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High Cretaceous biostratigraphy at Tercis, south-west France

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Abstract

The limestones in Tercis Quarry, Dax (Landes), south-west France expose high Upper Campanian and low Lower Maastrichtian in which ammonites occur and inoceramids and *Echinocorys* are common. The vertical ranges of these groups, combined with some evidence from other echinoids and the nannoplankton, provide correlations with the Biscay region, eastern England, north Germany and Poland. The appearance at Tercis of the much quoted Maastrichtian indices *Hoploscaphites constrictus* (J. SOWERBY) and *Pachydiscus neubergicus* (VON HAUER) is around the middle of the Lower Maastrichtian on the belemnite scale of northern Europe. The base of the Maastrichtian on the belemnite scale has not been fixed with precision in Tercis Quarry, but it must still be higher than the disappearance- level of *Globotruncanita calcarata* (CUSHMAN).

Key-words: Campanian, Maastrichtian, inoceramids, ammonites, *Echinocorys*, nannoplankton.

Résumé

Dans la carrière de Tercis, près de Dax (Landes, sud-ouest de la France), les calcaires du sommet du Campanien supérieur et de la base du Maastrichtien inférieur contiennent des ammonites; les inocérames et *Echinocorys* y sont fréquents.

L'extension verticale de ces groupes, appuyée par des observations concernant d'autres échinoïdes et le nannoplancton, permet des corrélations avec la Biscaye, l'est de l'Angleterre, l'Allemagne du nord et la Pologne.

A Tercis, les fossiles-guides maastrichtiens les plus cités, *Hoploscaphites constrictus* (J. SOWERBY) et *Pachydiscus neubergicus* (VON HAUER), apparaissent vers le milieu du Maastrichtien inférieur de l'échelle stratigraphique d'Europe du Nord, basée sur les bélemnites.

La base du Maastrichtien telle qu'elle est fixée sur cette même échelle n'a pu être tracée avec précision dans la carrière de Tercis. Elle doit se situer encore plus haut que le niveau où disparait *Globotruncanita calcarata* (CUSHMAN).

Mots-clefs: Campanien, Maastrichtien, inocérames, ammonites, *Echinocorys*, nannoplancton.

Introduction

The Campanian- Lower Maastrichtian limestones of Tercis contain a wider mixture of fossils for these stages than can be easily found anywhere else: ammonites, inoceramids, echinoids (particularly *Echinocorys*), planktic foraminifera and calcareous nannoplankton. For the most part, a direct stratigraphic comparison of these groups has not previously been found for these stages of the Cretaceous in a tethyan section - a section moreover that straddles the Campanian- Maastrichtian boundary in the boreal sense, and possibly in the tethyan sense. The principal limitation is that none of the fossils are well preserved.

Historical

The limestone-cliffs which form the banks of the River Adour some 7 km south-west of Dax (Landes) were probably known to the earliest geological explorers of the region. Charles LYELL, a foreigner, knew that "fossils of the chalk" could be found at Tercis (LYELL, 1838, p.340 and 479). By 1866, when the Geological Society of France organised an excursion to Tercis, the locality had already become one of the "top-spots" in south-west Aquitaine (POIGNANT, 1965).

As with so much of the geology of Aquitaine, the essence of the succession was worked out by ARNAUD. In a paper supposedly addressed to the stratigraphic position of the variegated clays in the core of the Tercis anticline (which he recognised were tectonically emplaced), ARNAUD (1886) described the whole Upper Cretaceous succession in relation to the quarries of the time. He found no evidence for any strata between the "Provencien" (= Turonian) and "middle" Campanian, and implied, without trying to explain, that the upper Turonien, the whole of the Coniacian, Santonian and lower Campanian were missing. For ARNAUD the lowest exposure in the upper part of the succession, the little quarry at Honterède, was already in the "Campanien moyen". He found that near the top of the succession of quarries on the east side of the river, the natural wall of La Grande Roque, running inland from the river, yielded Danian fossils. ARNAUD did not recognise the presence of either Dordonian or Maastrichtian: he regarded the Dordonian of COQUAND as a local facies of northern Aquitaine; ARNAUD's thick "Campanien,

zone supérieure'' embraced both Upper Campanian and Maastrichtian in the modern sense.

Subsequent work has only added a little stratigraphical detail to that of ARNAUD, and in some cases has actually introduced mistakes. Taxonomic studies of the ammonites by SEUNES (1890, 1892) and DE GROSSOUVRE (1901) and *Echinocorys* by ARNAUD (1902) and SEUNES (1890) produced surprisingly little improvement in correlation. Until our own work, nobody has tried to produce a measured section. The main reason for this lack of progress was that it was probably thought sufficient to record which quarry any specimen came from, and judging by museum labels, only ARNAUD thought it important to try to record specimens from subdivisions of ''La Grande Carrière'' or the ''Carrière d'Angoumé'', the only two exposures of any size.

A further problem for correlation with regions outside Aquitaine has been a lack of knowledge of the stratigraphical distribution in other regions of the groups of fossils found at Tercis. The inward looking approach is illustrated by the action of MUNIER-CHALMAS and DE LAPPARENT who created the Aturian stage, named after the River Adour, for a combination of Campanian and Maastrichtian marly limestones around the Bay of Biscay, and which probably included some or all of the ''Danian'' (DE LAPPARENT, 1893).

DAGUIN (1948, figs. 17-21) gave much the best account of the positions of named localities in and around Tercis. However, his Maastrichtian embraced the whole succession from the south side of Hontarède (Santonian?) northwards to La Pointe. Moreover, he regarded the Danian (as found in the higher quarries at Bédat) as Cretaceous. His faunal lists (1948, p.121) confuse Campanian and Maastrichtian, his ''Campanien'' fauna including typical Maastrichtian species, and vice versa.

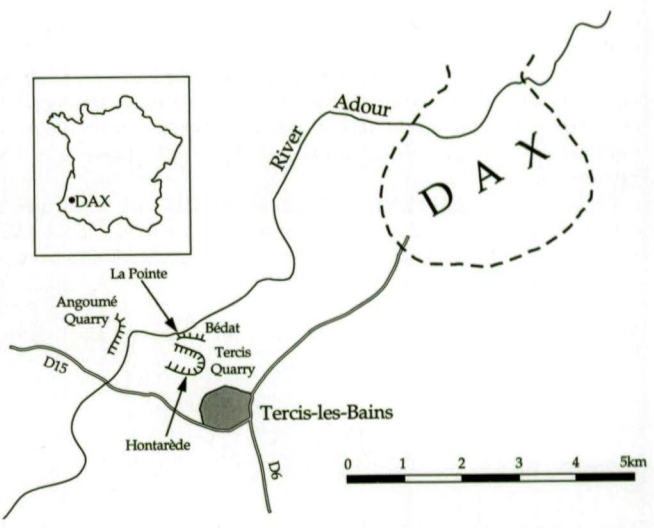
THIBAULT (1975) included a small geological map which shows the Campanian resting unconformably on Cenomanian on the north flank of the anticline. He gave only a general account of the succession, and although better than DAGUIN, still placed the base of the Maastrichtian too low in the succession.

