# Additional macrofossil biostratigraphic data on the Upper Coniacian and Santonian of the Olazagutia, Iturmendi and Zuazu sections in the Barranca (Navarra), northern Spain

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**Abstract:** The macrofossil biostratigraphy of the Coniacian – Santonian interval and the overlying Santonian was investigated in three sections (Zuazu, Iturmendi and Olazagutia) along an E – W traverse in the Barranca (Province of Navarra), northern Spain. The ammonite faunas show affinities to those of the French Corbières. At Zuazu, a lower Upper Coniacian *Protexanites bourgeoisi* ammonite Zone is recognised, followed by an hiatus that probably extends from the higher Upper Coniacian to the lower part of the Lower Santonian; the higher Lower or basal Middle Santonian beds here are rich in echinoids, notably the stratigraphically significant *Offaster nuciformis*. The remaining sections expose unbroken boundary interval successions, with the base of the Santonian being taken at the local FAD of the inoceramid *Cladoceramus undulatoplicatus*. At Iturmendi, the beds below and above this datum are assigned to a *Nowakites carezi* ammonite Zone. At Olazagutia, the beds below and above the FAD of *Cladoceramus undulatoplicatus*, up to the local FAD of *Texanites* of the *quinquenodosus-gallicus* group, marking the base of the *T. quinquenodossus* Zone, are treated as an unnamed ammonite Zone. The Coniacian part of this interval is virtually devoid of ammonites, but has yielded the Upper Coniacian inoceramid zonal index *Magadiceramus subquadratus*. At the base of the Santonian part of this interval, there is a succession of *Cladoceramus* acme-occurrences; the higher beds have yielded *Platyceramus* sp. and single records of the ammonites *Pseudoschloenbachia inconstans* and *Placenticeras polyopsis*, suggesting a correlation with the higher part of the *carezi* Zone at Iturmendi. The inferred Middle Santonian *quinquenodosus* Zone is followed by a *Jouaniceras hispanicum/Scalarites cingulatum* Zone with a diverse ammonite and inoceramid assemblage. The ammonites of the latter zone have affinities with those of the French Upper Santonian *Placenticeras paraplanum* Zone.

**Keywords:** Upper Coniacian, Santonian, Biostratigraphy, Ammonites, Inoceramids, Echinoids, Northern Spain

## 1. INTRODUCTION

This contribution focuses mainly on a preliminary record of the Upper Coniacian to Upper Santonian ammonite faunas of the Barranca with particular reference to the

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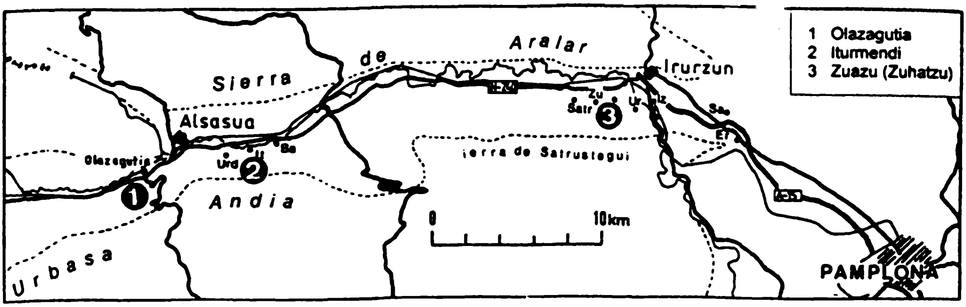

Fig. 1: Location map of the investigated sections within the Barranca (Navarra), northern Spain. Abbreviations: Urd= Urdiain, It= Iturmendi, Ba= Bacaicoa, Satr= Satrustegui, Zu= Zuazu, Ur= Urizola, Iz= Izurdiaga, Sa= Sarasate, Er= Erice de Iza

Coniacian – Santonian boundary in the Olazagutia Quarry, one of the three candidate boundary stratotypes.

At Olazagutia, the Upper Coniacian part has not yet been adequately investigated; ammonites are rare throughout the entire succession here, particular in the Upper Coniacian to Lower Santonian. This has hindered the establishment of an ammonite zonation for the interval in question. Furthermore, inoceramids are uncommon in the Upper Coniacian and the echinoid record across the Coniacian – Santonian boundary does not enable the boundary to be located precisely.

The adjacent Iturmendi and Zuazu sections are therefore of considerable importance because the data from these localities support a stratigraphic subdivision of the Olazagutia succession. Those localities also provide additional information on the ranges of the echinoids and ammonites. However, ammonites are also scarce in the Lower Santonian of these sections.

More detailed information on inoceramid and echinoid occurrences in the Coniacian – Santonian boundary interval at Olazagutia will be published later in the report of the Santonian working group.

## 2. GEOLOGICAL SITUATION OF THE BARRANCA

The Barranca represents a narrow, E-W striking valley along the Burunda-Araquil River, in the western part of the province of Navarra (Fig. 1), bordered by the Sierra de Aralar to the north and by the Sierra Andia, Sierra Satrustegui and Sierra de Urbasa to the south. It extends from Irurzun in the east to Olazagutia in the west, where it passes into the Vitoria Plain.

Structurally, the Upper Cretaceous strata form a large synclinorium, that is bordered to the north, along the Aralar Fault, by the Aralar Anticline which consists of Triassic and Jurassic limestones and dolomites and of Aptian – Albian reef limestones. In the south, the Satrustegui Fault runs parallel to the Aralar Fault and separates parts of the Upper Cretaceous synclinorium from the synclinorium of the Tertiary high plateau. Towards the east, the Barranca is limited by a NE-SW trending lineament, known as the Estella-Dax Diapir Zone (*sensu* Lotze, 1955), Estella Fault (*sensu* Schwentke,1990) or part of the

Transversals Basco-Landaise (*sensu* SCHOEFFLER, 1982). This fracture zone separates the Barranca from the Pamplona Basin. The Barranca can thus be interpreted as a graben structure (RAMIREZ, 1987).

Within the eastern Barranca, the predominantly WNW-ESE striking Upper Cretaceous strata are intensively, almost isoclinal folded and partly overturned. The axis of folding dips gently to the ESE. A system of E-W and N-S trending faults divide the synclinorium into well defined blocks. The margins of the synclinorium are marked by zones of faulting and overthrusting (KÜCHLER, 1983). The intensity of folding decreases towards the western Barranca.

