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

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ABSTRACT:

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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, Trachyscaphites spiniger, Pseudoxybeloceras phaleratum, Nostoceras* (*Bostrychoceras*) *polyplocum, Trachyscaphites pulcherrimus, 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 Upper Campanian *marroti* Zone, the onset of a third phase (UCTE) in the upper Upper Campanian *polyplocum* Zone.

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

CONTENTS

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, KÜCHLER *& 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 – KÜCHLER, 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* KÜCHLER 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 (KÜCHLER 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 (KÜCHLER & KUTZ 1989).

Area of Izurdiaga/Urrizola (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, Urrizola S, Urrizola E I and II sections – see Text-fig. 1C). The Santonian Upper Izurdiaga Limestone Formation (KÜCHLER 1998b) between Izurdiaga and Urrizola 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 Urrizola 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 Urrizola, 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 Urrizola 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).

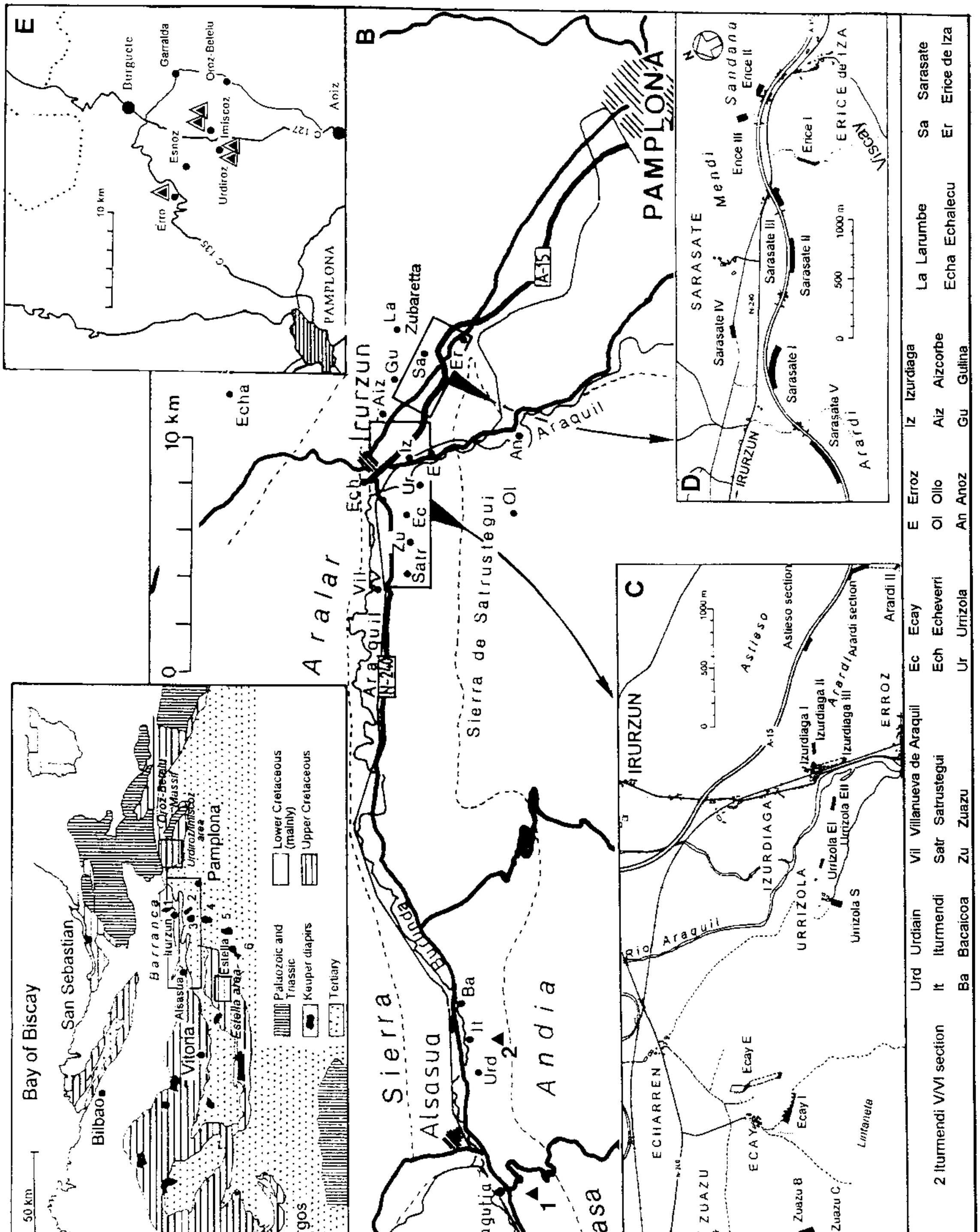

Fig. 1. Sketch-map of northern Spain, with location of the Barranca and other reference areas mentioned in the text (1A), the geographical location of the investigated sections in the western and eastern Barranca (1B-D), and location of investigated section west of the Oroz-Betelu Massif, eastern Navarra (1E)

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 *Gonioteuthis granulataquadrata* (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. granulataquadrata* 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 substage 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, BŁASZKIEWICZ 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 *Gonioteuthis* 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 *Gonioteuthis* coincides with the FAD of *Hoplitoplacenticeras* in Germany. In Westphalia (GIERS 1964) and in Lower Saxony, the LAD of *Gonioteuthis quadrata* (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 marroti* COQUAND (compare also KÜCHLER & KUTZ 1989, GRÄFE & WIEDMANN 1993).

In the Barranca the FAD of *H. marroti* 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, BŁASZKIEWICZ 1979, 1980). It is, however, not particularly well suited because it appears stratigraphically higher than *H. marroti,* 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 polyplocum* Zone.

MARTINEZ (1982) used a three-fold division of the Campanian for Lleida (Catalonian) with a *Diplacmoceras* *bidorsatum* (Lower Campanian), *Menabites delawarensis* (Middle Campanian) and a *Hoplitoplacenticeras vari* Zone (Upper Campanian). No characteristic ammonites are found in the Lower Campanian up to the lower Upper Campanian *H. coesfeldiense* Subzone. In the upper part of the Upper Campanian, MARTINEZ (1982) was able to recognise an ammonite assemblage which he referred to the *Bostrychoceras polyplocum* Subzone (= upper subzone of his *vari* Zone). The Upper Campanian ammonite localities are close to the villages of Torallola and Sensui, between Tremp and La Pobla de Segur. There, the fauna was collected from allochthonous, slumped successions of the Tremp Formation. Around the villages of Vila Vella and Montesqui (Sant Conelli), a comparable ammonite fauna was collected from autochthonous or parautochthonous strata. MARTINEZ (1982, p. 181) listed the following species: *Trachyscaphites pulcherrimus* (ROEMER), *Diplomoceras notabile*? WHITEAVES, *Neancyloceras* sp., *Solenoceras* sp., *Nostoceras* sp., *Didymoceras* sp., *Bostrychoceras polyplocum* (ROEMER), *Baculites* sp. 1, *Baculites* sp. 2, *Libycoceras ismaeli* (ZITTEL), *Tetragonites epigonus* KOSSMAT, *Gaudryceras navarrense* WIEDMANN, *Gaudryceras* cf. *navarrense*, *Anagaudryceras* sp., and *Phylloceras* (*Hypophylloceras*) *woodsi woodsi*? VAN HOEPEN.

KÜCHLER & KUTZ (1989) listed both Lower and Upper Campanian ammonite assemblages from Navarra (Barranca and Udiroz/Imiscoz area) and showed their vertical distribution in the succession based on detailed measured sections. They presented an integrated zonal scheme, based essentially on ammonite/echinoid assemblage zones. They recognised the four so-called standard ammonite zones of the French Campanian type area (KENNEDY 1986) and were also able to establish a twofold subdivision of the Upper Campanian *polyplocum* Zone based on rich ammonite faunas. In comparison with that of WIEDMANN (1979), later adopted by AMIOT (1982, Fig. 3.14), their Campanian zonal scheme represented a significant refinement.

In GISCHLER & *al.* (1994), WIEDMANN modified his proposed Campanian zonation for northern Spain (WIEDMANN 1979) and suggested a twofold subdivision of the Lower Campanian into a lower *Bevahites subquadratus* Zone and a higher assemblage zone with *Eupachydiscus levyi, Scaphites hippocrepis* and *Neocrioceras riosi*. He regarded the Lower Campanian *subquadratus* Zone as equivalent to the *Offaster pomeli*/*Micraster* (*Isomicraster*) sp. AZ (Assemblage Zone) *sensu* KÜCHLER & KUTZ (1989), and considered that the *E. levyi*/ *S. hippocrepis*/*N. riosi* Zone equated with the *S. hippocrepis* Zone *sensu* KÜCHLER & KUTZ (1989) of the Barranca.

The Upper Campanian succession described by SANTAMARIA (1996) from Alava, exhibits a sequence of ammonites comparable to that of KÜCHLER & KUTZ (1989). SANTAMARIA (1996) recognised a *Hoplitoplacenticeras marroti* assemblage and a *Pachydiscus haldemsis* assemblage. The first was inferred to correlate with the base, the latter with the top of the French *H. marroti* Zone *sensu* KENNEDY (1996). The assemblages were interpreted to correlate with the *H. marroti*/*Offaster pilula* AZ and the *haldemsis*/*conoidea* Zone *sensu* KÜCHLER & KUTZ (1989) respectively. However, since gaps in exposures occur between these two assemblages in Alava, SANTAMARIA (1996) was unable to recognise clear boundaries to the assemblages and hence did not present a zonal scheme. He correlated his youngest assemblage, the *Nostoceras* (*Bostrychoceras*) *polyplocum* assemblage, with the *B. polyplocum* Zone *sensu* KÜCHLER & KUTZ (1989).

An investigation of the material at the Museo de Ciencias Naturales de Alava in Vitoria and a re-examination of the sections listed in SANTAMARIA (1996), revealed only small differences in the stratigraphic position of his assemblages. The *H. marroti* assemblage from the locality Jauregui I correlates not with the *marroti*/*pilula* Zone but with the higher part of the *Echinocorys subglobosa* Zone of KÜCHLER & KUTZ (1989). It therefore corresponds not to the basal, but to the middle part of the *H. marroti* Standard Zone. The *P. haldemsis* assemblage from Puerto de Vitoria still yields *H. marroti* (C. CORRAL, *pers. comm.*) and is, otherwise comparable with the upper part of the *marroti* Zone [= *E. subglobosa* Zone to the *Trachyscaphites 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.*) *euskadiense* II KÜCHLER, several *Nostoceras* (*E.*) *unituberculatum* (BŁASZKIEWICZ), a single fragment of *N.* (*B.*) *polyplocum polyplocum* and *Pseudoxybeloceras interruptum* (SCHLÜTER). The occurrence of *N.* (*E.*) *euskadiense* II in the Jauregui II fauna indicates a slightly younger age than the *polyplocum* Zone, as it falls into the base of the *Didymoceras* [spp.]/*E. conoidea*-Zone *sensu* KÜCHLER & KUTZ (1989) or into the *Trachyscaphites pulcherrimus* Zone as used in this work.

LITHOSTRATIGRAPHY OF THE CAMPANIAN 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* VÖLTZ 1964, EWERT 1964, SCHWENTKE 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-bedded 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 Irurzun (*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 Erice de Iza and Ecay. In the west, near Ecay, 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 Erice 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 hiati 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 Irurzun, 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 substage 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

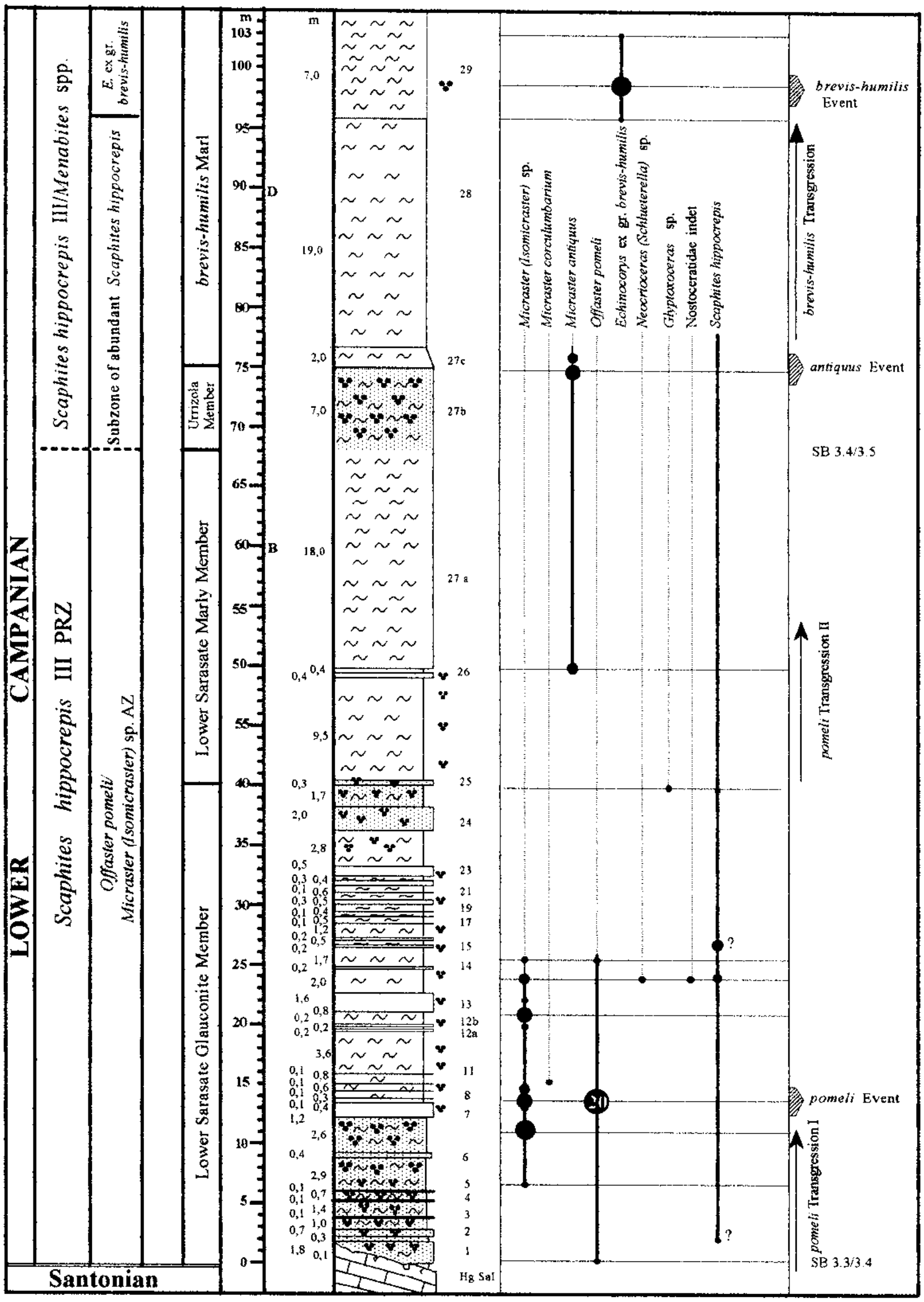

Fig. 2. Sarasate Ia section, 1.5 km west of Sarasate; Santonian limestones overlain discordantly by middle Lower Campanian glauconitic marl/marlstone alternations; integrated litho-, bio- and event stratigraphy

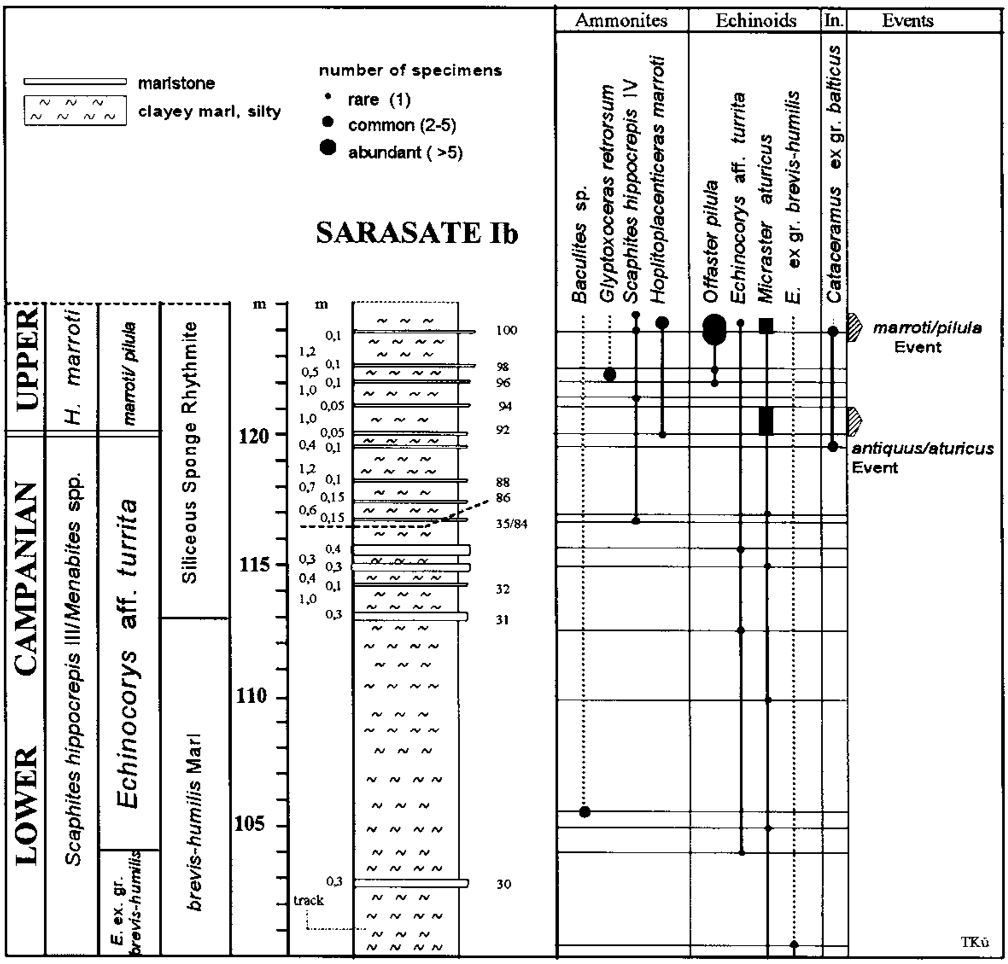

Fig. 3. Sarasate Ib section; boundary interval between Lower and Upper Campanian (*Scaphites hippocrepis* III/*Menabites* spp. Zone and *Hoplitoplacenticeras marroti* Zone); lithostratigraphic column, bio- and event stratigraphy and local ranges of stratigraphically important groups

and extends up into the middle Lower Campanian (*Echinocorys brevis – humilis* Zone), while Sarasate Ib extends from the *Echinocorys* 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-bedded, 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 phosphatised, and exhibits cracks and solution cavities. It is encrusted by serpulids and exogyrine oysters and penetrated by borings which, like the *Thalassinoides* 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 CARBAYO *& al.* (1978, p. 27), and based on the foraminifer cited, most probably *Dicarinella concavata* planktonic 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 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 glauconitised limestone pebbles were found in one of these pockets 0.6 to 1.3 m deep.

Based on the echinoid fauna, the basal, transgressive glauconitic sediments of the Sarasate Formation were assigned to the middle Lower Campanian. Sedimentological and biostratigraphical data indicate an hiatus that locally comprises the uppermost Upper Santonian and lowermost Lower Campanian. In the Sarasate I section the extent of the Campanian hiatus comprises the equivalent of the early Lower Campanian *Gonioteuthis granulataquadrata* and *lingua/quadrata* zones of the North German zonal scheme of SCHULZ & *al.* (1984) (*see* Text-figs 15-16) and, correspondingly, part of the *Placenticeras bidorsatum* ammonite Zone in the sense of the French zonation (*see* KENNEDY 1986) (*see* Text-fig. 16). The extent of the Santonian hiatus cannot be properly estimated because of the inadequate biostratigraphical data.

Five lithostratigraphical units are distinguished in the Sarasate I section (*see* Text-figs 2-3), in ascending order:

Lower Sarasate Glauconite Member (*Member A*) [section height 0-40 m]: (*see* Text-fig. 2). This consists of a closely-spaced alternation of silty, glauconitic marls/clay rich marls and thin-bedded (0.1 – 0.2 m) marlstones or nodular marlstone. The lowest ca. 13-14 m are highly glauconitic.

Lower Sarasate Marl Member (*Member B*) [section height 40 – 68 m]: The ca. 28 m thick succession is composed of slightly glauconitic, blue-grey silty marls with a gradually upward increasing glauconite content.

Urrizola Member (*Member C*) [section height 68-75 m]: At Sarasate I, the ca. 7 m thick member is composed of glauconitic marls to glauconite-rich marlstones which, because of their strong bioturbation and extraordinarily high glauconite content, are clearly distinguishable from the underlying members.

brevis – humilis Marl (*Member D*) [section height 75-113 m]: These greyish-blue, thin-bedded marls/ clayey marls (Text-figs 2-3) have a very low glauconite content, and are characterised by the calcisponge *Porosphaera nuciformis* and the eponymous echinoid *Echinocorys* ex gr. *brevis-humilis*.

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 SUBCOMISSION 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 *Scaphites hippocrepis*
(i) *Offaster pomeli/M.* (*Isomicraster*) sp. Assemblage Zone

The four lower zones enable a more refined subdivision of the widely occurring *Scaphites hippocrepis* III Total Range Zone and, consequently, a more precise dating of eustatic and tectoeustatic 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 (HgSal) 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. ERNST (*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*

ERNST 1970c, Text-fig. 4), which occurs in northern Germany in the lower Lower Campanian.

The *pomeli*/*Micraster* (*Isomicraster*) sp. AZ represents the middle Lower Campanian and falls in the *Scaphites hippocrepis* Partial Range Zone, as *Scaphites hippocrepis* DEKAY III occurs already in the basal, glauconitic part of the section. The zone ranges from the base of the Sarasate Formation to Member C (*see* Text-fig. 2). Member A is characterised by the abundance of irregular echinoids belonging to the genera *Micraster* and *Offaster*. On the other hand, ammonites are rare and hitherto known only from fragments of *S. hippocrepis* III, *Glyptoxoceras* sp. and *Neocrioceras* (*Schlueterella*?) sp. *S. hippocrepis* was first found *in situ* in bed SaI-13/14, 40 m above the base of the zone, associated with *Neocrioceras* (*Schlueterella*?) sp. and a single, indeterminable nostoceratid.

Subzone of abundant Scaphites hippocrepis: The subzone ranges from the base of Member C to the lower part of Member D at Sarasate I. It is defined by the acme-occurrence of *S. hippocrepis* III in the middle part of its total range. This acme is recognisable in more marginal sections, *e.g.* at Izurdiaga and Urrizola (*see* Text-figs. 9-10).

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.

Echinocorys aff. *turrita Partial Range Zone*: The base of the zone is defined by the FAD of the index taxon *E.* aff. *turrita* LAMBERT (Pl. 6, Figs 1-3), ca. 6.0 m above the *brevis – humilis* Event. The species occurs rarely and locally ranges up to the Upper Campanian *marroti*/*pilula* Event. Its occurrence seems to be limited to the Sarasate area, while in the glauconitic facies of the Izurdiaga/Urrizola area only *Echinocorys* aff. *gibba* LAMARCK is found (*see* Text-figs 10, 18). Both forms thus seem to be facies-dependent. The zone is also characterised by the first appearance of the *Micraster aturicus* lineage.

