Scaphitid ammonite correlation of the Late Maastrichtian deposits in Poland and Denmark

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Evolutionary changes in the ribbing density on body chambers in samples of the scaphitid ammonite *Hoploscaphites constrictus* (J. Sowerby, 1817) are used for time correlation of the Kazimierz Opoka (Late Maastrichtian, *Belemnella kazimiroviensis* Zone, Poland) with the Danish White Chalk succession. It is proposed that the upper part of the Kazimierz Opoka corresponds to the lower part of the *B. kazimiroviensis* Zone in Denmark while the lower part of the unit probably corresponds to the upper part of the *Belemnitella junior* Zone in Denmark. This correlation, if correct, suggests diachronism of the lower boundary of the *B. kazimiroviensis* Zone.

Key words: Maastrichtian, Scaphitidae, ammonites, Poland, Denmark, stratigraphy.

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Introduction

The Kazimierz Opoka is an informal lithostratigraphical term (Wyrwicka 1980) for the Late Maastrichtian siliceous chalk unit exposed along the Vistula River near Kazimierz Dolny (called also 'Kazimierz' or 'Kazimierz-on-Vistula'), Central Poland (Fig. 1A–C). This unit yields possibly one of the richest fossil assemblages known from the European Maastrichtian (see Abdel-Gawad 1986 and Radwański 1996 for comprehensive review).

Ammonites from the Kazimierz Opoka were described by Łopuski (1911), Pożaryska (1953), and Błaszkiewicz (1980). Radwański (1996) described predation traces on *Hoploscaphites constrictus* (J. Sowerby, 1817) whereas Marcinowski & Radwański (1996) commented on two pachydiscids from the top of Kazimierz Opoka [the specimen identified by them as *Anapachydiscus* cf. *terminus* Ward & Kennedy, 1993 resembles

Pachydiscus jacquoti Seunes, 1890 and is not related to *Menuites terminus* (Ward & Kennedy, 1993); the true *M. terminus* is more involute and densely ribbed, and has weaker umbilical bullae]. Another pachydiscid specimen and a fragmentary sphenodiscid, both from the top of Kazimierz Opoka, await description (Jagt & Machalski, unpublished). The importance of the Polish sequence is that it provides one of the stratigraphically youngest ammonite faunas in the European Cretaceous (Kennedy 1993).

Scaphitid ammonites in the Kazimierz Opoka are represented by only two species: *Hoploscaphites constrictus* (J. Sowerby, 1817), which is common, and *Acanthoscaphites varians* (Łopuski, 1911), which is rare. The present contribution focuses on the biostratigraphic significance of these ammonites.

The results of the present study were announced as an abstract at the Second International Symposium on Cretaceous Stage Boundaries (Machalski 1995). The material studied comprises my collection housed at the Institute of Paleobiology, Polish Academy of Sciences, Warsaw, Poland (abbreviated ZPAL) and the collection of Prof. R. Marcinowski housed at the Institute of Geology, University of Warsaw, Poland (abbreviated IGP/RM).

Geological setting

The Kazimierz Opoka is exposed at several localities near Kazimierz Dolny (Fig. 1A–C). These strata terminate the Late Cretaceous sequence exposed along the Middle Vistula River (Pożaryski 1938; Marcinowski & Radwański 1983).

In general, the Kazimierz Opoka is composed of siliceous chalk (called 'opoka' in Polish literature), with some marly and indurated limestone intercalations. Its lower part is exposed at the Town Quarry south of Kazimierz Dolny and in the Janowiec quarry. The upper portion is exposed in the Nasiłów and Bochotnica quarries and in a few small exposures in the centre and north of Kazimierz Dolny (Fig. 1B–C). A Late Maastrichtian age has been assigned to the whole unit (see below).

Underlying the Kazimierz Opoka are soft marls, also of Late Maastrichtian age (Błaszkiewicz 1980). The Kazimierz Opoka sequence is truncated by a burrowed omission surface of the incipient hardground type (Machalski & Walaszczyk 1987). Resting on this is greensand of Late Maastrichtian/Danian age, containing mixed and partially redeposited Maastrichtian and Danian fauna, including two fragmentary specimens of *Hoploscaphites constrictus* (Machalski & Walaszczyk 1988). The greensand is followed by gaizes and limestones of the so-called Siwak (Fig. 1B–C) dated as Early Danian by Hansen *et al.* (1989).

