the upper part of the subglobosa Zone, i.e. the second local Zone of the lower Upper Campanian (compare Text-fig. 14).

Event stratigraphy

Echinocorys conica/subglobosa Event: The abundance maximum of E. subglobosa in beds SaIII-12 to SaIII-10, associated with Temnocidaris sp. and Conulus haugi, falls in a short regressive pulse. This local subglobosa maximum is coeval with the conica/subglobosa Event in the Sarasate IV section.

Erice de Iza III (highest Upper Campanian)

The Erice III (Text-fig. 7) section was a temporary track-section on the small hill between the Sandaña and Mendi ranges (Topographical map Ollacarizqueta, sheet 115-10, 1: 10 000, R=600.500, H=4.750.500), ca. 750 m north of the village of Erice de Iza. The Upper Campanian strata, which dipped NE at 30° were poorly exposed and are now overgrown.

The succession comprises the uppermost Campanian, ranging from the topmost part of the polyplacum Zone up to the lowermost part of the archiacianum Zone. The base of the pulcherrimus Zone coincides with the base of the Didymoceras/Echinocorys conoidea Zone of KUCHLER & KUTZ (1989).

Lithostratigraphy

Erice Member I: The section exposes 23 m of silty to fine sandy, greyish-blue marls and marlstones that weather yellow to redish. They contain abundant quartz-agglutinating foraminifer (e.g. Navarella joaquini Citz & Rat), which are locally rock forming. The marlstones range in thickness from 0.2 to 0.3 m. Their upper surfaces are partly covered with inoceramid pavements or inoceramid debris, and there are also cm-thick pebble horizons. The pebbles form irregularly shaped aggregates, composed of inoceramid debris and of lituolid foraminifer (Lituolacea) packstones. These horizons are interpreted to represent mainly parautochthonous deposits, probably proximal tempestites.

Fauna and integrated biostratigraphy:

The Erice de Iza III section is characterised by the common occurrence of ammonites, large Pycnodonte vesicularis (LAMARCK) and inoceramid beds. The regular echinoid ?Gauthieria sp. also occurs.

Ammonites: The ammonite fauna is extremely rich in diversity and abundance, consisting almost exclusively of heteromorphs. Three ammonite associations may be distinguished, which correspond to the three biostratigraphical zones distinguished. In descending order these are:

1. Nostoceras (Bostryhoceras) polyplacum Zone represented by N. (B.) polyplacum spsp. indet

2. Trachyscaphites pulcherrimus Zone, represented by: T. pulcherrimus (ROEMER), N. (B.) polyplacum polyplacum (ROEMER), Pseudoxybeloceras (Parasolenoceras) interruptum (SCHLÜTER), Pseudoxybeloceras (P.) ?wernicki (WOLLEMANN), Nostoceras (Didymoceras) depressum (WIEDMANN), Pseudoxybeloceras sp., and Glyptoceras sp. indet.

3. Nostoceras (Didymoceras) archiacianum Zone, represented by: N. (D.) cf. archiacianum (D’ORBIGNY), Nostoceras (Didymoceras) sp. 1, Nostoceras (Didymoceras) cf. donezanum (MIKHAILEV), Gaudryceras mite (VON HAER), Polyxybeloceras pseudogautianum (YOKOYAMA), N. (B.) polyplacum spsp. indet., N. (B.) polyplacum polyplacum (ROEMER), and T. pulcherrimus.
Inoceramids: Inoceramid beds, some of which represent mass-occurrences, are concentrated in the interval between ErIII-12 and ErIII-15 (Association A), as well as in the upper part of the succession between beds ErIII-18 and ErIII-19 (Association B). The two associations comprise the following forms (identifications by K.-A. TRÖGER and G. LOPEZ):


Association B: *C. balticus haldemensis*, *Cataceramus sarumensis* (WOODS), *Cataceramus sagensis* (OWEN), and *Platyceramus alaeformis* (ZEKELI).

Echinoids: Beside a single find of *Echinocorys* ex gr. *conoidea* and sporadic *Micraster*, irregular echinoids are rare. On the other hand, regular echinoids belonging to the genus *?Gauthieria* occur at two horizons.

The faunal assemblage of the Erice III section is comparable to that of the middle and upper parts of the *pohylocum* Zone and the basal part of the *Didymoceras donezianum* Zone sensu BLASZKIEWICZ (1980) in central Poland. The middle and upper parts of the Polish *pohylocum* Zone may therefore correspond to the *pulcherrimus* Zone distinguished here (compare Text-fig. 16). The succeeding zone, defined in northern Spain by *N. (D.) archiacianum* or *N. (D.) cf. archiacianum*, is interpreted here as an equivalent of the *donezianum* Zone of BLASZKIEWICZ (1980).

According to BLASZKIEWICZ (1980, p. 13) the entry of *T. pulcherrimus* characterises the middle part of his *pohylocum* Zone. The top of the total range of the species lies, however, above that of the zonal index, in the middle part of his *donezianum* Zone.

In the Erice III section, the local FAD of *T. pulcherrimus* coincides with the first abundance maximum of *N. (B.) pohylocum pohylocum* in bed ErIII-12. At this locality, *T. pulcherrimus* still occurs ca. 6 m higher, above the upper boundary of the *pulcherrimus* Zone, which is placed here at the level of the first appearance of *N. cf. archiacianum* and *N. cf. donezianum* in bed ErIII-18.

**Event stratigraphy**

Ammonites and inoceramids are found mainly in the marlstone beds, occurring in abundance on the top surfaces or associated with thin pebble horizons. Seven event beds form a distinctive event bundle.

**N. (B.) pohylocum Event I:** The event is marked by the abundance of a coarsely-ribbed morphotype of *N. (B.) pohylocum pohylocum*, in the 0.3 m thick bed ErIII-12. Scaphitids are rare, but *T. pulcherrimus* has its local FAD at this level. Besides ammonites, small inoceramids (*C. balticus* ssp. indet) and *P.
vesiculäris also occur. At the top of the bed, a lag of intraclasts, reaching several centimetres in diameter, is developed.

polyplocum Event II: Event II is characterised by a more diverse ammonite fauna. The heteromorphs are dominated by coarsely ribbed N. (B.) polyplocum polyplocum. Forms with a low spire and a small whorl-section diameter that are referred to N. (Didymoceras) depressum (WIEDMANN) occur together with T. pulcherminus, Glyptoxoceras sp. ined., Pseudoxybeloceras (Pirusolenoceras) interruptum, and P. (Pirusolenoceras) wernickei.

Pseudoxybeloceras interruptum Bed I: This event and the succeeding marlstone are characterised exclusively by diplomoceratids. Beside the common index taxon, the bed yields P. (P.) wernickei, and rare inoceramids.

interruptum Bed II: In the second level of abundant P. interruptum, the index species co-occurs with Glyptoxoceras sp. ined.

N. (D.) archiacianum Event I: The event bed comprises an interval of 0.4 m. The basal, 0.2 m thick part of the event bed, is composed of a fine sandy glauconitic marlstone with inoceramid debris and abundant benthic foraminifer (ErIII-18a). It is covered by a lag of angular, 1.5 to 2.0 cm thick intraclasts composed of sand-agglutinating foraminifer (Navarella joaquini) and inoceramid debris. A pavement with completely preserved inoceramids and fragments of heteromorph ammonites is developed immediately above the pebble horizon. Ammonites occur particularly in the intraclasts lag and inoceramid plaster. The event is characterised by an ammonite fauna consisting solely of didymoceratids, accompanied by a diverse inoceramid fauna.

archiacianum Event II: It is represented by the 0.3 m thick silty or fine-sandy marlstone bed (ErIII-19) which, besides inoceramids, contains a relatively diverse ammonite fauna. It is dominated by the eponymous didymoceratid associated with T. pulcherminus, P. interruptum, Glyptoxoceras sp., Polypthychoceras (P.) pseudo-gaultianum, and Gaudryceras mite.

Pycnodonte vesiculäris Bed: This oyster layer is restricted to the top of the 0.3 m thick marlstone bed ErIII-20. Besides oysters, fragments of inoceramid internal moulds also occur.

Erice de Iza II (uppermost Upper Campanian – Lower Maastrichtian)

The exposure, which is today overgrown, is a motorway-cutting through the Sandaña hill, ca. 600 m north of Erice de Iza (Topographical map Ollacarizqueta, sheet 115-10, 1: 10 000, R=600.700, H=4.749.340).

The section (Text-fig. 8) starts in the upper Upper Campanian N. (D.) archiacianum Assemblage Zone and extends up to the Lower Maastrichtian Pachydiscus neu-bergicus/P. epiplectus Assemblage Zone. The latter zone is documented only by a low-diversity ammonite fauna. The index ammonite P. epiplectus (REDTENBAECHER) has not been found. The archiacianum and hyatti zones equate with the Didymoceras spp./Echinocorys conoidea Zone, and the neubergicus/epiplectus Zone corresponds to the P. neubergicus/Echinocorys heberti Zone sensu KUCHLER & KUTZ (1989).

Lithostratigraphy

Erice Member I (upper part): The lower, well exposed part of the section is composed of a 30 m thick alternation of silty marlstones (0.3 to 0.7 m thick) and marls (up to several metres thick) with common, sand-agglutinating benthic foraminifer. The 4.2 m thick interval, between beds ErII-21 and ErII-27, is penetrated by large Thalassinoides burrows. Above bed ErII-35, there is a ca. 60 – 70 m gap in the section because of a fault zone. Up-section, the thick-bedded alternation grades into a more marly succession with thin (0.1 – 0.2 m) limestone beds. This transition is either covered with talus or overgrown.

Erice Member II: The ca. 21 m thick succession, which is glauconitic at some levels, consists of a closely-spaced marl/marlstone alternation with marlstone beds 0.1 – 0.2 m thick.

Fauna and integrated biostratigraphy

The macrofauna consists of inoceramid bivalves, large thick-shelled oysters, rare ammonites and irregular echinoids. Inoceramids are common between beds ErII-21 and ErII-35, where they form event-beds. In the upper part of the section, only a single specimen, referred to Platyceramus aff. alaeformis was reported by LÓPEZ & al. (1992).

Echinoids: Micraster (Isomicraster) stolleyi LAMBERT characterises the 6 m thick interval between beds ErII-24 and ErII-30 and Cardiota isoergus (COTTEAU) occurs in ErII 29. Single specimens of Echinocorys gr. conoidea-herberti were found at the 70 m and 80 m levels respectively. In northern Spain, this taxon characterises both the highest Campanian and the Lower Maastrichtian. Echinocorys heberti (SEUNES) and Micraster aturi- cus occur in the poorly fossiliferous, thin-bedded alternation, above the exposure gap. In eastern Navarra, E. heberti enters together with Nostoceras hyatti STEPHENSON, but only in the highest part of the hyatti Zone. It is particularly characteristic of the Lower Maastrichtian. In the Erice II section, E. heberti occurs between beds ErII-68 and ErII-98.

Ammonites: Ammonites are rare throughout the section, and only poorly preserved specimens have been collected.
The occurrence of large-sized *N. hyatti* (Pl. 17, Fig. 2) (loose) between beds ErII-29 and ErII-35 indicates a latest Campanian age, base of *hyatti* Zone, for this part of the succession. An early Maastrichtian age for this part of the section was previously suggested on the basis of the inoceramid assemblage (LOPEZ & al. 1992) and the occurrence of *Endocostea goldfussi* (D'ORBIGNY) in bed ErII-21 (LOPEZ pers. comm. 1995). However, the same inoceramid assemblage was subsequently placed in the Upper Campanian in accordance with the ammonite biostratigraphy (LOPEZ 1996).

The topmost 10 m of the succession, in which *P. ex gr. neubergicus* was found, is unequivocally Maastrichtian. The identification of the Campanian/Maastrichtian boundary using the FAD of the ammonite species *P. neubergicus*, as accepted during the Brussels Symposium (see ODIN 1996a), was already applied earlier in northern Spain by KUCHLER & KUTZ (1989). However, it is difficult to apply this criterion in the Barranca, because the index species is extremely rare there.

**Desmophyllites larteti** SEUNES was found ca. 5 m below the FAD of *P. ex gr. neubergicus* (Text-fig. 8) but the former is a species, which ranges from the Upper Campanian to the Upper Maastrichtian (see KENNEDY & HENDERSON 1992). In northern Spain, it is known from the Campanian/ Maastrichtian boundary interval of eastern Navarra (KUCHLER & KUTZ 1989, KUCHLER & al. in press, KUTZ 1995), and also on the Biscay coast, where it ranges up to the Upper Maastrichtian *Menuites [Anapachydiscus]* terminus Zone (WARD & al. 1991; WARD & KENNEDY 1993). The highest report of *Platyceramus aff. alaeformis* (ZEKELI) is in bed ErII-85, where it co-occurs with *P. ex gr. neubergicus*. This agrees well with the Maastrichtian *Pachydiscus epiplectus* Zone of the Biscay coast, where *Pl. aff. alaeformis*, according to WARD & al. (1991), occurs only within that zone and does not range higher.

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**Fig. 8.** Erice II section; Campanian – Maastrichtian transition interval; biostratigraphy and ranges of ammonites, inoceramids and echinoids; filled circles: number of specimens collected per bed, arrows: specimens collected loose over a larger interval.
SELECTED SECTIONS IN THE AREA OF IZURDIAGA/URRIZOLA

Urrizola E II (middle Lower Campanian)

A natural exposure (Text-fig. 9) ca. 800 m east of the village of Urrizola (Topographical map Gulina, sheet 115-9, 1: 10 000, R = 595.470, H = 4.750.640) (see Text-fig. 1C).

Lithostratigraphy

Upper Izurdiaga Formation: The basal part of the section comprises a closely-spaced alternation of light grey, thin-bedded limestones and calcareous marls. The top surface of the formation, below the Urrizola Conglomerate, displays a wavy relief.

The formation at this locality lacks biostratigraphically significant taxa and is referred to the Santonian only by analogy with the type locality, Izurdiaga. At the latter locality a specimen of Texanites sp. (= Texanites gallicus COLLIGNON) reported by RADIG (1973, p. 16) from beds ca. 50 m below the top of the formation, and the foraminiferal assemblage described by CARBAYO & al. (1978, p. 27), both indicate a mid-Santonian age.

Sarasate Formation: Because of hiatus, the basal part of the formation in this area is characterised by the Urrizola Conglomerate, a nodular, yellowish unit, typically 0.2 – 0.3 m, locally up to 0.6 m thick (Pl. 4, Figs 2, 3, 5). It is composed of several different components: recrystallized micrites, silty components with pelagic micro-organisms and pebbles which also contain recrystallized micrites. The pebbles bear phosphatic crusts and are partly encrusted with bryozoans and oysters. They are embedded in a fine-silty marl which contains sand-sized glauconite grains and clear authigenic quartzes. The matrix is identical to the marls above the conglomerate.

The hardened and encrusted upper surface of the Urrizola Conglomerate indicates its hardground nature. Depressions in the surface may contain dm sized, glauconitised and partly bored pebbles. The Urrizola Conglomerate is discordantly overlain by carbonate-siliciclastic deposits with a very high glauconite content that imparts a distinct, green to violet-grey colour. To the east, towards Izurdiaga, these beds wedge out and the deposits resting on the conglomerate become progressively younger. As recognised by RADIG (1973), the Campanian deposits infill the previously existing relief of the Izurdiaga limestones.

Lower Sarasate Marl Member: Locally (see Text-fig. 9) these beds start with a 1.2 m thick glauconitic marl unit, the glauconitic equivalent of the Lower Sarasate Marl Member, which has a mid Early Campanian age [pomell M. (Isomicraster) sp. AZ].

Urrizola Member: The Urrizola Member is a 6.8 m thick, strongly bioturbated and highly glauconitic, more calcareous unit, which...
consists of clayey, glauconitic packstones, with 15-20% quartz in the silt fraction and ca. 40% glauconite grains in the sand fraction (glauconite sands). The upper part of the Urrizola Member is characterised by a distinct ichnofabric. The preservation of this ichnofabric and the occurrence of a gastropod fauna in the top part of the unit suggest high sedimentation rates and rapid embedding.

The sediment supply came from a shallow-marine area farther to the SW. The more proximal equivalents of the glauconite sands of Urrizola are found in the Ecay E section, ca. 400 m SE of the eponymous village. The 3 m thick succession exposed there is composed of bedded echinoid-inoceramid grainstones with benthic foraminifer (bar-sands).

brevis – humilis Marl: The succeeding part of the formation is composed of a unit of platy, greyish-blue, glauconitic marl, 5.2 m thick, containing rare echinoids of the Echinocorys brevis – humilis group. This is considered here to be the proximal equivalent of the brevis – humilis Marl (Member D).

Fauna and integrated biostratigraphy

Ammonites: The beds above the basal conglomerate contain rare, mostly poorly preserved Scaphites hippocrepis III (Pl. 8, Figs 3, 5, 6), Baculites sp. 1 (ribbed form) and Baculites sp. 2 (smooth form). The ribbed Baculites sp. 1 resembles Baculites sp. 1 sensu Kennedy (1986, e.g. Pl. 18, Figs 18-21), while Baculites sp. 2 is comparable with the smooth Baculites sp. 2 of Kennedy (1986). Ammonites become more common in the uppermost 1.2 m of the glauconite sands and especially at the top of the unit, in the Pachydiscus Bed, which yielded Eupachydiscus levyi and Menuites sp. nov.? (= M. auritocostatus (Schlüter) in Kuchler & Kutz 1989, Text-fig. 2) (see Pl. 8, Figs 7-8). Radig (1973) reported a specimen of Delawarella sp., which is referred here to Menabites (Delawarella) subdelawarenensis Collignon (see Pl. 7, Fig. 1).

Echinoids: Echinoids are represented by: Offaster pomeli, Micraster antiquus, Echinocorys ex gr. brevis – humilis, E. ex gr. conica and Coenoholotype sp. cited by Radig.

The association of advanced S. hippocrepis III, M. (D.) subdelawarenensis and E. levyi indicates the upper part of the Lower Campanian (=“Middle Campanian” sensu Wiedmann 1979 and other authors). It corresponds to that of the French M. (D.) delawarenensis Zone (compare Kennedy 1986, and Text-fig 16) and is an equivalent of the upper part of the zone, with E. levyi, S. hippocrepis, and Neocrioceras rosi sensu Wiedmann (in Gischler & al. 1994), i.e. of the second horizon of the Lacazina Limestones of Quintana/Alava (compare Text-Fig. 15).

Event stratigraphy

Three event horizons have been distinguished, in ascending order.

Pomeli Transgression: This transgression is locally indicated by the Urrizola Conglomerate. The composition of the components of the conglomerate clearly demonstrates the multi-phase nature of the reworking associated with the transgression. At least two distinct phases are clearly distinguishable, the pomeli I and pomeli II transgressions.