KIEKEN (1975) assigned 100 m to the Upper Campanian on the west side of the River Adour. Above his Campanian, he recorded chalky limestones with flints and hard marls with limestone nodules. By implication he put these beds into the Maastrichtian and his faunal list is: *Globotruncana contusa* (abundant), *Glt. stuarti*, *Glt. falsostuarti*, *Glt. stuartiformis* and numerous *Lagena* (all identified by C. MONCIARDINI), plus macrofossils: *Bostrychoceras polyplocum*, *Hamites recticostatus*, *Scaphites constrictus*, *Baculites anceps*, *Parapachydiscus neubergicus* var. *jacquoti*, *P. fresvillensis*, *P.colligatus*, *Inoceramus* gr. *regularis*, *Echinocorys arnaudi*, etc. This list is interesting because it is Maastrichtian in the tethyan sense where the Campanian- Maastrichtian boundary has generally been defined on ranges of foraminifera (often by the disappearance of *Globotruncanita calcarata*). On the other hand, as we shall show subsequently, the ammonite assemblage quoted is a mixture of Maastrichtian species in a boreal sense (e.g. *S. constrictus*) with species which would be unmistakably Campanian in northern Europe, e.g. *B. polyplocum*.

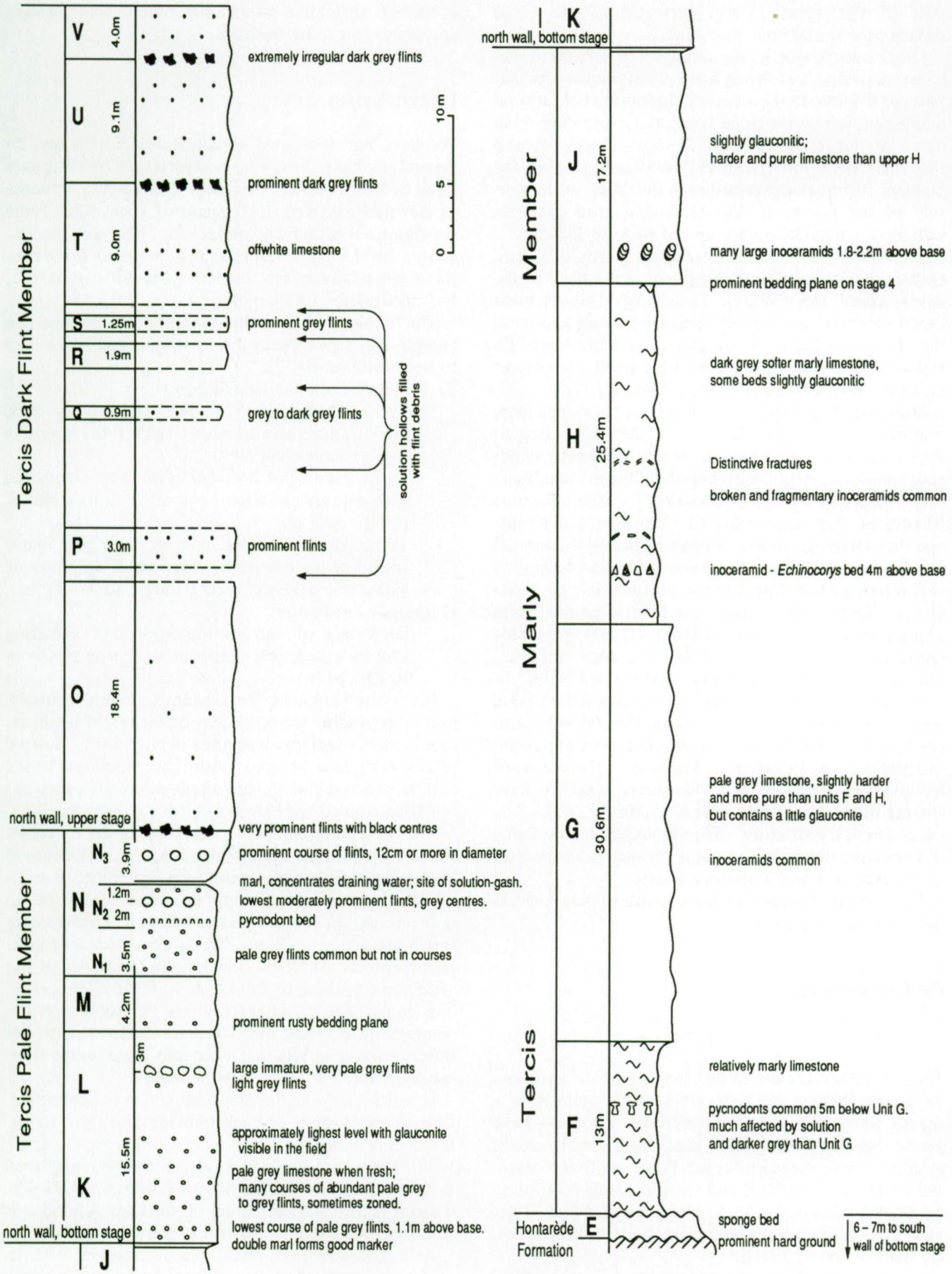
Named localities

The present quarry, some 1½ km north-west of the village of Tercis-les-Bains and 7 km west of Dax, was re-opened by the Usine d'Angoumé in 1968, and is here simply referred to as ''Tercis Quarry'' (Text-fig.1). Prior to 1968 there had been only limited quarrying this century on the east side of the River Adour, but there were a number of small workings, each with its own name. It can now be difficult to fix these, some being named after windmills which have since disappeared, some are now obliterated as separate entities by later quarrying, whilst several have been joined together. Even when DE GROSSOUVRE (1901) was writing there was disagreement between FALLOT and ARNAUD on what was meant by ''La carrière des Mottes''. Since there are museum labels with these old names, it is important to fix them as closely as possible. Good accounts of the relative positions of the localities were given by ARNAUD (1886) and DAGUIN (1948).

La Grande Carrière (= La Grande Carrière de Tercis = La Grande Carrière d'Avezac). The recent workings are an extension of this quarry. In its original sense (ARNAUD, 1886) this was in ''calcaire bleu, sans silex,.... quelques pyrites''. This corresponds to Units F to J of our section (Text-fig. 2); these units were regarded as Maastrichtian by DAGUIN. The base of Unit K still forms the north wall of the lowest stage of Tercis Quarry, and it is in Unit K that flints appear. More recent authors have included higher units with flints as



Text-fig. 1 — Sketch-map to show the position of Tercis Quarry and other localities mentioned in text.



Text-fig. 2 —Lithological succession of limestones in Tercis Quarry above Unit E, measured by JMH and Ray PARISH.

part of the same quarry, even before the Usine d'Angoumé re- started excavation.

On the north side of the Grande Carrière there was some quarrying but strong karstic solution means that parts of the limestone succession disappears beneath soil and vegetation on the slope facing the river, some 50 m north of the recent working. DAGUIN (1948) believed that these beds above Unit O had already reached the Danian. Although the exposure in the crags on the west side of the quarry is discontinuous, more complete sampling is possible higher up the slope to the east.

La Pointe and Falaise de Bédat. North of Tercis Quarry there are limestones exposed at the bend of the River Adour (La Pointe). These high Maastrichtian limestones form an impressive east-west wall known as the "Falaise de Bédat" in the dense woodland east of La Pointe. In the last century there were small quarries cut into the cliff at Bédat (DAGUIN, 1948, fig.17).

Hontarède (also known as Hentérade) is named after a spring at x = 159.00, y = 321.25. According to ARNAUD it exposed "calcaire blanc, dur, avec veines glauconieuses, irregulièrement distribuées: nombreux silex violacés, cariés, spongiaires". Mlle Suzanne BEYRIE of Dax, who collected from here many years ago, has kindly given us examples of the most common fossils: these are ribbed and smooth species of *Exogyra* in a lithology now found in the bottom beds of Tercis Quarry: La Grande Carrière and Hontarède now form a single quarry. According to KIEKEN (1975) Hontarède Quarry lay some 150 m south of "la grande carrière", but only 50 m south according to DAGUIN (1948).

