Die „Transitional“ Faunenprovinz der jüngsten Kreide und des frühen Paläozäns Polens und ihre Foraminiferen

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with 3 text-figures and 2 plates

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Abstract: The whole of Poland (excluding the Carpathians) belonged to the Transitional Faunal Province during the Late Cretaceous. This is demonstrated by the nature of a rich assemblage of planktonic Foraminifera from the Upper Albian to the Maastrichtian. The planktonic Foraminifera from the Transitional Province in the Late Cretaceous form an assemblage consisting of cosmopolitan and warm-water forms, characterized by an apparently higher tolerance to changes in temperature than the typical Tethyan forms. The diversity of the foraminiferal assemblage in the Transitional Province is poorer than that in the Tethys, particularly of keeled forms, but on the other hand it is almost twice as great as that in the Boreal Realm. The Upper Albian to Lower Turonian foraminiferal assemblages from the Polish Lowlands consist mainly of species having a wide geographic range but not extending further than 42°N; proper cosmopolitan forms are rare. However, the Upper Turonian to Lower Santonian assemblages consist mainly of cosmopolitan species with almost no warm-water forms. Again, from the Upper Santonian upwards, warm-water forms begin to dominate clearly over cosmopolitan species, particularly in the Maastrichtian. Neither benthonic nor planktonic Foraminifera typical of the Boreal Realm have been found in the Late Cretaceous of the Polish Lowlands.
The rich macrofauna of the Late Cretaceous of the Polish Lowlands is represented by forms typical of the North European Trough, though it does not provide too much information on the problem of provinciality. The only exceptions are the keeled Alpine pseudoceratitid ammonites, which are present both in the Lower and Upper Maastrichtian. The rich benthonic microfauna which allows the biostratigraphical subdivision of the Upper Cretaceous also has almost no value for provinciality studies. An exception is the warm-water assemblage of benthonic Foraminifera which originated during the Upper Maastrichtian in the Transitional Province in Belgium; this developed through space and time and reached the area of Poland during the Montian.

Kurzfassung: Ganz Polen mit Ausnahme der Karpaten gehörte während der jüngsten Kreide zur „Transitional Province“. Dies zeigt sich durch das häufige Vorkommen planktonischer Foraminiferen vom Ober-Alb bis ins Maastricht. Die Vergesellschaftungen der planktonischen Foraminiferen enthalten kosmopolitische und Warmwasser-Formen, die sich dadurch auszeichnen, daß sie Temperatur-Schwankungen besser tolerierten als die typischen Formen der Tethys. Die Vielfalt der Formen, die in der „Transitional Province“ vorkommen, ist geringer als in der Tethys, doch beinahe doppelt so groß wie in den borealen Gebieten. Die Foraminiferen-Vergesellschaftungen der polnischen Tiefebene bestehen vom Ober-Alb bis ins Unter-Turon hauptsächlich aus Formen, die eine große geographische Verbreitung aufweisen können, doch 42°N nicht überschreiten; typische Kosmopoliten sind selten. Dagegen enthalten die Vergesellschaftungen vom Ober-Turon bis ins Unter-Santon hauptsächlich kosmopolitische Arten und fast keinerlei Warmwasser-Formen. Vom Ober-Santon an jedoch dominieren wieder Warmwasser-Formen über die Kosmopoliten,

besonders im Maastricht. Weder benthonische noch planktonische Foraminiferen aus borealen Gebieten wurden in der späten Kreide der polnischen Tiefebene gefunden.
Die reiche Makrofauna der späten Kreide in Polen enthält typische Formen aus dem N-europäischen Becken und liefert somit keine Informationen für das Problem des Provinzialismus. Die einzige Ausnahme bilden gekielte alpine Pseudoceratiten bei den Ammoniten, die sowohl im Unter- als auch im Ober-Maastricht vorkommen. Auch die reiche benthonische Mikrofauna, mit der die Oberkreide biostratigraphisch unterteilt wird, ist nahezu wertlos, um Studien über den Provinzialismus anzustellen. Eine Ausnahme stellt jedoch die Warmwasser-Vergesellschaftung benthonischer Foraminiferen dar, die während des Ober-Maastricht in der „Transitional Province" in Belgien entsteht, sich später durch Raum und Zeit weiterentwickelt und Polen während des Mont erreicht.

