Correlation possibilities around the Jurassic/Cretaceous boundary

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Hoedemaeker, Ph.J., Correlation possibilities around the Jurassic/Cretaceous boundary. — Scripta Geol., 84: 1-64, 16 figs., Leiden, July 1987.

The present-day detailed knowledge of the zonation and the chronostratigraphic ranges of the fossils of the Mediterranean Berriasian makes it possible to re-evaluate critically the factual evidence on which the correlation of the Boreal sequence with the Tethyan standard is based. It turns out that the evidence is still very meagre and that correlation by means of marine fossils is only possible for time-intervals in which the sea level was high. Some important results of this investigation are:
1) The Valanginian age of the upper Ryazanian: the base of the *Tirnovella alpillensis* Subzone is stratigraphically closest to, or even coinciding with, the boundary between the lower and the upper Ryazanian and to the base of the German 'Wealden' unit 4.
2) The correlation of the English Cinder Beds with the upper Tithonian *Berriasella jacobi* Subzone.
3) The time-equivalence of the *jacobi* Subzone with the lower part of the Canadian *Buchia terebratuloides* Zone and with at least a part, or even the whole of the underlying *Buchia fischeriana* Zone, and therefore also with the upper Volgian *Taimyroceras taimyrense* Zone and with at least the major part, or even the whole, of the *Craspedites okensis* Zone.
4) The lack of any evidence for the East-European *Riasanites rjasanensis* Zone being older than the Mediterranean *Berriasella paramimouna* Subzone or younger than the *Berriasella picteti* Subzone.
5) The correlation of the *Buchia okensis* Zone with the lower part of the *Berriasella paramimouna* Subzone, and possibly with a small part of the *Dalmasiceras dalmasi* Subzone, but also with an interval in the lower part of the upper *Hectoroceras kochi* Zone.
6) The entire *Riasanites rjasanensis* Zone falling within the upper part of the *Hectoroceras kochi* Zone.
7) The top of the Siberian *Chetaites chetae* Zone being stratigraphically closest to the top of the Mediterranean *Pseudosubplanites grandis* Subzone and to the top of the German 'Wealden' unit 1.
As the author (Hoedemaeker, 1981, 1982, 1983, 1984) has proposed to draw the base of the Valanginian at the base of the *alpillensis* Subzone and the top of the Tithonian at the top of the *grandis* Subzone, the above correlations imply that the Berriasian/Valanginian boundary is stratigraphically closest to, or even coinciding with, the boundary between the lower and upper Ryazanian and that the Tithonian/Berriasian boundary, which is also the Jurassic/Cretaceous boundary, is closest to, or even coinciding with, the top of the *chetae* Zone.
The Jurassic/Cretaceous boundary correlates approximately with the base of 'Wealden' unit 2 in Germany, with the approximate base of the Royal faunicycle of the English Purbeck Beds, and with a level not far above the middle of the rock interval occupied by the North American *Buchia terebratuloides* Zone.

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Introduction

In contrast to most previous attempts at correlating the Boreal lowest Cretaceous succession with the Tethyan standard zonation, which were more or less handicapped by insufficient acquaintance with Tethyan ammonites and ammonite biostratigraphy, the attempt made here is handicapped by insufficient knowledge of boreal ammonites. Therefore the author as much as possible relied on the generic assignment of the ammonites given by Casey (1973) and Casey et al. (1977). Nevertheless this study may give a refreshing look on Tethyan-Boreal correlations from quite a different, Tethyan, point of view. This may give the discussion on the Tethyan-Boreal correlation of the Jurassic/Cretaceous boundary and its adjacent parts a new direction, which is the main purpose of this paper.

The intra-Boreal correlations of the *Hectoroceras kochi* and *Chetaites sibericus* zones attempted here (Fig. 8) should of course still be checked in the future. Sea-level fluctuations appear to be very useful as an additional correlation tool and control. The identification of corresponding sea-level falls in widely separated sections may supply the deficiency of good biostratigraphical control.

The correlations attempted here mainly concern the Berriasian Stage and its

boundaries. The correlation of the Boreal Valanginian with the Tethyan succession has excellently been done by Kemper et al. (1981). Only the Mediterranean ammonite zonation of the lower Valanginian is changed here according to the author's views (Hoedemaeker, 1982, 1983, 1984) and the stratigraphic position of the Valanginian/ Hauterivian boundary is lowered according to the propositions of the Colloque sur le Crétacé inférieur (Anonymous, 1965), which are fully endorsed by the author (1984).

The correlations given here, imperfect as they may be, do not contradict each other, but instead seem to support each other, as they should. They therefore inspire confidence, the more so as the correlations attempted here do not presuppose migration in time of ammonite taxa. Only the hitherto known ranges of fossils were used. For alternative correlations it was not possible to find any proof as yet. More study is obviously required, for there are still too many uncertainties.

Figure 1 reproduces the comprehensive results of the author's correlations and this figure should be consulted for every chapter.

Global sea-level changes as an additional correlation tool

Global sea-level changes (Vail et al., 1977, 1984; Vail & Todd, 1981) have marked effects on lithostratigraphy as well as on biostratigraphy.

In shallow marine areas, global sea-level falls produce for instance condensed deposits or unconformities at the same stratigraphic position in widely separated areas. Also, marine biotas suffer frome these sea-level falls, which induce rapid and important changes in the otherwise gradual succession of marine faunas (Jablonsky, 1980) due to

the decrease or disappearance of many shallow marine biotopes.

Ammonites appear to be very sensitive to widespread advances and withdrawals of the sea. The ammonite extinctions near the boundaries of the Mesozoic periods, which are the effect of withdrawals of the sea (second order cycles of Vail et al., 1977), are well-known. There is a marked correspondence between ammonite diversity and sea-level changes (Wiedmann, 1973; Kennedy, 1977, p. 298, fig. 33; Hallam, 1978, 1981): withdrawals of the sea from the continents correspond with high extinction rates, progressive gaining of the sea over the continents corresponds with renewed radiation.
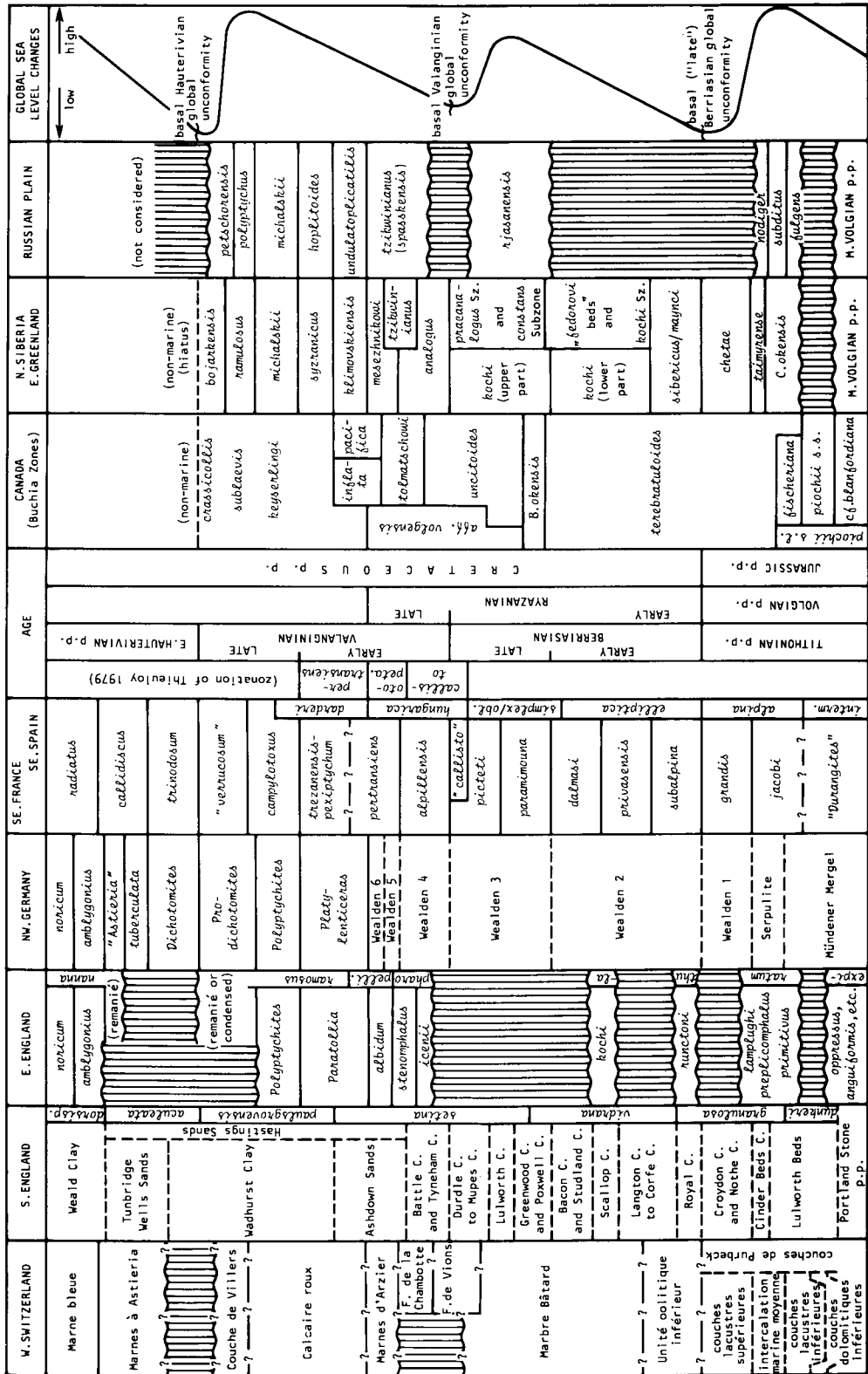
Hoedemaeker (1983, p. 454; 1984) has shown that the Neocomian global unconformities indicated on Vail's global coastal onlap curve (Vail & Todd, 1981, figs. 11, 13; Ziegler, 1982, encl. 38) correlate with conspicuous minima in the number of concurring ammonite species concomittant with rapid and profound turnovers in the composition of the successive ammonite faunas. A causal relation is assumed. It is of particular eco-stratigraphical interest that these turnovers in the ammonite succession are not restricted to shallow-water environments, but have exactly been found in rather deep marine (epibathyal) environments where deposition was continuous. Similar oligotaxic turnovers have been observed with Cambrian trilobite faunas separating the biomeres of Palmer (1965, 1984) of which the successive ammonite faunas are an exact copy. Also ostracode faunas respond markedly to sea-level changes (van Harten & van Hinte, 1984).

So even the third-order global cycles of relative sea-level change (Vail et al., 1977, p. 85) have notable effects on the extinction rate and diversity of ammonites, particularly at the species level. This allows accurate dating of the boundaries of Vail's sechrons (Vail et al., 1977, p. 55) in continuously deposited sequences and stresses the importance of the 'depositional sequences' of Vail et al. (1977, p. 53) (= synthems of Chang, 1975) as natural, well-correlatable steps in the history of the Earth. The chronostratigraphical implications of these sequences reach far beyond that of mere unconformity-bounded units. The sedimentary and faunal responses in various parts of the world to global sea-level changes are used here as an additional correlation tool in the Tethyan-Boreal correlations. It is assumed here that the diversity changes are exactly isochronous with the sea-level fluctuations: the stratigraphic intervals in which ammonite extinction rates are greatest correspond with falls of the sea level, minima in the mumber of concurring ammonite species correspond with the lowest stand of the sea level, and the appearance and rapid diversification of many new faunal elements that follow these diversity minima correspond with the subsequent rise of the sea level. This isochrony should of course still be verified independently, but it seems a good approximation at the moment.

On account of the effects of the sea-level fluctuations on the ammonite diversity, the lowest stands of the sea level during the earliest Cretaceous were correlated (Fig. 1) with (1) the uppermost *Pseudosubplanites grandis* Subzone, (2) the uppermost *Berriasella picteti* Subzone sensu Hoedemaeker (1982, 1983, 1984, fig. 1) (= top of the stratotype of the Berriasian = level in the lower part of the *Berriasella callisto* Subzone in the French

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Fig. 1. Chart showing the tentative correlation of the Tethyan standard succession with several Boreal successions. The lacunas in the stratigraphic records of eastern England and Eastern Europe are more considerable than often assumed. Correlations with the Tethyan successions are apt to be wrong when these lacunas are not taken into account. Hiatusses in the non-marine record are difficult to assess: there may be hiatusses at the top of the Portland Stone and at the top of the Serpulite. The zonations for cypridean ostracodes (Anderson, in Morter, 1984), dinoflagellates (Davey, 1979, 1982), and calpionellids are added in the columns for S. England, E. England, and for SE. France/SE. Spain, respectively.

Stratigraphic correlation chart (columns, left to right): GLOBAL SEA LEVEL CHANGES (low – high), RUSSIAN PLAIN, N. SIBERIA / E. GREENLAND, CANADA (Buchia Zones), AGE, SE. FRANCE / SE. SPAIN (zonation of Thieuloy 1979), NW. GERMANY, E. ENGLAND, S. ENGLAND, W. SWITZERLAND.

GLOBAL SEA LEVEL CHANGES:
- basal Hauterivian global unconformity
- basal Valanginian global unconformity
- basal ("late") Berriasian global unconformity

RUSSIAN PLAIN: (not considered); radiatus; petschorensis; polyptychus; michalskii; hoplitoides; undulatoplicatilis; tzikwinianus (spasskensis); riasanensis; nodiger; subditus; fulgens; M. VOLGIAN p.p.

N. SIBERIA / E. GREENLAND: (non-marine) (hiatus); bojarkensis; ramulosus; michalskii; syztanicus; klimovskiensis; mesezhnikowi; tzikwinianus analogus; "praeananalogus Sz." and constans Subzone; "fedorovi beds" and kochi Sz.; kochi (upper part); kochi (lower part); sibericus/maynci; chetae; taimyrense; C. okensis; M. VOLGIAN p.p.

CANADA (Buchia Zones): (non-marine); crassicollis; sublaevis; keyserlingi; inflata-pacifica; tolmatschowi; uncitoides; B. okensis; aff. volgensis; terebratuloides; fischeriana; piochii s.s.; cf. blanfordiana; piochii s.l.

AGE: CRETACEOUS p.p. — JURASSIC p.p.; E. HAUTERIVIAN p.p.; VALANGINIAN (LATE, EARLY); BERRIASIAN (LATE, EARLY); RYAZANIAN (LATE, EARLY); VOLGIAN p.p.; TITHONIAN p.p.

SE. FRANCE / SE. SPAIN (zonation of Thieuloy 1979): radiatus; callidiscus; trinodosum; "verrucosum"; campylotoxus; trezanensis-pexiptychum; pertransiens; alpillensis; "callisto"; picteti; paramimouna; dalmasi; privasensis; subalpina; grandis; jacobi; "Durangites"; (radava; pervar; hungarica; tkompex/obl.; ellipticus; alpina; intern.; peta-oto-, otto-callisa to transversus)

NW. GERMANY: noricum; amblygonius; "Asteria" tuberculata; Dichotomites; Pro-dichotomites; Polyptychites; Platylenticeras; Wealden 6; Wealden 5; Wealden 4; Wealden 3; Wealden 2; Wealden 1; Serpulite; Mündener Mergel

E. ENGLAND: noricum; amblygonius (remanié); (remanié or condensed); Polyptychites; Panatella; albidum; stenomphalus; iceni; kochi; runctoni; lamplughi; preplicomphalus; primitivus; oppressus; anguiformis; etc.

S. ENGLAND: Weald Clay; Tunbridge Wells Sands; Wadhurst Clay; Hastings Sands; Ashdown Sands; Battle C. and Tyneham C.; Durdle C. to Mupes C.; Lulworth C.; Greenwood C. and Poxwell C.; Bacon C. and Studland C.; Scallop C.; Langton C. to Corfe C.; Royal C.; Croydon C. and Nothe C.; Cinder Beds C.; Lulworth Beds; Portland Stone p.p.

W. SWITZERLAND: Marne bleue; Marnes à Asteria; Couche de Villers; Calcaire roux; Marnes d'Arzier; F. de la Chambotte; F. de Vions; Marbre Bâtard; Unité oolitique inférieure; couches lacustres supérieures; intercalation marine moyenne; couches lacustres inférieures; couches dolomitiques inférieures; couches de Purbeck

Legend:
- Non-sequence
- Ph.J.Hoedemaeker 1987
- ———— Base of non-marine deposits   obl. = oblonga
- — ? — Stratigraphic position uncertain   interm. = intermedia
- pelli. = pelliferum
- ———— Base of marine deposits
- donisap. = donisipinata

sense), and (3) with the uppermost *Saynoceras verrucosum* Subzone (in the restricted sense of Thieuloy, 1973, 1979). The highest stands of the sea level were correlated with (1) the *Berriasella jacobi* Subzone, (2) approximately with the *Berriasella paramimouna/ Berriasella picteti* subzonal boundary, and (3) possibly with the lowest *verrucosum* Subzone. Relatively rapid sea-level rises, which correspond with widespread transgressions, occur approximately near (1) the base of the *paramimouna* Subzone, (2) in the *Busnardoites campylotoxus* Subzone, and (3) near the base of the *Acanthodiscus radiatus* Subzone.

The author proposed that the lower boundaries of the Berriasian, Valanginian, and the Hauterivian stages should coincide with the levels in which the first new faunal elements appear after the marked ammonite diversity minima: the base of the Berriasian with the base of the *Subthurmannia subalpina* Subzone (Hoedemaeker, 1981, 1982), the base of the Valanginian with the base of the *Tirnovella alpillensis* Subzone (Hoedemaeker, 1982, 1983, 1984), and the base of the Hauterivian with the base of the *Himantoceras trinodosum* Subzone (Hoedemaeker, 1982, 1983, 1984). The manco of Vail's coastal onlap curve is the defective dating and consequently the difficulty of tying the distinct unconformities on the curve to outcrops on land. In this paper the author merely identified and correlated marked supra-regional turnovers in the ammonite faunal successions, which were ascribed to marked low stands of the sea level. The correlation of these low sea-level stands with Vail's sea-level curve is uncertain.

Correlations between marine and continental facies

THE BERRIASIAN/VALANGINIAN BOUNDARY IN THE PURBECK-WEALDEN SEQUENCE (Fig. 2)

Correlation with the Tethyan succession

According to recent correlations by the author (Hoedemaeker, 1984) the basal Valanginian transgression started with the entry and rapid diversification of Valanginian ammonites at the base of the *Tirnovella alpillensis* Subzone, immediately after a marked minimum in the number of co-occurring ammonite species, which can be ascribed to a global low sea-level stand. This low sea-level stand was also the cause of the lacunas, clear signs of emersion, or at least clear signs of marked reduction of water depth reported at the Berriasian/Valanginian boundary in the fringe of the Fosse vocontienne (SE France) by Donze & Le Hégarat (1965, p. 3709), Le Hégarat & Remane (1968, p. 64), Le Hégarat (1971, p. 483), and Cotillon (1971). Signs of near-emersion are also manifest in 'bed 8' in the middle of the 'Formation de Vions' in the French Jura Mountains (Donze, 1973c, p. 132), which is a near-continental intercalation amidst fully marine beds. This bed, which is directly correlatable with beds containing the calpionellid *Lorenziella* (Donze, 1973a, p. 6; 1975, p. 186; *Lorenziella* ranges from halfway the *picteti* Subzone upward and provides a maximum age), appears to be a key bed in Tethyan-Boreal correlation, for it contains the ostracodes *Protocythere mazenoti* (erroneously referred to as *P. paquieri* in Arnaud et al., 1981, p. 128, and in Clavel et al., 1986, p. 329), and *Cypridea obliqua* s.s. Wolburg, and the miospore *Bullasporis aequatorialis* Krutzsch (= *Gemmatriletes morulus* Pierce) (Taugourdieau-Lantz & Donze, 1971, p. 103, pl. 1, fig. 10; Donze, 1969, 1973a, pp. 5, 6, 1973c, p. 132; Dörhöfer & Norris, 1977, pp. 60, 64).

MEDITERRANEAN MARINE STANDARD		FRENCH JURA	GERMANY	PURBECK-WEALDEN SEQUENCE	ENGLAND
pertransiens Subzone p.p.	*otopeta* Subzone	Bed 8 of the Form. de Vions (=near continental Intercalation amidst fully marine beds)	Wealden 5+6		Hastings
alpillensis Subzone	*callisto* Subzone		Wealden 4		Battle / Tyneham
picteti Subzone		● ● ● ●		E F	Durdle Tisbury Brede / Mupes
paramimouna Subzone			Wealden 3	? — D	Lulworth / Greenwood / Poxwell

Vertical taxon labels (left to right across columns):

Mediterranean: *Protocythere mazenoti* — *Lorenziella*

French Jura: *Protocythere mazenoti* — *Lorenziella* — *Cypridea obliqua* (typical variety) — *Bullasponis aequatorialis*

Germany: *Protocythere obliqua* — *Protocythere obliqua* (typical variety) — *Bullasponis aequatorialis*

A Beginning of widespread Berrisian transgressive phase
B Sea level high
C Sea level low

D Peak in frequency of *Classopollis*
E Extensive freshwater deposits in N.Germany
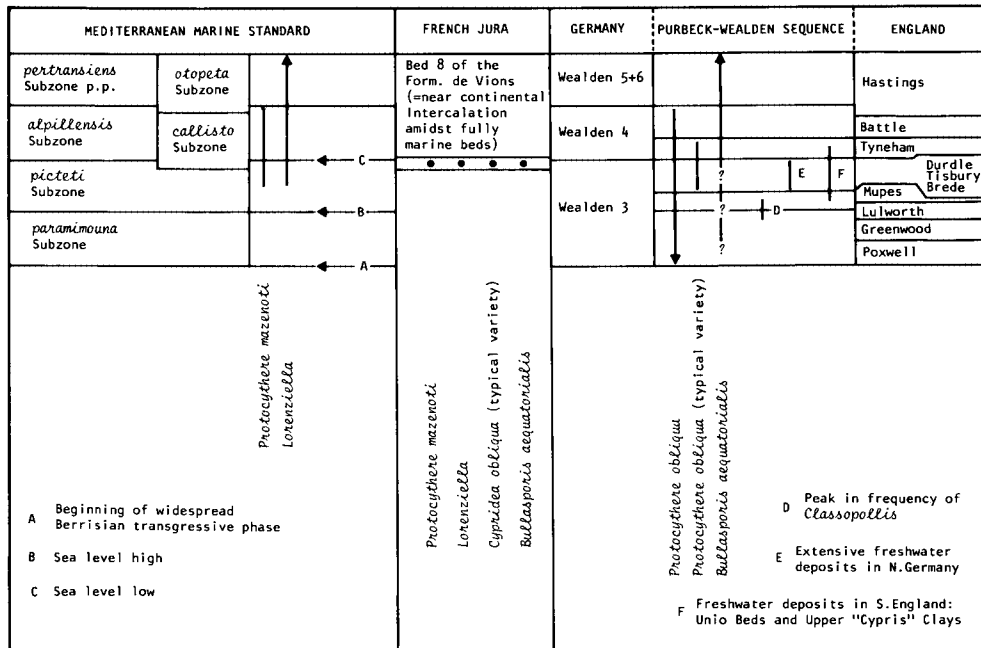F Freshwater deposits in S.England: Unio Beds and Upper "Cypris" Clays

Fig. 2. The meagre, but to my knowledge still the only available evidence for correlation of the Mediterranean Berriasian/Valanginian boundary with the Purbeck-Wealden sequence of England and Germany.