Micraster antiquus Event: A bed with small-sized M. antiquus occurs in the upper part of the glauconite sands. The tests of the echinoids are red-coloured, due to the weathering of the glauconite.

Pachydiscus bed: The top 0.5 m of the glauconite sands are characterised by common pachydiscids. The occurrence of E. ex gr. brevis-humilis at the top of the bed, suggests an hiatus, because in the thicker marl sections (compare the Sarasate I section) the entry/acme-occurrence of this species (brevis-humilis event) lies 18 – 19 m above the antiquus event. The Pachydiscus bed is interpreted as the maximum flooding surface.

Izurdiaga III (middle Lower Campanian)

Natural exposure (Topographical map Gulina, sheet 115-9, 1; 10 000, R =595.850, H=750.550) ca. 200 m south of the church of the village of Izurdiaga, immediately east of the Izurdiaga – Pamplona railway (Text-fig. 1C).

The Izurdiaga III section (Text-fig. 10) represents another section in the Santonian/Campanian boundary interval with a significant hiatus between the Izurdiaga Limestones and the Sarasate Formation. The extent of the Lower Campanian hiatus is markedly greater than in the Sarasate I section, and comprises almost the entire pomeli/M. (Isomicraster) sp. AZ.

The Upper Izurdiaga Formation (Kuchler 1998b) was investigated in detail at the type locality (Degenhartd 1983), but not precisely dated. Based on the record of Texanites gallicus (see Radig 1973), the upper 50 m of these limestones are at least mid-Santonian. At Olazagutia (see Text-fig. 1), Texanites first appears well above the last occurrence of Cladoceramus undulatoplicatus (Roemer) and consequently the beds with Texanites should be stratigraphically younger than uppermost Lower Santonian (compare Kuchler 1998b). About 17 m below the top of the Izurdiaga Group, Degenhartd (1983) found Eupachydiscus isculensis, which, according to Kennedy & al. (1995), first appears in the Middle Santonian and ranges into the Lower Campanian. In the Corbières, French Pyrenees, E. isculensis occurs in the T. gallicus Subzone and in the Placenticeras paraplanum Subzone (Upper Santonian). In the Barranca, however, E. isculensis is known to occur as low as the Middle Coniacian of Zuazu (compare Kuchler 1998b, Pl. 13, Figs 7-8).
Text-fig. 10 shows the Campanian part of the Izurdiaga succession. This natural exposure was described by Radig (1973) and logged in detail by Degenhardt (1983, p. 48 and Text-fig. III7). Both authors reported only irregular echinoids (O. pomeli, E. aff. gibba (Lamarck) and Micraster sp.) from the glauconitic marls, which enabled them to assign the marls broadly to the Lower Campanian.

**Lithostratigraphy**

According to Radig (1973) the Campanian rests conformably on the Izurdiaga Limestones which terminate in a hardground. On the other hand, Degenhardt (1983) reported a thin conglomerate at the boundary and noted a glauconitic development in the top 6 – 7 m of the Izurdiaga Limestones. Neither the hardground nor the conglomerate is exposed at present.

The base of the section is taken at a highly glauconitic, strongly bioturbated bed (IzIII-1) characterised by oysters and micrasterids, which probably represents the base of the Campanian succession.

The basal bed is overlain by a 7.3 m thick unit glauconitic marl belonging to the Lower Sarasate Marl Member. This is followed by a ca. 5.5 m thick unit, with harder, thick-bedded (up to 0.6 m) intercalations, belonging to the Urrizola Member, which is in turn overlain by a bed, 2.6 m thick, that represents the microfacial equivalent of the glauconite sands at Urrizola.

**Fauna and integrated biostratigraphy**

**Echinoids**: In the lower ca. 9 m of the Izurdiaga succession only M. antiquus was found during the present study; however, Radig (1973) reported O. pomeli from the same interval. The fauna becomes richer in the upper 5.6 m of the section where, besides the two species mentioned above, E. aff. gibba also occurs. At least 13 specimens of M. antiquus were collected by Degenhardt (1983) from the top 3.4 m of the section.

**Ammonites**: Ammonites (S. hippocrepis III and Baculites sp. 1) are reported from this section for the first time.

**Others groups**: Gastropods, oysters and other bivalves are common in the topmost 0.3 m of the glauconite sand bed IzIII-11, as in the Urrizola EII section.

The presence of advanced forms of S. hippocrepis III proves the mid-Early Campanian age of the succession. Based on a bio- and event stratigraphical comparison (Text-fig. 18) with the sec-
tions of Sarasate I, Sarasate II and Urrizola EII, the Izurdiaga III section most probably starts in the *pomeli/M. (Isomicraster) sp.* AZ, and largely belongs to the local Subzone of abundant *S. hippocrepis* (Text-Figs. 10, 14-15). In terms of both fauna and microfacies, the uppermost part of the succession represents an equivalent of the glauconite sands that occur in the vicinity of Urrizola. The other indicator of its stratigraphical position is the local *M. antiquus* Event, which is situated here, as in the other sections, ca. 1 m below the upper boundary of the glauconite sands. The material collected by DEGENHARDT (1983) most probably came from this level.

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**Fig. 11. Urrizola S section, Campanian – Maastrichtian transition interval**
**Urrizola S** (Campanian-Maastrichtian transition interval)

Natural section in erosional gullies ca. 50 m south of the village of Urrizola (Topographical map Gulina 115-9, 1: 10 000, R=594. 000, H= 4.750.550).

The section given here starts south of the road to Urrizola (Text-figs 1C, 11), ca. 20 m above the level of the road. Because of construction around a water spring the succession is now largely covered. The higher part, up to the base of the Tertiary Erroz Limestones, was previously already rather poorly exposed.

A cross-section of the succession from the Izurdiaga Limestones at Urrizola to the Erroz Limestones at Erroz was described and illustrated by RADIG (1973, p. 15, Text-fig. 9) who reported a fauna of irregular echinoids [*Echinocorys ovata* (LESKE)] from the beds south of the road to Urrizola.

**Lithostratigraphy**

**Erice Member II:** The higher Upper Campanian and Maastrichtian in the vicinity of Urrizola is composed of a ca. 47 m thick alternation of silty to sandy, blue to violet-grey glauconitic, soft sediments belonging to the Sarasate Formation. The contact with the underlying Izurdiaga Limestones is taken here as a provisional marker for the base of the Maastrichtian. The limited macrofaunal material available does not permit the exact position of the boundary to be determined at present. The *Cretirhynchia* Event lies about 20 m above an interval with inoceramid horizons. Despite the lack of heteromorph ammonites, this interval is regarded as time-equivalent to the beds with *Nostoceras hyatti* in the Erice II section. The *hyatti* Zone is indicated by a single specimen of *N. hyatti* (Pl. 17, Fig. 5) from glauconitic-sandy beds near Urrizola in the RADIG collection, which was cited (RADIG 1973, p. 17) as *Neancyloceras* sp.

About 8 m above the *Cretirhynchia* Event, *Anagaudryceras cf. lueneburgensis* occurs, a species cited mostly from the Maastrichtian (see BIRKELUND 1993).

**Event stratigraphy**

**Cretirhynchia Event:** This mass-occurrence of brachiopods (*Cretirhynchia* spp.) is limited to a single 0.8 m thick interval (UrS-100). The accompanying fauna comprises small echinoids (*Offaster* spp.). The event was originally reported from two localities in the Barranca: Urrizola and a now covered section west of the village of Erice de Iza (Erice I sensu KÜCHLER 1983), where *Cretirhynchia* ex gr. *arcuata-limbata* occurred together with *O. pomeli, O. pilula* and *Peroniaster* sp.

**SELECTED SECTIONS IN THE AREA OF ECAY**

**Ecay E (middle Lower Campanian)**

The isolated exposure, about 400 m SE of Ecay (Text-Fig. 1C), is a forest track section at 554 m altitude. Here there is a poor exposure of ca. 14 m of highly glauconitic, silty sediments belonging to the Sarasate Formation. The contact with the underlying Izurdiaga Formation is overgrown (compare KÜCHLER 1998b, Text-fig. 27)

**Lithostratigraphy**

**Urrizola Member:** The basal 2.1 m of the succession consist of well-bedded, olive to violet-green glauconite-rich deposits with lenses of echinoids (*Micraster* sp. and *Conulus* sp.) in the uppermost 0.3 to 0.4 m. These beds are followed by 12 m of highly glauconitic, softer marls.

Ammonites: Ammonites are extremely rare. The beds above the *Cretirhynchia* Event yielded *Anagaudryceras cf. lueneburgensis* (SCHLÜTER), *Baculites* sp., *Desmophyllites* sp., and *Sagalinites* sp. aff. *cala*.

The *Cretirhynchia* Event is taken here as a provisional marker for the base of the Maastrichtian. The limited macrofaunal material available does not permit the exact position of the boundary to be determined at present.

Brachiopods: *Brachiopods* are common, but only a single form, *Cretirhynchia* spp., is quoted here because of its characteristic abundance at and above the Campanian-Maastrichtian boundary in Navarra.

**Echinoids:** The more commonly occurring irregular echinoids are: *O. pilula, O. pomeli, Peroniaster cf. coteau* GAUTHIER, *Echinocorys* ex gr. *conoidea – heberti, Micraster aturicus,* and *Micraster (Isomicroastrum) aff. stolleyi* (loose finds). *Offaster* spp. occur as accompanying elements in the *Cretirhynchia* Event, but also occur in bed UrS-106, together with *Peroniaster cf. coteau* and *M. aturicus* and, rarely, up to 16 m above the *Cretirhynchia* Event. *E. ex gr. conoidea – heberti* is rare, occurring in the *Cretirhynchia* Event (2 specimens) and in bed UrS-94, 7 m below.

**Fauna and integrated biostratigraphy**

*Echinoids:* The more commonly occurring irregular echinoids are: *O. pilula, O. pomeli, Peroniaster cf. coteau* GAUTHIER, *Echinocorys ex gr. conoidea – heberti, Micraster aturicus,* and *Micraster (Isomicroastrum) aff. stolleyi* (loose finds). *Offaster* spp. occur as accompanying elements in the *Cretirhynchia* Event, but also occur in bed UrS-106, together with *Peroniaster cf. coteau* and *M. aturicus* and, rarely, up to 16 m above the *Cretirhynchia* Event. *E. ex gr. conoidea – heberti* is rare, occurring in the *Cretirhynchia* Event (2 specimens) and in bed UrS-94, 7 m below.

**Bivalves:** Inoceramids are abundant, but they occur mostly as shell debris beds. The other characteristic bivalve element is the large oyster *P. vesicularis*.

**SELECTED SECTIONS IN THE AREA OF ECAY**

**Ecay E (middle Lower Campanian)**

The isolated exposure, about 400 m SE of Ecay (Text-Fig. 1C), is a forest track section at 554 m altitude. Here there is a poor exposure of ca. 14 m of highly glauconitic, silty sediments belonging to the Sarasate Formation. The contact with the underlying Izurdiaga Formation is overgrown (compare KÜCHLER 1998b, Text-fig. 27)

**Lithostratigraphy**

**Urrizola Member:** The basal 2.1 m of the succession consist of well-bedded, olive to violet-green glauconite-rich deposits with lenses of echinoids (*Micraster* sp. and *Conulus* sp.) in the uppermost 0.3 to 0.4 m. These beds are followed by 12 m of highly glauconitic, softer marls.
Integrated Biostratigraphy

The stratigraphical position of the section is not clear. It is presumed to equate with deposits representing the subzone of abundant *S. hippocrepis* to the brevis – humilis Zone of the Urriola II section. This is supported by the occurrence at Ecay E of small-sized *Micraster*, which may correspond to the *Micraster antiquus* Event in the Urriola EII section.

**Ecay I (Upper Campanian)**

Natural exposure, partly in erosional gullies, ca. 160 m south of the village of Ecay (Topographical map Ecay, sheet 114-12, 1: 10 000, R=592.770, H=4.751.100) (Text-fig.1C)

Despite the poor exposure, this is currently the only section in the Barranca that provides a continuous succession from the upper part of the *Trachyscaphites spiniger* Zone to the *Nostoceras (N.) hyatti* Zone. The section starts north of a track, at the field fences. The lowermost 8 m are not included in the graphic section (Text-fig. 12).

Lithostratigraphy

Two-thirds of the succession consist of fine silty, micaceous, clayey marls, with intercalations of thin beds of marlstone beds containing intraclasts and inoceramid horizons. In the upper third of the succession there is a change to silter to fine sandy, well-bedded sediments. With a decrease in thickness of the marly beds intercalations of more compact, dm-thick beds appear, representing high energy sediments.

*Member F (Clayey Marl Member)*: The base of the succession is composed of a 4 m thick unit of silty, clayey marls (not figured).

*Member G*: This member consists of 5 m of silty-glaucinitic marls (not figured) with three intercalated marlstone beds, ca. 0.2 m thick, containing inoceramid accumulations. The glauconite content, 10 to 30% at the base, decreases steadily upwards, and the quartz content in the silt fraction increases slightly from 10 to ca. 20%. The sediments are mixed carbonate-siliciclastic rocks, dominated by liuolid foraminifer (*Lituolacea*) and a diverse calcareous benthos. The similarly high proportion of planktonic foraminifer (*Glabrotuncana*) indicates a relatively deep environment.

*Ecay Member*: The ca. 42 m thick Ecay Member consists mainly of fine silty, clayey and micaceous marls with intercalations of marlstones (on average 0.2 m thick) and thin intraclast beds with an enrichment of heteromorph ammonites and/or inoceramids.

*Ecre Member I*: A distinct lithological change, with an increase in terrigenous input in the form of quartz, starts in bed Ecl-110. The member consists of a 9 m thick alternation of more compact (on average 0.3 m thick) marlstones/siltstones and m-thick silty and clayey marls. The quartz content in the silt fraction increases from ca. 5% in the underlying marls to ca. 30% in this member. Beds Ecl-110 to Ecl-112 are clayey siltstones, *i.e.* quartz-rich inoceramid packstones, which contain exclusively benthonic foraminifer dominated by quartz-agglutinating forms. "Calcispheres" and planktonic foraminifer are absent. Ecl-116 is an inoceramid floatstone containing mainly agglutinating foraminifer. The floatstone texture, with partly cross-bedded inoceramid debris, comprising fragments of various thicknesses, indicates a tempestite event.

*Ecre Member II*: At Ecay, a 12 m thick closely-spaced alternation of fine arenitic, 0.1 m thick marlstones and dm-thick silty marls is exposed above a 6.5 m gap. The lower part of the alternation is characterised by inoceramid beds or beds with inoceramid debris. These deposits are siliciclastic wackestones to packstones, with 12 to 15% quartz in the silt fraction, and up to 5% glauconite. The rocks are dominated by benthic foraminifer, which comprise equal proportions of agglutinating and milolid forms.

Fauna and integrated biostratigraphy

The fauna comprises assemblages of echinoids (*O. pilula*, *Echinocorys* ex gr. *conoidea*, *Micraster* (Isomicroaster) sp., *Diplodetus cretaceous*) ammonites and inoceramids. The ammonites and inoceramids tend to occur in distinct horizons.

The inoceramid-rich horizons were not intensively collected. As only a few well preserved specimens (identified by K.-A. TRÖGER) are illustrated (Pl. 18, Figs 1-4, 6), the ranges and relative abundances of the inoceramids shown in Text-fig. 12 are not representative.

Six ammonite zones are distinguished, in ascending order: *T. spiniger*, *P. phaleratum*, *N. (B.) polyplacum*, *T. pulcherrimus*, *N. (D.) archiacianum*, and *N. (N.) hyatti*.

The first two zones replace the *Echinocorys conica* Zone of KÜCHLER & KUTZ (1989, Text-fig. 6). The echinoid species *E. ex gr. conica* occurs only in clayey marls in the vicinity of Sarasate, at a level equivalent to the *spiniger* Zone. The *polyplacum* Zone of KÜCHLER & KUTZ (1989) is here divided into two zones, a lower *polyplacum* Zone and an upper *pulcherrimus* Zone. The *Didymoceras/E. conoidea* Zone is replaced by two zones, the *N. (D.) archiacianum* and *N. (N.) hyatti* zones.

*Trachyscaphites spiniger* PRZ: Although the index taxon has not been found in the Ecay I section, the presence of the *spiniger* Zone is inferred by analogy with the Ecay II section, 200 m farther to the south (see Text-fig 19). In the latter exposure, *T. cf. spiniger* (Pl. 11, Figs 7-9) was found at the top of a 4 m thick, glauconitic unit. The abundance level of *Conulus haugi* in this unit also enables correlation with the Sarasate III section (Text-fig. 19).
Fig. 12. Ecay I section, integrated litho-, bio- and event stratigraphy in the Upper Campanian; ranges of ammonites, echinoids and (not representive) occurrences of inoceramids.
fig. 6). At Sarasate the glauconitic unit with a C. haugi level lies in the higher part of the local E. subglobosa Zone, or in the upper part of the Hoplitoplacenticeratites marrioti Zone, at the level of the E. conica/subglobosa/Event (compare Text-figs 6, 19).

**Pseudoxybeloceras phaleratum** PRZ: The base of the zone is defined by the FAD of *P. phaleratum* (see Pl. 12, Figs 11 -17) in bed EcI-94. In the lower part of the zone the index taxon occurs associated with *Pseudoxybeloceras* (*P.* sp., *Menites portlockii* (SPATH), *Scaphites gibbus* SCHLÜTER and smooth *Baculites* sp. 4. In the studied section the local LAD of the index ammonite corresponds to the FAD of *N. (B.) polyplocum*.

**Nostoceras** (Bostrychoceras) *polyplocum* PRZ: The base of the zone is defined by the FAD of the index ammonite in bed EcI-101b. In the lower half of the zone a few extremely large "german-type" forms of *N. polyplocum polyplocum* occur, i.e. macroconchs with over-sized tubercles on the last whorl and body chamber. *Nostoceras* (*E.*) *euskadiense* I (Pl. 13, Figs 2-6), the characteristic form of the zone, enters 5 m higher and ranges into the middle third of the zone. Rare *Nostoceras* (*E.*) *unituberculatum* (BLASZKIEWICZ), *Nostoceras* (*D.*) *depressum* (WIEDMANN), *T.* cf. *spiniger*, and *Hoplitoplacenticeratites* cf. *costulatum* (SCHLÜTER) are associated with *N. (E.) euskadiensi* I. The middle third of the zone is characterised by the abundance of the strongly ribbed *Baculites alavensis* SANTAMARIA (SANTAMARIA 1996, KLINGER & KÜCHLER 1998). *Pachyscluchos haldeanis* is also common. In the upper part of the *polyplocum* Zone ammonites are extremely rare.