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General Palaeogeography

Poland is situated in the central part of the Upper Cretaceous epicontinental basin of Europe, which was subjected to relatively intense Laramide movements. Post-Laramide erosion exposed pre-Cretaceous rocks in the central part of the basin and good, complete profiles of Upper Cretaceous sediments exist only along the margins. These are particularly well exposed in the area of the Holy Cross Mountains in central Poland (Fig. 1).

The Late Cretaceous basin of extra-Alpine central Europe streched north of the Tethyan ocean and was delineated by the Baltic and the Ukrainian shields to the north and to the southeast, respectively. It was connected by a shallow and temporarily inactive seaway to the Volga and Dnepr-Donetz basins to the east. Its connections with the Tethys were essentially continuous except for areas of large and rigid basement blocks such as the Bohemian and the (?)stable Upper Silesian massifs. The influence of these massifs, detectable over large areas of the Variscan Fold Belts, is mainly reflected by the reduced thickness and patchy preservation of Upper Cretaceous deposits in these areas. This influence may be traced as far as Poznan (Gubin) in the north and to the margins of the Upper Silesian massif in the south. It should be remembered that even these areas were completely flooded at the peak of the Late Cretaceous transgression, i. e. in the Turonian.

The Polish Lowlands represents the central part of the North European Cretaceous basin. Within this basin a deep trough developed with a rapidly subsiding floor and aulacogen features. This trough was oriented NW-SE, streching from Jutland and Scania through central Poland to merge with the Carpathian geosyncline south of Przemysl and Lwow. The Upper Cretaceous sequence in the trough is highly variable in thickness, usually over 750 m but occasionally up to 2500 m thick near Inowroclaw and Gniezno. Marly and marly-siliceous facies dominate while a chalky facies is absent.

The Upper Cretaceous sediments from the North European Lowlands and the North Sea, excluding the Polish trough and identical troughs with rapidly subsiding floors from Northern Germany and north of the Variscan Fold Belts, are fairly monotonous and originally not more than 750 m thick. The chalk facies is very common here. The sediments were deposited in water of relatively shallow depth. The monotonous lithology and the fairly uniform thickness of these deposits over large areas were not controlled by floor subsidence, as affected the troughs, but rather by an eustatic, gradual rise of sea level. Peripheral areas such as the margins of the Baltic shield (Bornholm, eastern Scania), and the Upper Silesian, Ukrainian and Ardennes massifs, are exceptions as they were characterized by a more elevated sea floor and hence coastal facies sediments (with numerous sedimentary breaks) were deposited. The coastal areas were as a rule narrow in relation to the width of the basin. The facies of these coastal areas as well as those of the adjoining basins were also influenced by the nature of land masses. Where land masses were characterized by low relief, and therefore erosion was not intense, a chalky facies dominates in