Angoumé. On the west side of the River Adour there was a series of exposures beside the railway, also enlarged by a number of quarries. The most important of these was the "Carrière d'Angoumé", the source of many museum specimens. This quarry seems to have corresponded with La Grande Carrière de Tercis. The exposures lay behind the office-buildings of the Usine d'Angoumé; the present obvious big quarry to the west of the Adour is in Palaeogene beds.

The Carrière du Four à Chaux, south of Angoumé, is now difficult to place.

Geological setting

STRUCTURE

Tercis-les-Bains is close to the core of an E-W anticline. In Tercis Quarry the beds are sensibly vertical in a region where the Tertiary-Quaternary sediments have gentle dips. The recognition that this anomaly results from evaporite-diapirism in the Trias was first recognised by DALLONI (1931), and there is a full description by DUPOUY-CAMET (1952). The plug of Upper Trias near Tercis is shown in a section on the 1:50,000 geological map (KIEKEN, 1975).

The high dip allows one to examine a stratigraphical thickness of more than 200 m in the present quarry, but it makes it difficult to assign loose material and museum specimens to precise horizons.

LITHOSTRATIGRAPHY

We have not attempted a sedimentological study. In general the high Cretaceous is represented by decimetre thick beds of micritic limestones with varying amounts of clay and scattered small grains of glauconite. Trace fossils are not prominent but include *Thalassinoides* and a large tubed *Chondrites*. In spite of the small grain size, there are relatively few obvious coccoliths preserved, but calcispheres are abundant.

The lithology is somewhat monotonous, but one can recognise in a broad way a four-fold division from top to bottom (Text-fig. 2):

Tercis Formation, subdivided into:

Tercis Dark Flint Member: limestones with obvious dark grey to nearly black flints (Units O to V) - more than 60 m.

Tercis Pale Flint Member: pale grey limestones with pale grey to almost colourless flints (Units K to N) - 30.3 m.

Tercis Marly Member: pale to dark grey marly limestone to limestone, with small amounts of glauconite at some levels (Units F to J) - 86 m.

Hontarède Formation:

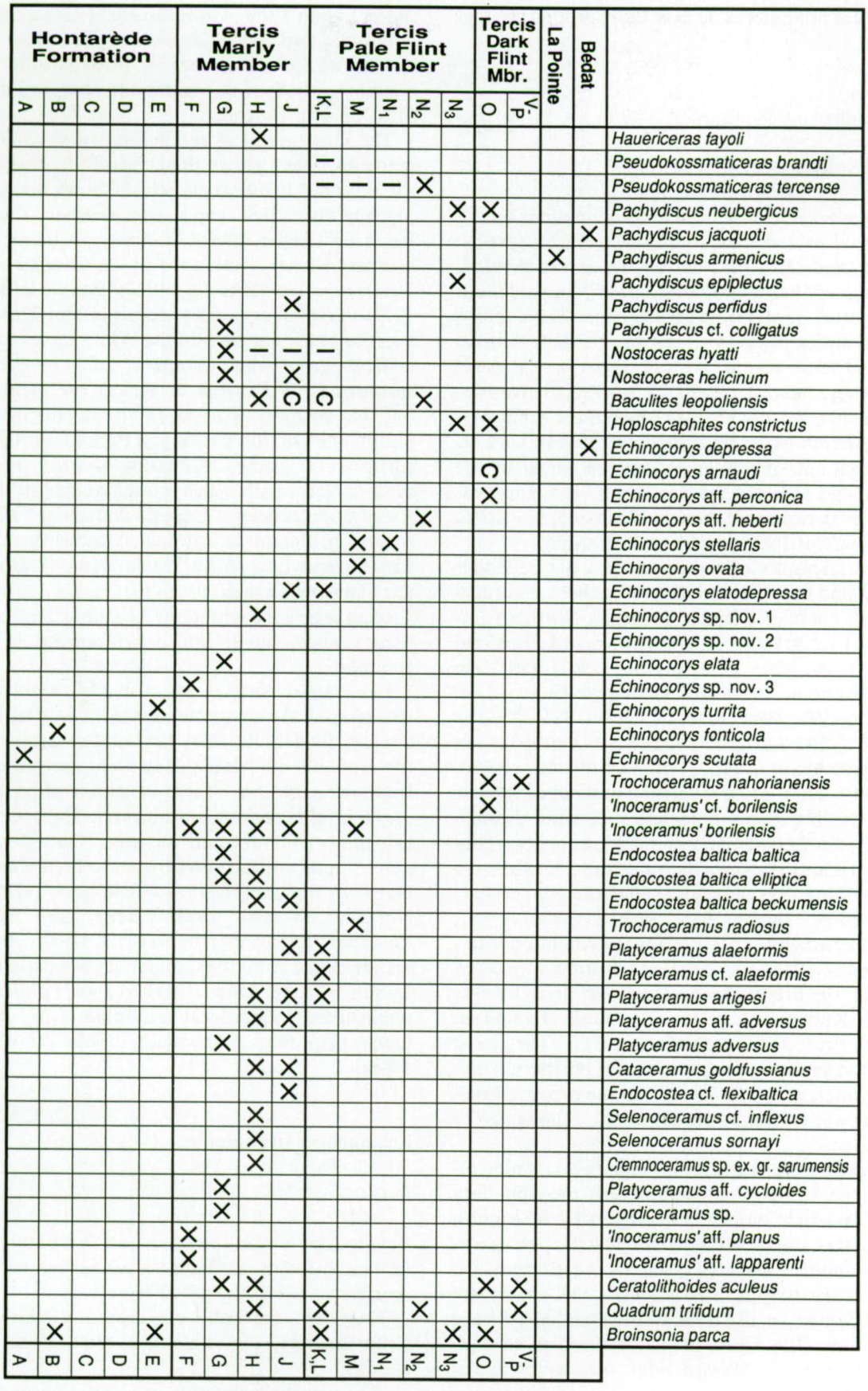
limestones of various lithologies but including slightly glauconitic, hard micro-sparite (Units A to E) - 30 m+

Below the Hontarède Formation, but with an uncertain relationship, are some tens of metres of a whiter, more chalky-looking limestone which forms karstic pillars. This is a bryozoan-rich, cavernous grainstone with occasional rudists and small echinoids. This has not been studied for this paper.

The succession matches neither those in the Pyrenees, further south in the Aquitaine basin, nor with those in Perigord and Saintonge in northern Aquitaine. In much of the Pyreneean trough the Campanian-Maastrichtian is an alternation of marls and turbidites in which macrofossils are scarce or absent. On the coast near Bayonne-Hendaye there are chalks (the Aturian facies) which also yield ammonites (see WARD & KENNEDY, in press), inoceramids and irregular echinoids, but not in numbers comparable to Tercis; many of these chalks are a quieter water facies, relatively rich in *Zoophycos* although some are interrupted by mass-flow deposits.

In northern Aquitaine the Campanian is either "tuffaceous" grainstone or packstone (as at Aubeterre-sur-Dronne) or a chalky, partly micritic limestone (PLATEL, 1989). The macro-fauna lacks all the main groups found at Tercis except as rarities (SÉRONIE-VIVIEN, 1972). The amount of true Maastrichtian in northern Aquitaine is still uncertain and comparison is therefore difficult.

As a generalisation, the Tercis Formation, with its recurrence of *Pycnodonte vesicularis* (LAMARCK), is a deeper water facies than those at outcrops in northern



Text-fig. 3 —Simplified distribution of fossils in Tercis Quarry and neighbouring localities. The records from La Pointe and Bédat are based on museum specimens; all other records are based on our own collecting.
c = common; x = occurs; | = probable occurrence.

Aquitaine, but not quite as deep as those around the Bay of Biscay.

