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The "Boreal" Early Cretaceous (Pre-Aptian) ammonite sequences of Nw Europe and their correlation with the western Mediterranean faunas

Le successioni ad ammoniti "Boreali" del Cretaceo inferiore (Pre-Aptiano) dell'Europa Nord Occidentale e loro correlazione con le faune mediterranee occidentali

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343: Stratigraphic Correlations Basins of Peritethyan
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ABSTRACT - Pre-Aptian ammonite faunas of the northern hemisphere fall into two distinct realms, Tethyan and Boreal. The NW European faunas belong to the West European Province of the Boreal Realm. They show a strong Tethyan influence at times, which is reflected in the current biostratigraphic schemes. Some Tethyan immigrants gave rise to endemic genera through allopatric speciation. Others quickly became extinct. The occurrence of immigrant forms means that NW Europe is a key area in correlation between Boreal and Tethyan realms.

KEYWORDS - Ammonites, Lower Cretaceous, Boreal-Tethyan correlation, NW Europe.

RIASSUNTO - Le faune ad ammoniti pre-Aptiane dell'emisfero nord ricadono in due dominii distinti, Tetideo e Boreale. Le faune dell'Europa nord occidentale appartengono alla Provincia Europea Occidentale del Dominio Boreale. Esse mostrano, a tratti, una forte influenza tetidea che si riflette negli attuali schemi biostratigrafici. Alcuni immigranti tetidei diedero vita a generi endemici attraverso speciazioni allopatriche mentre altri si estinsero velocemente. La presenza di forme immigranti dimostra che l'Europa nord occidentale è un'area chiave nella correlazione tra i dominii Boreale e Tetideo.

PAROLE-CHIAVE - Ammoniti, Cretaceo inferiore, correlazione Boreale-Tetide, Europa nord occidentale.

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1. - INTRODUCTION

In the northern hemisphere there were two distinct faunal phases during Early Cretaceous times (RAWSON, 1981). During Berriasian to early Barremian times the Boreal and Tethyan Realms were clearly differentiated. The former was characterised by perisphinctacean ammonites, the latter by a much more varied fauna including phylloceratids, lytoceratids and heteromorphs. During the Early Barremian the sea withdrew from many high boreal (Arctic) areas and the pattern broke down. Aptian and Albian faunas show only limited differentiation.

This review deals with the earlier, Berriasian to Barremian, phase, when the North Sea and contiguous North German basins formed a major Early Cretaceous depocentre which lay on the southern margin of the Boreal Realm and maintained at least intermittent connections with western Tethys (Fig. 1). The ammonite sequence is well known and often quoted as a standard for the Boreal Realm.

But this is rather misleading as the faunas show a strong Tethyan influence, sufficient to merit the recognition of a distinct West European Province (RAWSON, 1981, 1993a). In fact the first ammonite ever described from the province, *Ammonites rotula* (SOWERBY, 1827) from the Speeton Clay, became type species of the typically Tethyan genus *Spitidiscus*. Other Tethyan forms were figured from Speeton by YOUNG & BIRD (1828) and PHILLIPS (1829), so that as early as 1838 AGASSIZ (in D'ARCHIAC, 1838) was able to compare the fossils of the Speeton Clay with the Neocomian beds of the Jura.

The standard stage names developed during the 19th century were based on sequences in the West Mediterranean Province. They were first applied to NW Europe by KOENEN (1902) who, like some of his predecessors, figured some typical Tethyan taxa in his monograph. The occurrence of all the Valanginian to Hauterivian Tethyan and Tethyan derived forms so far known from the West European Province was reviewed by Kemper, RAWSON & THIEULOY (1981).

Since then, DOYLE (1989) and RAWSON (this volume) have added important new records from the Speeton Clay of eastern England. Further material from Germany has been figured by KEMPER & WIEDENROTH (1987), KEMPER (1992), QUENSEL (1988) and MUTTERLOSE (1992). The former two papers also refigured many of the specimens previously figured by KEMPER (1976) or KEMPER *et alii* (1981). Altogether a large number of immigrant forms have now been figured in these and earlier publications.

The Tethyan migrants often became extinct quickly, but sometimes gave rise through allopatric speciation to thriving endemic genera. None are known from the Ryazanian but they occur at several levels through the Valanginian to Barremian sequence, generally close to clearly defined sequence boundaries that represent rapid rises in sea level (RAWSON, 1993a; 1994). In addition, Boreal ammonites are found at some levels in the West Mediterranean Province. Thus Valanginian to Hauterivian zonations can be correlated with the West Mediteranean scheme with some confidence, Barremian ones more questionably (Fig. 2).