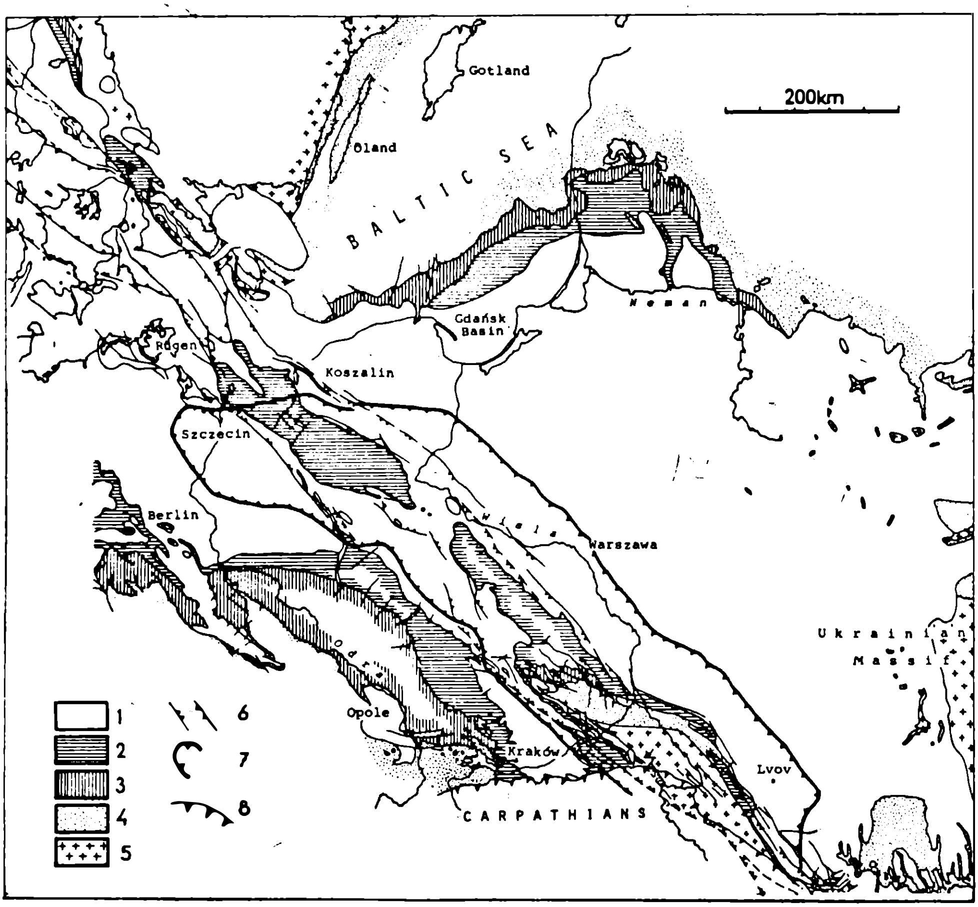

Fig. 1. Geological map of Poland and neighbouring areas without Cenozoic cover (after W. Pożaryski & W. Brochwicz-Lewiński 1978). – 1 – Cretaceous; 2 – Jurassic; 3 – Triassic; 4 – Paleozoic; 5 – Precambrian; 6 – main fault zones; 7 – boundary of Mid-Polish trough; 8 – northern boundary of the Carpathians.

marginal parts of the basin (Ukrainian massif and western part of the Baltic shield). When uplift and hence intense erosion took place, the supply of detrital material increased, while deposition of chalk continued (eastern Pomerania and some parts of the surroundings of the Ardennes).

In the palaeogeographic scheme outlined above, the area of Poland is particularly suitable for the study of Tethyan oceanic influences which migrated towards the epicontinental North European basin, in the direction of the proper Boreal Province.

Faunal Provinciality

The epicontinental Upper Cretaceous shows numerous features characteristic of the Boreal Province. Although carpet sponges occur in masses and sometimes attain rock-forming importance, typical reef facies are absent. The wealth of inoceramids, ammonites and belemnites, as well as the assemblages of pelecypods, echinoids and other macrofossils, are also characteristic of the Boreal Realm (Pożaryski 1938; Błaszkiewicz, in press; Cieśliński, in press). The whole assemblage comprises mainly cosmopolitan species. However, exceptions are rather numerous: e. g. *Sphenodiscus binckhorsti* Böhm from the Upper Maastrichtian, and *Placenticeras whitefieldi* Hyatt from the Lower Maastrichtian (Pożaryska 1953). Representatives of the

