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MAASTRICHTIAN EXTINCTIONS OF PLANKTONIC FORAMINIFERA IN CENTRAL AND EASTERN POLAND.

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ABSTRACT

Three main steps in the extinction of planktonic foraminifers can be distinguished in the axial zone of the Danish-Polish Trough during the latest Maastrichtian of the Central Poland (Foraminiferal Transitional Province):
1. The extinction in the late *Belemnitella junior* Zone of all species of *Globotruncana*.
2. The extinction in the late *Hoploscaphites constrictus crassus* Zone of all species of *Rugoglobigerina* which is shortly followed by 3;
3. The extinction of the last planktonic species of the genera *Heterohelix*, *Globigerinelloides* and *Guembelitria*.
The late Maastrichtian worldwide regression, which coincided with tectonic activity in the Danish-Polish Trough and the cooling of the climate following the regression were most probably responsible for the extinctions of planktonic foraminifers in the area studied during latest Maastrichtian.

Keywords: Poland, Maastrichtian, planktonic foraminifera, mass extinctions.

RESUMEN

En la zona axial del Surco Dano-Polaco se distinguen tres etapas principales en la extinción de los foraminíferos planctónicos durante el Maastrichtiense en Polonia central (Provincia transicional de Foraminíferos):
1. La extinción, en la parte superior de la Zona *Belemnitella junior*, de todas las especies de *Globotruncana*;
2. La extinción, en la parte superior es la Zona *Hoploscaphites constrisctus crassus*, de todas las especies de *Rugoglobigerina*, seguida de cerca por
3. La extinción de las últimas especies de foraminíferos planctónicos de los géneros *Heterohelix*, *Globigerinelloides* y *Guembelitria*.
La regresión global del Maastrichtiense superior, que coincide con una actividad tectónica en el surco Dano-Polaco, y el enfriamiento del clima siguiendo la regresión fueron muy probablemente los causantes de la extinción de los foraminíferos, en el área estudiada, durante el Maastrichtiense superior.

Palabras clave: Polonia, Maastrichtiense, foraminíferos planctónicos, extinción en masa.

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INTRODUCTION

There are three models of mass extinctions (Kauffman, 1986): gradational, catastrophic and stepped. One of the most intriguing and widely discussed mass extinctions in the history of the Earth is related to the Cretaceous/Tertiary boundary. Planktonic organism e.g. planktonic foraminifera and calcareous nannoplankton) are groups strongly affected at the K - T boundary. Detailed micropaleontological studies of pelagic sediments sections where the K-T boundary has been geochemically and paleomagnetically documented has shown that a few species survived the terminal Cretaceous extinction-event (Smit, 1979, 1982; Thierstein, 1981; Perch-Nielsen, 1982).

The extinction of Cretaceous planktonic foraminifera at the K-T boundary has been hitherto interpreted as graded (Herm. 1963; Lamolda *et al.*, 1983), catastrophic (Smit, 1982; Smit and ten Kate, 1983) and stepped (D'Hondt and Keller, 1985). All these sections are located in the Tethyan Province.

The purpose of this paper is to present the changes recorded in populations of planktonic foraminifera during the Maastrichtian in the foraminiferal Transitional Province (Pozaryska and Peryt, 1979) of the epicontinental Late Cretaceous sea of Central and Eastern Poland.

MATERIALS AND METHODS

The material for this investigation comes from the Maastrichtian outcrops of the Middle Vistula River Valley (Figs 1,2) and from the Sawin Borehole (Fig.1). In the borehole, samples have been taken every 5 metres while in the Middle Vistula River Valley they were collected irregularly, depending on the accessibility of the successiŏn.

Figure 1. Location of the studied areas.

An aliquot of 200-300 specimens from the 120-500 microns size fraction was used for the quantitative faunal analyses.

GEOLOGICAL SETTING

During the late Cretaceous the study area was located in the Danish Polish Trough, the axis of which was paralled to the south-western margin of the East European Platform. Tectonic uplift in the Maastrichtian resulted in the origin of the Mid-Polish Anticlinorium in the axis of the trough, the Szczecin —Lódź— Miechów Synclinorium on the western side and the Gdańsk —Warszawa— Lublin or Border Synclinorium on the eastern side (Pozaryski, 1964).

The Sawin Borehole is located on the border of the East European Platform (Fig. 2). The Maastrichtian deposits with a total thickness of 164 m, are white chalks with marl intercalations (Wyrwicka, 1984). The youngest deposits in the borehole are of early Late Maastrichtian age. The *Guembelitria cretacea* Zone, which was recorded in the Middle Vistula River Valley (Peryt, 1980), and which is an equivalent of the upper part of *Belemnitella junior* and *Hoploscaphites constrictus crassus* Zones of Blaszkiewicz (1980), is not recorded in the Sawin Borehole.