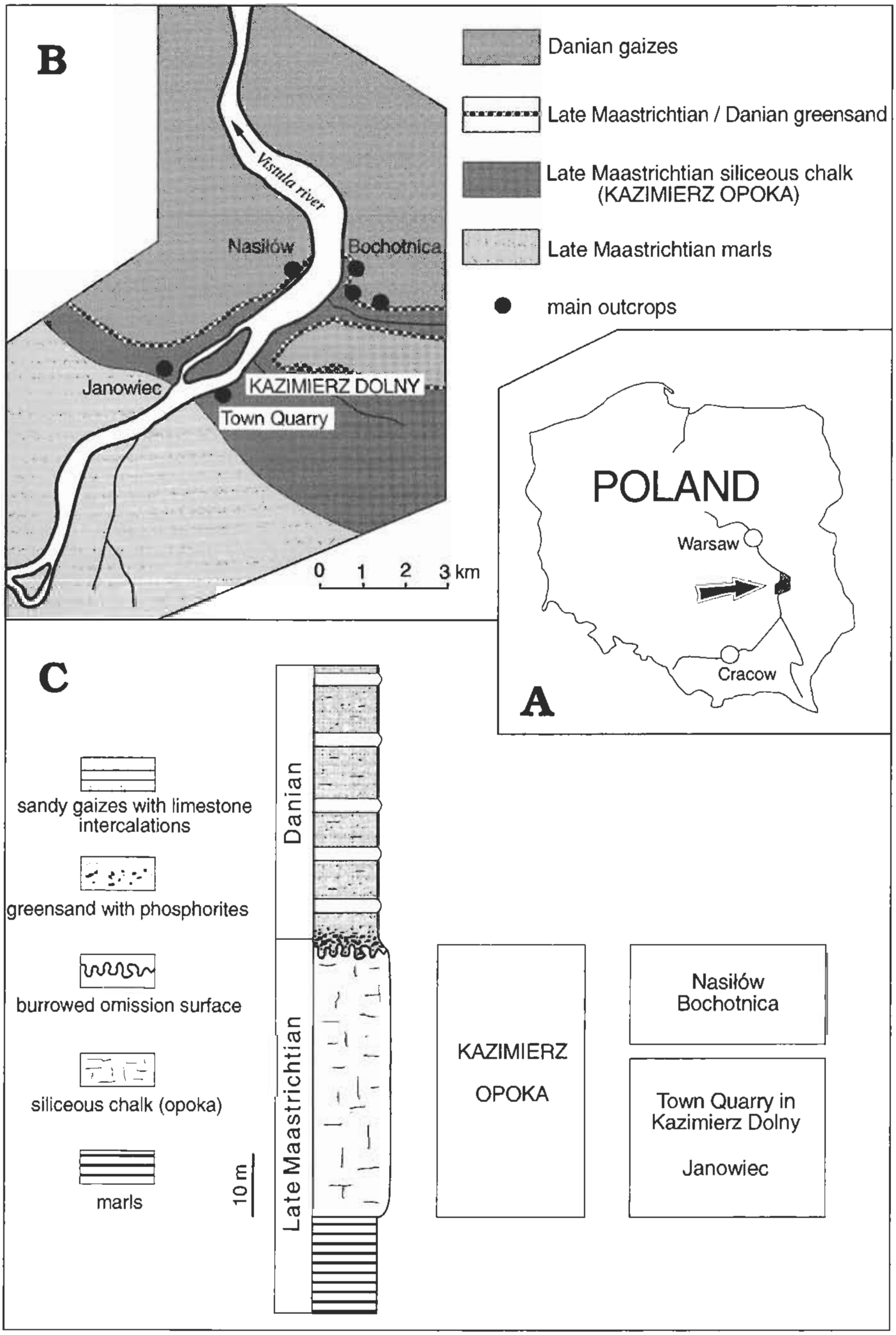

Fig. 1. Geological setting of the Kazimierz Opoka. **A**. Location map; the study area in **B** is arrowed. **B**. Geological map of the Kazimierz Dolny area. **C**. Stratigraphy and lithology of the Late Maastrichtian and Danian deposits in the environs of Kazimierz Dolny. The Kazimierz Opoka is divided into two parts corresponding to the lower and upper *H. constrictus* sample discussed in the text (see also Figs 4–5).

Previous stratigraphic work

That the Kazimierz Opoka is of the Late Maastrichtian age is undisputable. Macrofossil dating of the unit relies on belemnites (Kongiel 1962), ammonites (Błaszkiewicz 1980) and tegulated inoceramids (Abdel-Gawad 1986), microfossil biostratigraphy on planktic foraminifera (Peryt 1980), calcareous nannoplankton (Gaździcka 1978) and dinoflagellate cysts (Hansen *et al.* 1989).

The most detailed and widely used biostratigraphic zonation of the Maastrichtian Stage in the Boreal Realm is that based on belemnites. The Kazimierz Opoka is assigned to the late Late Maastrichtian *Belemnella kazimiroviensis* Zone (total range zone) of the standard West European belemnite scheme based on the presence of the index taxon *Belemnella kazimiroviensis* (Skołozdrówna) throughout the unit (see Kongiel 1962, and a review in Abdel-Gawad 1986). It should be noted that this species name has been incorrectly spelled *casimirovensis* in many papers, but the original spelling was *kazimiroviensis* (see Skołozdrówna 1932).