Hoplitoplacenticeras marroti/Offaster pilula Assemblage Zone: The zone is characterised by the acme-occurrence of the two index taxa. As well as *Micraster* (*Micraster aturicus* SEUNES and *M. antiquus* COTTEAU), ammonites [*S. hippocrepis* (DEKAY) IV, *Glyptoxoceras retrorsum* (SCHLÜTER) and hoplitoplacenticeratids] become more common. *S. hippocrepis* (DEKAY) IV is regarded as a new chronological subspecies (KÜCHLER 2000a), with characters that correspond to the forms referred by KENNEDY & *al.* (1992b, Pl. 1, Figs 1 and 13) to *Scaphites haugi* DE GROSSOUVRE. *S. hippocrepis* IV is, however, not, conspecific with the type specimen of *S. haugi*, as described and refigured by KENNEDY (1986).

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).

Offaster pomeli Transgression I: At Sarasate I, the basal Campanian transgressive succession rests with erosive contact on the Santonian hardground. The *pomeli* Transgression is marked by a glauconitic facies and a thinning upward sequence. The hardground is overlain here by beds belonging to the *O. pomeli*/*M.* (*Isomicraster*) sp. AZ, which corresponds to the upper *pilula* Zone (upper Lower Campanian) of northern Germany and southern England (KÜCHLER & KUTZ 1989) (*see* Text-fig. 16).

Offaster pomeli Event: This is the level of the first Lower Campanian mass-occurrence of the echinoid genus *Offaster.* This genus first appears in northern Spain at least as low as the upper Lower Santonian, from which the species *Offaster nuciformis* ERNST was reported (*compare* Zuazu section, KÜCHLER 1998b). Apart from Sarasate I, the *pomeli* Event is also known from the Astieso section (KÜCHLER, *in prep*.) (*see* Text-fig. 1).

At Sarasate I, the event lies ca. 13.5 m above the erosion surface (HgSaI) 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 (RADIG 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 the 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).

Offaster pomeli Transgression II: In the upper third of the *S. hippocrepis* III Zone or the *pomeli*/*M*. (*Isomicraster*) sp. AZ, the change from a highly glauconitic marl/marlstone alternation to distal clayey marls without glauconite, documents the transgressive pulse.

Micraster antiquus Event: The event is characterised by an horizon with abundant small *Micraster antiquus,* ca. 2 m below the top of the Urrizola Member.

Echinocorys brevis – humilis Transgression: The next transgressive pulse is marked, even in relatively distal successions, by a strong facies change in the upper part of the local Subzone of abundant *Scaphites hippocrepis,* which is interpreted here as the beginning of sequence 3.5 of HAQ & *al.* (1987). Near Sarasate, strongly bioturbated glauconite marls of the Urrizola Member are overlain by distal greyish-blue marls/clayey marls. The eponymous echinoid *E*. ex gr. *brevis-humilis* first appears 19 m above the transgression surface, indicating a much more complete succession here than in the Izurdiaga III and Urrizola EII 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).

marroti/pilula Event: This is an *Offaster pilula* mass-occurrence in the basal part of the Upper Campanian. At Sarasate I, this level is ca. 1.5 m thick; because of the common co-occurrence of the ammonite species *Hoplitoplacenticeras marroti*, it is referred to as the *marroti/pilula* Event. The occurrence of *H. marroti* unequivocally dates the horizon as earliest Late Campanian *marroti* Zone

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

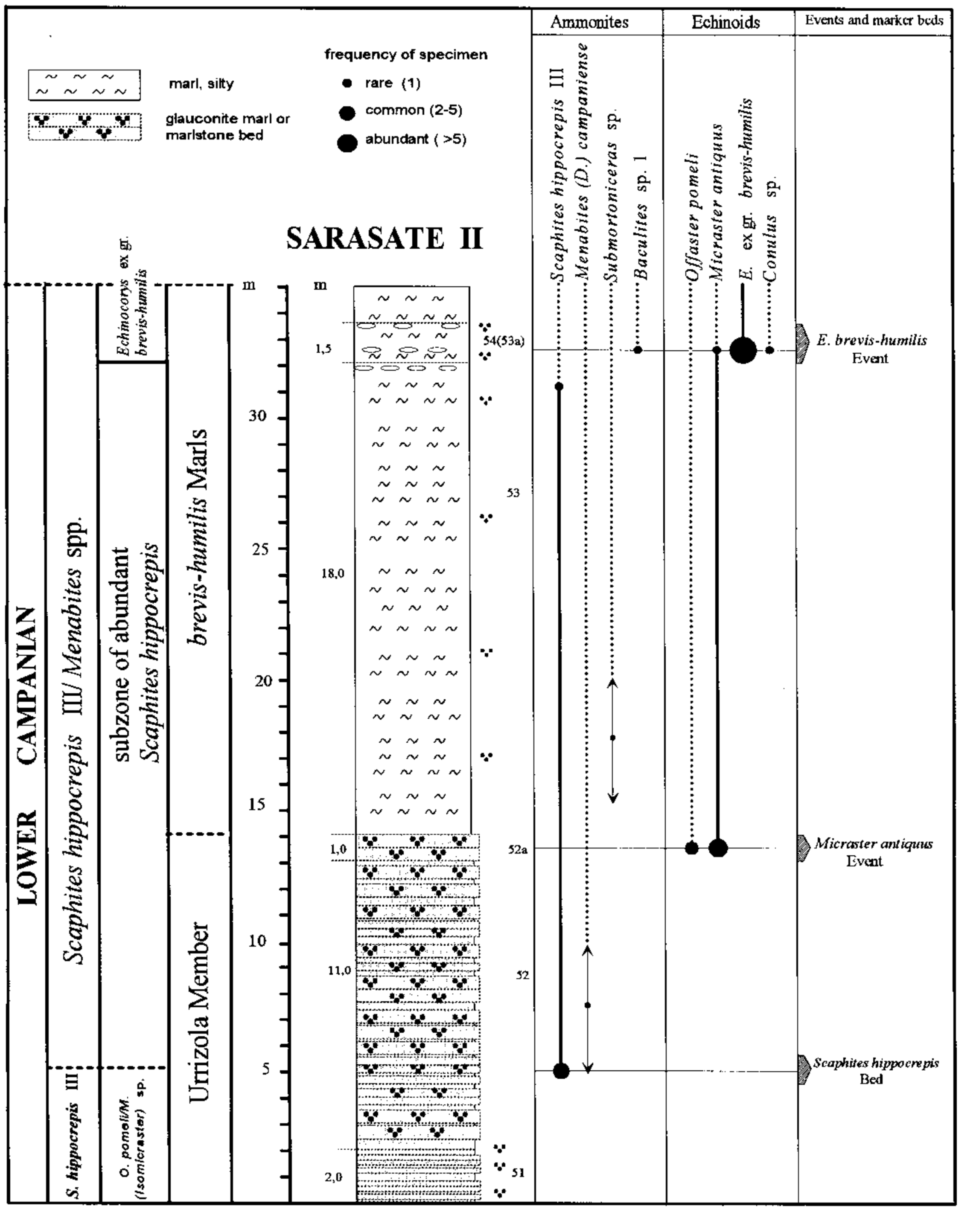

Fig. 4. Sarasate II section; lithostratigraphical column, bio- and event stratigraphy and vertical ranges of ammonites and echinoids

Sarasate (*see* Text-fig. 1D, Plate 1, Fig. B), is now largely overgrown. The motorway here cuts through the NE flank of the Sandaña/Sollaondi 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 Izurdiaga 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 calcisponges (*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 *Submortoniceras* 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 *Submortoniceras* 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 (KÜCHLER & 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 rhythmically 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 (*Porosphaera*) 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.

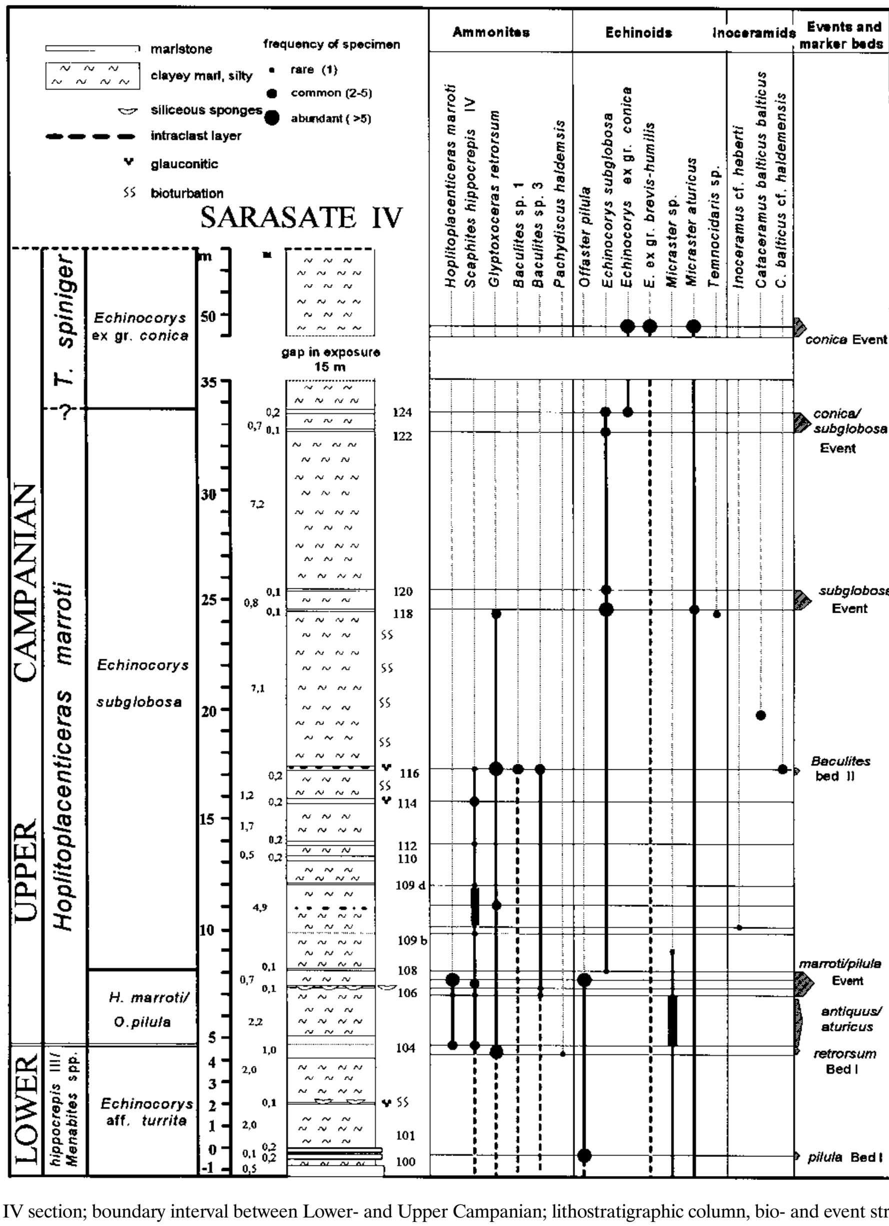

Fig. 5. Sarasate IV section; boundary interval between Lower- and Upper Campanian; lithostratigraphic column, bio- and event stratigraphy and local ranges of ammonites, irregular echinoids and inoceramids

Fauna and integrated biostratigraphy

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

The FAD of *Hoplitoplacenticeras marroti* (Pl. 9, Figs 1-2, 3, 7-8), is in bed SaIV-104. It marks the base of the European basal Upper Campanian *marroti* Zone and the local *marroti*/*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 haldemsis (SCHLÜTER) (Pl. 9, Fig. 4), appears at the same level as *H. marroti*. Throughout the local *marroti*/*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 *Glyptoxoceras 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 Upper Campanian (*see* Text-fig. 5). *Baculites* sp. 3, including both smooth and fine-ribbed variants, occurs commonly in the *marroti*/*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 *marroti*/*pilula* Event. Its late first appearance in northern Spain in the Upper Campanian *marroti* 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 *marroti*/*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 haldemsis*/*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. *conoidea* (*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 Ecay 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 Ib section). Amongst poorly preserved specimens from the Clayey Marl Member of Sarasate IV, K.-A. TRÖGER identified *Cataceramus balticus* (BÖHM), *C. balticus* cf. *haldemensis* (GIERS), and *Inoceramus* cf. *heberti* FALLOT. *Cordiceramus subsarumensis*? 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 *marroti*/*pilula* event-sequence.

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 *marroti*/*pilula* Event. The former level marks the base of an acme-zone of *O. pilula* around the Lower/Upper Campanian boundary in northern Spain.

Glyptoxoceras 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. marroti*. 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 *marroti*/*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. *Glyptoxoceras 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; 1:10 000, 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?).

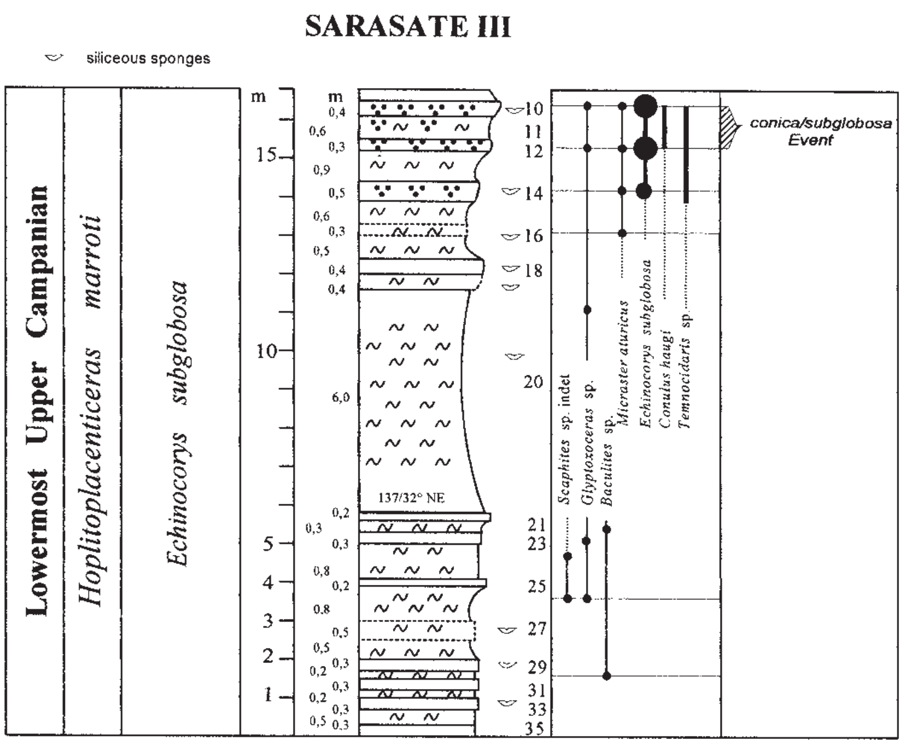

Fig. 6. Sarasate III section, south of the petrol station between Sarasate and Erice de Iza; lithostratigraphic column, bio- and event stratigraphy and vertical ranges of stratigraphically important groups

Lithostratigraphy

The succession starts within the *brevis – humilis* 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: *Glyptoxoceras* sp., *Baculites* sp., *Scaphites* sp. indet., *Hoplitoplacenticeras* sp. indet (loose) and *Pachydiscus* sp. (loose) (*see* also Text-fig. 6).

Echinoids: The upper part of the section is characterised by the common occurrence of irregular and regular echinoids. Most of the material was collected from the talus and comprises *Micraster aturicus*, *M. antiquus*, *M. gourdoni* COTTEAU, *Echinocorys subglobosa*, *E.* ex gr. *brevis-humilis*, *Conulus haugi*, and *Temnocidaris* sp. (*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 *polyplocum* 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 KÜCHLER & 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 reddish. They contain abundant quartz-agglutinating foraminifer (*e.g. Navarella joaquini* CIRY & 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* (*Bostrychoceras*) *polyplocum* Zone represented by *N.* (*B.*) *polyplocum* ssp. indet

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

(3) *Nostoceras* (*Didymoceras*) *archiacianum* Zone, represented by: *N.* (*D.*) cf. *archiacianum* (D'ORBIGNY), *Nostoceras* (*Didymoceras*) sp. 1, *Nostoceras* (*Didymoceras*) cf. *donezianum* (MIKHAILOV), *Gaudryceras mite* (VON HAUER), *Polyptychoceras pseudogaultianum* (YOKOYAMA), *N.* (*B.*) *polyplocum* ssp. indet., *N.* (*B.*) *polyplocum polyplocum* (ROEMER), and *T. pulcherrimus.*

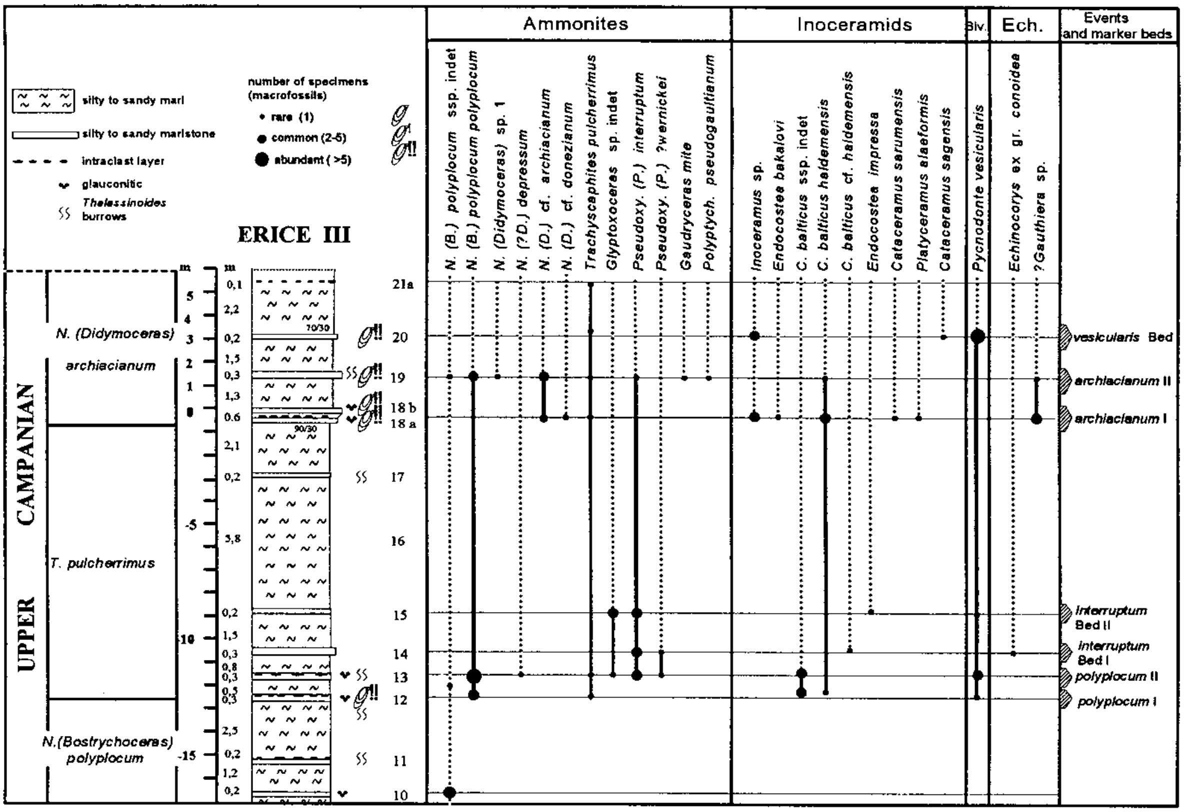

Fig. 7. Erice III section; Upper Campanian; integrated bio- and event stratigraphy; local ranges of ammonites, bivalves and echinoids

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 A: *Cataceramus balticus* ssp. indet., *C. balticus haldemensis* (GIERS), *C. balticus* cf. *haldemensis.*

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 *polyplocum* Zone and the basal part of the *Didymoceras donezianum* Zone *sensu* BŁASZKIEWICZ (1980) in central Poland. The middle and upper parts of the Polish *polyplocum* 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 BŁASZKIEWICZ (1980).

According to BŁASZKIEWICZ (1980, p. 13) the entry of *T. pulcherrimus* characterises the middle part of his *polyplocum* 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.*) *polyplocum polyplocum* 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.*) *polyplocum Event I*: The event is marked by the abundance of a coarsely-ribbed morphotype of *N.* (*B.*) *polyplocum polyplocum*, 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.*

vesicularis 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. pulcherrimus*, *Glyptoxoceras* sp. indet, *Pseudoxybeloceras* (*Parasolenoceras*) *interruptum*, and *P.* (*Parasolenoceras*) ?*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. indet.

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. pulcherrimus*, *P. interruptum*, *Glyptoxoceras* sp., *Polyptychoceras* (*P.*) *pseudogaultianum*, and *Gaudryceras mite*.

Pycnodonte vesicularis 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 neubergicus*/*P. epiplectus* Assemblage Zone. The latter zone is documented only by a low-diversity ammonite fauna. The index ammonite *P. epiplectus* (REDTENBACHER) 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* KÜCHLER & 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 LOPEZ & *al.* (1992).

Echinoids: *Micraster* (*Isomicraster*) *stolleyi* LAMBERT characterises the 6 m thick interval between beds ErII-24 and ErII-30 and *Cardiotaxis heberti* (COTTEAU) occurs in ErII 29. Single specimens of *Echinocorys* ex gr. *conoidea-heberti* 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 aturicus* 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.

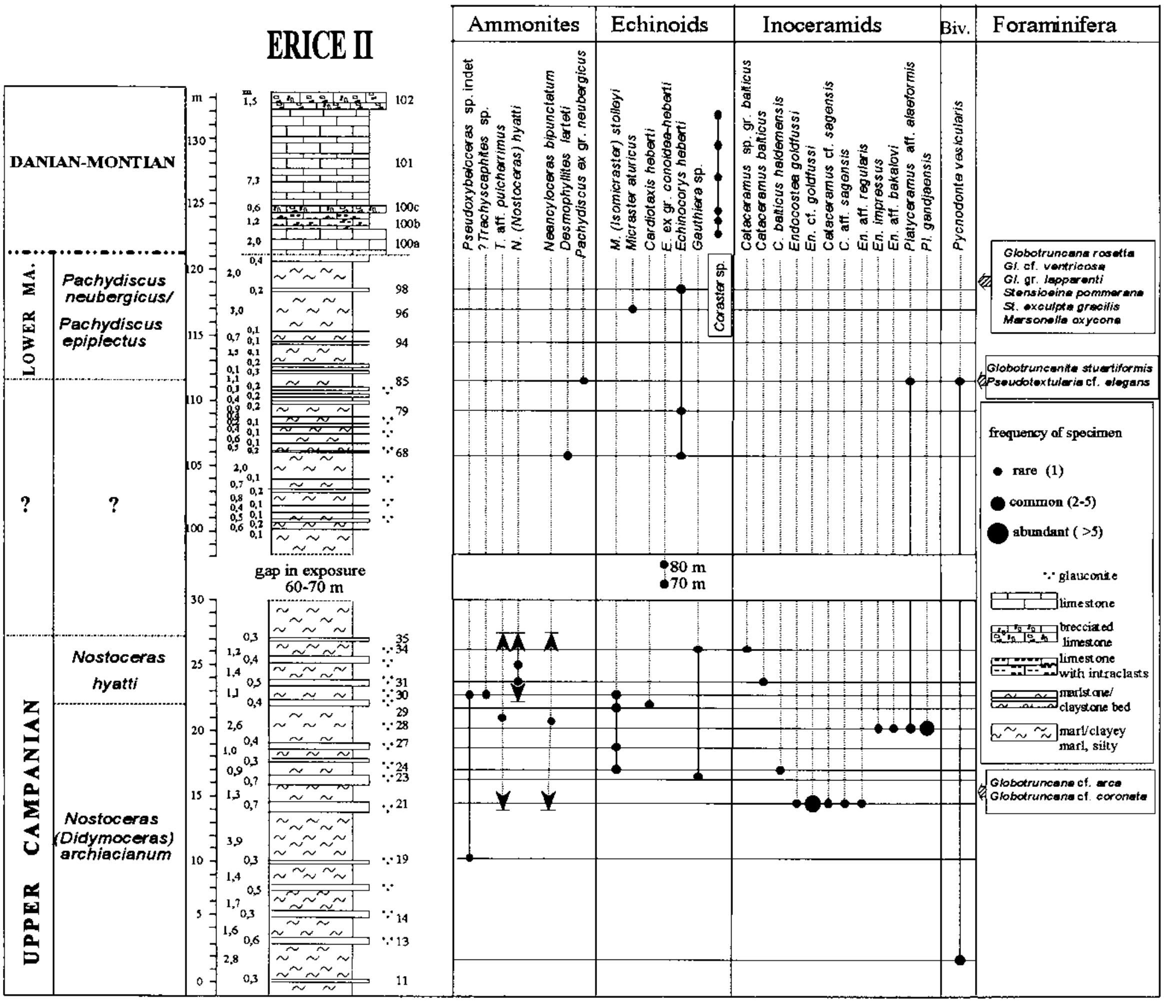

Fig. 8. Erice II section; Campanian – Maastrichtian transition interval; biostratigraphy and ranges of ammonites, inoceramids and echinoids; filled circles: number of specimens collected per bed, arrows: specimens collected loose over a larger interval

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 KÜCHLER & 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* (*see* 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 (KÜCHLER & KUTZ 1989, KÜCHLER & *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.