P. mazenoti ranges from a level within the *Berriasella picteti* Subzone up to the base of the *Tirnovella pertransiens* Subzone, where it is replaced by *P. paquieri* (Donze, 1973a, p. 6, 1975, fig. 1); it thus provides a minimum age. Bed 8 of the 'Formation de Vions' apparently represents the lowest stand of the Mediterranean sea level at that time and for that reason is interpreted to correlate with the base of the lowest Valanginian *alpillensis* Subzone. The 'Formation de Vions' thus probably bridges the Berriasian/Valanginian boundary sensu Hoedemaeker (1982, pp. 46, 62; 1983, p. 454; 1984).

The occurrence of *Calpionellopsis* sp. and of a poorly preserved *Berriasella* (whose ornamentation more resembles the straight-ribbed *B. jauberti* than the flexuously ribbed *B. moesica*, with which it has been compared by Clavel et al., 1986, p. 330, pl. 2, fig. 2) in the lower part of the 'Formation de Vions' does not make it necessary to attribute an older age to the formation as a whole (as was done by Clavel et al., 1986, fig. 7: upper *paramimouna* and *picteti* subzones), or to its base: *B. jauberti* and *Calpionellopsis* also occur in the upper part of the *picteti* Subzone and even higher (see Fig. 1).

Correlation with the Boreal succession

According to Anderson (Anderson & Bazley, 1971, p. 73) *C. valdensis valdensis* Wolburg, non Sowerby, should be incorporated in *C. obliqua* Wolburg. *C. obliqua* sensu Anderson ranges from the upper part of the middle Purbeck (Corfe faunicycle) up to the basal Hastings Beds in England (Anderson & Bazley, 1971, pl. 5) and from just above the base of Wealden ostracode unit 2 up to the top of unit 4 in northern Germany (Wolburg, 1959, figs. 8, 26; Wick & Wolburg, 1962, table 15). Consequently, bed 8 of the 'Formation de Vions' (= base of the *alpillensis* Subzone) should be older than the top of Wealden unit 4.

Bullasporis aequatorialis appears according to Dörhöfer & Norris (1977, pp. 60, 64) at the base of palynosuite Hils 3, but according to Dörhöfer (1979, text-figs. 2, 3a) at the base of his palynozone IV (= top of palynosuite Hils 3). Palynosuite Hils 3 is equivalent to Wealden unit 3. This means that the base of the *alpillensis* Subzone should be correlated with a level between the first appearance of *B. aequatorialis* (probably somewhere in Wealden unit 3) and the top of Wealden unit 4.

Wolburg (1959, pp. 283, 284) found the typical variety of *C. obliqua* sensu Wolburg) only in the lower part of Wealden unit 4, whereas Anderson (1962, p. 27) identified this variety from above the marine band of the Mupes faunicycle upward and Anderson & Bazley (1971, pl. 18, fig. 4) illustrated it from the Brede fauniclycle, which correlates with levels in the upper part of Wealden unit 3. If the typical variety of *C. obliqua* really has the restricted range as was suggested by Wolburg and Anderson, then the base of the Valanginian correlates with a level just below, at, or just above the base of Wealden unit 4. This has already been suggested by Taugourdieau-Lantz & Donze (1971, p. 103) and by Donze & Le Hégarat (1972, p. 517).

Perhaps the low sea-level stand that gave rise to bed 8 of the 'Formation de Vions' corresponds with the extensive fresh-water deposits just below the base of Wealden unit 4 (Wick & Wolburg, 1962, p. 200, table 14). The increase in the marine influence from the base of Wealden unit 4 upward (Wick & Wolburg, 1962, table 14) – in the Wealden units 5 and 6 the marine influences are preponderant – is a reflection of the slow rise of the sea level directly after the low stand. The renewed radiation of cypridean forms from the base of Wealden unit 4 upward (Wolburg, 1959, fig. 8) may reflect changing conditions due to this sea-level rise.

Conclusions

This suggests a more precise correlation of the base of the Valanginian with the base of Wealden unit 4 and with the approximate base of the Tyneham faunicycle of the English Purbeck Beds with which Anderson (1962, fig. 3) correlated the base of Wealden unit 4.

This correlation is supported by the ammonite evidence (Kemper et al., 1981, p. 305), which suggests that the upper part of the German 'Wealden' has already a Valanginian age.

If we interpret, in accordance with Herngreen et al. (1980, p. 361), the peaks in the abundance of the palynomorph *Classopollis* in the Dutch 'Wealden' as being 'near to the coast' and the abundant presence of *Botryococcus* as an indication of a fresh-water environment, then we may interpret the peak in the abundance of *Classopollis* intercalated in a *Botryococcus*-dominated sequence halfway Wealden unit 3 in the eastern Netherlands (Burger, 1966; Herngreen et al., 1980, figs. 2, 4) as an indication of a marked temporary gaining of the sea over the continent. This marked marine influence halfway Wealden unit 3 also occurs in northwestern Germany (Wick & Wolburg, 1962, table 14) and likely corresponds with the quasi-marine intercalation of the Lulworth faunicycle of the English Purbeck sequence (Anderson, 1962, fig. 3; Anderson & Hughes, 1964, p. 908; Kemper, 1973, table 1). This temporary extension of the sea could, in support of the correlation of the base of the Valanginian with the base of Wealden unit 4, well be correlated with the high sea-level stand around the Mediterranean *paramimouna/picteti* subzonal boundary, where the maximum in the number of concurring ammonite species also suggests a maximum extension of the sea. The euhaline marine incursion events of the Poxwell and Greenwood faunicycles (Morter, 1984, fig. 2) are nicely compatible with the widespread transgressive phase that begins at the beginning of

the *paramimouna* Subchron, whereas the fresh-water deposits on top of the Lulworth cycle, viz. the Unio Beds and the Upper 'Cypris' Clays (which comprise the Mupes to Tyneham cycles) were probably laid down during the low stand of the sea level in late *picteti* and earliest *alpillensis* times (Fig. 2).

It is relevant to note here that the base of Wealden unit 2 of northern Germany correlates through the entry of *Cypridea altissima* with the base of the Royal faunicycle of the English Purbeck Beds. The base of Wealden unit 3 correlates through the entry of *Cypridea rectidorsata* with the base of the Poxwell faunicycle.

In accordance with the views of Anderson (in Anderson & Bazley, 1971), the boundary between the Purbeck Beds and the Wealden in England is drawn at the top of the Battle faunicycle. Morter (1984, p. 228), however, prefers the base of the Lulworth cycle for this boundary.

It should be reminded that the major part of the German 'Wealden' (units 1, 2, 3, and the greater part of unit 4) correlate with the English Purbeck Beds; only the top part of unit 4 and units 5 and 6 correspond with the basal part of the English Wealden.

AGE OF THE CINDER BEDS (Fig. 3)

The Cinder Beds are situated at the boundary between cypridean ostracode assemblages 2 and 3 of Anderson (1973). This boundary is situated in the lower part of the old *C. granulosa fasciculata* Zone (Anderson & Bazley, 1971) and approximately halfway the new *C. granulosa* Zone (Anderson, in Morter, 1984). Anderson & Hughes (1964), Marek et al. (1974), and Anderson (1973) correlated the Cinder Beds with (1) the base of Wealden unit 1 in northern Germany (judging from the ostracodes it correlates with the boundary between the Serpulite Member and Wealden unit 1 at which the Peveril and Cinder Beds faunicycles seem to be missing or are condensed) and with (2) microfaunal horizon A of the Polish Purbeck deposits, but also with (3) the 'intercalation marine moyenne' high in the Purbeck beds of the Swiss Jura Mountains, which, like the Cinder Beds, seem to top the cypridean assemblage 2 reported by Anderson (1973, p. 106) from the 'couches lacustres inférieures'.

From the 'couches lacustres supérieures' above this marine intercalation Anderson (1973, p. 107) identified (Fig. 3) *C. tumescens* and *C. granulosa protogranulosa,* whose ranges concur in the English Purbeck Beds below, but also above the Cinder Beds (Anderson & Bazley, 1971, pl. 5). Near Feurtilles this interval yielded *C. granulosa fasciculata* and *Macrodentina mediostricta,* which only occur together in the beds above the Cinder Beds (Anderson & Bazley, 1971, p. 39).

Crucial, however, is the correlation of these beds with the Mediterranean marine standard sequence. The 'intercalation marine moyenne' probably belongs to the same general marine interlude near the top of the Purbeck beds in the Jura Mountain region as the marine intercalation in the upper part of the Purbeck beds in the Cluse de Chailles, near Menthières, and in the Mont Salève (Savoi, France). Although in the Cluse de Chailles *Cypridea dunkeri* has still been reported from 0.5 m above the marine intercalation (Donze, 1973b, p. 129), the latter should not necessarily be older than the Cinder Beds, which close the English range of *C. dunkeri.* This Savoian marine intercalation yielded (Fig. 3) the ostracode *Protocythere revili* (Donze, 1975, p. 185) and the ammonites *Pseudosubplanites lorioli, P. combesi,* and *Pseudoneocomites* ex gr. *allobrogensis-suprajurensis* (Arkell, 1956, pp. 85, 88; Donze, 1958, p. 132; 1973b, p. 129; Clavel et al., 1986, pp. 322-327) . The known ranges of these species do not cross the upper boundary of the *Pseudosubplanites grandis* Subzone (Le Hégerat, 1971, table 1; Donze, 1975, fig. 1; Hoedemaeker, 1982, encl. 1). Since these marine intercalations are here considered to
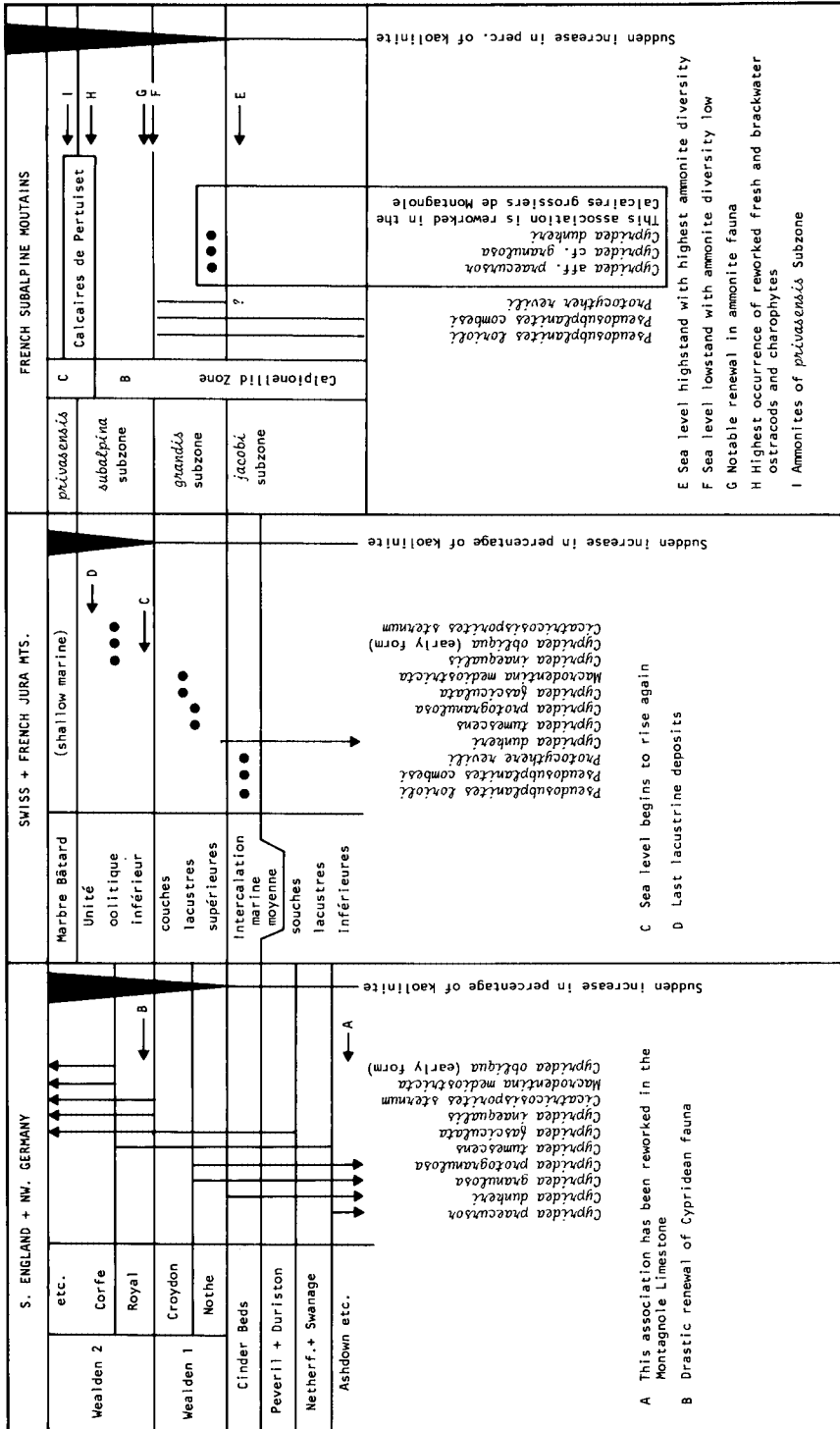
Fig. 3. The meagre evidence available for correlating the Cinder Beds of the English Purbeck Beds with the Tethyan standard succession and for correlating the Tethyan Tithonian/Berriasian (*grandis/ subalpina*) boundary with the Purbeck-Wealden sequence of England and Germany.

be of the same age as the Cinder Beds, the latter cannot be younger than the *grandis* Subzone.

From the 'calcaires grossiers de Montagnole' (Chartreuse Mountains, SE France) in the *grandis* Subzone (Le Hégarat, 1971, p. 460), Donze (1964, pp. 119, 120; 1965, p. 548) reported reworked *C.* aff. *valdensis praecursor* (= *C.* aff. *tumescens praecursor* in Anderson & Bazley, 1971, p. 89), *C.* cf. *granulosa*, and (Donze, 1973b, p. 130) *C. dunkeri*. This reworked cypridean association characterizes the lower part of the middle Purbeck below the Cinder Beds (Anderson & Bazley, 1971, pl. 5). Consequently, the minimum age of the Cinder Beds could at the most be slightly younger than that of the 'calcaires grossiers de Montagnole', still within the *grandis* Subzone. However, because of the reworking, the Cinder Beds may well be older!

The rapid decrease of the number of concurring ammonite species in the *grandis* Subzone (Le Hégarat, 1971; Hoedemaeker, 1981, fig. 1; 1982, pp. 17, 58, fig. 2) is an indication of the severe detorioration of the biotopes due to the rapid fall of the sea level after the high stand in the *Berriasella jacobi* Subzone with its high diversity in ammonite species. On account of the ammonite diversity curve the lowest stand of the sea level was reached in the late *grandis* Subchron. It seems obvious to assume that the 'intercalation marine moyenne', correlated with the Cinder Beds, coincides with the peak of the sea-level high in the *Berriasella jacobi* Subzone and that the overlying 'couches lacustres supérieures' correlate with the following sea-level low of the *grandis* Subzone. If this is true, the *jacobi* sea-level high would then have caused the deposition of the Cinder Beds, the Serpulite Member, the 'intercalation marine moyenne', etc. This would also mean that the deposits above these marine intercalations should necessarily be of younger, viz. *grandis* age.

This assumption is in accordance with, and checked by, the findings of Persoz & Remane (1976, figs. 10, 25), who found a sudden increase in the percentage of kaolinite at the base of the *grandis* Subzone of Le Chevallon, and halfway Remane's calpionellid zone B of the Bec de l'Echaillon (this is also near the base of the *grandis* Subzone, because calpionellid zone B comprises the *jacobi*, the *grandis*, and a part of the thin *subalpina* subzones). In the Swiss Jura Mountains this increase has been found at a slightly higher level, viz. near the base of the 'unité oolitique inférieur' (Fig. 3). A similar marked increase in kaolinite has been found by Sladen (1983, figs. 2, 5) and Sladen & Batten (1984) directly above the Cinder Beds in southern England and the Serpulite Member in northern Germany. This increase in kaolinite has been ascribed to a marked change in the midwest-European climat from warm semi-arid subtropical to warm humid-temperate. If this rapid increase of kaolinite took place at approximately the same time, as is assumed, it would imply that at least the greater part of the *grandis* Subzone indeed correlates with beds above the Cinder Beds. A *jacobi* age for the Cinder Beds seems therefore most plausible.

THE 'UNITE OOLITIQUE INFERIEUR'

The correlation of the Cinder Beds with the *jacobi* Subzone is supported by the inferred age of the 'unité oolitique inférieur' in the Jura Mountains. The latter should be younger than the Cinder Beds since it contains the miospore *Cicatricosisporites sternum* (Dörhöfer & Norris, 1977, p. 63), which according to Dörhöfer (1979, fig. 3a) starts its range in palynozone III directly above the Cinder Beds (Fig. 3). Oertli (1966, p. 95) reported *Cypridea inaequalis* and an early representative (same evolutionary stage as in Wealden

unit 2) of *C. valdensis* Wolburg, non Sowerby (= *C. obliqua* sensu Anderson) from the 'Oolitische Kalke und Mergel' (= 'unité oolitique inférieur') thus indicating a level slightly above the base of Wealden unit 2 and of the Corfe faunicycle of the English Purbeck, thus notably above the Cinder Beds. The fact that in the French subalpine mountains (Le Hégarat, 1971, p. 467, fig. 54, pp. 473, 474) the highest level with reworked fresh- and brackish-water ostracodes and charophytes occurs in the lower part of the 'calcaires grossiers du Col de Pertuiset' at the base of Remane's calpionellid zone C, which is situated (Hoedemaeker, 1982, p. 29) below the top of the *Subthurmannia (Strambergella) subalpina* Subzone, implies that the highest lacustrine and brackish-water deposits in the Jura Mountain region, which occur high in the 'unité oolitique inférieur', are probably not younger than the *subalpina* Subzone. The base of the so-called 'Marbre Bâtard' directly upon the 'unité oolitique inférieur' has been dated by Le Hégarat (1971, pp. 475, 482) and by Clavel et al. (1986, pp. 327-328) as middle *occitanica* Chron, i.e. *Berriasella privasensis* Subchron. The ammonites reported by Gidon (1948, p. 285) from the Col de Pertuiset were re-identified by Le Hégarat (1971, pp. 467, 468) and have been sampled from the top part of the 'calcaires grossiers' in the basal *privasensis* Subzone (Fig. 3).

The appearance and rapid diversification of an entirely new ammonite fauna in the *subalpina* Subzone in the Mediterranean region (Le Hégarat, 1971; Hoedemaeker, 1981, fig. 1; 1982, pp. 17, 58, fig. 2) indicates that new biotopes were created and that the sea level was already rising again. This may well be connected with the increasing marine influence during the deposition of the 'unité oolitique inférieur'. The major part of that unit may therefore have been deposited in *subalpina* times.

JURASSIC/CRETACEOUS BOUNDARY IN THE PURBECK-WEALDEN SEQUENCE

If the above correlations are approximately true, the boundary between the *grandis* and *subalpina* subzones, where Hoedemaeker (1981, p. 245; 1982, p. 64; 1983, p. 455) preferred to draw the Jurassic/Cretaceous boundary, may correlate with a level close to the base of the 'unité oolitique inférieur', which is the base of the type Neocomian and therefore the top of the Tithonian by definition (Oppel, 1865, p. 535) and hence with a level close to the boundary between Wealden units 1 and 2. The striking renewal of the cypridean assemblages, which sets in at the base of the German Wealden unit 2 (Wolburg, 1959, fig. 8) and in the Royal faunicycle of the English Purbeck beds (Anderson & Bazley, 1971, pl. 5), may be ascribed to the onset of the same rise of the sea level. The bases of Wealden unit 2 and of the Royal faunicycle are here correlated with the Jurassic/Cretaceous boundary as favoured by the author.

From these correlations can also be deduced that the whole of the Berriasian Stage falls within the range of *Cypridea obliqua* Wolburg, sensu Anderson. The equation of the Berriasian with the German Wealden units 2 and 3 seems reasonably close to reality.

The Ryazanian and the Boreal Valanginian in Europe

RIASANITES RJASANENSIS ZONE

This zone needs a separate chapter, because it is neither really Boreal nor really Tethyan and because its fauna is mainly endemic. It is bounded by the appearance and disappearance of *Riasanites*. Let us first evaluate its correlation with the Tethyan standard succession (Fig. 4).

Correlation with the Tethyan standard succession

In the Caucasus Mountains (Grigorieva, 1938; Sakharov, 1975, 1979, 1984; Kimchiashvili, 1976), and in The Crimea (Drushchits, 1975; Kvantaliani & Lysenko, 1979) *Riasanites* (or its subgenus *Tauricoceras*) has invariably been reported from beds overlying an interval with many representatives of *Dalmasiceras* and (in the Caucasus) with *Subthurmannia occitanica*; this interval is correlatable with the *Dalmasiceras dalmasi* Subzone.