In comparison with the belemnite zonation, dating of the Kazimierz Opoka with other fossil groups yields less refined or equivocal results. A possible exception are dinoflagellates as discussed by Hansen *et al.* (1989), who considered the upper part of the Kazimierz Opoka exposed at Nasiłów (Fig. 1B–C) to represent the lower part of the latest Maastrichtian *Palynodinium grallator* Zone of the classical Danish White Chalk sequence (Hansen 1977). In Denmark this zone corresponds with the *Belemnella kazimiroviensis* Zone, and may be subdivided into three subzones. These are in ascending order: the *Tanyosphaeridium magdalium* Subzone, the *Thalassiphora pelagica* Subzone and the *P. grallator–Chiropteridium inornatum* Subzone (Hansen 1977, 1979; Hultberg & Malmgren 1987). The upper part of the Kazimierz Opoka as exposed in the Nasiłów quarry was assigned implicitly to the *Tanyosphaeridium magdalium* Subzone by Hansen *et al.* (1989), the remaining two subzones being missing in the Nasiłów section. In Denmark these subzones comprise between 5 and 10 metres of the chalk, depending on the locality (Hansen 1977, 1979; Hultberg & Malmgren 1987).

Hoploscaphites constrictus (J. Sowerby, 1817)

This species (Figs 2–3) occurs throughout the Kazimierz Opoka. All specimens studied fall within the range of variation of this strongly dimorphic and variable species as defined by Makowski (1962) and Kennedy (1986, 1987). More than 300 specimens have been collected, the macroconch to microconch ratio being 3:1 (for example, a collection of 77 specimens from the Town Quarry comprises 58 macroconchs and 19 microconchs).

It should be noted that the specimens interpreted recently, solely due to their small size, to be 'male microconchs' by Radwański (1996: figs 2,