Apart from up to 2000 m of Albian clays and about 400 m of Campanian – Maastrichtian silty marls, the Cretaceous succession of the Barranca is composed of marine carbonates. The Cenomanian to Maastrichtian succession reaches a thickness of about 800 to 1050 m in the eastern part (DEGENHARDT, 1983; KÜCHLER, 1983, 1998, 2000) and up to 1350 m in the western part of the Barranca (KANNENBERG, 1985; ZANDER, 1988).

The marly to calcareous Coniacian and Santonian strata follow, from west to east, the northern flank of the Tertiary high plateau. RAMÍREZ DEL POZO (1971) and ZANDER (1988) quoted about 400–600 m of Coniacian strata, composed of marls and alternations of marls, calcareous marls and marly limestones in the western Barranca, where the lowermost part of the Lower Coniacian is missing. The Santonian, locally reduced by hiatuses, reaches its maximum thickness of ca. 230 m in the Olazagutia Quarry (KANNENBERG, 1985), where the succession appears comparatively complete.

The Coniacian to Santonian successions become more calcareous towards the eastern Barranca, accompanied by a progressive decrease in thickness, thus indicating shallowing of the Barranca basin from the west to the east. This basin configuration, however, was complicated by numerous uplifted and downthrusted blocks (KÜCHLER, 1998).

In the area between Satrustegui and Zuazu (Fig. 1), the Coniacian succession is about 200 m thick, and the Santonian is reduced to about 100 m (KÜCHLER, 1998), becoming less towards the east. About 1.5 km south of Irurzun, the entire Coniacian and Santonian reach a thickness of less than 250 m at Izurdiaga (DEGENHARDT, 1983; KÜCHLER, 1983, 1998), due to condensation and/or hiatuses. Sections in the investigated area, e.g. in the areas around Izurdiaga, Urrizola, Zuazu and Iturmendi, are partly overgrown and there are only moderately good exposures around the Coniacian – Santonian boundary. However, these sections yielded a highly diverse macrofauna, of which the echinoids are the most abundant group.

## 3. SANTONIAN STAGE AND SUBSTAGE BOUNDARIES

The base of the Santonian is taken here at FAD of *Cladoceramus undulatoplicatus* (ROEMER) as proposed at the Second International Symposium on Cretaceous Stage Boundaries, Brussels, 1995 (LAMOLDA & HANCOCK, 1996). The extinction of *Cladoceramus undulatoplicatus* is taken as a possible datum for the base of the Middle Santonian, also in accordance with LAMOLDA & HANCOCK (1996). However, at Olazagutia, this datum is uncertain and controversial, as discussed below.

The position of the base of the Upper Santonian (taken at the FAD of the inoceramid *Cordiceramus muelleri* (PETRASCHECK)) has not been precisely determined (see discussion

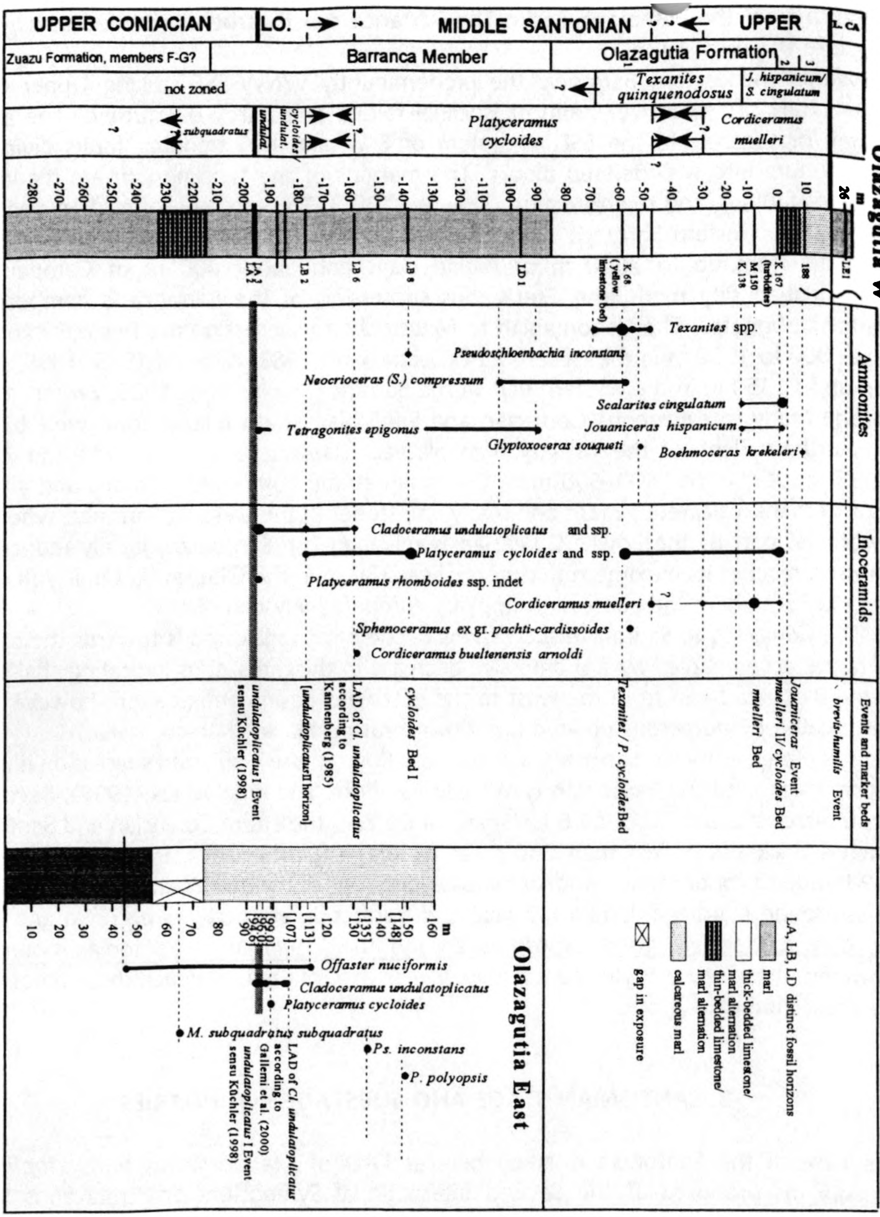


Fig. 2: Litho-, bio- and event stratigraphic subdivisions of the Santonian in the Olazagutia West section (modified after Küchler, 1998). Macrofossil distribution (ammonites and inoceramids). Lithologic column (highly simplified) and metre scale after Kannenberg (1985); inoceramid and ammonite data mainly based on the investigation of Kannenberg (1985), with some inoceramid data from López (1990, 1992). Macrofossil distribution of the Olazagutia East section according to Gallemí et al. (1997) and Gallemí pers. comm. (2001), compare also Fig. 4.