In the Caucasus (Sakharov, 1975, p. 71; 1979, pp. 183, 184) the first doubtful *Riasanites* (later referred to as *Tauricoceras* by Sakharov, 1984, p. 39) has been sampled from the so-called *'Tirnovella' berriasensis* Subzone, exposed along the river Urukh. These *berriasensis* beds yielded besides *'T.' berriasensis* also the first *Euthymiceras*. Since Le Hégarat (1971, p. 132) and Kvantaliani & Lysenko (1979, pp. 630-632) have shown that *Euthymiceras* starts its range above beds with *Dalmasiceras punctatum* of the *dalmasi* Subzone and as Hoedemaeker (1982, pp. 33, 34) has shown that *Subthurmannia berriasensis* reaches into the *paramimouna* Subzone, these *berriasensis* beds had best be correlated with the lower *paramimouna* Subzone. This is in accordance with the views of Sakharov (1975, p. 73, table 2). However, it cannot be excluded that these beds correlate with the top part of the *dalmasi* Subzone. This depends on the exact entry of *Euthymiceras*, which is anyhow in the neighbourhood of the *dalmasi/paramimouna* subzonal boundary.

It is impossible to evaluate whether all ammonites referred to as *Euthymiceras* really belong to that narrow group around *E. euthymi* (Pictet). Some of them may belong to the *'E.' transfigurabilis* (Bogosl.) group (excluded from *Euthymiceras* by Le Hégarat, 1971, p. 130) or to the *'E.' transcaspius* (Lupp.) group (= type species of the genus *Transcaspiites* Luppov). Stratigraphically all three groups appear in beds that are younger than the *Dalmasiceras*-bearing beds of the *dalmasi* Subzone,
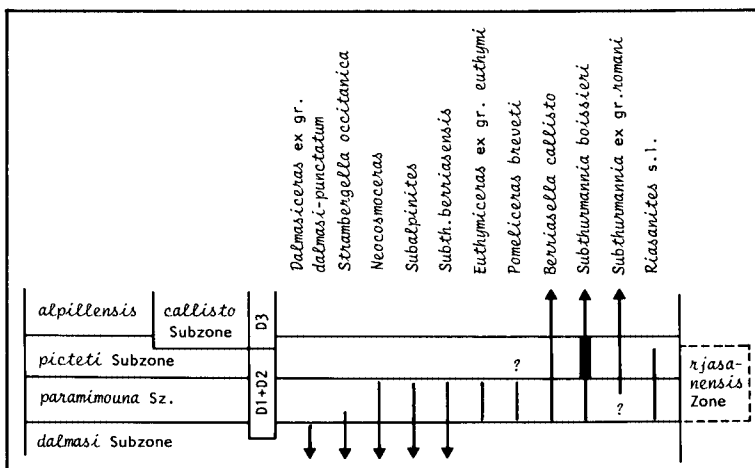

Fig. 4. Known ranges of the ammonites found in association with *Riasanites* s.l. There is no biostratigraphical evidence yet to assume that the *rjasanensis* Zone has a greater vertical extension than the one given in this figure.

which implies that any bed from which *Euthymiceras* has been reported cannot be detectably older than the *paramimouna* Subzone. The generic name *Euthymiceras* is used in this paper only when it has in some way been associated with the species name *euthymi*.

Also in Mangyshlak the first rare *Riasanites* occur in the lowest recognized unit of Berriasian age, the *Neocosmoceras* and *Septaliphoria semenovi* Local Zone, together with *Euthymiceras, Neocosmoceras,* some new forms of *Subalpinites,* and *Transcaspiites* (Luppov et al., 1975, p. 131; 1979, p. 160; 1984, pp. 45-51). According to the hitherto known Mediterranean ammonite ranges also this assemblage had best be correlated with the *paramimouna* Subzone, in which *Neocosmoceras* abounds and becomes extinct, *Subalpinites* has its acme, and in which *Euthymiceras* is supposed to begin (Le Hégarat, 1971, p. 132, tables 8, 14, 15; Kvantaliani & Lysenko, 1979, pp. 630-632).

In the Caucasus and in Mangyshlak, the species *R. rjasanensis* starts its range higher, in beds with the last representatives of *Neocosmoceras,* and with '*Euthymiceras*' *transfigurabilis,* in the Caucasus additionally with *Pomeliceras breveti,* and in Mangyshlak additionally with *Subthurmannia* cf. *romani* and *Calpionellopsis simplex* (Sazonova & Sazonov, 1983); these beds are also correlatable with the *Berriasella paramimouna* Subzone. In the Caucasus, *R. rjasanensis* has its acme in the upper part of its range together with *Berriasella callisto* and with the acme of *Subthurmannia boissieri,* which designates the *Berriasella picteti* Subzone (Le Hégarat, 1971, table 10; Hoedemaeker, 1982, encl. 3). However, calpionellid subzone D3, which begins in the topmost part of the *picteti* Subzone, has not been reported (Makareva, 1979, p. 169; 1984, p. 141) and may be absent, which suggests that these beds are still below the top of the *picteti* Subzone. In the Caucasus, Mangyshlak, and The Crimea, the Berriasian ammonite assemblage is separated from the Valanginian assemblage by a hiatus, as in the stratotype of the Berriasian.

The latest (still suspect) identifications (Marek, 1967; Dembrowska & Marek, 1975, p. 111; Marek & Raczyn'ska, 1979, p. 449; Marek, 1983, p. 58) of the Tethyan ammonites that occur together with *Riasanites rjasanensis* and *Riasanites* sp. in Poland also provisionally points to a correlation with the *paramimouna-picteti* subzones. Not one ammonite diagnostic for the *occitanica* Zone has been reported.

Concluding it can be stated that with respect to the ammonites there is no reason to assume that the base of the lower Ryazanian (= *rjasanensis* Zone) is detectably older than the base of the Tethyan *paramimouna* Subzone, nor that the top of the lower Ryazanian of the Russian plain would be younger than the top of the *picteti* Subzone sensu Hoedemaeker, 1982, 1984 (note: the top part of Hoedemaeker's *picteti* subzone is equivalent to the basal part of the French *callisto* Subzone, see Fig. 5). The *Neocosmoceras* and *Euthymiceras* from the basal *rjasanensis* Zone of the Russian Platform (Sazonova & Sazonov, 1983, p. 442, table 2; Mesezhnikov, 1979, pl. 1, fig. 1) do not contradict this correlation, nor do the *Spiticeras (Spiticeras)* sp. (= *Olcostephanus* cf. *pronus* in Bogoslovsky, 1897, pl. 4, fig. 5) and the *Berriasella* cf. *picteti* (= *Hoplites* cf. *privasensis* in Bogoslovsky, 1897, pl. 5, fig. 11). The Ryazanian transgression apparently entered the Russian plains and the Polish Furrow only when the sea level reached the high stands during the late Berriasian (= *paramimouna* and *picteti* subchrons).

The conspicuous turnover (Sazonova & Sazonov, 1983, p. 442, even use the term: biological eruption) from the lower Ryazanian ammonite assemblage with Tethyan affinities to the quite different upper Ryazanian assemblage with Boreal affinities in which *Surites* (and its subgenera), and *Peregrinoceras* predominate (Casey, 1973; Saks, 1975; Casey et al., 1977; Sazonova, 1977; Sazonova & Sazonov, 1979, 1983; Mesezhnikov et al., 1979; Mesezhnikov, 1984) thus seems to come about at the same time as the faunal

turnover in the Mediterranean region, viz. directly above the *picteti/alpillensis* subzonal boundary, where Hoedemaeker (1982, 1983, 1984) proposed to draw the base of the Valanginian. A comparable change from a Tethyan ammonite fauna (with *Spiticeras*) to a Boreal ammonite fauna (with *Surites*) took place in North America in the same time interval, i.e. between the early part of the *Buchia uncitoides* Zone and the late part of the *Buchia tolmatschowi* Zone on Vancouver Island (Jeletzky, 1965, 1984, p. 216). It is plausible to assume that these turnovers are due to the same global retreat of the sea and are contemporaneous. The contemporaneous southward shift of the Boreal faunas is in accordance with the theory of Kemper (1983) that the Valanginian was a relatively cool period.

Correlation of the Boreal succession

This involves the correlation of the *rjasanensis* Zone with the *Hectoroceras kochi* and *Buchia okensis* zones.

The correlation of the *rjasanensis* Zone with the *Hectoroceras kochi* Zone still poses problems. *H. kochi* has been found in the lower Ryazanian (according to Casey et al., 1977, pp. 15, 22, pl. 1, fig. 4, pl. 2, fig. 6; Mesezhnikov et al., 1979, pp. 76, 77, pl. 1, figs. 5, 7; Mesezhnikov, 1984, pp. 58, 64, in the lower part near Kuzminskoye and Kostino; according to Sazonova & Sazonov, 1983, p. 442, in the upper part, near Kostino). This only means that the ranges of *Riasanites* and *Hectoroceras* are overlapping, and therefore the almost general assumption that the entire *kochi* Zone falls within or should be equated with the *rjasanensis* Zone seems premature. According to the correlations given in the section on the *Buchia okensis* Zone, the *rjasanensis* Zone can only be equated with the upper part of the *kochi* Zone.

The presence of *Surites* in the *rjasanensis* Zone or in the Boreal *Hectoroceras kochi* Zone has explicitly been denied by Sazonova & Sazonov (1979a, p. 492; 1979b, p. 91; 1983; table 2; in Saks, 1975, p. 90). According to these authors the *rjasanensis* and *kochi* zones end with the appearance of *Surites*. The lowest beds with *Surites* on the Russian Platform contain only reworked *Riasanites*, whereas the forms of '*Surites*' mentioned from the Siberian *kochi* Zone (in Saks, 1975, pp. 22, 24, pl. 5, fig. 3, pl. 9, fig. 1, pl. 10, fig. 1) would not belong to *Surites* s.s. (hence the quotation marks). However, Mesezhnikov (1984, pp. 58, 64; Casey et al., 1977, p. 15; Mesezhnikov et al., 1979, pp. 73-79) persistently opposes this view by stressing the co-occurrence of *Riasanites* with *Surites* (which according to Casey, 1973, pp. 246, 250, includes '*Olcostephanus*' *suprasubditus* Bogosl.) on the Russian Platform, while Saks (1975, pp. 22, 24), Alekseev (1984, pp. 84, 87. 88, pl. 12, figs. 1, 2), and Surlyk (1973, p. 91; Surlyk et al., 1973, p. 59) described the co-occurrence of *Hectoroceras* with *Surites* in Siberia and Greenland. Although it is likely that reworking has taken place (cf. Casey, 1973, p. 220) in the extremely condensed sandstone unit (about 0.5 m thick with phosphorite nodules and erosion surfaces) that forms the boundary between the lower Ryazanian *rjasanensis* Zone and the upper Ryazanian *tzikwinianus* Zone, it seems that the presence of *Surites* below this boundary bed is well established now.

Anyhow, the strong increase in the number and diversity of *Surites* (and its subgenera) at the end of the *rjasanensis* Zone as well as of the *kochi* Zone is a conspicuous biostratigraphic phenomenon observable all over the Boreal Realm. As many of these *Surites* species are the same, near contemporaneity may be assumed for the top of the *rjasanensis* Zone and the top of the *kochi* Zone. This assumption implies that the *Surites analogus* Zone should largely correlate with the Tethyan *alpillensis* Subzone.

Finally it should be noted that according to Sazonova & Sazonov (1983, p. 445) the upper Volgian *Garniericeras* found in the basal horizon of the Ryazanian near Kuzmins-koye (Casey et al., 1977, pp. 15, 22, pl. 2, figs. 4, 5, 7; Mesezhnikov et al., 1979, pp. 76, 77, pl. 1, figs. 3, 4; Mesezhnikov,1984, pp. 58, 64) is reworked. In these beds reworked phosphatized ammonites can readily be distinguished from fossils in situ: the former are black, glossy, and rounded and have a P_2O_5-content that exceeds 20%, whereas the latter are in 'sandy-clay preservation' with less than 12% P_2O_5. The view of Sazonova & Sazonov is accepted here, because it explains the anomalous co-occurrence in this horizon not only of *Riasanites rjasanensis* with *Garniericeras subclypeiforme*, but also of *Buchia okensis* with *Buchia fischeriana* (Zakharov, 1981, pp. 225, 227). The latter co-occurrence compelled Jeletzky (1984, p. 237) to suppose that this unfigured *Buchia okensis* should be a *Buchia* n. sp. aff. *okensis*, which Zakharov synonymized with *B. okensis*. This would, however, mean that a few *B.* n. sp. aff. *okensis* – of which Jeletzky (1984, pp. 197, 205) wrote that it appears to be endemic on the North American Pacific slope and only migrated northward into the Arctic regions of that continent, but that it probably does not occur anywhere in northern Eurasia – would already early in its existence have migrated via the Arctic Canadian seaway to a secluded Eurasian spot far from its distribution area. This seems very unlikely. So it can safely be assumed that the *B. okensis* from the basal Ryazanian near Kuzminskoye is a true *B. okensis*. If this assumption is true, the base of the Ryazanian cannot be older than the appearance of *B. okensis* about halfway in the *Hectoroceras kochi* Zone (see below) as it is developed in Jameson Land, E. Greenland (Surlyk, 1973, p. 91).

The mere finding of *B. okensis* and *Riasanites* in situ in the basal horizon of the Ryazanian near Kostino gives no indication as to whether the base of the East-European Ryazanian can be correlated with the base of the *okensis* Zone. There are however two observations that are important with respect to the correlation of the *okensis* Zone.

Firstly, *Hectoroceras* (Casey et al., 1977, pp. 15, 22, pl. 1, fig. 4, pl. 2, fig. 6; Mesezhnikov et al., 1979, pp. 76, 77, pl. 1, figs. 5, 7) and *Buchia unschensis* (Mesezhni-kov et al., 1979, p. 76; Zakharov, 1981, p. 225) occur immediately on top of the basal Ryazanian layer. In Arctic Canada and E. Greenland the last *B. unschensis* and *B. terebratuloides* co-occur with the first rare *B. okensis* s.s. in the boundary beds between the *terebratuloides* and *okensis* zones (Jeletzky, 1984 pp. 223, 225; Håkansson et al., 1981, fig. 3; Surlyk & Zakharov, 1982, p. 749). In Siberia, the last *B. unschensis* occurs together with the first *B. okensis* in bed 16 of exposure 32 on the Paks Peninsula (Zakharov, 1981, pp. 116, 121). Thus the ranges of *B. unschensis* and *B. okensis* are slightly overlapping. This would suggest that the base of the East-European Ryazanian, which is close to the base of the *paramimouna* Subzone, would at least also be close to the base of the *okensis* Zone. It also would suggest that the entire *okensis* Zone is of *paramimouna* age, unless the specimens of *B. unschensis* from this bed are reworked too. This correlation is not contradicted by the occurrence of *B. okensis* in the Caucasus Mountains (Sakharov, 1975, pp. 70, 79), where it has been sampled only from beds correlatable with the upper *paramimouna* Subzone and/or the lower *picteti* Subzone, nor by its occurrence in Mangyshlak (Luppov et al., 1979, p. 162; 1984, pp. 51, 52), where it has been found together with *B. uncitoides* and *B. volgensis* in beds, which also correlate with the *paramimouna* Subzone.

Secondly, Jeletzky (1973, p. 60; 1984, pp. 237, 238) observed that the specimens of *B. okensis* figured in the literature from the Ryazanian along the river Oka (including the lectotype from the *Surites spasskensis* Zone), but also the specimens from the *Buchia volgensis* Local Zone in Mangyshlak (Luppov et al., 1979, pl. 2, fig. 4), which correspond with the upper *paramimouna* Subzone, are only comparable with late forms such as occur

in the topmost part of the Canadian *okensis* Zone and in the basal part of the overlying *uncitoides* Zone. This seems to suggest that the base of the Boreal *okensis* Zone is older than the base of the *rjasanensis* Zone and the *paramimouna* Subzone. This suggestion would imply that the Boreal *okensis* Zone includes at least a part of the Mediterranean *dalmasi* Subzone and that only the topmost part of the *okensis* Zone may be incorporated in the East-European Ryazanian and in the *paramimouna* Subzone. It also would imply that the entry of *B. okensis* in the Caucasus and Mangyshlak was notably belated and that the specimens of *B. unschensis* from the *Hectoroceras* bed near Kuzminskoye are reworked.

At this stage of the discussion we do not know which of these two correlations is correct. From these observations can nevertheless be gathered that the *B. okensis* Zone in any case occupies an interval in the neighbourhood of the base of the *paramimouna* Subzone: either just above, or just below (in the latter case only the basal part of the *paramimouna* Subzone may be included in the *okensis* Zone). In the section dealing with the *Buchia okensis* s.s. Zone it will be explained why these two observations are only seemingly contrasting and in fact support each other.

THE BERRIASIAN/VALANGINIAN BOUNDARY IN THE BOREAL MARINE SEQUENCE

The midwest-European *Platylenticeras* beds (with *Paratollia* and *Propolyptychites*) are correlated with the *Paratollia* beds in England (with *Platylenticeras, Propolyptychites, Pseudogarnieria, Menjaites*) and with the *Pseudogarnieria undulatoplicatilis* Zone in Eastern Europe (with *Menjaites*) (Casey, 1973, pp. 211, 223; Casey et al., 1977, p. 25; Kemper et al., 1981, pp. 278, 305), because these beds have several ammonite taxa in common. They directly follow beds that can be correlated with the top of the Ryazanian.

In SE France the occurrence of *Platylenticeras* is restricted to the stratigraphic interval that Thieuloy (1977, fig. 3) and Busnardo & Thieuloy (1979, table 3, p. 64) called the *Thurmanniceras pertransiens* Zone (Fig. 5). This is not the *pertransiens* Subzone in the original sense of Le Hégerat & Remane (1968), Le Hégarat (1971), and Thieuloy (1973), as shown by Hoedemaeker (1982, 1983). The latter subzone comprises the *otopeta* Zone of Thieuloy (1977) and approximately the lower part of the *pertransiens* Zone sensu Thieuloy (1977). The two different *pertransiens* zones have an overlap of 29 m in the Barret-le-Bas section (Fig. 6; compare Remane & Thieuloy, 1973, fig. 33, Busnardo, 1979, fig. 5, and Thieuloy, 1979, fig. 13), which is very confusing. In order to avoid confusion and to enhance stability in stratigraphic nomenclature Hoedemaeker (1982, 1983, 1984) used the *pertransiens* Subzone in its original sense and synonymized Thieuloy's '*otopeta* Zone' with the lower part of it. The interval between the original *pertransiens* Subzone and the *Busnardoites campylotoxus* Subzone was provisionally referred to as *Sarasinella trezanensis - Kilianella pexiptycha* Assemblage Zone. The lower boundaries of neither Thieuloy's (1977) '*pertransiens*' Zone nor Hoedemaeker's (1982) *trezanensis-pexiptycha* Assemblage Subzone (both biozones occupy nearly the same interval, Fig. 5) have been clearly defined in a biostratigraphical sense. The lowest occurring French *Platylenticeras, P. latum tenue*, has been interpreted to be derived from somewhere near this lower boundary (compare Thieuloy, 1973, table 2 and 1977, p. 401, fig. 3), but also characterizes the lowest part (*P. robustum* Zone) of the midwest-European *Platylenticeras* beds (Kemper, 1961, p. 82). There is thus no biostratigraphical reason yet to assume that the base of these *Platylenticeras* beds would correlate with a

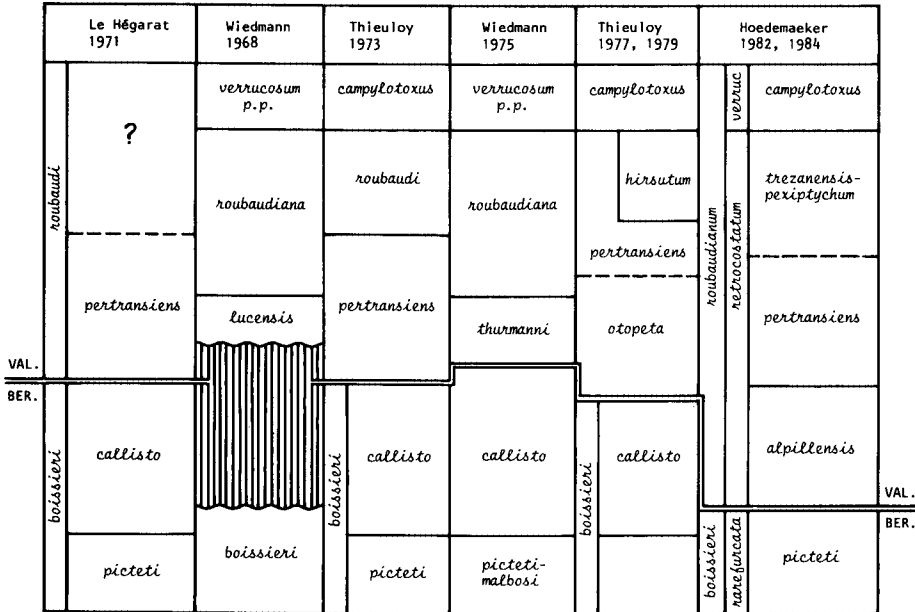|	Le Hégarat 1971	Wiedmann 1968	Thieuloy 1973	Wiedmann 1975	Thieuloy 1977, 1979		Hoedemaeker 1982, 1984	
roubaudi	*?*	*verrucosum p.p.*	*campylotoxus*	*verrucosum p.p.*	*campylotoxus*	*verruc*	*campylotoxus*	
		roubaudiana	*roubaudi*	*roubaudiana*	*hirsutum*	*roubaudianum* / *retrocostatum*	*trezanensis-pexiptychum*	
	pertransiens		*pertransiens*		*pertransiens*		*pertransiens*	
		lucensis		*thurmanni*	*otopeta*			
VAL. / **BER.**								**VAL.** / **BER.**
boissieri	*callisto*		*callisto*	*callisto*	*callisto*	*boissieri*	*alpillensis*	
	picteti	*boissieri*	*picteti*	*picteti-malbosi*		*narefurcata*	*picteti*	

Fig. 5. Several different zonations at both sides of the Berriasian/Valanginian boundary and their correlation. The lacuna on top of the Berriasian stratotype is indicated in the second column from the left. Note the different interpretations of the stratigraphic position of the Berriasian/Valanginian boundary.

level detectably below Thieuloy's (1977) latest concept of the *'pertransiens'* Zone (which includes the top part of the original *pertransiens* Subzone). This correlation is supported by the first appearance of dinoflagellates of the *Spiniferites ramosus* group not far above the base of the *Paratollia* beds in England (Davey, 1979, figs. 5, 6), but also close to the base of the *trezanensis-pexiptychum* assemblage in SE Spain (H. Leereveld, Laboratory of Palaeobotany and Palynology, Utrecht, personal communication).