Biostratigraphy

General background

For many years there have been diverse opinions on the stratigraphical age of the succession in Tercis quarry. When we started this work, our team was also divided. Everyone agreed that Unit O was Lower Maastrichtian. The ammonites (JMH and WJK) and *Echinocorys* (NBP) both indicated that the base of the Maastrichtian in the boreal sense was at or close to the base of Unit O. On the other hand, Units F to L seemed to give conflicting evidence, mainly because some of the echinoids, particularly *Echinocorys* from the lower part of Unit H, suggested that the quarry embraced the whole of the Campanian and much of the Santonian. This apparent conflict of evidence arose from considerable ignorance of the top part of the Campanian in Europe.

The biostratigraphy of the upper part of the Upper Campanian and basal Maastrichtian has been described on the north coast of County Antrim in Northern Ireland (Fletcher & Wood, 1978), in Norfolk, England (Peake & Hancock, 1970; Wood, 1967, 1988), in Schleswig-Holstein in north Germany (Schulz & Weitschat, 1975, 1981; Schulz, 1978, 1985; Schulz *et al.*, 1984; Schönfeld, 1990), and the central Vistula Valley (Pozaryski, 1960; Blaszkiewicz, 1980; Peryt, 1980). There are a surprising number of regions where one might expect a complete succession through the upper Upper Campanian into the Maastrichtian, but which, for various reasons, the succession is absent or incomplete: Limburg in Belgium and the Netherlands (Schmid, 1959; Jagt, 1988; Robaszynski *et al.*, 1985), southern Sweden, except for the Malmö borings (Christensen, 1984), Denmark at the surface (Floris *et al.*, 1971), the Braunschweig-Hannover area (Ernst, Schmid & Klischies, 1979), the Opole Trough in south-west Poland (Tarkowski, 1991). The most serious gap in available evidence is from northern Aquitaine where there is now evidence that the preserved succession may not extend to the top of the Campanian in the boreal sense.

In all these northern European regions the major divisions of the Upper Campanian, plus the boundary with the Maastrichtian, has been fixed by belemnites (Christensen, 1990). Although a few Upper Cretaceous belemnites have now been recorded from the French Pyrénées (Christensen *et al.*, 1990), they are uppermost Santonian and basal Campanian, and do not help our study. We know of no occurrences of high Campanian or lower Maastrichtian belemnites in the Pyreneean-Biscay region.

Ammonites are scarce or absent in most of the chalk-facies of northern Europe, and when they do occur it is generally only in a restricted part of the succession. Only in the Lublin Trough in south-east Poland can a proper ammonite succession be worked out (Blaszkiewicz, 1980), and fortunately can be fitted into the belemnite zonation. Much of our ammonite comparison of Tercis must be with Poland.

The most practical subdivision of the high Campanian and Maastrichtian in northern Europe should be by the echinoid *Echinocorys* which shows many stratigraphically distinctive shapes. For example, five subzones based on species of *Echinocorys* can be recognised in southern England within the Lower Campanian Zone of *Offaster pilula* (Gaster, 1937; Peake in Hancock, 1972). *Echinocorys* does occur in north Antrim but because of the hardness of the White Limestone they are difficult to extract complete, and the few species recorded by Fletcher & Wood (1978) include only one that we have found at Tercis. In Norfolk the upper part of the Beeston Chalk and Paramoudra Chalk have suffered periglacial shattering, thereby breaking up most larger fossils, such as echinoids. At Lägerdorf-Kronsmoor in north Germany undamaged *Echinocorys* is rare. In Poland it is notable that all the Campanian *Echinocorys* figured by Maczynska (1989) are from the Miechów Trough, north of Cracow, not the Lublin Trough where the ammonite-belemnite stratigraphy has been studied, but in which *Echinocorys* is much less common.

Inoceramid bivalves are also well known for their stratigraphical value, often spreading across the boreal-tethyan divide (Dhondt, 1983 and subsequent paper in this volume by AVD). However, inoceramids suffer from the same limitations of preservation as *Echinocorys* in the regions of northern Europe where the belemnite zonation can be used. Only fragments of inoceramids are recorded from the high Campanian in Northern Ireland (Fletcher & Wood, 1978) and from Norfolk (Wood, 1988); none are listed from Lägerdorf-Kronsmoor by Schulz (1978). Inoceramids are identified from the Campanian-Maastrichtian of the Lublin Trough (and elsewhere) in Poland, but the published stratigraphical resolution is too crude to be much help (e.g. Ciéslinski, 1966; Abdel-Gawad, 1986).

Echinocorys stratigraphy

Introduction

Echinocorys make up the second most common group of macro-fossils at Tercis after inoceramids. Several species were first described from here.

They are potentially of great stratigraphical value. Unfortunately, this statement requires some qualifications:

a) The literature abounds in specific misidentifications of this variable echinoid, arising from over-reliance on the general shape, without sufficient reference to other morphological features.

b) Many of the names are ancient, were never accompanied by a description in the modern sense, and no neotypes have been designated. Some of these species, e.g. *E. ovata* (LESKE), have had many interpretations.
c) Inflated forms become more inflated with ontogeny. Hence the ambitus becomes more rounded and the base less clearly defined. The *Echinocorys* assemblages at Tercis are broadly of large individuals, and hence show features of late ontogeny. Elsewhere it is known that there are also geographical variations in the shape and size of the pore-pairs but few of the specimens from Tercis are sufficiently well preserved to investigate this.
d) Some species occur in dimorphic pairs: one form has an essentially broad flat base, with a relatively sharp ambitus, and sides sloping fairly straightly upwards to the apical system, which itself is often prominent; an accompanying form with a more rounded and inflated test, having a gently curved ambitus, leading to the base being more retracted laterally and less flat. A good example of this is provided by *E. depressula* GRIFFITH & BRYDONE and *E. tectiformis* BRYDONE. Study of the material collected by GASTER (1937) from Sussex shows that he mis-identified as *E. depressula* flat-based, angular specimens which BRYDONE had named *E. tectiformis* in Hampshire. Both perfectly identifiable "species" do occur in both counties, where they have identical vertical ranges: more rounded *E. depressula* predominate in the softer chalks of Hampshire, whilst the angular *E. tectiformis* is dominant in the chalk of Sussex, with its repeated hardgrounds, and where true *E. depressula* is relatively uncommon. The two are conspecific, notwithstanding their strikingly dissimilar shapes, but their other morphological features remain identical.

An example of this phenomenon is shown by *Echinocorys elatodepressa* (GRATELOUP) (q.v.)
e) There are homeomorphs in general shape of the test at widely separated stratigraphical levels. This has caused great confusion in the literature, e.g. ROWE (1900) identified a tall form from the Upper Santonian of Kent, England, as *Echinocorys pyramidata* (PORTLOCK) which is actually a top Campanian species.

In spite of these difficulties and variable parameters, one can trace continuous (though non-linear) evolutionary changes in *Echinocorys*. The characteristic shape of one horizon is probably never exactly mimicked at any other horizon. The extreme forms, e.g. *Echinocorys turrita* LAMBERT, are very useful and reliable stratigraphic markers, but at other times the mimicry is harder to recognise without detailed study of the apical system, which is not always possible in specimens from Tercis because of poor preservation.

In the absence of any monograph that distinguishes chrono- species, taxonomy becomes somewhat arbitrary, even after allowance has been made for ecologically-controlled shape-variations. We have had to select, within the rules of priority, names of those figured species which seem to fit most closely the forms we describe, irrespective of the stratigraphic attributions (sometimes suspect) by the quoted author.

SYSTEMATIC PALAEONTOLOGY

Echinocorys depressa (EICHWALD, 1860)

1979 *Echinocorys depressus* (Eichwald) - GONGADZE, p.90, pl.20, fig. 1a-d.