The Maastrichtian deposits outcropping in the Middle Vistula River Valley, south of Pulawy, belong to a tectonic unit known as the Border Synclinorium (Fig. 2). They are about 370 m. thick (Pozaryski, 1938; Blaszkiewicz, 1980) and comprise two lithological units (Figs 3, 5). In the lower Maastrichtian there are 120 m. of siliceous limestones (locally called *opoka*. In the Upper Maastrichtian, 200 m. of marls with intercalations of chalk, are present. Higher in the profile. 50 m of siliceous limestone (*opoka*) with marl intercalations are found. These are terminated by a 1 m. thick hardground that has an irregular, densely burrowed, upper surface.

This hardground is overlain by a marly glauconitic sandstone 30 cm thick. This bed is placed by different authors either in the Lower Tertiary (e.g. Pozaryska, 1965, 1967; Blaszkiewicz, 1980; Gaździcka, 1978) or in the uppermost Maastrichtian (e.g. Po-

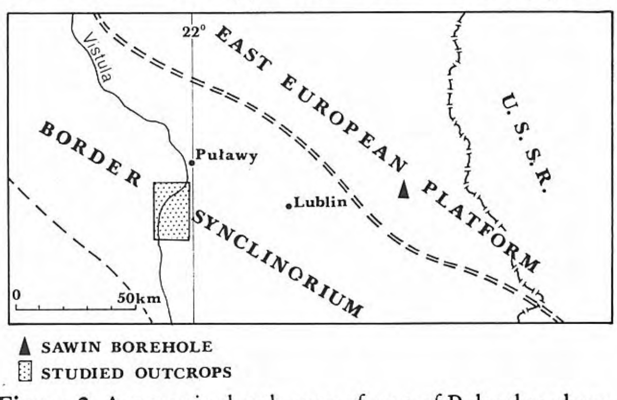

Figure 2. A tectonic sketch-map of part of Poland to show the geotectonic setting of the studied areas.

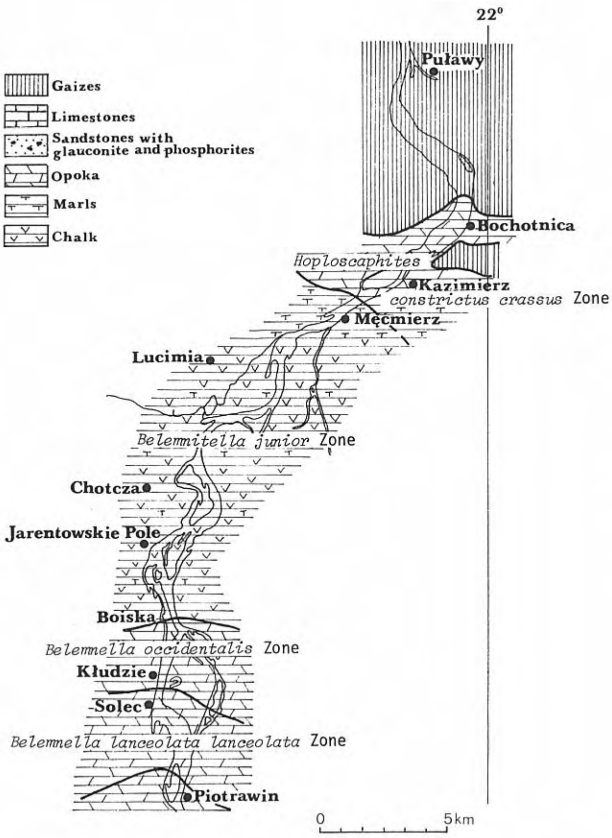

Figure 3. The Maastrichtian facies distribution, location of the outcrops and the boundaries of the ammonite zones in the Middle Vistula River Valley (taken from Abdel-Gawad, 1986).

zaryski, 1938; Kongiel, 1962; Abdel-Gawad, 1986).

The analysis of the planktonic foraminiferal assemblages occuring in this bed confirms the earlier results of Pozaryska (1965).

The Late Maastrichtian species *Guembelitria cretacea* Cushman, *Heterohelix globulosa* (Ehrenberg), *Heterohelix* sp., *Rugoglobigerina macrocephala* Brönnimann, *Globigerinelloides multispina* (Lalicker), and *Globotruncanella* sp. show distinct signs of redeposition. Their co-occurence with species such as *Globoconusa daubjergensis* (Brönnimann), *Globigerina triloculinoides* Plummer, *S. pseudobulloides* (Plummer), indicates a middle Late Danian (cf. Luterbacher and Premoli-Silva, 1964; Salaj *et al.*, 1976; Smit, 1982) age for the overall assemblage.