in Küchler, 1998), but it lies between beds KM85 (-47 m) and M90 (-41 m) (see Fig. 2). Some distance above the base, an ammonite assemblage with affinities to those of the French and German Upper Santonian occurs (see discussion in Küchler & Wagreich, 2002).

## 4. THE SECTIONS

### 4.1. Olazagutia (Fig. 2)

The so-called Olazagutia Quarry was proposed by Gundolf Ernst (in Schulz et al., 1984) as one of the possible stratotypes of the Coniacian-Santonian boundary interval (Birkelund et al., 1984) and selected as one of three candidate boundary stratotypes in Brussels 1995 (Lamolda & Hancock, 1996). The Cantera (= quarry) de Margas or Cantera Egibil of the Cementos Portland S.A. is located on the northern edge of the Sierra de Urbasa, south of Olazagutia (Fig. 1). The section has been described by Ramirez del Pozo (1971), Radig (1973), Wiedmann (1979), Lamolda & Melinte (2000), Lamolda et al. (1981, 1999), Martins (1988), Gräfe (1994), Gallemí et al. (1997, 2000), and Küchler & Wagreich (2002). Some of these references contain partial faunal lists. The only detailed measurement of the entire succession, however, was that given by Kannenberg (1985). Based on macrofossil and microfossil biostratigraphic data, Wolz & Zander (1987) compared the Olazagutia section with sections in the Barranca (Iturmendi section) and the Vitoria Plain (San Roman section) respectively. A preliminary zonation, based mainly on data from Kannenberg (1985), was given by Küchler (1998).

When Kannenberg (1985) studied the quarry, the oldest exposed strata were of Late Coniacian age and the section ranged up into the middle Lower Campanian, the latter indicated by the foraminifera and the echinoid fauna. Kannenberg (1985) measured a thickness of about 326 m for the entire succession. He used as datum for his section (level zero) an horizon of glauconitic calciturbidites (beds K 167, see Fig. 2), from which he measured down-section as well as up-section. This conspicuous horizon is found in the highest part of the section on the western side of the quarry. It falls in terms of microfossil, nannofossil and macrofossil biostratigraphy in the Late Santonian (Küchler & Wagreich, 2002). In terms of inoceramid biostratigraphy, it belongs to the *Cordiceramus muelleri* Zone (sensu Küchler, 1998). Starting at the base of the quarry, beds and distinct fossil horizons e.g. LA, LB, LD and LE were numbered by Kannenberg (1985) in ascending order. However, due to the progressive exploitation of the quarry over the years, the lower parts of Kannenberg's sections at the west face (Olazagutia W in Fig. 2) are either no longer accessible or can be recognised only with difficulty. Furthermore, the upper parts of the quarry have not been re-measured. Nevertheless, both the recent finds and those of Kannenberg have been plotted against the lithological column and the metre scale used by him (Fig. 2).

Previously published ammonite records from Olazagutia mostly lack precise documentation of the horizon, suggesting that most of the collected material derived from the talus. This is also largely true for the amateur and museum collections that have been investigated in this work. Apart from rare *Jouaniceras hispanicum* Wiedmann from the interval around the glauconitic calciturbidites, there are two additional biostratigraphically important specimens, single unhorizoned finds of *Placenticeras polyopsis* (Dujardin) and *Eupachydiscus isculensis* (Redtenbacher) in the collection of W. [redacted] nhagen/Wolfsburg. Two *Glyptoxoceras* specimens, one of which is a *Glyptoxoceras souqueti* Collignon, are housed in the collection of the Museo de Ciencias Naturales de Alava, Vitoria-Gasteiz. The scarce records of *in situ* finds are mainly based on Kannenberg (1985), on material collected by other members of the Berlin Cretaceous working group in the 1980s, and on Martínez (unpubl. report of Gallemí et al., 2000). Martínez quoted single finds of *Damesites* sp., *Placenticeras polyopsis* and *Pseudoschloenbachia inconstans* tens of meters above the Coniacian – Santonian boundary in the east face section (Olazagutia East in Fig. 2). Only a few new finds can be added.

A continuous succession of marls and calcareous marls crosses the Coniacian – Santonian boundary interval. In the lower part of the quarry scarce occurrences (not shown on Fig. 2) of the Upper Coniacian index inoceramid *Magadiceramus subquadratus* (Schlüter) have been recorded by López (1996) and López (in Gallemí et al., 1997). Kannenberg (1985) recognised two *Cl. undulatoplicatus* horizons ca. 19–20 m apart. The local FAD of *Cl. undulatoplicatus* was reported by him to lie ca. 1 m below the lowermost *Cladoceramus*-acme (fossil horizon LA3, referred to as the *undulatoplicatus* I Event by Küchler (1998)) at the ca. –197 m level. The second *Cladoceramus* horizon, based on loose specimens of *Cl. undulatoplicatus* (compare Kannenberg, 1985, Fig. 11), was inferred by Kannenberg to lie at the LB 2 level. The LO of *Cl. undulatoplicatus* was reported by him at the LB 6 level.