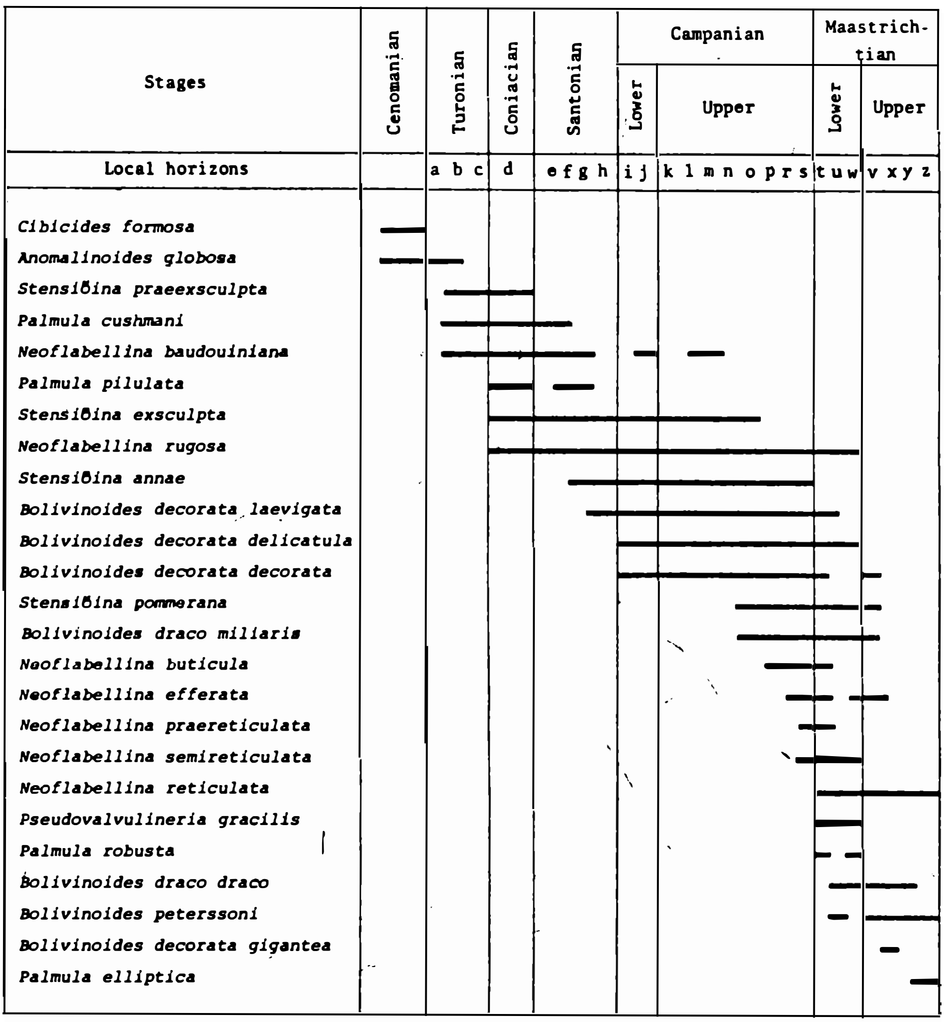

Fig. 2. Stratigraphy of the Upper Cretaceous in Polish Middle Vistula valley, based on benthonic foraminifera (After Pożaryska 1956).