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 hiati, 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 [*pomeli*/ *M.* (*Isomicraster*) sp. AZ].

Urrizola Member: The Urrizola Member is a 6.8 m thick, strongly bioturbated and highly glauconitic, more calcareous unit, which

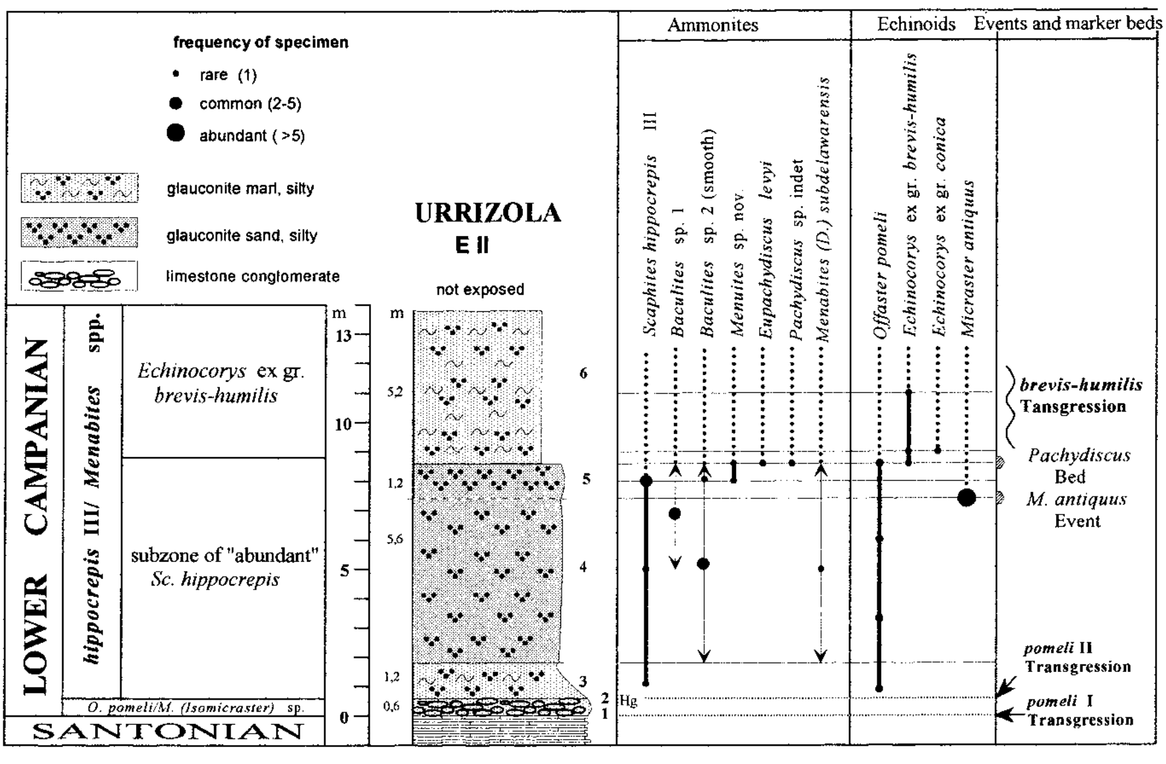

Fig. 9. Urrizola E II section; Santonian overlain by middle Lower Campanian conglomerates; Lower Campanian bio- and event stratigraphy and ranges of selected fossil groups; filled circles: number of specimens collected per bed, arrows and circles: specimens collected loose over a larger interval

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 up to the top of the glauconite sands 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 KÜCHLER & 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*) *subdelawarensis* 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 *Coenholectypus* sp. cited by RADIG.

The association of advanced *S. hippocrepis* III, *M.* (*D.*) *subdelawarensis* 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.*) *delawarensis* 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 riosi 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 (KÜCHLER 1998b) was investigated in detail at the type locality (DEGENHARDT 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* KÜCHLER 1998b). About 17 m below the top of the Izurdiaga Group, DEGENHARDT (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* KÜCHLER 1998b, Pl. 13, Figs 7-8).

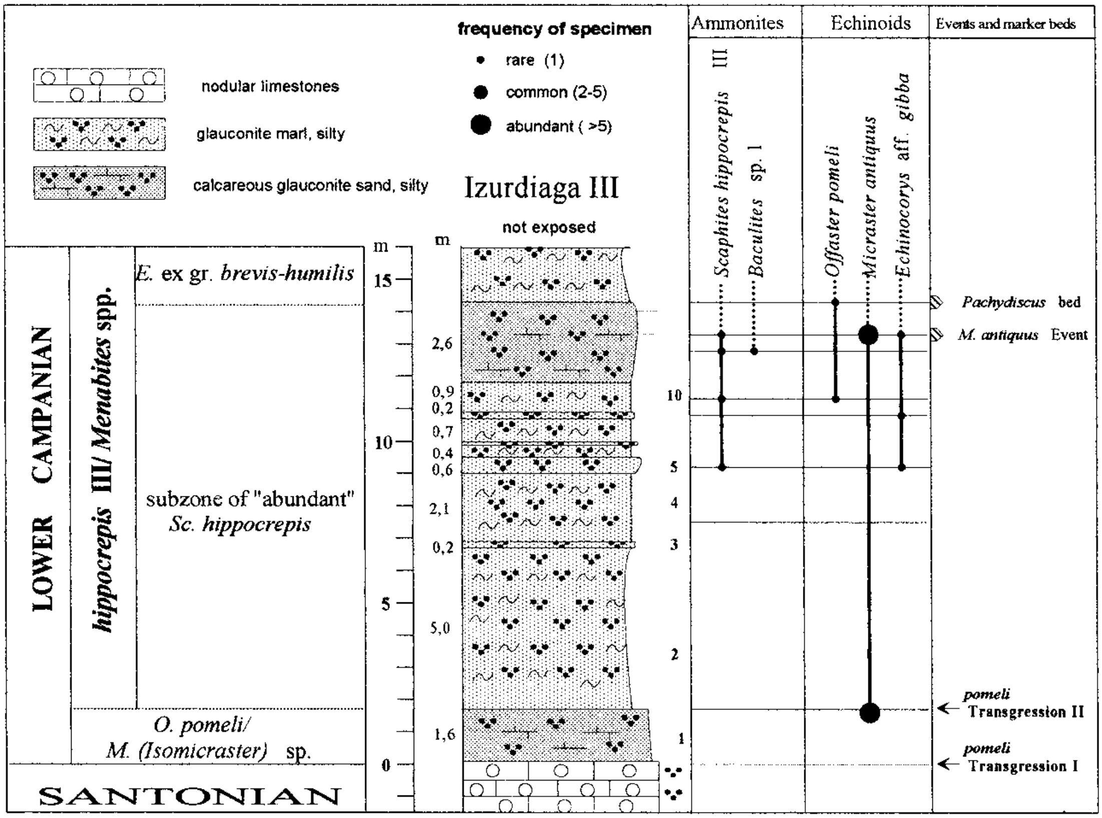

Fig. 10. Irzurdiaga III section; Upper? Santonian glauconitic limestones overlain concordantly by middle Lower Campanian glauconite sands

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 sections 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.

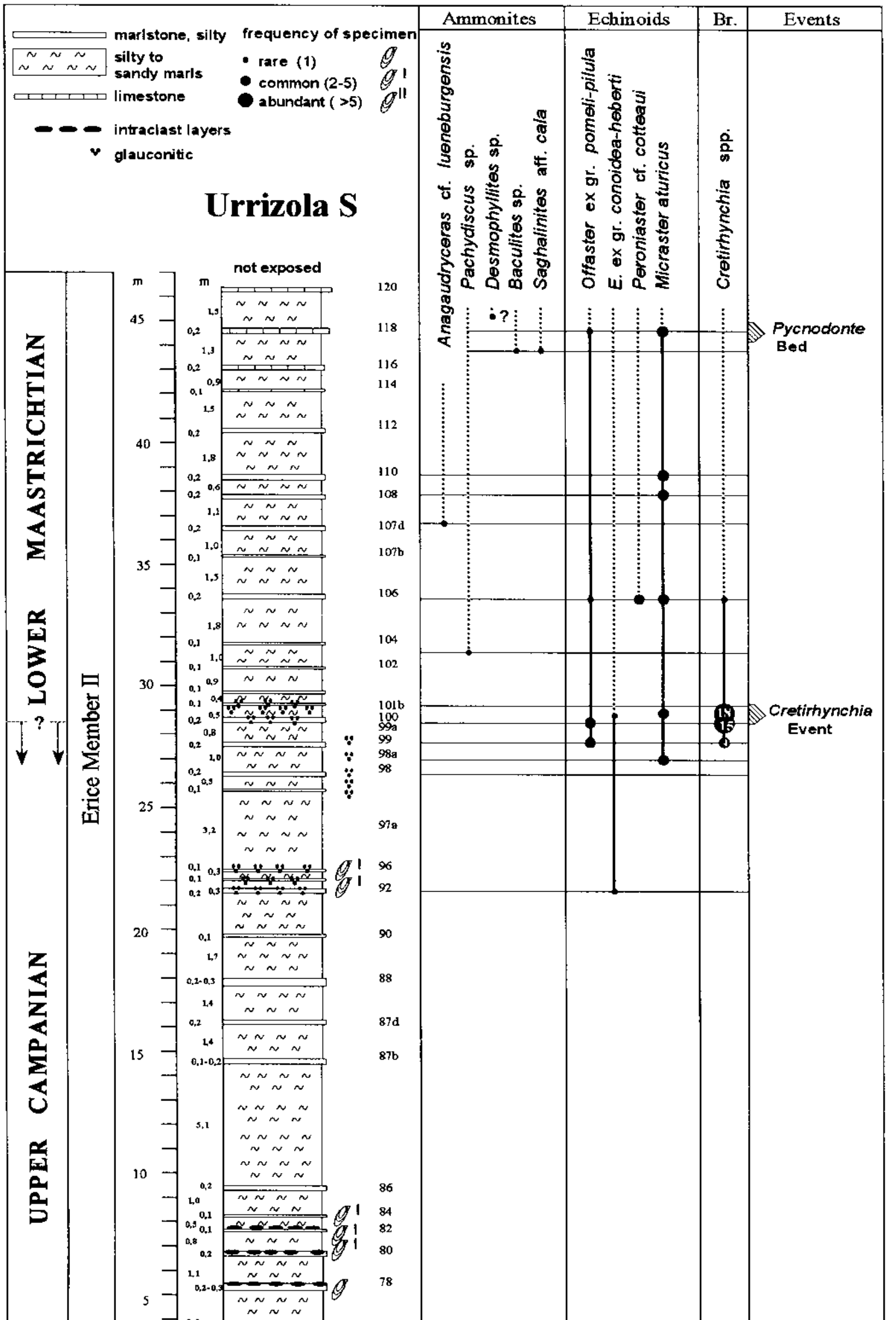

Fig. 11. Urrizola S section, Campanian – Maastrichtian transition interval

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 marls (1 – 1.5 m) and marlstones (0.1 – 0.2 m), which become yellow or reddish on weathering. The lower ca. 29 m of the member, up to the *Cretirhynchia* Event, is partly highly glauconitic and bioturbated. The lower 22 m contain several horizons with inoceramids or inoceramid debris, in some cases with associated intraclast layers (lituolacea/inoceramid debris packstones), representing a tempestite facies. The glauconite content decreases in the upper 18 m of the member and some more calcareous beds appear towards the top.

Fauna and integrated biostratigraphy

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

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. *cotteaui* GAUTHIER, *Echinocorys* ex gr. *conoidea – heberti*, *Micraster aturicus,* and *Micraster* (*Isomicraster*) 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. *cotteaui* 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.

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

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 Urrizola 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 Urrizola 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 siltier 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-glauconitic 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 lituolid foraminifer (Lituolacea) and a diverse calcareous benthos. The similarly high proportion of planktonic foraminifer (*Globotruncana*) 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.

Erice Member I: A distinct lithological change, with an increase in terrigenous input in the form of quartz, starts in bed EcI-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 EcI-110 to EcI-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. EcI-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**.**

Erice 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 miliolid forms.

Fauna and integrated biostratigraphy

The fauna comprises assemblages of echinoids (*O. pilula*, *Echinocorys* ex gr. *conoidea*, *Micraster* (*Isomicraster*) 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.*) *polyplocum*, *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 *polyplocum* Zone of KÜCHLER & KUTZ (1989) is here divided into two zones, a lower *polyplocum* 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-

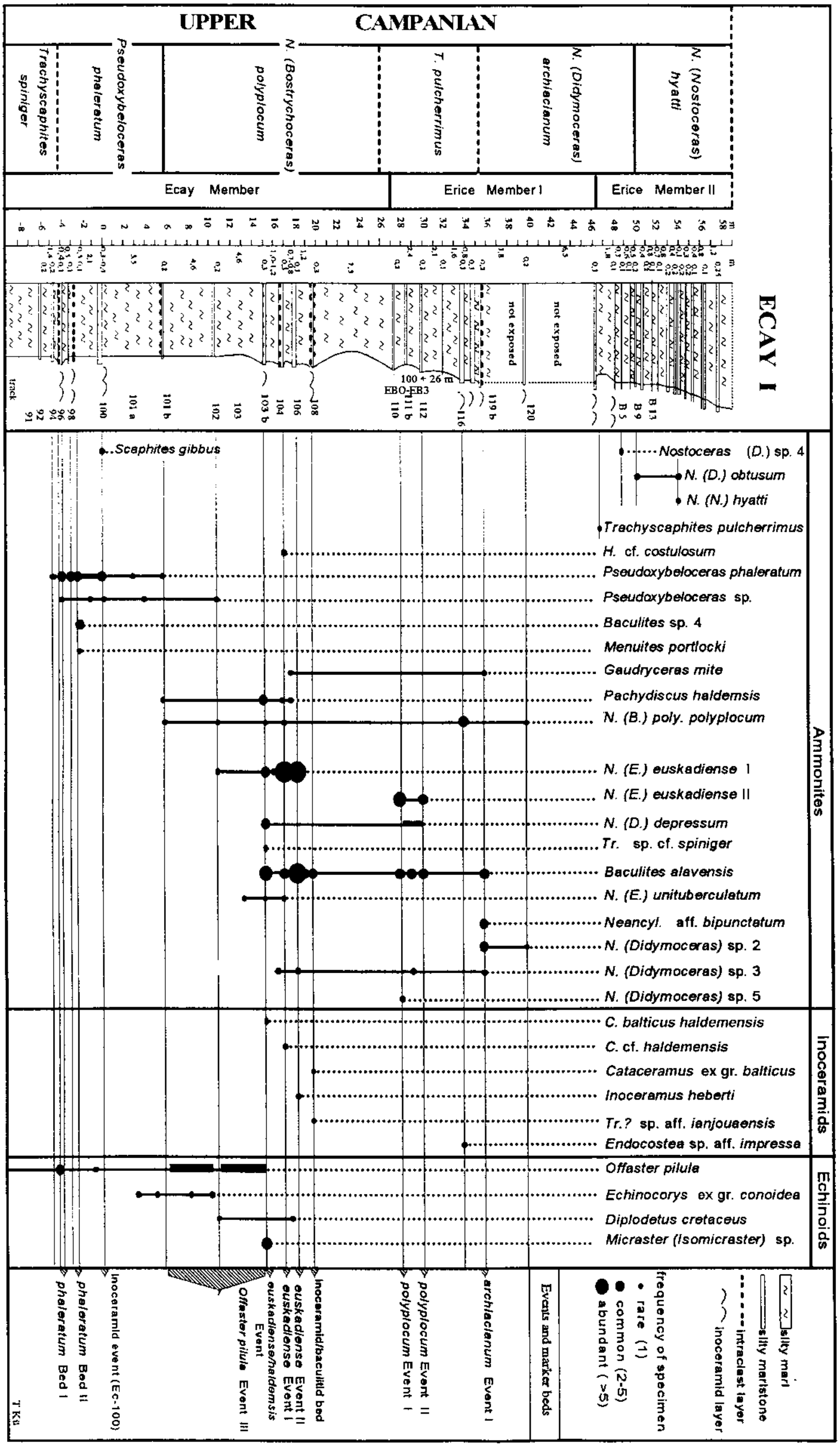

Fig. 12. Ecay I section, integrated litho-, bio- and event stratigraphy in the Upper Campanian; ranges of ammonites, echinoids and (not representive) occurrences of inoceramids

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 *Hoplitoplacenticeras marroti* 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., *Menuites portlocki* (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* (BŁASZKIEWICZ), *Nostoceras* (*D.*) *depressum* (WIEDMANN), *T.* cf. *spiniger*, and *Hoplitoplacenticeras* cf. *costulosum* (SCHLÜTER) are associated with *N.* (*E.*) *euskadiense* I. The middle third of the zone is characterised by the abundance of the strongly ribbed *Baculites alavensis* SANTAMARIA (SANTAMARIA 1996, KLINGER & KÜCHLER 1998). *Pachydiscus haldemsis* is also common. In the upper third of the *polyplocum* Zone ammonites are extremely rare.

Trachyscaphites 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.*) *euskadiense* 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 *Neancyloceras* aff. *bipunctatum* (*see* 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.*).

Offaster 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 *Diplodetus cretaceus*.

Nostoceras (*E.*) *euskadiense 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 *euskadiense/haldemsis*, *euskadiense* I and II events, and an inoceramid/baculitid bed at the top. The species *N.* (*E.*) *euskadiense* 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 intraclast 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. euskadiense* II) in a ca. 3 m thick interval. In the western part of the section (not shown), on the eastern bank of a brook

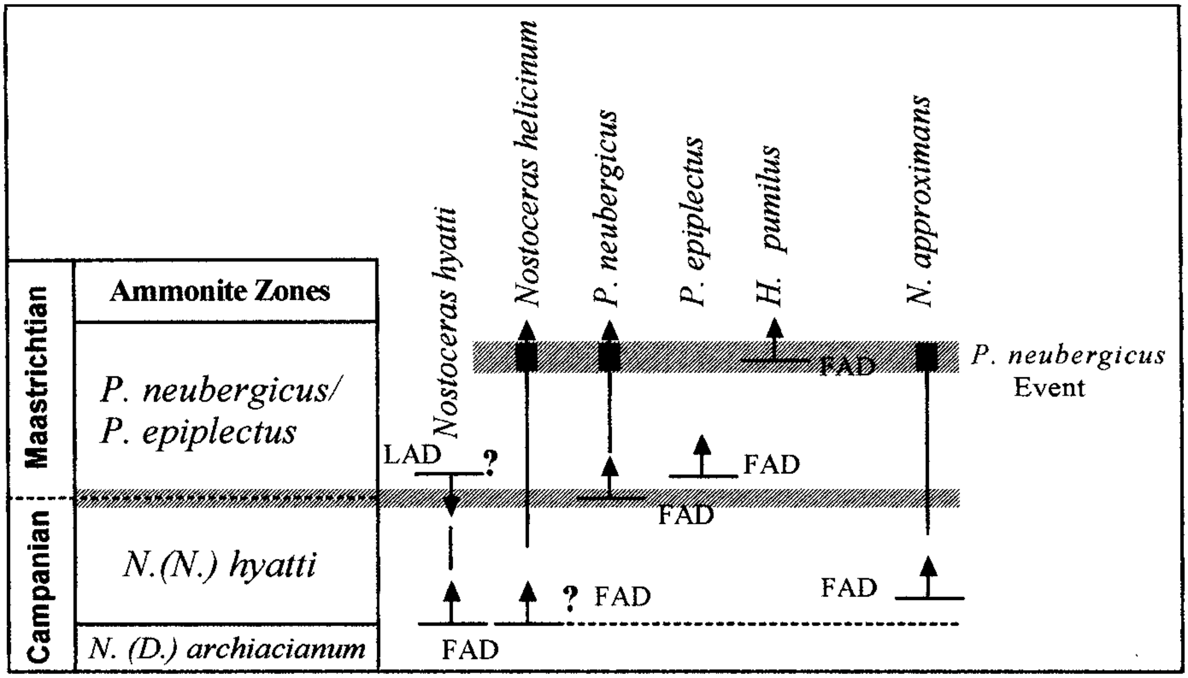

Fig. 13. Ammonite succession in the Campanian – Maastrichtian boundary interval of northern Spain

(EB=brook section), this interval is rich in fossils. In the lower part three 0.05 to 0.10 m thick intraclast horizons (EB_0-Eb_2) 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 (BŁASZKIEWICZ 1980) (*see* Text-fig. 16) will be discussed.

Basal Campanian (unnamed interval)

Because of extensive hiati 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 hiati. 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 predominant *Glyptoxoceras* spp. which, in the western Barranca, comprises *Glyptoxoceras* cf. *aquisgranense* (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 *Bevahites subquadratus* Zone. The index species, *B. subquadratus* COLLIGNON and *Submortoniceras tenuicostulatum* 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.