The following account is essentially an expansion of two recent contributions to IGCP Project 362 (Tethyan-Boreal Cretaceous) - a short account of the NW European ammonite zonations in *Newsletter 1* and a talk with abstract on Tethyan immigrants to eastern England given at the first meeting of Project 362 at Coimbra (RAWSON, 1993b, c). For each stage I firstly discuss the zonally important genera and then summarise the occurence of Tethyan immigrants, especially those that are important for correlation.

2. - THE FAUNAL SEQUENCES

The ammonite zonation of the West European Province currently used has evolved over the last hundred years and owes much to work in the first quarter of this century by Koenen, Spath and Stolley. More detailed collecting over the last 30 years has refined the sequence considerably but much work remains to be done.

2.1. - THE RYAZANIAN SEQUENCE

NW Germany was non-marine at this time, but marine sediments extend over much of the North Sea Basin into eastern England (RAWSON, 1992, map. 1). The Ryazanian (approximately equivalent to the Late Berriasian) ammonites are exclusively boreal, identical with or close to species from East Greenland and the Russian Platform.

The eastern England succession was described by CASEY (1973). Unfortunately the sequence consists mainly of thin, often condensed sands and the ammonites were collected mainly from temporary sections, no longer visible. The zonation based on this record is (from top to bottom):

Peregrinoceras albidum
Surites (Bojarkia) stenomphalus
Surites (Lynnia) icenii
Hectoroceras kochi
Runctonia runctoni

East Greenland is the type area for the *kochi* Zone, Norfolk or south Lincolnshire for the remaining zones. The earliest known Tethyan immigrant is the nucleus of a *Neocomites?* cf. *trezanensis* from the base of the Claxby Ironstone of Lincolnshire, figured by KEMPER *et alii* (1981). This came from a transgressive horizon that contains very late *Peregrinoceras* of latest Ryazanian or, more likely, earliest Valanginian age. The appearance