This correlation implies however that at least the lower part of the Valanginian *pertransiens* Subzone (in the original sense), which is essentially equivalent to the *Thurmanniceras otopeta* Zone of Thieuloy (1977) (Hoedemaeker, 1982, pp. 26, 47, 61; 1983, p. 451), together with the Valanginian *Tirnovella alpillensis* Subzone of Hoedemaeker (1982, 1983, 1984), which is time-equivalent to the major upper part of the French *callisto* Subzone (not preserved in the stratotype of the Berriasian), comprise at least a large part of the upper Ryazanian (Fig. 1).

As the top of the lower Ryazanian is presumably not younger than the top of the *picteti* Subzone (see previous section), it also means that the boundary between the *picteti* and *alpillensis* subzones, which according to Hoedemaeker (1982, 1983, 1984) should be the Berriasian/Valanginian boundary, is stratigraphically closest to, if not coinciding with, the boundary between the lower and upper Ryazanian. This correlation is supported by the results of Kemper et al. (1981), who excellently demonstrated that the lowest part of the Valanginian extends below the *Platylenticeras* and *Paratollia* beds and is therefore time-equivalent with at least a part of the upper Ryazanian.

This correlation is also supported by the presence of Valanginian *Thurmanniceras* (= *T.* cf. *stippi* in Imlay and Jones, 1970, pl. 13, fig. 10, and *'Neocomites (Parandiceras) cf. rota'* in Jeletzky, 1964b, pl. 16, fig. 5, which is a true *Thurmanniceras*) in the basal part of the *Buchia pacifica* Zone, which can be equated with the upper part of the upper Ryazanian *mesezhnikowi* Zone (Zakharov, 1981, table 3; Surlyk & Zakharov, 1982,

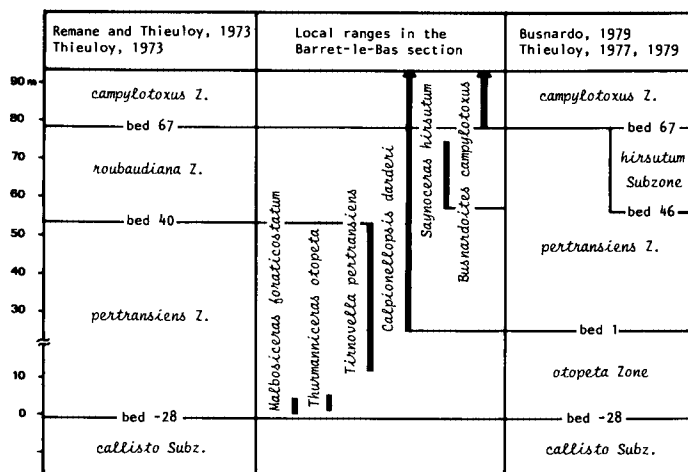| Remane and Thieuloy, 1973 Thieuloy, 1973	Local ranges in the Barret-le-Bas section	Busnardo, 1979 Thieuloy, 1977, 1979

Fig. 6. Stratigraphical relation between the *pertransiens* Zone sensu Thieuloy, 1973, and sensu Thieuloy, 1979, elucidated on the basis of one and the same section at Barret-le-Bas Les Sausses (Drôme, France).

table 3; Jeletzky, 1984, p. 217). The range of *Thurmanniceras* begins at the base of the *alpillensis* Subzone (Hoedemaeker, 1982, 1983), but this genus only becomes frequent at the base of the *pertransiens* Subzone.

Neither is this correlation in disaccord with the correlation (on unpublished palynological evidence) of the base of the South-English Hastings Beds with a level approximately in the middle of the East-Anglian *Surites stenomphalus* Zone (Rawson et al., 1978, fig. 3; Rawson & Riley, 1982, fig. 4). The base of the Hastings Beds also correlates with a level just below the top of the German Wealden unit 4 (Kemper, 1973; Anderson & Hughes, 1964; Anderson & Bazley, 1971), because of the co-occurrence of true *Cypridea wicheri* and *C. setina florida* with the last *C. obliqua* (= *C. valdensis valdensis* Wolburg, non Sowerby) and *C. tuberculata adjuncta* (= *C. jonesi* in Wolburg, 1959). The base of the *alpillensis* Subzone, which is closest to the base of Wealden unit 4 (see Fig. 3), should therefore be notably lower than the level halfway the *stenomphalus* Zone.

The slow rise of the Valanginian sea level, which started in *alpillensis* times, should also have caused the transgression in the North Sea Basin, usually called the 'late Kimmerian unconformity'. This transgression made feel its influence already at the base of the Upper Spilsby Sandstone in *Surites icenii* times in East England (Casey, 1973, p. 214; Rawson et al., 1978, p. 33; Rawson & Riley, 1982, p. 2634). The *icenii* Zone may therefore be interpreted as of earliest Valanginian age. If the *icenii* Zone really correlates with at least a part of the Siberian *analogus* Zone, as is generally assumed (Casey, 1973, table 2, p. 222; Casey et al., 1977, table 2, p. 23; Surlyk, 1978, table 1; Zeiss, 1983, table 1; Jeletzky, 1984, fig. 9), then this would be an independent support of our correlation of the basal Valanginian with the *analogus* Zone as was already inferred in the previous section. The basal Valanginian transgression apparently produced also the striking turnover from anaerobic to well-oxygenated bottom conditions at the base of the Valhall Formation in the subsurface of the North Sea. On palynological evidence the base of the Valhall Formation has been correlated by Rawson & Riley (1982, fig. 17) approximately with the base of the *Surites stenomphalus* Zone, by Birkelund et al. (1983, p. 68), however, with the 'lowest Valanginian' (= *Paratollia* beds). It is surmised here that, on

account of the dinoflagellates listed by Birkelund et al. (1983, p. 63), also ammonite zones below the *Paratollia* beds may be represented at the base of the Valhall Formation in the E-1 well. The concurrent range of *Scriniodinium pharo, Phoberocysta neocomica,* and *Pseudoceratium pelliferum,* for instance, is also time-equivalent with the *albidum* Zone (Davey, 1979, text-fig. 5). There may be some condensation at the base of the Valhall Formation and some mixing of the cuttings investigated from near the base of that formation, because of the apparent concurrence of species which should not concur.

The above correlations of the base of the Tethyan Valanginian in the Boreal region imply anyhow that the Ryazanian Stage straddles the Berriasian/Valanginian boundary. It had therefore better be abandoned as a stage name. The lower Ryazanian is of late Berriasian age (*paramimouna* and *picteti* subzones) and the upper Ryazanian of early Valanginian age (*alpillensis* and lower *pertransiens* subzones).

With respect to the global sea-level changes and the resulting unconformities it should be noted that the unconformity at the base of the Valhall Formation, the so-called 'late Kimmerian unconformity', has been named by Vail & Todd (1981, p. 231) the 'basal late Berriasian (133) unconformity'. The number between the brackets refers to the age in millions of years of the time scale of van Hinte (1976). In this time scale the absolute age of 133 Ma refers to the top of the *grandis* Subzone, which is considered the base of the 'late Berriasian' by van Hinte and Vail. As they equated the early and late Berriasian with the early and late Ryazanian respectively, they also correlated the base of the Valhall Formation with the top of the *grandis* Subzone. According to the correlations adopted here, however, the totality of the Berriasian Stage lies between the top of the *grandis* Subzone and the base of the Valhall Formation: the top of the Berriasian has thus been correlated with its base. This illustrates the inaccuracy of the age indications of Vail & Todd (1981) around the Jurassic/Cretaceous boundary. Recently, Vail et al. (1984) revised the ages of the various unconformities, but still equated the early and late Berriasian with the early and late Ryazanian, respectively. Not only the age of the 'late Kimmerian unconformity' at the base of the Valhall Formation has been changed into 'latest Berriasian (132)', but also its position on the coastal onlap curve: it now coincides with the lowest stand of their Cretaceous coastal onlap curve, which is the next higher unconformity than the one that Vail & Todd had identified as such in 1981. The 'early late Berriasian (133) unconformity', however, still exists and an extra 'mid early Berriasian (134) unconformity' has been introduced. It seems as if local North Sea noise has been interpreted as global signals.

THE VALANGINIAN/HAUTERIVIAN BOUNDARY IN THE BOREAL MARINE SEQUENCE (Fig. 7)

The author fully agrees with the excellent correlations between the Tethyan and Boreal Valanginian and Hauterivian by Thieuloy (1973, 1977, 1979) and Kemper et al. (1981): *Polyptychites* is restricted in SE France to the *campylotoxus* Subzone, *Prodichotomites* enters near the top of the *campylotoxus* Subzone and ranges through the '*verrucosum*' (sensu Thieuloy) and *trinodosum* subzones, and *Dichotomites* only occurs in the *trinodosum* and *callidiscus* subzones (see also Hoedemaeker, 1984, fig. 2). These correlations are corroborated by the presence of *Saynoceras verrucosum* and *Valanginites* in the lower (not the lowest) part of the *Prodichotomites* beds in N. Germany, and by the occurrence of *Dicostella, Oosterella,* and the first *Himantoceras*-like heteromorphs (*Juddiceras* and *Crioceratites?* sp.) in the German *Dichotomites* s.s. beds. The finding of *Acanthodiscus*

zones	ranges of ammonites and ostracodes in N.GERMANY, SWITZERLAND, ENGLAND	ranges of ammonites and ostracodes in S.E.FRANCE	subzones
noricum	*Acanthodiscus* *Leopoldia* *Eleniceras* *Crioceratitidae* *P.triplicata*	*Dicostella* *Eleniceras* *Acanthodiscus* *Leopoldia* *Crioceratitidae* *P.triplicata*	radiatus
amblygonium			
"Astieria"	*Dicostella* *P.frankei*		callidiscus
tuberculata			
Dichotomites	*Dichotomites* *Protocythere praetriplicata*	*Dichotomites* *P.frankei*	trinodosum
Pro-dichotomites	*Prodichotomites* *Saynoceras verrucosum* *Valanginites*	*Prodichotomites* *Saynoceras verrucosum* *Valanginites* *P.praetriplicata*	verrucosum
Polyptychites	*Polyptychites* *Platylenticeras latum tenue*	*Polyptychites* *Platylenticeras latum tenue*	campylotoxus
Platylenticeras	*Platylenticeras*	*Platylenticeras*	trezanensis-pexiptychum
Wealden 5+6			pertransiens

Fig. 7. Chart showing the ranges of Valanginian and lower Hauterivian ostracode species and ammonite genera and species that the Boreal and Tethyan realms have in common.

(*A. radiatus, A. ottmeri, A. vaceki*), *Leopoldia*, and *Eleniceras* (Kemper, 1976, p. 57, pl. 26, figs. 1, 2; Thiermann, 1963, p. 354) in the upper part of the *amblygonium* Zone and in the *noricum* Zone, correlates this interval with the Tethyan *radiatus* Zone.

The correlation on ammonites is confirmed by ostracodes (Bartenstein & Bettensteadt, 1962, fig. 18, table 17; Donze & Thieuloy, 1975, pp. 1661-1664; Donze, 1976, figs. 2-4): *Protocythere praetriplicata* occurs in the *Prodichotomites* beds and in the *verrucosum* Subzone, *P. frankei* appears in the *Dichotomites* beds and in the *trinodosum* Subzone, and the first *P. triplicata* has been encountered in the upper part of the Swiss 'Marnes à Bryozoaires', which are the equivalents of the 'Marnes à Astieria', and in the *callidiscus* Subzone.

Emphasis should be laid on the marked turnover in the fauna mentioned by Kemper (1978, pp. A1-23, A1-24: 'beträchtlicher Faunenschnitt') at the boundary between the *Prodichotomites* and *Dichotomites* beds in N. Germany, where the oxygen-poor *Ammovertella cellensis* foraminiferal assemblage changes into the oxygen-rich *Epistomina caracolla caracolla* foraminiferal assemblage, where true *Dichotomites, Crioceratites?, Oosterella,* and *Varlheideites* begin their ranges rapidly followed by those of *Juddiceras* and *Dicostella*, and where *Polyptychites* and *Euryptychites* become extinct.

Directly on top of the beds with *Homolsomites quatsinoensis* and *Buchia crassicollis* in British Columbia a specimen of *Valanginites* has been found (Jeletzky, 1973, p. 72, pl. 1, fig. 3). Since *Valanginites* does not occur above the 'verrucosum' Subzone (in the restricted sense of Thieuloy), the beds with *H. quatsinoensis* and *B. crassicollis* cannot be younger than this subzone.

Kemper and Jeletzky (1979, fig. 9) rightly correlated the *H. quatsinoensis-B. crassicollis* beds of British Columbia with: (1) the beds with *Ringnesiceras (Ringnesiceras) tozeri, R. (Elleficeras) ellefense, H.* cf. and aff. *quatsinoensis,* and *B. crassicollis* in the Sverdrup Islands; (2) the beds with *R. (R.) tozeri, H. bojarkensis* (a form very close to *H.* aff. *quatsinoensis* of the Sverdrup Isl.), and *B. crassicollis* in Siberia; and (3) the *R. (E.)*

petschorensis Zone in the Petchora basin, which probably also contains *R. (E.) ellefense*. They correlated however these *Homolsomites* beds also with the *Dichotomites* s.s. beds of N. Germany although these two sequences have no species in common. This correlation cannot be upheld since the German *Dichotomites* s.s. beds correlate with the Mediterranean *trinodosum* Subzone and are thus younger than the *'verrucosum'* Subzone (in the restricted sense of Thieuloy, 1973). The *Homolsomites* beds should therefore correlate with the upper part of the German *Prodichotomites* beds.

The above mentioned (Kemper, 1978) faunal turnover at the boundary between the Boreal *Prodichotomites* and *Dichotomites* beds is time-equivalent with the major faunal turnover at the boundary between the Mediterranean *'verrucosum'* and *trinodosum* subzones (Hoedemaeker, 1984, fig. 2). This boundary either correlates with non-sequences (Switzerland, E. England, Greenland, Eastern Europe; see Fig. 1), or with a change from marine to non-marine beds (Canada, Siberia). All these notable contemporaneous changes can be ascribed to a prominent lowering of the sea level. This marked boundary can be found world-wide and has been proposed as the boundary between the Valanginian and Hauterivian stages by Hoedemaeker (1982, p. 63; 1983, p. 455; 1984, pp. 142-145). The drastic renewal of the ostracode fauna at the base of the Wealden *Cypridea aculeata* Zone in England (Anderson, 1971, p. 130) is ascribed here to the same event.

Attempt at some intra-Boreal correlations (Fig. 8)

HECTOROCERAS KOCHI ZONE

Before we discuss the correlations between the Tethyan and Boreal realms in further detail, we should direct our attention to the intra-Boreal correlation of some ammonite assemblages (Fig. 8). In particular the correlation of the beds with *Hectoroceras*, united under the name *Hectoroceras kochi* Zone, poses some problems, because *Hectoroceras* occurs in two quite different ammonite assemblages (generic assignments, where possible, according to Casey, 1973, and Casey et al., 1977).

Hectoroceras kochi appears before *Borealites* and is at its appearance associated with *Shulginites tolijensis* and *S. pseudokochi* in the outcrops along the river Maurynya (northern Ural Mountains; Mesezhnikov et al., 1983, p. 105), or with the last representatives of the genus *Chetaites* in the outcrops along the river Kheta (Khatanga depression; Alekseev, 1984, pp. 84, 87: his *kochi* Subzone).

Along the northern trans-Uralian river Yatriya (in Saks, 1975, pp. 58, 60; Golbert & Klimova, 1979, p.37), for instance, *H. kochi* (referred to as *H. tolijense*, but according to Casey, 1973, p. 240, a form close to *H. kochi tenuicostatum*) occurs in large numbers together with a multifarious association of *Borealites* species (*B. federovi, B. radialis, B. explicatus, B. mirus,* and stratigraphically higher also with *B.? suritiformis*). Representatives of *Surites* or *Peregrinoceras* have been reported only from above these beds. Similar assemblages have been reported from the *kochi* Zone along the Yany-manya and Tolya rivers in the northern Ural Mountains (in Saks, 1975, pp. 69-74; Golbert & Klimova, 1979).

The assemblage of the East-Anglian *kochi* Zone (Casey, 1973, pp. 199, 200) is essentially the same: *H. kochi kochi, H. kochi tenuicostatum, H.* cf. *kochi magnum, H. larwoodi,* and *Borealites* cf. *fedorovi*.
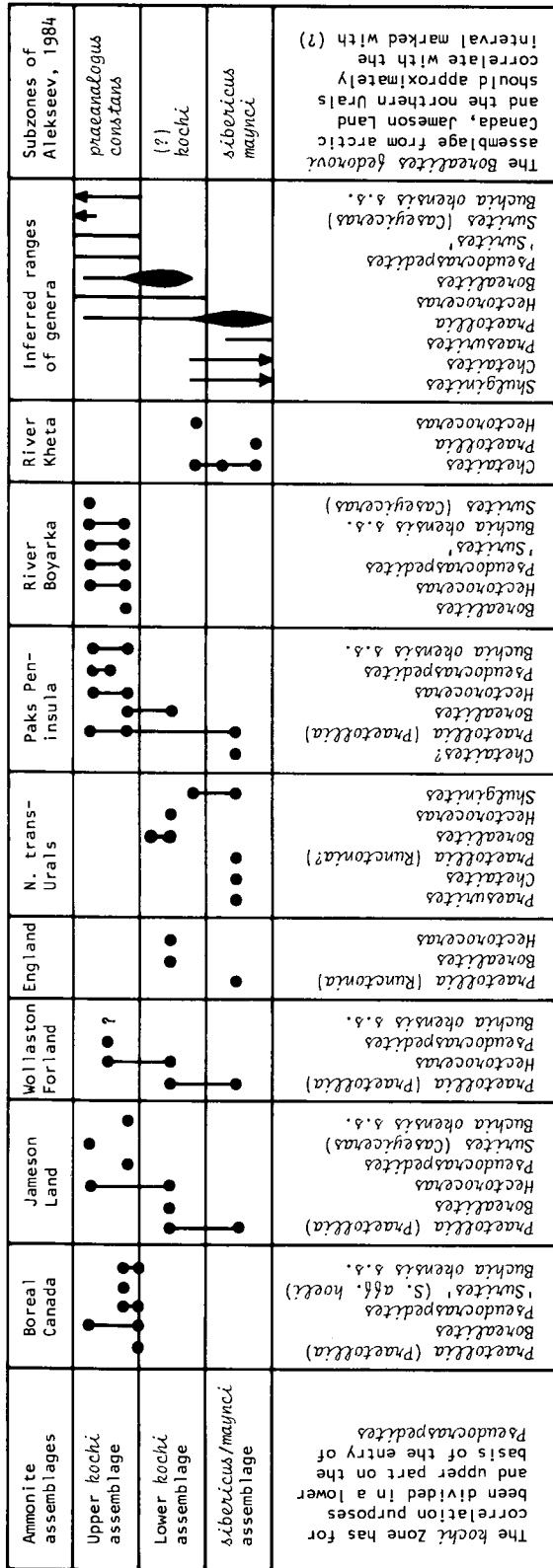
Fig. 8. Correlation of comparable faunal assemblages, which show the same successive order in various remote parts of the Boreal Realm (generic assignment according to Casey, 1973, and Casey et al., 1977) and ranges of ammonite genera deduced from these correlations. The *kochi* Zone can for correlation purposes conveniently be divided into a lower and an upper part on the basis of the absence or presence of *Pseudocraspedites* and '*Surites*'. The interrogation mark in the subzonal succession of Alekseev (1984) marks the stratigraphic position of the ammonite assemblage from the *Borealites fedorovi* beds in Canada, Jameson Land and the northern Ural Mountains. The range of *Ronkinites* is not marked.

Along the river Boyarka in the north-Siberian Khatanga depression (in Saks, 1975, pp. 22, 23, 24; Casey, 1973; Casey et al., 1977), however, *H. kochi* has been collected from an interval that yielded quite a different ammonite assemblage, viz. *Pseudocraspedites* (*Ps. anglicus, 'Subcraspedites plicomphalus'* Shulgina, non Sowerby, *'Peregrinoceras pressulum'* Shulgina, non Bogoslovsky, *'Peregrinoceras subpressulum'* Shulgina, non Bogoslovsky), *Ronkinites* (*R. rossicus*), *'Surites'* (*S. spasskensis, S.* cf. *tzikwinianus, S.* cf. *subtzikwinianus, S.* cf. *clementianus*), and only one species of *Borealites* (*B. 'suprasubditus'* Shulgina, non Bogoslovsky). From the lower part of the *Hectoroceras* beds along the river Boyarka (= Alekseev's *constans* Subzone), Alekseev (1984, p. 84, fig. 2) described in addition *'Surites (Surites)' furcatus, Borealites constans,* and *'Craspedites'* spp., whereas the upper part (= Alekseev's *praeanalogus* Subzone) additionally yielded *Surites (Caseyiceras) subquadratus, S. (C.) praeanalogus,* and the topmost part also *S. (C.) subanalogus.* It should be noted that Sazonova & Sazonov (1979a, p. 492) deny the presence of *Surites* in the *kochi* Zone, which throws doubt on the correctness of the generic assignment of the ammonites united here under *'Surites'*, while the presence of *Craspedites* above the base of the *sibericus* Zone is seriously doubted by many ammonitologists, hence the quotation marks.