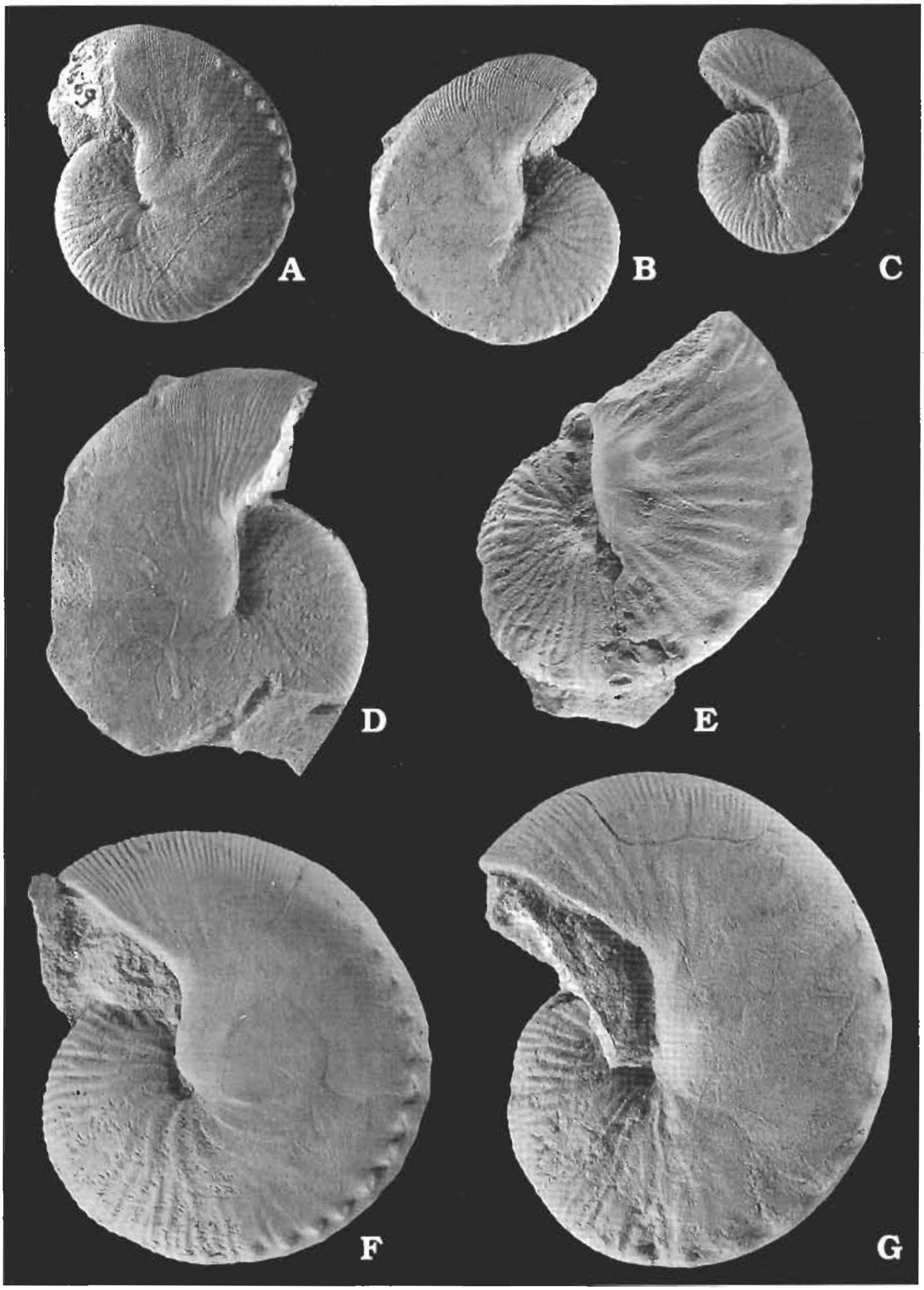

Fig. 2. *Hoploscaphites constrictus* (J. Sowerby, 1817) from the Kazimierz Opoka, mature macroconchs (**A–B**, **D–G**) and a mature microconch (**C**). **A**. ZPAL Am. XII/69. **B**. ZPAL Am. XII/116; **C**. ZPAL Am. XII/16. **D**. ZPAL Am. XII/128; **E**. IGP/RM Na 1. **F**. ZPAL Am. XII/62. **G**. ZPAL Am. XII/63. **A**, **C**, **E–G** are from the Nasiłów quarry; **B**, **D** are from the Town Quarry at Kazimierz Dolny. All specimens × 1.

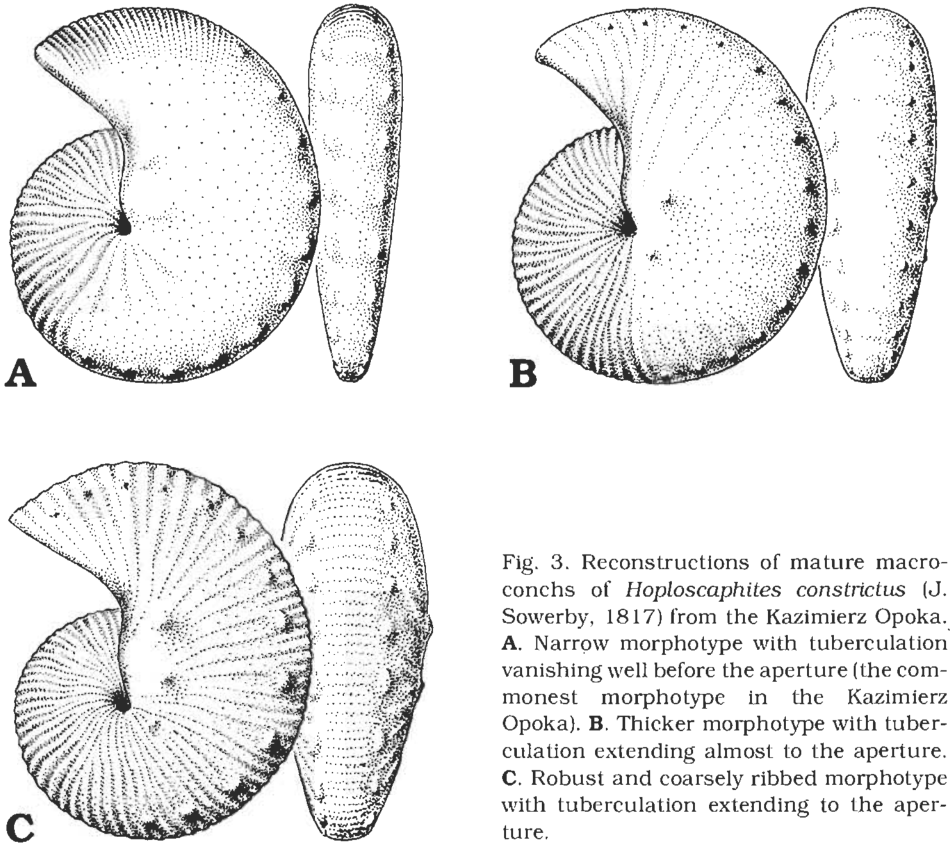

Fig. 3. Reconstructions of mature macroconchs of *Hoploscaphites constrictus* (J. Sowerby, 1817) from the Kazimierz Opoka. **A**. Narrow morphotype with tuberculation vanishing well before the aperture (the commonest morphotype in the Kazimierz Opoka). **B**. Thicker morphotype with tuberculation extending almost to the aperture. **C**. Robust and coarsely ribbed morphotype with tuberculation extending to the aperture.

4) clearly represent small macroconchs comparable to those shown here in Fig. 2A–B. Both specimens illustrated by Radwański have distinct umbilical swelling (bulge), which is a macroconch feature in *Hoploscaphites constrictus* and in many other scaphitids (see e.g., Makowski 1962; Cobban 1969; Kennedy 1986, 1989). In contrast, the umbilical wall of microconchs is concave (Fig. 2C). There is also no reason to assume the presence of 'miniconchs' (*sensu* Matyja 1986) in populations of *H. constrictus* as proposed recently by Radwański (1996: p. 127). He evidently disregarded the size-variation of *H. constrictus*. According to my data, the shell diameter of mature macroconchs from the Kazimierz Opoka ranges from 34 to 71 mm whereas the shell diameter of mature microconchs ranges from 23 to 39 mm (the dimorphs defined not only by size but also by other features). A size-overlap between both dimorphs in the scaphitids was also noted by Cobban (1969) and Landmann & Waage (1993).