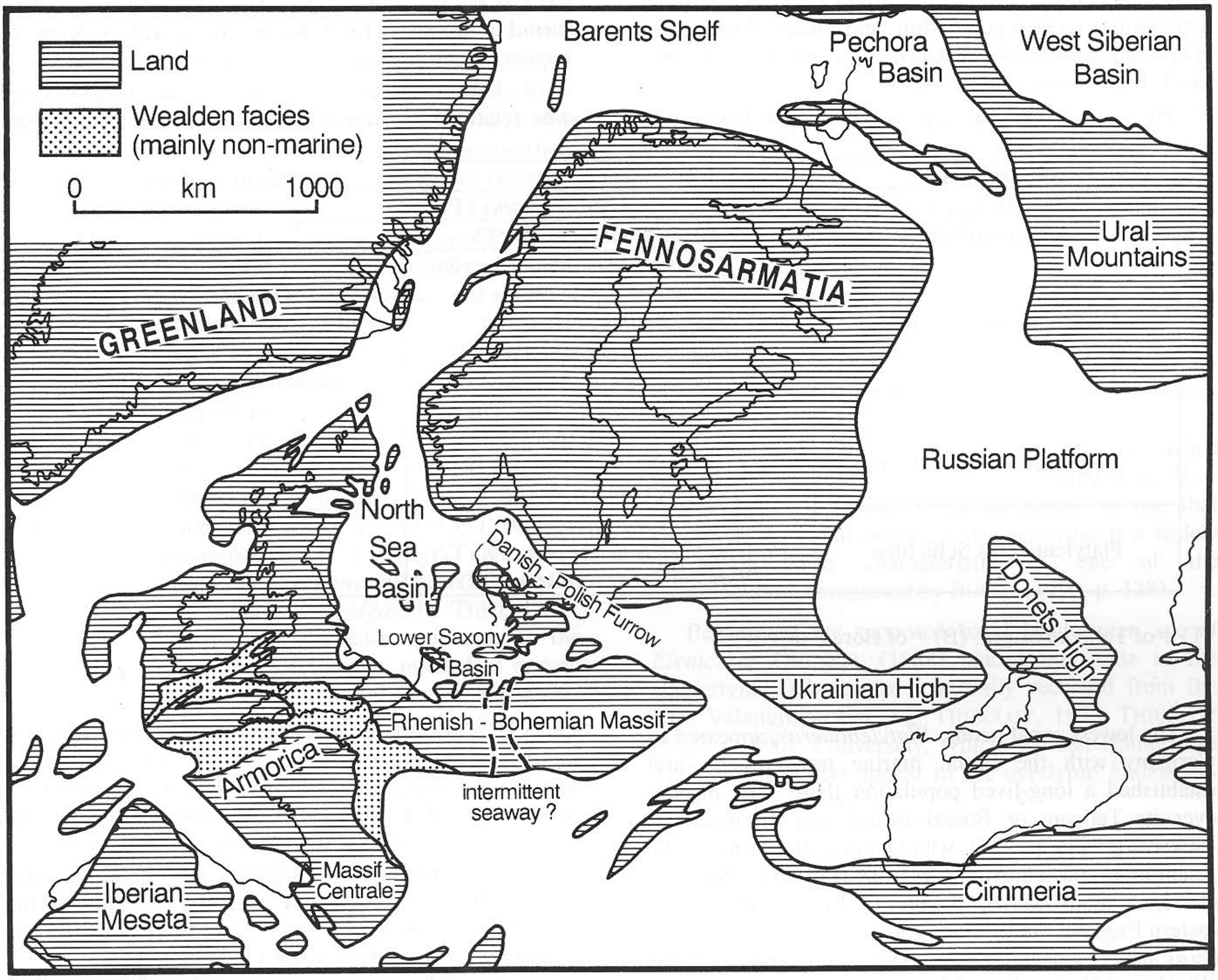

Fig. 1. The palaeogeographic framework - connections between the West European Province and adjacent regions.
- *Il quadro paelogeografico e le connessioni tra la provincia europea occidentale e le regioni adiacenti.*

of this form may predate that of *Platylenticeras* in North Germany.

2.2. - The Valanginian sequence

A marine transgression at the beginning of the Valanginian brought the sea back to North Germany, where thick mudrocks with marginal sands began to accmulate in the Lower Saxony Basin. A detailed zonation has evolved which provides a standard for NW Europe. In practice the zones effectively represent individual assemblages from scattered brickpits that were placed into sequence. Thus the zonal limits often are not well defined and it is possible that there are still gaps in the proven succession. Nor have type sections been formally named. In the literature, individual localities were often associated with a particular assemblage (zone).

But as more than one locality may be associated with a single zone while some localities span a zonal boundary, the table below indicates the "locus typicus" of the index species rather than a type locality for the zone (based on information in Kemper, 1961, 1978 and Jeletzky & Kemper, 1988).

Unfortunately even in some of the most recent papers (e.g. Kemper, 1992) the horizon of figured ammonites is generalised rather than being referred to a specific zone. This makes it difficult to assess the exact horizon of some immigrant ammonites.The English Valanginian sequence is thin and incomplete, but a simplified version of the German zonation can be applied (RAWSON *et alii*, 1978).

The German zonal scheme is (from top to bottom):

old division	zone	"locus typicus"
Astierien Sch.	*Olcostephanus densicostatus* (T)	
Arnoldien Sch.	*Dicostella tuberculata* (T)	Ottensen
Dichotomiten Schichten	*Dichotomites bidichotomoides* (B) *Dichotomites triptychoides* (B) *Dichotomites crassus* (B) *Prodichotomites polytomus* (B) *Prodichotomites hollwedensis* (B)	Ottensen Hasslage-Nord Varlheide, Sud Stadthagen Twiehausen, near Hollwede
Polyptychiten Schichten	*Polyptychites hapkei* (B) *Polyptychites clarkei* (B) *Polyptychites multicostatus* (B) *Polyptychites pavlowi* (B)	Hollwede Lindhorst Lindhorst) Osterwald
Platylenticeras Schichten	*Platylenticeras involutum* (T?) *Platylenticeras heteropleurum* (T?) *Platylenticeras robustum* (T?)	Buckeburg Barsinghausen Gronau

(T) = of Tethyan origin, (B) = of Boreal origin

The lowest zonal genus, *Platylenticeras*, appeared in Germany with the initial marine transgression and established a long-lived population there. The dispute over its Tethyan or Boreal origin was discussed by RAWSON (1993a, p. 234), who favoured the former. The zonation of the *Platylenticeras* beds follows KEMPER (1961, as modified 1973, table 1). Equivalent beds in eastern England are thin and incomplete, but *Platylenticeras* never appears to have successfully replaced the already established boreal lineage, represented early in the Valanginian by *Costamenjaites* and allied late Craspeditinae.

Boreal Polyptychitinae spread over the whole of NW Europe later in the Early Valanginian, first appearing in north Germany in the upper part of the *Platylenticeras* beds. After *Platylenticeras* died out polyptychitinids dominated the faunas of the whole West European Province till very late in the Valanginian, when they began to peter out as Tethyan immigrants occupied the region.

The initially broad zonal subdivision of the polyptychine sequence (e.g. KOENEN, 1902; STOLLEY, 1937) has been much modified by KEMPER in a series of important papers, starting in 1971. The present-day version dates from KEMPER (1976, table 6), tabulated 2 years before some of the index species were formally named. There have been minor subsequent modifications, as follows:

1. JELETZKY & KEMPER (1988) placed the former zonal index *Polyptychites euomphalus* in synonymy with *P. pavlowi* and therefore renamed the zone.

2. JELETZKY & KEMPER (1988) showed that the index for the highest *Polyptychites Zone, P. sphaeroidalis*, was poorly known and that many of the ammonites formerly assigned to it belong to a new species, *P. hapkei*, which therefore became the zonal index.