In 1997, Gallemí et al. started a re-investigation by measuring the east face of the quarry (Olazagutia E in figs 2 and 4). In contrast to the west face section of Kannenberg (1985), the zero level of the east face section was placed at the base of the quarry, south of its first fault zone, and the section was measured upwards from this datum (Figs. 2, 4). The only in situ find of *Magadiceramus subquadratus* came from the 65 m level (Gallemí pers. comm., 2001). The re-investigation has shown six levels of *undulatoplicatus* occurrences in the east face section between levels 94. 6 and 97.9 m. Küchler (1998) pointed out that, within this interval, four levels of inoceramid concentrations could be distinguished over a maximum interval of 1.3 m (compare Olazagutia E, in Fig. 4), and interpreted this interval to correspond to Kannenberg's "first *undulatoplicatus*-acme" at fossil horizon LA3 i.e. the *undulatoplicatus* I Event of Küchler (1998). Level 4 of *undulatoplicatus* reported by Gallemí et al. (1997) is assumed herein to correspond to the top of the *undulatoplicatus* I Event (–196 m level on the west face). Gallemí et al. (2000) reported two additional levels of *Cl. undulatoplicatus* higher up-section, with the LAD of *Cl. undulatoplicatus* at the 107 m level. The "second *undulatoplicatus* maximum", mentioned by Kannenberg (1985) (*undulatoplicatus* II Event of Küchler, 1998) was not recognised in 1997

In the interval between the FAD of *Cladoceramus undulatoplicatus* and the first *Texanites* in the west face section, ammonites are rare (Fig. 2). The long ranging *Tetragonites epigonus* Kossmat was found in bed LA3, at the -196 m level sensu Kannenberg (1985). A second specimen was collected at the -90 m level. *Pseudoschloenbachia inconstans* (de Grossouvre), the first typical Early Santonian ammonite, occurs in bed LB8 (at about the -139 m level), ca. 10 m above the local LAD of *Cl. undulatoplicatus* reported by Kannenberg (1985) in LB6 and thus in the Middle Santonian. *Neocrioceras (Schlueterella) compressum* Klinger was found in the interval between the -105 m and -100 m levels and a second specimen came from K69 (–58m).

The lowest find of *Texanites quinquenodosus* (REDTENBACHER), collected loose from the talus between bed 58 and bed 60, came from an interval between -65 m and -67 m. *Texanites* of the *quinquenodosus-gallicus* group are quite common in bed K68 and above that level. A single specimen of *Glyptoxoceras souqueti* is recorded from K77 at the -53 m level.

The lowest finds of *Scalarites cingulatum* (SCHLÜTER) and *Jouaniceras hispanicum* WIEDMANN derive approximately from bed 138–139 (-14 m level).

### 4.2. Iturmendi II section

The Iturmendi section consisting of two separate exposures (Iturmendi I and II), was measured and described by ZANDER (1988). These sections were exposed in the 1980s on the northern slope of the Sierra Andia (Fig. 1). The Iturmendi I section started in the Middle Coniacian about 400 m south-east of the eponymous village, and the top of the Iturmendi II section was dated as Early Campanian. Today, only parts of the Middle Coniacian are accessible south-west of Iturmendi.

The base of the Iturmendi II section, including the Coniacian – Santonian boundary, was located at an altitude of 600 and 650 m. The section was about 130 m thick, comprising 44 m of Upper Coniacian, 20 m of Santonian and 66 m of Lower Campanian. At Iturmendi, the Santonian strata are reduced by an hiatus and Lower Campanian dark marls rest concordantly on Lower Santonian strata.

The Coniacian – Santonian succession consists of 31 m grey to dark grey marls followed by an alternation of calcareous marls and marly limestones with a total thickness of 33 m.

An occurrence of *Cladoceramus undulatoplicatus* at the 44 m level of the section (Bed ItII-42 sensu ZANDER, 1988) was taken by KÜCHLER (1998, Fig. 29), and is tentatively taken herein, to mark the base of the Santonian. However, in the absence of inoceramid records below this datum, there is no evidence whatsoever to show that this represents the true FAD of the taxon. Single *in situ* records of *Nowakites carezi* 1–2 m and 12–13 m below the inferred base of the Santonian suggest that this interval can also be correlated with the (Santonian) *Nowakites carezi* Zone (sensu KENNEDY et al., 1995). If the local occurrence of *Cl. undulatoplicatus* should prove to be the true FAD, the *carezi* Zone at Iturmendi would fall into the Upper Coniacian. This would be in accordance with Coniacian records of *N. carezi* from Romania, Bulgaria and Armenia (references in KENNEDY et al., 1995), but not with its exclusively Lower and Middle Santonian range in the French Corbières. KENNEDY (pers. comm., 2002) assumed that the interval with *N. carezi* may well be Lower Santonian rather than Upper Coniacian.

*Pseudoschloenbachia inconstans* (DE GROSSOUVRE), *Glyptoxoceras* sp. and *Damesites sugato* (Forbes) occur 13 m above the inferred base of the Santonian at the 57 m level of the section (ZANDER, 1988 and Fig. 4). Inoceramids (*Platyceramus* sp.) were found at the 50 m, 57 m and 62 m levels. The ammonite records, albeit in the absence of the zonal index, could also indicate the *Nowakites carezi* Zone.

The boundary between the Santonian and Campanian is marked by a hiatus at the 64 m level of the section. Planktic foraminifera indicate the Lower Campanian *Globotruncanita elevata* Zone (ZANDER, 1988). The associated irregular echinoids, *Cardiaster lehmani* (STOLLEY) and *Echinocorys* ex gr. *conica*, support a middle Early Campanian age (see KÜCHLER, 2000).