The large number of the collected specimens invites a biometric study of the material such as that presented by Dzik (1990). Most of the specimens, however, are imprecisely located within the sections and many are incomplete or deformed. In view of this, the collected material is divided into only two samples, corresponding to the lower and upper part of the Kazimierz Opoka (Fig. 1C).

The most interesting differences between the samples concern mature macroconchs of the species (Figs 2A–B, D–G; 3–4). Although these differences are surely affected by the sample size (the lower sample being much smaller than the upper one), they fit the general morphological trend, most probably evolutionary in character, observed in many European Late Maastrichtian sections (Birkelund 1979, 1982, 1993; Kennedy 1986, 1987). As elsewhere in Europe, the mature macroconchs of *H. constrictus* from the Kazimierz Opoka show the following changes going up the section:

1) increase in shell inflation

2) decrease in rib density near the aperture

3) extension of the ventrolateral tuberculation progressively towards the aperture.

Particularly fat, coarsely ribbed morphotypes with the tuberculation extending to the aperture (Fig. 3C) are often classified informally as 'variety' *crassus* Łopuski, 1911 (Birkelund 1979, 1993; Kennedy 1986, 1987; Kennedy *et al.* 1986). This 'variety', established by Łopuski (1911) based on specimens from the Kazimierz Opoka (without precise indication of the level), is said to spread gradually through the populations of *H. constrictus* towards the top of the *B. kazimiroviensis* Zone. It should be noted, however, that the understanding of this 'variety' by subsequent authors departs from that of Łopuski (1911), who differentiated his *Scaphites constrictus* Sow. var. *crassus* from the nominal species only by the 'enormous thickness of the conch' (*cf.* Radwański 1996).

I have never seen any robust specimens of *H. constrictus* from the lower part of the Kazimierz Opoka. They appear in subordinate number in the upper part of the unit, being connected there by intermediate forms with the rest of the material (Fig. 3A–C). It is thus very probable that the specimens described by Łopuski (1911) originated from the upper part of the Kazimierz Opoka. In light of the lack of the robust morphotype in the lower part of the Kazimierz Opoka and its scarcity in the upper part of this unit the application of the name *Hoploscaphites constrictus crassus* (Łopuski, 1911) to the whole material of *H. constrictus* from the Kazimierz Opoka (Błaszkiewicz 1980) seems to be particularly unfortunate. In contrast to the Kazimierz Opoka, the robust, coarsely ribbed specimens are very common in the latest Maastrichtian sample of *H. constrictus* from Stevns Klint, Denmark (Birkelund 1993: pl. 17: 16–23).

A full set of data concerning the samples of *H. constrictus* from the Kazimierz Opoka and the taxonomic discussion will be presented elsewhere. Stratigraphically, the most important character is the variation in ribbing density near aperture in mature macroconchs. This character was treated quantitatively in the Danish White Chalk material and presented diagramatically by Birkelund (1979: fig. 2; 1993: fig. 7; redrawn here as the Fig. 5 A–B). Following this author, the total number of ribs on the last