On the Paks Peninsula (northern Siberia) the lower 4 m of the interval assigned to the *kochi* Zone yielded *H. kochi, Borealites* sp., *Praetollia maynci,* and *P. contigua,* the middle 3.5 m yielded *Pseudocraspedites* cf. *anglicus,* and from the upper 2.7 m were reported *H.* cf. *kochi, Pseudocraspedites* cf. *anglicus,* and *Praetollia* cf. *maynci* (in Saks, 1975, pp. 36, 37, 38; Casey et al., 1977, p. 31, pl. 2, figs. 8, 9). It should be noted here that this occurrence of *Praetollia*, if true, is the highest one (i.e. in the *Buchia jasikovi* Zone) ever mentioned for this genus.

In Jameson Land (E. Greenland) an association of *H. kochi, Borealites* cf. *antiquus* (= *B. fedorovi* according to Jeletzky, 1984, p. 233), and *P. maynci* (in the Crinoid Bjerg Member) is followed by an association (in the Muslingeelv Member) of *H. kochi, Pseudocraspedites* (= *'Subcraspedites* aff. *suprasubditus'* Jeletzky, non Bogoslovsky) and the first true *Buchia okensis,* and a little higher in the succession by an association of *H. kochi* and *Surites* aff. *poreckoensis* (Surlyk, 1973, p. 91; Surlyk et al., 1973). Also in Wollaston Forland (E. Greenland) (Surlyk, 1978, pp. 31, 32) *H. kochi* co-occurs in the lower part of its range with *Praetollia maynci* and is halfway its range associated with *Pseudocraspedites anglicus.*

It seems that, within the interval in which *Hectoroceras* can be found, beds with *Borealites* and/or *Praetollia* without *Pseudocraspedites* or *'Surites'* are invariably followed by beds with *Pseudocraspedites* and/or *'Surites'* and with a few last *Borealites* or *Praetollia*, thus dividing the *kochi* Zone into a lower and an upper part, provisionally on the basis of the entry of *Pseudocraspedites.*

Alekseev (1984, fig. 2) has recently divided the *kochi* Zone into 3 subzones: a lower *Hectoroceras kochi* Subzone, a middle *Borealites constans* Subzone, and an upper *Caseyiceras praeanalogus* Subzone. Because of the absence of *Borealites, 'Surites',* and *Pseudocraspedites,* the lowest subzone belongs to the lower part of the *kochi* Zone as it is understood in this paper, whereas the middle subzone, which contains *Pseudocraspedites* and *'Surites'*, already belongs to the upper part of the *kochi* Zone as it is understood in this paper.

However, the assemblage of *H. kochi* with *Praetollia* and *Borealites,* but still without *Pseudocraspedites* and *'Surites'* (as it occurs in the northern Urals and in eastern Greenland), has not yet been reported from the Boyarka and Kheta rivers. This assemblage, which in this paper will merely for convenience sake be referred to as *'Borealites fedorovi* assemblage', should be sought for between the *kochi* Subzone along

the river Kheta and the *constans* Subzone along the river Boyarka.

In this respect it should be noted that in Artic Canada no *Hectoroceras* has been found yet, but that in several localities in the Sverdrup Islands and northwestern Canada an ammonite succession has been found very similar to, and correlatable with, the succession in the *kochi* Zone of Jameson Land (Jeletzky, 1964b, pls 1-3, table 1; 1973, pp. 47, 50, 53, fig. 3; 1982, p. 13; 1984, pp. 223-225, 233). In these localities the uppermost beds of the *Buchia terebratuloides* Zone also yielded *Borealites fedorovi* (= *B. antiquus*) and *Praetollia maynci* var. *aberrans*. The only other ammonite found was referred to as *Ronkinites* n. sp. aff. *rossica* (Jeletzky, 1984, p. 223). These beds lie without apparent hiatus just below the basal beds of the *Buchia okensis* s.s. Zone, which, as in Jameson Land, yielded *Pseudocraspedites* (= Jeletzky's (1964b) '*Craspedites (Subcraspedites) aff. suprasubditus*' and '*C. (S.) aff. spasskensis*'). In addition these beds yielded ammonites at first referred to as '*Craspedites (Subcraspedites) aff. hoeli* (Freb.)' (Jeletzky, 1964b, pl. 3, figs. 1, 3; 1971, fig. 2; 1973, p. 53; 1974, fig. 2), but later synonymized with *Borealites? suritiformis* Klimova (Jeletzky, 1982; 1984, p. 235). This Canadian ammonite seems however closest to the forms of '*Surites*' mentioned in Saks (1975) from the *kochi* Zone along the river Boyarka. The lower part of the *Buchia uncitoides* Zone in northwest Canada yielded an ammonite form referred to by Jeletzky (1958, pp. 6, 46; 1964a, pl. 4, figs. 8, 11; 1973, p. 56) as '*Tollia* cf. *payeri*', which Casey (1973, p. 244) incorporated in *Borealites*. If this is true, it is the highest occurrence ever mentioned for this genus.

As this faunal succession is repeated in several places, it strongly suggests that the entry of *Pseudocraspedites* is stratigraphically close to the entry of true *B. okensis*. On the Mackenzie King Island, however, *Pseudocraspedites anglicus* has been collected just below the base of the *okensis* Zone (Jeletzky, 1984, p. 225). This means that *Pseudocraspedites* enters presumably slightly below the base of the *okensis* Zone, but it also means that the lower *kochi* Zone, as conceived here, is older than the *okensis* Zone. It should be noted that the *B. terebratuloides/B. okensis* boundary beds, in which the last *B. unschensis* occurs together with the first rare true *B. okensis*, are in Canada included in the *B. terebratuloides* Zone, in Siberia however in the *B. okensis* Zone (Fig. 10).

Thus also the base of the *okensis* Zone cuts the range of *Hectoroceras* into two, perhaps unequal parts, as was already rightly assumed by Jeletzky (1982, p. 14).

This would explain the absence of *B. okensis* in beds that are here provisionally assigned to the lower *kochi* Zone, viz. Alekseev's *kochi* Subzone along the river Kheta, the *kochi* Zone along the Yatriya, Yany-manya, Maurynya, and Tolya rivers, the East-Anglian *kochi* Zone, the *kochi* beds of the Crinoid Bjerg Member, the *Borealites fedorovi* beds on the Sverdrup Islands, and at least a part of the lower 30 m of the *kochi* Zone in Wollaston Forland. To the upper *kochi* Zone were provisionally assigned: the *kochi* beds of the Muslingeelv Member, at least the upper 30 m of the *kochi* Zone in Wollaston Forland, the *Buchia okensis* Zone on the Sverdrup Islands, and the *kochi* beds along the river Boyarka (= Alekseev's *constans* and *praeanalogus* subzones). Though *Pseudocraspedites* has been found only in the middle part of the *kochi* Zone of the Paks Peninsula, the totality of that zone correlates only with the upper *kochi* Zone, because many *Buchia okensis* have been mentioned from its base upward (Zakharov, 1981, p. 121, exposure 32, bed 16 and exposure 31, bed 1). A tentative correlation is shown in Fig. 8.

Whenever the *kochi* Zone is used in correlation tables, one should ask oneself which *kochi* Zone stood model: the upper *kochi* Zone of the river Boyarka in northern Siberia, the lower *kochi* Zone of the northern Ural Mountains, or the entire *kochi* Zone of eastern Greenland.

CHETAITES SIBERICUS ZONE

The ammonites reported in Saks (1975, pp. 15-18) as being derived from the type section of the *Chetaites sibericus* Zone along the river Kheta in the Khatanga Depression are: *Hectoroceras* (according to Saks, 1975, p. 15, in the lower 4 m, according to Casey et al., 1977, p. 22, however, in the upper part), doubtful *Praetollia, Borealites* (*B.* cf. *suprasubditus* Shulgina, non Bogoslovsky), *Pseudocraspedites* ('*Subcraspedites*' ex gr. *anglicus*), several forms of '*Surites*' (*Surites* sp., *S.* cf. *tzikwinianus, S.* aff. *tzikwinianus*) and '*Argentiniceras?*' (of uncertain systematic position). This assemblage can hardly be distinguished from the assemblage considered characteristic for the upper *kochi* Zone along the river Boyarka except for the presence of a few forms of Volgian affinity, viz. *Chetaites* sp. (collected in situ), *Ch. sibericus*, and '*Paracraspedites stenomphaloides*' Shulgina, non Swinnerton (which Casey et al., 1977, p. 25, assigned to *Taimyrosphinctes*); the latter two were not collected in situ. The composition of the *sibericus* assemblage described in Saks (1975) is highly anomalous and cannot be equated with any other known ammonite assemblage.

However, Alekseev (1984, p. 82) has, on the basis of much newly collected material, drastically changed the picture sketched above of the *sibericus* Zone (Fig. 8). In the lowest 3 m of the Kheta section he found *Praetollia* (*P. maynci, P. dispar, P. singularis*), Runctonia (*R. bukatyi*), *Pachypraetollia* (*P. crassus*) together with *Chetaites sibericus*. The middle 1.5 m yielded *Chetaites*, whereas the upper visible metre of the section yielded the first *Hectoroceras kochi* still together with *Chetaites*. Alekseev transferred this upper part into the *kochi* Zone. This makes the *sibericus* Zone equivalent to the *maynci* Zone in Greenland, which begins with the entry of *P. maynci* and ends with the entry of *H. kochi* (Surlyk, 1978, p. 31). According to the range charts of Alekseev *Hectoroceras, Borealites, Pseudocraspedites*, and '*Surites*' do not occur in the *sibericus* Zone.

The *sibericus* Zone is also exposed along the river Yany-manya in the near-polar trans-Urals, where *Chetaites sibericus* has been found in situ together with *Praetollia (Runctonia?)* sp. below the first occurrence of *Hectoroceras* and *Borealites* (Casey et al., 1977, pp. 26, 31, pl. 1, fig. 3, pl. 2, fig. 3); Mesezhnikov et al. (1983, pp. 104, 105) described *Praesurites elegans*, *Praetollia singularis, P.* aff. *maynci*, *Shulginites tolijensis*, and *S. pseudokochi* from the *sibericus* Zone along the river Maurynya of the same region.

The ammonite assemblage collected from the interval assigned to the *sibericus* Zone in the Paks Peninsula consists of *Praetollia maynci, P. contigua, Borealites bodylevskii*, and a doubtful specimen referred to as *Chetaites* (?) sp. (in Saks, 1975; Casey et al., 1977, p. 31, pl. 2, figs. 8, 9). Because of the absence of *Hectoroceras*, which has only been found directly above these beds, a part of this interval may correlate with the *Praetollia maynci* Zone. However, a part of it should also correlate with the lower *kochi* Zone, because of the presence of *Borealites*, which has its acme in the lower *kochi* Zone, and because of the entry of *B. okensis* directly above the top of that interval (Zakharov, 1981, p. 121), which indicates the upper *kochi* Zone (see foregoing section).

If *Runctonia* can really be considered a subgenus of *Praetollia* (Casey et al., 1977, p. 31; Alekseev, 1984, p. 102) instead of a *Taimyroceras* (Jeletzky, 1979, p. 6; 1984, p. 230), then the correlation of the East-Anglian *Runctonia runctoni* Zone with the *maynci* Zone seems the most appropriate.

In order to avoid confusion the zone between the top of the *chetae* Zone and the base of the lower *kochi* Zone (i.e. below the appearance of *Hectoroceras)* will in this paper be referred to as *sibericus-maynci* Zone.

Marine Tethyan-Boreal correlations (Figs. 9-10)

The most reasonable correlations of the two *kochi* assemblages with the standard Tethyan succession can be done only via the *Buchia* assemblage zones of North America and Greenland thanks to the co-occurrence of ammonites of Tethyan affinity and buchias of Boreal affinity in the upper Tithonian and Berriasian of California, Oregon, and British Columbia. It has to be expected that the local ranges of the ammonites in the sparsely ammonitiferous sequences of these countries, could not by far be a reflection of their total ranges; they had best be regarded as weak representations of peak occurrences elsewhere. This should be born in mind when correlating.

As the main problem in the correlation of the *kochi* assemblages pivots around the age of the base of the *Buchia okensis* s.s. Zone in terms of the Tethyan standard subdivision, it appears better to deviate in our discussion from the normal stratigraphic order and to try to demarcate the interval under consideration first from above and after that from below.

BUCHIA UNCITOIDES S.L. ZONE

Because of the palaeobiogeographic distribution of *B. okensis*, which is extremely rare in California but frequent in Canada where it characterises a separate zone, there are two different concepts of the *uncitoides* Zone, viz. the wide (Californian) concept of Jones et al. (1969) and the restricted (British Columbian) one of Jeletzky (1950) (Fig. 11).

The wide concept

In Oregon and California the lower two-thirds of the *uncitoides* Zone sensu Jones et al. (1969) contain (Imlay & Jones, 1970): *Spiticeras (Spiticeras)* cf. *S. (S.) cautleyi, S. (S.)* cf. *S. (S.) serpentinum, S. (S.)* cf. *S. (S.) uhligi, S. (Kilianiceras)* sp. juv., *S. (Negreliceras) stonyense, Neocosmoceras euchrense* and *N.? crossi*. The upper third did not yield any ammonite. This ammonite assemblage does not permit a precise correlation with the Mediterranean standard.

The genus *Spiticeras* s.l. in the Mediterranean province is particularly frequent in the *paramimouna, picteti,* and *alpillensis* subzones and has its undoubted frequency peak in the *picteti* Subzone (Le Hégarat, 1971, table 16; Hoedemaeker, 1982, encl. 2, 3). As 'Negreliceras' *praenegreli* Djan. from the *jacobi* Subzone had better be included in *Proniceras* (Hoedemaeker, 1981, p. 246, note 13; 1982, p. 69, note 12), the first true *Negreliceras* appears in the *subalpina* Subzone; it becomes extinct in the *alpillensis* Subzone. The greatest frequency of *Neocosmoceras* in the Mediterranean province is in the *privasensis, dalmasi,* and *paramimouna* subzones. This genus also begins in the *subalpina* Subzone and has not been found above the *paramimouna* Subzone (Le Hégarat, 1971, table 8).

The presence of *Neocosmoceras* indicates therefore that the base of the Californian *uncitoides* Zone is older than the top of the *paramimouna* Subzone. The presence of *Negreliceras* with certainty from 390 m above the base upward (USGS Mesozoic locality M4066, Imlay & Jones, 1970, pp. 26, 35, pl. 4, figs. 11-13) indicates that at least the upper three-quarters of the Californian *uncitoides* Zone are younger than the base of the Mediterranean *subalpina* Subzone. The relatively great frequency of *Spiticeras* is an
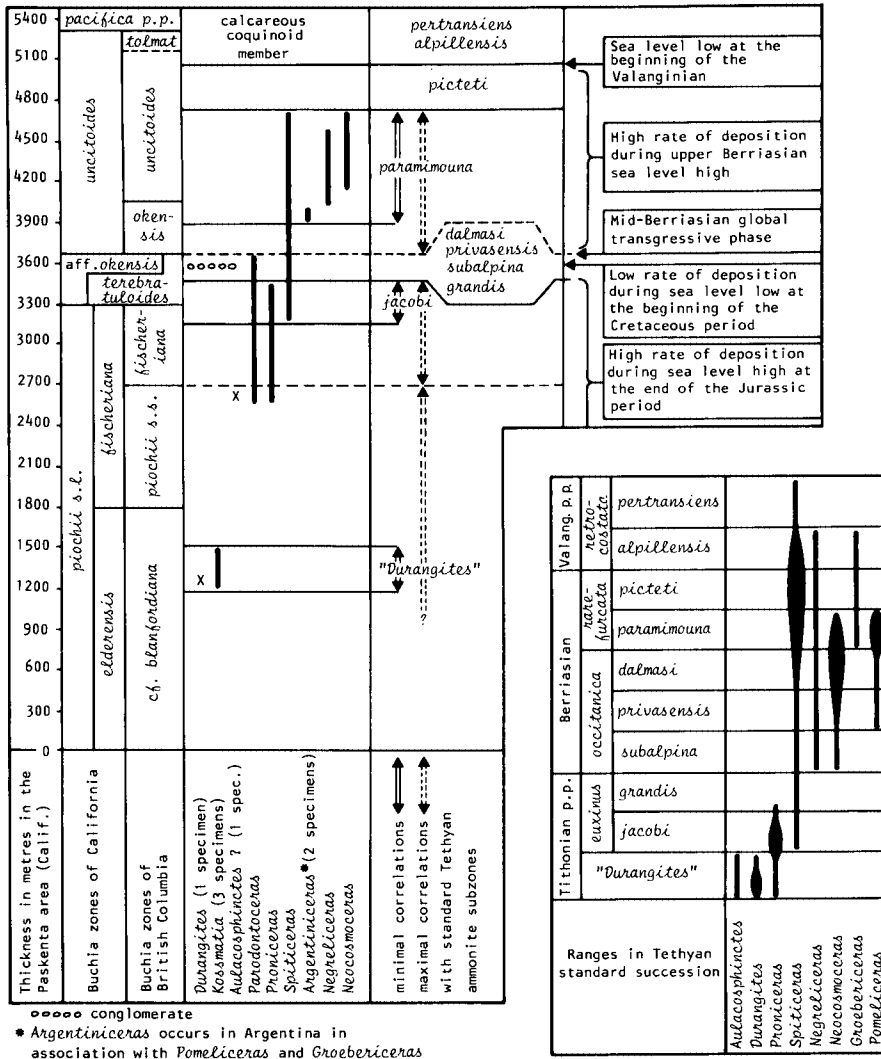
Fig. 9. Correlation chart of the western North-American *Buchia* zones with the Tethyan standard succession. The thicknesses given for the various *Buchia* zones are those of the Paskenta area in California. The ranges of the ammonite genera are given according to the positions mentioned for the various USGS Mesozoic localities (Jones et al, 1969; Imlay & Jones, 1970). Only those genera are given that permit a correlation with the Mediterranean standard succession. This figure clearly shows the inaccuracy of the Tethyan-Boreal correlations, and also the different rates of deposition. The very low rate of deposition just below the lower boundary of the *okensis* Zone may be the explanation why that boundary has generally been favoured as the Jurassic/Cretaceous boundary. However, the upper third of the *terebratuloides* Zone probably correlates with the totality of the *Strambergella occitanica* Zone. The base of the *Strambergella subalpina* Subzone, which is the position of the Jurassic/Cretaceous boundary preferred by the author, should be drawn slightly above the level with the last *Proniceras*.

Fig. 10. Ranges of the stratigraphically important *Buchia* species and the probable correlation of the *Buchia* zones distinguished by Jeletzky (1984) with those of Zakharov (1981). Our interpretation is that strata contemporaneous with (probably a large part of) the *piochii* s.s. Zone of British Columbia are not present in northern Siberia.

RANGES OF BUCHIA SPECIES IN BRITISH COLUMBIA ACCORDING TO JELETZKY (1984) AND IN NORTHERN SIBERIA ACCORDING TO ZAKHAROV (1981)
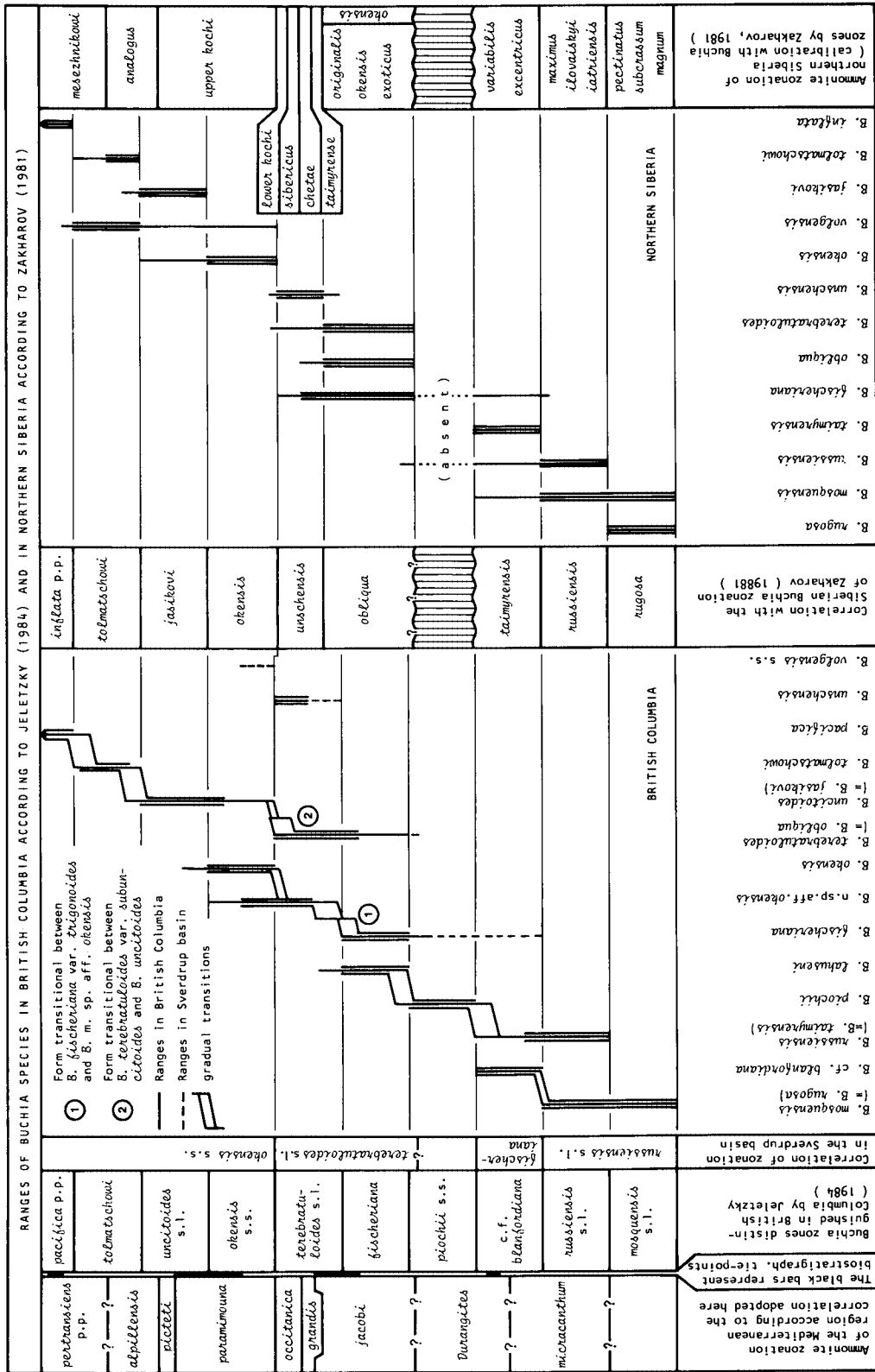
indication that the base of the *uncitoides* Zone sensu Jones et al. (1969) may not be much older than the *paramimouna* Subzone.