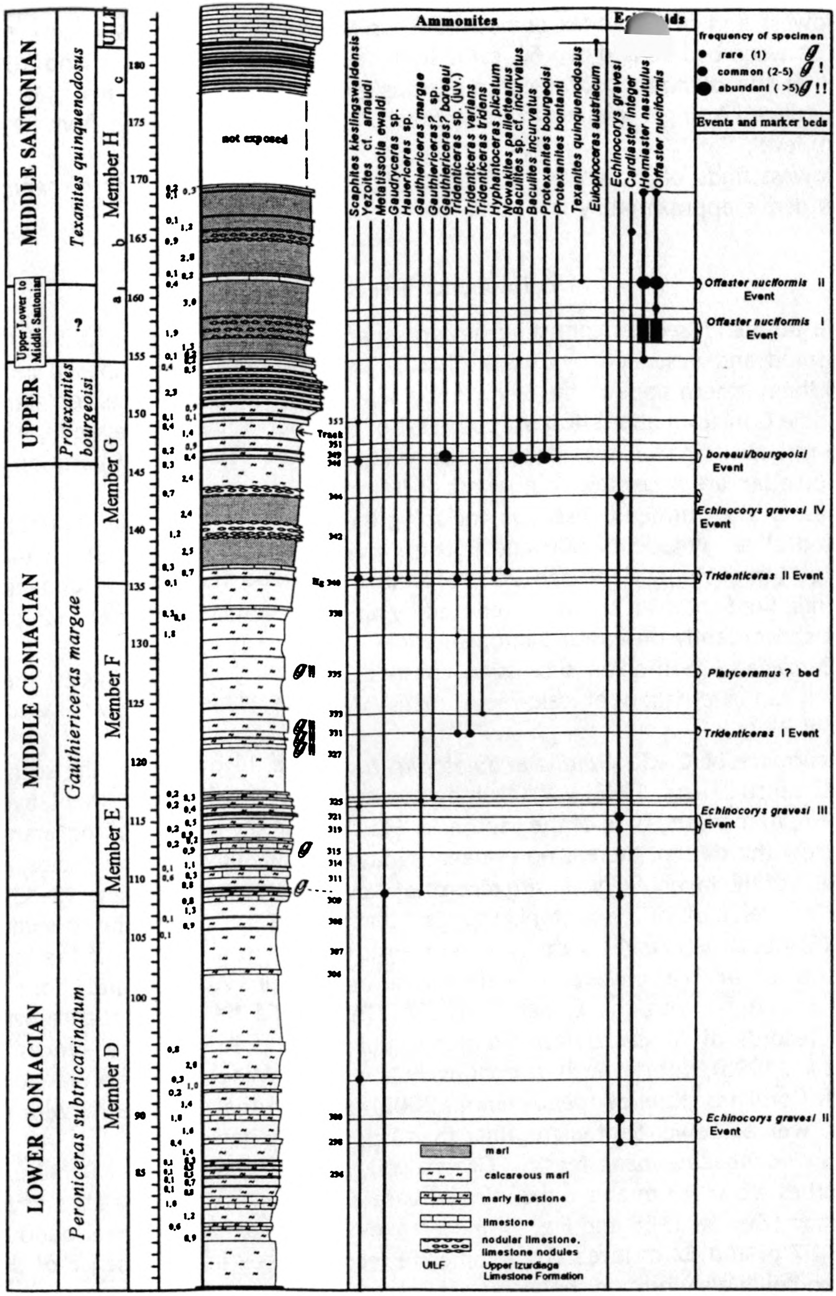


Fig. 3: Litho-, bio- and event stratigraphy in the upper Lower Coniacian to the Middle Santonian of the Zuazu C section (after Küchler, 1998). Vertical ranges of ammonites and echinoids. The latter group does not include *Micraster*, the most abundant taxon throughout the section.

### 4.3. Zuazu C section (Fig. 3)

The Coniacian – Santonian boundary interval is exposed about 900 m south of Zuazu (Zuhatzu)/Araquil (Fig. 1). The lithostratigraphy of the Zuazu section, the macrofossil content and the vertical ranges of selected fossil groups were described in detail by Küchler (1998). The biostratigraphical subdivision was based mainly on ammonites, but the Coniacian – Santonian boundary was drawn on lithological criteria at the conspicuous lithofacies change from rhythmically bedded nodular limestones and marls to the succeeding dark *Offaster* Marls (lower part of Member H of the Zuazu Formation in Fig. 3). This lithochange reflects a significant but imprecisely dated hiatus (see below).

The Coniacian – Santonian boundary is taken at the top of bed ZuC-362, at the 154.8 m level of the section (figs 3, 4). A mass-occurrence of ammonites (*boreaui/ bourgeoisi* Event) is located around the 146 m level, ca. 8.8 m below the lithofacies change. *Gauthiericeras? boreaui* (de Grossouvre), *Protexanites bourgeoisi* (d'Orbigny) and *Baculites* sp. cf. *incurvatus* are abundant; *Scaphites kieslingswaldensis* Langenhan & Grundey is common; and there are single records of *Protexanites bontanti* (de Grossouvre) and *Baculites incurvatus* Dujardin. In the interval between the event and the lithofacies change, there are records of *S. kieslingswaldensis* and *B.* sp. cf. *incurvatus*, with the last record of the latter taxon in the boundary bed ZuC-362. This interval has not yielded any inoceramids, so its position within the inoceramid biostratigraphical scheme cannot be determined.

The ammonite event represents the base of the *Protexanites bourgeoisi* Zone sensu Santamaría (1992). The FAD of *Protexanites bontanti* indicates a Late Coniacian age and enables a correlation with the lower part of the terminal Coniacian *Paratexanites serratomarginatus* standard ammonite Zone (cf. Küchler, 1998, figs. 25, 26). On the limited ammonite evidence, the overlying interval is assigned to the *bourgeoisi* Zone, there being no evidence of the *Hemitissotia* faunas described by Santamaria (1992) and Wiedmann (1979) that mark the top of the Coniacian in the Burgos area of Spain.

The echinoid *Offaster nuciformis* Ernst appears at the base of bed ZuC-364, near the base of the *Offaster* Marls and about 1.3 m above the inferred Coniacian – Santonian boundary (Fig. 3). In the succeeding 1.9 m interval, the species is associated with *Hemiaster nasutulus* Sorignet and reaches its first acme-occurrence (*nuciformis* I Event). *H. nasutulus* enters just above the boundary and ranges up to the 169 m level, the local LAD of *O. nuciformis*. The local FAD of the Santonian ammonite index, *Texanites quinquenodosus* (Redtenbacher), coincides with the higher of two mass-occurrences of *H. nasutulus* and *O. nuciformis* (*nuciformis* II Event) in bed ZuC-366.

Other echinoids, such as *Cardiaster integer* (Agassiz) and *Echinocorys*, range throughout both the Coniacian and the Santonian successions. Within the Coniacian – Santonian boundary interval at Zuazu, *Echinocorys gravesi* is found at a level around 143 m and *Cardiaster integer* at a level around 165 m at Zuazu (Fig. 3). At Olazagutia, *Echinocorys* (*E.* gr. *scutata*) was found only above the boundary, never below (pers. comm. J. Gallemí, 2001). *Micraster*, the most abundant macrofossil group in the Coniacian and Santonian of the whole Barranca, is not taken into consideration herein, due to the lack of a detailed study.