**Trachysclaphtes pulcherrimus** PRZ: In more distal sections, such as Ecay, the lower boundary of the zone, based on the Erice III section, is taken at the FAD of the subspecies *N. (E.) euskadiensi* II. The subspecies occurs together with *N. (B.) polyplocum polyplocum* (see Pl. 13, Fig. 1; Pl. 14, Fig. 3).

**Nostoceras** (Didymoceras) *archiacianum* AZ: The base of the zone in the Ecay I section is identified by the FAD of *Neancylcoceras* aff. *navarresi* (SANTAMARIA 1996, KLINGER & KÜCHLER 1998), *N. diymoceras* sp. 2 (Pl. 16, Figs 7-9) in bed EcI-119b. *N. (Didymoceras)* sp. 2 (Pl. 16, Fig. 6) and *N. (Didymoceras)* sp. 3, which are typical of the zone, appear at the same level. *N. (Didymoceras)* sp. 2 resembles the specimens figured by ZABORSKI (1985, Figs 12-13 only) as *Didymoceras* aff. *hornbyense* (WHITEAVES).

Other forms present include *B. alavensis*, *Gaudryceras mite* (VON HAUER) and a fragment of the large-sized *Nostoceras* (*Didymoceras*) sp. 5. The topmost part of the zone has yielded a single, poorly preserved specimen of *T. pulcherrimus* and a single specimen of *Nostoceras* (*Didymoceras*) sp. 4.

**Nostoceras** (Nostoceras) *hyatti* AZ: The base of the zone at Ecay is placed at the FAD of *Nostoceras obtusum*. *N. hyatti* appears only 3.5 m above this level (see discussion of the boundary below).

**Event stratigraphy**

**Pseudoxybeloceras phaleratum Beds**: The two abundance maxima of pseudoxybeloceratids are linked to two dm-thick pebble horizons in a 1.9 m thick unit (beds EcI-94 to EcI-96) (see Text-fig. 12). These yielded *P. phaleratum* and pseudoxybeloceratids resembling *P. wernickei* of authors.

**Inoceramid event**: This event is represented by a conspicuous bed (EcI-100) with a mass-occurrence of inoceramids that have not yet been identified. It lies within the *P. phaleratum* Zone, above the two *P. phaleratum* horizons. A probable equivalent of this inoceramid event is known from the vicinity of Erro in eastern Navarra, 32 km away (KÜCHLER & KUTZ, in prep.).

**Offenter pilula Event III**: It is a 8-9 m thick interval in which the index taxon is abundant, representing the third Campanian acme-horizon of *O. pilula* in the Barranca. The associated echinoids are *Echinocorys* ex gr. *conoidea* and *Diplodactys cretacea*.

**Nostoceras** (*E.*) *euskadiensi* Events: This event-bundle comprises four, closely-spaced, storm event deposits within a 5 m thick interval between beds EcI-103b and EcI-108. These are, in ascending order; the *euskadiensi/haldemis*, *euskadiensi* I and II events, and an inoceramid/baculitid bed at the top. The species *N. (E.) euskadiensi* I and/or *B. alavensis* dominate within the event deposits.

The event deposits display a similar internal structure to the shell-bank sequence described by AIGNER (1985). An unfossiliferous, indurated marlstone bed, some cm-thick, is overlain by a one cm-thick horizon of intraclasts (floatstones composed of sand-agglutinating benthic foraminifer). Still higher follows a cm-thick fossiliferous, i.e. ammonite-rich, horizon which may terminate in an inoceramid layer.

The taphocenoses are composed mainly of heteromorph ammonites. There is a complete lack of scaphitids in both the event-beds and the background sediment. Some of the intraclasts beds wedge out very quickly to the west. The macrofossils are patchily distributed and tend to occur in nest-like accumulations. Some of the nostoceratids occur completely preserved in both horizontal as well as in vertical position.

The fragments mostly consist of either the first three whorls or the last whorl including the body chamber. The minute spines of the bostrychoceratids are partly preserved as external moulds in the sediment. Fragments of the phragmocone and the body chamber are often found close together.

**Nostoceras** (Bostrychoceras) *polyplocum* Events: At Ecay, this event bundle represents the distal equivalents of the event beds exposed at Erice de Iza. It is characterised by an enrichment of baculitids (*B. alavensis*) and nostoceratids (*N. euskadiensi* II) in a ca. 3 m thick interval. In the western part of the section (not shown), on the eastern bank of a brook
(EB=brook section), this interval is rich in fossils. In the lower part three 0.05 to 0.10 m thick intraclast horizons (EB1–EB2) are intercalated separated by hard, 0.6–0.7 m thick clayey marls. In the clayey marls, the ammonites are relatively complete but immediately above the intraclast layers they are preserved only as fragments. In the eastern part of the section, the intraclast layers are absent and the equivalent interval, between beds EcI-110 and EcI-112, contains three poorly fossiliferous harder beds. The entire interval corresponds to beds EB0–EB3 of the brook section.

_Nostoceras_ (Didymoceras) archiacianum Event I: This event is marked by a lag deposit of green-coated pebbles and fragments of _B. alavensis_, _Pachydiscus_ sp., _Nostoceras_ (Didymoceras) spp. and _N. aff. bipunctatum_.

AMMONITE ZONATION IN NAVARRA AND ITS CORRELATION WITH REGIONAL AND OTHER EUROPEAN STANDARD ZONATIONS

Based on new ammonite material from the Barranca and from the area west of the Basque Oroz-Betelu Massif (see also Kutz 1995; Küchler & al, in press) the zonation of Küchler & Kutz (1989) is significantly refined in this paper. A subdivision of the Campanian to Lower Maastrichtian interval of northern Spain into a succession of ten partial range and assemblage zones is proposed, based on bed-by-bed collecting from several measured sections. The correlation of the zonation with regional schemes and the standard zonations applied in France (Kennedy 1986), Germany (Schulz & al. 1984) and Poland (Blaszkiewicz 1980) (see Text-fig. 16) will be discussed.

Basal Campanian (unnamed interval)

Because of extensive hiatus at the Santonian/Campanian boundary resulting from the Wernigerode tectonic movements _sensu_ Stille (1924), the basal Campanian is largely missing in Navarra and in many other areas of northern Spain. In the Barranca, the hiatus spans the equivalents of the _granulataquadrata_ and _lingua/quadrata_ Zones of the zonal scheme used in northern Germany.

In northern Spain, this boundary hiatus is generally overprinted by younger events, resulting in even larger hiatus. The Campanian successions hence usually start with the middle Lower Campanian _S. hippocrepis_ III Partial Range Zone (=PRZ). In this context, the _S. hippocrepis_ Zone of Wiedmann (1979) does not represent the lowermost Campanian, but is the lowest zone, which can be recognised locally.
Scaphites hippocrepis III Partial Range Zone

The base of the zone is defined at the FAD of S. hippocrepis (DeKay) III COBBAN. Based on new data, the base of the hippocrepis Zone, as distinguished in Navarra by KÜCHLER & KUTZ (1989), has to be shifted down to the base of the exposed Campanian succession in the Sarasate I section (Text-fig. 2). The FAD of the index species there is just above the basal hardground, but below the level of the Offaster pomeli Event. Consequently, the local O. pomeli/M. (Isomicraster) sp. Assemblage Zone (=AZ) falls within the range of S. hippocrepis and in the herein introduced hippocrepis III PRZ (Text-fig. 14). In most parts of the zone, S. hippocrepis is rare and found associated only with Neancyloceras (Schlueterella) sp., Glyptoxoceras sp. and unidentified nostoceratids. It occurs more commonly in the higher part of its zone in the Sarasate II section (Text-fig. 4).

Specimens of S. hippocrepis from the O. pomeli/M. (Isomicraster) sp. Zone are small forms with small lateral ribs and poorly developed ventrolateral tubercles on the spire, displaying the characteristics of COBBAN’s (1969) subspecies hippocrepis III. On the other hand, the rounded ventro-lateral tubercles, developed only on the hook, indicate a rather early form of this subspecies. The presence of early and late forms of S. hippocrepis III in succeeding levels, and the distinct ammonite faunas that accompany or replace them, allows a subdivision of the European hippocrepis Total Range Zone (=TRZ) into a S. hippocrepis III PRZ and a S. hippocrepis III/Menabites spp. AZ (Text-figs 14, 16). Early forms of S. hippocrepis occur in marginal parts of the eastern Barranca. In distal areas, they are replaced by a fauna of dominant Glyptoxoceras spp. which, in the western Barranca, comprises Glyptoxoceras cf. aquigranense (SCHLÜTER), Pachydiscus duelmensis (SCHLÜTER) and Baculites sp.

WIEDMANN (in GISCHLER & al. 1994, p. 210, Text-fig. 2) correlated the O. pomeli/M. (Isomicraster) sp. Zone with his Spanish Bevalhites subquadratus Zone. The index species, B. subquadratus COLLIGNON and Submortoniceras tenuicosulatum COLLIGNON, have, however, not yet been found in Navarra. On the other hand, S. hippocrepis does not occur at this stratigraphic level in the Burgos Region, presumably due to its preference for shallower environments.

<table>
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<tr>
<th>Substages</th>
<th>Ammonite Zones</th>
<th>Local echinoid partial range zones, park zones, and ammonite/echinoid assemblage zones</th>
<th>Inoceramid Assemblages</th>
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<td>Pachydiscus neubergicus/</td>
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<td>Platyceramus aff. alaeformis</td>
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<tr>
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<td>LOWER</td>
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<td>Subzone of “abundant” Scaphites hippocrepis</td>
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<tr>
<td>Santonian</td>
<td>Scalarites cingulatum</td>
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Fig. 14. Upper Santonian to Lower Maastrichtian integrated biostratigraphy of the Barranca
It cannot be excluded that the Spanish *subquadratus Zone sensu* Wiedmann already falls into the basal part of the range of *S. hippocrepis III*, since Wiese & al. (1996) reported one *B. subquadratus*, *S. hippocrepis III* and *Gyptosoceras retrorsum* (Schütter) from the basal 3.0 m of the so-called Holaster similis Marl from Langre (Cantabria), which confirms the above statement. At Langre, the fauna occurs above a hardground that, as in the Barranca, incorporates a significant hiatus, including at least the lowermost Campanian. The occurrence of *S. hippocrepis III* dates the onset of sedimentation as mid-Early Campanian in that area.

**Germany and southern England:** The *pomeli/M. (Isomicraster)* sp. AZ of the Barranca corresponds to the interval of the *hippocrepis III* PRZ. It was assumed to correlate with the middle Lower Campanian and regarded as equivalent to the upper part of the *Offaster pilula Zone* or basal *Galeola senonensis Zone* used in north-west Germany and southern England (see Küchler & Kutz 1989). The interbasinally correlatable *Offaster Event* serves as a correlation datum.

In the eastern Barranca, the peak occurrence of *O. pomeli (= pomeli Event*) is located within an acme-zone of *Micraster (Isomicraster)* sp. In this interval, *O. pomeli* is associated with *Echinocorys scutata cincta* Brydone and *Micraster corcularium Desor*. This echinoid assemblage, together with the *Offaster Event*, correlates with the higher part of the *pilula Zone* recognised in southern England (Gaster 1924, Bailey & al. 1983) and the top of the *pilula to pilula/senonensis Zone* of Lägerdorf (Ernst 1963a, Schulz & al. 1984) and Lower Saxony (Ernst 1963b, Tab. 1; 1970a) in northern Germany. Comparable faunas to those of Navarra are described from the above-mentioned areas. In southern England, an association with *O. pilula* and *E. cincta* occurs, whereas the German successions are characterised by an assemblage of *O. pilula* and *Micraster (Gibbaster) gibbus* (Lamarck). In the Barranca, the *Offaster Event* is marked by a peak occurrence of *O. pomeli*, in Germany by an assemblage of *O. pilula* together with *O. pomeli*, and in southern England by *O. pilula* only.

In northern Germany, the *Offaster Event* lies above the FAD of the index ammonite *Placenticeras bidorsatum*, which is restricted to the *granulataquadrata Zone* (lowermost Upper Campanian) in Lower Saxony (Hanover-Braunschweig area). There, *P. bidorsatum* occurs together with *Eupachydiscus isculensis* (Ernst & al. 1979, Fig. 11). In addition, Müller & Wollemann (1906) reported *Hauericeras pseudogardeni* (Schütter), *Scaphites binodosus* Roemer and *Crioceras serta [= Scalarites cingulatum (Schütter)] from the Braunschweig area. The source locality at Broitzen was
assigned by Ernst (1968) to the basal Lower Campanian (granulataquadrata Zone).

A comparable ammonite fauna occurs in the area of Dülmen (Westphalia), from where an association of P. bidorsatum, Pachydiscus duelmensis (SCHLÜTER), H. pseudogordani, Tetragonites obscurus (SCHLÜTER), S. bino-
dosus, Scalarites cingulatum and Gomioeuthus quadrata was described by SCHLÜTER (1871-1876). KENNEDY &
KAPLAN (1995) revised this fauna and assigned it to the granulataquadrata to lingu/quadrata Zone (Lowermost
Campanian). However, they doubted the occurrence of P. bidorsatum in the lower granulataquadrata Zone in
Westphalia and proposed that it ranged no higher than the lingu/quadrata Zone.

The Offaster Event lies stratigraphically below the FAD of S. hippocrepis III, both in southern England
(BAILEY & al. 1983, Fig. 3) and Lower Saxony (SCHMID & ERNST 1975, Fig. 2; ERNST & al. 1979, Fig. 11), where S. hippocrepis was found in the uppermost Lower Campanian (e.g. conica/papillosa Zone = conica/gracilis
Zone sensu SCHULZ & al. 1984).

In Westphalia, S. hippocrepis III occurs already in the senonensis Zone, or possibly even lower, in the pilula
Zone (WIPPCHE 1994, 1995) (Text-fig. 15). Single finds of S. hippocrepis with features typical of S. hippocrepis II are reported to occur as low as the lingu/quadrata Zone.

France: The Offaster event lies stratigraphically below the FAD of S. hippocrepis III, both in southern England (BAILEY & al. 1983, Fig. 3) and Lower Saxony (SCHMID & ERNST 1975, Fig. 2; ERNST & al. 1979, Fig. 11), where S. hippocrepis was found in the uppermost Lower Campanian (e.g. conica/papillosa Zone = conica/gracilis
Zone sensu SCHULZ & al. 1984).

In Westphalia, S. hippocrepis III occurs already in the senonensis Zone, or possibly even lower, in the pilula
Zone (WIPPCHE 1994, 1995) (Text-fig. 15). Single finds of S. hippocrepis with features typical of S. hippocrepis II are reported to occur as low as the lingu/quadrata Zone.

P. bidorsatum has not yet been found in Spain, possibly
due to its limited geographic distribution: It has been
recorded so far from France (Santonian and Campanian
type areas), Germany (Lower Saxony, Westphalia) and
from the Gosau in Austria (SUMMESBERGER 1979, 1985).

In the northern Aquitaine P. bidorsatum occurs in an interval (Assise P1 and P2 sensu ARNAUD 1878) that was
referred to the P. bidorsatum and Menabites (Delawarella)
delawarensis zones by KENNEDY (1986). An intermediate
form between S. hippocrepis II and III occurs in Assise P1
sensu lato (KENNEDY 1986), and DE GROSOUVRE (1901)
recorded S. hippocrepis just above the FAD of P. bidorsat-
um in P1b.

The French bidorsatum Zone appears to comprise the entire Assise P1 unit. However, if the FAD of S. hippocre-

Scaphites hippocrepis III/Menabites spp. Assemblage Zone

The zone is characterised by advanced forms of S. hippocrepis III, characterised by ventro-lateral tubercles

that extend from the spire to the hook and are clavate in macroconchs, as in typical hippocrepis III sensu COBBAN
(1969). These larger forms replace the generally small-
sized forms that occur in the underlying hippocrepis III
PRZ or pomelii/M. (Isomicraster) sp. AZ.

The appearance of Menabites, and the species M. (D.)
delawarensis, is less significant, as Menabites is extremely
rare in northern Spain and central Europe. The scarce
finds from the Barranca come from different localities.

At Urrizola Menabites (Delawarella) subdelawarensis (PL 7,
Fig. 1) is found associated with S. hippocrepis III (PL 8,
Figs 3, 5, 6), Pachydiscus sp., Eupachydiscus leyi (PL 7,
Fig. 2), Menabites ??nov. (PL 8, Figs 7, 8), distantly and
strongly ribbed Baculites sp. 1 and nearly smooth
Baculites sp. 2. A single find of Menabites (Australiella)
australis (PL 8, Fig. 1) comes from the Arardi section
(2.5 km south-east of the village of Erroz (see
Text-fig. 1C), and the single finds of M. (D.) campaniense
and Submortoniceras sp. [probably Submortoniceras con-
damyi COLLIGNON; H. C. KLINGER, pers. comm. 1997]
came from the Sarasate II section (Text-figs 1b, 4).

In the uppermost part of the hippocrepis III/Menabites
spp. AZ (compare Sarasate Ib, Text-fig. 3), still in the
uppermost Lower Campanian, a late form of S. hippocre-

pis enters. This late form, following the nomenclature
applied by COBBAN (1969), is called subspecies hippocrepis IV (KUCHLER 2000a). Macro- and microconchs of
this new subspecies differ from those of hippocrepis III in
possessing five bullate to conical umbilical tubercles and
strongly clavate ventro-lateral tubercles on the body
chamber. This subspecies characterises the lowermost
Upper Campanian Hoplitoplacenticeras marroti Zone of the
Barranca (compare Sarasate Ib and Sarasate IV, Text-
figs 3, 5). In the Barranca, its exact range within the Lower
Campanian is poorly documented. Consequently, despite its stratigraphical potential, S. hippocrepis IV has not
been used for zonation. However, it may well be possible that
this interval equates, at least in part, with the Scaphites gibbus
Zone of Westphalia (ARNOLD 1964) and the gibbus
Zone sensu SCHMID & ERNST (1975) of Lower Saxony.
The lower part of the hippocrepis III/Menabites spp. AZ. (= Subzone of abundant S. hippocrepis) obviously correlates with the upper part of the E. levyi, S. hippocrepis and Neocrioceras riosi assemblage Zone of the Spanish province of Burgos (Rio Losa valley) (Wiedmann in Gisclier & al. 1994, Text-fig. 2; compare also Text-fig. 15).