The restricted concept

Correlation with the Tethyan succession — Jeletzky (1984, pp. 207, 208, 211, 214, 217) has convincingly shown that the Californian *uncitoides* Zone sensu Jones et al. (1969) comprises besides the *uncitoides* s.l. Zone in the restricted sense of Jeletzky also the overlying *Buchia tolmatschowi* Zone and the underlying *Buchia okensis* s.s. Zone (Fig. 11). The latter comprises at least the lower 390 m (= lower quarter) of the Californian *uncitoides* Zone (USGS Mesozoic locality M4066, Jones et al., 1969, pp. A2, A13), for at the 390 m level a few specimens of *Buchia okensis* s.s. have been found. They are associated with *S. (Negreliceras) stonyense*, which implies that the top of the *Buchia okensis* s.s. Zone is younger than the base of the *subalpina* Subzone.

On western Vancouver Island the lower three-fifth of the rock interval occupied by the restricted *uncitoides* s.l. Zone sensu Jeletzky yielded a Tethyan ammonite assemblage identified by Jeletzky (1964a, 1965, 1984, pp. 214, 215) as: *Spiticeras (Spiticeras)* cf. *scriptum*, *S. (S.)* cf. *mosjvari*, *S. (Negreliceras) stonyense* (formerly referred to as *Spiticeras (Spiticeras)* sp.), *S. (Groebericeras)* sp. indet.?, *Neocosmoceras* sp. (formerly referred to as *Berriasella (Protacanthodiscus)* sp. nov. aff. *B. (P.) micheicus*), and *Neocomites* (s.l.) sp. nov. indet. The generic position of the strange '*Neocomites* (s.l.)' cannot be ascertained yet, whereas the specimen of '*Groebericeras*' is too evolute to belong to that subgenus; it may be a *Negreliceras*. Although Enay (1973, p. 305) observed that the inner whorls of *Spiticeras ('Spiticeras')* sp. are reminiscent of *Proniceras*, the nodular swellings on the umbilical rim separate this form from that subgenus and range it convincingly into *S. (N.) stonyense*. The occurrence of *Neocosmoceras* at the top of the ammonite-bearing part (51 m above the base) indicates that the whole lower three-fifth of the rock interval occupied by the *uncitoides* s.l. Zone on western Vancouver Island cannot be younger than the Mediterranean *paramimouna* Subzone. On account of the maximal age derived for the top of the *okensis* s.s. Zone, also the base of the restricted *uncitoides* Zone could not be older than the *subalpina* Subzone. As in California, no ammonites have been found here in the upper two-fifth of the *uncitoides* s.l. Zone.

Correlation with the Boreal succession — The conspicuous change in the Boreal ammonite fauna characterised by the strong increase in the diversity of *Surites* close to the *kochi-analogus* zonal boundary in Siberia and E. Greenland, was thought to be at least nearly time-equivalent with the similarly conspicuous increase in the diversity of *Surites* at the top of the *Riasanites rjasanensis* Zone in Eastern Europe (see section on the correlation of this zone). The top of the latter is stratigraphically close to the top of the *picteti* Subzone, which also marks the onset of a marked change in the ammonite faunal succession in the Mediterranean province. These faunal turnovers were causally related and ascribed to a global fall of the sea level at the *picteti/alpillensis* subzonal boundary; they were therefore supposed to have occurred at the same time. This interpretation is independently supported by, and consistent with, the age deduced (in the section on the Berriasian/Valanginian boundary in the Boreal marine sequence) for the first occurrence of *Surites* in the North Sea Basin, which also appears to be stratigraphically close to the *picteti/ alpillensis* subzonal boundary and which also marks the onset of a transgressive sequence. The Boreal *analogus* Zone was therefore interpreted to correlate largely with the Tethyan *alpillensis* Subzone.

CALIFORNIA	BRIT.COLUMBIA	SIBERIA
	tolmatschowi	*tolmatschowi*
uncitoides	*uncitoides*	*jasikovi*
	okensis	*okensis*
aff.*okensis*	*terebratuloides*	*unschensis*

Fig. 11. Correlation of the lowermost Cretaceous *Buchia* zones adopted in this paper.

The presence of *Borealites* (= Jeletzky's '*Tollia* cf. *payeri*') in the lower part of the *uncitoides* Zone (= uppermost part of the Husky Formation in northern Yukon; Jeletzky, 1958, pp. 6, 46; 1964b, p. 24, pl. 4, fig. 11; 1971, p. 5; 1973, p. 56) indicates that these beds cannot be younger than the *kochi* Zone. The occurrence of *Surites* aff. *analogus* in the top part of the *uncitoides* Zone in the western Richardson Mountains (Jeletzky, 1961, p. 9; 1964b; 1971, p. 5; 1973, p. 57), however, may suggest a correlation of the upper part of this zone with a part of the Siberian *Surites analogus* Zone. A similar correlation has been made by Zakharov (1979, table 1; 1981, table 3) and by Surlyk & Zakharov (1982, table 3), who found that the Siberian *Buchia jasikovi* Zone, which comprises the same interval as the *uncitoides* Zone, viz. between the *okensis* and *tolmatschowi* zones, corresponds to the upper part of the upper *kochi* Zone and the lower part of the *analogus* Zone. If the *analogus* Zone really correlates with the *alpillensis* Subzone, as is supposed here, it means that the *uncitoides* Zone should straddle the *picteti/alpillensis* subzonal boundary and the attendent fall of the global sea-level.

This correlation is, again, supported by the rather abrupt shallowing of the basin at the boundary between the Lower Shale-Siltstone Division (Husky Formation) and the Buff Sandstone Member of the overlying Lower Sandstone Division in the upper part of the *uncitoides* Zone in the western Richardson Mountains (Jeletzky, 1961, p. 9) and at the boundary between the non-calcareous Shale Member and the white-weathering calcareous coquinoid member in the upper part of the *uncitoides* Zone in the Taseko Lakes area (Jeletzky & Tipper, 1968, p. 23; Jeletzky, 1984, p. 211). Also this shallowing could well be related to the rapid fall of the sea level that caused the faunal turnover at the *picteti/alpillensis* subzonal boundary (= basal Valanginian global unconformity of Vail & Todd, 1981). It ushers in the essentially Valanginian group of *Buchia keyserlingi*, variants of which timidly appear in the top part of the *uncitoides* Zone in Vancouver Island (Jeletzky, 1984, p. 214).

Conclusion — According to the above correlations, the restricted *uncitoides* s.l. Zone sensu Jeletzky is younger than the *grandis* Subzone (= maximum age of the base = maximum age of the top *okensis* Zone). It comprises at least (= minimum age of the base) the upper part of the *paramimouna* Subzone, the entire *picteti* Subzone, and at least (= minimum age of the top) a part of the *alpillensis* Subzone. The upper part of the upper *kochi* Zone incorporates therefore at least the upper part of the *paramimouna* Subzone and the entire *picteti* Subzone.

THE CALIFORNIAN *BUCHIA 'ELDERENSIS'* ZONE

In the following three paragraphs we will try to approach the age of the *Buchia okensis* Zone stratigraphically from below. Before we can make a correlation with the Tethyan

and Boreal successions, however, we first have to correlate the Californian *Buchia* zones with those of British Columbia (Figs. 9, 10, 12). The lower 1800 m of the *B. piochii* s.l. Zone sensu Jones et al. (1969) in California are generally referred to as the *Buchia elderensis* Subzone (Jones et al., 1969), because they contain many specimens of *B. 'elderensis'* and only a very few typical *B. piochii*. Zakharov (1981, p. 94) and Jeletzky (1984, p. 186) synonymized *B. 'elderensis'* Anderson with *B. russiensis* (Pavlow). These *B. russiensis* s.l.-bearing beds in California are followed by beds in which *B. piochii* s.s. is abundant and which comprise the upper 1500 m of the *B. piochii* s.l. Zone (Jones et al., 1969, p. A9) . The upper 1500 m also yielded *B. fischeriana* (Jones et al., 1969, pp. A6, A7, A9) and were therefore referred to as the *Buchia fischeriana* Subzone (Jones et al., 1969, pp. A5, A7). Jeletzky (1984, pp. 191, 193) correlates the lower part of the *fischeriana* Subzone sensu Jones et al. with his restricted *B. piochii* s.s Zone, to which most *B. piochii* s.s. are confined, and the upper part with his restricted *B. fischeriana* Zone, in which *B. piochii* s.s. is replaced by its direct descendant *B. lahuseni* s.l. The *piochii* s.l. Zone is directly overlain by the *Buchia* aff. *okensis* Zone sensu Jones et al. (1969), which in the Paskenta area (California) reaches a thickness of 360 m. The latter zone has been equated and synonymized by Jeletzky (1984, p. 196) with the *Buchia terebratuloides* Zone (sensu Jeletzky & Tipper, 1968, pp. 10, 11) in British Columbia. We follow this equation and use the names *B.* aff. *okensis* Zone and *terebratuloides* Zone interchangeably.

It should be noted that what is written in the text and the locality descriptions of Jones et al. (1969) and Imlay & Jones (1970), differs from what is shown in figure 1 of the latter paper. In this figure the boundary between the lower 1800 m and the upper 1500 m of the *piochii* s.l. Zone, i.e. where *B. piochii* s.s. takes over from *B. russiensis* s.l., should be drawn between the last *Kossmatia* and the first *Parodontoceras*; furthermore the boundary between the *'elderensis'* and *fischeriana* subzones is shifted upward to about 600 m below the top of the *piochii* s.l. Zone without any explanation; perhaps it designates the true entry of *B. fischeriana* in California; finally the *piochii* s.l. Zone should not include the *B.* aff. *okensis* Zone.

Buchia cf. *blanfordiana* zone

As the beds with *B. russiensis* s.l. in California, i.e. the former *elderensis* Zone of Jones et al. (1969), are truncated at the base by a major thrustfault separating the Great Valley Sequence from the underlying Franciscan Sequence, they may correspond only with the upper part of the stratigraphic interval that in British Columbia contains *B. russiensis* s.l. This interval has been divided from bottom to top in (Fig. 12): the *B. russiensis* s.l. Zone of Jeletzky (1984, pp. 185-189) (= former *Buchia* n. sp. aff. *piochii* Zone of Jeletzky & Tipper, 1968) and the *B.* cf. *blanfordiana* Zone (Jeletzky, 1950; 1965, p. 17; 1984, p. 184; Jeletzky & Tipper, 1968, p. 12;), in which *B. russiensis* is still common.

At least the greater part of the Californian *russiensis*-bearing beds seems to correlate only with the *B.* cf. *blanfordiana* Zone sensu Jeletzky (1965, p. 18; Imlay & Jones, 1970, p. B12) for three reasons:
1) The presence, though rare, of forms (figured by Jones et al., 1969, p. A10, pl. 2, figs. 38, 40-42) that according to Jeletzky (1984, pp. 185, 186) are indistinguishable from *B.* cf. *blanfordiana*.
2) The presence, though rare, of forms (figured by Jones et al., 1969, pl. 2, figs. 39, 43-45) that according to Jeletzky (1984, p. 185) are indistinguishable from *B. taimyrensis* (Jeletzky, 1984, pp. 185, 186, considers *B. taimyrensis* to be a mere variant of *B. russiensis)*.
3) Especially indicative is finally the absence (Jones et al., 1969, p. A11; Imlay & Jones, 1970, p. B11; Jeletzky, 1984, p. 186) of *Buchia mosquensis*. The specimen of *B. 'aff.*

mosquensis' figured by Anderson (1945, pl. 4, fig. 12) from the lowest part of the Californian *russiensis* beds (Jones et al., 1969, p. A10, USGS Mesozoic locality 29494) has been synonymized with *B. russiensis* (Jones et al., 1969, p. A10; Jeletzky, 1984, p. 186). Late forms of *B. mosquensis* on the other hand are not rare in the British Columbian *russiensis* s.l. Zone in the restricted sense of Jeletzky (1984) and are considered to be the direct ancestors of *B.* cf. *blanfordiana* (Jeletzky, 1984, p. 185).

Correlation with the Boreal succession

The approximate correlation of the Californian equivalent of the *B.* cf. *blanfordiana* Zone with the Siberian *Taimyrosphinctes excentricus* and *Epivirgatites variabilis* zones (Zakharov, 1981, pp. 223, 224, table 3; Surlyk & Zakharov, 1982, table 3; Jeletzky, 1984, p. 186), with which Zakharov equated his *Buchia taimyrensis* Zone – in which *B. mosquensis* is also virtually absent –, seems quite acceptable.

The hiatus between the middle and the upper Volgian in Greenland, England, eastern Europe, and Siberia (Callomon & Birkelund, 1982, table 3; Sazonova & Sazonov, 1979a, table 1; 1983, table 1) may have had the same cause as the hiatus that closes the *B.* cf. *blanfordiana* Zone on western Vancouver Island and as the regression that characterizes the *B.* cf. *blanfordiana* Zone in the Taseko Lakes area (Jeletzky, 1984, p. 184). In this respect it should be noted that in the Canadian Arctic (Jeletzky, 1966; 1984, pp. 218, 219, 221, 225, 229) the fauna of large *B. fischeriana* and *B. richardsonensis* is associated with many forms of *Dorsoplanites, Laugeites,* and doubtful *Pavlovia.* This ammonite assemblage suggests a correlation with the upper part of the middle Volgian (Jeletzky, 1984, p. 229). This correlation would at first sight seem to be in disaccord with the age inferred for the *B.* cf. *blanfordiana* Zone, which is appreciably older than the *fischeriana* Zone in British Columbia. However, in northern Greenland (Håkansson et al., 1981, fig. 3) and in Siberia (Zakharov, 1981, p. 102; Surlyk & Zakharov, 1982, table 3) *B. fischeriana* starts its range in the *Dorsoplanites maximus* Zone and is already frequent in the *Taimyrosphinctes excentricus* Zone. This proves that the base of the *B. fischeriana* Zone in western North America is considerably younger than in the Arctic regions. These *Dorsoplanites* beds do not correlate with the British Columbian *fischeriana* Zone, but with the *B.* cf. *blanfordiana* Zone (Fig. 12).

CALIFORNIA		BRIT. COLUMBIA	SVERDRUP ISL.	SIBERIA
aff. *okensis*		*terebratuloides*	*terebratuloides*	*unschensis*
piochii s.l.	*fischeriana*	*fischeriana*		*obliqua*
		piochii s.s.	? ? ?	
	elderensis	cf. *blanfordiana*	*fischeriana*	*taimyrensis*
serpentinite + fault		*russiensis*	*russiensis*	*russiensis*

Fig. 12. Correlation of the uppermost Jurassic *Buchia* zones adopted in this paper.

Correlation with the Tethyan succession

Kutek & Zeiss (1974, 1975) and Zeiss (1977, 1983) have shown that the lower boundary of the east European middle Volgian (*Zaraiskites scythicus* Zone) can approximately be correlated with the lower boundary of the middle European upper Tithonian (*Pseudovir-*

gatites scruposus Zone). Consequently, the *excentricus* and *variabilis* zones should corre-
late with an interval rather high in the upper Tithonian. This correlation is nicely
confirmed by the correlation of at least a part of the cf. *blanfordiana* Zone with a part of
the *'Durangites'* Zone, discussed below.

Only the upper 600 m of the lower 1800 m of the Californian *piochii* s.l. Zone,
which is equivalent to the *B.* cf. *blanfordiana* Zone, yielded 4 specimens of Tethyan
ammonites (Anderson, 1945; Jones et al., 1969; Imlay & Jones, 1970): *Kossmatia* (*K.
dilleri, K. tehamaensis, K. kleinsorgensis*; the latter is close to *K. purisima* Verma &
Westermann, 1973) and doubtful *Durangites* (*D.* aff. *vulgaris*). Also on western Vancou-
ver Island the *B.* cf. *blanfordiana* Zone yielded a few Tethyan ammonites, at first
(Jeletzky, 1965, pl. 2, figs. 5, 9) compared with *Substeueroceras stantoni* and *Gymnodis-
coceras*, but later (Jeletzky, 1984, p. 188) with *Paraberriasella* sp. and (after Enay, 1973,
p. 305) with *Substreblites*, respectively. The latter form is too poorly preserved to allow
generic identification, whereas the inclusion of the first form into *Paraberriasella* is
rejected here; the unhorizonted specimen from the Manning Park area (British Colum-
bia) that according to Jeletzky (1984, pp. 188, 193, pl. 4, fig. 14) would be conspecific
with the first form, does not resemble *Paraberriasella* either, but is reminiscent of
Aulacosphinctes mirandus Collignon, 1960.

From the upper 1500 m of the Californian *piochii* s.l. Zone, which are equivalent to
the *B. piochii* s.s. and *B. fischeriana* zones in British Columbia, have been identified
(Imlay & Jones, 1970): *Parodontoceras storrsi, Aulacosphinctes?* sp. juv., and *Groeberi-
ceras? baileyi*. The latter species is not a *Groebericeras,* but may be related to *Protothur-
mannia* as Jeletzky (1984, p. 207) suggested. In British Columbia the upper part of the
piochii s.s. Zone yielded a juvenile *Proniceras* and an ammonite doubtfully referred to as
Nothostephanus? (Jeletzky, 1958, p. 5; 1984, pp. 191, 253, pl. 4, fig. 8).

This North-American succession with its sparse ammonites is closely comparable
with the succession in Mexico, where beds in which *Kossmatia* has its acme also precede
beds in which *Parodontoceras, Substeueroceras,* and *Proniceras* have their acmes (Burck-
hardt, 1912; Imlay, 1939; Verma & Westermann, 1973). In Mexico the acme of *Kossma-
tia* coincides with the acme of *Durangites*; the *Durangites-Kossmatia* fauna gradually
merges into the *Parodontoceras-Substeueroceras-Proniceras* fauna. In the Mediterranean
province, however, *Kossmatia* is virtually absent, but a diverse *Durangites* fauna is
present even with the same species, for instance *D. vulgaris, D. astillerensis,* D. sp. ex gr.
acanthicus, D. sp. ex gr. *densestriatus* and *D. acanthicus* (Oloriz & Tavera, 1981, p. 503;
Vígh, 1984, p. 25, table 1; Haas, 1984, p. 68, pl. 20, fig. 8, table 3; Cecca et al., 1983, pl.
5, fig. 1). This correspondence of at least three species indicates that the Mexican and
Mediterranean acmes of *Durangites* are contemporaneous. The view of Jeletzky (1984,
p. 179) that the *Durangites*-bearing beds of Mexico are not contemporaneous with those
of the Mediterranean region cannot be upheld.

The beds in which the acme of *Durangites* occurs in the Mediterranean region were
united in the *'Durangites'* Zone (Enay & Geyssant, 1975, p. 45; Oloriz & Tavera, 1981,
p. 503; Vígh, 1984, table 1; Haas, 1984, table 3). This genus timidly appears below the
'Durangites' Zone (Enay & Geyssant, 1975, pp. 45, 49), but is apparently so rare below
that zone that it has not been found there by Oloriz & Tavera (1981), Vígh (1984), nor by
Haas (1984). Since also one unfigured specimen of *Kossmatia* has been reported from the
'Durangites' Zone (Oloriz & Tavera, 1981, p. 503), there is at this moment no impedi-
ment to correlate the *Kossmatia*-bearing beds of California (i.e. at least the upper part of
the *B.* cf. *blanfordiana* Zone) indirectly via Mexico with the *'Durangites'* Zone of the.
Mediterranean upper Tithonian. This implies that at least the Siberian *Epivirgatites
variabilis* Zone correlates with a part of the Tethyan *'Durangites'* Zone. The unfigured

specimens of *Buchia*, referred to by Burckhardt (1912, pp. 206, 221) as '*Aucella du groupe mosquensis*' and as '*Aucella, voisine de l'Aucella mosquensis*' from beds with abundant *Durangites* and with *Kossmatia* (Burckhardt's locality 23, 'Couches à Durangites') in Mexico, may be conspecific with *B.* cf. *blanfordiana*, a late species of the *mosquensis* group (Jeletzky, 1984, p. 185).

The presence of *Kossmatia* in beds that are older than the Mediterranean '*Durangites*' Zone cannot be ascertained yet. Cantú Chapa (1967, cuadro 1) correlates his *Kossmatia victoris* and *Pseudolissoceras zitteli* Zone (he found only one fragment of each species) on the one hand with the *Durangites* beds in northern Mexico, which are, as we have seen, the equivalents of the Mediterranean upper Tithonian '*Durangites*' Zone, on the other hand with the Argentine *P. zitteli* Zone, which according to H. Leanza (personal communication, 1985) largely correlates with the middle lower Tithonian *Haploceras verruciferum* Zone of Oloriz & Tavera (1981, p. 494). However, true *P. zitteli* has a smaller umbilicus than the specimen depicted by Cantú Chapa (1967, pl. 1, fig. 5), whereas the presence of *Aulacosphinctoides* and of a possible *Tithopeltoceras* in the *victoris-zitteli* unit, rather suggests a late Tithonian age for this unit. *Richterella richteri* from the middle part of the lower Tithonian, has often been included in *Kossmatia*, but has no relation whatsoever with that genus (Avram, 1974, 1976; Sapunov, 1977; Cecca, 1986). It is also questionable whether the Kimmeridgian ammonites from New Zealand referred to as *Kossmatia* (Fleming, 1960, pp. 265-268; Stevens, 1974, pp. 743, 746) really belong to that genus (Verma & Westermann, 1973, pp. 209-211; Enay, 1973, p. 299). *Kossmatia novoseelandica* (Hochstetter), the only figured specimen of these ammonites (Marwick, 1953, pl. 16, figs. 1,2), is not a *Kossmatia*, but resembles *Parodontoceras* suggesting a late Tithonian age for these beds.