The dating of the interval of the *Offaster* Marls between the lithofacies change and the FAD of *Texanites quinquenodosus* presents difficulties since, in the absence of

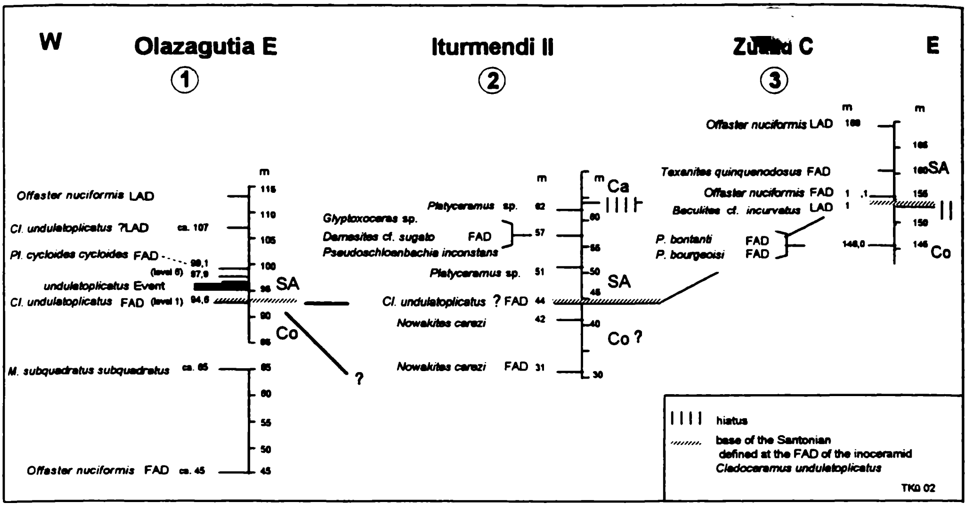


Fig. 4: Simplified correlation of the Coniacian – Santonian boundary interval between Olazagutia (data from Gallemí et al., 1997 and Gallemí pers. comm., 2001), Iturmendi (after Zander, 1988) and Zuazu (after Küchler, 1998). Ammonite and inoceramid occurrences and the first appearance datum (FO) of the echinoid *Offaster nuciformis* are plotted against the FO of *Cladoceramus undulatoplicatus* and the metre scales used in individual sections.

ammonites and inoceramids, it is entirely dependent upon extrapolation of extremely sparse *Offaster nuciformis* data from other localities.

At Olazagutia, the FAD of *O. nuciformis* is located about 20 m below the only *in situ* find of the Upper Coniacian inoceramid index, *Magadiceramus subquadratus* (Gallemi, pers. comm., 2001). At Soto de la Marina, near Santander (Cantabria), rare *O. nuciformis* (2 specimens) have been found together with the basal Santonian index *Cladoceramus undulatoplicatus* in the middle part of the range of the latter species (Oppermann, 1996). At Olazagutia, loose specimens of *O. nuciformis* are recorded 6 m above the LAD of *Cl. undulatoplicatus* of Gallemi et al. (2000) in the east face section, at the equivalent level of Kannenberg's (1985) "second *undulatoplicatus* acme" (see figs 2, 4). However, Kannenberg (1985) reported *Cl. undulatoplicatus* at an even higher level (LB6) in the west face section. Since neither Kannenberg's second *undulatoplicatus* acme, nor his LAD of *Cl. undulatoplicatus* have been confirmed by the subsequent investigation, it is not possible at present to state categorically whether the the LAD of *O. nuciformis* at Olazagutia lies in the upper part of the range of *Cl. undulatoplicatus*, i.e. upper Lower Santonian, or above that range, i.e. lower Middle Santonian. If Kannenberg's data can be accepted, the LAD of *O. nuciformis* falls in the upper Lower Santonian at Olazagutia.

The Zuazu occurrences of *O. nuciformis* are inferred to lie above the *undulatoplicatus* Zone of Olazagutia, in the upper part of the range of *Cl. undulatoplicatus* or above that interval, i.e. in the lowermost Middle Santonian in comparison to Olazagutia (compare figs. 2, 5).

Hence, *O. nuciformis* is known to range in Spain from the Upper Coniacian (Olazagutia) to the lowermost Middle Santonian (Zuazu).

Arising from this discussion, the evidence suggests that the find of *Texanites quinquenodosus* at Zuazu may represent a relative low record in the Middle Santonian.

In view of the fact that it is not possible to date the interval in the lower part of the *Offaster* Marls between the inferred Coniacian – Santonian boundary and the FO of *Texanites* satisfactorily, the extent of the hiatus at the boundary remains uncertain. It is probably safe to assume that the higher part of the Upper Coniacian *Paratexanites serratomarginatus* Zone is missing. Whether or not the absence of inoceramids, specifically *Cl. undulatoplicatus,* from the *Offaster* Marls, implies that the basal Santonian inoceramid events are also missing at the hiatus, cannot be determined, and it would be unsafe to draw this inference even though it may be correct. All that can be suggested is that this interval may well represent the higher part of the Lower Santonian or the basal beds of the Middle Santonian.

## 5. TENTATIVE AMMONITE ZONATION OF THE OLAZAGUTIA SECTION

It must be stated that the local ranges of the selected organism groups recorded here are only approximate and that the scattered ammonite occurrences do not allow the zonal boundaries to be accurately placed.

### 5.1. unnamed ammonite zone

This interval extends from the base of the quarry up to the FAD of *Texanites* (Fig. 2). It is divided into two parts, an Upper Coniacian part below the FAD of *Cladoceramus undulatoplicatus*; and a Santonian part above this datum.

The beds below the FAD of *Cl. undulatoplicatus* have yielded the Upper Coniacian inoceramid index *Magadiceramus subquadratus*, but no ammonites apart from a record (Wiedmann, 1979; Küchler, 1998) of a specimen of *Hemitissotia turzoi* Karrenberg collected loose. This ammonite record suggests correlation with the *Hemitissotia* sp. Zone established in the Burgos area of northern Spain by Santamaría (1992), i.e. the equivalent of the upper part of the terminal Upper Coniacian *Paratexanites serratomarginatus* Zone (see Küchler, 1998, Fig. 26).