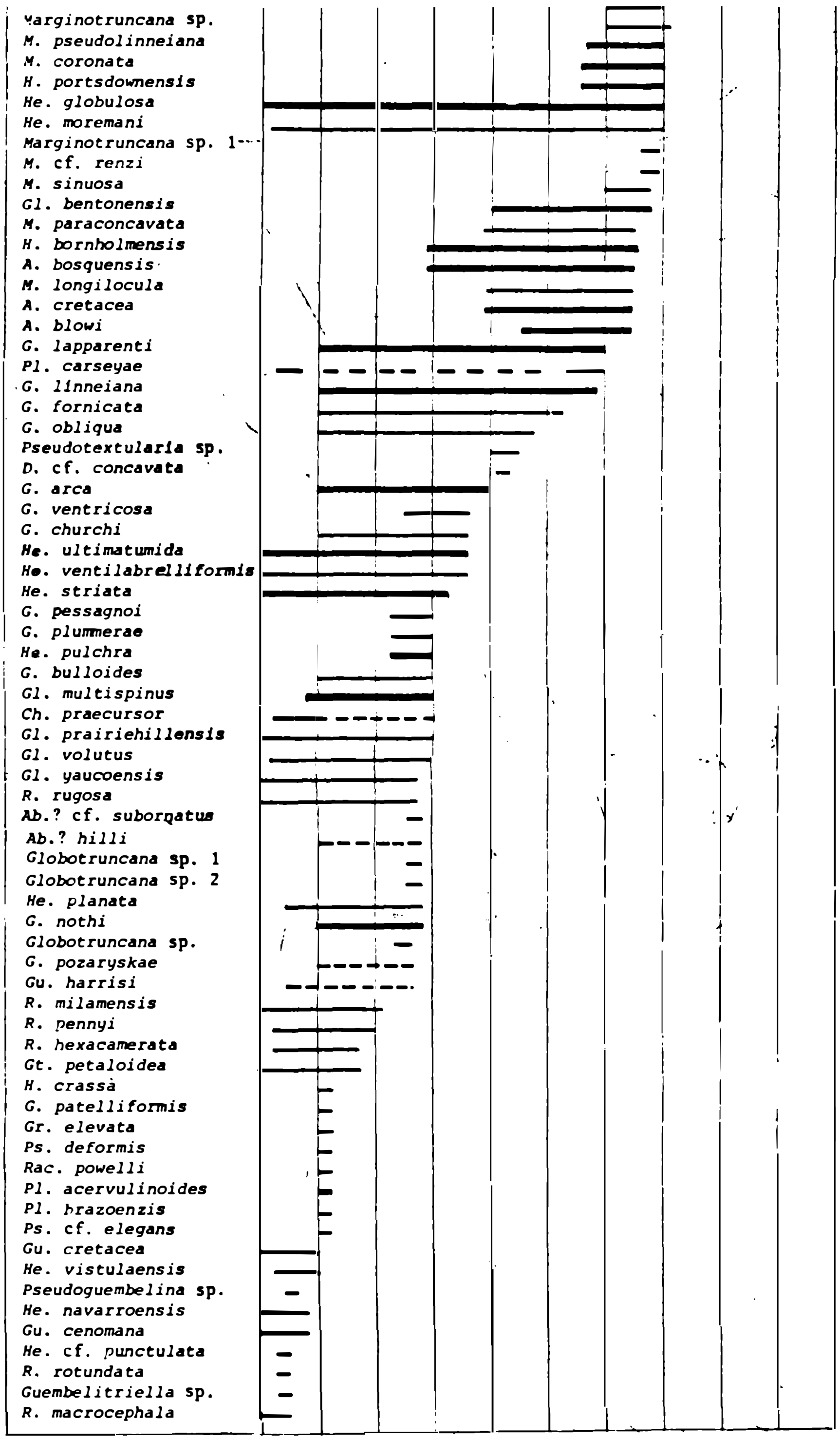

Fig. 3. Ranges of planktonic foraminifera in the Upper Cretaceous section of the Vistula River valley (after Peryt 1979). Thick lines: cosmopolitan species; thin lines: latitudinally-restricted species of the Tethyan and Transitional provinces.

H. – *Hedbergella*
Gl. *Globigerinelloides*
Pr. – *Praeglobotruncana*
Hl. – *Helvetoglobotruncana*
Ro. – *Rotalipora*
D. *Dicarinella*
Wh. – *Whiteinella*
M. – *Marginotruncana*
He. – *Heterohelix*
A. – *Archaeoglobigerina*
G. – *Globotruncana*
Pl. – *Planoglobulina*
Ch. – *Chiloguembelina*
R. – *Rugoglobigerina*
Ab. – *Abathomphalus*
Gu. – *Guembelitria*
Gt. – *Globotruncanella*
Gr. – *Globotruncanita*
Ps. – *Pseudotextularia*
Rac. – *Racemiguembelina*