THE LOWER PART OF THE *BUCHIA TEREBRATULOIDES* S.L. ZONE

Correlation with the Tethyan succession

The *Buchia* aff. *okensis* Zone of Jones et al. (1969) in California, which has been synonymized (Jeletzky, 1984, p. 196) with the *Buchia terebratuloides* Zone of Jeletzky & Tipper (1968), yielded a Tethyan ammonite fauna identified by Imlay & Jones (1970) as: *Bochianites? glennensis, Substeueroceras stantoni* (which resembles the Mexican *S. catorcense* and *S. subquadratum*), *S.* cf. *kellumi, Parodontoceras reedi, P.* cf. *storrsi, Spiticeras* cf. *obliquenodosum, Spiticeras* sp., *Proniceras maupinense, Proniceras* sp. juv., *Blanfordiceras californicum*, and *Blanfordiceras* sp. indet. (the specimens called '*Blanfordiceras*' belong to *Pseudoblanfordia*).

In the Mediterranean province *Spiticeras (Spiticeras)* has never been found below the *jacobi* Subzone. On the other hand *Proniceras*, which has its acme in the *jacobi* Subzone (Djanélidzé, 1922; Le Hégarat, 1971, table 16; Memmi & Salaj, 1975, tables 1-5; Hoedemaeker, 1981, fig.1), does not cross the upper boundary of that subzone except for one specimen of *P. toucasi* mentioned from the *grandis* Subzone (Le Hégarat, 1971, table 16). The co-occurrence of *Spiticeras* s.s. and *Proniceras* therefore indicates the *jacobi* Subzone (Fig. 9).

According to Jones et al. (1969, p. A18, fig. 5) and Imlay & Jones (1970, pp. B11, B25, B27,) *Proniceras* has been found with certainty up to the approximate middle of the rock interval in the Paskenta area assigned to the *B.* aff. *okensis* Zone (USGS Mesozoic localities 29591, 29592 = together with *B.* n. sp. aff. *okensis* c. 60 m below a conglomerate); *Spiticeras (Spiticeras)* has been found with certainty from 'a few hundred feet' below the top of the underlying *Buchia fischeriana* Zone upward (USGS Mesozoic localities 1085 and M2605). The specimen from M2605 (Imlay & Jones, 1970, p. B34, pl. 3, fig. 25; in their text-fig. 1 erroneously drawn as being derived from directly above the top of the *fischeriana* Zone instead of directly below it) is a true *Spiticeras (Spiticeras)* because of the diagnostic bituberculate stage on the inner whorls. This means that at least the lower

half of the rock interval occupied by the *B.* aff. *okensis* Zone in California and at least the upper 'few hundred feet' of the underlying *fischeriana* Zone could only be equated with the Mediterranean *jacobi* Subzone (Fig. 9). It must be stressed here that this correlation is the most reliable one of this entire paper, because it involves the co-occurrence of two phylogenetically related groups, which have a worldwide distribution and are everywhere quite common. The evolution from *Proniceras* into *Spiticeras* s.s. can be regarded as contemporaneous all over the world.

This correlation implies that the British Columbian *fischeriana* Zone sensu Jeletzky & Tipper (1968) either straddles the *'Durangites'/jacobi* subzonal boundary or wholly correlates with the lower part of the *jacobi* Subzone. The presence of *Proniceras* in the upper part of the underlying *piochii* s.s. Zone may indicate the beginning of the Tethyan acme of this genus and is an indication that the stratigraphic position of the *'Durangites'/jacobi* subzonal boundary may be much closer to the base of the *fischeriana* Zone than is suggested by the lowest find of *Spiticeras (Spiticeras).* Consequently the *piochii* s. s. Zone, with the possible exception of its top part, seems to correlate best with the highest part of the *'Durangites'* Zone. This is in accordance with the possible presence of *Aulacosphinctes* (Imlay & Jones, 1970, pl. 12, figs. 1, 2), for this genus becomes extinct in the immediate neighbourhood of the *'Durangites'/jacobi* subzonal boundary.

As Jeletzky (1984, pp. 179, 180) disagrees with the author (Hoedemaeker, 1982, p. 68, note 3) about the inclusion of *'Hoplites' beneckei* Jacob and *'Pseudargentiniceras' flandrini* le Hégarat (from the Mediterranean *jacobi* and *grandis* subzones) in *Substeueroceras,* these forms are not considered in the correlations attempted here. Similarly *Berriasella* will not be considered in these correlations, because true *Berriasella* is endemic in the Mediterranean and Indo-Malagasian regions but absent in North and South America. The ammonites from the Americas referred to as *Berriasella* by various authors either belong to *Parodontoceras* or to yet unnamed genera.

Correlation with the Boreal succession

The lowest part of the *terebratuloides* Zone in the Canadian Arctic yielded (Jeletzky, 1984, p. 219) *Craspedites* s.s. and *Subcraspedites* s.s. reminiscent of *C. (S.) sowerbyi, C. (S.) preplicomphalus,* and *C. (C.) subditus.* About halfway these so-called *Craspedites-Subcraspedites* beds *Buchia unschensis* starts its range. The ammonites, but also the entry of *B. unschensis,* which in Siberia timidly appears in the upper part of the *Craspedites (Craspedites) okensis* Zone (Fig. 10) and in the *C. (C.) subditus* Zone along the river Pechora (Zakharov, 1981; Mesezhnikov et al., 1979, p. 67, table 3), point to a correlation of the lowest part of the *terebratuloides* Zone of Arctic Canada with the English *C. (S.) preplicomphalus* Zone, the East-European *C. (C.) subditus* Zone, and at least a part of the Siberian *C. (C.) okensis* Zone (Jeletzky, 1984, p. 231). The incorporation of *B. obliqua* as a variant in *B. terebratuloides* by Jeletzky (1973, pp. 47, 50; 1984, p. 196) suggests that the totality of the Siberian *obliqua* Zone (Zakharov, 1979, table 1; 1981, table 3; Surlyk & Zakharov, 1982, table 3), and therefore also the totality of the *C. (C.) okensis* Zone and at least the greater part of the *K. fulgens* Zone, should be incorporated in the *terebratuloides* Zone of the Canadian Arctic.

However, before a reasonable Tethyan-Boreal correlation is possible, the measure of asynchrony of the base of the *terebratuloides* Zone in North America should be evaluated. The co-occurrence of *B. terebratuloides* with rare *Buchia piochii* s.s. and numerous *B. fischeriana* in the lower part of the interval occupied by the *Craspedites-Subcraspedites* fauna, i.e. below the appearance of *B. unschensis,* suggests that the base of the *terebratuloides* Zone in the Canadian Arctic is older than its base in British Columbia and that it correlates with a level at, or just below, the top of the *piochii* s.s. Zone (Jeletzky, 1984, p. 231), because in British Columbia the last *B. piochii* occurs in

the basal part of the *fischeriana* Zone (Jeletzky, 1984, pp. 191, 194). This means that the lower part of the *Craspedites-Subcraspedites* Beds probably incorporates the entire *fischeriana* Zone and possibly even the top part of the *piochii* s.s. Zone of British Columbia, and that the British Columbian *fischeriana* Zone probably correlates with an interval low in the Siberian *C. (C.) okensis* Zone, i.e. with an interval below the entry of *B. unschensis*. The presence of *Buchia lahuseni* in the Russian *Kachpurites fulgens* and *Craspedites subditus* zones (Mikhailov, 1966, p. 105; Startseva et al., 1979, p. 103; Zakharov, 1981, p. 93) as well as in the British Columbian *fischeriana* Zone (Jeletzky & Tipper, 1968, p. 11; Jeletzky, 1984, pp. 193, 194) confirms this correlation. The base of the *B. terebratuloides* Zone in British Columbia is therefore appreciably younger than in the Canadian Arctic (Figs 10, 12). Also the chronostratigraphic intervals occupied by the *fischeriana* Zone in British Columbia and the *fischeriana* Zone in the Sverdrup Basin (Jeletzky, 1984, p. 225, discussed earlier in this section) are quite different and are not even overlapping. A true Boreal equivalent of the *piochii* s. s. Zone does not seem to exist, though it cannot be ruled out that the top part of this zone correlates with the basal part of the Siberian *Craspedites okensis* Zone, because of the presence of rare *B. piochii* low in the *Craspedites-Subcraspedites* beds of Arctic Canada.

The so-called *Craspedites (Taimyroceras) canadensis - Buchia unschensis* fauna of Arctic Canada (Jeletzky, 1966) yielded *T. canadense* and its varieties. This species occurs with the same varieties also in the *T. taimyrense* Zone in Siberia (in Saks, 1975, p. 33) with which the Canadian fauna has been correlated (Jeletzky, 1971, pp. 3, 4; 1973, fig. 3; 1984, p. 233; Zakharov, 1979; Surlyk & Zakharov, 1982; Zeiss, 1983). Though the direct stratigraphical relation of the *canadensis-unschensis* fauna with the *Craspedites-Subcraspedites* fauna cannot be observed in the field, the former should be stratigraphically above the latter, because *B. unschensis* is already abundant in the former. However, the beds with the *canadensis-unschensis* fauna are still below the middle of the *terebratuloides* Zone (Jeletzky, 1984, p. 229), because *Buchia* n. sp. aff. *okensis*, which characterizes the higher parts of the *terebratuloides Zone*, is still absent.

Conclusions

Concluding we may say that the lower half (up to the approximate middle) of the rock interval occupied by the *terebratuloides* Zone in California and British Columbia as well as at least the upper part but probably the totality of the *fischeriana* Zone in British Columbia (and perhaps the top part of the *piochii* s.s. Zone) correlate with the Mediterranean *jacobi* Subzone (Fig. 1), but also with the totality of the *C. okensis* and *T. taimyrense* zones in Siberia (Fig. 10).

Almost the same correlation has been made by Kutek & Zeiss (1974, table 1) and by Zeiss (1977, table 2). This correlation is in contrast with the often made equation of the upper Volgian with the lower Berriasian (Donze, 1958, 1965; Casey, 1973; Casey et al., 1977; Zeiss, 1965, 1979, 1983; Sazonova & Sazonov, 1979, 1983; Marek et al., 1974; Marek & Raczynska, 1979), which is based of the following reasons:

Firstly, the English Lulworth Beds (topped by the Cinder Beds) have been correlated with the upper Volgian, but allegedly also (via its supposed equivalents, the Purbeck beds of the Jura Mountains) with the lower Berriasian on account of the brackwater ostracodes reworked in the marine beds of the 'calcaires grossiers' of Montagnole and Pertuiset. However the available evidence (discussed above), though admittedly meagre, consistently points to a probable correlation of the Cinder Beds with the *jacobi* Subzone. This implies that the Lulworth Beds are not of early Berriasian age, but older, viz. late Tithonian.

Secondly the Cinder Beds have been correlated with the base of the Ryazanian Stage on account of the direct and supposedly conformable superposition in Poland of marine *Riasanites* beds upon Purbeck beds whose top (microfaunal horizon A) correlates by means of ostracodes with the Cinder Beds and with the north-German Serpulite Member. But at the same time the *Riasanites* beds have been correlated on account of the co-occurrence of *Riasanites rjasanensis* and *Subthurmannia boissieri* in the Caucasus, with the base of the upper Berriasian *boissieri* Zone. The *boissieri* Zone has always been synonymized with the upper Berriasian. Before 1971 both were used in the wide sense of Kilian, 1888, of Mazenot, 1939, and of the 'Colloque sur le Crétacé inférieur' (Anonymous, 1965). In 1971, however, Le Hégarat subdivided this zone into an *occitanica* Zone (below) and the *boissieri* Zone (above). He still confined the upper Berriasian to this restricted *boissieri* Zone. We came to the conclusion that there is not any evidence yet for the *Riasanites* beds being older than the restricted *boissieri* Zone sensu Le Hégarat and for the Cinder Beds being younger than the *grandis* Subzone. This implies an important hiatus between microfaunal horizon A and the suprajacent *Riasanites* beds in Poland. Marek et al. (1974, p. 322) reported that the marine deposits of Berriasian age locally lie immediately upon microfaunal horizons B and C, which are stratigraphically below A. This suggests an unconformity. The stratigraphic relations of the Jurassic/Cretaceous boundary beds in Poland are otherwise still not clear.

THE UPPER PART OF THE *BUCHIA TEREBRATULOIDES* S.L. ZONE

The upper part of the *terebratuloides* Zone in the United States and in British Columbia yielded with certainty only *Spiticeras* sp. (Imlay & Jones, 1970, pp. B20, B25, USGS Mesozoic locality 1085), *Parodontoceras reedi* (at the base of the upper third of the *B. aff. okensis* Zone: Imlay & Jones, 1970, pp. B20, B27, USGS Mesozoic locality M2599; in the uppermost *terebratuloides* Zone: Jeletzky, 1984, p. 197, formerly referred to as *P. callistoides*, Jeletzky, 1971, p. 3), and two unidentifiable fragments (Jeletzky, 1984, pl. 1, figs. 4, 5) referred to as *Substeueroceras*? sp. undet. juv. This assemblage does not permit any direct correlation with the Tethyan standard subdivision, save that it is probably younger than the *jacobi* Subzone.

In the section on the intra-Boreal correlation of the *Hectoroceras kochi* Zone we found that *Pseudocraspedites* appears presumably slightly below the base of the *B. okensis* Zone. As the base of the upper *kochi* Zone is here provisionally conceived to begin with the entry of *Pseudocraspedites*, it means that the top of the *terebratuloides* Zone, and thus also the base of the *B. okensis* Zone, is just above the base of the upper *kochi* Zone. In the foregoing section we have seen that the lower half of the Californian rock interval occupied by the *terebratuloides* Zone can be equated with the upper part of the *jacobi* Subzone, but also with at least a part of the Siberian *Craspedites okensis* and with the *Taimyroceras taimyrense* Zone. This means that the upper half of the beds occupied by the *terebratuloides* Zone should be time-equivalent with the combined *Chetaites chetae, sibericus-maynci,* and lower *kochi* zones, plus the basal part of the upper *kochi* Zone.

This correlation also has far-reaching consequences for the age of the *Buchia okensis* Zone in terms of the Tethyan standard subdivision (Fig. 13). For if the *okensis* Zone would be equated with the Tethyan *grandis* Subzone, as was surmised by Jeletzky (1971, p. 5; 1973, p. 54; 1974, p. 703; 1979, p. 57), then there would be no room for the *chetae, sibericus-maynci,* lower *kochi,* and basal upper *kochi* zones between the contiguous *jacobi* and *grandis* subzones. If the *B. okensis* Zone would be equated with the

praeanalogus Sz. / constans Subz.	upper kochi Zone	B. okensis Zone
"fedorovi beds" / kochi Subzone	lower kochi Zone	This interval should include at least a large part of the occitanica Zone
sibericus Subz. / maynci Subz.	sibericus Zone	
chetae Zone		grandis Subz.
taimyrense Zone		jacobi Subz.
C. okensis Zone		

Fig. 13. This figure explains why the *Buchia okensis* Zone cannot be correlated with the *jacobi* Subzone, nor with the so-called '*grandis-jacobi*' Zone, but that it correlates with a stratigraphic interval that lies well above the base of the *occitanica* Zone.

lower Berriasian (Jeletzky, 1950 , p. 39; 1958, p. 5; 1960, p. 5; 1965, p. 21), which according to Hoedemaeker (1981, 1982) should begin with the *subalpina* Subzone, then the *chetae, sibericus-maynci*, lower *kochi*, and basal upper *kochi* zones would be crammed into the *grandis* Subzone, which is equally improbable. The *B. okensis* s.s. Zone should therefore be appreciably younger than the *jacobi* Subzone, in other words, it should correlate with an interval at least rather far above the base of the *occitanica* Zone; the upper *terebratuloides* Zone thus comprises the *grandis* Subzone and at least a large part of the *occitanica* Zone.

BUCHIA OKENSIS S.S. ZONE

Correlation with the Tethyan succession

The age of the *okensis* s.s. Zone in terms of the standard Tethyan subdivision is crucial. It is unnecessary to say that in view of the age determined for the lower *terebratuloides* Zone (see above) the correlation of the *okensis* Zone, even partly, with the *jacobi* Subzone (Jeletzky, 1982, 1984, p. 210, figs. 5, 10) is quite impossible.

The Californian correlatives of the *B. okensis* s.s. Zone, i.e. the lower quarter of the rock interval occupied by the *B. uncitoides* Zone sensu Jones et al. (1969) (Jeletzky, 1984, pp. 207, 208, 211, 214), yielded with certainty only *Spiticeras (Negreliceras) stonyense* (USGS Mesozoic locality M4066) and *Spiticeras (Spiticeras)* cf. *S. (S.) serpentinum* (USGS Mesozoic locality M2598) (Imlay & Jones, 1970, pp. 27, 33-35, pl. 3, fig. 20, pl. 4, figs. 11-13). This association merely implies that the top of the *okensis* s.s. Zone is younger than the appearance of *Negreliceras*, which is in the *subalpina* Subzone.

In the Taseko Lakes area in British Columbia the upper part of the *okensis* s.s. Zone yielded ammonites of Tethyan affinity identified (Jeletzky & Tipper, 1968, pp. 146, 170; Jeletzky, 1970, pl. 23, fig. 14; 1971, p. 4; 1974, p. 703; 1984, p. 207, pl. 2, figs. 2-6,

pl. 3, fig. 1) as: *Fauriella* n. sp. aff. *gallica*, two ammonite forms tentatively assigned to *Protothurmannia* (n. sp. A and B), and '*Argentiniceras*' cf. *noduliferum*. The '*Argentiniceras*' seems closer to '*A*'. *bituberculatum* with which it has initially been compared (Jeletzky, 1971, p. 4; 1975, p. 122). It is doubted here whether *bituberculatum* Leanza and *noduliferum* Steuer belong to the genus *Argenticeras*. The author fails to see why the forms referred to as *Protothurmannia* had to be separated from *Subthurmannia*. However that may be, this assemblage does not provide any direct correlative clue with the standard Tethyan succession either. However '*A*'. *noduliferum* and '*A*'. *bituberculatum* have hitherto been found restricted to the *noduliferum* Zone in Argentina. This suggests that at least the ammonite-bearing upper part of the *okensis* s.s. Zone in British Columbia correlates with this Argentine zone (Fig. 14) (Jeletzky, 1984, p. 210). The *noduliferum* Zone yielded also *Groebericeras bifrons* and *Pomeliceras egregium*, which enables a correlation of this zone with the Mediterranean standard succession. *Groebericeras* is represented in the Mediterranean province by '*Ammonites*' *rocardi* Pomel (1889, pl. 8, figs. 3-5; morphologically very close to *G. poblanense* Cantú Chapa, 1967, pl. 2, fig. 3) from the *paramimouna* Subzone of Algeria and Spain (Hoedemaeker, 1982, pp. 38, 78, encl. 2) and by *Groebericeras* aff. *G. bifrons* Leanza (Hoedemaeker, 1982, pl. 4, fig. 3) (= *Groebericeras* mentioned by Wiedmann in Allemann et al., 1975, p. 17) from the *picteti* and *alpillensis* subzones in S. Spain. The adumbilical parts of the flanks of these compressed forms are smooth. '*Reineckia*' *egregia* Steuer, 1897 is not a *Himalayites* nor a *Neocosmoceras*, in which it has been included by Gerth (1925) and Leanza (1945), respectively. This species has all the characteristics of *Pomeliceras*, which is very similar to the Upper Jurassic *Himalayites*, but differs from the latter in developing a row of umbilical tubercles. This species was therefore included in the genus *Pomeliceras*. Since in the Mediterranean province *Pomeliceras* has not been found above the *paraminouna* Subzone and *Groebericeras* not below it, the co-occurrence of *Pomeliceras* and *Groebericeras* is restricted to the *paramimouna* subzone. According to Mediterranean standards therefore a *paramimouna* age is, indirectly via Argentina, suggested for the upper part of the *okensis* s.s. Zone (Fig. 14).

However, the top of the *B. okensis* Zone cannot, from a Tethyan point of view, be younger than the lower *paramimouna* Subzone because of the minimal age determined here for the lower boundary of the restricted *uncitoides* Zone sensu Jeletzky. This means that the upper part of the *okensis* Zone presumably correlates with an interval in the lower part of the *paramimouna* Subzone, unless *Argentiniceras* and *Groebericeras* also would occur in lower beds. This cannot be proven, because the *noduliferum* Zone in Argentina is underlain by a thick unfossiliferous sequence, which separates it from the *Substeueroceras koeneni* Zone: 45 m in the Mallín Redondo section, 50 m in the section along the Arroyo de Yeso (Leanza, 1945, p. 87, 88), and the 98 m of Steuer's (1897) Malargue II beds (Hector Leanza, personal communication).

The correlation made above of the upper part of the *okensis* Zone with an interval in the lower *paramimouna* Subzone is consistent with the age derived for this zone in the Mediterranean Realm (see discussion on the *rjasanensis* Zone) on totally independent arguments. We may therefore be confident that this correlation is close to reality.

From the description of the single non-figured ammonite referred to by Steuer (1897, pp. 19, 72) as '*Aspidoceras* n. sp. indet.' in the list of fossils from the Malargue III beds that later (Leanza, 1945, correlation table) were incorporated in the *noduliferum* Zone in Argentina, can be gathered that it is probably not a true *Aspidoceras*. According to Steuer's description this specimen might be morphologically close to *Aspidostephanus latior* and *Aspidostephanus depressus* from the Loncoche III beds, which are correlatable with the Malargue III beds. However that may be, before a restudy of the specimen in question, Steuer's '*Aspidoceras*' can certainly not be used as an argument (Jeletzky, 1984, p. 210) that the *noduliferum* Zone has been deposited in *jacobi-grandis* times.
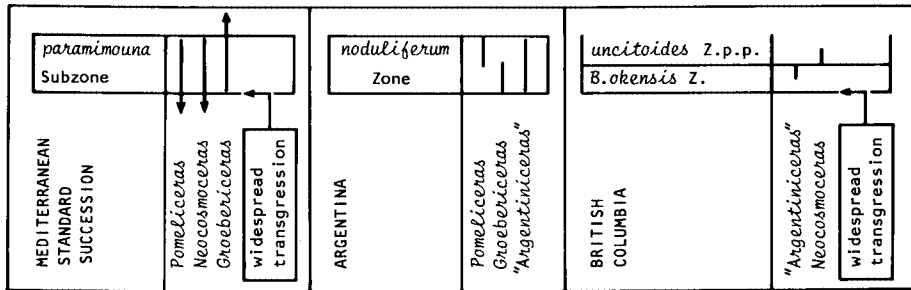
MEDITERRANEAN STANDARD SUCCESSION		ARGENTINA		BRITISH COLUMBIA	
paramimouna Subzone	*Pomeliceras* *Neocosmoceras* *Groebericeras* — widespread transgression	*noduliferum* Zone	*Pomeliceras* *Groebericeras* "*Argentiniceras*"	*uncitoides* Z.p.p. / B. *okensis* Z.	"*Argentiniceras*" *Neocosmoceras* — widespread transgression

Fig. 14. The age of the *B. okensis* Zone can only be approached indirectly via Argentina. It biostratigraphically correlates with the *paramimouna* Subzone. The bases of both the *paramimouna* Subzone and the *okensis* Zone mark the beginning of a widespread transgressive phase of global significance and can be considered approximately contemporaneous. On account of the presence of *Neocosmoceras* also the lower part of the overlying *uncitoides* Zone correlates with the *paramimouna* Subzone. The *okensis* Zone can therefore only be equated with the lower part of the *paramimouna* Subzone.