Wiedmann's zone is based on only a few specimens from several, widely spaced localities in Alava and Burgos. The lower part of his zone, characterised by marls and marly limestones, is exposed near the villages of Villamedrones, Nocedo and Quintanilla de Ojada (Burgos). These successions yielded Neocrioceras (Schlueterella) riosi Wiedmann, Pachydiscus (P.) precolligatus Collignon and Pachydiscus (P.) cf. bassae (Collignon). From the second level, the limestones of Quintana (alava), Wiedmann quoted E. levyi and Eupachydiscus grossouvrei (Kossmat), and the only find of S. hippocrepis came from west of the road between the villages of San Millán de San Zadornil and Acebedo near Bovedo/Alava (Locality 21 sensu Wiedmann 1962, p. 216 or "Fundpunkt 245" of Radig (1973, p. 23; Text-fig. 16).

The hippocrepis III/Menabites spp. AZ of the Barranca also equates with the "Lower Sponge Rhythmites" of Langre (Cantabria), in the hippocrepis III Zone of Wiese & al. (1996).

This unit has yielded an assemblage comprising S. hippocrepis, M. (D.) delawarrensis and Pachydiscus cf. launayi de Grossouvre, with Submortoniceras tenuicosutatum and S. gibbus Schlueter occurring at the top of the unit.

In Germany, both Menabites (Delawarella) and Submortoniceras are absent (compare Lommerzhem 1995; Wippich 1995) and the genus Hoplitoplacenticeras is considered to be an unequivocal index for the Upper Campanian. The Gober fauna should therefore be understood as being mainly early Late Campanian in age, with part at least falling into the early Late Campanian so-called Overlap-Zone, i.e. the gracilis/mucronata Zone of Schmid & Ernst (1975, Fig. 2). This latter zone has yielded S. hippocrepis, S. gibbus, S. cobbani and Bostrychoceras (Mobergoceras) junior Schmid & Ernst.

The hippocrepis III/Menabites spp. AZ of the Barranca thus correlates with only the lower part of the delawarrensis Zone sensu lato in France and the USA. Its upper boundary is taken at the FAD of H. marroti.
Fig. 16. Comparison of the European Campanian to Lower Maastrichtian cephalopod zonations and typical ammonite assemblages; zones are not to scale; zonal indices are underlined; other quoted taxa are abundant and/or significant for correlation; proposed ammonite zonation for Lower Saxony based on authors cited and on material in the collection of G. ERNST, FU Berlin.
Zone interval. In addition, Tetragonites obscurus (SCHLÜTER), Pseudoxybelocera (Pseudoxybelocera) quadrinodosum (JIMBO), Hauericeras cf. welschi de GROSSOUVRE, Pachydiscus launayi de GROSSOUVRE, Pachydiscus cf. letensiss (SCHLÜTER), Baculites sp. A, Baculites sp. B, Scaphites cobbani BIRKELUND and the first representatives of S. gibbus are recorded from the uppermost part of the zone (WIPPICH 1994, p. 65; WIPPICH 1995, Text-fig. 3).

**Hoplitoplacenticeras marroti Partial Range Zone**

The marroti PRZ in northern Spain was first documented in the Sarasate sections of the Barranca, where there is a rich zonal fauna (KÜCHLER & KUTZ 1989; Text-fig. 3). H. marroti occurs there in a similar assemblage and at a similar stratigraphical level as in Ariège, France (KENNEDY, HANSOTTE & al. 1992b). The base of the zone at Sarasate, defined by the FAD of the index taxon, coincides with the local FAD of Pachydiscus haldemsi. This horizon is accurately positioned, within an event stratigraphical framework, between two abundance-levels of O. pilula. In the Barranca, the marroti Zone is characterised by the rather limited range, albeit common occurrence, of the zonal index.

The ammonite fauna of the marroti PRZ (Text-fig. 5) comprises mainly heteromorphs. Glyptoceratids occur commonly, represented by a form that is closest to G. retrorsum and treated here as a small-sized variant of SCHLÜTER's species. Other heteromorphs in the fauna are Baculites sp. 1, Baculites sp. 3, and S. hippocrepis IV.

In the Barranca, S. hippocrepis IV persists to the middle part of the Echinocorys subglobosa Zone (Text-fig. 5). In the Urdiroz/Imiscoz area, this species was found just below the FAD of T. spiniger (see KUCHLER & KUTZ 1989, Text-fig. 5, KUTZ 1995).

**Trachyscaphites spiniger Partial Range Zone**

The base of the second Upper Campanian ammonite zone proposed herein is taken at the FAD of Trachyscaphites spiniger (Text-fig. 16). WIEDMANN (1979) already introduced a spiniger Zone for northern Spain but placed it in the basal part of the Upper Campanian. He later redefined it as the H. marroti & T. spiniger Zone (see GRAFE & WIEDMANN 1993, Text-fig. 24). GRAFE (in GRAFE & WIEDMANN 1993 and GRAFE 1994, Text-fig. 14) placed the base of the H. marroti & T. spiniger Zone still lower and correlated it, based on a sequence stratigraphical interpretation, with the Menabites delawarensis Zone sensu HAQ & al. (1987) or HANCOCK (1991). This can be shown to be incorrect in northern Spain. The investigations in Navarra, and also in Alava by SANTAMARIA (1996), show that T. spiniger, as in Germany, enters well above the FAD of Hoplitoplacenticeras.

T. spiniger is common both in the Barranca and in the area west of the Oroz-Betelu Massif (=Urdiroz/Imiscoz area, compare Text-fig. 1E), (see KUTZ 1987, 1995; KUCHLER & KUTZ 1989). However, the base of the spiniger Zone can be placed precisely at present only in the area of Urdiroz/Imiscoz. The boundary there lies about 20-23 m above the red Santonian dolomites of the Urdiroz I section of KUTZ (1995), on the track from the C-127 to the village of Urdiroz. In this area, T. spiniger appears just below the Echinocorys conica Peak of KUCHLER & KUTZ (1989). This event, which is termed the Echinocorys subglobosa/E. conica Event in this paper, is traceable over a distance of about 40 km. It marks the base of the local E. ex gr. conica Zone in the Barranca (Text-fig. 5), which equates with the Pachydiscus haldemsi / Echinocorys conoides Zone of the Urdiroz/Imiscoz area. In the Sarasate IV section, the event lies (Text-fig. 5) ca. 29 m above the FAD of H. marroti.

In the marly facies of the Urdiroz/Imiscoz area, the most common ammonite of the spiniger Zone (=lower part of the haldemsi/conoides Zone sensu KUTZ 1987 and KUCHLER & KUTZ 1989) is P. haldemsi. In the Juanedehaco I section, this species is associated with H. sp. cf. marroti and strongly deformed baculitids. In the Imiscoz area, Belgium and Germany: The ammonite fauna of southwestern France represents an intermediate assemblage between those of northern Spain and the German-Belgian border area (compare JAGT & al. 1995). In the latter area, JAGT & al. (1995) cited H. marroti, Pachydiscus subrobus tus (SEUNES) and S. hippocrepis III from the middle Lower Campanian to basal Upper Campanian Vaals Formation; and reported S. gibbus from the succeeding Zeven Wegen Member (Gulpen Formation).
area (Text-fig. 1E). *P. haldemsi*s first occurs ca. 3 to 4 m above the subglobosa/conica Event (compare KUTZ 1995)

T. cf. spiniger is common in the marginal, glauconitic facies of the Barranca (near Urrizola and south of Ecay – Text-figs 1C, 19), where it is associated with *Pachydiscus* sp., *Tetragonites* sp., and *Saghalinites* sp. It is extremely rare or even absent in the clayey marl facies of distal areas of the Barranca (e.g. Sarasate IV section – Text-fig. 5).

**Germany:** The *spiniger* Zone of northern Spain corresponds to the *Patagiosites* [*Pachydiscus* stobaei/Galeola papillosa basiplana Zone of SCHMID & ERNST (1975) (= papillosa basiplana/spiniger Zone of SCHULZ 1985) (Text-fig. 16).

In the white chalk facies of Lower Saxony, *T. spiniger* occurs commonly only in the middle part of the zone, where it is associated with *Hoplitoplacenticeras vari*.* T. spiniger* is absent from the underlying *Echinocorys conica/Beleninitella mucronata* Zone, which has yielded a rich scaphitid fauna, including *S. gibbus* associated with *Hoplitoplacenticeras dolbergense* (SCHLÜTER).

*T. spiniger* likewise first enters in the lower part of the *stobaei/basiplana* Zone (SCHULZ 1978, p. 80; SCHULZ & al. 1984, p. 213) in the north German standard section at Lägerdorf, but it is documented by only a single specimen. The type locality of *T. spiniger*, Darup in Westphalia, is also assumed to correlate with the interval between the *stobaei/basiplana* Zone and the *vulgaris/basiplana* Zone (ERNST 1971, p. 173). In eastern Münsterland, *T. spiniger* is absent (GIERS 1964, p. 285; WOLF 1991, Text-fig. 5).

**Pseudoxybeloceras phaleratum** Partial Range Zone

The base of the zone is defined by the FAD of *P. phaleratum* (GRIEPENKERL); the zone in Navarre is marked by an acme-occurrence of the index species together with a small-sized *Pseudoxybeloceras* sp. that resembles *Pseudoxybeloceras* wernecki (WOLLEMAN) of authors. In the Ecay I section (Text-fig. 12), the smooth *Baculites* sp. 4 and *Menites portlocki* (SMITH) occur less commonly. The first record of *Trachyscaphites gibbus* from Navarra came from that zone. In a more proximal section near Ecay (not figured), *P. phaleratum* occurs associated with *Hoplitoplacenticeras* sp. and *T. cf. spiniger*.

In the Juandezehco III section (KUTZ 1995, Text-fig. 5) of the Urdiroz/Imísoz area (Text-fig. 1E), *P. phaleratum* appears around beds B7 to B8, where it is associated with *P. haldemsi*s and *Pachydiscus subrobustus* (SEUNES); in the Urdiroz I section of KUTZ (1995, Text-fig. 6) *P. phaleratum* occurs in Bed A, at about the 40 m level, a few metres below the FAD of *N. (Bostrychoceras)* *polyplocum* (KÜCHLER & KUTZ, in prep.). The zone has also been proved south of the village of Erro (Text-fig. 1E), where single specimens of *P. cf. phaleratum* co-occur with *T. spiniger* and *P. haldemsi*s.

**Germany:** The ammonite assemblage of the *phaleratum* Zone is comparable to that of the upper Vorhelm Beds in Westphalia (GIERS 1964), which are assumed to correlate with the upper *Galerites vulgaris* Zone of northern Germany (compare Text-fig. 16). GIERS (1964) reported the following forms from the upper Vorhelm Beds (nomenclature revised by KAPLAN & al. 1996): *Hoplitoplacenticeras vari* (SCHLÜTER), *H. costulosum* (SCHLÜTER), *Pachydiscus haldemsi*s (= *P. koeneni* DE GROSSOUVRE), *Patagiosites stobaei* (NILSSON) [= *Pachydiscus patagosius* (SCHLÜTER)], *Pachydiscus subrobustus* SEUNES, *Pachydiscus* sp. [= *Menites auritocostatus* (SCHLÜTER)] and baculitids. KAPLAN & al. (1996) additionally quoted *Scaphites gibbus* and *Phylloceras bodei* (MÜLLER & WOLLEMAN).

In the Teutonia Quarry of Lower Saxony, the *vulgaris* Zone is characterised by single specimens of *P. phaleratum* and *T. spiniger* (compare KHOSSROVSCHAHIAN 1972).

**Poland:** Direct correlation of the *phaleratum* Zone is also possible with the Middle Vistula section, Central Poland (compare Text-fig. 16). The *phaleratum* Zone of the Barranca corresponds to the upper part of the *phaleratum* Zone sensu BLASZKIEWICZ (1980, p. 13), because BLASZKIEWICZ (1980) defined his *phaleratum* Zone with the appearance of *T. spiniger spiniger*, whereas *P. phaleratum* first enters in the upper part of the zone. This latter interval, contains, besides the index taxon, *T. spiniger* posterior BLASZKIEWICZ and *Pachydiscus haldemsi*s.

**Nostoceras (Bostrychoceras) polyplocum** Partial Range Zone

The base of the zone is defined by the FAD of the species *N. (B.)* *polyplocum*. KÜCHLER & KUTZ (1989) cited the abundance in Navarra of a second species, *Nostoceras* (*Euskadiceras*) *euskadiense* KÜCHLER (= *Bostrychoceras* sp. nov. sensu KÜCHLER & KUTZ 1989), which appears slightly later. In the absence of the zonal index, this species can be used to define the lower part of the *polyplocum* Zone in northern Spain. It also occurs in the Aquitaine, France, where it was figured by KENNEDY (1986) as *N. (B.)* *polyplocum*.

*N. (B.)* *polyplocum* and *N. (E.)* *euskadiense* represent two distinct evolutionary lineages differing in the curvature of the body chamber, mode of tuberculation and size in relation to the size of ribs (Pl. 13). In Navarra, *N. (B.)* *polyplocum* is rarer than in northern
Europe and, compared to specimens from Germany, markedly smaller.

In the Barranca, the polypliocum Zone is currently well exposed only near Ecay, where it is about 22 m thick. It also occurs in the centre of the village of Sarasate and in the motorway-cutting east of the petrol station between Sarasate and Erice de Iza (Text-fig. 1D). At Ecay, N. (B.) polypliocum enters ca. 5 m below the first appearance of N. (E.) euskadiense and ranges up to the Nostoceras (Didymoceras) archiacianum Zone. The subspecies N. (B.) polypliocum schluteri of BLASZKIEWICZ (1980, Pl. 2, Figs 1, 4, 9-11) is represented by two un-horizoned specimens from the area of Sarasate. The lower part of the polypliocum Zone is characterised by the rare occurrence of *P. haldemsi*, *Pseudoxybeloceras* sp., *N. (B.)* polypliocum polypliocum and the subspecies N. (E.) euskadiense I. The latter species, as well as the strongly ribbed Baculites alavensis (see also KLINGER & KUCHLER 1998), have their maximum occurrences in the middle part of the zone, where *Nostoceras (Didymoceras) depressum* (WIEDMANN), N. (E.) unituberculatum (BLASZKIEWICZ) and Gaudryceras mitre (VON HAUER) first appear. *Pachydiscus haldemsi* is relatively common in this interval, which has also provided the highest record of a T. cf. spiniger.

A comparatively thick polypliocum Zone succession, estimated at 25 to 70 m, is developed in the calcareous marl facies of the Urdiroz/Imiscoz and Erro areas, eastern Navarra. In the Urdiroz III section, near the village of Urdiroz (KUCHLER & KUTZ, in prep.), the lower part of the zone is characterised by N. (E.) euskadiensi I, *B. alavensis* and *P. haldemsi*. N. (E.) euskadiensi I is found there within a succession of debris flows that contain especially abundant baculitids. In the upper part of the zone, exposed at Imiscoz (Juandechaco I section of KUTZ 1987, 1995), only N. (B.) polypliocum polypliocum occurs (compare KUCHLER & al., in press, Text-fig. 2).

**Remarks on the ammonite fauna:** Most of the European nöstoceratid species that occur in an interval corresponding to the upper polypliocum Zone and lower donezianum Zone sensu BLASZKIEWICZ (1980), represent intermediate forms between *Bostrychoceras* HYATT and *Didymoceras* HYATT. This means that a clear distinction between the two genera, using the criteria of HYATT strictly, i.e. the type of phragmocone coil (closely or loosely coiled) and the type of tuberculation (the permanent absence or presence of a bituberculation in the early and late ontogenetic stages), is impossible. Hence a simplification of the generic classification of these forms as applied by KENNEDY & SUMMESBERGER (1984) is adopted herein, with both *Bostrychoceras* and *Didymoceras* being regarded as subgenera of the genus *Nostoceras*.

In the case of N. (B.) polypliocum, the interpretation of WIEDMANN (1962) and BLASZKIEWICZ (1980, p. 13) is followed, interpreting it as a stratigraphically restricted species differentiated into several geographical and chronological subspecies, and clearly distinct both from co-occurring forms such as *N. (Euskadiceras) unituberculatum* and N. (E.) euskadiensi, as well as from evolutionarily successive forms such as *N. (Didymoceras) archiacianum* (d’ORBIGNY).

In the Middle Vistula section, BLASZKIEWICZ (1980) demonstrated the occurrence of two subspecies of *N. (B.) polypliocum*, i.e. the nominative subspecies and N. (B.) polypliocum schluteri. The two subspecies may also be distinguished in the polypliocum material from Navarra. N. (B.) polypliocum polypliocum, according to BLASZKIEWICZ (1980, Pl. 1, Figs 1-9; Pl. 2, Figs 2-3, 5-6), is characterised by the absence of tubercles and by the presence of simple, closely spaced ribs that can bifurcate at the junction of the outer and lower whorl face in early phylogenetic stages. Evolutionarily more advanced forms display either two weakly developed rows of small tubercles (micro-tubercles) or only a lower row of well developed tubercles corresponding to WIEDMANN’s (1962) concept of the subspecies polypliocum. The forms with a lower row of strong tubercles may also possess a very poorly developed upper row of tubercles. In northern Spain, in contrast to Poland, the nominative subspecies occurs at the base of the polypliocum Zone and ranges up into the *N. (Didymoceras) archiacianum* Zone, with local abundance peaks in the upper part of the polypliocum Zone and lower part of the succeeding *pulcherrimus* Zone. BLASZKIEWICZ’S subspecies schluteri, documented in northern Spain for the first time by two specimens, is assumed here to represent an essentially Boreal geographical subspecies that migrated southwards occasionally.

**Poland:** BLASZKIEWICZ (1980) recognised three informal subdivisions (lower, middle and upper) of the polypliocum Zone, of which the lower one corresponds to the polypliocum Zone of northern Spain (Text-fig. 16). N. (E.) unituberculatum seems to have its main concentration in the middle Vistula valley of Central Poland, with rare occurrences noted in Austria (compare KENNEDY & SUMMESBERGER 1984, Pl. 9, Figs 12-13), and Lower Saxony in northern Germany (NIEBUHR 1995) and in northern Spain. On the other hand, N. (E.) euskadiensi appears to dominate in the faunas of southern Europe, particularly in northern Spain (Navarra – KUCHLER 1996, 2000b, Alava – SANTAMARIA 1996 and Catalonia – see also MARTINEZ 1982, Pl. 28, Fig. 3), and France. The species N. (B.) polypliocum seems to dominate in central Europe (Germany, Austria, Poland) and is markedly rarer in northern Spain.