Substages	Ammonite Zones	Local echinoid partial range zones, peak zones, and ammonite/echinoid assemblage zones	Inoceramid Assemblages
Lower Maastrichtian	*Pachydiscus neubergicus/ Pachydiscus epiplectus*	*Echinocorys heberti*	*Platyceramus* aff. *alaeformis*
UPPER CAMPANIAN	*Nostoceras(N.) hyatti*		
	N. (D.) archiacianum	*Echinocorys* ex gr. *conoidea*	*En.* cf. *goldfussi* *Pl. gandjaensis*
	Trachyscaphites pulcherrimus		*C. balticus haldemensis* *En. impressus*
	N. (B.) polyplocum		*Tochoceramus?* sp.
	Pseudoxybeloceras phaleratum		
	Trachyscaphites spiniger	*Echinocorys* ex gr. *conica*	*Inoceramus heberti*
	Hoplitoplacenticeras marroti	*Echinocorys subglobosa*	*C. balticus haldemensis*
		H. marroti/Offaster pilula	
LOWER CAMPANIAN	*Scaphites hippocrepis* III/ *Menabites* spp.	*Echinocorys* aff. *turrita*	no record
		Echinocorys ex gr. *brevis-humilis*	
		Subzone of "abundant" *Scaphites hippocrepis*	
	Scaphites hippocrepis III	*Offaster pomeli/ M. (Isomicraster)* sp.	TKü
Upper Santonian	*Jouaniceras hispanicum/ Scalarites cingulatum*		*Cordiceramus muelleri*

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 *Glyptoxoceras retrorsum* (SCHLÜTER) from the basal 3.0 m of the so-called *Holaster similis* Marls 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 corculumbarium* 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 (Hannover-Braunschweig area). There, *P. bidorsatum* occurs together with *Eupachydiscus isculensis* (ERNST & *al.* 1979, Fig. 11). In addition, MÜLLER & WOLLEMANN (1906) reported *Hauericeras pseudogardeni* (SCHLÜTER), *Scaphites binodosus* ROEMER and *Crioceras serta* [= *Scalarites cingulatum* (SCHLÜTER)] from the Braunschweig area. The source locality at Broitzen was

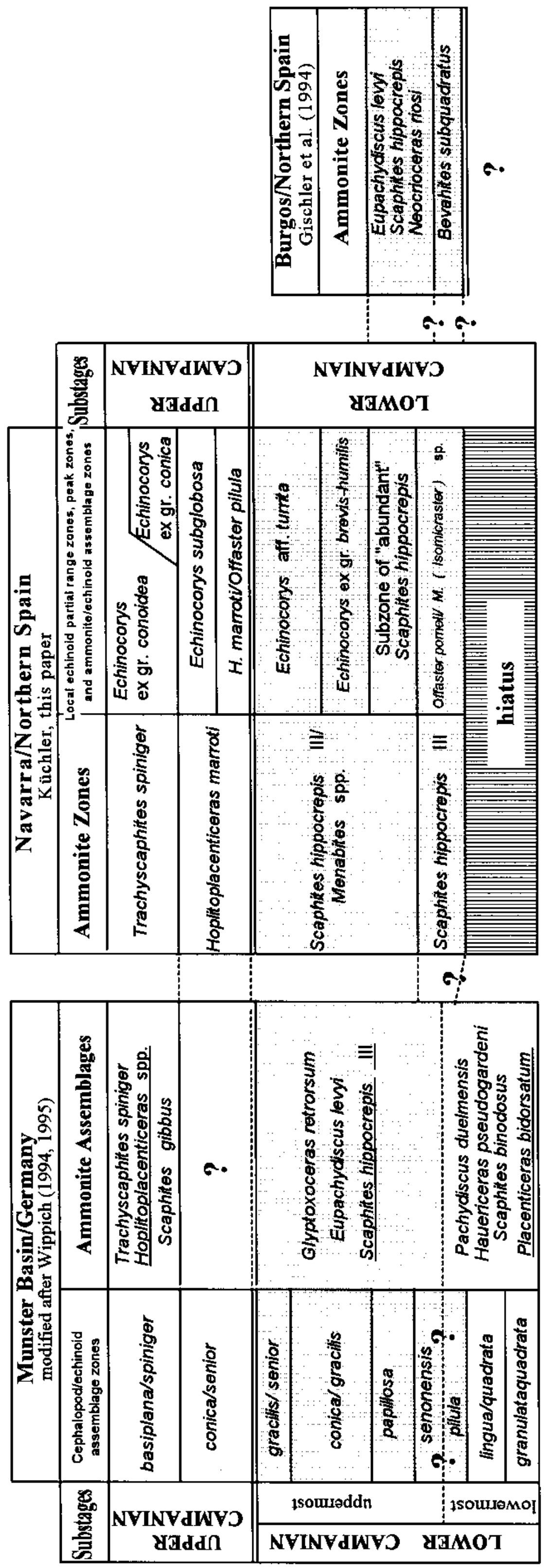

Fig. 15. Correlation of Campanian zonations established in the Munster basin, Germany and the Navarra and Burgos areas, northern Spain

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. pseudogardeni*, *Tetragonites obscurus* (SCHLÜTER), *S. binodosus, Scalarites cingulatum* and *Gonioteuthis quadrata* was described by SCHLÜTER (1871-1876). KENNEDY & KAPLAN (1995) revised this fauna and assigned it to the *granulataquadrata* to *lingua/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 *lingua/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 (WIPPICH 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 *lingua/quadrata* Zone.

France: The *Offaster pomeli/M*. (*Isomicraster*) sp. AZ of the Barranca was interpreted as an equivalent of the French *bidorsatum* Zone by KÜCHLER & KUTZ (1989). However, *P. bidorsatum* ranges into the higher Lower Campanian in France (KENNEDY 1986) and has a longer range than in Germany. In the upper part of its range *P. bidorsatum* overlaps with *S. hippocrepis* III and local occurrences of *Menabites* (*Delawarella*) *campaniense*, while in Lower Saxony it is restricted to the *granulataquadrata* Zone. In Westphalia, it occurs preferentially in the overlying *lingua/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 P^1 and P^2 *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 P^1 *sensu* lato (KENNEDY 1986), and DE GROSSOUVRE (1901) recorded *S. hippocrepis* just above the FAD of *P. bidorsatum* in P^{1b}.

The French *bidorsatum* Zone appears to comprise the entire Assise P^1 unit. However, if the FAD of *S. hippocrepis* is taken as a new zonal marker, it could be argued that the *bidorsatum* Zone corresponds only to Assise P^{1a} (which equates approximately with the interval from the *granulataquadrata* to ?*lingua/quadrata* Zone of Germany). In this context, the *hippocrepis* III PRZ of northern Spain can be regarded as an equivalent of the higher part of the French *bidorsatum* Zone, *i.e*. Assise P^{1b}.

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 *pomeli/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 levyi* (Pl. 7, Fig. 2), *Menuites* sp. ?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) came from the Arardi section (Arardi II) 1.5 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 condamyi* COLLIGNON; H. C. KLINGER, *pers. comm*. 1997] came from the Sarasate II section (Text-figs 1d, 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. hippocrepis* enters. This late form, following the nomenclature applied by COBBAN (1969), is called subspecies *hippocrepis* IV (KÜCHLER 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* GISCHLER & *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 Villamerdones, Nocedo and Quintanilla la 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* III, *M.* (*D.*) *delawarensis* and *Pachydiscus* cf. *launayi* DE GROSSOUVRE, with *Submortoniceras tenuicostulatum* and *S. gibbus* SCHLÜTER occurring at the top of the unit.

France: Correlation of the French *M.* (*D.*) *delawarensis* Zone into other areas of Europe is still problematic. According to KENNEDY (1984, 1986) ammonites are extremely rare in this interval in the northern Aquitaine, and the exact stratigraphical position of the few specimens of *Menabites* cannot be determined. They show an overlap with *P. bidorsatum*, *S. hippocrepis* and also with *H. marroti* (KENNEDY 1986, Tab. 2).

The *Menabites* recorded by DE GROSSOUVRE (1901) from Assise P^1 are inferred not to co-occur with *S. hippocrepis*, and the occurrence of *E. levyi* in this unit is doubted by KENNEDY (1986). In his opinion, all the *Menabites* finds came from the overlying *delawarensis* Zone (*compare* Text-fig. 16), which has definitely yielded only *M.* (*D.*) *delawarensis*, *M.* (*Delawarella*) *campaniense* and *M.* (*Australiella*) cf. *besairei* (COLLIGNON). Other species reported by KENNEDY (1986, Tab. 2) from Assise P^2, such as *Pachydiscus launayi*, *P.* cf. *complanatus* COLLIGNON, *H. marroti*, *Submortoniceras* sp., *Glyptoxoceras retrorsum*, *Baculites* sp. 1, *Baculites* sp. 2 , *Baculites* sp. 4 and *S. hippocrepis,* cannot be unequivocally attributed to this zone.

USA: The zonal assemblage with *E. levyi*, *M.* (*D.*) *subdelawarensis, M.* (*A.*) *australis* and *S. hippocrepis* III found in the Barranca enables a correlation with the *delawarensis* Zone of the USA.

The probable co-occurrence of *Menabites* spp. and the Upper Campanian index species *H. marroti* in France fits the situation in the Gober Chalk, NE Texas, where an association of *M.* (*D.*) *delawarensis* together with *S. hippocrepis* III and *Hoplitoplacenticeras* aff. *plasticum* PAULKE was recorded by COBBAN & KENNEDY (1992). In my opinion, either due to condensation or to the long vertical range of *M.* (*D.*) *delawarensis* and other *Menabites* species, the *delawarensis* and *marroti* zones in these two areas cannot be separated with confidence. It also seems that *S. hippocrepis* has a longer range in the USA than previously thought, as has already been pointed out (KÜCHLER & KUTZ 1989) in the case of northern Spain and Israel (Z. LEWY, *pers. comm*. 1999).

Subsequent work of KENNEDY & al. (1997) has shown the very long range of *M.* (*D.*) *delawarensis* in the Gulf Coast. The upper limit of it range is marked by an association of diverse *Menabites* (*Delawarella*) and *Trachyscaphites spiniger spiniger*, in this case, well above the disappearance of *S. hippocrepis* III in Mississippi and Alabama.

The interpretation of the Gober fauna from Texas as equivalent to the upper Lower Campanian *Belemnitella mucronata* Zone (COBBAN & KENNEDY 1992) is therefore considered here to be incorrect.

In Germany, both *Menabites* (*Delawarella*) and *Submortoniceras* are absent (*compare* LOMMERZHEIM 1995; WIPPICH 1995) and the genus *Hoplitoplacenticeras* is considered to be an unequivocal index for the Upper Campanian. The Gober fauna should therefore best 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 *delawarensis* Zone *sensu lato* in France and the USA. Its upper boundary is taken at the FAD of *H. marroti*.

Germany: In Westphalia (Text-fig. 15), the stratigraphical interval from the *papillosa* Zone to the *gracilis*/*senior* Zone equates with the Spanish *hippocrepis* III/*Menabites* spp. AZ, as indicated by the occurrence of *S. hippocrepis* III (WIPPICH 1995, Pl. 10, figs. 9-13; Pl. 11, Figs. 1?, 2, 5-7), as well as by the associated echinoid and ammonite assemblages. An assemblage comprising *G. retrorsum*, *E. levyi* and *S. hippocrepis* III (= Assemblage 2 *sensu* WIPPICH 1994) is characteristic of the *senonensis* to *conica*/*gracilis*

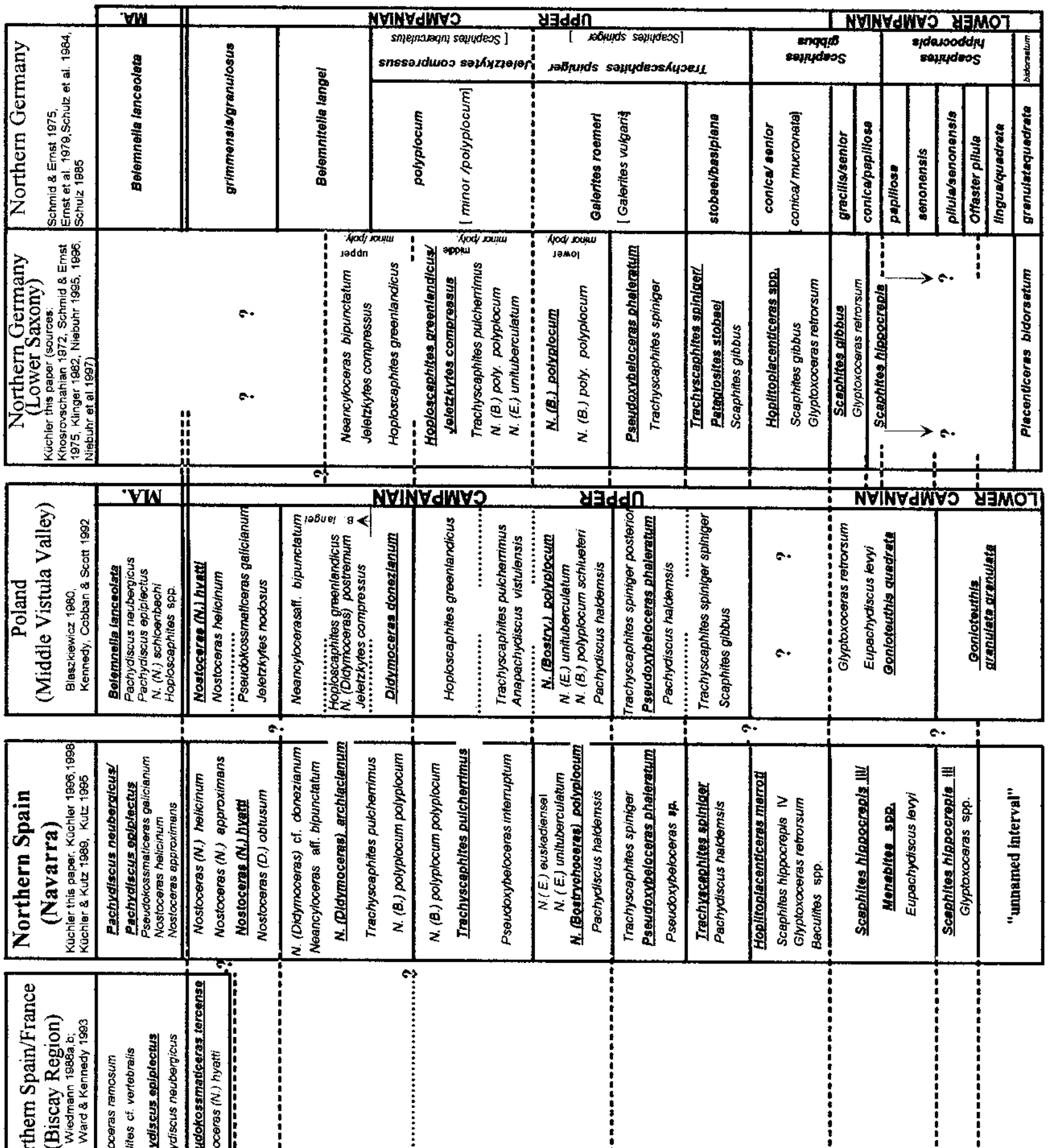

Fig. 16. Comparison of the European Campanian to Lower Maastrichtian cephalopod zonations and typical ammonite assemblages; zones are not to scale; zonal indices are underlined; other quoted taxa are abundant and/or significant for correlation; proposed ammonite zonation for Lower Saxony based on authors cited and on material in the collection of G. ERNST, FU Berlin

Zone interval. In addition, *Tetragonites obscurus* (SCHLÜTER), *Pseudoxybeloceras* (*Pseudoxybeloceras*) *quadrinodosum* (JIMBO), *Hauericeras* cf. *welschi* DE GROSSOUVRE, *Pachydiscus launayi* DE GROSSOUVRE, *Pachydiscus* cf. *lettensis* (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 haldemsis*. 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. Glyptoxoceratids 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 KÜCHLER & KUTZ 1989, Text-fig. 5, KUTZ 1995).

France: *H. marroti* is used as the index species for the lowermost Upper Campanian in the Aquitaine (*see* KENNEDY 1986), where it occurs in Assise P^3 *sensu* ARNAUD (1877, 1878). Assise P^3 has additionally yielded elements that elsewhere are typical of the *polyplocum* Zone. According to KENNEDY (1986), the only typical elements of the *marroti* Zone besides *H. marroti* are *S. gibbus*, *S. haugi*, and *Baculites* sp. 2.

The *marroti* zonal assemblage from the Barranca can be directly compared with the "Nalzen fauna" from Ariège, described by KENNEDY, HANSOTTE & *al.* (1992). This fauna comprises, besides *H. marroti*, *Hoplitoplacenticeras* sp. juv., *S. hippocrepis* IV, *Desmophyllites diphylloides* (FORBES), *Eupachydiscus* cf. *isculensis*, *Baculites* sp. and dominant *Glyptoxoceras aquisgranense* (SCHLÜTER).

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 subrobustus* (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).

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* GRÄFE & WIEDMANN 1993, Text-fig. 24). GRÄFE (*in* GRÄFE & WIEDMANN 1993 and GRÄFE 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; KÜCHLER & 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 KÜCHLER & 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 haldemsis* / *Echinocorys conoidea* 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 *haldemsis*/*conoidea* Zone *sensu* KUTZ 1987 and KÜCHLER & KUTZ 1989) is *P. haldemsis*. In the Juandechaco I section, this species is associated with *H.* sp. cf. *marroti* and strongly deformed baculitids. In the Imiscoz area (Text-fig. 1E). *P. haldemsis* 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/Belemnitella 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 Navarra is marked by an acme-occurrence of the index species together with a small-sized *Pseudoxybeloceras* sp. that resembles *Pseudoxybeloceras* (*Pseudoxybeloceras*) *wernickei* (WOLLEMAN) of authors. In the Ecay I section (Text-fig. 12), the smooth *Baculites* sp. 4 and *Menuites portlocki* (SPATH) 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 Juandechaco III section (KUTZ 1995, Text-fig. 5) of the Urdiroz/Imiscoz area (Text-fig. 1E), *P. phaleratum* appears around beds B7 to B8, where it is associated with *P. haldemsis* 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. haldemsis*.

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 haldemsis* (=*P. koeneni* DE GROSSOUVRE), *Patagiosites stobaei* (NILSSON) [=*Pachydiscus patagiosus* (SCHLÜTER)], *Pachydiscus subrobustus* SEUNES, *Pachydiscus* sp. [= *Menuites auritocostatus* (SCHLÜTER)] and baculitids. KAPLAN & *al.* (1996) additionally quoted *Scaphites gibbus* and *Phylloceras bodei* (MÜLLER & WOLLEMANN).

In the Teutonia Quarry of Lower Saxony, the *vulgaris* Zone is characterised by single specimens of *P. phaleratum* and *T. spiniger* (*compare* KHOSROVSCHAHIAN 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* BŁASZKIEWICZ (1980, p. 13), because BŁASZKIEWICZ (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* BŁASZKIEWICZ and *Pachydiscus haldemsis*.

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 *polyplocum* 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.*) *polyplocum* 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.*) *polyplocum schlueteri* of BŁASZKIEWICZ (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 *polyplocum* Zone is characterised by the rare occurrence of *P. haldemsis*, *Pseudoxybeloceras* sp., *N.* (*B.*) *polyplocum polyplocum* and the subspecies *N.* (*E.*) *euskadiense* I. The latter species, as well as the strongly ribbed *Baculites alavensis* (*see also* KLINGER & KÜCHLER 1998), have their maximum occurrences in the middle part of the zone, where *Nostoceras* (*Didymoceras*) *depressum* (WIEDMANN), *N.* (*E.*) *unituberculatum* (BŁASZKIEWICZ) and *Gaudryceras mite* (VON HAUER) first appear. *Pachydiscus haldemsis* is relatively common in this interval, which has also provided the highest record of a *T.* cf. *spiniger*

A comparatively thick *polyplocum* 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 (KÜCHLER & KUTZ, *in prep.*), the lower part of the zone is characterised by *N.* (*E.*) *euskadiense* I, *B. alavensis* and *P. haldemsis. N.* (*E.*) *euskadiense* 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.*) *polyplocum polyplocum* occurs (*compare* KÜCHLER & *al.*, *in press*, Text-fig. 2).

Remarks on the ammonite fauna: Most of the European nostoceratid species that occur in an interval corresponding to the upper *polyplocum* Zone and lower *donezianum* Zone *sensu* BŁASZKIEWICZ (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 coiling (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.*) *polyplocum*, the interpretation of WIEDMANN (1962) and BŁASZKIEWICZ (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.*) *euskadiense*, as well as from evolutionarily successive forms such as *N.* (*Didymoceras*) *archiacianum* (D'ORBIGNY).

In the Middle Vistula section, BŁASZKIEWICZ (1980) demonstrated the occurrence of two subspecies of *N.* (*B.*) *polyplocum*, *i.e.* the nominative subspecies and *N.* (*B.*) *polyplocum schlueteri*. The two subspecies may also be distinguished in the *polyplocum* material from Navarra. *N.* (*B.*) *polyplocum polyplocum*, according to BŁASZKIEWICZ (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 *polyplocum*. 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 *polyplocum* Zone and ranges up into the *N.* (*Didymoceras*) *archiacianum* Zone, with local abundance peaks in the upper part of the *polyplocum* Zone and lower part of the succeeding *pulcherrimus* Zone. BŁASZKIEWICZ's subspecies *schlueteri*, 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: BŁASZKIEWICZ (1980) recognised three informal subdivisions (lower, middle and upper) of the *polyplocum* Zone, of which the lower one corresponds to the *polyplocum* 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.*) *euskadiense* appears to dominate in the faunas of southern Europe, particularly in northern Spain (Navarra – KÜCHLER 1996, 2000b, Alava – SANTAMARIA 1996 and Catalonia – *see also* MARTINEZ 1982, Pl. 28, Fig. 3), and France. The species *N.* (*B.*) *polyplocum* seems to dominate in central Europe (Germany, Austria, Poland) and is markedly rarer in northern Spain.

BŁASZKIEWICZ (1980) defined his *polyplocum* Zone with the coincident FADs of *N.* (*B.*) *polyplocum schlueteri* 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* BŁASZKIEWICZ) first appears in the middle part of BŁASZKIEWICZ'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. haldemsis* (?=*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*/*Bostychoceras 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*/*polyplocum* Zone of SCHMID & ERNST (1975) is assumed to lie somewhat higher, and to correlate with the base of the middle part of the *minor*/*polyplocum* Zone *sensu* NIEBUHR (KÜCHLER 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 KÜCHLER & KUTZ (1989). Where well dated, *T. pulcherrimus* appears elsewhere in Europe in the middle part of the total range of *N.* (*B.*) *polyplocum* (BŁASZKIEWICZ 1980, KÜCHLER & KUTZ 1989; KÜCHLER 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 polyplocum* and, especially, by a pseudoxybeloceratid fauna consisting of *Pseudoxybeloceras* (*Parasolenoceras*) *interruptum*, *P.* (*P.*) ?*wernickei* and *Glyptoxoceras* 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*.

In eastern Navarra, in the Urdiroz/Imiscoz area and in the environs of the village of Erro, the *pulcherrimus* Zone is represented by an approximately 10 m thick marly succession. In this area, the zone is dominated by *N.* (*B.*) *polyplocum polyplocum*. Near Imiscoz, *T. pulcherrimus* is common. It enters at bed B25a of the Juandechaco I section (KÜCHLER & al., *in press*, Text-fig. 2).

Poland: The *pulcherrimus* Zone corresponds to the middle and upper parts of the *polyplocum* Zone *sensu* BŁASZKIEWICZ (1980, p. 13). According to that author, the middle part of his *polyplocum* Zone is characterised by the FAD of *Anapachydiscus vistulensis* BŁASZKIEWICZ and *T. pulcherrimus*. The latter species, however, ranges, as in northern Spain, up to the middle part of the succeeding *Didymoceras donezianum* Zone, above the LAD of *N.* (*B.*) *polyplocum polyplocum*. In the upper part of the *polyplocum* Zone BŁASZKIEWICZ (1980) cited *N.* (*Didymoceras*) cf. *secoense* (YOUNG), *Menuites portlocki portlocki* (SHARPE) and *Hoploscaphites greenlandicus* (DONOVAN).

Germany (*Lower Saxony*): The assemblage of sparse *N.* [(*B.*) *polyplocum*] *unituberculatum, N.* (*B.*) *polyplocum*, *T. pulcherrimus* and *Jeletzkytes compressus* together with more abundant *H. greenlandicus*, reported (NIEBUHR 1996, NIEBUHR & *al.* 1997) from the middle *minor*/*polyplocum* Zone of the Lehrte West Syncline, equates with the assemblage from the middle and upper part of the Polish *polyplocum* Zone (*see* Text-fig. 16). On the basis of the local FAD of *T. pulcherrimus* in this interval (NIEBUHR 1996), the middle part of the German *minor*/*polyplocum* Zone is interpreted here to be a boreal and more distal equivalent of the *pulcherrimus* Zone as defined here.