Pozaryska (1965) recorded a hiatus comprising of the "Zyrzyn Beds" in this section, and Gaździcka (1975) ascribed "Zyrzyn Beds" to the upper part of *Nephrolithus frequens* Zone. According to Gaździcka (1978), the stratigraphical hiatus in the section described comprises the uppermost part of the *Nephrolithus frequens* Zone and *Markalius inversus* Zone.

Above this glauconitic sandstone, the *siwak* (alternating hard gaizes and marls) is found. It is assigned to the Upper Danian.

DISCUSSION OF DATA

Planktonic foraminifera exhibit correlation between the test morphology and the depth on the one hand and between the test morphology and latitudinal provincialism on the other (e.g. Bé and Tolderlund, 1981; Bé, 1977).

During the Maastrichtian the study area belonged to the foraminiferal Transitional Province (Pozaryska and Peryt, 1979) and was located within a shelf area, over which the wates depth is known to have changed (Zapalowicz-Bilan, 1982; Abdel-Gawad, 1986; Peryt, 1988).

Quantitative analyses from both the investigated areas have shown fluctuations in the abundance of the dominant species of planktonic foraminifera during the Maastrichtian (Figs. 4, 5).

Abundance fluctuations, which reflect a relative success of species within the total foraminiferal population, are sensitive palaeoclimatic and palaeoceanographic indicators (Keller, 1986). Most of the species of planktonic foraminifera occuring in these Maastrichtian deposits are shown in Plates I - II.

Sawin Borehole (Fig. 4)

The planktonic foraminiferal fauna of Maastrichtian age recovered from the Sawin Borehole is highly variable. According to Murray (1986) the P/B ratio may be regarded as one of the factors indicating the depth of the sea and the distance from the shore. In the studied section, the P/B ratio reaches its maximum valuel in the Lower Maastrichtian and varies between 30 and 70%. It then decreases considerably (to 10-40%) in the lowermost part of the Upper Maastrichtian. Higher in the profile, in the upper part of lowermost Upper Mastrichtian. The P/B ratio rapidly decreases to between 0 and 5% (Peryt, 1988). This means that the number of planktonic foraminifers in this part of the section becomes insuficient for quantitative studies and gives a picture of catastrophic extinction in the diagram. In reality, however, planktonic foraminifera are present almost up to the top of the Maastrichtian section (Fig. 4). Particular species gradually disappear due to the shallowing of the basin (Peryt, 1988), and the last species which disappear are *Globigerinelloides multispina* (Lalicker) and *G. volutus* (White).

Quantitative and qualitative analyses of planktonic foraminiferal populations show that, in the borehole, at any time the dominant species belongs mostly to one genus and rarely to two genera. A time of dominance is commonly short; during the Early Maastrichtian to early Late Maastrichtian interval six changes of dominant species and genera are recorded (Fig. 4).