Besides *Pomeliceras* and *Groebericeras* do not occur in the *jacobi* or *grandis* subzones.

The stratigraphic position of the lower boundary of the *B. okensis* Zone is difficult to assess on the basis of American fossil evidence. We can only infer that it cannot be too far below the base of the *paramimouna* Subzone, because sufficient room should be reserved for the equivalents of the *chetae, sibericus/maynci*, lower *kochi* (which includes Alekseev's *kochi* Subzone and the *Borealites fedorovi* assemblage), and basal upper *kochi* zones above the *jacobi* Subzone (Fig. 13).

However, the conspicuously widespread occurrence of the *okensis* Zone indicates that the stand of the global sea level (Vail & Todd, 1981) was at that time apparently high enough to allow extensive transgressions. Widespread transgressions generally set in near the beginning of the *paramimouna* Subchron, while the highest stand of the Berriasian sea level was only reached at the end of the *paramimouna* Subchron and at the beginning of the *picteti* Subchron, when the margins of the French 'Fosse vocontienne' became inundated and the Berriasian sediments reached their maximal extension (Cotillon, 1971; Le Hégarat, 1971, pp. 482, 483). The widespread occurrence of the *okensis* Zone is therefore entirely compatible and nicely tallies with the entire zone being equivalent to the lower part of the *paramimouna* Subzone (Figs. 10, 13).

Consequences for the Tethyan-Boreal correlation

This throws doubt on a possible correlation of the lower part of the *B. okensis* Zone with at least a considerable part of the *dalmasi* Subzone, as was implicated by the observation of Jeletzky (1973, 1984) that only late forms of *B. okensis* have been depicted in literature from the East- European Ryazanian and from the *Buchia volgensis* Local Zone of Mangyshlak. This correlation could neither be checked nor supported yet by any other observation, as all age indications obtained through the association of *B. okensis* with other fossils invariably point to an early *paramimouna* age for the *okensis* Zone. The author is therefore inclined to regard the specimens of *B. unschensis* from the bed with *Hectoroceras* and *B. okensis* near the base of the *rjasanensis* Zone near Kostino as not being reworked from beds that are detectably older. If this is true, it implies that this *Hectoroceras* bed correlates at least with the basal part of the *B. okensis* Zone. This is an

independent confirmation of the age of the base of the *okensis* Zone, because we have shown that the base of the *rjasanensis* Zone cannot be detectably older than the *paramimouna* Subzone. As the *okensis* Zone correlates only with the lower part of the *paramimouna* Subzone, it should only occupy the lowest part of the *rjasanensis* Zone (the latter zone includes the entire *paramimouna* and *picteti* subzones). This readily explains why the Ryazanian of the Russian platform yielded only late forms of *B. okensis*: early forms should be confined to the basal phosphoritic sandstone bed, if preserved at all. The correlation of the *okensis* Zone with the lower *paramimouna* Subzone also readily explains the occurrence of only late forms of *B. okensis* in the *Buchia volgensis* Local zone (correlatable with the upper *paramimouna* subzone) of Mangyshlak (Luppov et al., 1984).

It is only now that we can adequately approach the age of the upper *Hectoroceras kochi* Zone. The age of the lower *kochi* Zone will be discussed below in connection with the Jurassic/Cretaceous boundary.

As the basal part of the upper *kochi* Zone, as conceived here, correlates with the top part of the *terebratuloides* Zone (see section on the *kochi* Zone) and the upper part of the upper *kochi* Zone with the lower part of the *uncitoides* Zone (see corresponding section) (Zakharov, 1979, table 1; 1981, table 3; Surlyk & Zakharov, 1982, table 3), the *okensis* s.s. Zone necessarily correlates only with an interval in the lower part of the upper *kochi* Zone.

This suggests that, in view of the age inferred for the *okensis* Zone, the upper *kochi* Zone comprises the uppermost part of the *dalmasi* Subzone, the *paramimouna* Subzone, and the *picteti* Subzone. It also suggests that the *rjasanensis* Zone correlates only with the major part (except the basal part and possibly the uppermost part) of the upper *kochi* Zone. The chronostratigraphic scope of the Ryazanian Stage on the Russian Platform is much smaller than in Siberia, where it additionally includes the lower *kochi* Zone and the *sibericus/maynci* Zone.

The specimen from Argentina referred to by Leanza (1945, p. 62, pl. 11, figs. 3, 4) as '*Neocomites* cf. *occitanicus*' is a *Tirnovella* of the *pertransiens* group. It is derived from bed 'm-n' (Arroyo de Yeso) directly above the last occurrence of *Spiticeras* and indicates a Valanginian age (*pertransiens* Subzone). Leanza (1945, p. 63) stresses that this form is very close to, if not identical with, '*Hoplites occitanicus* (Pictet)' in Toucas (1890, pl. 18, fig. 5), which is totally unrelated to *Subthurmannia occitanica*, but is the holotype of *Dalmasiceras sublaeve* Mazenot (1939) from the *jacobi* Subzone. Leanzàs error is understandable, because *Dalmasiceras* is notoriously homoeomorphous with *Tirnovella* of the *pertransiens* group (which however lacks the characteristic comma-shaped umbilical crests and the resultant typical curvature of the ribs of *Dalmasiceras*) and Le Hégarat (1971, p. 206) even assumed an ancestor-descendant relationship. This specimen cannot be used as an argument (Jeletzky, 1984, p. 210) that the Argentine *damesi* Zone should correlate with the Mediterranean *occitanica* Zone. On the contrary. On account of this find bed 'm-n' should be separated from the *damesi* Zone and included in the *Neocomites wichmanni* Zone. The *damesi* Zone should be correlated with the *picteti* and *alpillensis* subzones, while the upper part of the *paramimouna* Subzone may also be incorporated in it. This means that the *damesi* Zone is also time-equivalent with the *Buchia uncitoides* Zone, as was already suggested by Jeletzky (1984, p. 215) on entirely different grounds.

THE JURASSIC/CRETACEOUS BOUNDARY IN THE BOREAL MARINE SEQUENCE

In 1981 and 1982 the author adduced arguments in favour of a Jurassic/Cretaceous boundary coinciding with the boundary between the *Pseudosubplanites grandis* and the *Subthurmannia (Strambergella) subalpina* subzones. At this boundary a profound and rapid turnover in the succession of ammonite assemblages occurs, which practically

Boreal zones		Tethyan zones	
praeanalogus Sz. *constans* Subz.	upper *kochi* Zone	*picteti* Subz. *paramimouna* Subz.	interprovincially correlatable horizon
„*fedorovi* beds" *kochi* Subzone	lower *kochi* Zone	*dalmasi* *privasensis*	
sibericus/maynci Zone		*subalpina*	
chetae Zone		*grandis*	
taimyrense Zone		*jacobi* Subzone	interprovincially correlatable horizon
C. okensis Zone			

Fig. 15. Diagram showing that through interpolation the *chetae/sibericus* zonal boundary appears to be stratigraphically closest to the *grandis/subalpina* subzonal boundary. Direct biostratigraphic correlation is unfortunately not possible except for the fact that both boundaries are major faunal turnovers assigned to the same lowering of the global sea level.

coincides with the base of the *Calpionella elliptica* Zone. This Jurassic/Cretaceous boundary should be situated somewhere between the following two interprovincially correlatable horizons:

1) The *B. okensis* s.s. Zone, which is interpreted here to correlate with the lower part of the *Berriasella paramimouna* Subzone, but also with an interval in the lower part of the upper *Hectoroceras kochi* Zone.

2) The lower *terebratuloides* s.l. Zone of British Columbia and California, which correlates with the upper part of the *Berriasella jacobi* Subzone, but also with the upper *Craspedites okensis* and *Taimyroceras taimyrensis* zones.

Thus the Mediterranean *grandis, subalpina, privasensis, and dalmasi* subzones, which fill up the interval between the two interprovincially correlatable horizons, should approximately cover the same time-interval as the boreal *chetae, sibericus-maynci,* lower *kochi,* and lowest upper *kochi* zones. It seems likely that the *grandis/subalpina* subzonal boundary is chronostratigraphically closest to the *chetae/sibericus* zonal boundary (Fig. 15).

The ammonite fauna of the *chetae* Zone is characterized by the last representatives of *Craspedites, Subcraspedites, Taimyroceras, Volgidiscus, Praechetaites,* and *Garniericeras* (Fig. 16). The same association also characterizes the *taimyrense* and *okensis* zones. In the overlying *sibericus* Zone none of these genera occurs anymore; this zone is instead characterized by a totally new association consisting of the first representatives of *Praetollia, Runctonia, Pachypraetollia,* and *Praesurites.* Only *Chetaites,* which appears at the base of the *chetae* Zone, and *Shulginites,* which appears near the top of that zone, cross the *chetae/sibericus* zonal boundary and become extinct just above the top of the *sibericus* Zone. It is therefore plausible to assume that the rapid and conspicuous change in the composition of the ammonite assemblages at the base of the *sibericus-maynci* Zone has the same cause (viz. the onset of the rise of the sea level after the lowest stand at the top of the *grandis* Subzone) and therefore occurred at the same time as the equally conspicuous change at the base of the *subalpina* Subzone (Le Hégarat, 1971; Hoedemaeker, 1981, 1982, 1983). This implies that the top of the Tethyan Tithonian sensu Hoedemaeker (= top *grandis* Subzone) correlates with the top of the Siberian Volgian (= top *chetae* Zone). Since the lower boundaries of the Tithonian and Volgian coincide, these stages should comprise the same time-interval.
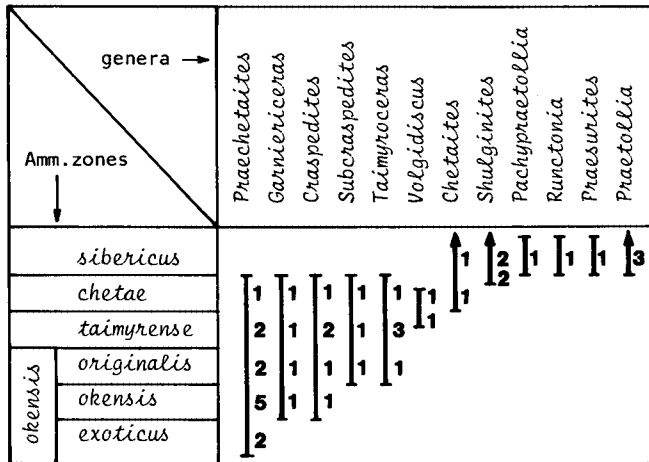
Amm. zones	genera →	Praechetaites	Garniericeras	Craspedites	Subcraspedites	Taimyroceras	Volgidiscus	Chetaites	Shulginites	Pachypraetollia	Runctonia	Praesurites	Praetollia
	sibericus							1	2/2	1	1	1	3
	chetae	1	1	1	1	1	1	1					
	taimyrense	2	1	2	1	3	1						
okensis	originalis	2	1	1	1	1							
	okensis	5	1	1									
	exoticus	2											

Fig. 16. Range chart showing the conspicuous turnover in the ammonite fauna at the *chetae/sibericus* zonal boundary. For each zone the numbers of known species are given.

Consequently it can be assumed that the *sibericus-maynci* Zone and the lower *kochi* Zone together correlate with the *occitanica* Zone. So, correlation of the East-Anglian *kochi* Zone (= *Borealites fedorovi* beds of the lower *kochi* Zone) with an interval in the upper part of the *occitanica* Zone and of the *Praetollia (Runctonia) runctoni* Zone (= *sibericus-maynci* Zone) with an interval near the base of the *occitanica* zone seems realistic. Of the marine incursions in the Purbeck beds only those of the Royal (Morter, 1984, fig. 2) and Scallop faunicycles remain available to correlate with the marine transgressions of the *runctoni* and *kochi* zones of eastern England, respectively.

This correlation is entirely in accordance with and supports our independent correlation of the Cinder Beds with the *jacobi* Subzone by means of ostracodes, clay minerals, and sea level-fluctuations. It is also in support of Kelly's (1983, p. 291) correlation of the Cinder Beds with levels older than the phase of condensation of the *runctoni* Zone. Also the seeming discrepancy between the Russian and English ranges of the bivalves *Anopea sphenoidea* and *A. brachowi*, as noted by Kelly (1983, fig. 5), does not exist anymore, whereas the presence of *B. volgensis* in the East-Anglian *stenomphalus* Zone (Casey, 1973, pp. 204, 211; Kelly, 1983, p. 289) nicely coincides with the acme of *B. volgensis* in the *tolmatschowi* Zone (Zakharov, 1981). Finally it does not contradict the latest view of Casey et al. (1977, p. 22) that the Cinder Beds correlate with a level (in or) older than the *runctoni* Zone on account of the presence of the dinoflagellate *Cannosphaeropsis* n. sp. (= *Cannosphaeropsis thula* Davey, 1982) which is rare above the *runctoni* Zone, but frequent in and below this zone.

How does this boundary correlate with the western North-American sequence? As the lower half of the rock interval occupied by the *B.* aff. *okensis* Zone in California can be equated with the *jacobi* Subzone and the upper half with the *grandis, subalpina, privasensis,* and *dalmasi* subzones, the Jurassic/Cretaceous boundary should be situated not far above the middle of the Californian *B.* aff. *okensis* beds. Apparently the sedimentation rate of the lower part was many times faster than that of the upper part. This may be due to the high sea-level stand during the *jacobi* Subchron and the low stand during the late *grandis* Subchron and *occitanica* Chron, respectively (Fig. 9).

The presence of *Parodontoceras reedi* with certainty at the base of the upper third

of the rock interval occupied by the *B*. aff. *okensis* Zone in California (Imlay & Jones, 1970, p. B27, USGS Mesozoic locality M2599) and in the uppermost *terebratuloides* Zone of the SW marginal sandy facies belt of the Tyaughton Trough in British Columbia (Jeletzky, 1984, p. 197, pl. 1, figs. 1-3) would mean that this species is rather indicative of the *occitanica* Zone than of an older zone and that the range of the genus *Parodontoceras* transects the Jurassic/Cretaceous boundary (Fig. 9).

In relation with this, it is interesting to note that Biró-Bagóczky (1980, p. 143) listed unfigured ammonites referred to as *Odontoceras callistoides* (= *Parodontoceras*), *Berriasella inaequicostata*, and *Andesites fasciculatus* (which were hitherto considered restricted to the upper Tithonian) together with *Argentiniceras bituberculatum*, *Thurmannites (?) discoidales*, and *Hoplites malbosiformis* (which were hitherto considered restricted to the Berriasian) as being derived from a 50 m thick interval of very shallow marine deposits (faunal zone V) in Chile.

Conclusions

It cannot be pretended that all above correlations are accurate, far from that; but it is the best we can do with the available evidence. In general we may say that the evidence is meagre and hardly sufficient, but the evidence presented here for those units that can be correlated appears to be (sometimes astonishingly) consistent and never contradictory. This inspires confidence and the correlations may not be far from reality. Deviations from the above correlations can only be made by violating the evidence presented, unless this turns out to be erroneous on the basis of more and new unequivocal evidence, which is urgently needed.

What is the bearing of all the above correlations on the ultimate choice or on the stratigraphic position of the Jurassic/Cretaceous boundary? Provided that this boundary will be chosen, in accordance with the generally accepted tradition, to coincide with the boundary between the Tithonian and Berriasian stages, our study reveals that only one level clearly emerges as the internationally attainable and therefore undoubtedly best boundary between the Jurassic and Cretaceous systems, viz. the boundary between the *grandis* and *subalpina* subzones. This is the only boundary that does not conflict with previously held concepts:

1) It corresponds with the original concept of the top of the Tithonian Stage (Oppel, 1865, p. 535), which has been defined to end where the type Neocomian begins, thus at the base of the so-called 'Unité Oolitique Inférieur' in the Swiss Jura Mountains (Hoedemaeker, 1982, p. 59). The latter rock-unit has a *subalpina* age.

2) It does not violate the original faunal diagnosis of the Tithonian, because none of the ranges of perisphinctacean ammonites listed by Oppel (1865) for the stage do cross the *grandis/subalpina* subzonal boundary (Hoedemaeker, 1982, p. 60). The entire ammonite assemblage described by Zittel (1868) from the Stramberger Schichten (which attained a kind of stratotypical appreciation for the upper Tithonian) remains diagnostic for that substage.

3) It does not conflict with, but supports the original concept of the Berriasian Stage (Coquand, 1869, 1870, 1871, 1875). This has originally been conceived as the beds that contain the ammonite assemblage described by Pictet (1867) (Hoedemaeker, 1982, pp. 20, 59). This assemblage comprises only the *boissieri* Zone sensu Kilian (1888, pp. 191, 196) and sensu the 'Colloque sur le Crétacé inférieur' (Anonymous, 1965), which Kilian has always regarded as representing the true Berriasian (Mazenot, 1939, p. 261), and

which has later (Le Hégarat, 1971) been subdivided into the *occitanica* Zone below and the *boissieri* Zone above. In order to avoid confusion and to enhance stability in stratigraphic nomenclature, Hoedemaeker (1982, pp. 21, 28) rebaptized the *'boissieri'* Zone sensu Le Hégarat into *rarefurcata* Zone. The undivided *boissieri* Zone sensu the 'Colloque sur le Crétacé inférieur' (= *boissieri* Superzone sensu Hoedemaeker, 1982) begins with the *subalpina* Subzone and is considered by the author to represent again the whole of the Berriasian. It should be stressed that not one of the ammonite species that diagnoses the *boissieri* Superzone occurs in the *grandis* Subzone, whereas only very few ammonite forms of the *grandis* Subzone occur above the top of that subzone only to disappear slightly higher. The *grandis/subalpina* subzonal boundary practically coincides with the lower boundary of the *Calpionella elliptica* Zone, which assures worldwide correlatability.

4) It agrees with the general assumption that the Jurassic/Cretaceous boundary is situated between the Volgian and Ryazanian stages, even if the latter is conceived to begin with the *sibericus-maynci* Zone, which is an appreciable – though permissible – extension of this stage as it was originally conceived (viz. only the *rjasanensis* and *tzikwinianus* zones).

5) The Portlandian remains the uppermost stage of the Jurassic System, even if it is conceived (Cope et al., 1980, p. 85) to include the *primitivus, preplicomphalus,* and *lamplughi* zones, which is also an appreciable, though permissible, extension of this stage as it was originally conceived.

6) It does not change the concept of the upper Tithonian held by the North and South American stratigraphers in its essence, for the *Parodontoceras-Substeueroceras-Proniceras* beds and the Argentine *koeneni* Zone remain in the Tithonian. However, non-typical *Parodontoceras* (*P. reedi*) also occur in younger beds.

7) It does not change the interpretation of maps and literature. Maps remain valid and do not need to be redrawn.

If the lower boundary of the *jacobi* Subzone would be chosen as the Jurassic/Cretaceous boundary, as was voted for after the 'Colloque sur la limite Jurassique-Crétacé' in 1973, all these seven points would be unacceptably violated.

It has to be admitted that the possibly contemporaneous turnovers in the ammonite faunal successions between the middle and upper Volgian in Eastern Europe and Siberia, between the English *oppressus* and *primitivus* zones, between the Mediterranean *'Durangites'* and *jacobi* subzones and between the American *Kossmatia-Durangites* beds and *Substeueroceras-Parodontoceras* beds, involve a renewal at the family level, but, if not obliterated by a hiatus, they appear to be gradual ones, in which the renewal of the fauna is concomitant with the extinction of the old one. Roughly speaking it involves the gradual replacement of a dorsoplanitid-dominated fauna into a craspeditid-dominated fauna in the Boreal Realm and of a himalayitid-dominated fauna into a neocomitid-dominated fauna in the Tethyan Realm. These faunal turnovers may be correlated with the low stand of the sea level that has initiated the deposition of the Purbeck Beds in Western Europe.

Also it has to be admitted that the *'Durangites'/jacobi* subzonal boundary, which still needs a biostratigraphic characterisation, will be closest to the Jurassic/Cretaceous boundary as it was originally conceived by d'Orbigny (1842-51, p. 611), when he accepted the Portland Beds as the topmost beds of the Jurassic System and the Purbeck Beds as the lowest Cretaceous.

Though the faunal turnover at the *grandis/subalpina* subzonal boundary does not involve a renewal at the family level, the event was more catastrophic, for instead of a rapid though gradual replacement, the near totality of the ammonite fauna was wiped out before the renewal set in (Hoedemaeker, 1981, p. 214; 1982, pp. 17, 58). It apparently

represents the maximum retreat of the sea. The stratigraphical importance of a faunal turnover should not so much be measured by the height of the taxonomic level of the fossils appearing or disappearing in the turnover, as by the depth of the oligotaxic minimum in the diversity curve, i.e. by the smallness of the number of species that actually cross the boundary. The deeper the oligotaxic minimum, the greater the number of last occurrences and first appearances that cluster close to the boundary, and the smaller the ammonite sample needed to decide whether one is just below or just above this boundary. In theory the beginning of the total range of the first ammonite species that appears in a continuously deposited sequence above the level of the oligotaxic minimum, should designate the boundary.

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Manuscript received 2 February 1987.

ERRATA SCRIPTA GEOLOGICA 84.

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