Amongst the echinoids from the ARNAUD collection in the Université Pierre et Marie-Curie, Paris, is a specimen labelled "*Echinocorys semiglobus*, Garumnien, Tercis, Bédat". This is a typical *E. depressa* (EICHWALD) as found in the Danian elsewhere in Europe, but larger. There are at least four other specimens labelled "*Echinocorys semiglobus*" in the same museum from Bédat, confirming that the succession at Bédat extends into the Palaeocene.

Echinocorys arnaudi SEUNES, 1888

*1888 *Echinocorys Arnaudi* SEUNES p.813, pl.31, fig.1a-d.
1898 *Echinocorys vulgaris* var. *Ciplyensis* LAMBERT, p.182, pl.5, figs. 15-16.
1959 *Echinocorys ciplyensis* Lambert - POSLAVSKAIA & MOSKVIN, p.259, pl.9, fig. 2a-b.
1988 *Echinocorys arnaudi* Seunes - ALIEV, p.193, pl. 3b, fig. 3a,b; pl.4a, fig. 1a,b.

DISCUSSION
The original description by ARNAUD is unsatisfactory. The species has a distinctive side-profile: markedly lower than long, rounded in front but the rear forms a roughly 45 degree slope so that the apical system is distinctly anterior (SEUNES' upper view on pl.31, fig.1a has been oriented to obscure the ex-central position of the apical system). The base is flat. One of the smaller species of *Echinocorys* at Tercis.

OCCURRENCE
Common in the bottom third of Unit O. At Trimingham, Norfolk, occurs in the White Chalk with *Ostrea lunata* (PEAKE & HANCOCK, 1970, fig. 7), between beds B and E which lie in the Zone of *Belemnella sumensis* of the Lower Maastrichtian.

Echinocorys aff. *perconica* (VON HAGENOW sensu LAMBERT, 1903)

1903 *Echinocorys perconicus* Hagenow - LAMBERT, p.83, pl. 6, fig.10.
?1959 *Echinocorys renngarteni* POSLAVSKAIA & MOSKVIN, p.260, pl.10, fig. 2a,b.
non 1959 *Echinocorys perconicus* Hagenow - POSLAVSKAIA & MOSKVIN, p.260, pl.9, fig. 3a,b; pl.10, fig.1.

DISCUSSION
This form is close to *E. arnaudi* SEUNES, and interme-

diates between the two species occur in the lower part of Unit O at Tercis, but it differs from *E. arnaudi* itself in having a more central apical system, and having a smaller length: height ratio (although it is still longer than high). The projecting apical system shown in LAMBERT's specimen (1903, pl.6, fig.10) is not always present.

OCCURRENCE
Lower part of Unit O in Tercis Quarry.

Echinocorys aff. *heberti* SEUNES 1890

*1890 *Echinocorys Heberti* SEUNES, p.26, pl.3, fig.3; pl.4, fig.2.
?non 1902 *Echinocorys Heberti* Seunes - ARNAUD, p.92.

DISCUSSION
This very tall form, sometimes growing to a great size, is typically nearly symmetrical from front to back in side-view, although there is some variation in detail in this symmetry. The prominent slightly raised apical system is not shown in the figure by SEUNES (1890, pl.4, fig.2).
Typical specimens from Norfolk, England, are even bigger.

OCCURRENCE
Unit N2 in Tercis Quarry. According to SEUNES this species occurs with *Micraster aturicus* HÉBERT at Tercis and Angoumé. ARNAUD (1902, p.32) records it from the lowest hard limestones above the marls above Hontarède, which would place it around Unit J in Tercis Quarry. At Sidestrand, Norfolk, it occurs in the upper part of the Porosphaera Beds and lower part of the Sponge Beds, i.e. Zone of *Belemnella obtusa*. Recorded by GALLEMI (1982) from Catalonia and KÜCHLER & KUTZ (1989) from Navarra from the Lower Maastrichtian.

Echinocorys stellaris LAMBERT, 1903

?1902 *Echinocorys pyramidalis* ARNAUD, p.36.
*1903 *Echinocorys cotteaui* var. *stellaris* LAMBERT, p.86, pl.5, fig.8

DISCUSSION
This small form may be no more than a juvenile form of *E. heberti* SEUNES but it has a relatively short apical system. LAMBERT's specimen came from Tercis.

OCCURRENCE
Units M and N1 in Tercis Quarry. Porosphaera Beds, Sidestrand, Norfolk (= Zone of *Belemnella obtusa* in the Lower Maastrichtian).

Echinocorys ovata (LESKE, 1778)

non 1903 *Echinocorys ovatus* Leske, 1778 - LAMBERT, p.69, pl.4, figs.6, 7; pl. 5, figs.1,2.
1979 *Echinocorys ovatus* Leske, 1778, - GONGADZE, p.76, pl. 7, figs.1a-f.

DISCUSSION
Echinocorys ovata has been often quoted and usually misinterpreted. GONGADZE's figures are excellent. The base is flat and nearly as broad as the whole test, i.e. there is little or no retraction of the base, and these features are maintained into more adult specimens 90 mm long. Little or no elongation of the test.

OCCURRENCE
Upper part of Unit M at Tercis Quarry. In Norfolk, England, this species has so far only been found loose on the shore between Cromer Lighthouse and Overstrand, i.e. they could be top Campanian or basal Maastrichtian on the belemnite standard.

Echinocorys elatodepressa (GRATELOUP, 1836)

*1836 *Ananchytes conoidea* var. *elato-depressa* GRATELOUP, p.63, pl. 2, fig.8.
1902 *Echinocorys fere scutatus* ARNAUD, p.34, pl.5; pl. 6, lower figure.
1902 *Echinocorys elato-depressus* var. *depressus* ARNAUD, pl. 6, upper figure; pl. 7.
non 1902 *Echinocorys elato-depressus* var. *elatus* ARNAUD, pl. 8, pl. 9.

DISCUSSION
This species illustrates the dimorphism referred to in the introduction, where squat and relatively tall forms occur alongside one another. GRATELOUP's curious trivial name suggests that he had already recognised this, as does ARNAUD's creation of two varietal names. Actually, ARNAUD's var. *elata* is a different species which occurs distinctly lower in Tercis Quarry. In contrast, GRATELOUP's figure (pl. 2, fig.8) illustrates well the tall form; GRATELOUP's specimen probably came from Tercis.

The lower form, not actually squat in this species, is the more common at Tercis. In side-view, the anterior slope is vertical or nearly so. The base may be retracted, i.e. appreciably narrower than the total width of the inflated test. In the conical form the height is much greater than the width. Both varieties show the apical system to be central in lateral view, except in ARNAUD's variety *E. ferescutata*. The superficial similarity to *E. heberti* SEUNES suggests that this form is the one that ARNAUD identified with SEUNES' species.

OCCURRENCE
Units J and K in Tercis Quarry. Not known from else-

where and hence its horizon in northern Europe is unknown.

Echinocorys sp.nov. 1

1843 *Ananchytes conoideus* Goldfuss - PORTLOCK, p.354, pl. 18, fig. 1a,b.
1903 *Echinocorys ovatus* Leske, forme haute - LAMBERT, p. 69, pl. 4, figs.6, 7 only.
1935 *Echinocorys subglobosus* var. *fonticola* Arnaud - SMISER, p. 19 pars, fig.4d (p.18).

DISCUSSION
With only one specimen of this form, it is impossible to give satisfactory distinctions, but in side-profile there is a sudden kink in the front-slope about one third of the height above the base, well seen in LAMBERT's figures (1903, pl. 4, fig.6).