The oldest Maastrichtian population are domi-

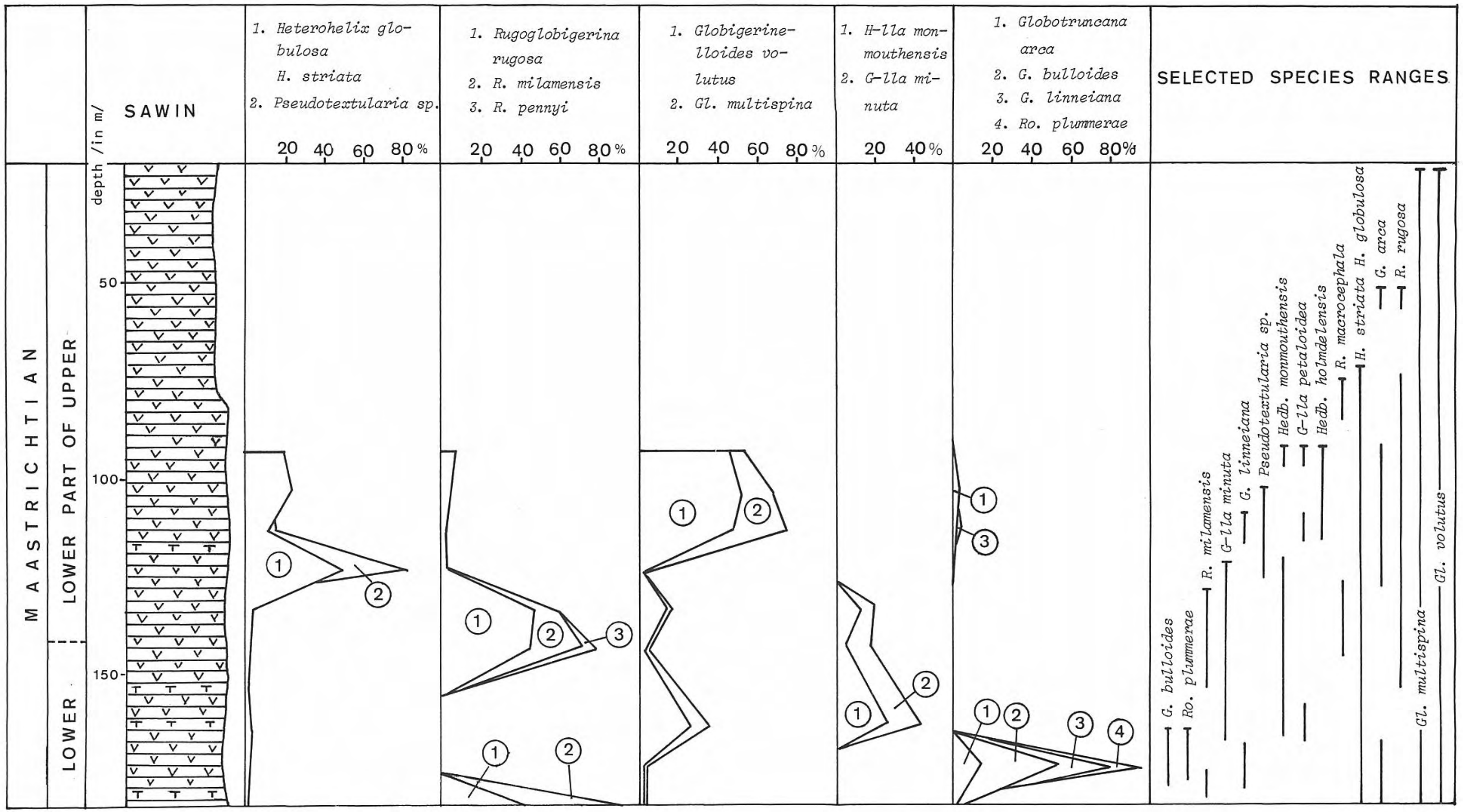

Figure 4. Relative abundance of dominant species and selected species ranges plotted against the Maastrichtian succession of the Sawin borehole. The foraminiferal data is based on counts of 200 - 300 specimens of the 120 - 500 microns size fraction.
Explanation to the lithology as in Fig. 3. *G.= Globotruncana, Ro.= Rosita, R.= Rugoglobigerina, G-lla= Globotruncanella, Hedb.= Hedbergella, H.= Heterohelix, Gl.= Globigerinelloides.*

nated by *Rugoglobigerina rugosa* (Plummer) and *R. milamensis* Smith and Pessagno and then this genus disappears and its place is taken by double-keeled globotruncanids. The latter disappear after a short time of dominance and the population of planktonic foraminifers is dominated by *Globigerinelloides volutus* (White), *Hedbergella monmouthensis* (Olsson), and *Globotruncanella minuta* Caron and González-Donoso. In earliest Late Maastrichtian the reappearance of *Rugoglobigerina* is observed and again the dominant species are *Rugoglobigerina rugosa* (Plummer) and *R. milamensis* Smith and Pessagno. After a short interval they again reduce in importance and the population is dominated by heterohelicids (*Heterohelix globulosa* (Ehrenberg), *H. striata* (Ehrenberg), and *Pseudotextularia elegans* (Rzehak)). The latter disappear quickly while *Heterohelix globulosa* (Ehrenberg) and *H. striata* (Ehrenberg) remain the dominant species along with *Globigerinelloides volutus* (White) and *G. multispina* (Lalicker) in the youngest analyzed population. The frequent change of dominant species in the Early and early Late Maastrichtian, the migration of *Rugoglobigerina* and *Globotruncana*, the considerable changes of P/B ratio, low diversity, and the predominance of *Heterohelix*, *Hedbergella*, and *Globigerinelloides* indicate the location of the study area relativaly near to the shore line where even small changes of waters depth resulted in a considerable quantitative variation in the composition of the planktonic foraminiferal populations (cf. Bé and Tolderlund, 1971; Sliter, 1972; Caron, 1983; Hart and Ball, 1986).

Middle Vistula River Valley section (Fig. 5)

The area of the Middle Vistula River Valley was located near the axis of the Polish-Danish Trough and the planktonic foraminiferal assemblages are relatively highly diversified (Peryt, 1980). The P/B ratio values indicate middle-outer shelf water depths and rather greater distance from the shore during the Early to middle Late Maastrichtian and a nearer shore environment in the latest Maastrichtian (cf. Abdel-Gawad, 1986). The considerable distance from the shore and the greater water depth (compared to the Sawin area) resulted in the fact that changes of sea level, of both eustatic and tectonic origin, did not greatly affect the planktonic foraminiferal populations, especially those in the earlier Maastrichtian.

Populations of planktonic foraminifers in the Early Maastrichtian are characterized by a high diversity and a lack of a dominant species. Approximately 80% of the population is formed by 7-8 species, and occurring along with the surface-waters morphotypes (*Heterohelix*, *Globigerinelloides*) are the intermediate water-depth morphotypes (*Archaeoglobigerina*, *Rugoglobigerina*) and the deeper water morphotypes (*Globotruncana*).