BLASZKIEWICZ (1980) defined his polypliocum Zone with the coincident FADs of N. (B.) polypliocum schluteri
and N. (E.) unituberculatum. The nominative subspecies, *polyplocum*, appears markedly higher, in the upper part of his zone, and persists, as in northern Spain, higher up into the lower part of the succeeding donezianum Zone. In Navarra, however, the base of the zone is marked by the FAD of *N. (B.) polyplocum polyplocum*, while *N. (E.) euskadiense* appears slightly higher and occurs abundantly together with *N. (E.) unituberculatum* in the middle part of the zone. *N. (E.) euskadiense* (=Didymoceras sp. nov. sensu Blaszkiewicz) first appears in the middle part of Blaszkiewicz’s *polyplocum* Zone in Poland, i.e. in an equivalent of the pulcherrimus Zone as defined here. Other ammonites common in both areas are *P. haldemensis* (=Pachydiscus koeneni de Grossouvre) and *T. spiniger*, which ranges up to the pulcherrimus Zone.

**Germany (Lower Saxony):** The *polyplocum* Zone as defined here may correspond to the lower Belemnitella minor/Bestychoceras *polyplocum* Zone of Niebuhr 1996 and Niebuhr & al. 1997. However, only rare *N. (B.) polyplocum* (non-tuberculate *N. (B.) polyplocum polyplocum*) occur in this interval, and the characteristic Polish assemblage with abundant *N. (E.) unituberculatum* and *N. (B.) polyplocum schlueteri* is missing. The base of the minor/poly-locum Zone of Schmid & Ernst (1975) is assumed to lie somewhat higher, and to correlate with the base of the middle part of the minor/poly-locum Zone sensu Niebuhr (Kuchler 1998a, Niebuhr 1996).

**Trachyscaphites pulcherrimus Partial Range Zone**

The base of the zone is defined at the FAD of *T. pulcherrimus*. It correlates with the base of the Didymoceras/Echinocorys conoidea Zone of Kuchler & Kutz (1989). Where well dated, *T. pulcherrimus* appears elsewhere in Europe in the middle part of the total range of *N. (B.) polyplocum* (Blaszkiewicz 1980, Kuchler & Kutz 1989; Kuchler 1998a, Niebuhr 1996) and ranges up into the succeeding archiacianum or donezianum Zone.

In the silty to sandy marl facies of proximal areas (e.g. Erice III section – Text-fig. 7), the *pulcherrimus* Zone is characterised, beside the index taxon, by coarsely ribbed *N. (B.) polyplocum* and, especially, by a pseudoxybeloceratid fauna consisting of Pseudoxybeloceras (Parasolenoceras) interruptum, *P. (P.) ?wernickei* and Glyptococeras sp.

In more distal sections (e.g. Ecay I – Text-fig. 12), scaphitids and pseudoxybeloceratids are either completely absent or extremely rare as is the ecologic morphotype of *N. (B.) polyplocum polyplocum*. The zonal assemblage is dominated there by late forms of the *euskadiense* lineage *N. (E.) euskadiense II* and *B. alavensis*.

**Nostoceras (Didymoceras) archiacianum Assemblage Zone**

In Navarra, the base of the zone is characterised by the coincident FADs of *N. (D.)* cf. archiacianum (D’Orbigny) and Neancyloceras aff. bipunctatum (Schlüter). The zone is additionally characterised by a peak occurrence of didymoceratids, mostly still undescribed species. The Polish index species *Didymoceras donezianum* (Mikhailov) is rare, but in combination with the co-occurring *N. aff. bipunctatum*, it is possible to cor-
relate the Spanish *archiacianum* Zone with the *donezianum* Zone of the Middle Vistula section.

In the Erice III section (Text-fig. 7), where the lower part of the zone is well exposed, it begins, besides the index taxa, scarce *N. (B.) polyplolum polyplolum*, *N. (D.) cf. donezianum* (Pl. 14, Fig. 2), *Nostoceras (Didymoceras)* sp. 1, *T. pulcherrimus*, *Pseudoxybeloceras (P.) interruptum*, *PohpKyrtoceras pseudogauldianum* (YOKOVAMA) and *Gaudryceras mite*. *Nostoceras (Didymoceras)* sp. 1 (no. ErIII-19/3, Pl. 16, Figs 1-3) resembles the form figured by MOROZUMI (1985, Pl. 16, Figs 1-3) as *Didymoceras awajiense* (YABE), characterised by a higher spire and coarser tuberculation.

At Ecay (Text-fig. 12), the base of the zone is marked by the appearances of *N. aff. bipunctatum* (Pl. 16, Figs 7-9), *Nostoceras (Didymoceras)* sp. 2 and *N. (Didymoceras)* sp. 3. *N. (Didymoceras)* sp. 2 resembles *Didymoceras aff. hombyense* (WHITEAVES) sensu ZABORSKI (1985, Figs 12-13) (compare also Pl. 16, Fig. 6). The three listed heteromorphs are associated with *B. alavensis*.

In eastern Navarra, in the Juandechoaco I section near Imiscoz (compare Text-fig. 1E), *N. (Didymoceras) archiacianum* appears in bed Jul-25d (compare KUTZ 1987, Pl. 9, Fig. 1; and KÜCHLER & al., in press, Text-fig. 2; Pl. 2, Figs 3-4, 12-13; and Pl. 15, Fig. 5 of this paper). This level corresponds to the base of the *Didymoceras/E. conoidea Zone sensu KÜCHLER & KUTZ* (1989, Text-fig. 7) which approximates with the 100 m level in the section. The basal part of the *archiacianum* Zone is characterised by an acme of *T. pulcherrimus* (see KUTZ 1995, Text-fig. 3) and the zonal assemblage according to KÜCHLER & al. (in press) is *T. pulcherrimus, N. archiacianum* and *N. (E.) euskadiense* II.

Coeval strata near the village of Erro (Text-fig. 1E) (Erro A and Erro SE sections – KÜCHLER, in prep.), yielded *N. (Didymoceras)* cf. *archiacianum* (Pl. 15, Figs 1, 4), intermediate forms between *N. (B.) polyplolum* and *N. (D.) archiacianum* (Pl. 15, Figs 2, 7-8), *Pseudoxybeloceras (P.) interruptum*, *P. phaleratum* and *Neancyloceras aff. bipunctatum*.

**France**: In France, *N. (D.) archiacianum* was first described from beds with *Radiolites crateriformis* at Royan (Charente-Maritime, SE France), which correspond to Assise Q of ARNAUD (1878). KENNEDY (1986, Table 2) reported *Pachydiscus (P.) colligatus* (BINKHORST), *Pachydiscus (P.) oldhami* (SHARPE), *N. (Bostrychoceras) polyplolum*, *Pseudoxybeloceras (P.) cf. interruptum* and *T. pulcherrimus* from this unit. The *archiacianum* Zone as distinguished in northern Spain may be therefore correlated with the fauna of Assise Q.

**Poland**: A correlation of the *archiacianum* Zone with the *Didymoceras donezianum* Zone is inferred here (Text-fig. 16), although the *donezianum* Zone in Poland is dominated by boreal and largely endemic scaphitids, particularly *H. greenlandicus*. At the type locality of the *donezianum* Zone at Ciszyca Górna, nostoceratids are generally rare, and the index *N. (D.) donezianum* is extremely rare. BLASZKIEWICZ (1980) defined the base of the zone at the FAD of the subspecies *Menuites portlocki posterior* BLASZKIEWICZ. Both forms, *N. (D.) donezianum* and *M. portlocki posterior*, occur exclusively within the lower part of the *donezianum* Zone, where they are associated with *Menuites [Anapachydiscus] wittekindi* (SCHLÜTER).

The middle part of the zone is characterised by the total range of *N. (Didymoceras) postremum* (BLASZKIEWICZ) and the LADs of *J. compressus*, *T. pulcherrimus* and *H. greenlandicus*. According to BLASZKIEWICZ, *Belemnella langei* JELETZKY and Pachydiscus cf. oldhami also enter in the same part of the zone. The *donezianum* Zone has also yielded *Didymoceras densecostatum* (WIEDMANN), *Gaudryceras mite* and *Neancyloceras bipunctatum*.

*N. bipunctatum* appears to be the most important species for inter-regional correlation. The only problem arises with its FAD in Poland, which cannot be recognised precisely based on the data presented by BLASZKIEWICZ (1980).

**Germany**: At its type locality, Ahlten in Lower Saxony, *N. bipunctatum* occurs in the so-called Ahlten Opoka Facies. It ranges throughout an interval that was assigned to the *langei* Zone by NIEBUHR (1996) and later (NIEBUHR & al. 1997), more correctly, to the *N. bipunctatum/Galerites roemerii* Zone. *J. compressus*, restricted to the *donezianum* Zone in Poland, occurs earlier in northern Germany, approximately contemporaneous with *H. greenlandicus* in the so-called “Bostrychoceras-free beds” of the minor/polyplolum Zone sensu SCHMID & ERNST (1975), which the same authors also termed the *Acanthoscaphites tuberculatus* Zone.

NIEBUHR & al. (1997) recorded the following taxa from the *bipunctatum/roemerii* Zone (corresponding to the upper part of the minor/polyplolum and part of the *langei zones sensu SCHMID & ERNST 1975 and SCHULZ & al. 1984; see Text-fig. 16): *N. bipunctatum*, *J. compressus*, *H. greenlandicus*, *H. ikorfilesis* BIRKELUND, *T. pulcherrimus*, *Leyrites elegans* (MORBERG) and *Nostoceras* sp. nov. The co-occurrence of the first three taxa enables a possible correlation of the *bipunctatum/roemerii* Zone with the lower and middle part of the *donezianum* Zone in Poland (compare KÜCHLER 1996, NIEBUHR & al. 1997). This provides a link to the *archiacianum* Zone of the more southerly faunal provinces (e.g. France and Spain).
Nostoceras (Nostoceras) hyatti Assemblage Zone

The hyatti Zone is defined herein as an assemblage zone, characterised by Nostoceras (Nostoceras) hyatti Stéphenson and Nostoceras (N.) helicinum (Shumard) as zonal indices, together with Nostoceras (N.) approximans (Conrad) and N. (Didymoceras) obtusum Howarth. The latter two species are more significant in the more southern areas and transitional areas to the Boreal realm, such as northern Spain and southern France. The base of the zone should be placed at the middle 118 m level of the Juandechaco I section.

The base of the zone in this Barranca section was therefore placed at the FAD of N. hyatti and/or N. helicinum. However, the first occurrences of all these taxa and their relationships are unclear, and require detailed investigation.

In the Ecay section of the Barranca (Text-fig. 12), N. hyatti appears slightly above the appearance of N. (D.) obtusum, a form described from Barra do Dande, Angola (Howarth 1965), where it co-occurs with N. hyatti and N. helicinum. The base of the zone in this Barranca section was therefore placed at the FAD of N. obtusum. In the Erice II section (Text-fig. 8), the base of the zone is placed at the FAD of N. hyatti; the lower part of the zone here yielded an assemblage consisting of large-sized N. hyatti, Trachycaphites sp. indet., Pseudoxybeloceras sp. indet. and Neancyloceras aff. bipunctatum.

In the Imisocz area, on the other hand, the FAD of N. hyatti (=Nostoceras sp. in Kuchler & Kutz 1989, Kutz in press) lies stratigraphically very high, e.g. (compare Kuchler & al., in press), in bed Ju I-50, at about the 167 m level of the Juandechaco I section. N. hyatti enters here locally well above N. (N.) helicinum, which has its FAD at about the 118 m level. The local FAD of N. hyatti in this section is only 28 m below the FAD of Pachydiscus neubergicus (von Hauber). In the Juandechaco I section, the base of the hyatti Zone is drawn at the FAD of N. helicinum in Bed Jul-27 (Kuchler & al., in press, Text-fig. 2; and Text-fig. 17 in the present paper). As in the Barranca, the fauna is poor in the Imisocz area, where it comprises N. hyatti, N. helicinum (= Nostoceras sp. of Kutz 1987, Pl. 10, Figs 1-2), Nostoceras approximans, Pseudokossmaticeras brandti (Redtenbacher), Desmophyllites larteti (Seunes), Glyptoceras sp. and Pseudoxybeloceras interruptum (see Kuchler & al., in press).

The find of a single N. hyatti, formerly referred to Cirroceras (Cirroceras) polyplum Zumayense Wiedmann by Wiedmann (1962) in the Pseudokossmaticeras tercense Zone sensu Wiedmann (1988a, b) and sensu Ward & Kennedy (1993), additionally enables the recognition of the hyatti Zone at Zumaya in the Basque province of Guipuzcoa. The base of the tercense Zone was defined there by the FAD of P. tercense (Seunes). The lower part of this generally ammonite-poor zone yields only N. hyatti and Gaudryceras varagurense Kossmat (compare Ward & Kennedy 1993, p. 14).

In comparison with the ammonite succession recognised in France and Poland (see discussion below), it is assumed that the tercense Zone of these authors represents only the upper part of the hyatti zone as used here (see Text-fig. 16).

Poland: The hyatti Zone, as used in northern Spain, is assumed to correlate with the Nostoceras pozaryskii Zone of Blaszkiewicz (1980), although a direct correlation is scarcely possible because Jeletzkites nodosus (Owen) (=Acanthoscaphites praecavuspinosus Blaszkiewicz) is used to define the base of the zone in Poland. According to Kennedy & al. (1992a), N. pozaryskii, the type material of which appears to comprise both N. hyatti and N. helicinum, appears well above the base of the 60 m thick Pozaryski Zone, and certainly in the highest 20 m exposed in the Piotrawin Quarry. The typical assemblage of the Pozaryski Zone includes N. hyatti and J. nodosus (Blaszkiewicz 1980, Kennedy & Cobban 1993). Another characteristic member of the assemblage is Pseudokossmaticeras galicianum (Favre), which is known from the Middle Vistula section and also from Arkansas, USA. In both Poland and Spain this species ranges up into the lowermost Maastrichtian. N. hyatti likewise ranges up into the Lower Maastrichtian in northern Spain (compare Kuchler & al., in press).

According to Blaszkiewicz (1980) and Kennedy, Cobban & al. (1992) the ‘hyatti’ zonal assemblage of the Middle Vistula section comprises the following forms: N. hyatti (=N. pozaryskii Blaszkiewicz, 1980, Pl. 10, Figs 8, 9, 12), N. helicinum (=N. pozaryskii Blaszkiewicz, 1980, Pl. 10, Figs 1-7, 11, 13, 15), J. nodosus, P. galicianum, Pachydiscus perfidus de Grossouvre, N. aff. bipunctatum, Hoploscaphites vistulensis Blaszkiewicz, Hoploscaphites minutus Blaszkiewicz, Hoploscaphites angulatus (Lopyski), Pachydiscus (P.) cf. colligatus lautambilicus Blaszkiewicz, Pseudophyllites indra (Forbes), Placenticeras meeki (Bohm), Hauriercera aff. sulcatum Knir and Belenmites langei Jeletzky.

France: At Tercis-les-Bains, Landes, the proposed type locality of the Campanian/Maastrichtian boundary (compare Odin 1996b), the hyatti Zone was formally defined by Hancock & Kennedy (1993) as an assemblage zone. The zonal indices N. hyatti and N. helicinum were found in the uppermost 8 m of the lithostratigraphical unit G (see Hancock & al. 1993, Text-figs 3-4). The cited zonal assemblage comprises the following forms: Hauriercera fayoli (de Grossouvre), Pseudokossmaticeras brandti (Redtenbacher), Ps. tercense (Seunes), P. (P.) perfidus (De
The specimens described and figured by NOWAK appear. In contrast to the Barranca, Immediately above that level, occur slightly below the upper half of the Graphic succession. On the basis of the photographs of Didymoceras onturum (BLASZKIEWICZ) (see KÜCHLER & ODIN, in press), they therefore come from an interval that has yielded the bulk of the material of ODIN, KÜCHLER & ODIN (1993). Only two Nostoceras were collected from the quarry by HANCOCK & KENNEDY themselves. One specimen (OUM KZ 16835) (see HANCOCK & KENNEDY 1993, Pl. 18, Figs 2, 3) was referred to N. hyatti, the other, which was not figured, (OUM KZ 16834) to N. helicinum. These are supposed to have come from the top 8 m of Unit G of HANCOCK & al. (1993). WARD & ORR (1997), however, doubted that these specimen were collected from that interval because they are too low in the stratigraphic succession. On the basis of the photographs of OUM KZ 16835, the specimen in question more closely compare ODIN & ODIN 1994). Two Nostoceras were collected in units G to L, i.e. below unit M. The FAD of P. tercense according to those authors lies in unit K, L in which unit the species co-occurs with P. brandti.

New data (WARD & ORR 1997), as well as horizoned material collected by G. S. ODIN in recent years, give a more detailed picture of the zonal boundary, the ammonite succession and faunal composition of the hyatti Zone at Tercis (compare KÜCHLER & ODIN, in press). It should also be noted that the lithostratigraphical subdivisions of HANCOCK are not practicable in the Tercis quarry (ODIN, pers. comm.) (compare ODIN & ODIN 1994). Only two Nostoceras were collected from the quarry by HANCOCK & KENNEDY themselves. One specimen (OUM KZ 16835) (see HANCOCK & KENNEDY 1993, Pl. 18, Figs 2, 3) was referred to N. hyatti, the other, which was not figured, (OUM KZ 16834) to N. helicinum. These are supposed to have come from the top 8 m of Unit G of HANCOCK & al. (1993). WARD & ORR (1997), however, doubted that these specimen were collected from that interval because they are too low in the stratigraphic succession. On the basis of the photographs of OUM KZ 16835, the specimen in question more closely resembles a loosely coiled spire of a Nostoceras (Didymoceras) species, probably of the archiaicianum – donezianum group. The finds are from between the 35.6 and 43.6 levels in the section measured by ODIN & ODIN (1994). They therefore come from an interval that has yielded the bulk of the material of N. (B.) polyplocum polyplocum and N. (Didymoceras) postremum (BLASZKIEWICZ) (see KÜCHLER & ODIN, in press), i.e. probably from an equivalent of the N. (D.) archiaicianum Zone as proposed here.

The lower part of the hyatti Zone at Tercis is marked by the appearance of large-sized N. hyatti (compare KÜCHLER & ODIN, in press), as in the Barranca. N. helicinum enters higher and P. tercense and N. approximans occur slightly below the upper half of the hyatti Zone. Immediately above that level, Hoploscaphites pumilus STEPHENSON appears. In contrast to the Barranca, N. obtusum first enters at the Campanian-Maastrichtian boundary (KÜCHLER & ODIN, in press).

Pachydiscus neubergicus/Pachydiscus epiplectus Assemblage Zone

The basal Maastrichtian ammonite zone, the neubergicus/epiplectus Zone, is defined here as an assemblage Zone. It is best exposed in eastern Navarra, in the Juandecharo I and ‘Steilhang of Imiscoz’ sections sensu KUTZ (1987, 1995), situated near the village of Imiscoz, south west of the Oroz-Betu Massif (compare KÜCHLER & KUTZ 1989; KUTZ 1995, KÜCHLER & al, in press; Text-figs 2-3), and in the sections in the area farther to the NW, east of the Erro village of Eiro (compare KÜCHLER & al., in press, Text-fig. 4).