OCCURRENCE
Top part of Unit H at Tercis Quarry. The specimen of Portlock came from the White Limestone at Larne in County Antrim or Dungiven in County Derry of Northern Ireland; in either place it was probably from the Zone of *Belemnitella langei* as used in the British Isles. The Belgian specimens are said to be from the Craie d'Obourg at Harmignies; our own collecting at Harmignies shows that there is a great stratigraphical thickness exposed there and it is more likely that they came from the Craie de Nouvelles.

Echinocorys sp. nov. 2

1843 *Ananchytes ovatus* Lamarck - PORTLOCK, p. 354, pl. 8, fig.2a,b.
?1903 *Echinocorys pyramidatus* Portlock - LAMBERT, p. 71, pl. 4, figs.4, 5.
1970 *Echincorys* aff. *conoidea* Goldfuss - PEAKE & HANCOCK, p.318.

DISCUSSION
This form shows some affinity to *Echinocorys marginata* (GOLDFUSS, 1826) but is distinguished by its elongated apical system which is distinctly anterior even in more rounded specimens. This species is a homeomorph of *Echinocorys elevata* BRYDONE, 1912 (p.109, pl.1, fig.2) which led us to believe at first that the lower part of Unit H was Upper Santonian. The Tercis species differs from the true *E. elevata* in having a less elongated apical system (exceptionally long in *E. elevata*) and has a broader base.

OCCURRENCE
Common in Unit H at Tercis Quarry, particularly in the inoceramid-*Echinocorys* bed, 4 m above the base. PORTLOCK recorded his specimen from the lower part of the White Limestone in County Derry, i.e. lower part of the Zone of *Belemnitella langei*. In Norfolk this species is very characteristic of the middle part of the Beeston Chalk (in the *Echinocorys* Band about 8-9 m above the base of the Beeston Chalk at Caistor St. Edmunds Pit, Norwich), i.e. low in the Zone of *Belemnitella langei* in the British sense.

It is probably the species recorded by FLETCHER & WOOD (1978 p.100) from the topmost metre of Portrush Chalk A.

Echinocorys elata ARNAUD, 1902

*1902 *Echinocorys elatodepressus* var. *elatus* ARNAUD, pls. 8 and 9.
1979 *Echinocorys elatus* Arnaud - GONGADZE, p. 79, pl. 10, fig.1a-e.

DISCUSSION
ARNAUD considered his specimen to be the tall variety of GRATELOUP's species, but the latter is distinctly conical. *E. elata* has rounded, inflated sides, with a smaller height: diameter ratio.

OCCURRENCE
Top part of Unit G at Tercis Quarry. There is a similar but much larger individual preserved as an internal mould in flint in the collections of the University of Copenhagen, labelled "Møn" but which probably came from Hvide Klint. No examples have been found in the British Isles.

Echinocorys sp. nov. 3

DISCUSSION
The nearest described species is *Echinocorys edhemi* BÖHM (1927, p.193, pl. 12, figs.1, 1a) from which it differs in being slightly elongated; and having a more symmetrical, almost semi-circular side profile, although it is nearly vertical in the front for about one third of its height. The form figured by GONGADZE (1979, pl. 19, figs.1a-e) as *E. edhemi* is close but this also has a more rounded base than the Tercis form.

OCCURRENCE
Bottom half metre of Unit F at Tercis Quarry. A similar form has been found at Catton Pit, Norwich, somewhere close to the Catton Sponge Bed, i.e. from near the summit of the Weybourne Chalk or the very base of the Beeston Chalk.

Echinocorys turrita LAMBERT, 1903

*1903 *Echinocorys gibbus* var. *turrita* LAMBERT, p.60.
1959 *Echinocorys turritus* Lambert, 1903 - POSLAVSKAIA & MOSKVIN, p.257, pl. 7, fig.1a, b.

DISCUSSION

This species is very tall relative to the transverse diameter of the base (1.21 to 1.24) for a non-conical form. In side- profile the front is steep to nearly vertical for more than half the height; the back starts to slope forward about one quarter of the way up the side. The specimen figured by POSLAVSKAIA & MOSKVIN is a typical example.

OCCURRENCE

Unit E at Tercis Quarry. In southern England (Hampshire and West Sussex) this species is characteristic of the top part of the Zone of *Gonioteuthis quadrata* (i.e. the Subzone of *Gonioteuthis quadrata gracilis),* immediately below the beds with *Echinocorys conica fastigata* LAMBERT.

Echinocorys fonticola ARNAUD, 1902

*1902 *Echinocorys fonticola* ARNAUD, p. 31, pls. 2, 3, 4.

1903 *Echinocorys fonticola* Arnaud, LAMBERT, p. 63, pl. 3, figs.3, 4.

DISCUSSION

This large inflated, depressed and very rounded form has a short apical system. It is not likely to be confused with any other species.

OCCURRENCE

Collected loose in Tercis Quarry but apparently from the rusty glauconitic limestone of Unit B, around 5 m below the base of Unit E, and below the prominent double band of pale grey to grey carious flints. ARNAUD mentions several occurrences from northern Aquitaine, but otherwise it is unrecorded outside south-west France. A closely similar form occurs at the base of the Hagenowia Horizon in the bottom of the Zone of *Gonioteuthis quadrata* in southern England.

Echinocorys scutata LESKE, 1778

1970 *Echinocorys scutata* Leske - PEAKE & MELVILLE, p. 57, pls. 1, 2.

DISCUSSION

Echinocorys scutata, the type species of the genus, has a long and complicated bibliographical history, but is best interpreted by the neotype designated by PEAKE & MELVILLE (1970): British Museum (Natural History) E. 8721. It is a form only slightly taller and less inflated than *E. fonticola* ARNAUD, and therefore has a more clearly defined base. The side-profile is rather evenly round with a central apical system, so that the front and rear slopes are almost symmetrical. Specimens from Tercis are slightly taller than *E. scutata* s.s. and are thus transitional to *Echinocorys scutata striata* LAMBERT (1903, pl. 2, fig. 1).