In the late Early Maastrichtian (Late *Belemnella lanceolata lanceolata* Zone and *Belemnella occidentalis* Zone), *Globotruncana* disappears and the population are dominated by *Rugoglobigerina rugosa* (Plummer) and *R. milamensis* Smith and Pessagno.

During the early Late Maastrichtian (Early *Belemnitella junior* Zone) *Globigerinelloides volutus* (White), *G. multispina* (Lalicker), *Heterohelix striata* (Ehrenberg) and *H. globulosa* (Ehrenberg) dominate the populations.

In the middle of the *Belemnitella junior* Zone, *Globotruncana* again becomes (together with *Globigerinelloides multispina* (Lalicker) and *G. volutus* (White)) an important element of the microfauna. However, after a short interval this genus finally disappears from this region. This event may be correlated with the reappearance of *Globotruncana* in the Sawin borehole at depth 93-123 m where, however, it did not dominate the populations. In the Late *Belemnitella junior* Zone heterohelicids begin to dominate.

It is worth mentioning that *Guembelitria cretacea* Cushman appears at that time. This species is regarded as and indicator of unfavourable environmental conditions for other species of planktonic foraminifera (Smit, 1982). Simultaneously, in the planktonic foraminiferal populations dwarfed forms, twinned forms, heterohelicids with a curved axis, and forms with additional chambers are quite often found. All these characteristies of the fauna appear to indicate unfavourable, stressed conditions for planktonic foraminifers (Hansen *et al.*, 1986; Hultberg and Malmgrem, 1987).

In the Middle *Hoploscaphites crasus* Zone *Rugoglobigerina* again appears, but its contribution to the assemblages does not reach 20%; the most frequent species *Rugoglobigerina rugosa* (Plummer) reaches 11%.

In the latest *Hoploscaphites constrictus crassus* Zone the contribution of *Guembelitria cretacea* Cushman to the fauna exceeds 20%. This species becomes (along with *Heterohelix striata* (Ehrenberg) and *H. globulosa* (Ehrenberg)) one of the dominant species in the latest Maastrichtian planktonic foraminiferal populations.

All species of planktonic foraminifers disappears below the hardground. This stratigraphic hiatus comprises the uppermost Maastrichtian and Lower Danian (Pozaryska, 1965; Gaździcka, 1978).

INTERPRETATION OF THE DATA

Considering the high P/B ratio values and a considerable contribution of intermediate and deeper-water morphotypes to the populations (cf. Murray, 1976; Caron, 1983; Hart and Ball, 1986) it may be supposed that during the earliest Maastrichtian both the regions were located outer in the shelf zone (cf. Abdel-Gawad, 1986; Peryt, 1987).