Because *H. greenlandicus* and *J. compressus* are the most significant index-species for the Boreal Realm in this interval, KÜCHLER (1998a) proposed a *greenlandicus*/*compressus* Assemblage Zone (*see* Text-fig. 16) in accordance with data from SCHMID & ERNST (1975) and NIEBUHR (1996). This zone should be understood as a replacement for the higher part of the *minor*/*polyplocum* Zone.

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 correlate 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 yielded, besides the index taxa, scarce *N.* (*B.*) *polyplocum polyplocum*, *N.* (*D.*) cf. *donezianum* (Pl. 14, Fig. 2), *Nostoceras* (*Didymoceras*) sp. 1, *T. pulcherrimus*, *Pseudoxybeloceras* (*P.*) *interruptum*, *Polyptychoceras pseudogaultianum* (YOKOYAMA) and *Gaudryceras mite*. *Nostoceras* (*Didymoceras*) sp. 1 (no. ErIII-19/3, Pl. 16, Figs 1-3) resembles the form figured by MOROZUMI (1985, Pl. 14, Figs 1-2) 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. *hornbyense* (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 Juandechaco I section near Imiscoz (*compare* Text-fig. 1E), *N.* (*Didymoceras*) *archiacianum* appears in bed JuI-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.*) *polyplocum* and *N.* (*D.*) *archiacianum* (Pl. 15, Fig. 2), *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*) *polyplocum*, *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. BŁASZKIEWICZ (1980) defined the base of the zone at the FAD of the subspecies *Menuites portlocki posterior* BŁASZKIEWICZ. 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* (BŁASZKIEWICZ) and the LADs of *J. compressus*, *T. pulcherrimus* and *H. greenlandicus*. According to BŁASZKIEWICZ, *Belemnitella 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* cf. *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 BŁASZKIEWICZ (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 roemeri* 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*/*polyplocum* 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*/*roemeri* Zone (corresponding to the upper part of the *minor*/*polyplocum* 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. ikorfatensis* BIRKELUND, *T. pulcherrimus, Lewyites elegans* (MORBERG) and *Nostoceras* sp. nov. The co-occurrence of the first three taxa enables a possible correlation of the *bipunctatum*/*roemeri* 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* STEPHENSON 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 more or less coincident FADs 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*, ?*Trachyscaphites* sp. indet., *Pseudoxybeloceras* sp. indet. and *Neancyloceras* aff. *bipunctatum*.

In the Imiscoz area, on the other hand, the FAD of *N. hyatti* (=*Nostoceras* sp. in KÜCHLER & KUTZ 1989, KUTZ 1995) lies stratigraphically very high, *e.g.* (*compare* KÜCHLER & *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 HAUER). In the Juandechaco I section, the base of the *hyatti* Zone is drawn at the FAD of *N. helicinum* in Bed JuI-27 (KÜCHLER & *al.*, *in press*, Text-fig. 2; and Text-fig. 17 in the present paper). As in the Barranca, the fauna is poor in the Imiscoz 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), *Glyptoxoceras* sp. and *Pseudoxybeloceras interruptum* (see KÜCHLER & *al.,* in press).

The find of a single *N. hyatti*, formerly referred to *Cirroceras* (*Cirroceras*) *polyplocum 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 BŁASZKIEWICZ (1980), although a direct correlation is scarcely possible because *Jeletzkytes nodosus* (OWEN) (=*Acanthoscaphites praequadrispinosus* BŁASZKIEWICZ) 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 *pozaryskii* Zone, and certainly in the highest 20 m exposed in the Piotrawin Quarry. The typical assemblage of the *pozaryskii* Zone includes *N. hyatti* and *J. nodosus* (BŁASZKIEWICZ 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* KÜCHLER & *al*., *in press*).

According to BŁASZKIEWICZ (1980) and KENNEDY, COBBAN & *al.* (1992) the '*hyatti'* zonal assemblage of the Middle Vistula section comprises the following forms: *N. hyatti* (=*N. pozaryskii* BŁASZKIEWICZ, 1980, Pl. 10, Figs 8, 9, 12), *N. helicinum* (=*N. pozaryskii* BŁASZKIEWICZ, 1980, Pl. 10, Figs 1-7, 11, 13, 15), *J. nodosus*, *P. galicianum*, *Pachydiscus perfidus* DE GROSSOUVRE, *N.* aff. *bipunctatum*, *Hoploscaphites vistulensis* BŁASZKIEWICZ, *Hoploscaphites minimus* BŁASZKIEWICZ, *Hoploscaphites angulatus* (ŁOPUSKI), *Pachydiscus* (*P.*) cf. *colligatus latiumbilicatus* BŁASZKIEWICZ, *Pseudophyllites indra* (FORBES), *Placenticeras meeki* (BÖHM), *Hauericeras* aff. *sulcatum* KNER and *Belemnitella 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: *Hauericeras fayoli* (DE GROSSOUVRE), *Pseudokossmaticeras brandti* (REDTENBACHER), *Ps. tercense* (SEUNES), *P.* (*P.*) *perfidus* (DE

GROSSOUVRE), *Pachydiscus* (*Pachydiscus*) *subrobustus* (SEUNES), *P.* (*Pachydiscus*) cf. *colligatus* (BINKHORST), *N.* (*N.*) *hyatti*, *N.* (*N.*) *helicinum*, and *Baculites leopoliensis* NOWAK. The specimens described and figured by HANCOCK & KENNEDY (1993) represent mainly material from museum collections. Only a few specimens referred to *N. hyatti* 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 *archiacianum* – *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* (BŁASZKIEWICZ) (*see* KÜCHLER & ODIN, *in press*)*, i.e.* probably from an equivalent of the *N.* (*D.*) *archiacianum* 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 Juandechaco I and 'Steilhang of Imiscoz' sections *sensu* KUTZ (1987, 1995), situated near the village of Imiscoz, south west of the Oroz-Betelu 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 Erro (*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 larteti*, *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 Juandechaco 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 larteti*, *Gaudryceras kayei*, *Baculites* sp. and *Eubaculites lyelli* (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. larteti* 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 larteti*; 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 *Saghalinites 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* KÜCHLER 1995, KÜCHLER *& al.*, *in press*). In Navarra, this event lies somewhat above 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 (KÜCHLER 1995, *see also* KÜCHLER *& 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 bio-events 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. aturicus*, *H. marroti/O. pilula*, *E. subglobosa*, *E. conica/E. subglobosa*, *O. pilula* III, *N. euskadiense*, *N. polyplocum*, *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 *polyplocum* Zone. Tectonism was accompanied by noticeable sedimentological changes, hiati 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 lay in the fact that detailed stratigraphical investigations had already been carried

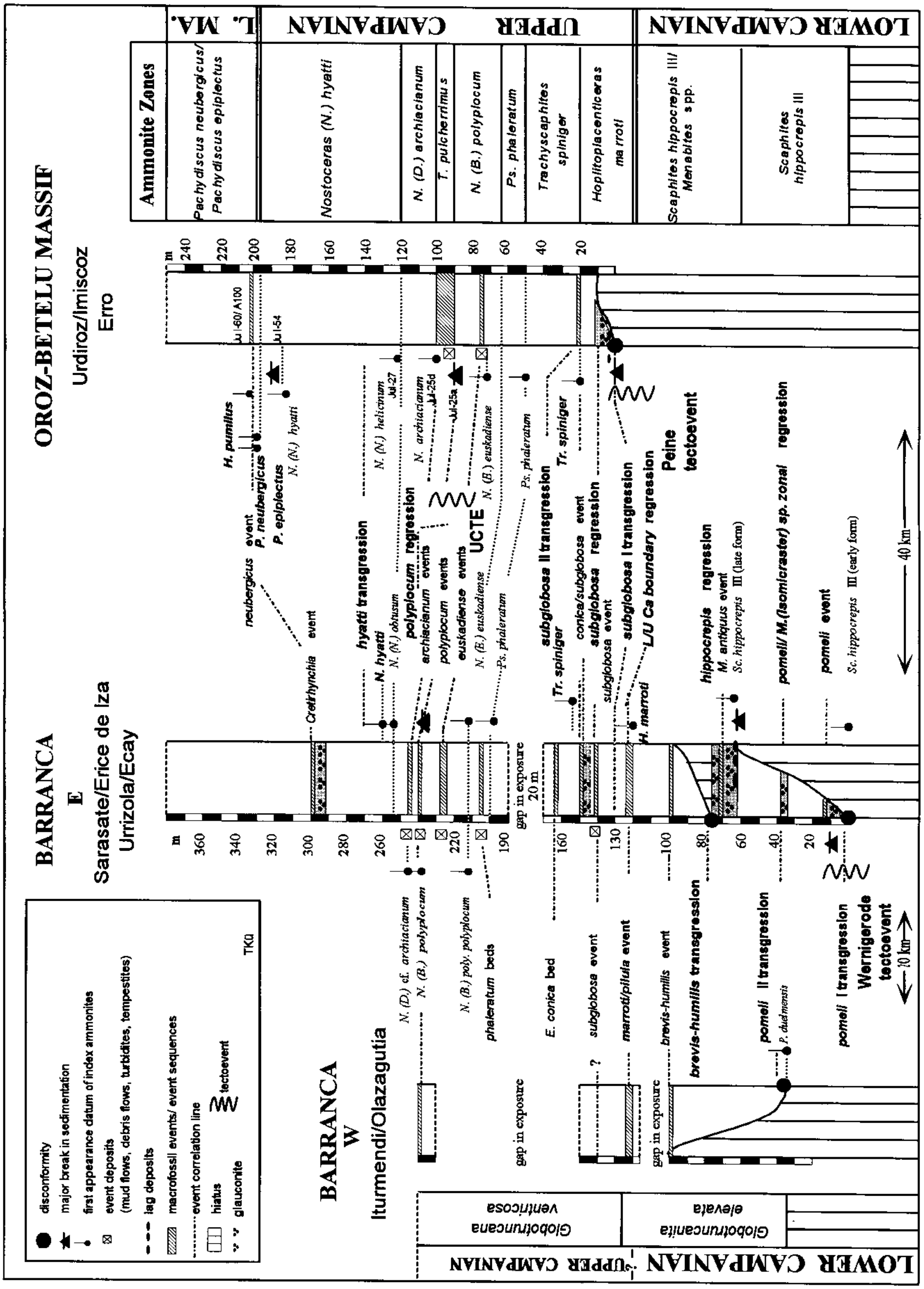

Fig. 17. Bio- and event stratigraphical correlation of the Campanian successions of the Barranca and the Oroz-Betelu Massif; data for Iturmendi and Olazagutia based on ZANDER (1988) and KANNENBERG (1985); data for Urdiroz, Imiscoz and Erro, based on KUTZ (1987, 1995), KÜCHLER & KUTZ (1989) and KÜCHLER & *al.* (*in press*).

out in the area of Iturmendi and Alsasua (ZANDER 1988) and in the area of Urdiroz/ Imiscoz (KUTZ 1987, 1995; KÜCHLER & KUTZ 1989, KÜCHLER & *al*., in press). In the western Barranca, biozonation was based mainly on planktonic foraminifer, 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, KÜCHLER & KUTZ 1989, FLOQUET 1991, GRÄFE 1994, GRÄFE & 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 western 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 Urrizola 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 KÜCHLER 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 asymetrica* Zone) *sensu* KÜCHLER (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 (*granulataquadrat*a 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 *Gonioteuthis granulata granulata* Zone, *sensu* BŁASZKIEWICZ (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 Lägerdorf 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 hiati (*see* Text-fig. 18). South of Izurdiaga (Arardi II section at mount Arardi) (*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* KÜCHLER 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 levelling 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 *Globotruncana 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 *polyplocum* 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 HAQ *& al.* (1987) and the *Delawarella delawarensis* Zone of authors is well documented in northern Spain (Burgos – *compare* GISCHLER & *al*. 1994, GRÄFE 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

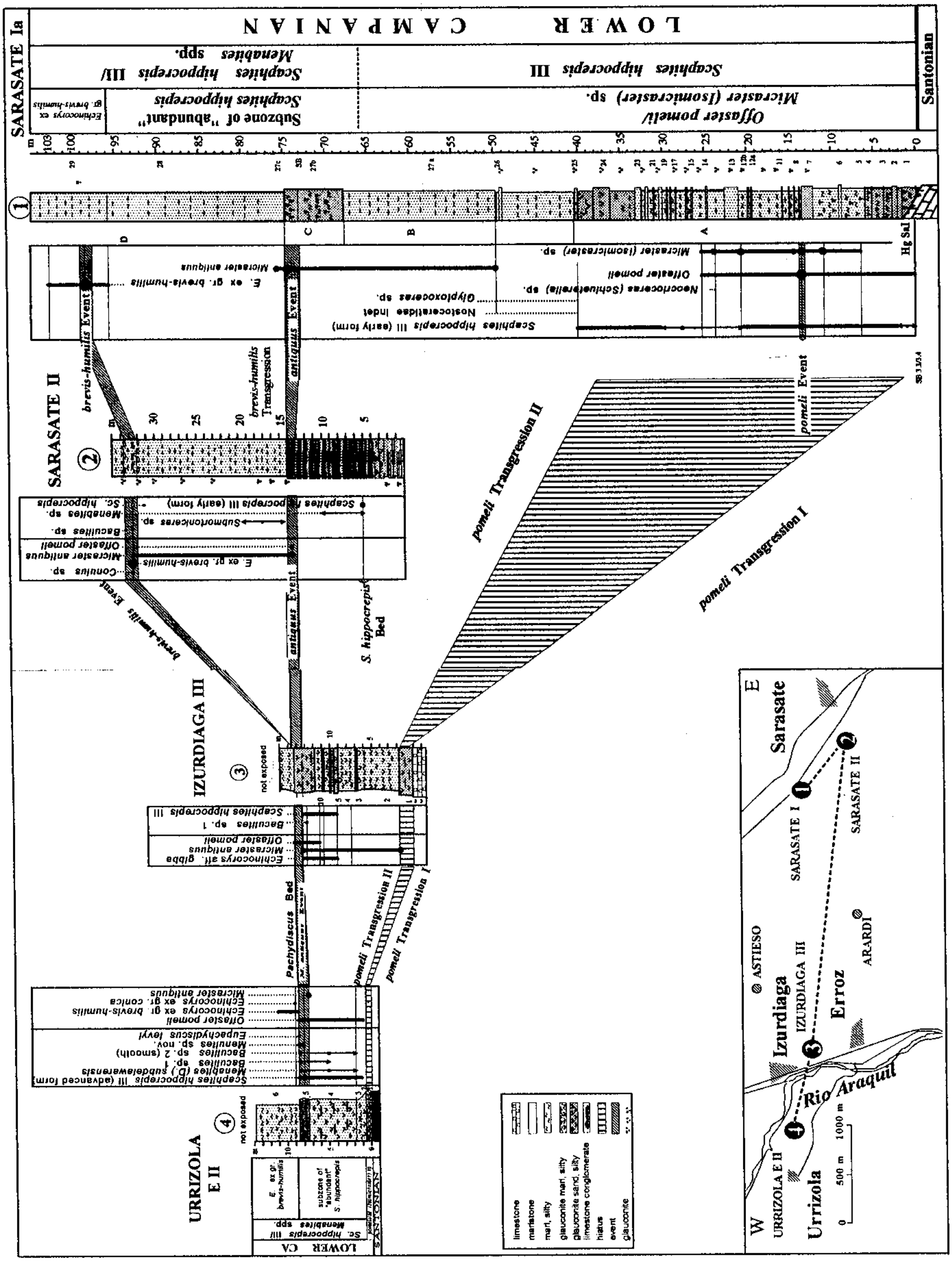

Fig. 18. Early Campanian palaeogeography and facies development of the eastern Barranca. Event stratigraphical correlation of four different sections in relation to a submarine swell. The isopachs and the rapid facies change from NW to SE in the area of Irurzun indicate an elongate E-W submarine swell, 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 hiati 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 Irurzun 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 basinal 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 Basque-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 siliceous 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 GRÄFE & WIEDMANN (1993) and GRÄFE (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 Ib 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 quadrata* and *Belemnitella 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* Brydone above the Upper Downed Marl (M2).

The mass-occurrence of *O. pilula* at Downed is possibly the correlative 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, reddish limestone containing green-coated limestone nodules that rests nonsequentially on dolomites or *Lacazina*-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 (KUTZ 1987; 1995, Text-fig. 6) this horizon is overlain by a unit of grey calcareous marls (KÜCHLER, *in prep*.), while near Imiscoz, in the Juandechaco 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 *Globotruncana 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, Oteo and Antoñana, SCHWENTKE & WIEDMANN (1985) first noted a contradictory development, with a deepening phase (down to middle shelf) in the lower *Globotruncana 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 GRÄFE (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 & GRÄFE (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).

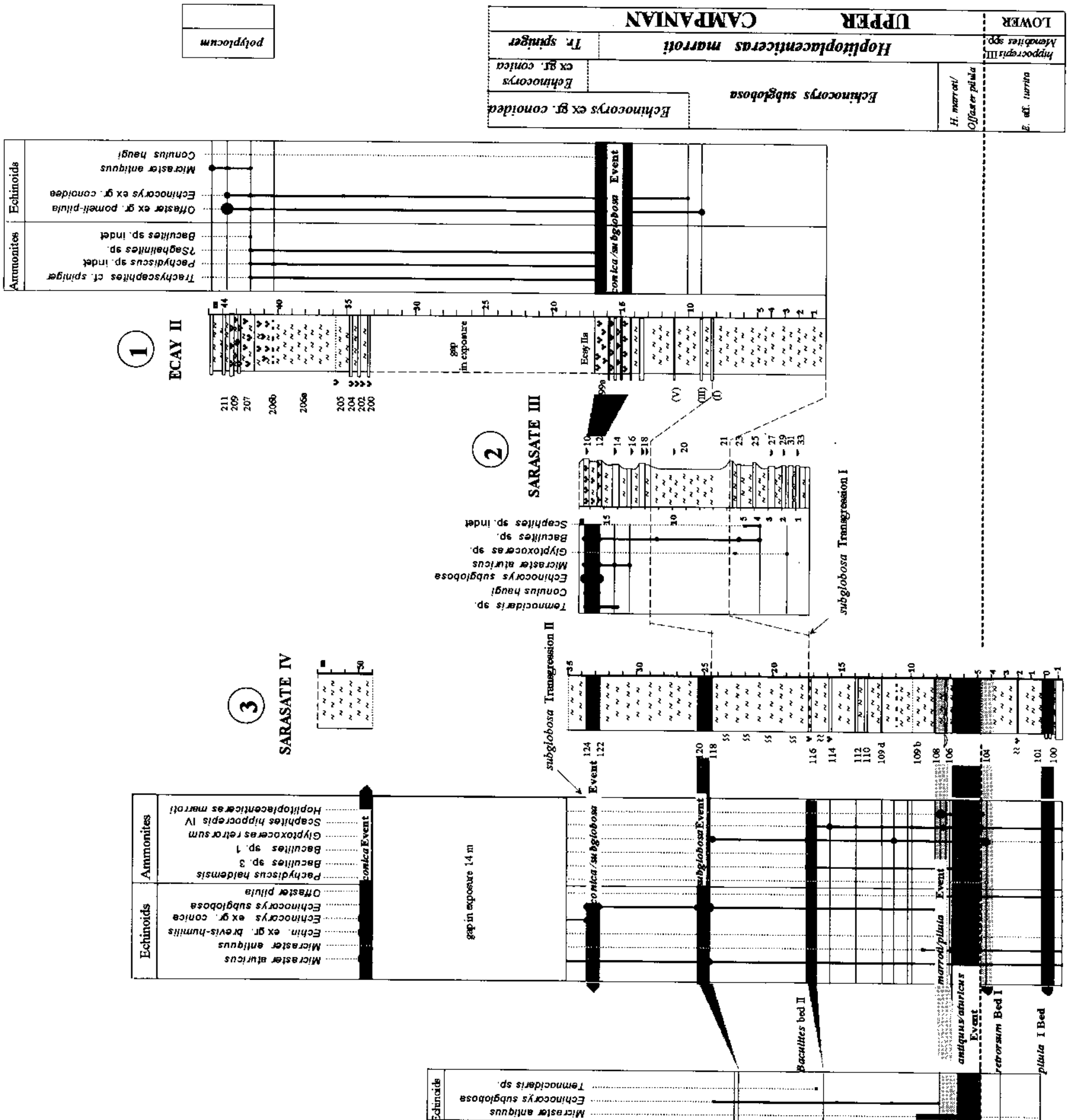

Fig. 19. Integrated bio- and event stratigraphy, local FADs and ranges of stratigraphically important macrofaunal elements in the Lower/Upper Campanian boundary interval of the Barranca. In addition to an east-west traverse through the Barranca, the diagram shows a transect from the Sarasate III section, 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* KÜCHLER & KUTZ 1989, Text-figs 5-6), the acme of *E. subglobosa* or *E.* ex gr. *subglobosa – ovata* 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 recorded 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 *spiniger* Zone (= *haldemsis/conoidea* Zone *sensu* KÜCHLER & 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 & KÜCHLER 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 – KÜCHLER & 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 EcI-103 to EcI-108 at Ecay/Araquil, eastern Barranca (Text-fig. 12). However, in contrast to Urdiroz, four sedimentological events can be distinguished 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* I 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 pachydiscid 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 & KÜCHLER 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 depositional area from a deep subtidal, through a prodelta facies, to a sandy calcarenite facies of the shallow subtidal. The facies is marked by episodic storm events, with the occurrence of siltstones 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*) *polyplocum* 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 correlatable 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; KÜCHLER & KUTZ 1989). The ammonite assemblages are composed of *N.* (*B.*) *polyplocum polyplocum*, *Pseudoxybeloceras* sp., and *Glyptoxoceras* sp. near Urdiroz and of *Pseudoxybeloceras* sp., *N.* (*B.*) *polyplocum polyplocum*, and *Trachyscaphites pulcherrimus* near Imiscoz.

In the western Barranca (*see* Text-fig. 17), the top of the 10 m thick Iturmendi IV section of ZANDER (1988) seems to correspond to the *polyplocum* 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 correlatable between the localities Erro, Imiscoz, and Garralda. It characterises a *ca.* 0.6 m thick horizon that is well developed at Erro (*compare* KÜCHLER & *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 (KÜCHLER & 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

proposed ten zones enable a correlation with successions in northern Spain (Cantabria, Burgos and Guipúzcoa provinces) and with those of classic European Campanian areas: the Aquitaine (France); Westphalia and Lower Saxony (Germany) and the Middle Vistula valley (Poland).