As discussed earlier, it is unsafe to correlate this interval with the apparently equivalent interval below the *Cl. undulatoplicatus* occurrence at Iturmendi which contains *Nowakites carezi.*

The interval between the FAD of *Cl. undulatoplicatus* up to the FAD of *Texanites* has yielded no biostratigraphically significant ammonites other than single horizoned finds of *Pseudoschloenbachia inconstans* and of *Placenticeras polyopsis. Ps. inconstans* and *Pl. polyopsis* may be restricted in Spain to the Lower and Middle Santonian, while *Pl. polyopsis* is known to range throughout the entire Santonian elsewhere (Kennedy et al., 1995). The Santonian part of the unnamed interval corresponds to the lower part of the broad *Placenticeras polyopsis* Zone used elsewhere in Europe. The records of these two ammonites also suggest that the interval in question may represent the Lower Santonian portion of the *Nowakites carezi Zone* sensu Kennedy et al. (1995) which, in the French

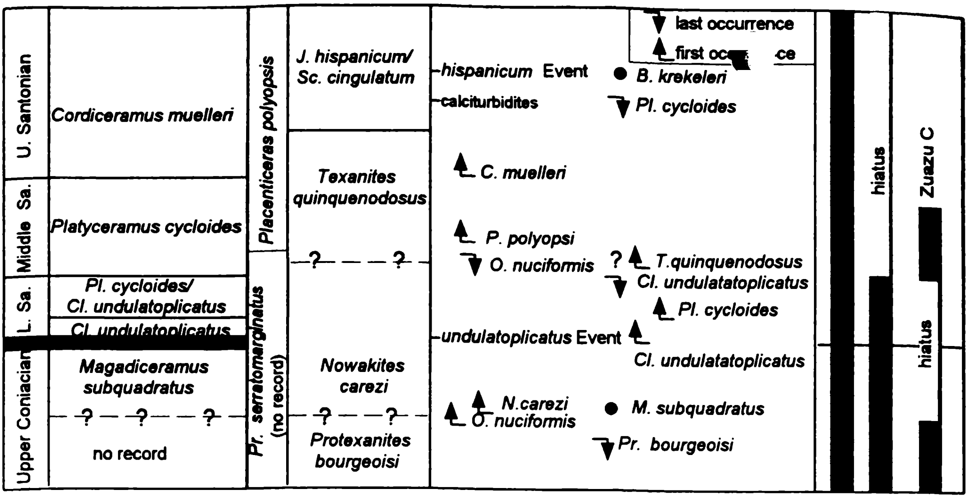


Fig. 5: Integrated biostratigraphy and marker beds of macrofossils around the Coniacian – Santonian boundary derived from three sections in the Barranca, northern Spain.

Corbières, yielded the zonal index, *Pseudoschloenbachia inconstans, Muniericeras lapparenti* and *Placenticeras polyopsis*. This interval can therefore be correlated tentatively with the interval at Iturmendi between the occurrence of *Cl. undulatoplicatus* and the hiatus at the Santonian – Campanian boundary, and assigned questionably to the higher part of the *Nowakites carezi* Zone.

### 5.2. *Texanites quinquenodosus* Zone

The base of the zone is taken at the FAD of *Texanites quinquenodosus*, based on a specimen collected loose from the interval between -65 and -67 m of Kannenberg's (1985) section on the west face of the quarry. *Texanites* of the *quinquenodosus-gallicus* group are relatively common in bed K68 (the yellow limestone bed) and for a few metres above that level (Fig. 2).

The top of the zone is taken at the base of the *Jouaniceras hispanicum/Scalarites cingulatum* Zone. There is a single record of *Glyptoxoceras souqueti* from bed K67, in the upper part of the range of *Texanites*. There are no ammonite records between the local LAD of *Texanites* and the top of the zone, but the FAD of the Upper Santonian inoceramid index, *Cordiceramus muelleri*, falls within this interval.

There is evidence that the entry of *Texanites quinquenodosus* and/or *T. gallicus* is later in continuous and expanded basinal sections than in the more marginal sections such as Zuazu. At Olazagutia, it lies high above the recognised local range of *Cladoceramus undulatoplicatus*.

The late entry of *Texanites* in the Santonian is also reported from Cantabria, northern Spain (Oppermann, 1996) as well as from the French Corbiéres (Kennedy et al., 1995).

### 5.3. *Jouaniceras hispanicum / Scalarites cingulatum* Zone

The zone is defined as an assemblage zone of the two nominate index ammonites (see discussion in KÜCHLER, 1998; KÜCHLER & WAGREICH, 2002). The ammonite fauna shows affinities with the French *Placenticeras paraplanum* Zone fauna (compare KENNEDY et al., 1995) which yields, beside the characteristic *Placenticeras paraplanum* WIEDMANN and *Pl. maherndli* SUMMESBERGER, comparable faunal elements such as *Jouaniceras sicardi* (DE GROSSOUVRE) and *Boehmoceras krekeleri.*

## 6. CONCLUSIONS

Macrofossil biostratigraphy data on the Coniacian – Santonian interval and the overlying Santonian based on three northern Spanish sections (Olazagutia, Zuazu and Iturmendi) are presented. The Upper Coniacian ammonite and inoceramid succession at Olazagutia is poorly known. At Zuazu, an ammonite rich lower Upper Coniacian *Protexanites bourgeoisi* ammonite Zone is recognised, followed by an hiatus.

The Iturmendi and Olazagutia sections expose unbroken boundary interval successions, with the base of the Santonian being taken at the local FAD of the inoceramid *Cladoceramus undulatoplicatus.* At Iturmendi, the beds below and above this datum are assigned to a *Nowakites carezi* ammonite Zone.

A three-fold division by means of ammonites can be applied to the Santonian succession at Olazagutia. The beds below and above the FAD of *Cl. undulatoplicatus*, up to the local FAD of *Texanites* are treated as an unnamed ammonite Zone. The Coniacian part of this interval is virtually devoid of ammonites, but has yielded the Upper Coniacian inoceramid zonal index *Magadiceramus subquadratus.* The Santonian part of the unnamed interval is assumed to be an equivalent of the *Nowakites carezi* Zone and correlative of the higher part of that zone at Iturmendi. It corresponds to the lower part of the broad *Placenticeras polyopsis* Zone used elsewhere in Europe.