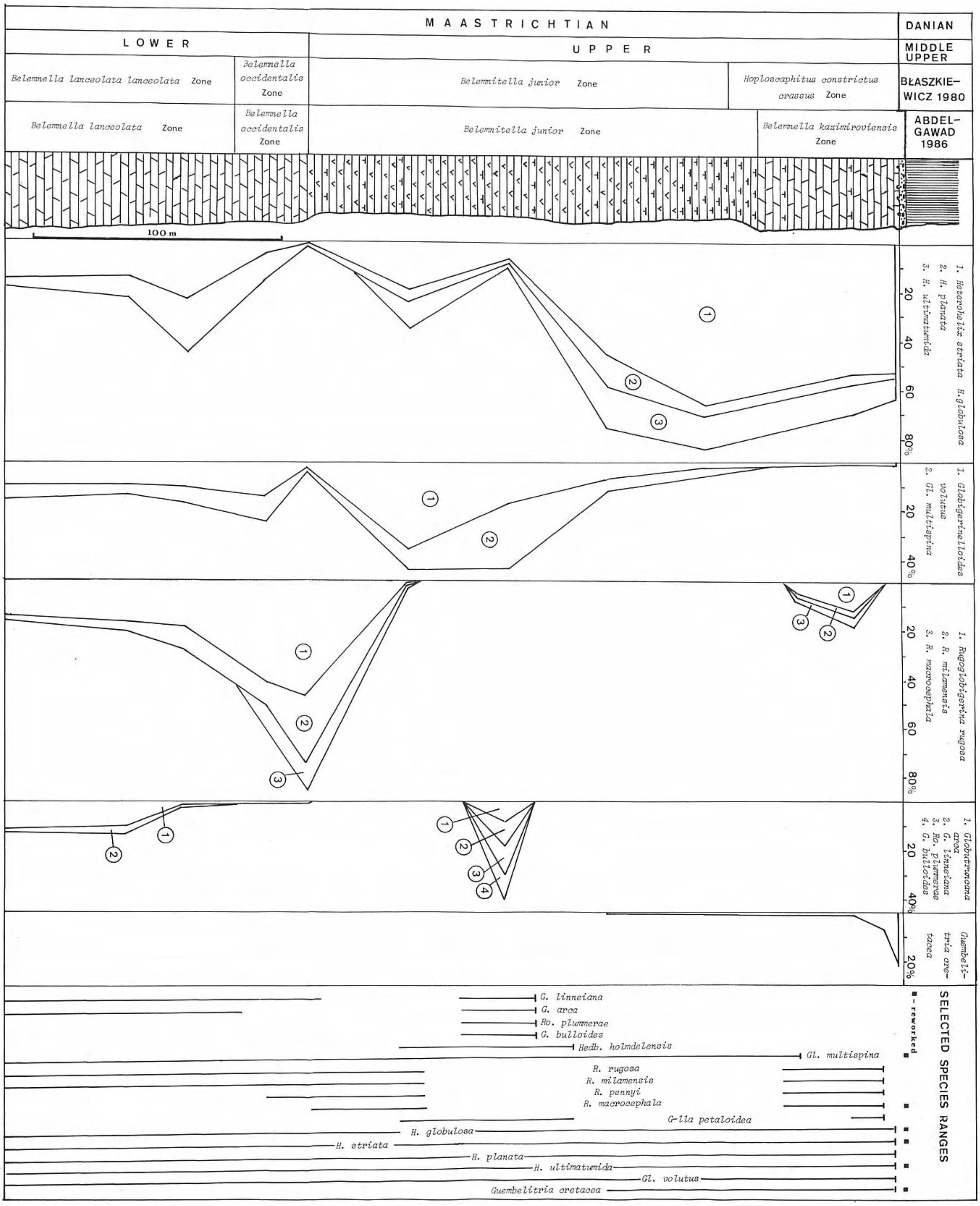

Figure 5. Relative abundance of dominant species and selected species ranges plotted against the Maastrichtian succession of the Middle Vistula River Valley. The foraminiferal data is based on counts of 200 - 300 specimens of the 120 - 500 microns size fraction. Explanation as in Fig. 3 and 4.

The gradual disappearance of *Globotruncana* in the Middle Vistula River region during the middle Early Maastrichtian and its replacement by *Rugoglobigerina* (an intermediate water depth morphotype) along with the increased contribution of *Heterohelix* and, in the more marginal part of the sedimentary basin (Sawin area), the rapid disapearance of *Globotuncana* and the dominance of *Globigerinelloides multispina* (Lalicker), *G. volutus* (White), *Hedbergella monnmouthensis* (Olsson) and *Globotruncanella minuta* Caron and González-Donoso all indicate the considerable shallowing of the sea. The domination of the planktonic foraminiferal populations in the latest Early Maastrichtian by *Rugoglobigerina* in both the studied areas indicates the deepening of the basin.

The next change in the composition of the assemblages takes place in the early Late Maastrichtian. A rapid decline of *Rugoglobigerina* in the entire area and the dominance of *Globigerinelloides* and *Heterohelix* in the population from the Middle Vistula River Valley and of heterohelicids in the Sawin populations, indicate a considerable shallowing of the sea.

During the middle part of the *Belemnitella junior* Zone of the Middle Vistula River area the contribution of *Globigerinelloides* is stable, the contribution of *Heterohelix* diminishes, and *Globotruncana* reappears and represents 40% of the populations. In the Sawin area populations are dominated by *Globigerinelloides* and *Heterohelix*, whereas *Globotruncana* is a subordinate component (2-5%). Such characteristics indicate a deepening of the basin. After the short interval characterised by the presence of *Globotruncana* the Late *Belemnitella junior* Zone populations are dominated by *Heterohelix* and *Guembelitria* in the Middle Vistula River area whereas in the Sawin area the number of planktonic foraminifers is so small that they are to be neglected during quantitative analysis. This indicates very shallow basin.

CONCLUSIONS

Qualitative and quantitative analyses of planktonic foraminiferal populations from Central and Eastern Poland indicates the changes of sea level which occurred during the Maastrichtian. It seems that the changes were both of eustatic origin and related to tectonic movements during Late Maastrichtian which led to the development of the Middle Polish Anticlinorium (Pozaryski, 1960; Kutek and Glazek, 1972). The Late Maastrichtian, worldwide regression which coincided with tectonic activity in the Polish-Danian Trough and the cooling of the climate which followed the regression were most probably responsible for the extinction of planktonic foraminifers in the area studied during the latest Maastrichtian, i.e., earlier than in oceanic regions (cf. Smit, 1982; Lamolda *et al.*, 1983; Caron, 1985; Fig. 6). Three main steps in the extinction of the planktonic foraminifers can be distinguished in the axial zone of Danish-Polish Trough during the latest Maastrichtian in Central Poland (Foraminiferal Transitional Province):