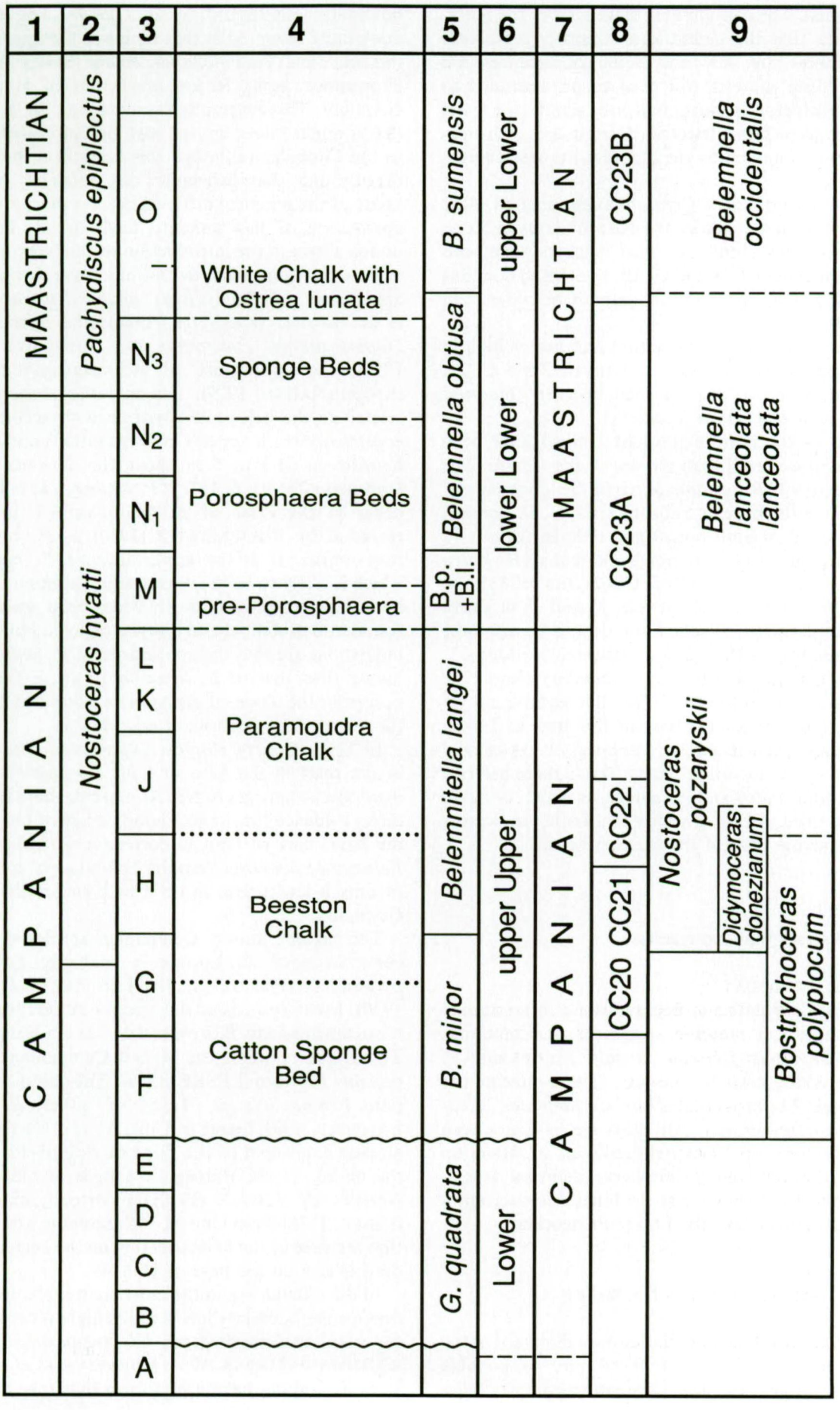
OCCURRENCE

Several specimens from Unit A in Tercis Quarry, i.e. from the lower part of the old Hontarède Quarry with a whiter, less glauconitic limestone, around 15 to 28 m below Unit E. *Echinocorys scutata* s.s. comes from the upper part of the Zone of *Micraster coranguinum* in southern England, i.e. upper part of the Lower Santonian. *E. scutata striata* comes from the middle Santonian Zone of *Uintacrinus socialis*. The Tercis specimens would appear to be forms which are found close to the junction of the *coranguinum* and *socialis* Zones. Quite apart from the fact that many British authors lazily refer every *Echincorys* to *E. scutata*, there are numerous records with this name from elsewhere in Europe which also belong to other species.

Nannofossil stratigraphy

Work on the nannofossil biostratigraphy is still in progress and to date only 29 samples have been processed

Text-fig. 4 —Sub-division and correlation of the succession in Tercis Quarry.
Column 1. Position of the Campanian- Maastrichtian boundary placed at lowest level of unequivocal Maastrichtian ammonites in Tercis Quarry.
Column 2. Ammonite assemblage-zones in Tercis Quarry; note that *Nostoceras hyatti* itself has not been found in Units M or N.
Column 3. Succession of units in Tercis Quarry (see Text-fig.2). Thicknesses not to scale; note particularly an exaggerated thickness for Units M and N.
Column 4. Succession in Norfolk, England, as used by PEAKE & HANCOCK (1970) correlated with Tercis Quarry by *Echinocorys*.
Column 5. Belemnite zonation as used in England.
Columns 6, 7. Stage and sub-stage boundaries as used in north Germany. The base of the Campanian is taken down to include part of Unit A on nannoplankton evidence.
Column 8. Nannoplankton zonation in tethyan regions, but the base of Zone CC23B (on the disappearance-level of *Broinsonia parca*) is placed near the top of the Zone of *Belemnella obtusa* from evidence from Kronsmoor.
Column 9. Ammonite zonation in Poland by BLASZKIEWICZ (1980) but modified by evidence from Tercis Quarry.


1
2
3
4
5
6
7
8
9
MAASTRICHTIAN
CAMPANIAN
Pachydiscus epiplectus
Nostoceras hyatti
O
N3
N2
N1
M
L
K
J
H
G
F
E
D
C
B
A
White Chalk with Ostrea lunata
Sponge Beds
Porosphaera Beds
pre-Porosphaera
Paramoudra Chalk
Beeston Chalk
Catton Sponge Bed
B. sumensis
Belemnella obtusa
Belemnella lanceolata
B.p. +B.l.
Belemnitella langei
B. minor
G. quadrata
upper Lower
lower Lower
upper Upper
Lower
MAASTRICHTIAN
CAMPANIAN
CC23B
CC23A
CC22
CC21
CC20
Belemnella occidentalis
Belemnella lanceolata lanceolata
Nostoceras pozaryskii
Didymoceras donezianum
Bostrychoceras polyplocum

and examined. The considerable diagenesis of the limestones means that the nannoflora is poorly preserved. The diversities are low and some occurrences are sporadic. More samples will need to be examined to obtain a satisfactory picture, but three significant zonal boundaries have been detected. Correlation with northern Europe is limited by the fact that the assemblages are tethyan.

The first occurrence of *Ceratolithoides aculeus*, near the base of Unit G, marks the base of tethyan Zone CC20. Below this event, no zonal markers have been detected for Zones CC18 and CC19, but Unit B contains *Broinsonia parca*, and therefore cannot be older than Zone CC18.

The first occurrence of *Quadrum trifidum* is high in Unit H and marks the base of tethyan Zone CC22. CC21 cannot yet be distinguished because *Quadrum sissinghi* has not yet been found.

Unit N2 to the bottom third of Unit O have been sampled in more detail than the rest of the section. The last occurrence of *Broinsonia parca* in the lower part of Unit O marks the base of Subzone CC23B. *B. parca* is a species found in both boreal and tethyan realms. In the Kronsmoor section in north Germany, *B. parca* ranges up to chalk between Beds Gb621 and mB623 (see SCHULZ, 1978, fig. 2), i.e. between 25 and 28 m above the appearance of *Belemnella lanceolata* at Kronsmoor, and near the top of the Zone of *Belemnella obtusa*.

The Campanian-Maastrichtian boundary should lie within nannofossil Subzone CC23A, but we have not yet been able to demarcate the base of this zone at Tercis.

The highest occurrences of *Nannoconus* are usually still within the Campanian but at Tercis there are two taxa, *N. truitti truitti* and *N. elongatus* which occur in the bottom third of Unit O which on all other indicators is well above the base of the Maastrichtian.

Integrated stratigraphical results

LA POINTE AND BÉDAT

The cliffs at La Pointe and Bédat have not been studied for this paper but museum specimens of ammonites include *Pachydiscus jacquoti jacquoti* SEUNES and *P. armenicus* ATABEKIAN & AKOPIAN. These indicate the lower Upper Maastrichtian Zone of *Menuites* [*Anapachydiscus*] *fresvillensis*. Although we have not seen evidence for the top Maastrichtian Zone of *Menuites terminus*, the echinoid *Echinocorys depressa* (EICHWALD) from Bédat shows that the limestone succession at Tercis continues into the Lower Palaeocene.

CAMPANIAN-MAASTRICHTIAN BOUNDARY

When Cretaceous stage boundaries were discussed at the Copenhagen meeting in 1983, there were six possible markers suggested for the Campanian-Maastrichtian boundary (BIRKELUND *et al.*, 1984). The definition marginally favoured at that time was the appearance of the belemnite *Belemnella lanceolata* (SCHLOTHEIM), at Kronsmoor, some 50 km north-west of Hamburg in Germany. This belemnite standard has the advantages that it might be recognised with precision from Ireland to the Caucasus (although this has still to be tested in detail), and that belemnites are relatively common. Some of the practical difficulties for a more widespread application of this standard have already been mentioned above in the introduction to the biostratigraphy.