- The topmost Santonian and basal Campanian in large parts of Navarra and many other Spanish areas are usually absent. In the Barranca, the hiatus comprises an interval extending at least from the *Marsupites testudinarius* Zone to the *lingua/quadrata* Zone in terms of the central European zonation. This boundary hiatus is locally overprinted by younger events, resulting in larger hiati.
- The oldest Campanian strata in the Barranca belong to the *Scaphites hippocrepis* III Partial Range Zone. In addition to early forms of *S. hippocrepis* III, this zone contains an irregular echinoid fauna that enables direct correlation with north-western German and southern English sections, indicating equivalence with the middle Lower Campanian upper *Offaster pilula* or basal *Galeola senonensis* Zone of those areas. In basinal facies, the zone is represented by a *Glyptoxoceras/Neocrioceras* assemblage in which *S. hippocrepis* is either very rare or absent. The zone is assumed to correlate with the *Bevahites subquadratus* Zone of the Burgos province, northern Spain (*sensu* WIEDMANN *in*: GISCHLER & *al.* 1994).
- The *hippocrepis* III/*Menabites* spp. Zone is marked by the appearance of advanced forms of *S. hippocrepis* III, occurring together with *Eupachydiscus levyi* (DE GROSSOUVRE), *Menabites* (*Delawarella*) *campaniense* COLLIGNON, *Menabites* (*Australiella*) *australis* (BESAIRIE), *Menabites* (*Delawarella*) *subdelawarensis* COLLIGNON, *Submortoniceras* sp., and *Baculites* spp. The Spanish assemblage corresponds well with that from the *senonensis* to *gracilis/senior* zones of Westphalia, Germany, which have yielded *Scaphites hippocrepis* III and *E. levyi* (see WIPPICH 1995). The fauna of *Menabites* spp. links to the French and North American *Menabites* (*Delawarella*) *delawarensis* Zone.
- The base of the Upper Campanian is taken at the FAD of *Hoplitoplacenticeras marroti* (COQUAND). The interval that corresponds to the classic French *marroti* Zone is divided into three partial range zones (in ascending order): *H. marroti*, *Trachyscaphites spiniger*, and *Pseudoxybeloceras phaleratum* zones.
- The *marroti* Zone is characterised by a rich fauna of *H. marroti*, *S. hippocrepis* IV, *Glyptoxoceras retrorsum*, *Baculites* spp., and *Pachydiscus haldemsis*. This assemblage is coeval with the fauna from Ariège (France), and with that of the Beckum Beds of Westphalia (Germany) and the *Echinocorys conica/Belemnitella senior* Zone of Lower Saxony (Germany).
- *Trachyscaphites spiniger* enters well above the FAD of *Hoplitoplacenticeras* in northern Spain, as does in northern Germany. The co-occurrence of this species with *P. haldemsis* characterises the *spiniger* Zone. This zone correlates with the German *Patagiosites stobai/Galeola papilosa basiplana* Zone.
- The *phaleratum* Zone contains, besides the dominant index taxon, *Pseudoxybeloceras* 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* (*Bostrychoceras*) *polyplocum*, *Trachyscaphites pulcherrimus*, *Nostoceras* (*Didymoceras*) *archiacianum*, and *Nostoceras* (*Nostoceras*) *hyatti* zones.
- The base of the *polyplocum* Zone is taken at the FAD of the index species. *Nostoceras* (*Euskadiceras*) *euskadiense* I KÜCHLER is characteristic and abundant in the middle part of the zone. The assemblage yields rare *N.* (*B.*) *polyplocum schlueteri* (BŁASZKIEWICZ) and *N.* (*E.*) *unituberculatum* (BŁASZKIEWICZ), which are known to occur in the lower part of *polyplocum* Zone as applied in Poland.
- The FAD of *Trachyscaphites pulcherrimus* (ROEMER) defines the base of the succeeding *pulcherrimus* Zone. The ammonite fauna is dominated either by coarsely ribbed *N.* (*B.*) *polyplocum polyplocum*, *Pseudoxybeloceras 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 *donezianum* 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 Navarra 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 neubergicus/Pachydiscus epiplectus* Zone is taken at the FAD of *Pachydiscus neubergicus* (Von Hauer). The local FAD of *Pachydiscus epiplectus* (REDTENBACHER) is somewhat higher. The ammonite assemblage comprises *Pseudokossmaticeras* spp., *Saghalinites* spp., *Desmo-*

phyllites larteti (SEUNES), *Nostoceras hyatti*, *N. helicinum. N. approximans, Hoploscaphites pumilus* STEPHENSON, *Anagaudryceras lueneburgense* (SCHLÜTER) and *Baculites* spp. The zone corresponds to the basal Lower Maastrichtian. It replaces the *neubergicus/heberti* Zone of KÜCHLER & KUTZ (1989) and it correlates with the *epiplectus* Zone of the Biscay region of WARD & KENNEDY (1993) and with the uppermost part of the *hyatti* Zone and the *epiplectus* Zone as defined by HANCOCK & KENNEDY (1993) at Tercis, France.

- Twelve of the recognised bio-events are significant for regional correlation (in ascending order): the *Offaster pomeli*, *Micraster antiquus*, *Echinocorys* ex gr. *brevis-humilis*, *M. antiquus/M. aturicus*, *Hoplitoplacenticeras marroti/ O. pilula*, *E. subglobosa*, *E. conica/E. subglobosa*, *O. pilula* III, *Nostoceras euskadiense*, *N. polyplocum*, *N. archiacianum*, and *Pachydiscus neubergicus* (=*Cretirhynchia*) Event. The three *Offaster* maxima are traceable to northern Germany, southern England and northern Ireland.
- The bio-events are characterised by mass-occurrences of irregular echinoids and monospecific or taxonomically more variable, mostly heteromorph ammonite assemblages.
- 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.
- Within a basin to swell transect, the Lower Campanian transgressive and regressive events are more conspicuously developed close to the Anoz-Ollo salt structure in the eastern Barranca.
- The record of Campanian deposits starts after the *pomeli* Transgression I (middle Lower Campanian *hippocrepis* III PRZ); above paleo-highs, particularly in the western Barranca, the record starts somewhat later, after the 2nd transgressive pulse (*pomeli* Transgression II), in the middle part of the *hippocrepis* III PRZ.
- The *hippocrepis* Regression correlates with the global sea-level fall in the *hippocrepis* III/ *Menabites* spp. or basal *M.* (*Delawarella*) *delawarensis* Zone of authors.
- The onset of the *brevis-humilis* Transgression falls in the middle part of the *hippocrepis* III/*Menabites* spp. Zone.
- In the eastern Barranca, the Lower/Upper Campanian boundary regression is only weakly expressed by a shallowing trend.
- With the early Late Campanian (middle part of the *marroti* Zone) *subglobosa* Transgression I, full marine sedimentation started on the Basque Oroz-Betelu Massif. At the same time more northern faunal elements immigrated into the study area; these included *Echinocorys subglobosa*, which appeared in the Lower Campanian in northern Europe.
- The pronounced *subglobosa* Regression, which began in south-western Navarra in the upper part of the *marroti* PRZ, caused the progradation of a delta.
- 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 *pulcherrimus* 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 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

PLATE 5

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

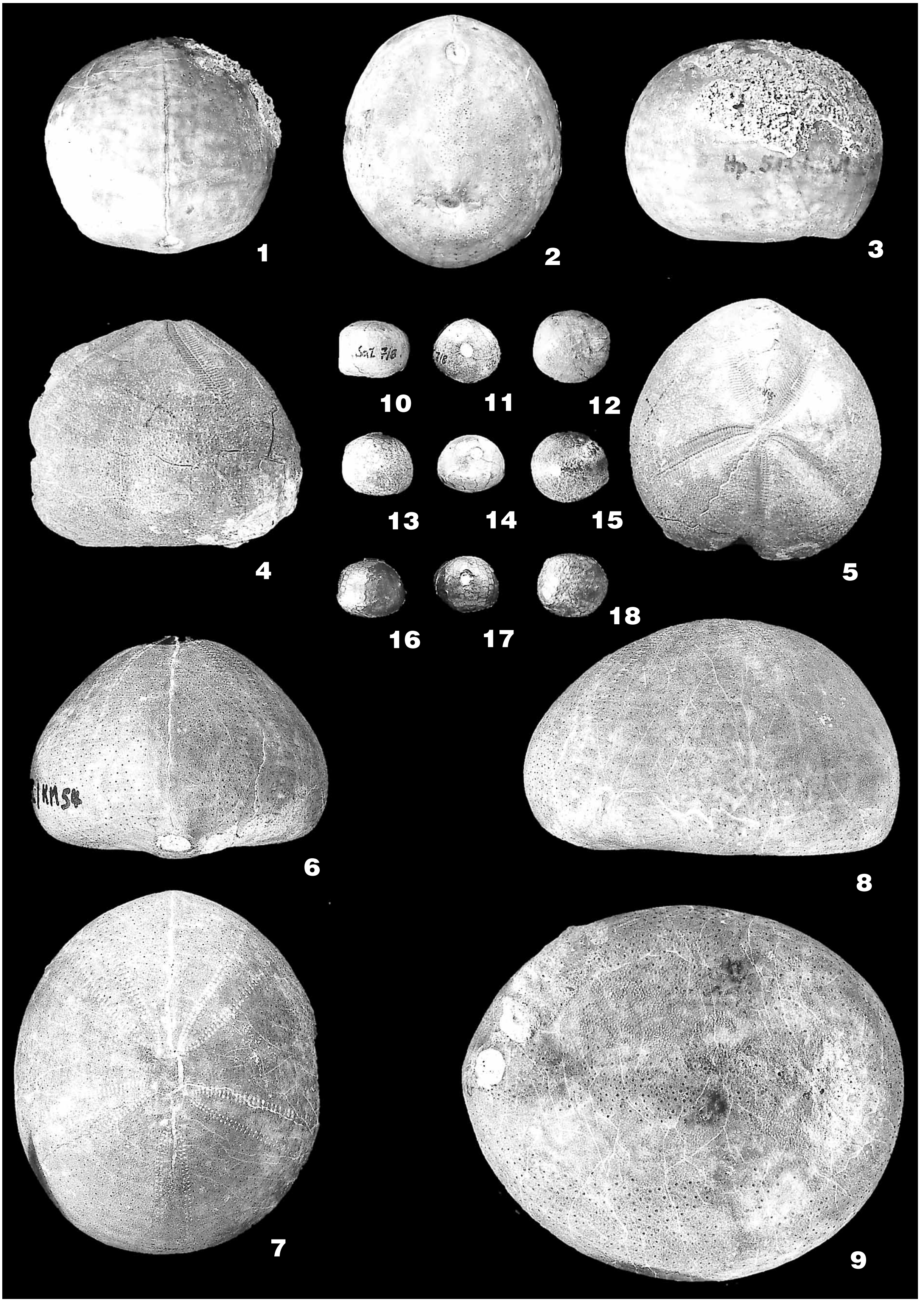

PLATE 6

Irregular echinoids from the Lower and Upper Campanian of the Barranca

1-3 – *Echinocorys* aff. *turrita* LAMBERT, unregistered specimen; uppermost Lower Campanian, *Echinocorys* aff. *turrita* PRZ (=*Scaphites hippocrepis* III/*Menabites* spp. AZ), loose below *marroti*/ *pilula* Event; Sarasate I

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

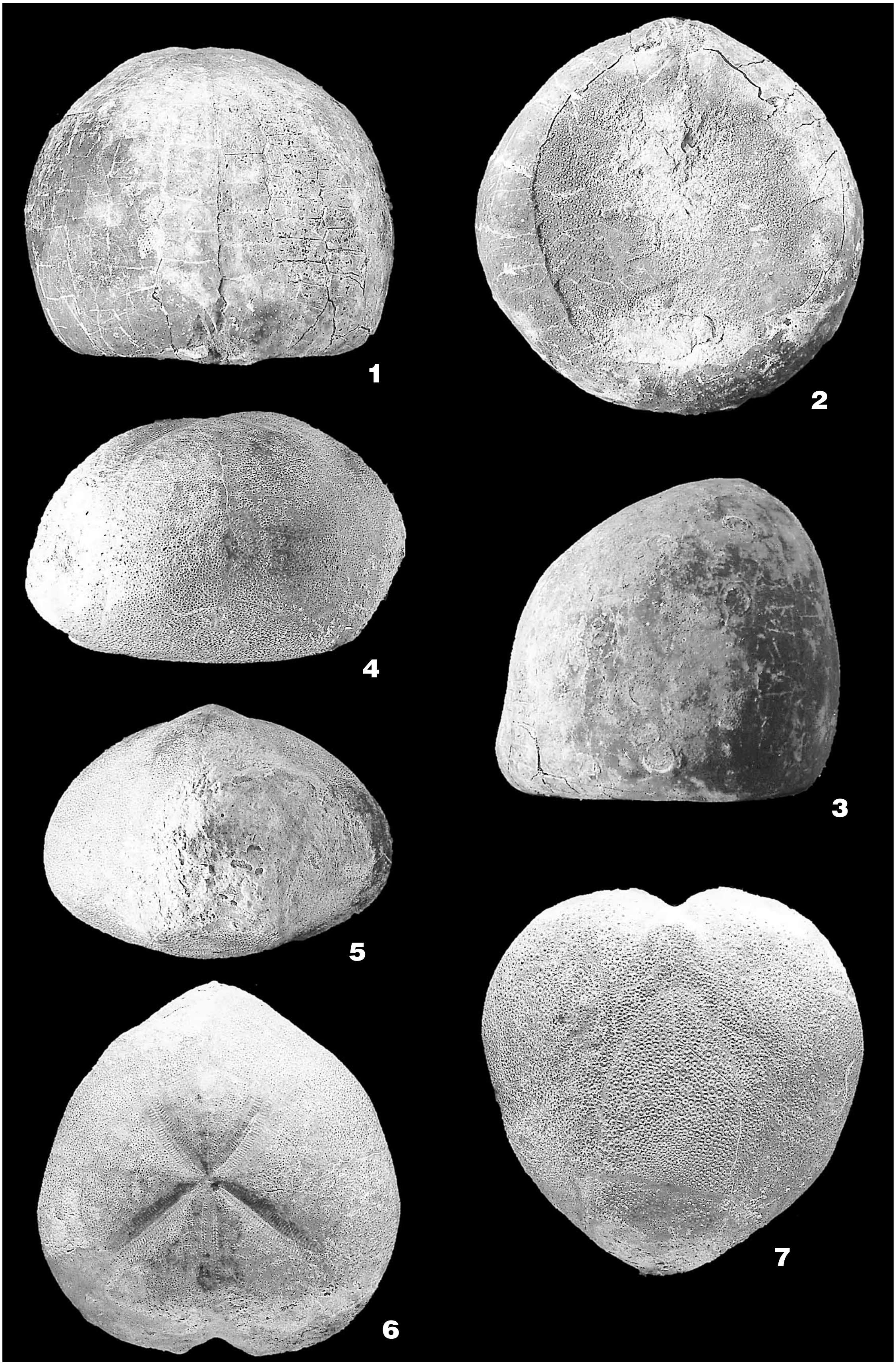

PLATE 7

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


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PLATE 8

Ammonites from the uppermost Lower Campanian of the Barranca

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

2 – *Submortoniceras* sp., specimen SaII-53/*; 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/*, 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

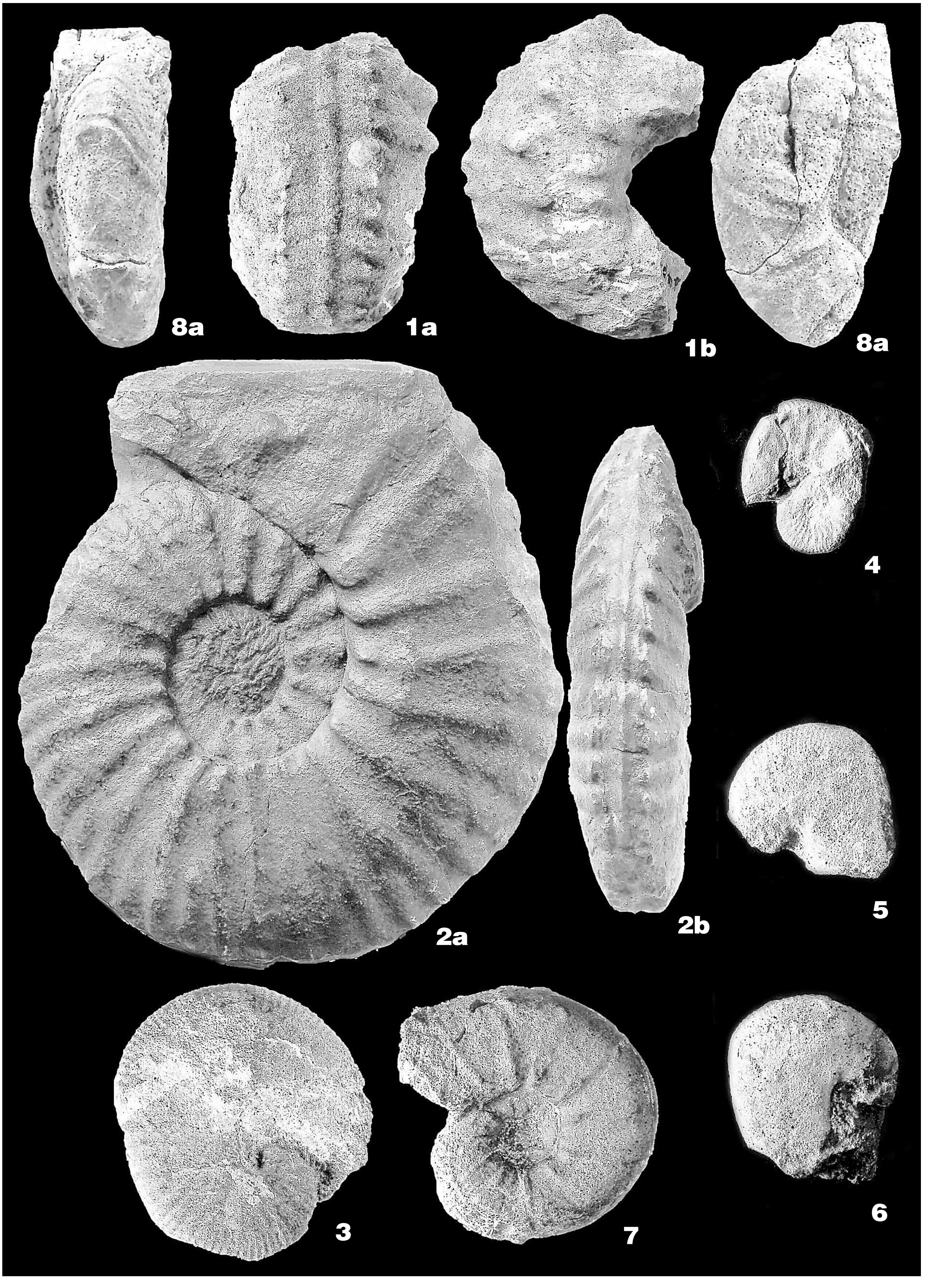
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PLATE 9

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)

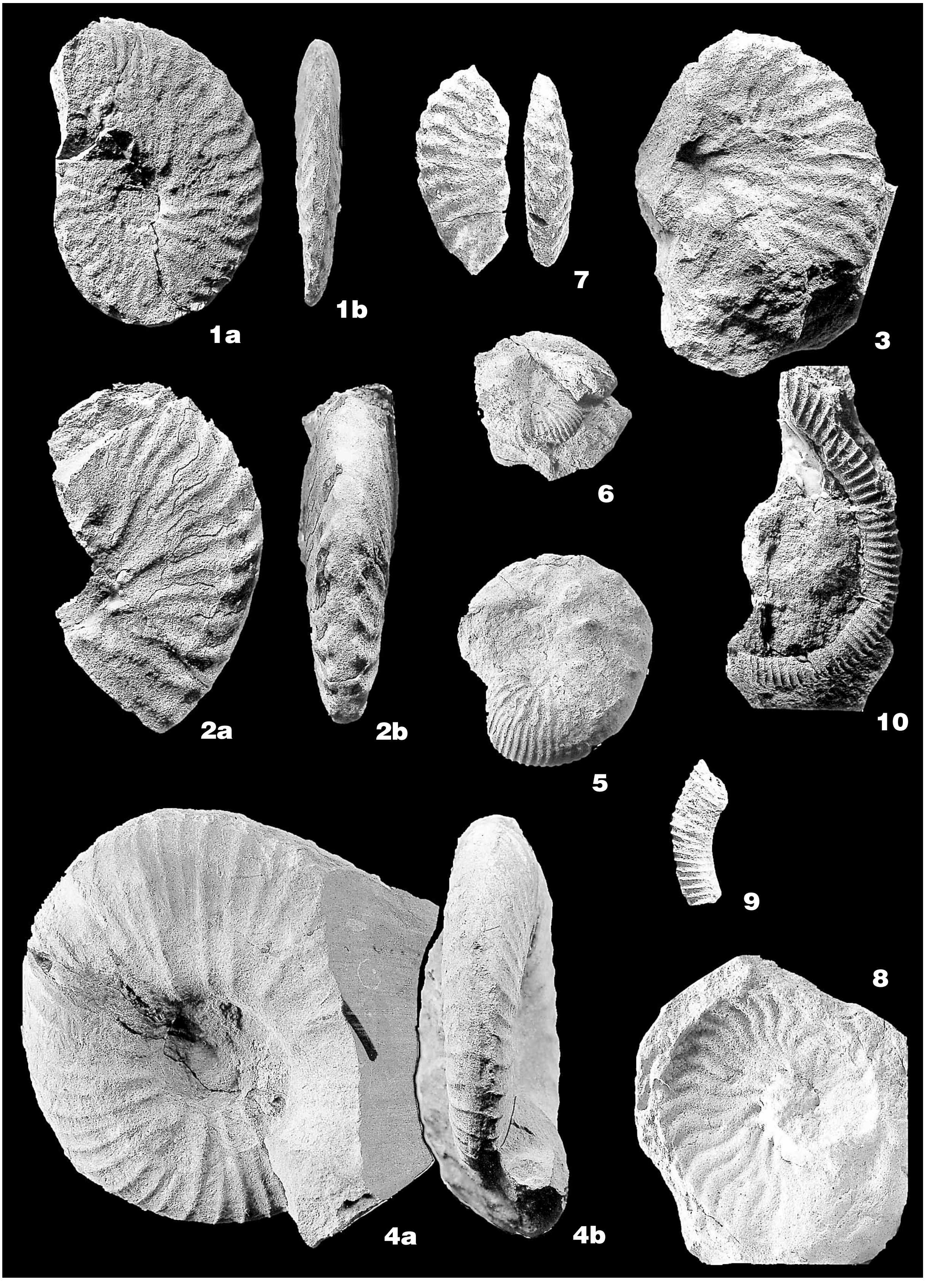
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PLATE 10

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 *marroti/pilula* AZ (= *marroti* PRZ), *marroti/pilula* Event; Sarasate; 7-9 – SaI-100/p1, 10-12 – Sa-100/p2