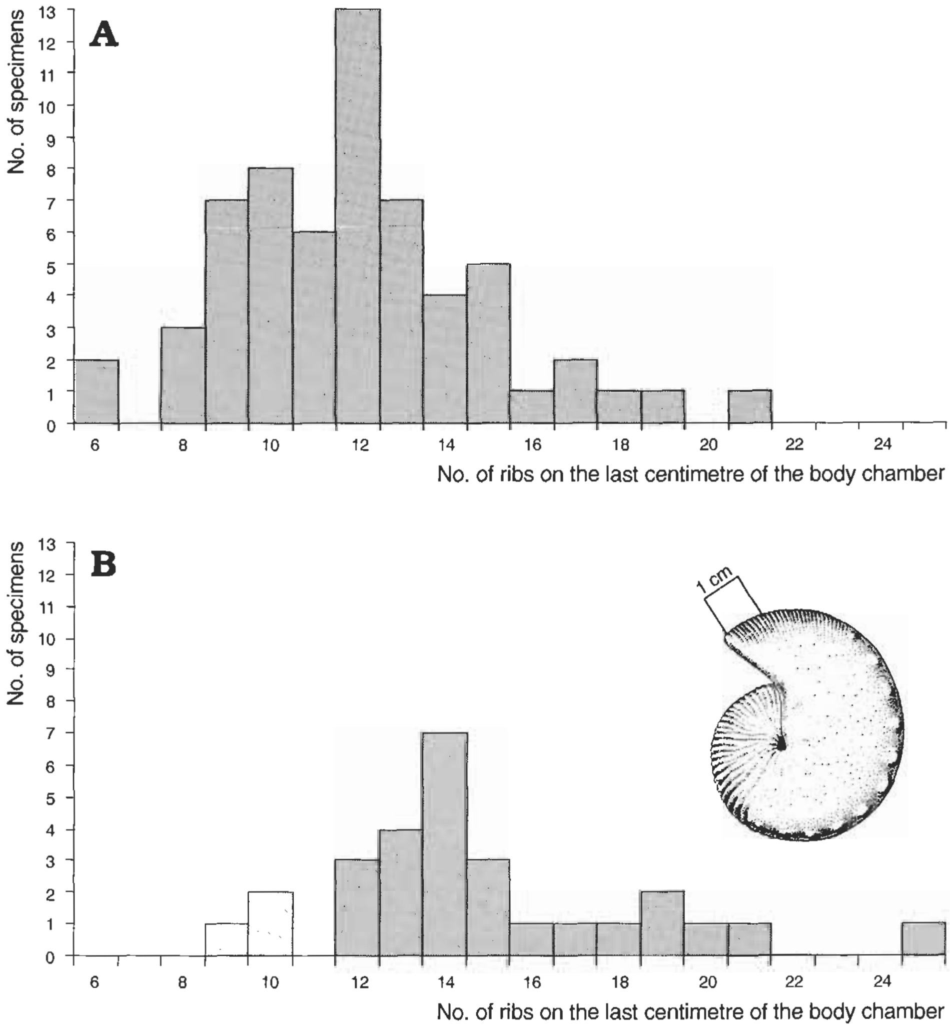

Fig. 4. Variation in rib density on the body chamber of mature macroconchs of *Hoploscaphites constrictus* (J. Sowerby, 1817) from the Late Maastrichtian Kazimierz Opoka, as measured by the number of ribs on the last centimetre of the body chamber. **A**. Upper sample. **B**. Lower sample.

centimetre of the body chamber is used here as an index of the rib density near aperture (Figs 4–5).

In the lower sample from the Kazimierz Opoka the number of ribs ranges from 9 to 25 (mean — 15) and in the upper sample from 6 to 21 (mean — 12) (Fig. 4). These values can be compared (Fig. 5) with those given by Birkelund (1979, 1993) for two successive samples from the lower and upper part of the *B. kazimiroviensis* Zone in Denmark, respectively (her third sample from much lower in the Maastrichtian is not taken into account here, since it comprises only one specimen of *H. constrictus*).