The base of the zone is taken at the FAD of Pachydiscus neubergicus in the Imiscoz section. The second index ammonite, Pachydiscus epiplectus (REDTENBACHER), appears slightly higher. From the neubergicus Event, just above the FAD of P. neubergicus, KUTZ (1995, p. 301, Text-fig. 8) listed, besides the two index taxa, Desmophyllites lateti, Saghalinites sp., Ps. brandti, Ps. galicianum (FAVRE), Anagaudryceras lueneburgense (SCHLÜTER), Baculites sp. and H. constrictus (J. SOWERBY). The latter species, however, is better referred to H. pumilus (compare KÜCHLER & al., in press; MACHALSKI & ODIN, in press). The Juandecharo I section yielded N. hyatti, N. helicinum, N. approximans, P. neubergicus, P. epiplectus, Baculites spp., and H. pumilus (see KÜCHLER & al., in press). A highly diverse fauna with P. neubergicus, Ps. brandti, N. hyatti, N. approximans, N. helicinum, Saghalinites sp., Desmophyllites lateti, Gaudryceras kayei, Baculites sp. and Eubaculites hyllicus (D’ORBIGNY) comes from the Erro II section, east of Erro (KÜCHLER & al., in press). At Erro itself, the ammonite association is dominated by Saghalinites sp., D. lateti and nostoceratids, whereas in approximately coeval deposits in a road-cutting near the village of Garralda (see Text-fig. 1E for location) the ammonites are dominated by pachydiscids (P. neubergicus) and pseudokossmaticeratids (Ps. galicianum and Ps. brandti).

In the Barranca, the zone is documented only by single finds of P. ex gr. neubergicus and Desmophyllites lateti; near Erice de Iza (Text-fig. 1, 8) and, at Urrizola (Urrizola S section – Text-fig. 11) by Anagaudryceras cf. lueneburgense, Saghalinites aff. cala, Desmophyllites sp. and Baculites sp.

The neubergicus/epiplectus Assemblage Zone corresponds to the Pachydiscus epiplectus Zone introduced by WARD & KENNEDY (1993) in the Biscay region (Zumaya section). The base of the epiplectus Zone of WARD & KENNEDY (1993) is taken at the FAD of the index taxon, which enters only slightly earlier than P. neubergicus.

France: In the Tercis Quarry, the base of the Maastrichtian was previously defined by the FAD of P. neubergicus in unit N3 of the Tercis Pale Flint Member (HANCOCK & KENNEDY 1993, HANCOCK & al. 1993). The base of their proposed P. epiplectus Zone likewise lies in
unit N3. ODIN (1996a) later placed the Ca/Ma boundary some metres lower, at the 116.9 level.

The epiplectus Zone of HANCOCK & KENNEDY (1993) is defined as an assemblage zone, characterised by the co-occurrence of P. epiplectus, P. neubergicus and H. constrictus (for new data on the hoploscaphitids see MACHALSKI & ODIN, in press). HANCOCK & KENNEDY (1993) additionally cited un-horizoned finds of Saghainites wrighti BIRKELUND and Anagaudryceras lueneburgense.

Unit N3 is characterised by common P. neubergicus and P. epiplectus and, according to the data of HANCOCK & KENNEDY (1993), is assumed to equate with the neubergicus Event of Navarra (see KUCHLER 1995, KUCHLER & al., in press). In Navarra, this event lies somewhat below the FAD of P. neubergicus and above the base of the neubergicus/epiplectus Zone. Hence the base of the epiplectus Zone of KENNEDY & HANCOCK (1993) at Tercis does not correspond to the FAD of P. neubergicus in Navarra and clearly lies higher. Consequently the highest part of the hyatti Zone and the epiplectus Zone, as defined by HANCOCK & KENNEDY (1993) at Tercis, fall into the epiplectus/neubergicus Zone of Navarra.

The Campanian/Maastrichtian boundary interval in Navarra comprises the following succession of FADs (Text-fig. 13):

1. The FAD of N. hyatti. It lies well below the base of the Maastrichtian (FAD of Pachydiscus neubergicus). N. hyatti ranges into the Lower Maastrichtian.

2. The FAD of N. helicinum. It coincides with or is slightly above that of N. hyatti.

3. The FAD of P. neubergicus, which lies slightly below the FAD of P. epiplectus (REDTENBACHER).

4. The local FAD of H. pumilus. It is located above the FAD of P. neubergicus and P. epiplectus, within the so-called P. neubergicus Event (KUCHLER 1995, see also KUCHLER & al., in press).

CAMPANIAN – LOWER MAASTRICHTIAN EVENTS AND CORRELATION

In the ca. 400 m thick Campanian and Lower Maastrichtian marine succession of the Barranca 16 bioevents or event sequences are recognised. The twelve most significant events for regional correlation are (in ascending order): the Offaster pomeli, Micraster antiquus, Echinocorys ex gr. brevis – humilis, M. antiquus/M. atarius, H. marroti/O. pilula, E. subglobosa, E. conica/E. subglobosa, O. pilula III, N. euskadiense, N. polyplocus, N. archiacianum and P. neubergicus (=Cretirhynchia) events. Their origin is closely linked to the 7 transgressive and 7 regressive pulses described below (see Text-fig. 17). However, some of them, the regressive and transgressive pulses recognised in the late marroti and early archiacianum zones require further research. The tectonic phase recognised at the Santonian/Campanian boundary coincides with the Wernigerode Phase (STILLE 1924), and that in the lower Upper Campanian in southern Navarra probably equates with the Peine Phase (RIEDEL 1940). A third phase of uplift started in the late Late Campanian polyplocus Zone. Tectonism was accompanied by noticeable sedimentological changes, hiatus and salt movements.

The phenotypic record of the bioevents is represented mostly by fossil accumulations. These are either beds with mass-occurrences of irregular echinoids (Echinocorys, Micraster, Offaster) in thin horizons, or sets of horizons (event sequences) with ammonite mass-occurrences. The latter are characterised by either monospecific or more taxonomically variable ammonite assemblages. The Campanian in northern Spain includes striking event-sequences, comprising frequency maxima of heteromorph ammonites: these are either scaphitid – diplomoceratid or nostoceratid – diplomoceratid assemblages. Such events are interpreted as population bursts and mass mortality events and are mostly associated with high energy deposits (mass flows or tempestites). They characterise regressive developments.

The maximum flooding events or overlapping events are particularly characterised by abundance-maxima of irregular echinoids of the genus Echinocorys. In similar palaeogeographical situations these acme-events are readily correlatable on a regional scale. The Offaster events, on the other hand posses an inter-regional correlation potential, and can be recognised in other parts of Europe.

The stratigraphical position of the events in northern Spain can be tied to the ammonite zonation, thereby enabling interbasinal correlation. On a regional scale the local zonal scheme based on echinoid partial-range zones, peak zones and ammonite-echinoid assemblage zones, permits even higher resolution within the Spanish ammonite zones.

The single events and event sequences of the eastern Barranca were first tested with respect to their regional geographical range and correlation potential. Their occurrence and biostratigraphical position were investigated in the western Barranca, about 20 km to the west, and in the area around the Oroz-Betelu Massif, about 40 km to the east (see Text-fig. 1). Despite small local differences, both of these comparative areas closely resemble the study area of the eastern Barranca with respect to their palaeogeographical position, facies development and faunal assemblages. A further advantage in using these areas for correlation lies in the fact that detailed stratigraphical investigations had already been carried...
Fig. 17. Bio- and event stratigraphical correlation of the Campanian successions of the Barranca and the Oroz-Betelu Massif; data for Iturmendi and Olazagutia based on Zander (1988) and Kannenberg (1985); data for Urdioz, Imiscoz and Erro, based on Kutz (1987, 1995), Küchler & Kutz (1989) and Küchler & al. (in press).
out in the area of Iturmendi and Alsasua (Zander 1988) and in the area of Urdiroz/ Imiscoz (Kutz 1987, 1995; Kuchler & Kutz 1989, Kuchler & al., in press). In the western Barranca, biozonation was based mainly on planktonic foraminifera, with rare occurrences of ammonites and irregular echinoids enabling correlation with the eastern Barranca. In the Urdiroz/ Imiscoz area, which is characterised, like the eastern Barranca, by a rich fauna of ammonites, inoceramids and irregular echinoids, a zonal scheme based on ammonite/echinoid assemblage zones was already in existence.

Wernigerode Tectoevent

In northern Spain, tectonic movements starting in the latest Santonian can be recognised. They are indicated by an increase in terrigenous input, sharp discontinuities associated with distinct facies changes, marked regional hiati at the Santonian/Campanian boundary and an intensification of the salt tectonics at main faults (compare Amiot 1983b, c; Amiot & al. 1983, Wiedmann & al. 1983, Kuchler & Kutz 1989, Floquet 1991, Grafe 1994, Grafe & Wiedmann 1993).

In addition to these criteria, the movements are indicated by contradictory bathymetric trends in the development of different parts of the Barranca. In the eastern Barranca, and in the transitional area to the Vitoria Basin, analysis of the plankton/benthos ratio of the foraminiferal assemblages indicates a general deepening, which led from the outer shelf to the region of the shelf margin (Wolz & Zander 1987). In contrast, the eastern Barranca, particularly the area between Uritzola and Sarasate, was a continuously shallowing region, with the commencement of a shallow subtidal and intertidal carbonate sedimentation represented by glauconitic limestones and/or oyster limestones. Some parts of the depositional area may even have experienced emersion (Radig 1973). These movements are also indicated by the hiati in the Campanian/Santonian boundary interval in the Sarasate I section (Text-fig. 2) and discordant contacts between Santonian shallow-marine carbonates and Campanian siliciclastic deposits (Pl. 2). The source area of the terrigenous material was the Ebro Massif, located to the south and south-east which, according to Ramirez & Olive (1987), was undergoing uplift at this time. In the eastern Barranca, there was increased uplift of the Anoz-Ollo salt structure. Reactivation of the salt structure caused a migration of salt to the south, resulting in the development of a primary rim-syncline to the north and uplift to the south.

In the western Barranca the tectonic movements caused differential uplift, as well as rotation of tectonic blocks in the Alsasua area (Iturmendi section – Zander 1988; Olazagutia section – Kannenberg 1985 and Kuchler 1998b, Text-fig. 28). Precise dating of the onset and duration of the tectonic activities in the Barranca is not possible because of repeated erosion/deposition phases during the succeeding late Early Campanian transgressions. The movements may be approximately dated as Late Santonian and Early Campanian, corresponding to the boundary hiatus. However, based on the facts that Upper Santonian strata belonging to the upper Jouaniceras hispanicum/Scalarites cingulatum Zone (= upper Dicarinella asymmetrica Zone) sensu Kuchler (1998b and in prep.) are still preserved at Olazagutia, and the oldest Campanian deposits preserved in the Sarasate I section belong to the pomeli/M. (Isomicraster) sp. Zone, the movements may be dated, in terms of the northern European zonation, between the Marsupites testudinarius Zone and the lingua/quadrata Zone. They thus correspond in time to the Wernigerode Phase, the younger phase of the Subhercynian movements, sensu Stille (1924, p. 152). This phase, which comprised two tectonic pulses, started in Germany in the latest Santonian Marsupites Zone (Voigt 1929, p. 49) and lasted until the earliest Campanian (granulata/quadrata Zone (see Mortimore & al. 1998).

Offaster pomeli Transgression I

The pomeli Transgression represents an event that can be traced at least as far as northern Germany and southern England, and which coincides in time with the pilula Transgression of Ernst (1963b, 1968). Contemporaneous transgressive tendencies are also recognisable in the Middle Vistula section, Central Poland, where they are expressed by an horizon of glauconitic sediments with evidence of reworking in the lower third of the Goniotheuthis granulata granulata Zone, sensu Blasz-Kiewicz (1980, pp. 11-12, Text-fig. 2).

In northern Spain, the transgression is named after the echinoid Offaster pomeli, a form closely related to Offaster pilula, which occurs in the glauconitic facies of the transgressive systems tract. As in the Lagerdorf section, northern Germany, O. pomeli occurs more frequently than O. pilula (Ernst 1963a) immediately above the transgression surface. The occurrence of both these forms thus seems to be dependent upon their position in the sequence. O. pomeli seems to dominate in the transgressive systems tract, while O. pilula occurs more commonly in regressive parts of a sequence, i.e. in the late highstand systems tract.

In the Barranca, the transgressive trend is clearly documented in the Sarasate I section by the erosional surface
at the top of the Izurdiaga Limestones, the succeeding glauconitic facies, and the thinning-upward sequence.

**Offaster pomeli Event**

The lowest Lower Campanian mass-occurrence of *Offaster* is interpreted herein in sequence stratigraphical terms as a maximum flooding event. It is documented in two sections of the eastern Barranca: the Sarasate I section (Text-fig. 2), and on the SE slope of the Astieso (compare Radig 1973) within the primary rim-syncline of the Anoz-Ollo salt-swell (Text-fig. 18). Because of erosion during the succeeding regression it is absent from the top and margins of the anticline.

The *pomeli* Event is absent from both the western Barranca and eastern Navarra (Urdiroz/Imiscoz area) (see Text-fig. 17). However, as *Offaster* preferentially occurs in relatively shallow-water environments with glauconitic and fine-grained sediments in the eastern Barranca, its absence from the markedly deeper environments of both the western Barranca (see Zander 1988) and the Urdiroz/Imiscoz area was probably controlled by bathymetry and facies.

**pomeli/M (Isomicraster) sp. zonal Regression**

The *pomeli* Transgression was masked, however, by the final movements of the Wernigerode Tectoevent and the associated salt movements. In the Early Campanian, the area between Sarasate and Ecay was a palaeo-high with a pronounced palaeo-relief. Because of salt tectonics the area was uplifted to above wave base and underwent erosion, resulting in the infilling of the rim-syncline of the Anoz-Ollo salt structure.

In marginal parts of this structure, cm- to dm-thick conglomerates occur, indicating at least two phases of reworking and increasing hiatus (see Text-fig. 18). South of Izurdiaga (Araridi II section at mount Araridi) (see Text-fig. 1) and at Urrizola, this Urrizola Conglomerate reaches a thickness of up to 0.6 m.

**Offaster pomeli Transgression II**

In the structurally strongly partitioned Barranca (compare Kuchler 1998b, Text-fig. 28), sedimentation on swell or horst areas began with the second Lower Campanian transgressive pulse. In the eastern Barranca this is particularly well documented on the margins of the Anoz-Ollo salt-structure at Izurdiaga and Urrizola (see Text-figs 17, 18), where the beginning of the transgression took place in the middle part of the *hippocrepis* III Partial Range Zone, i.e. the middle part of the *pomeli/M* (Isomicraster) sp. Assemblage Zone. This resulted in leveling of the previously existing relief of the local Izurdiaga limestones. The sediments that overlie the second transgressive conglomerate layer near Urrizola belong to the local Subzone of *S. hippocrepis* or *hippocrepis* III/Menabites spp. AZ. In the rim-syncline of the salt structure, an increase of relative sea-level is indicated by a facies change from glauconitic clayey marls/marlstones to distal marls (Sarasate I section – see Text-fig. 2).

In the western Barranca, the sediments of this transgression cover a palaeo-high in the area of Iturmendi (Iturmendi II section of Zander 1988) and represent the oldest Campanian deposits there. Silty, clayey marls belonging to the *Globotruncanana elevata* Zone and assigned to the upper Lower Campanian by Zander (1988) rest nonsequentially on Lower Santonian (*Cladoceramus undulatoplicatus* Zone or *Dicarinella concavata* Zone) calcareous marls and limestones.

**Scaphites hippocrepis Regression**

In the Campanian of northern Spain two regressions, the so-called *pohyllocum* and the (herein proposed) *hippocrepis* regressions, are the most pronounced regressive events. The latter starts at the beginning of the middle Lower Campanian *hippocrepis* III/Menabites spp. AZ. The marked 3rd order sea-level fall, corresponding to the late highstand of the UZA 3.5 of Haug & al. (1987) and the *Delawarella delawarensis* Zone of authors is well documented in northern Spain (Burgos – compare Gischler & al. 1994, Grafe 1994 and Santander provinces – compare Wiese & al. 1996) but is generally mis-dated.

In the eastern Barranca, it is expressed by a gradual increase in the glauconite content of the marls. In the traverse from basal sections (Sarasate) toward the Anoz-Ollo salt structure (Text-fig. 18), the marls pass into bedded glauconitic marls/marlstones, then into glauconitic marls and, near Izurdiaga and Urrizola, into quartziferous glauconite sands. SW of the latter area, carbonate bar-sands occur at Ecay.

**Micraster antiquus Event**

This event is related to the *hippocrepis* Regression. The *antiquus* Event consists of a locally very well marked, 1.0 to 1.5 m thick, horizon with a mass-occurrence of small-sized *M. antiquus*. It has so far been recognised only in five sections in the eastern Barranca, where it is developed at the top of the Urrizola Member (lower part of the
Fig. 18. Early Campanian palaeogeography and facies development of the eastern Barranca. Event stratigraphical correlation of four different sections in relation to a submarine swell. The isopachs and the rapid facies change from NW to SE in the area of Irurzun indicate an elongate E-W submarine swell, interpreted as a salt-swell with a northern rim-syncline along the line Sarasate–Irurzun and steep flank along the line Erice-Ecay, corresponding to the present position of the Anoz und Ollo salt diapirs.
local Subzone of abundant *S. hippocrepis*). In the western Barranca and in the Urdiroz/Imiscoz area, it is absent due to major stratigraphical hiatus in the Lower Campanian *(compare Text-fig. 17)*.

**Echinocorys brevis – humilis Transgression**

The *brevis – humilis* Transgression starts in the lowest third of the *hippocrepis* III/Menabites spp. Zone *(compare Text-fig. 18)*, and is documented in the surroundings of Iruzun by a relative sea-level rise and deepening of the basin. In the primary rim-syncline of the Anoz-Ollo Salt-swell the sandy glauconitic sediments pass into dark clayey marls (Sarasate I and II – Text-figs 2, 4). The eponymous echinoid appears well above the transgression surface (ca. 19 m) in basal successions.

**Echinocorys brevis – humilis Event**

This mass-occurrence of *Echinocorys* ex gr. *brevis-humilis* in the eastern Barranca is confined to a m-thick horizon in marl facies. It represents a short-lived bloom of the eponymous echinoid and can be classified as an eco-event sensu *ERNST & al.* (1983). This population burst probably reflects not only particularly favourable ecological conditions, but it also seems to be linked to cessation of the tectonic activities in the Busque-Cantabrian Region in general, and the end of uplift of the Anoz-Ollo salt swell. This also led to a levelling of the relief between the swell and the rim-syncline. Because the *brevis – humilis* Event is noted over every swell area of the Barranca, it is an overlapping event or, in sequence stratigraphical terminology, a maximum flooding event *(see Text-figs 17-18)*.