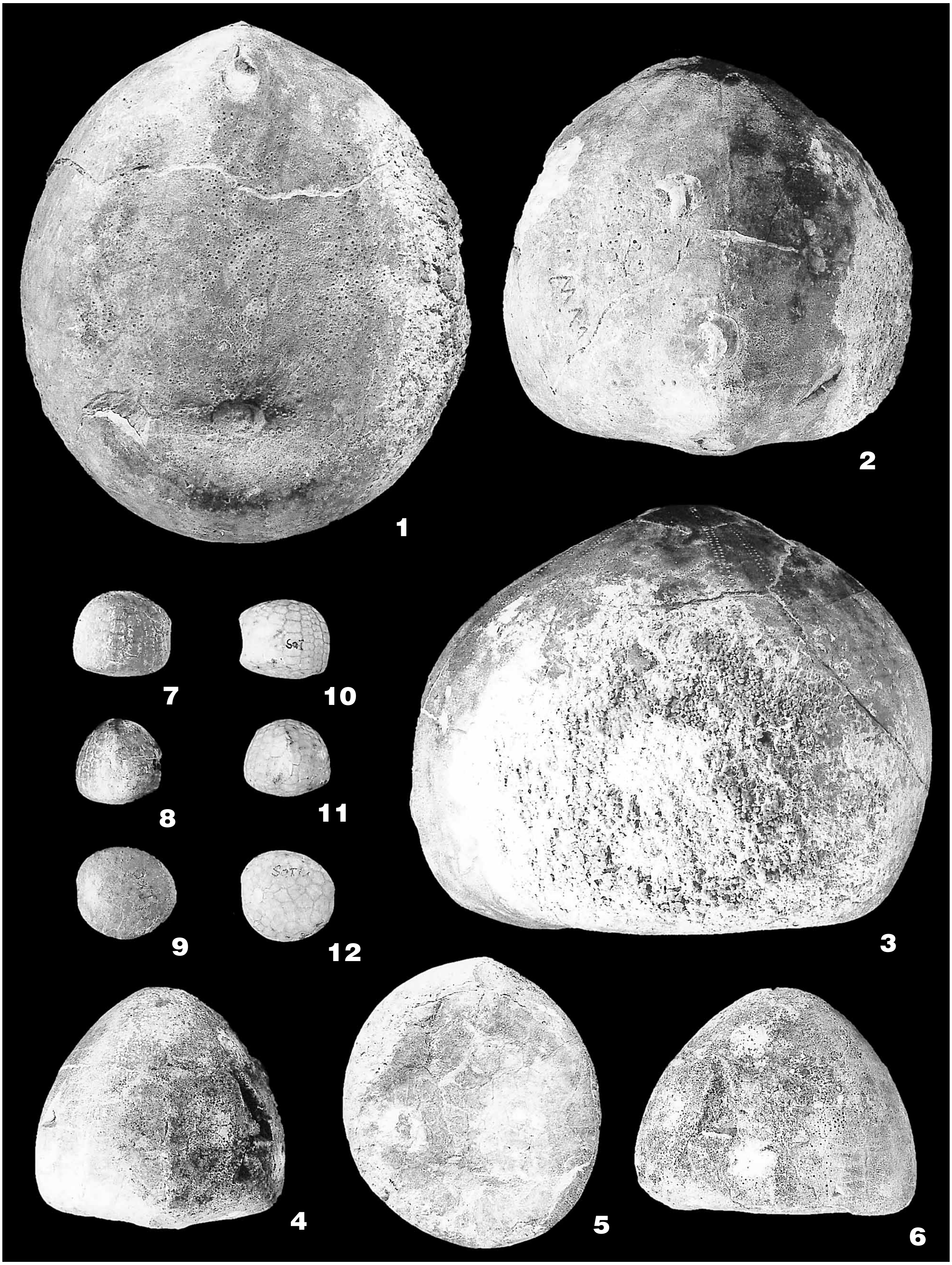
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PLATE 11

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

1-2, 5-6 – *Trachyscaphites spiniger* (SCHLÜTER), Upper Campanian; 1-2 – UrdI-261291, basal *Trachyscaphites spiniger* PRZ (=local *P. haldemsis*/*E. conoidea*) approximatly *subglobosa*/ *conica* Event; ca. 20-25 m above the boundary between Santonian red dolomites and Campanian blue calcareous marls Urdiroz; 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/*; 9 – EcSIIa-199a/2

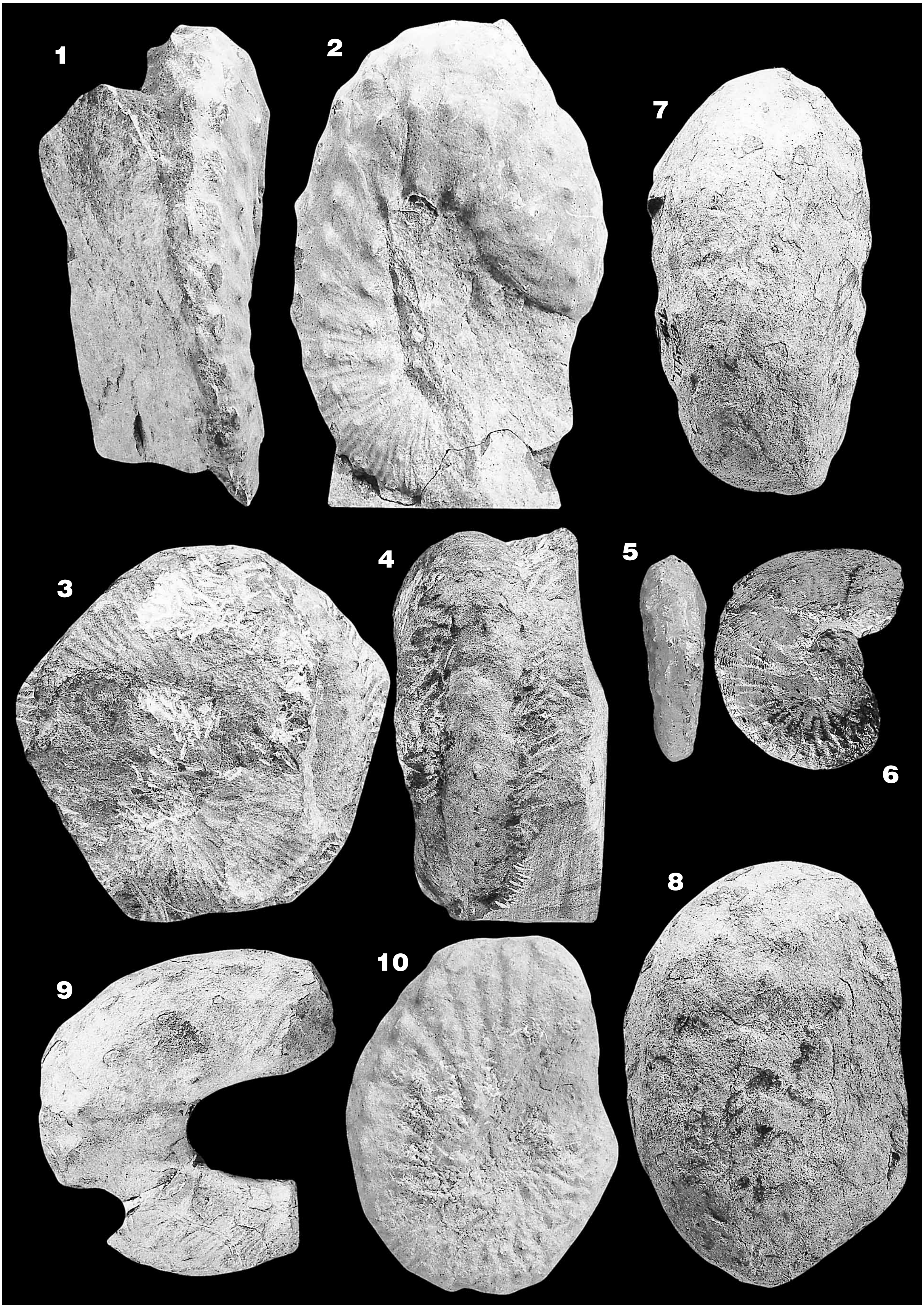
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PLATE 12

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

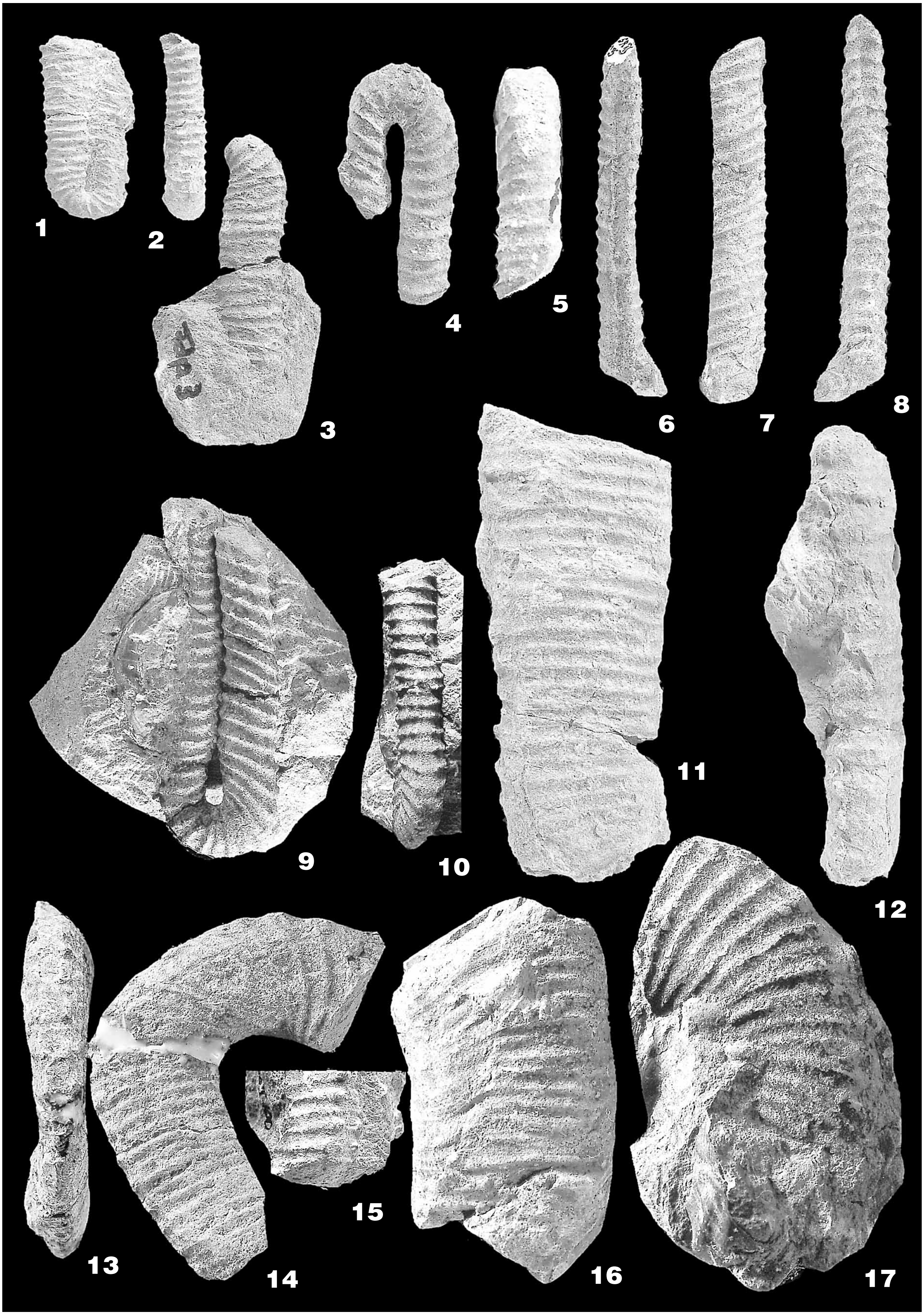
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PLATE 13

Ammonites from the Upper Campanian of the Barranca

1 – *Nostoceras* (*Bostrychoceras*) *polyplocum polyplocum* (ROEMER), EcI-116/1, part of a microconch; Upper Campanian, *pulcherrimus* PRZ

2-5 – *Nostoceras* (*Euskadiceras*) *euskadiense* I KÜCHLER, Upper Campanian, *Nostoceras (Bostrychoceras) polyplocum* 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

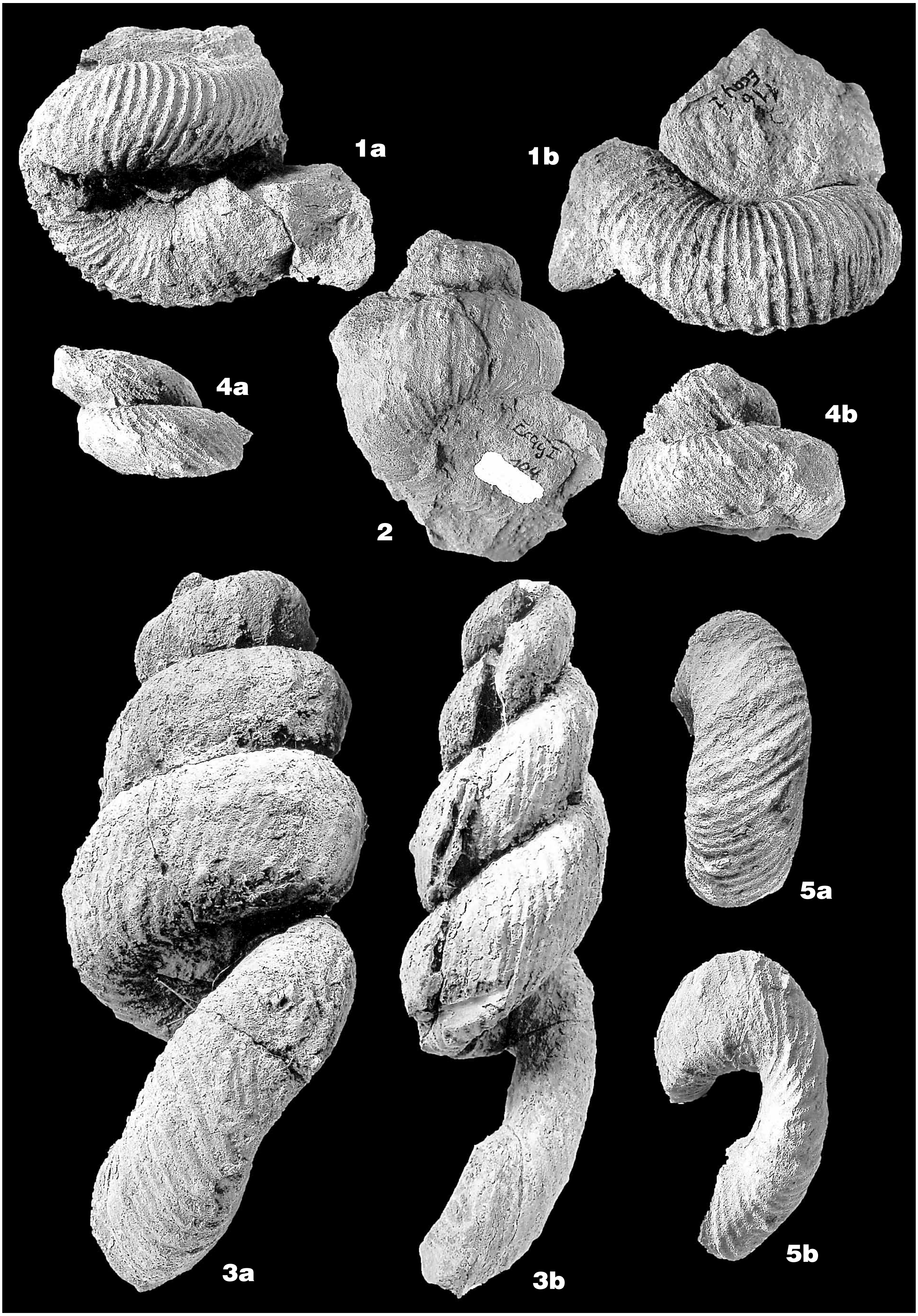
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PLATE 14

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

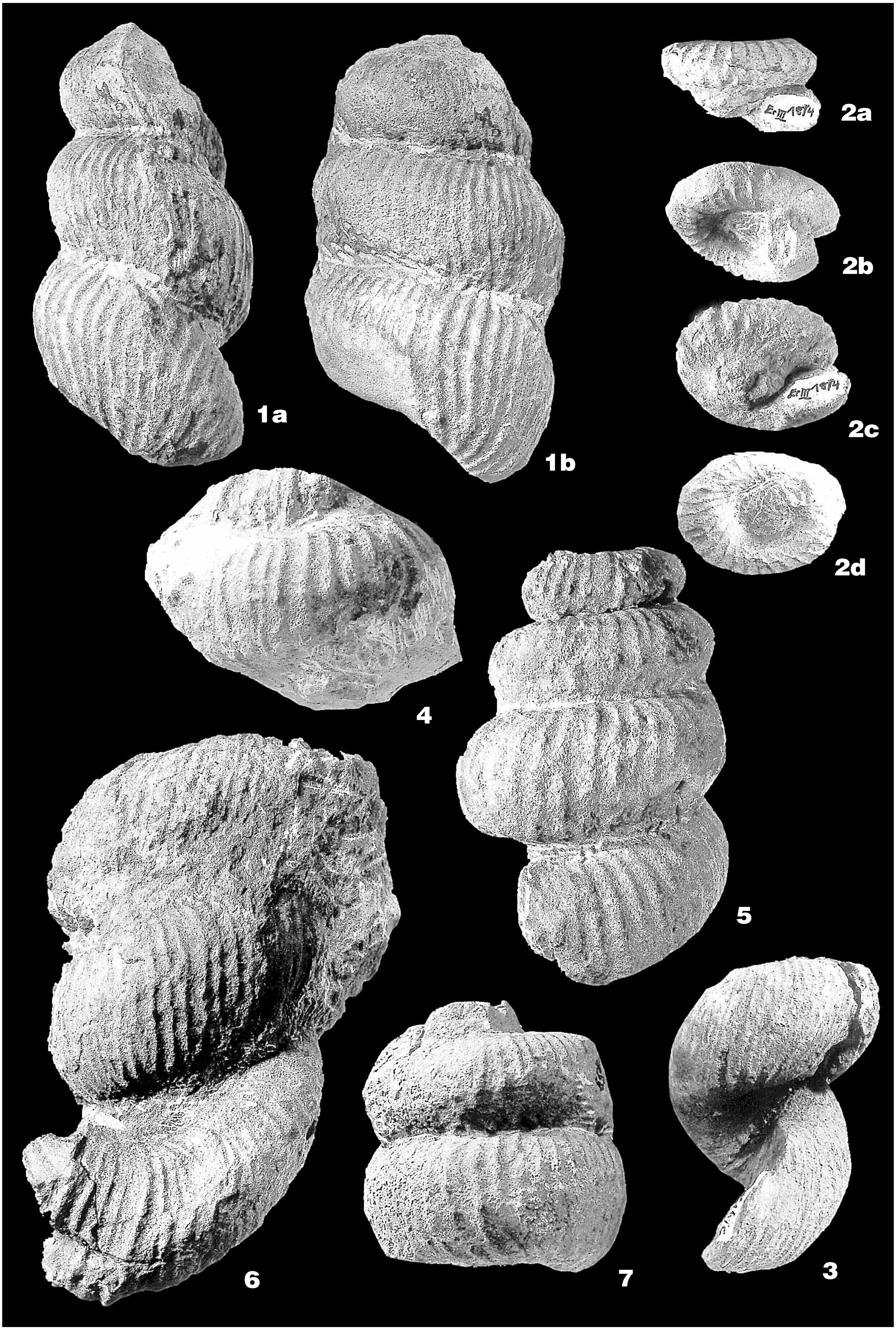
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PLATE 15

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 – ErroA-46/*, a microconch, 5 – JuI-25d/1, (ex KUTZ collection); Juandechaco I section at Imiscoz, eastern Navarra; 6 – ErIII-19/1, a microconch

2 – *Nostoceras* (*Bostrychoceras*) *polyplocum* m.f. *N.* (*Didymoceras*) *archiacianum* (D'ORBIGNY), ErroA-50/1(17794); Upper Campanian, *archiacianum* Zone; Erro, eastern Navarra

7 – *Nostoceras* (*Euskadiceras*) *unituberculatum* (BŁASZKIEWICZ), 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

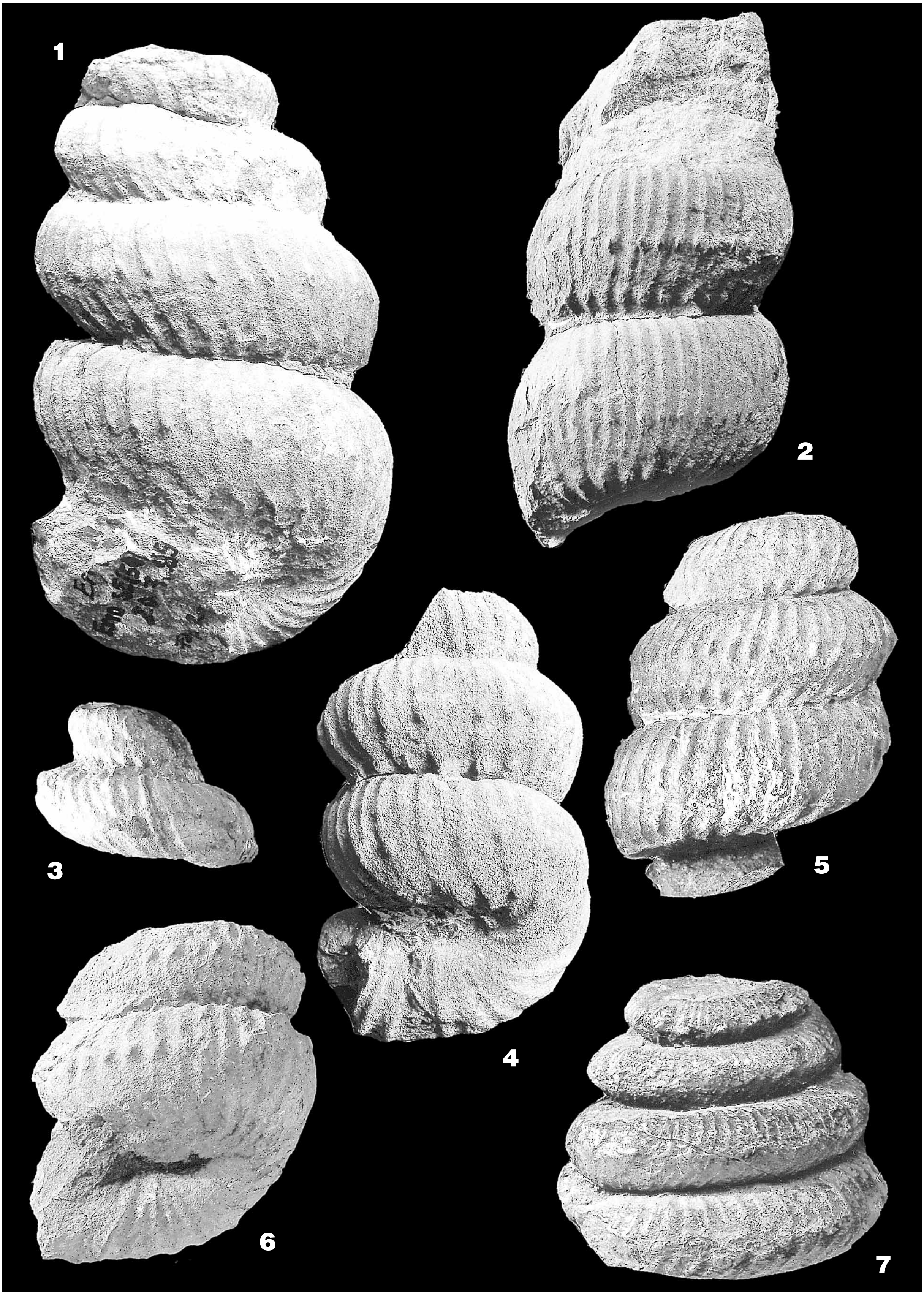
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PLATE 16

Ammonites from the higher Upper Campanian of the Barranca

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

7-9 – *Neancyloceras* aff. *bipunctatum* (SCHLÜTER), EcI-119b/5; Upper Campanian, base of the *archiacianum* Zone