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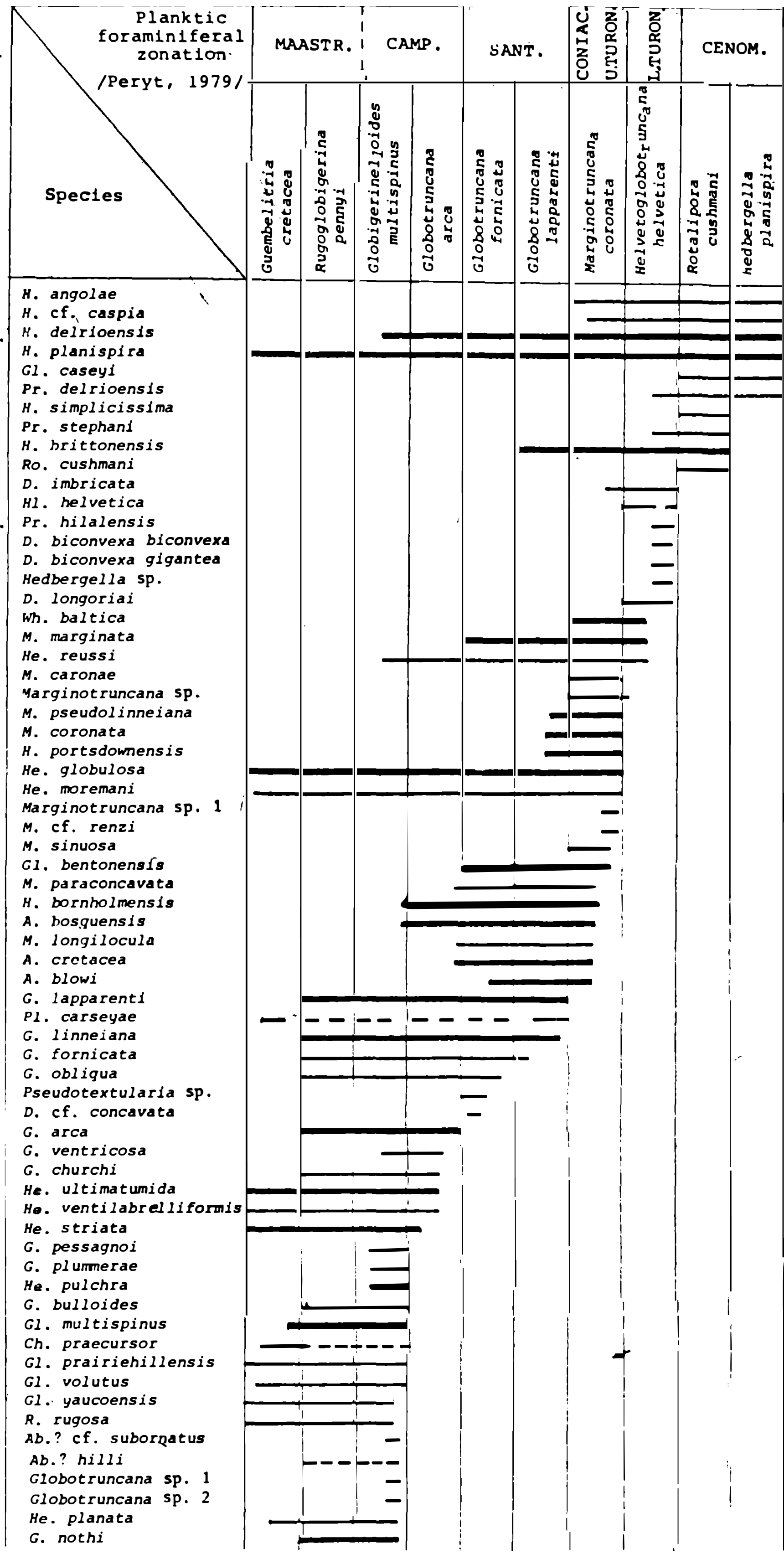
Planktic foraminiferal zonation /Peryt, 1979/
Species
MAASTR.
CAMP.
SANT.
CONIAC.
U.TURON.
L.TURON.
CENOM.
Guembelitria cretacea
Rugoglobigerina pennyi
Globigerinelloides multispinus
Globotruncana arca
Globotruncana fornicata
Globotruncana lapparenti
Marginotruncana coronata
Helvetoglobotruncana helvetica
Rotalipora cushmani
Hedbergella planispira
H. angolae
H. cf. caspia
H. delrioensis
H. planispira
Gl. caseyi
Pr. delrioensis
H. simplicissima
Pr. stephani
H. brittonensis
Ro. cushmani
D. imbricata
Hl. helvetica
Pr. hilalensis
D. biconvexa biconvexa
D. biconvexa gigantea
Hedbergella sp.
D. longoriai
Wh. baltica
M. marginata
He. reussi
M. caronae
Marginotruncana sp.
M. pseudolinneiana
M. coronata
H. portsdownensis
He. globulosa
He. moremani
Marginotruncana sp. 1
M. cf. renzi
M. sinuosa
Gl. bentonensis
M. paraconcavata
H. bornholmensis
A. bosquensis
M. longilocula
A. cretacea
A. blowi
G. lapparenti
Pl. carseyae
G. linneiana
G. fornicata
G. obliqua
Pseudotextularia sp.
D. cf. concavata
G. arca
G. ventricosa
G. churchi
He. ultimatumida
He. ventilabrelliformis
He. striata
G. pessagnoi
G. plummerae
He. pulchra
G. bulloides
Gl. multispinus
Ch. praecursor
Gl. prairiehillensis
Gl. volutus
Gl. yaucoensis
R. rugosa
Ab.? cf. subornatus
Ab.? hilli
Globotruncana sp. 1
Globotruncana sp. 2
He. planata
G. nothi