The inferred Middle Santonian *quinquenodosus* Zone is followed by an Upper Santonian *Jouaniceras hispanicum/ Scalarites cingulatum* Zone.

The local FAD of the *Texanites quinquenodosus – gallicus* group is far above the LAD of *Cl. undulatoplicatus* in the northern Spanish sections.

The FAD of the echinoid *Offaster nuciformis* in the Barranca lies in the Upper Coniacian, at Olazagutia probably within the *Magadiceramus subquadratus* inoceramid Zone. The LAD of the echinoid species is at the top of the Lower Santonian, i.e. at the top or above of the range of *Cl. undulatoplicatus* at Olazagutia, and lies in the lower part of the Middle Santonian *Texanites quinquenodosus* Zone at Zuazu.

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**Plate 1**

All figures of natural size. Ammonites are housed in the private collections of T. KÜCHLER (Bielefeld) and W. JUDENHAGEN (Wolfsburg). Photographs by T. KÜCHLER.

Fig. 1: *Nowakites carezi* (DE GROSSOUVRE) (It II-39.5). Iturmendi; probably upper Upper Coniacian *Nowakites carezi* Zone, Iturmendi II section, from a level between 42 and 43 m *sensu* ZANDER (1988). Coll. KÜCHLER.

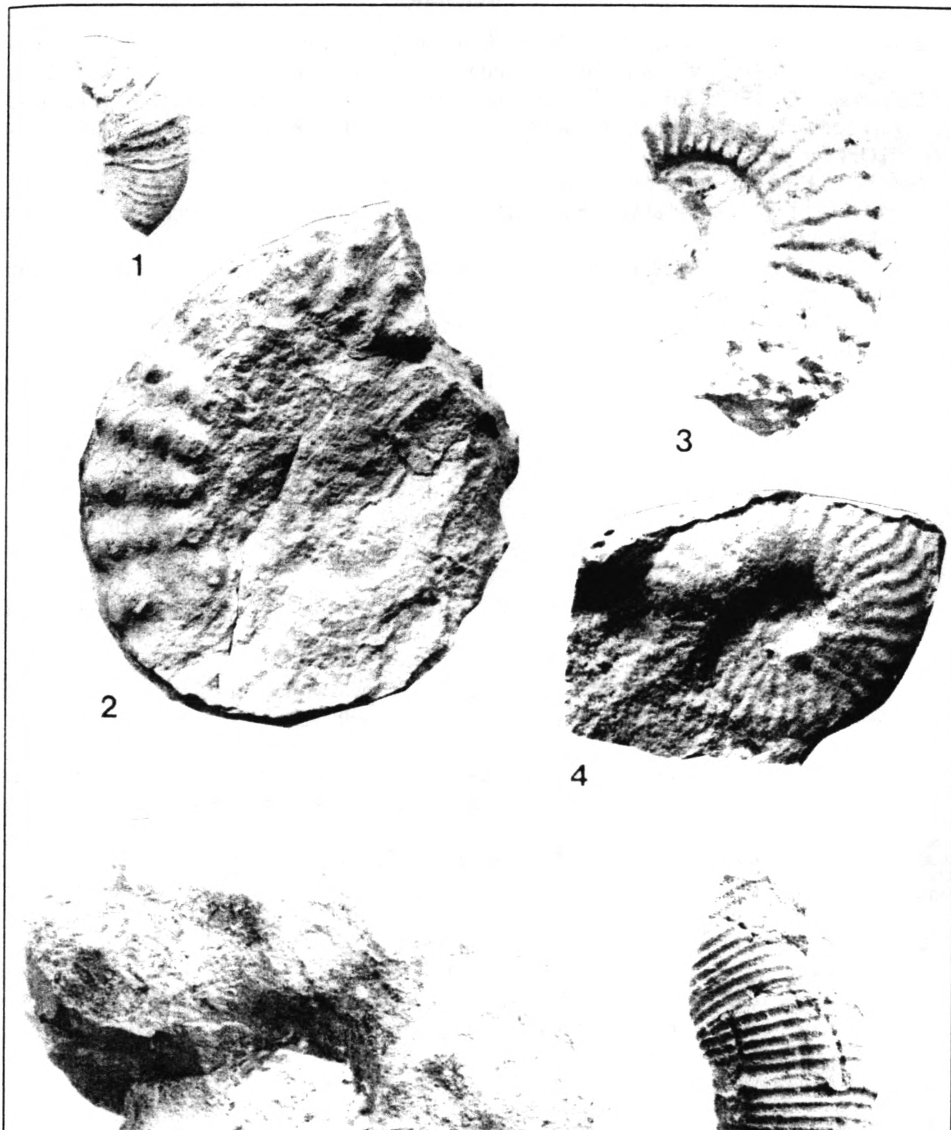
Fig. 2: *Texanites quinquenodosus* (REDTENBACHER) (unregistered). Olazagutia; Middle Santonian *Texanites quinquenodosus* Zone, west part of the quarry, from the talus between beds 58 to 60 (= -65 to -67 m) *sensu* KANNENBERG (1985). Coll. G. ERNST (15.4.84).

Fig. 3: *Texanites quinquenodosus* (REDTENBACHER) (ZuC-366). Zuazu, Middle Santonian, *Texanites quinquenodosus* Zone, level 161m. Coll. KÜCHLER.

Fig. 4: *Pseudoschloenbachia inconstans* (DE GROSSOUVRE) (plaster cast, unregistered). Olazagutia; Lower Santonian (unnamed ammonite interval; *Pl. cycloides* inoceramid Zone), 0.5 m above inoceramid and ammonite bed (= ? LB8) *sensu* KANNENBERG (1985). Coll. KÜCHLER.

Fig. 5: *Placenticeras polyopsis* (DUJARDIN) (unregistered). Olazagutia Quarry; Santonian, from the talus. Coll. W. JUDENHAGEN.

Fig. 6: *Neocrioceras (Schlueterella) compressum* KLINGER (unregistered). Olazagutia; west part of the quarry around the -100 m level (LC10?) *sensu* KANNENBERG (1985). Coll. KÜCHLER (3. 7. 97).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