3. The index species of the *D. bidichotomus* Zone was renamed *D. bidichotomoides* by KEMPER (1978). QUENSEL (1988) later suggested splitting the *bidichotomoides* Zone into two zones, *bidichotomoides*, below and *ivanovi* above. Quensel's divisions are regarded here as subzones of the original *bidichotomoides* Zone. The last *Prodichotomites* occurs in the *tuberculata* Zone.

Tethyan immigrants appeared alongside the Polyptychitinae on several occasions. The first horizon is at the base of the *hollwedensis* Zone. Here large, inflated *Olcostephanus* appear, forming STOLLEY's (1937) "*Proastieria*" fauna. A single specimen was figured by KEMPER *et alii* (1981, pl. 35, figs 1, 2) as *O. (O.)* sp., and later identified by BULOT (1990, p. 87) as *O. (O.) guebhardi* KILIAN.

These inflated *Olcostephanus* survived to the middle of the *hollwedensis* Zone, when a whole group of Tethyan genera invaded the area - *Bochianites, Saynoceras, Valanginites, Karakaschiceras* and *Neohoploceras*. Most spread across the whole region but *Saynoceras* and *Valanginites* were filtered out before reaching England. Many examples of this distinctive fauna have been figured by KEMPER *et alii* (1981) and earlier workers, KEMPER & WIEDENROTH (1987), KEMPER (1992) and MUTTERLOSE (1992).

Both these and later Valanginian ammonites are known from England only from condensed or remanie Upper Valanginian beds. But in the thick Upper Valanginian succession in north German there are other important immigration horizons higher in the sequence. The majority of immigrants were neocomitids and olcostephanids, but rarer heteromorphs occur.

The neocomitid *Varlheideites peregrinus* (RAWSON & KEMPER, 1978) was described from the *crassus* Zone of Varlheide, where a single *Oosterella* aff. *cultrata* was discovered too (KEMPER *et alii*, 1981, p. 302, pl. 37, figs 9-10). *Varlheideites* or a similar neocomitid is known also from the *bidichotomoides* Zone (QUENSEL, 1988).

A mass occurrence of *Bochianites neocomiensis* in core samples from the western margin of the Lower Saxony Basin is less well dated but lies somewhere within the *polytomus ?* to *triptychoides* Zones (KEMPER *et alii*, 1981, p. 266).

Crioceratites-like heteromorphs first appear in the *triptychoides* Zone, together with the apparently endemic heteromorph *Juddiceras*. They are quite common at this level (KEMPER *et alii*, 1981) while through the remainder of the Valanginian there are only spasmodic records of fragmentary specimens.

KEMPER (1992) figured two from the "Upper Valanginian" of the Mitteland Canal while both QUENSEL (1988, pl. II.1/3) and MUTTERLOSE (1992, pl. 7, figs 1-2) illustrated fragments from the *tuberculata* Zone. The fragments figured by KEMPER *et alii* (1981, pl. 34, figs. 16-17), QUENSEL (1988, pl. II 1/3, fig. 1 and MUTTERLOSE (1992, pl. 7, figs 1-2) have all been assigned to a new taxon, *Criohimantoceras gigas*, by THIEULOY & BULOT (1993), with MUTTERLOSE's specimen as the holotype. However, this specimen is much less curved than the *triptychoides* Zone material figured and recorded by KEMPER *et alii* (1981) so at least two taxa are probably represented.

A second neocomitid genus, *Dicostella*, first appears in the middle of the *bidichotomoides* Zone where several species occur (KEMPER *et alii*, 1981; QUENSEL, 1988 - *ivanovi* Subzone). It provides the zonal index for the overlying *tuberculata* Zone, named by KEMPER *et alii* (1981) following their reidentification of the index species of KEMPER's (1971) *Dicostella pitrei* Zone, which in turn had been proposed for the "Arnoldien Schichten" of former workers. Ottensen was the main locality for these faunas.

Other neocomitids also occur as rarities in the upper part of the Valanginian. KEMPER *et alii* (1981) figured several examples, most from the *tuberculata* Zone or just beneath.

A form similar to their *Neocomites* sp. A occurs in the transgression horizon at Sarstedt (KEMPER, 1992, pl. 37, fig. 3), associated with *Dicostella* aff. *tuberculata*. Other neocomitids from just above the transgression horizon have been assigned to *Eleniceras* and *Neocomites* (KEMPER & WIEDENROTH, 1987, pl. 7, figs 2-3; KEMPER, 1992, pl. 37, fig. 1), supposedly of Hauterivian age but probably latest Valanginian. KEMPER (1992, pl. 37, fig. 5) also figured a more involute *Neocomites* from the Valanginian/ Hauterivian boundary at Niedermehnen.