Possible ammonite definitions have included: the appearance of *Pachydiscus neubergicus neubergicus* (VON HAUER) (KENNEDY, 1984); the appearance of *Hoploscaphites constrictus* (J. SOWERBY) (VOIGT, 1956); the appearance of *Acanthoscaphites tridens* (KNER) (NAIDIN, 1979). The only one of these directly related to the belemnite zonation with accuracy is *H. constrictus* which appears between mB603 and mB605 at Kronsmoor, 3.5 to 5 m above the appearance of *B. lanceolata* (SCHULZ, 1978). *P. neubergicus* is known to occur in the Zone of *B. lanceolata* s.l. in Poland, recorded by BLASZKIEWICZ (1980) as *P. neubergicus raricostatus*. It is the appearance of *P. neubergicus* which is likely to be the most useful ammonite-standard because it is a geographically widespread species, being found in both boreal and tethyan regions. However, the indications are that the appearance of *P. neubergicus* is higher than that of *B. lanceolata* s.s.: in Germany it occurs in the Zone of *Belemnella obtusa* at Lüneburg (SCHMID, 1955; SCHULZ *et al.*, 1984).

In Tercis Quarry *Hoploscaphites constrictus* appears in the marl at the base of Unit N3 and *Pachydiscus neubergicus* appears in N3. At present, there is no other direct evidence for the stratigraphic age of Unit N3, but the basal part of Unit O correlates with the Zone of *Belemnella sumensis* from the *Echinocorys*, a difference of only a few metres in the Chalk succession in north Germany.

The highest known Campanian species of *Echinocorys* in northern Europe is probably *Echinocorys pyramidata* (PORTLOCK, 1843) (PEAKE & HANCOCK, 1970). Many records of this species in the literature are misidentifications. *E. pyramidata* has not been found in Tercis Quarry where the highest Campanian species is possibly *E. ovata* (LESKE, 1778). The oldest Maastrichtian *Echinocorys* at Tercis is either *E. stellaris* LAMBERT, 1903 found in Units M and N1 (but this is already equivalent to the Zone of *Belemnella obtusa* if the dating of the Porosphaera Beds at Sidestrand in Norfolk by SCHULZ (1979) is correct), or *E. ovata* (LESKE, 1778) from Unit M. At present it would appear that the base of the Maastrichtian on the belemnite standard is around the base of Unit M.

In the tethyan realm the most commonly used definition for the boundary has been the highest occurrence of the planktic foraminiferan *Globotruncanita calcarata* (CUSHMAN) (MARKS, 1984; ROBASZYNSKI *et al.*, 1984). Various authors have now shown that this standard is

older than the belemnite and ammonite standards, e.g. SALAJ & WIEDMANN (1989) from a study of the El Kef section in Tunisia; SCHÖNFELD & BURNETT (1991) from a comparison of the benthic foraminifera and nannoplankton in north Germany and DSDP cores; HANCOCK *et al.*, (1992) by eustatic sea-level correlation between Mississippi and north Germany; BURNETT *et al.* (1992) from multiple arguments. The disappearance-level of *G. calcarata* in Tercis Quarry should occur above Unit H and well below Unit M, probably around the top of Unit J or low in Unit K, if the correlation between Mississippi and north-west Europe by HANCOCK *et al.* (1992) is correct.

THE LOWER PART OF THE TERCIS MARLY MEMBER AND THE BASE OF THE ZONE OF *NOSTOCERAS HYATTI*

The occurrence of *Nostoceras hyatti* STEPHENSON and *N. helicinum* (SHUMARD) in the top quarter of Unit G shows that the *hyatti* Zone extends as low as this in Tercis Quarry. We have found no ammonites in Unit F or the lower three-quarters of Unit G.

The occurrence of *Echinocorys* sp. nov. 2 low in Unit H shows that the *hyatti* Zone should extend down to the lower half of the Beeston Chalk, that is to the base or very low in the Zone of *Belemnitella langei* as used in the British Isles. This British horizon correlates on fossil content with somewhere in the middle of the Zone of *Nostoceras* [*Bostrychoceras*] *polyplocum* as used at Lägerdorf-Kronsmoor in Germany, and around the base of the Zone of *Belemnitella langei* as used in Poland, i.e. the base of the ammonite Zone of *Didymoceras donezianum* as used by BLASZKIEWICZ (1980).

This correlation, involving several geographic steps, must be somewhat tentative, but there are some direct ammonite indications that the *hyatti* Zone at Tercis extends much lower than the *hyatti* Zone in Poland, at least to the base of the *D. donezianum* Zone as shown by BLASZKIEWICZ, 1980 in his Table 1. The following Polish pre-*hyatti* Zone forms occur at Tercis: *Didymoceras* cf. *secoense* YOUNG (see subsequent paper by JMH & WJK) in the Université Pierre et Marie-Curie and Bruno CAHUZAC collections; *Didymoceras varium* BLASZKIEWICZ is the commonest species of *Didymoceras* in the CAHUZAC collection (although some of these might have come from the lower part of the Tercis Marly Member), a species of the *polyplocum* Zone in Poland. In addition, *Pachydiscus* cf. *colligatus* from the top quarter of Unit G is a form more typical of the *polyplocum* Zone.

There would seem to be some doubt if the Zone of *Didymoceras donezianum* can be distinguished at present anywhere outside Poland.

UNITS F AND LOWER THREE QUARTERS OF UNIT G

The common fossils in these units are bivalves and irregular echinoids other than *Echinocorys*. From the lower half of Unit G we have obtained: *Cyclaster munieri* (SEUNES, 1888, pl.28, figs. 4a-c), *Cardiaster integer* (AGASSIZ) and *Micraster* ex. gr. *M. mengaudi* (LAMBERT). The records of RADIG (1973) from the Basque Basin would date this assemblage as Upper Santonian (but RADIG would date *Micraster corcolumbarium* DESOR as top Santonian - Lower Campanian, whereas we have found this species in Unit H; STOKES (1975) and GALLEMI (1982) date this species as definitely Upper Campanian). The inoceramids and nannoplankton indicate Campanian, and Upper Campanian rather than Lower. The base of Zone CC20 is no higher than the bottom few metres of Unit G, which must be at least mid-Campanian (PERCH-NIELSEN, 1979). The solitary identifiable *Echinocorys* from the base of Unit F would be around the top of the Zone of *Belemnitella minor* (mid Upper Campanian) as used in Norfolk.

BELOW UNIT F - THE HONTAREDE FORMATION

Below Unit F are some 30 m of hard limestones characterised by their obvious glauconite but low mud-content. Even a standard lithological log is difficult to construct because of probable strike-faulting. There are also signs of stratigraphical condensation, such as echinoids heavily encrusted with epifauna and possible hardgrounds. Interpretation is made difficult by extensive recent solution along bedding planes and/or fault planes. It is certain that the total stratigraphical range is considerable for Unit E, containing *Echinocorys turrita*, is possibly top Lower Campanian, whilst the basal part of this succession, with *Echinocorys scutata* s.s., is believed to be Lower Santonian.

The karstic limestone further south has not been studied but contains *Periaster elatus* (DES MOULINS) which is generally regarded as Cenomanian.

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In this paper the work on bivalves has been by AVD, on the ammonites by WJK & JMH, on *Echinocorys* by NBP, on other echinoids by RBS, on nannoplankton by JB. The data have been integrated and the paper written by JMH.

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