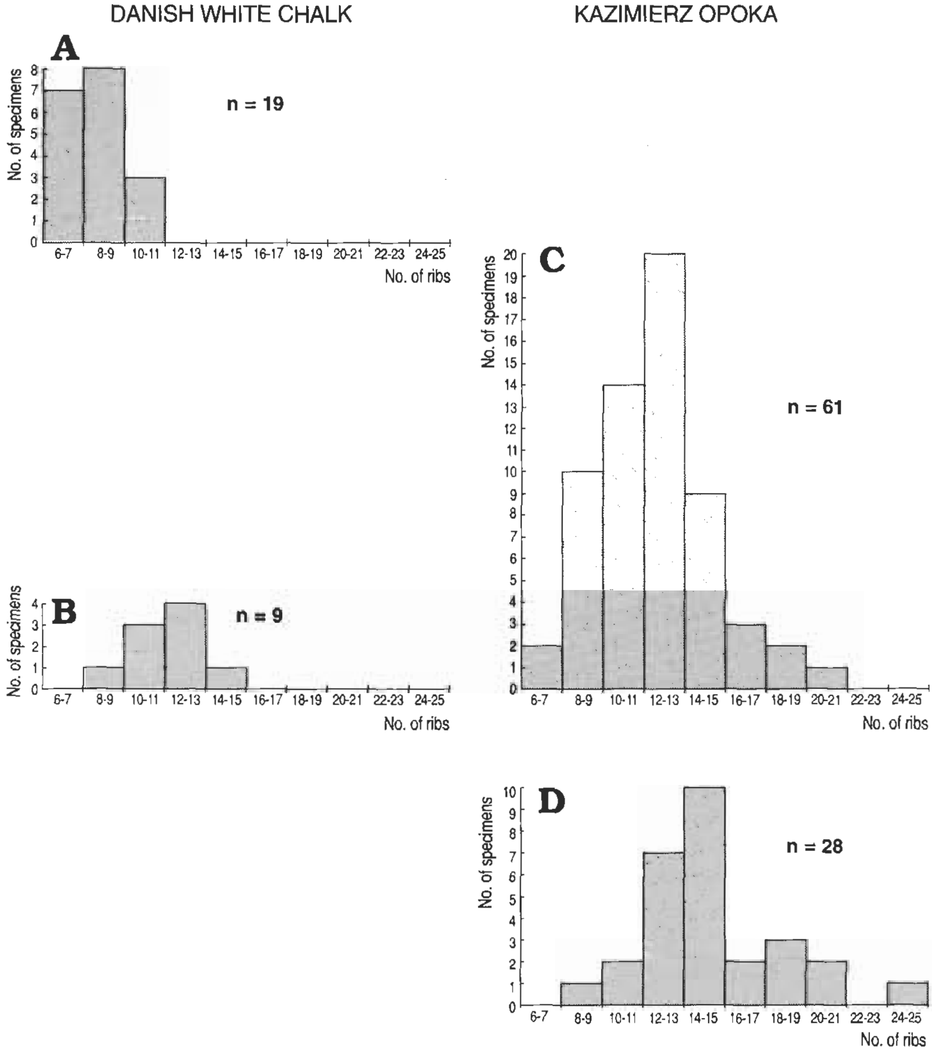

Fig. 5. Variation in rib density on the last centimetre of body chamber of mature macroconchs of *Hoploscaphites constrictus* (J. Sowerby, 1817) in Danish and Polish samples and their proposed time correlation. **A**. Upper sample from the *Belemnella kazimiroviensis* Zone in Denmark. **B**. Lower sample from the *Belemnella kazimiroviensis* Zone in Denmark. **C**. Upper sample from the Kazimierz Opoka. **D**. Lower sample from the Kazimierz Opoka. **A–B** redrawn from Birkelund (1979: fig. 2; 1993: fig. 7).

The mean values of the ribbing index in both Kazimierz Opoka samples significantly exceed that for the upper Danish *B. kazimiroviensis* Zone sample (Fig. 5). If the changes in ribbing were truly evolutionary and synchronous in both regions, then the Kazimierz Opoka must be older than the upper part of the *B. kazimiroviensis* Zone in Denmark. The upper sample from the Kazimierz Opoka composes well with the lower sample from Denmark (Fig. 5). The upper part of the Kazimierz Opoka may thus be regarded as a time equivalent of the lower part of the *B. kazimiroviensis* Zone in Denmark. The lower sample from the Kazimierz Opoka includes a greater proportion of fine-ribbed specimens in comparison with the lower Danish *B. kazimiroviensis* sample (Fig. 5). Although the samples differ in size, this may suggest that the lower part of the Kazimierz Opoka is older than the Danish *B. kazimiroviensis* Zone. It may correspond to the upper part of the early Late Maastrichtian *Belemnitella junior* Zone in Denmark, from which, unfortunately, no representative data on the variation in ribbing of *H. constrictus* are yet available.

Acanthoscaphites varians (Łopuski, 1911)

This is another, multituberculate scaphitid of the Kazimierz Opoka. The holotype (Łopuski 1911: pl. 4: 1–3; refigured in Błaszkiewicz & Szymakowska 1989: pl. 167: 1) was said to be from Kazimierz Dolny, but without a precise indication of its horizon. All of the other specimens from the Kazimierz Opoka (four macroconchs in total) come from the Town Quarry, south of Kazimierz Dolny. It is thus reasonable to assume that this species is restricted to the lower part of the Kazimierz Opoka.

Outside Poland *A. varians* has been reported from Germany, Belgium, Denmark and European Russia (this latter occurence is, however, represented by an undeterminable specimen, see Birkelund 1993). Danish records, when precisely located within the sequence, come only from the top of the *Belemnella occidentalis* Zone and from the lower part of the *Belemnitella junior* Zone (Hillerslev and Rørdal localities, see Birkelund 1993). This applies also to other occurrences — in Germany (Schmid 1965; Birkelund 1982) and Belgium (Jagt & Kennedy 1989). It should be noted, however, that the Polish specimens of *A. varians* differ significantly from 'western' specimens assigned to this species.

The species, based originally on a single specimen, was defined by Łopuski (1911) as possessing 7 rows of tubercles (one siphonal row and three on the flanks). Łopuski also noted the gradual fading away of the tubercles and the transformation of umbilical tubercles into umbilical bullae during the ontogeny of his specimen, resulting in the presence only of umbilical bullae on its body chamber. Subsequent findings, exemplified by the specimen figured here (Fig. 6), show that this is a typical feature of the Kazimierz Opoka specimens. A particularly large macroconch of the species, which was recently found by Dr. A. Pisera (Institute of Paleobiology, Polish Academy of Sciences, Warsaw) in the Late Maastrichtian deposits in Rejowiec, about 100 km east of the Kazimierz Dolny region, shows the same morphology.

In contrast, the tuberculation of the 'western' specimens consists of 7–9 rows of tubercles which continue unchanged along most of the body chamber. Only on the youngest parts of the body chamber in Danish specimens has the loss of some rows of tubercles been observed (Birkelund

Fig. 6. Mature macroconch of *Acanthoscaphites varians* (Łopuski, 1911) from the Town Quarry south of Kazimierz Dolny, lower part of the Kazimierz Opoka, Late Maastrichtian; ZPAL Am. XII/400; × 0.75.