This specimen looks close to *N. (Teschenites)* of the *flucticulus* group. An *Oosterella* aff. *villanovae* came from the same level (KEMPER, 1992, pl. 33, fig. 3).

The highest Valanginian *densicostatus* zone was formerly known as the "Astierien Schichten" - the level where a second wave of *Olcostephanus* appeared in the German succession. Examples were illustrated for the first time by KEMPER *et alii* (1981) and further material was figured by MUTTERLOSE (1992) (refigured by KEMPER, 1992). Because the species were left in open nomenclature in KEMPER *et alii*'s (1981) review the zone remained unnamed.

It was subsequently called the "*Olcostephanus* spp." Zone (RAWSON, 1983). QUENSEL (1988) then named it the *paucinodum* Zone, based on the identification of a minor element of the fauna as "cf. *Eleniceras paucinodum*", an enigmatic species first described by NEUMAYR & UHLIG (1881).

The choice of such a poorly understood taxon as zonal index is inappropriate. *Olcostephanus* has long been recognised as the characteristic ammonite of this level, and now that some forms have been firmly identified (BULOT in MUTTERLOSE, 1992) and illustrated as *Olcostephanus densicostatus* I am proposing to use that species as the zonal index. *O. densicostatus* is a widely distributed form characteristic of one of the "chronoclines" recognised by BULOT (1990, p. 128).

Because of the supposed basal Hauterivian age of *Eleniceras* QUENSEL (1988) placed this zone in the Hauterivian. *Eleniceras* is actually recorded from the Late Valanginian too (e.g. THIEULOY, 1977; THIEULOY *et alii*., 1990). Conversely, typical earliest Hauterivian *Acanthodiscus* first appear in the overlying *Endemoceras* beds (see below).

2.3. - THE HAUTERIVIAN SEQUENCE

Thick mudrocks continued to accumulate in north Germany and there is a well-developed succession in the Speeton Clay of eastern England. The faunal sequence is similar in both areas so that a common zonation can be applied to most of the sequence. The modern zonation dates from RAWSON's (1971a, 1971b) study of the Speeton Clay sequence of eastern England, which drew on earlier published work including THIERMANN's (1963) recognition of the *amblygonium* and *noricum* Zones in north Germany.

North Germany is therefore the type area for these lowest two zones and the coastal section at Speeton is the type locality for the remainder, with two exceptions. When KEMPER & RAWSON (in KEMPER, 1973) expanded the "English" zonation to north Germany they used *S. staffi* as an alternative to *S. speetonensis* and *S. (C). discofalcatus* as an alternative to *S. marginatus* and *C. variabilis,* reflecting differences in the abundance of the *Simbirskites* species. The *inversum* Zone was first used in North Germany by KEMPER (1976, table 7).

At Speeton the base of each zone was defined by the first appearance of the index species.

The zonation, from top to bottom, is:

ENGLAND	GERMANY
S. (Simbirskites) marginatus	*S. (C.) discofalcatus* (pars)
Simbirskites (Craspedodiscus) gottschei	
S. (Milanowskia) speetonensis	*S. (M.) staffi*
Simbirskites (Speetoniceras) inversum	
Endemoceras regale	
Endemoceras noricum	
Endemoceras amblygonium	

The ammonite faunas show considerable diversity and include typical Tethyan species at some levels. *Endemoceras* is the characteristic and dominant genus of the first three zones. It is an endemic neocomitid apparently derived by allopatric speciation from a Tethyan-derived *Neocomites (Teschenites)*. In Germany *Acanthodiscus* appeared with *Endemoceras*. Much prized by collectors it is a quite rare genus though relatively abundant in collections! Few of the museum specimens have an accurate horizon recorded but it is known from the upper part of the *amblygonium* Zone and the *noricum* Zone (KEMPER *et alii*, 1981; QUENSEL, 1988). Compared with the French material, the German forms are fairly advanced *Acanthodiscus* with a broad siphonal band characteristic of the middle part of the *radiatus* Zone (BULOT *et alii*, 1993, p. 39). So the previous provisional correlation of the base of the underlying *amblygonium* Zone with the base of the underlying *radiatus* Zone (THIERMANN, 1963; RAWSON, 1971b) still appears the best approximation.

Acanthodiscus failed to reach eastern England, where the equivalent beds are condensed but very fossiliferous. However, younger Early Hauterivian faunas are best known from England (Speeton Clay) where the *regale* Zone faunas are better developed than in the poorly fossilferous German sections. Here olcostephanids reappear in the upper part of the *regale* Zone where *Olcostephanus* of the *sayni* group, *Jeannoticeras jeannoti* and the apparently endemic micromorph form *Parastieria peltoceroides* all occur (KEMPER *et alii*, 1981; DOYLE, 1989).