**Lower/Upper Campanian boundary Regression**

The terminal Early Campanian slight sea-level fall noted in Navarra is expressed in the eastern Barranca mainly by a facies change from distal clayey marls to more proximal silty marl/marlstone rhythmites, starting in the upper *Echinocorys aff. turrita* Zone. The rhythmites are characterised by silicicaceous sponges and the heteromorph ammonite assemblage that appears in the late highstand systems tract.

**Peine Tectoevent**

A phase of tectonic inversion, which can be approximately dated as Late Campanian, is documented by an hiatus in the Estella section that comprises the entire Lower Campanian *(see SCHWENTKE & WIEDMANN 1985)*. Sedimentation in the Estella area was influenced by movements of the Estella and Maestu diapirs during this period. An hiatus was also reported from boreholes in the Sierra de Urbasa, which, according to GRAFE & WIEDMANN (1993) and GRAFE (1994), comprised the entire Lower Campanian, the *Globotruncana elevata* Zone.

The above-mentioned regression in northern Spain seems to be partly tectonically induced and may correspond to the Peine Phase that was originally described from NW Germany by RIEDEL (1940). The tectonic activities are probably attributable to a slowing or cessation of the sea-floor spreading in the Bay of Biscay. The end of the spreading was associated with a change in the direction of movement of Iberia as a consequence of plate convergence. According to SCHWENTKE (1990), this NW movement of Iberia resulted in dextral strike-slip tectonics and basin inversion.

**Hoplitoplacenticeras marroti/Offaster pilula Event**

The second Campanian *Offaster* acme, corresponding to the *marroti/pilula* Event of the Barranca, falls in the basal Upper Campanian *(see Sarasate I b and IV sections, Text-figs 3, 5)*. It is one of the inter-regionally correlatable and stratigraphically important events in the regressive cycle in the Lower/Upper Campanian boundary interval.

From the chalk facies succession of Downed Quarry near Portsmouth in southern England, GALE (1980, p. 139, Text-fig, 3) also described an *Offaster* maximum. The succession there includes a sequence of hardgrounds in the *Gonioteuthis quadra*ta and *Belenitella mucronata* Overlap Zone. Three horizons from this condensed interval can be correlated with the northern Spanish section Sarasate IV. These are: (1) the top of the so-called A beds, represented by a phosphatized hardground overlain by a lag of reworked fossils including *Scaphites hippocrepis*, *Glyptoxoceras* sp., *Baculites* spp., abundant *G. quadrata* and brachiopods; (2) level 4 of the B beds, with a mass-occurrence of *Offaster pilula*; and (3) the entry of *Echinocorys subconicula* Brydome above the Upper Downed Marl (M2).

The mass-occurrence of *O. pilula* at Downed is possibly the correlate of the pilula Event of the Barranca. The entry of *E. subconicula* may then correspond to the renewed occurrence of *Echinocorys* ex gr. *conica* in northern Spain, which also lies above the pilula-acme. *E. ex gr. conica* (Pl. 16, Figs 4-6) from the Barranca is very similar to specimens of *E. subconicula* figured by *BRYDONE & GRIFFITH* (1911, Pl. 3, Figs 6-10).
**Echinocorys subglobosa Transgression I**

The onset of the subglobosa Transgression I (see Text-fig. 19) in the eastern Barranca is in the middle part of the marroti PRZ, and corresponds to the base of the subglobosa PRZ from which the name is taken. In the Sarasate IV section (Text-figs 5, 19), the transgressive surface (SaIV-116), a pebble horizon with green-coated nodules, is overlain by clayey marls. The latter indicate a marked deepening, which resulted in a gradual disappearance of heteromorph ammonites.

As in the case of the pomeli Transgression, two transgressive pulses, subglobosa I and subglobosa II (Text-figs 17, 19) can be distinguished. The first transgressive pulse is indicated in eastern Navarra by the onlap of a fully marine facies onto the Basque Oroz-Betelu Massif. These deposits, overlying Santonian shallow-marine limestones and dolomites are, as discussed earlier, probably of Late Campanian age. They start with a bed of glauconitic, redish limestone containing green-coated limestone nodules that rests nonsequentially on dolomites or orbitoides-limestones. The origin of this bed has not been investigated in detail, but KUTZ (1995), who traced this horizon in every section that he studied, considered that it was either a ‘nodular hardground’ or a diagenetically overprinted transgression conglomerate.

In the Urdiroz I section (KÜCHLER 1987; 1995, Text-fig. 6) this horizon is overlain by a unit of grey calcareous marls (KÜCHLER, in prep.), while near Imiscoz, in the Juandecheaco III section (KUTZ 1995, Text-fig. 5), it is followed by a ca. 4 m thick unit of glauconitic limestones grading upwards into alternating marls and calcareous marls.

In the area east of Erro (Text-fig. 1E) metre-thick glauconitic limestones passing into glauconitic marls are developed (KÜCHLER, in prep.). The latter have yielded inoceramids, rare ammonites and echinoids. The find of a specimen of Echinocorys ex gr. subglobosa – ovata indicates, as in the Barranca, that the onset of the transgression lies in the marroti Zone (see Text-fig. 17, 19). Consequently, in the area between Urdiroz and Imiscoz, the entire Lower Campanian and part of the basal Upper Campanian falls into an hiatus.

**Echinocorys subglobosa Regression**

This event indicates regressive tendencies in the upper subglobosa Zone which are reflected in the marginal sections of the Barranca either by a shallowing and increase of the fine clastic input in a siliceous sponges facies (Sarasate III, Text-fig. 6) or by silty glauconite-rich sediments (Ecay II section, Text-fig. 19).

In the western Barranca (Iturmendi IV/V section, see Text-fig.19), ZANDER (1988), on the basis of foraminiferal dating, inferred a contemporaneous shallowing of the sedimentary basin in the terminal Early Campanian Globotruncanca ventricosa Zone. By means of event stratigraphical correlation (local FAD of Echinocorys subglobosa) this interval is assumed herein to correlate with the upper part of the Upper Campanian marroti PRZ (= subglobosa Zone) (see Text-figs 17, 19). On the basis of a steadily increasing proportion of benthonic foraminifer in the P/B ratio (from 60 to 80%) and analysis of the microfaunal assemblages ZANDER (1988) postulated a shift in the depositional environment from the upper continental slope to the outer shelf. She attributed the concomitant increase in silt content to the influence of a delta system lying in an area farther to the south. The beginning of the delta development may be more or less precisely dated in the Estella area.

In south-western Navarra, near the villages of Contrasta, Oto and Antoñana, SCHWENTKE & WIEDMANN (1985) first noted a contradictory development, with a deepening phase (down to middle shelf) in the lower Globotruncanca ventricosa Zone (= lower Upper Campanian in the sense used here). Only close to the Lower/Upper Campanian boundary (defined by foraminifer, i.e. upper ventricosa Zone) was there a radical change in the character of sedimentation, expressed by a continuous increase in quartz content, intercalations of thin red sandstone beds, and a marked decrease in the diversity and quantity of planktonic foraminifer. In the Upper Campanian (Orbitoides media Zone) the facies became increasingly sandy with a decrease in carbonate in the background sedimentation. [Orbitoides media according to CAUS & GOMEZ-GARRIDO (1989) appears in the southern central Pyrenees in the ventricosa Zone and ranges up to the calcarata Zone. In the Basque-Cantabrian Region, according to GRAFE (1994), the base of the media Zone lies likewise in the upper part of the ventricosa Zone, and in the upper part of the zone with H. marroti and T. spiniger of WIEDMANN & GRAFE (1993)]. These sandy sediments were interpreted by SCHWENTKE & WIEDMANN (1985) as part of a delta system prograding from the SW. This progradation continued until the late Late Campanian and led to the deposition of fluvial sandstones in south-western Navarra.

**Echinocorys conica/Echinocorys subglobosa Event**

This event documents a sea-level highstand and maximum flooding event. It represents the first datum that can be used for correlation between the Oroz-Betelu Massif and the Barranca (Text-fig. 17).
Fig. 19. Integrated bio- and event stratigraphy, local FADs and ranges of stratigraphically important macrofaunal elements in the Lower/Upper Campanian boundary interval of the Barranca. In addition to an east-west traverse through the Barranca, the diagram shows a transect from the Sarasate III section, situated over a swell, through the Ecay II and Iturmendi V/VI sections in an intermediate position, to the basinal Sarasate IV section.
In the condensed sections of the Barranca (see Text-fig. 19) and the Urdiroz/Imiscoz area (see KUCHLER & KUTZ 1989, Text-figs 5-6), the acme of *E. subglobosa* or *E. ex gr. subglobosa – ova* and *E. ex gr. conica* approximates to the FADs of *Trachyscaphites spiniger* and *Echinocorys ex gr. conoidea*.

**Echinocorys subglobosa** Transgression II

This transgressive pulse is again more clearly record- ed in the Urdiroz/Imiscoz and Erro areas, where it is expressed by distal clayey marls, with predominant pachydiscids occurring above the *conica/subglobosa* Event. These marls are dated as *spinger* Zone (= *haldem-sis/conoidea* Zone sensu KUCHLER & KUTZ 1989). In the Barranca, this transgressive pulse is more difficult to recognise because of gaps in exposure.

**Offaster pilula** Event III

The third *pilula*-acme in the Barranca, on the basis of the associated ammonites, lies in the lower part of the *polyplocum* Zone as defined herein (Text.-fig. 12). This event has not been recognised in the Urdiroz/Imiscoz area and in the western Barranca. A comparable *Offaster pilula* mass-occurrence, with *Offaster pilula planatus* Brydone is found in the Altachuile Breccia of the Ballintoy Chalk of Northern Ireland (see FLETCHER & WOOD 1978, p. 97), which is at a similar stratigraphical position. The Altachuile breccia represents a submarine slide that may have been tectonically induced.

**Upper Campanian Tectoevent (UCTE)**

An increase in tectonism at the beginning of the *polyplocum* Zone is also documented in the Iberian shelf. In Navarra, it probably led to the so-called *euskadiense* Events in the middle part of the *polyplocum* Zone and to the deposition of slumps, debrites and conglomerates in the southern central Pyrenees (see MARTINEZ 1982, CAUS & GOMEZ-GARRIDO 1989). The latter reflect the beginning of compressive movements within the Pyrenees, i.e. the collision between the Iberian and the European plates. The predominant siliciclastic sedimentation is associated with an infilling of the basins (LAMOLDA & al. 1981; ENGESER 1985, ENGESER & al. 1984) and led to a shallowing upward cycle, which can be compared with the *polyplocum* regression of German authors (ERNST & al. 1979, ERNST & KUCHLER 1992, NIEBUHR 1995, NIEBUHR & al. 1997).

**Nostoceras (Euskadiceras) euskadiense Events**

The mass-occurrences of nostoceratids and baculitids in the lower part of the *polyplocum* Zone of northern Spain are associated with high energy deposits (Text-fig. 12).

In the Urdiroz/Imiscoz area (Urdiroz III section – KUCHLER & KUTZ, in prep.), the *euskadiense* Events are confined to a ca. 2 m thick debris flow. Large-sized *N. (B.)* *polyplocum* already appear below the debrite, and hence the stratigraphical position of the debrite agrees well with the event sequence in the *polyplocum* Zone of the Barranca. Moreover, the ammonite fauna of the debrite corresponds well in its quantitative composition to that in the interval from beds Ecl-I-103 to Ecl-I-108 at Ecay/Araquil, eastern Barranca (Text-fig. 12). However, in contrast to Urdiroz, four sedimentological events can be distin- guished within this 5 m thick interval at Ecay. In both areas, the ammonite assemblages restricted to these anomalous sediments are dominated by *Nostoceras (E.) euskadiense* 1 and *Baculites alavensis*, with pachydiscids and gaudryceratids representing subordinate elements. In the Urdiroz III section there is, likewise, an horizon with *Pachydiscus haldemsis* (*euskadiense/haldemsis* Event) below or at the base of the debrite. This horizon is very probably traceable as far as the Santander area (Soto de la Marina section), where the so-called *Upper balticus* Event of BRÜNNING (1996) is additionally marked by a pachydis- cid horizon with *P. haldemsis*. At Soto de la Marina this event lies at the base of a limestone formation not far above the base of the *polyplocum* Zone and hence it most probably correlates with the *euskadiense/haldemsis* Event at the base of the *euskadiense* event-sequence in Navarra.

**polyplocum Regression**

The sea-level fall in the study area reflects that of the global cycle chart of HAQ & al. (1987), the so-called ‘*polyplocum*’ regression of German authors (ERNST & al. 1979, ERNST & KUCHLER 1992, NIEBUHR 1995, NIEBUHR & al. 1997).

In the eastern Barranca, the increasing regressive tendencies are recognised slightly later, at the boundary of the *polyplocum* and *pulcherrimus* zones, i.e. in the middle part of the Total Range Zone of *N. (Bostrychoceras) polyplocum*. The regression is reflected by a shift in the depo- sitional area from a deep subtidal, through a prodelta facies, to a sandy calcarenite facies of the shallow subti- dal. The facies is marked by episodic storm events, with the occurrence of silstones and tempestites. Associated with the lithofacies change is a marked faunal turnover. Oysters (*Pycnodonte vesiculare*) and inoceramids increase in numbers. The *Bostrychoceras – Baculites – Pachydiscus*
ammonite assemblage is replaced by a Bostrychoceras – Scaphites-Pseudoxybeloceras assemblage, while substrate-dependent, irregular echinoids of the genera Micraster and Echinocorys are replaced by regular forms belonging to the genus ?Gauthieria.

N. (Bostrychoceras) polyplcumb Events

Horizons of ammonite accumulations in the pulcherrimus Zone are interpreted here as representing mass mortalities related to episodic storm events. Due to the similar palaeogeographical position in the shelf area of the sections concerned, these events are traceable in Navarra from the eastern Barranca to the Urdiroz/Imiscoz area. They occur there in the same bio- and sequence stratigraphical position, namely in the late highstand or early lowstand.

The events of the Erice III section (ErIII-12 and ErIII-13) (Text-fig. 7) comprise identical faunal assemblages that are easily correlative with the events represented by beds B20 and B25a/b of the Juandechaco I section and beds P32a and P 32b of the Urdiroz I section (see Text-fig. 17, and also KUTZ 1995, Text-figs 3, 6; KUCHLER & KUTZ 1989). The ammonite assemblages are composed of N. (B.) polyplcumb polyplcumb, Pseudoxybeloceras sp., and Glyptococeras sp. near Urdiroz and of Pseudoxybeloceras sp., N. (B.) polyplcumb polyplcumb, and Trachyscaphites pulcherrimus near Imiscoz.

In the western Barranca (see Text-fig. 17), the top of the 10 m thick Iturendi IV section of ZANDER (1988) seems to correspond to the polyplcumb Event of the Erice III section. The event character of this horizon is not particularly well developed here, but horizons with Pseudoxybeloceras (P.) cf. interruptum and rare indeterminable Nostoceras (Bostrychoceras) sp. are a characteristic feature.

Nostoceras hyatti Transgression

This Upper Campanian transgression pulse is dated as late hyatti Zone in Navarra. In western Navarra (Urdiroz/Imiscoz area), the tempestite facies is followed by more distal calcisphere mudstones, while a similar transgressive trend can be recognised in the more nearshore areas of the Barranca, where there is a gradual upwards change into glauconitic and silty sediments.

Pachydiscus neubergicus (= Cretirhynchia) Event

The neubergicus Event is defined here as a mass-occurrence of ammonites in the Lower Maastrichtian neubergicus/epiplectus Zone. The composition of the ammonite assemblage varies, however, according to its position in the basin The eponymous Pachydiscus neubergicus occurs in both distal and more proximal environments and thus represents the most significant faunal element of the event, albeit not necessarily the most common.

In eastern Navarra, the event is easily recognisable and correlative between the localities Erro, Imiscoz, and Garralda. It characterises a ca. 0.6 m thick horizon that is well developed at Erro (compare KUCHLER & al, in press; Text-fig. 4). In the traverse from distal (Erro) to more proximal (Garralda) environments, a gradual change can be observed from a Saghalinites – Desmophyllites – Nostoceras ammonite assemblage near Erro through a Pachydiscus – Nostoceras – Pseudokossmaticeras assemblage near Imiscoz, to a Pachydiscus – Pseudokossmaticeras-dominated assemblage near Garralda.

From Imiscoz, KUTZ (1987) reported rare specimens of the brachiopod genus Cretirhynchia from the neubergicus Event. In Navarra, Cretirhynchia was known previously only from the Lower Maastrichtian. It can therefore be inferred that the neubergicus Event, which is dominated by ammonites in more basinward positions, equates with the Cretirhynchia Event of the Barranca in more nearshore positions. In the eastern Barranca the event is documented by a mass-occurrence of the eponymous brachiopod in the Urrizola S section (Text-fig. 11) and it is also known from a now destroyed exposure, west of Erice de Iza. Between these two localities, there are differences in the small echinoid (Offaster and Peroniaster) component of the event assemblage.

CONCLUSIONS

• In the eastern Barranca, a northern and a southern facies belt can be recognised: the clayey Vitoria Formation (AMIOT 1982) and the glauconitic marl/marlstone alternations of the Sarasate Formation (KUCHLER & KUTZ 1989). The Sarasate Formation is divided into ten members: Lower Sarasate Glauconite Member, Lower Sarasate Marl Member, Urrizola Member, Brevishumilis Marl, Siliceous Sponge Rhythmites, Clayey Marl Member, Upper Sarasate Glauconite Member, Ecay Member, Erice Member I and Erice Member II.

• Deposition was influenced by uplift of the Anoz-Ollo salt structure during the latest Santonian and early Campanian. The presence of a submarine salt-swell with a northern rim-syncline is indicated by the Lower Campanian isopachs, rapid facies-changes and increasing hiati from NW to SE.

• The ammonite zonation for the Campanian – Lower Maastrichtian of northern Spain is greatly refined. The
The base of the Upper Campanian is taken at the FAD of *Hoplitoplacenticeras* in northern Spain, as does in northern Germany. The co-occurrence of this species with *P. haldemsi* characterises the *spiniger* Zone. This zone correlates with the German *Patagiosites stobaii/Galeola papillosa basiplana* Zone.