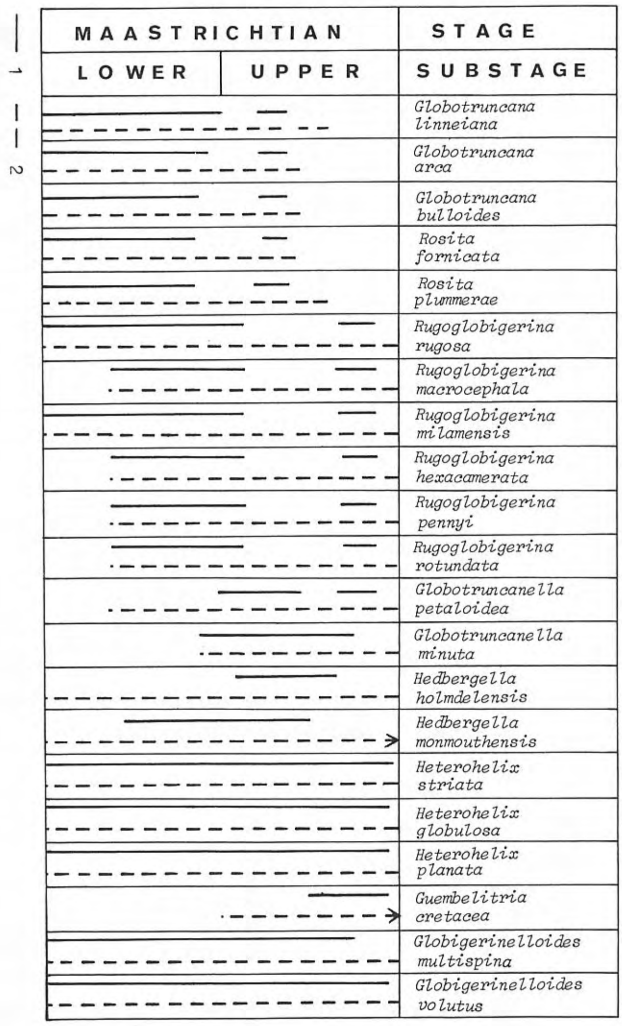

Figura 6. Stratigraphic distribution of selected species of planktonic foraminifera in studied areas (continous lines) with comparative ranges in other areas-dashed lines-after Smit (1982), Lamolda *et al* (1983) and Caron (1985).

1. The extinction in the Late *Belemnitella junior* Zone of all species of *Globotruncana;*

2. The extinction in the Late *Hoploscaphites constrictus crassus* Zone of all species of *Rugoglobigerina*, shortly followed by

3. The extinction of the last planktonic species of the genera *Heterohelix, Globigerinelloides* and *Guembelitria.*

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Plate I

1, 2 *Globotruncana orientalis* El Naggar; Chotcza, ×80.
3, 4 *Globotruncana arca* (Cushman); Chotcza, ×90.
5, 10 *Rosita fornicata* (Plummer); Chotcza, 5 ×102; 10 ×115.
6, 7 *Globotruncana linneiana* (d'Orbigny); Chotcza, ×100.
8, 9 *Globotruncana arca* (Cushman); Chotcza, ×90.
11, 12 *Rosita fornicata* (Plummer); Chotcza, ×100.
13, 14 *Rosita plummerae* (Gandolfi); Chotcza, ×90.
15, 19 *Globotruncana sp*., Sawin borehole, depth 173 m, ×105.
17, 18 *Globotruncana bulloides* Vogler; Sawin borehole, depth 183 m, ×105.
16 *Rugoglobigerina milamensis* Smith and Pessagno; Sawin borehole, depth 183 m, ×90.
20 *Rugoglobigerina rugosa* (Plummer); Kazimierz, ×105
21 *Rugoglobigerina milamensis* Smith and Pessagno; Kazimierz, ×110.
22 *Rugoglobigerina macrocephala* Brönnimann; Sawin borehole, depth 93 m, ×170.
23 *Rugloglobigerina pennyi* Brönnimann; Kazimierz, ×80.