Spitidiscus pavlowi appeared briefly at the top of the zone. Immediately afterwards there was a major mid Hauterivian faunal turnover, coinciding with a sequence boundary that marks an important sea level rise of global extent (RAWSON, 1993a).

Boreal *Simbirskites* (*Speetoniceras*) replaced *Endemoceras* at the base of the *inversum* Zone. An evolving plexus of Simbirskitinae then occupied the whole West European Province until very early in the Barremian. With the earliest forms came high Arctic *Homolsomites* and rare Tethyan *Crioceratites* and *?Megacrioceras* -all in the same thin bed (C7H) at the base of the *inversum* Zone at Speeton.

This first *Crioceratites* gave rise by allopatric speciation to the endemic heteromorph *Aegocrioceras* which first appears immediately above this level and for a short while became the dominant ammonite across the whole NW European area: English *Aegocrioceras* were monographed by RAWSON (1975) and German examples illustrated by KEMPER & WIEDENROTH (1987) and KEMPER (1992).

A second invasion of *Crioceratites* is marked by common examples of the *nolani/duvali* group high in the *inversum* Zone in both England and Germany (e.g. KEMPER *et alii*, 1981, pl. 34, fig. 3, 4; KEMPER, 1992, pl. 55-57).

From then upwards it occurs scattered through the Upper Hauterivian sequence though these younger forms remain poorly known. In the middle of the *speetonensis* Zone at Speeton *Spitidiscus* reappeared briefly, represented by the type species, *S. rotula*. Similar forms occur in the upper part of the Gildehauser Sandstone of north Germany and the nearby Losser Sandstone in the Netherlands (KEMPER *et alii*, 1981; KEMPER, 1992, pls 55-57).

2.4. - THE BARREMIAN SEQUENCE

Barremian sequences occur in both Germany and England, mainly in mudrock or calcareous mudrock facies. The zonation currently used is based mainly on KOENEN's (1902, 1908) and STOLLEY's (1908) work in north Germany, as modified slightly by KEMPER (1976, p. 75). As with the Valanginian, the zonation was established by placing individual faunas from scattered sections into sequence.

Unfortunately, although rich horizons are sometimes found (e.g. IMMEL & MUTTERLOSE, 1980), ammonites are rare or absent at many levels and no detailed, bed-by-bed sequence has been established. Thus the stratigraphic accuracy of the zonation remains uncertain.

The lower part of the zonation (*variabilis* to lower *denckmanni* zones) has been proved in outline at Speeton, though once again identifiable forms are scarce and fragmentary (RAWSON & MUTTERLOSE, 1983). The *bidentatum* Zone is more fossiliferous there, but the intervening upper *denckmanni* to *stolleyi* zones are difficult to identify due to poor exposure.

The lowest Barremian zone has a different simbirskitid index in each area.

The zonation, from top to bottom, is:

ZONE	TYPE LOCALITY*
Parancyloceras bidentatum	Sarstedt (Moorberg)
Simancyloceras stolleyi	Behrenbostel
Simancyloceras pinguel/"Ancyloceras" innexum	Mellendorf
Paracrioceras denckmanni	Mellendorf
Paracrioceras elegans	Hildesheim
"Hoplocrioceras" fissicostatum	Hildesheim
"Hoplocrioceras" rarocinctum	Querum
Simbirskites (Cr.) variabilis (= S. (C.) discofalcatus (pars) in Germany)	Speeton, England

*based mainly on KOENEN (1902)

Very early in the Barremian (end of the *variabilis/discofalcatus* Zone) the simbirskitids died out and the NW European Barremian faunas became almost exclusively heteromorph, consisting of Tethyan or Tethyan-derived endemic species whose exact biogeographical affinities are difficult to interpret; the problem is discussed in detail by RAWSON (this volume).

The later Barremian heteromorphs show a more obvious Tethyan connection, apparently linked to a possible sea level rise that is marked at Speeton by a sharp facies changes from somewhat calcareous mudrocks to a dark, pyritic shale at the base of the *bidentatum* Zone. This was accompanied by the appearance of numerous *Aconeceras nisoides, Toxoceratoides,* the apparently endemic *Parancyloceras* and, more remarkably, small *Heteroceras* (RAWSON, this volume). With the exception of *Heteroceras* all these forms are recorded also from north Germany, from where KEMPER (1973) has also described *Spinocrioceras*, a distinctive trituberculate crioceratitid from the lower part of the *bidentatum* Zone.

3. CORRELATION WITH THE WEST MEDITERRANEAN FAUNAS

In addition to the Tethyan ammonites recorded here from north-west Europe, boreal or even Tethyan-derived forms occasionally migrated in the opposite direction, to marginal areas of the West Mediterranean Province. This happened almost exclusively in the Valanginian unless some poorly known Barremian heteromorphs also followed the same trend. The migrant forms give several tie-points where faunas from the two realms can be correlated (Fig. 2). The Mediterranean zonation is based on a recent revision by HOEDEMAEKER, COMPANY *et alii* (1993) on behalf of IGCP Project 262.