1993). On these specimens, however, this process begins with the rows on the inner parts of the flanks, whereas on the Polish specimens it starts with the loss of the siphonal row. Another difference lies in the ribbing density of body chamber, which is decidedly greater in the case of Belgian, German and Danish forms. This is clearly recognizable when comparing the specimen shown in Fig. 6 with those of approximately the same size illustrated by Schmid (1965), Jagt & Kennedy (1989) and Birkelund (1993).

The above differences warrant the separation of the 'western' specimens previously assigned to *A. varians* to at least a subspecific level. This needs reconsideration of the original specimens and is beyond the scope of the present paper. Whatever the taxonomic position of the 'western' specimens, *Acanthoscaphites varians* sensu stricto seems to be an endemic form with no unequivocal records outside Poland and can not be used for interregional correlation.

Discussion

The time correlation of the Kazimierz Opoka with the Danish White Chalk succession, based on the changes in ribbing density of *H. constrictus*, is consistent with results obtained by Hansen *et al.* (1989) on the basis of the dinoflagellate record. The upper part of the Kazimierz Opoka may be correlated with the lower part of the *Belemnella kazimiroviensis* Zone and of its equivalent dinoflagellate *Palynodinium grallator* Zone (i.e. with the *Tanyosphaeridium magdalium* Subzone) in Denmark. The beds corresponding to the upper part of the *B. kazimiroviensis* Zone and the equivalent *Thalassipora pelagica* and *P. grallator–Chiropteridium inornatum* subzones of Denmark are thus missing in the Kazimierz Opoka section. The lower part of the Kazimierz Opoka may correspond to the upper part of the *Belemnitella junior* Zone in Denmark.

As the entire sequence of the Kazimierz Opoka is assigned to the *B. kazimiroviensis* Zone, the correlation presented above, if correct, suggests some diachronism in the position of the lower boundary of this zone. *Belemnella kazimiroviensis* originated in the eastern part of the Russian Platform, where transitional populations between *Belemnella sumensis* and *Belemnella kazimiroviensis* are known (Naidin 1973; Christensen 1976, 1979). The range of *Belemnella kazimiroviensis* on the eastern part of the Russian Platform is equal to the entire Late Maastrichtian substage; to the west of this area the species appears significantly later (Naidin 1973). It is thus probable that this trend also persisted further westwards and that the species appeared earlier in Poland than in Denmark.

It is worth noting that the very late first appearance datum of *Belemnella kazimiroviensis* within the Maastrichtian stratotype sequence (Jagt 1995) suggests its significantly later appearance in that region, when compared to its occurrences further east. It seems also reasonable to conclude that this belemnite never reached more westerly areas, being totally absent in the Late Maastrichtian faunas of France which correlate with the *Belemnella kazimiroviensis* Zone based on the dominance of the 'variety' *crassus* within the populations of *H. constrictus* (Kennedy 1986; Kennedy *et al.* 1986).

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Addendum

After the present paper was submitted for publication I learned from Prof. W.K. Christensen (Geological Museum, Copenhagen) that he has been working on the chronostratigraphy of the *Belemnella kazimiroviensis* Zone in Europe and came to a similar conclusion about the significant diachronism of the lower boundary of this zone. The results of Prof. Christensen's work will be published in December 1996 (Christensen, W.K. in press. A review of the Upper Campanian and Maastrichtian belemnite biostratigraphy of Europe. — *Cretaceous Research* **17**).

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Korelacja późnomastrychckich osadów Polski oraz Danii na podstawie skafitów

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Streszczenie

Opoki odsłonięte w okolicach Kazimierza Dolnego i określane nieformalnie jako Opoki z Kazimierza (Fig. 1) reprezentują poziom *Belemnella kazimiroviensis* późnego mastrychtu w standardowym europejskim schemacie biostratygraficznym. Amonity z grupy skafitów reprezentowane są tu przez dwa gatunki: *Hoploscaphites constrictus* (J. Sowerby, 1817) oraz *Acanthoscaphites varians* (Łopuski, 1911).

Zmiany ewolucyjne w rozkładzie gęstości użebrowania komory mieszkalnej obserwowane w próbkach makrokonch *H. constrictus* wykorzystano do korelacji wiekowej Opok z Kazimierza z klasycznym profilem kredy piszącej w Danii (Fig. 2–5). Ustalono, że górna część Opok z Kazimierza odpowiada wiekowo dolnej części poziomu *B. kazimiroviensis* w Danii. Dolna część Opok z Kazimierza wydaje się natomiast odpowiadać górnej części poziomu *Belemnitella junior* w Danii. Korelacja ta znajduje poparcie w danych uzyskanych na podstawie cyst wiciowców. Wskazuje ona na diachronizm dolnej granicy poziomu *B. kazimiroviensis*, odzwierciedlający zapewne powolną migrację tego gatunku ku zachodowi Europy.

A. varians (Fig. 6), choć identyfikowany od czasu do czasu w materiałach z mastrychtu Europy Zachodniej, wydaje się być formą endemiczną dla utworów późnego mastrychtu Polski i jako taki nie może być użyty do korelacji międzyregionalnej.