PLATE I

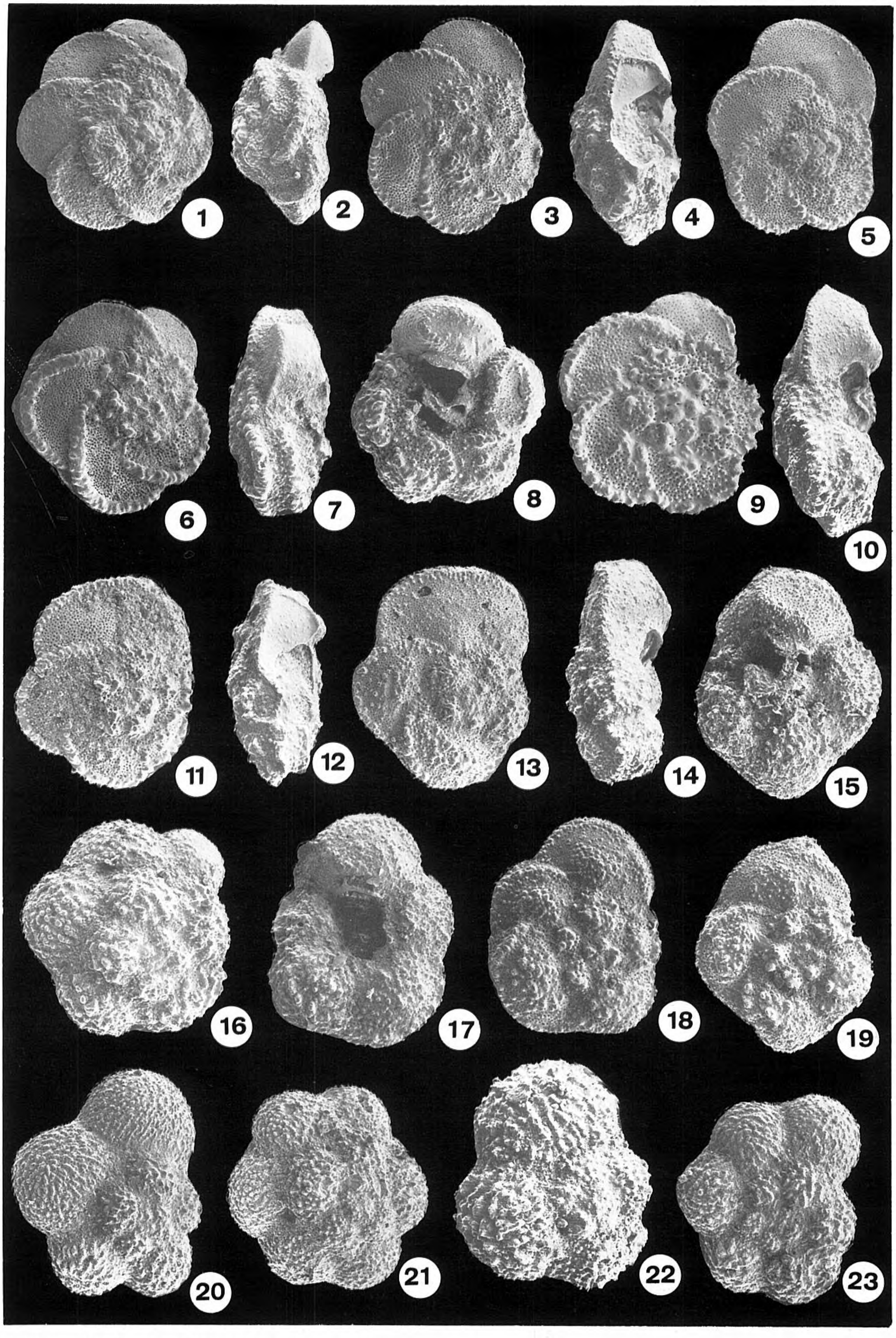

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Plate II

1 *Heterohelix striata* (Ehrenberg); Chotcza, ×150.
2 *Heterohelix globulosa* (Ehrenberg); Lucimia, ×120.
3 *Racemiguembelina powelli* Smith and Pessagno; Chotcza, ×100.
4 *Planoglogulina carseyae* (Plummer); Kazimierz, ×190.
5 *Guembelitria cretacea* Cushman; Kazimierz, ×190.
6 *Heterohelix ultimatumida* (White); Lucimia, ×140.
7, 13 *Heterohelix planata* (Cushman); Lucimia, ×140.
8 *Heterohelix pulchra* (Brotzen); Mećmierz, ×150.
9 *Heterohelix vistulaensis* Peryt; Kazimierz, ×300.
10 *Heterohelix ventilabrelliformis* (van der Sluis); Mećmierz, ×150.
11, 12 *Pseudotextularia* sp., Sawin borehole, depth 123 m, ×100.
14 *Globigerinelloides multispina* (Lalicker); Chotcza, ×110.
15 *Globigerinelloides volutus* (White); Chotcza, ×200.
16, 18 *Herdbergella monmouthensis* (Olsson); Kazimierz, ×160.
17 *Guembelitria cretacea* Cushman; Kazimierz, ×250.
19, 20 *Globotruncanella* sp., Sawin borehole, depth 93 m, ×220.
21, 22 *Hedbergella holmdelensis* Olsson; Sawin borehore; depth 93 m ×220.
23, 24 *Globotruncanella petaloidea* (Gandolfi); Chotcza, ×150.

PLATE II