Platylenticeras comparable with early German forms (*robustum* Zone) appear very high in the *otopeta* Zone of south-eastern France (KEMPER *et alii*, 1981), but the next firm tie between the two regions is not until the base of the *hollwedensis* Zone. Here, large, sphaeroidal *Olcostephanus* of the *guebhardi* group occur through the lower part of the zone, indicating a correlation with the upper *campylotoxum* Zone. The Lower/Upper Valanginian boundary lies in about the middle of the *hollwedensis* Zone, where *Saynoceras verrucosum* appears (KEMPER *et alii*, 1981).

Varlheideites peregrinus (RAWSON & KEMPER, 1978), first described from the north German *crassus* Zone, has now been found in the upper part of the *verrucosum* Zone of the south-east of France, where it forms a distinct *peregrinus* Horizon (BULOT *et alii*, 1993). *Crassus* Zone dichotomitids occur there at the same level.

Correlation of the younger Valanginian beds is more tenuous. BULOT *et alii* (1993) correlated the top of the *crassus* Zone with the base of the *nicklesi* Horizon because of the occurrence in the latter of *Dichotomites petschi* and *D. evolutus.* However, at least one of these taxa is now known to extend into the basal *triptychoides* Zone in Germany (MUTTERLOSE, 1992). It appears more appropriate to provisionally correlate the base of the latter zone with the base of the *nicklesi* Horizon as crioceratitid hetermorphs (*Himantoceras* group) first appear at this level in both areas. Occurrences of the related genus *Criohimantoceras* led BULOT *et alii* (1993) to correlate the upper *triptychoides*, *bidichotomoides* and lower *tuberculata* Zones with the *furcillata* Horizon. Unfortunately, *Criohimantoceras* is so rare and poorly known that its scattered records in north Germany and France are of very limited stratigraphic value. *Dicostella* also gives little help. It is not common in France, where occurrences in SE France and the Paris Basin were reviewed by THIEULOY *et alii* (1990). It appears to be another neocomitid that reached its peak of development in the West European Province. Hence the correlation of the beds above the *triptychoides/nicklesi* level shown in Fig. 2 is very provisional: an approximate correlation of the *densicostatus* Zone with the *"callidiscus"* Zone of BULOT *et alii* (1993) (= *callidiscus* and overlying unnamed horizons in Fig. 2) is based on the occurrence of *"Eleniceras"* and common *Olcostphanus densicostatus* in both areas (BULOT *et alii*, 1993).