- **The phaleratum Zone** contains, besides the dominant index taxon, *Pseudoxylebeloceras* sp., rare *Pachydiscus subrobustus* (*SEUNES*) and *Menuites portlocki* (*SPATH*). It correlates with the upper part of the *Neancyloceras phaleratum* Zone of the Middle Vistula section, central Poland and upper Vorhelm Beds in Westphalia, Germany.

- **Four zones are recognised in the uppermost Upper Campanian (in ascending order):** the *Nostoceras (Bosrhyocheras)* polyplocum, *Trachyscaphites pulcherminus*, *Nostoceras (Didymoceras)* archiacianum, and *Nostoceras (Nostoceras) hyatti* zones.

- The base of the *polyplocum* Zone is taken at the FAD of the index species. *Nostoceras (Euskadicasus)* euskadiense *KUCHLER* is characteristic and abundant in the middle part of the zone. The assemblage yields rare *N. (B.) polyplocum schluekeri* (*BLASZKIEWICZ*) and *N. (E.) unituberculatum* (*BLASZKIEWICZ*), which are known to occur in the lower part of *polyplocum* Zone as applied in Poland.

- The FAD of *Trachyscaphites pulcherminus* (*ROEMER*) defines the base of the succeeding *pulcherminus* Zone. The ammonite fauna is dominated either by coarsely ribbed *N. (B.) polyplocum polyplocum*, *Pseudoxylebeloceras interruptum* and *Ps. ?wernickei or by N. (E.) euskadiense II and Baculites alavensis SANTAMARIA*. The zonal assemblage corresponds to that of the middle and upper parts of the Polish *polyplocum* Zone.

- **The archiacianum Zone** represents an equivalent of the Polish *doneziun* Zone. Its lower boundary is marked by the coincident FADs of *Nostoceras (Didymoceras)* cf. *archiacianum* (*D’ORBIGNY*) and *Neancyloceras aff. bipunctatum* (*SCHLÜTER*), and the zone is characterised by other species of *Nostoceras (Didymoceras)*.

- The *hyatti* Assemblage Zone is characterised by the FADs of *Nostoceras (Nostoceras) hyatti* *STEPHENSON* and *Nostoceras (N.) helicinum* (*SHUMARD*). In Navarta the zone is documented by rare occurrences of the index taxa associated with *N. (Didymoceras) obtusum* *HOWARTH* and *Nostoceras approximans* (*CONRAD*).

- The lower boundary of the *Pachydiscus neuber- gicus/Pachydiscus epileptus* Zone is taken at the FAD of *Pachydiscus neubergericus* (*VON HAUER*). The local FAD of *Pachydiscus epileptus* (*REDTENBACHER*) is somewhat higher. The ammonite assemblage comprises *Pseudokossmaticeras* sp., *Saghalinites* sp., *Desmo-
• With the early Late Campanian (middle part of the
• In the eastern Barranca, the Lower/Upper Campanian
• The onset of a further transgressive pulse (subglobosa II) occurred in the lower spiniger Zone.
• The polyplocum Regression of authors started in Navarra in the middle part of the Total Range Zone of N. (B.) polyplocum, i.e. in the pulcherimna Zone. In western and eastern Navarra it is expressed by the development of a tempestite facies which lasted up to the early hyatti Zone, and is displaced by the hyatti Transgression.
• The tectonic phase that is documented at the Santonian/Campanian boundary by discordances, hiati and salt tectonics, is related to the Wernigerode Phase of STILLE (1924). The onset of a second phase falls in the lower Upper Campanian marroti PRZ, the onset of a third phase (UCTE) in the upper Campanian polyplocum Zone.

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PLATES 5-18

All figures, except Pl. 7 are natural size; abbreviations of registration numbers of specimens (horizoned finds) in author’s private collection consist of (1) section symbol (e.g. Ast – Astieso; ArII – Arardi II; SaI – Sarasate I; UrEII – Urrizola East II; EcI – Ecay I, ErII – Erice II, IzIII – Izurdiaga III) (2) bed number; (3) number of the specimen from this particular bed or (4) asterisks for unregistered specimens (e.g. Ecay I section, bed number 104, specimen 3 = EcI-104/3); loose finds are labelled with the location or section symbol and a number of the individual specimen. Additional abbreviations used are: GPIT, Geologisch Paläontologisches Institut und Museum Tübingen, Germany; MCNA, Museo de Ciencias Naturales de Alava, Vitoria, Basque Country.
Irregular echinoids from the Lower Campanian of the Barranca

1-3 – *Echinocorys scutata cincta* BRYDONE, Ast-512/614 m/1; Mid-Lower Campanian, local *Offaster pomeli/M. (Isomicraster)* sp. Assemblage Zone (=*Scaphites hippocrepis* III PRZ); Astieso, SE of the cemetery of Izurdiaga

4-5 – *Micraster (Isomicraster)* sp., unregistered specimen; Lower Campanian, *Offaster pomeli/M. (Isomicraster)* sp. Zone; Sarasate I, loose up to 20 m above hardground HgSa I

6-9 – *Echinocorys* ex gr. *brevis-humilis*, SaII-(53a)54-1/1; Lower Campanian, local *brevis – humilis* Peak Zone (= uppermost *hippocrepis III/Menabites* spp. AZ), *brevis – humilis* Event

10-18 – *Offaster pomeli* MUNIER-CHALMAS; Lower Campanian, *pomeli/M. (Isomicraster)* sp. AZ, *pomeli* Event; 10-12 – SaI-(7-8)/22580-1, 13-15 – SaI-(7-8)/22580-2, 16-18 – SaI-(7-8)/22580-3
Irregular echinoids from the Lower and Upper Campanian of the Barranca


4-7 – *Micraster aturicus* Cotteau, SaIV-79001; lowermost Upper Campanian, local *Echinocorys* ex gr. *conica* Zone (=*Trachyscaphites spiniger* PRZ), loose below *coni-ca* Event
PLATE 7

Ammonites from the Lower Campanian of the Barranca

1 – *Menabites (Delawarella) subdelawarensis* Collignon, GPIT -Radig 1963 – L14.2981 (Wiedmann Collection); Original of the specimen cited by Radig (1973, p. 17) as *Delawarella* sp.; mid-Lower Campanian, loose from the glauconitic beds of Urrizola, local Subzone of abundant *S. hippocrepis* (= *Scaphites hippocrepis* III/*Menabites* spp. AZ); Urrizola, Urrizola E II section herein; × 0.85

2 – *Eupachydiscus levyi* (De Grossouvre), UrEII-5/3; mid-Lower Campanian, local Subzone of abundant *S. hippocrepis* (= *Scaphites hippocrepis* III/*Menabites* spp. AZ); Urrizola Member; × 0.85

3 – *Menabites (Delawarella) campaniense* (De Grossouvre), ?SaII-52/1; mid-Lower Campanian, local Subzone of abundant *S. hippocrepis* (= *Scaphites hippocrepis* III/*Menabites* spp. AZ); Sarasate, loose find within SaII-52; × 0.85
PLATE 8

Ammonites from the uppermost Lower Campanian of the Barranca

1 – *Menabites (Australiella) australis* (BESARIE), ArII-1; Lower Campanian, *S. hippocrepis* III/*Menabites* spp. AZ.

2 – *Submortoniceras* sp., specimen SaII-53/a; Lower Campanian, *S. hippocrepis* III/*Menabites* spp. AZ.

3-6 – *Scaphites hippocrepis* (DeKay) III; Lower Campanian; 3 – UrEII-5/1, macroconch, *S. hippocrepis* III/*Menabites* spp. AZ; 4 – SaII-52/a, microconch, *Scaphites hippocrepis* III PRZ; 5 – IzIII-11/1, macroconch, *S. hippocrepis* III/*Menabites* spp. AZ; 6 – Iz III-11/2, macroconch, *S. hippocrepis* III/*Menabites* spp. AZ.

7-8 – *Menuites* sp. ?nov.; Lower Campanian, *S. hippocrepis* III/*Menabites* spp. AZ; Urrizola; 7 – UrEII-5/2, 8 – UrEII-5/1.
PLATE 9

Ammonites from the lowermost Upper Campanian of the Barranca

1-3, 7-8 – *Hoplitoplacenticeras marroti* (COQUAND), basal Upper Campanian, local *marroti/pilula* AZ (*marroti* PRZ); Sarasate; 1 – SaIV-106/1, 2 – SaIb-101/1, 3 – SaIV-105/1, 7 – SaIV-?104/2, 8 – SaIV-106/2

4 – *Pachydiscus haldemsis* (SCHLÜTER), SaIV-104/3; basal Upper Campanian, local *marroti/pilula* AZ (*=marroti* PRZ)

5-6 – *Scaphites hippocrepis* (DEKay) IV KÜCHLER, basal Upper Campanian, *marroti* PRZ, Sarasate; 5 – holotype MCNA 9628 (=SaIV/14688), macroconch; Sarasate IV, bed 106; 6 – paratype MCNA 9629 (=SaIV-116/1), microconch; Sarasate IV, local *Echinocorys subglobosa* PRZ, bed 116

9-10 – *Glyptoxoceras retrorsum* (SCHLÜTER); 9 – SaIV-104b/2; basal Upper Campanian, local *marroti/pilula* AZ (*=basal marroti* PRZ); 10 – SaIV-104a/1; uppermost Lower Campanian, topmost part *S. hippocrepis* III/Menabites spp. AZ (*=local Echinocorys aff. turrita* PRZ)
PLATE 10

Irregular echinoids from the lowermost Upper Campanian of the Barranca

1-3 – *Echinocorys subglobosa* (GOLDFUSS), SaIII-M11/1; Lower Upper Campanian, local *subglobosa* PRZ (=*marroti* PRZ)

4-6 – *Echinocorys ex gr. conica* (AGASSIZ), SaIV14.5.81 (Ernst Collection); lowermost Upper Campanian, local *Echinocorys ex gr. conica* PRZ (=*Trachyscaphites spiniger* PRZ), *conica* Event

7-12 – *Offaster pilula* (LAMARCK), lowermost Upper Campanian, local *marrotipilula* AZ (=*marroti* PRZ), *marrotipilula* Event; Sarasate; 7-9 – SaI-100/p1, 10-12 – Sa-100/p2
PLATE 11

Ammonites from the higher Upper Campanian of the Barranca and the Urdiroy/Imiscoz area

1-2, 5-6 – *Trachyscaphites spiniger* (SCHLÜTER), Upper Campanian; 1-2 – UrdI-261291, basal *Trachyscaphites spiniger* PRZ (=local *P. haldensis/E. conoidea*) approximately subglobosa/conica Event; ca. 20-25 m above the boundary between Santonian red dolomites and Campanian blue calcareous marls Urdiroy; 5-6 – unregistered specimen from the W. JUDENHAGEN (Wolfsburg) collection 1978; Upper Campanian; from the talus at the highway near the petrol station of Sarasate, Barranca

3-4, 10 – *Trachyscaphites pulcherrimus* (ROEMER); Upper Campanian, *Nostoceras (Didymoceras) archiacianum* AZ; Erice de Iza, Barranca; 3-4 – ErIII-19/(unregistered); 10 – ErIII-(21-22)/22983

7-8, 9 – *Trachyscaphites cf. spiniger* (SCHLÜTER); Upper Campanian, *Trachyscaphites spiniger* PRZ; Ecay/Araquil; 7-8 – EcSIIa-199a*/5*; 9 – EcSIIa-199a/2
PLATE 12

Ammonites from the Upper Campanian of the Barranca

1-3 – *Pseudoxybeloceras (Parasolenoceras) ?wernickei* (WOLLEMAN), Upper Campanian, *Trachyscaphites pulcherrimus* Partial Range Zone; Erice de Iza; 1-2 – ErIII-13/10; 3 – ErIII-14/1

4-10 – *Pseudoxybeloceras (Parasolenoceras) cf. interruptum* (SCHLÜTER), Upper Campanian, *pulcherrimus* PRZ; Erice de Iza; 4-5 – ErIII-15/5, 6-8 – ErIII-15a, 9-10 – ErIII-14/2

11-17 – *Pseudoxybeloceras phaleratum* (GRIEPENKERL), Upper Campanian *Pseudoxybeloceras phaleratum* PRZ, Ecay; 11-12 – EcI-98/1a, 13-14 – EcI-98/(1b-c)/1, 15 – EcI-100/2, 16 –EcI-(98-100)/III, 17 – EcI-98/2
PLATE 13

Ammonites from the Upper Campanian of the Barranca

1 – Nostoceras (Bostrychoceras) polyplounced polyplucked (Roemer), EcI-116/1, part of a microconch; Upper Campanian, pulcherrimus PRZ.

2-5 – Nostoceras (Euskadiceras) euskadiense Küchler, Upper Campanian, Nostoceras (Bostrychoceras) polyplucked PRZ, euskadiense Event I; Ecay/Araquil; 2 – MCNA 9052 [=EcI/104-1], paratype, spire microconch; 3 – MCNA 9055 [=EcI/104-3], paratype, macroconch; 4 – MCNA 9053 [=EcI/104-2a], paratype, spire microconch; 5 – MCNA 9054 [=EcI/104-2b], paratype, body chamber microconch
PLATE 14

Ammonites from the Upper Campanian of the Barranca and the Urdiroz/Imiscoz area

1, 3, 5, 6-7 – *Nostoceras (Bostrychoceras) polyplocum polyplocum* (ROEMER); Upper Campanian, *pulcherrimus* PRZ; 1 – ErIII-13/5, 3 – EcI-116/2, 5 – Urdiroz I-P 32a (ex KUTZ collection), 6 – specimen ErIII-13/1; Erice de Iza, 7 – specimen ErIII-12/1; Erice de Iza

2 – *Nostoceras (Didymoceras) cf. donezianum* (MIKHAILOV); ErIII-19/1; Upper Campanian, *archiacianum* Zone

4 – *Nostoceras (Didymoceras) cf. archiacianum* (D’ORBIGNY); ErIII-19/4; Upper Campanian, *archiacianum* Zone
PLATE 15

Ammonites from the higher Upper Campanian of the Barranca and eastern Navarra

1, 3-6 – Nostoceras (Didymoceras) cf. archiacianum (d’ORBIGNY); Upper Campanian, archiacianum Zone; 1 – ErroSE-50/*, a macroconch; Erro, eastern Navarra; 3 – ErIII-19/2, 4 – ErrO-A-46/*, a microconch, 5 – Jul-25d/1, (ex KUTZ collection); Juandeñacho I section at Imiscoz, eastern Navarra; 6 – ErIII-19/1, a microconch

2 – Nostoceras (Bostrychoceras) polylocum m.f. N. (Didymoceras) archiacianum (d’ORBIGNY), ErrO-A-50/1(17794); Upper Campanian, archiacianum Zone; Erro, eastern Navarra

7 – Nostoceras (Euskadiceras) unituberculatum (Blaszkiewicz), MCNA 9627, plaster cast of unregistered specimen in the W. Judenhagen (Wolfsburg) collection; Upper Campanian; Sarasate, from the talus at the motorway section near the petrol station of Sarasate, Barranca
PLATE 16

Ammonites from the higher Upper Campanian of the Barranca

1-3 – Nostoceras (Didymoceras) sp. 1, ErIII-19/3, Upper Campanian, base of the archiaianum Zone

4-5 – Nostoceras (Didymoceras) depressum (Wiedmann), EcI-(100+26m)/4; Upper Campanian, pulcherrimus PRZ; 4 – lower whorl face, 5 – lateral view with lower whorl face facing upwards

6 – Nostoceras (Didymoceras) sp. 2, EcI-119b/7; Upper Campanian, base of the archiaianum Zone

7-9 – Neancyloceras aff. bipunctatum (Schlüter), EcI-119b/5; Upper Campanian, base of the archiaianum Zone
Ammonites from the higher Upper Campanian of the Barranca and the Urdiroz/Imiscoz area

1 – *Nostoceras (Didymoceras) obtusum* HOWARTH, EcIb/9; Upper Campanian, base of the *Nostoceras hyatti* AZ (= uppermost part of the *Didymoceras/E. conoidea* Zone sensu KÜCHLER & KUTZ 1989)

2-6 – *Nostoceras (Nostoceras) hyatti* STEPHENSON; Upper Campanian, *hyatti* AZ; 2 – ErII-31/1, 3 – loose find ErII-(30-36)/1, 4 – EcIB-(19-20)/2, 5 – GPIT -F. RADIG 1963 – L 14.2985, Locality Ir.21 (Wiedmann collection); Urrizola, labelled “glauko-nitische Schichten bei Urrizola”?40-50 m above the top of the Izurdiaga Limestones; 6 – Juandechaco I section, bed Ju-54, ex KUTZ collection (Pr.Lu-54-10.9.83), Imiscoz
PLATE 18

Inoceramids from the upper Campanian of the Barranca

1 – *Inoceramus heberti* FALLOT; EcI-104/*; Upper Campanian, *polyplocum* Zone; Ecay/Araquil

2 – *Endocostea* sp. aff. *impressa* (d’ORBIGNY); EcI-116/*; Upper Campanian, *pulcherrimus* Zone

3, 5 – *Cataceramus balticus haldemensis* (GIERS); Upper Campanian; 3 – EcI-103/1; *polyplocum* Zone, 5 – ErII-24/*; *archiacianum* Zone, Erice de Iza

4 – *Cataceramus balticus* cf. *haldemensis* (GIERS), EcI-104/1; Upper Campanian, *polyplocum* Zone

6 – *Trochoceramus*? sp. aff. *ianjonaensis* (SORNAY), Ec(B1)-108/*; Upper Campanian, *polyplocum* Zone
A – Geological map of western Navarra (1: 200 000) with the Barranca (the valley of the Burunda-Araquil river); B – Motorway-cuttings at the A-15 between Irurzun and Erice de Iza, at the northern edge of the Arardi mount.
Santonian-Campanian boundary at Sarasate I; 1-2 – Upper Izurdiaga Limestone Formation unconformable overlain by glauconitic alternations of marl and marlstones (Sarasate Formation); 3 – Bored, mineralised and encrusted Santonian top hardground (HgSaI)
Lower-Upper Campanian boundary succession of Sarasate IV; 1 – Erosional gullies of Sarasate IV, south of the Mendi range, north-east of Sarasate; exposed at the beginning of the 80ees; 2 – The boundary lies east of the pylon; 3 – Erosional gullies in the Upper Campanian *Echinocorys subglobosa* Zone
Santonian-Campanian boundary sequence and hiatus conglomerate at Urrizola EII and Arardi II; 1 – Urrizola EII; Santonian limestone-marl alternations overlain by the Urrizola Conglomerate, middle Lower Campanian glauconitic marls, and glauconite sands; 2-3 – Urrizola Conglomerate exposed east of the Urrizola village (scale: marker = 14.0 cm in Fig. 2); 4-5 – Urrizola Conglomerate at Arardi II; southern edge of Arardi mount.