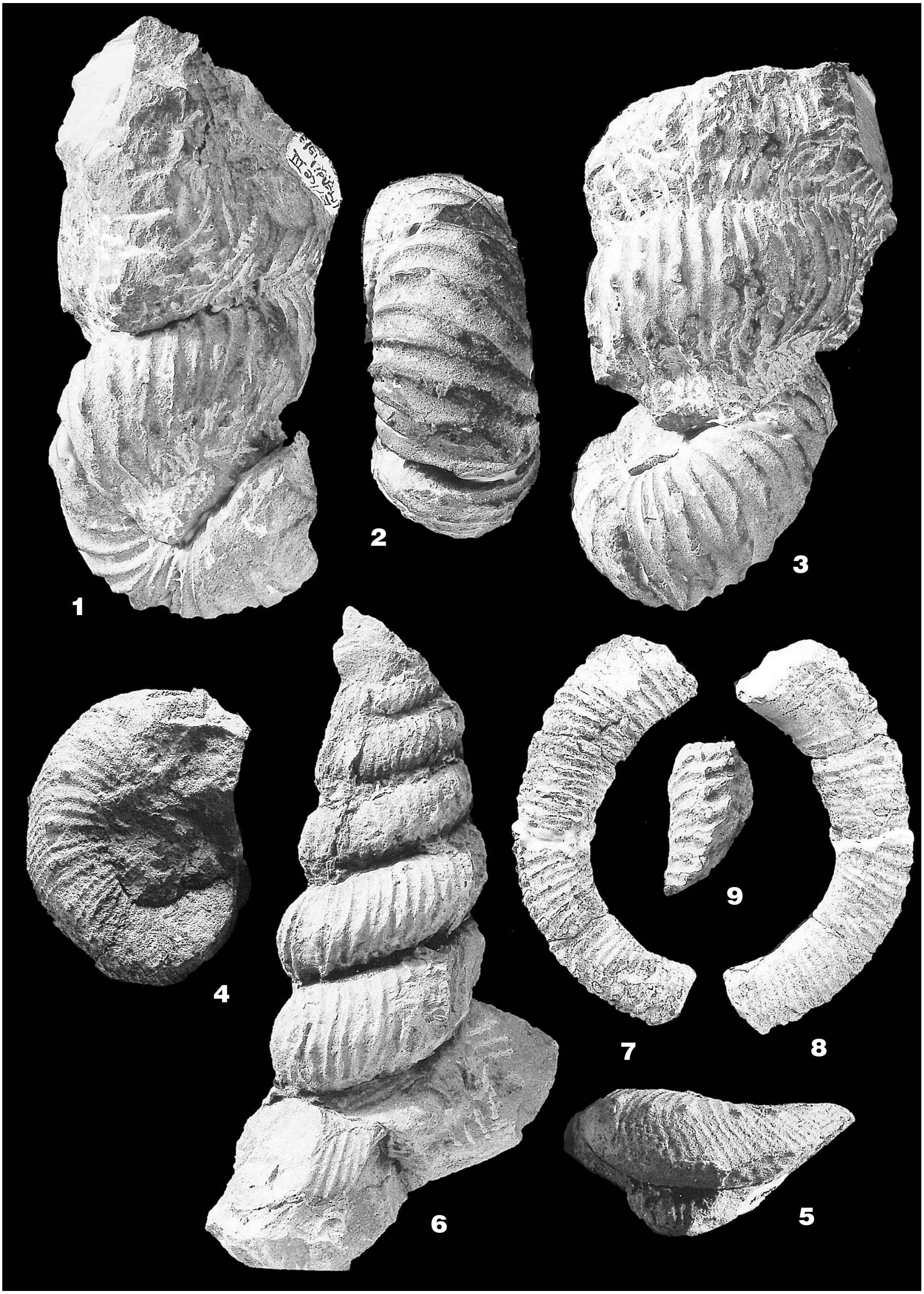
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PLATE 17

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 "glaukonitische 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

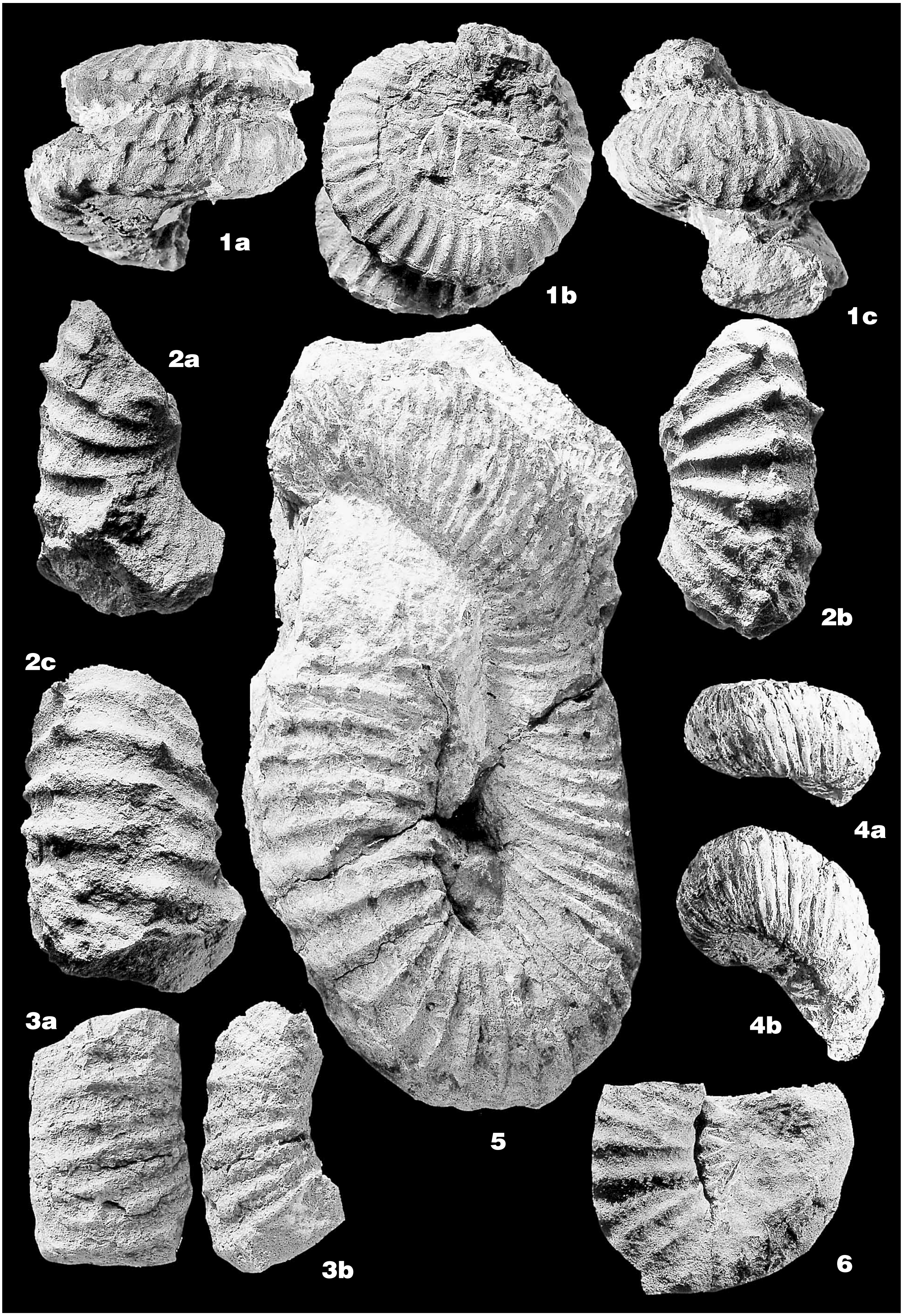
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PLATE 18

Inoceramids from the upper Campanian of the Barranca

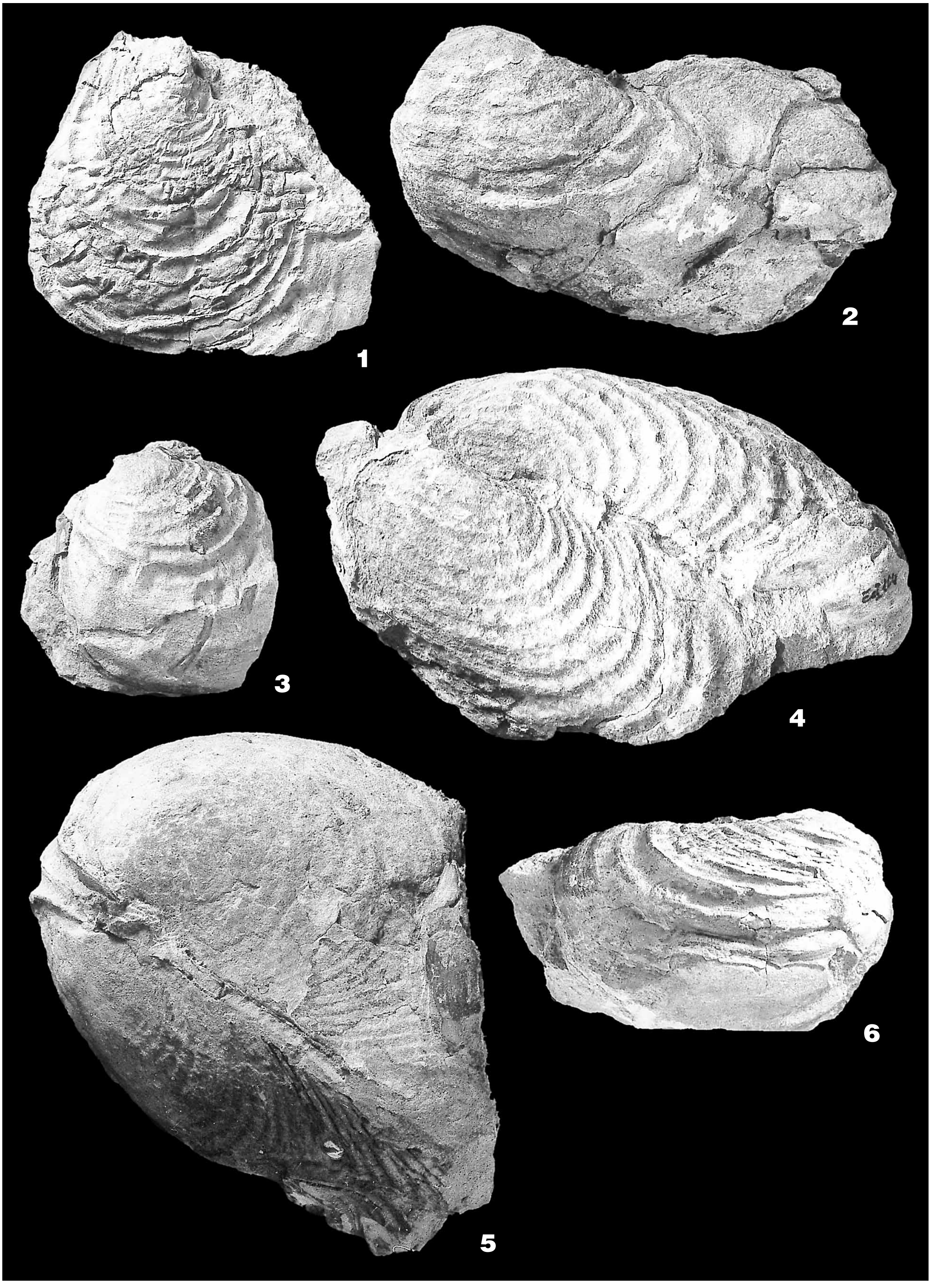
1 – *Inoceramus heberti* FALLOT, EcI-104/*; Upper Campanian, *polyplocum* Zone; Ecay/Araquil

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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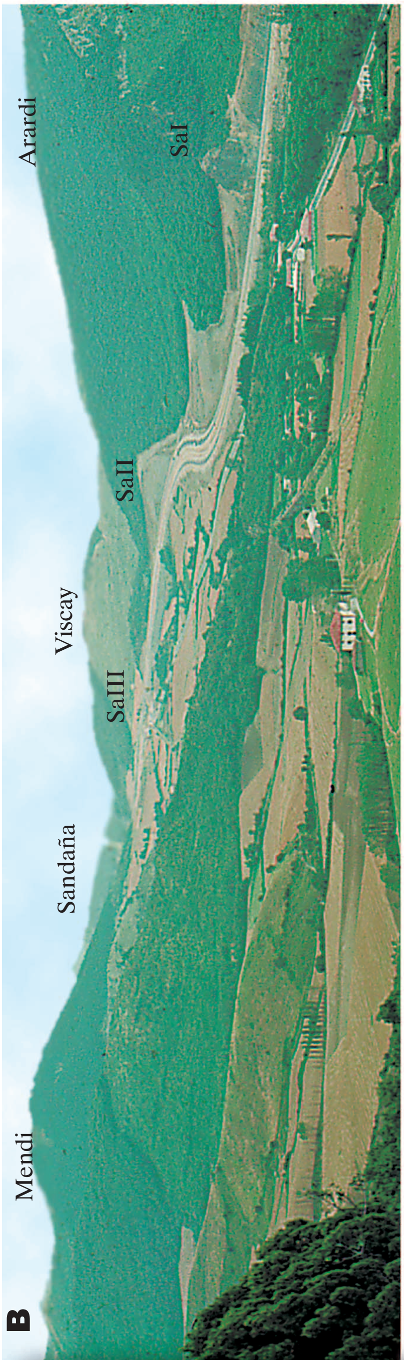
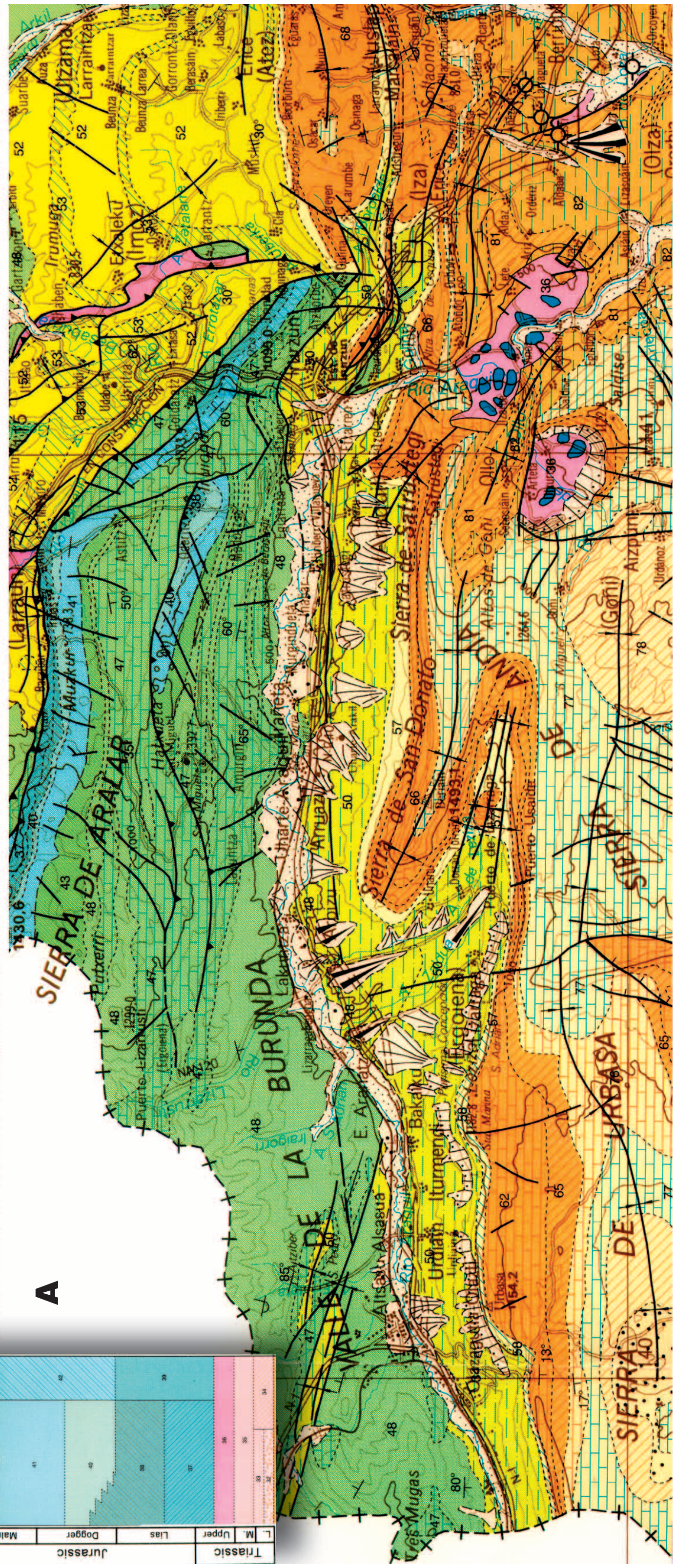
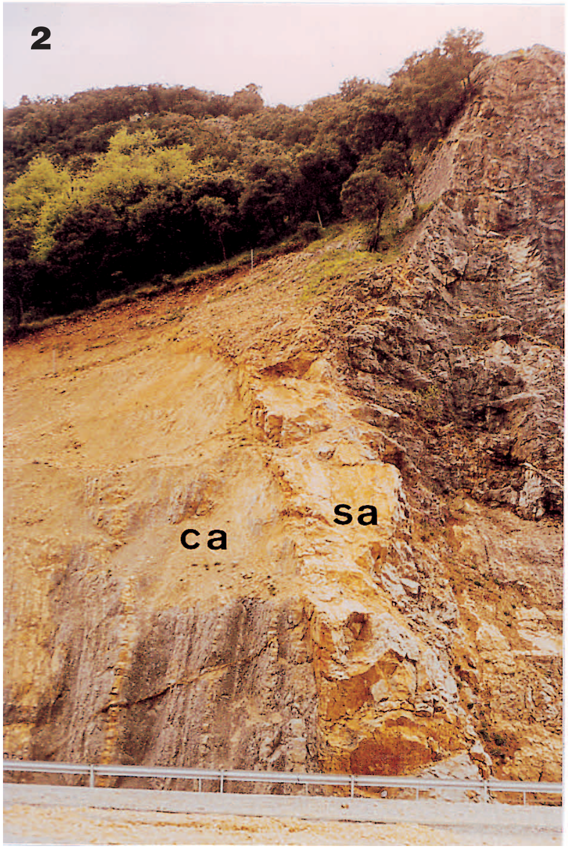
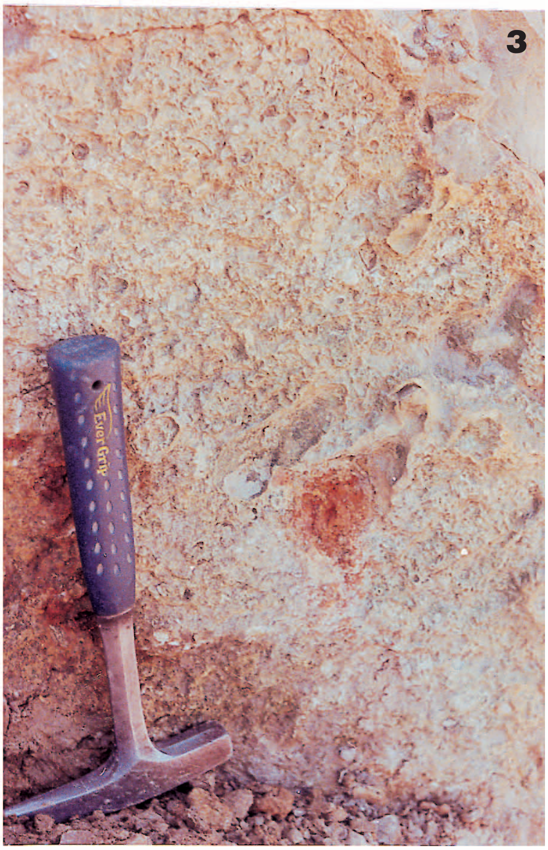




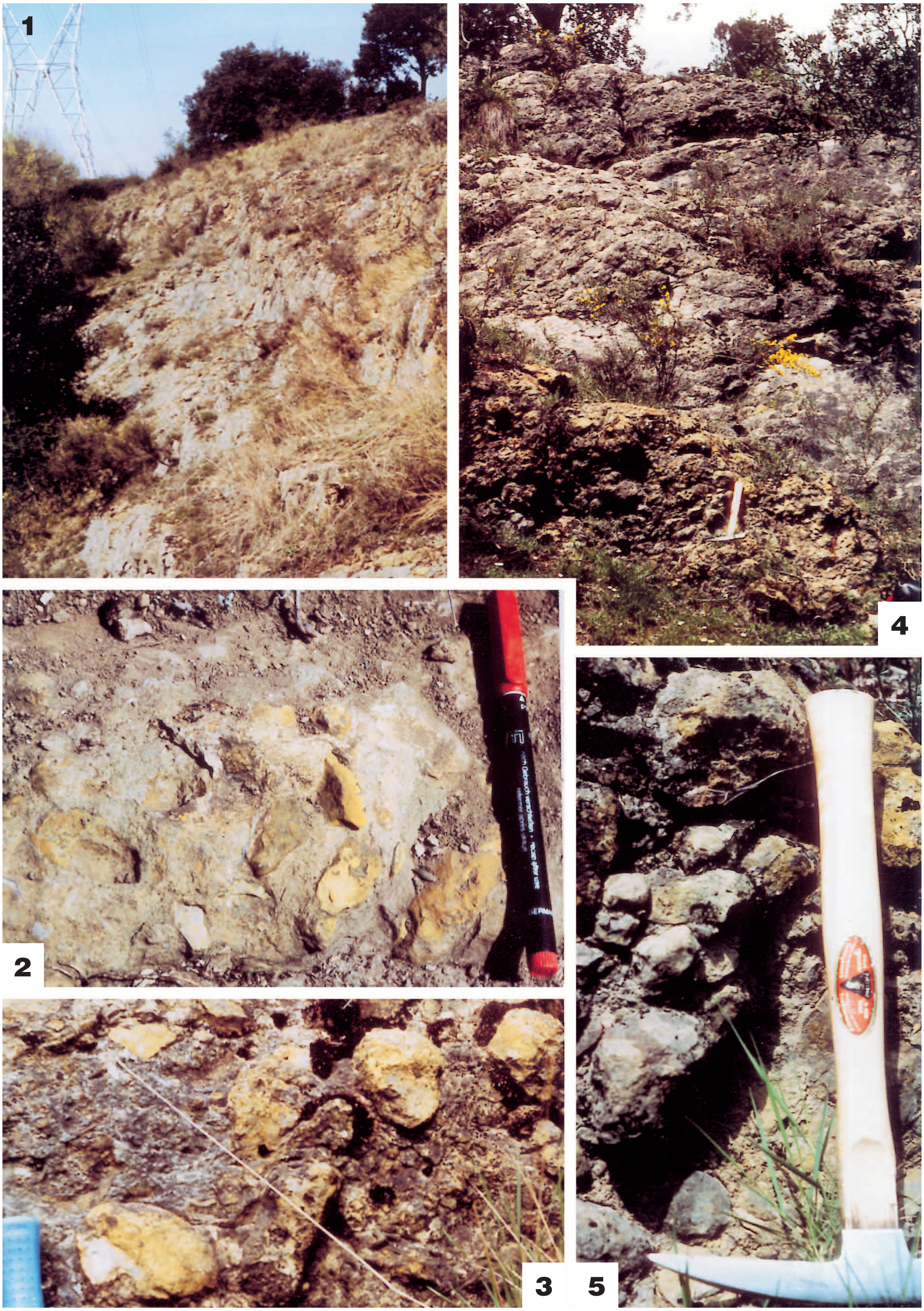
A – Geological map of western Navarra (1: 200 000) with the Barranca (the valley of the Burunda-Araquil river); B – Motorway-cuttings at the A-15 between Irurzun and Erice de Iza, at the northern edge of the Arardi mount





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 – Erosinal gullies of Sarasate IV, south of the Mendi range, north-east of Sarasate; exposed at the beginning of the 80tees; 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