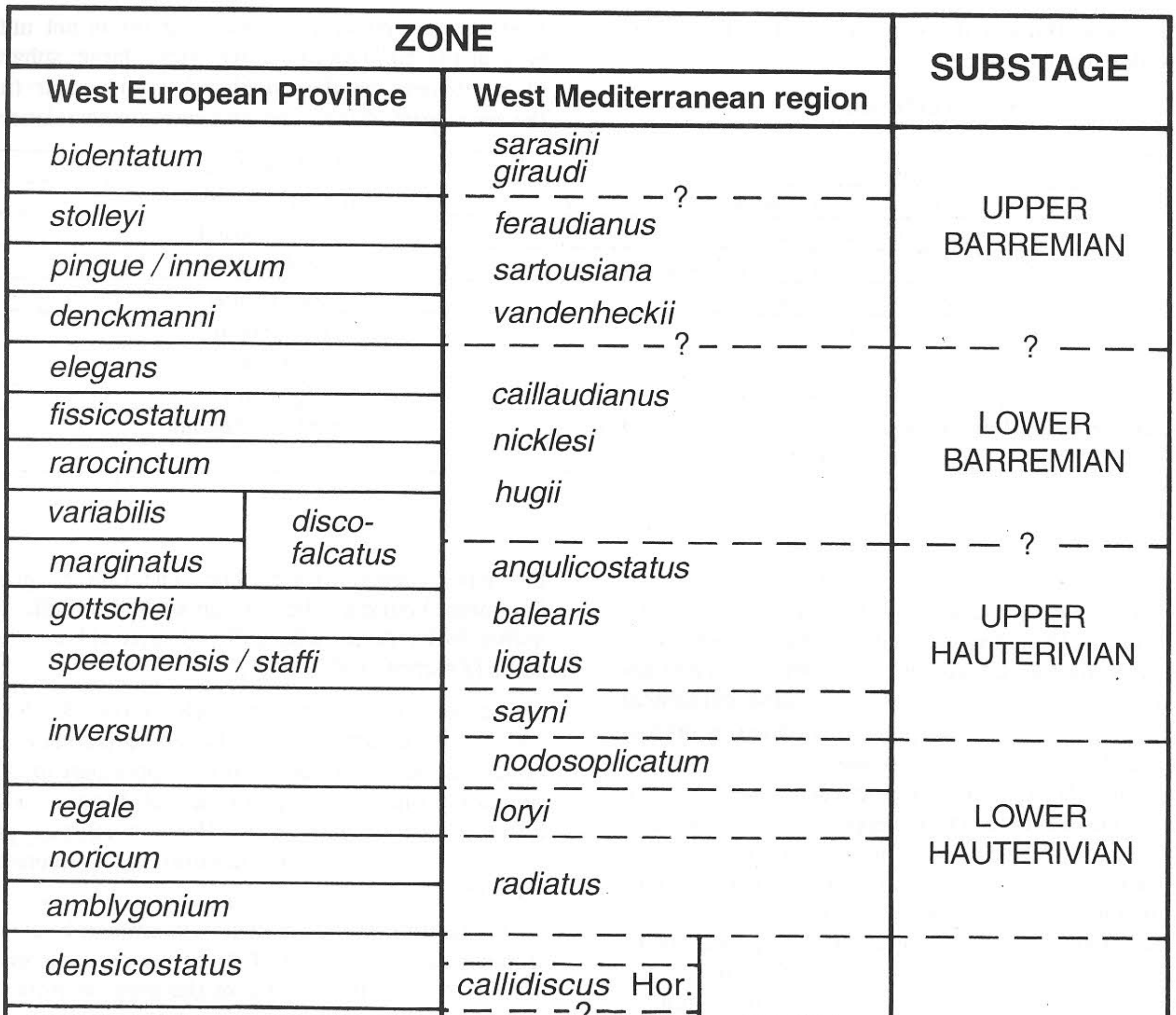

Fig. 2. The zonation of the West European Province and its correlation with the Mediterranean Region. Dashed lines indicate an approximate correlation with the West European Province, dashed lines and ? indicate greater uncertainty.
- Zonazione della Provincia Europea Occidentale e correlazione con la regione mediterranea. Le linee tratteggiate indicano una correlazione *approssimativa con la Provincia Europea Occidentale, tratteggi e ? indicano maggiore incertezza.*

This leaves the intervening *bidichotomoides* and *tuberculatus* Zones to correlate approximately with the *furcillata* Horizon.

The base of the Hauterivian is conditionally placed at the base of the *amblygonium* zone, as discussed above. Very close correlations can be made between the Speeton (England) and French mid Hauterivian sequences (BULOT *et alii*, 1993; BULOT & RAWSON, in prep). The occurrence of *Jeannoticeras jeannoti* in the upper part of the Speeton *regale* Zone gives a firm tie to the upper *loryi* Zone, the base of the *nodosoplicatum* Zone correlates with the base of the *inversum* Zone while BULOT *et alii*'s (1993) redefined *sayni* Zone corresponds to the upper part of the *inversum* Zone.

KEMPER *et alii* (1981) took the first (and only) appearance of *Crioceratites (Paracrioceras) spathi* at the base of the *variabilis* Zone at Speeton to mark the base of the Barremian there. This coincides with a horizon in about the middle of the German *discofalcatus* Zone. There a related form, *C. (P.) strombecki* (KOENEN), is close to the Tethyan *"E." emerici* group. However, in the Mediterranean area such forms range from the upper part of the *angulicostata* Zone (top Hauterivian) through much of the Lower Barremian. Thus the correlation shown in Fig. 2 is only tentative. The same is true for the Lower/ Upper Barremian boundary, which is based on the superficial resemblance of the coarsely-ribbed, trituberculate inner whorls of some *denckmanni* Zone crioceratitids to the *barremense* group at the base of the French Upper Barremian (RAWSON, 1994). Possibly the boundary should be drawn slightly lower, in or at the base of the *elegans* Zone.

Spinocrioceras of the lower *bidentatum* Zone was originally regarded as a "boreal" heteromorph. It is now known from SE France (DELANOY, 1992), northern Italy (CECCA & LANDRA, 1994) and the Caucasus (KOTETISHVILI, 1970) and probably originated in the West Mediterranean Region. There it occurs in the *feraudianus* and *giraudi* Zones. Together with *Heteroceras* from the *bidentatum* Zone at Speeton, this record and the evidence of a sea-level rise at about the base of the *giraudi* Zone suggests a provisional correlation of the *giraudi* and *sarasini* Zones with the *bidentatum* Zone.

The *Aconeceras* of the *bidentatum* Zone are regarded as "Tethyan" immigrants, but the genus is not known from adjoining areas of Tethys at this time. Hence RAWSON (this volume) has suggested that its appearance in the West European Province may represent immigration from the eastern Pacific via a proto-Gulf Stream through the opening North Atlantic.

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