strongly keeled ammonite genus *Hauericeras*, which may be also considered as a warm-water form, also occur in the Maastrichtian. Warm-water influences are clearly shown in the foraminiferal microfauna. These Tethyan influences are well marked in the Upper Cretaceous of the Szczecin-Miechow synclinorium (Gawor-Biedowa 1972; Heller 1975), and on a much smaller scale in the marginal synclinorium (Peryt 1979). This statement applies only to the planktonic Foraminifera, which have been used for the biozonation of these sediments (Pl. 1). Although a general zonation of the Upper Cretaceous in Poland has been made using the benthonic Foraminifera (Pożaryska 1955) (Fig. 2), they do not display provinciality.

The provinciality of various groups of organisms in the Late Cretaceous was noted in the nineteenth century. The faunal provinces most widely accepted include the Tethys, Boreal, Antiboreal and the Indopacific, and with respect to the Late Cretaceous planktonic Foraminifera of these provinces can also be recognized. Scheibnerová (1971a, 1971b), differentiated the following foraminiferal provinces in the Late Cretaceous: Tropical (Tethys), Boreal, Austral and two Transitional Provinces situated north and south of the Tethyan Province. The same provinces, i. e. Tethyan, Meridional (= Transitional) and Boreal, were recognized in Europe in the Lower Paleocene (Szczechura & Pożaryska 1976). In Europe, the northern boundary of the Tethyan Province coincides with the northern margin of the Alpine ranges, and the boundary between the Transitional and the Boreal Provinces occurs at about 42°N (Bailey 1978).

Studies on the distribution of Recent species of planktonic Foraminifera have shown that the occurrence of the genus *Globorotalia* is closely related to warm waters, whereas *Globigerina* predominates in temperate and cold waters as well as in nearshore zones (Phleger 1960). Similar results were obtained in Poland for Late Cretaceous planktonic Foraminifera (Peryt 1979) as well as for Lower Paleocene benthonic Foraminifera (Szczechura & Pożaryska 1976). Bé & Tolderlund (1971) found that the majority of spinose species are surface dwellers or live in the upper parts of the euphotic zone (down to 10m depth); all the species of *Globigerinoides* and some *Globigerina* belong to this group. The majority of non-spinose species live at subsurface depths, i.e. at a depth of over 50m and often even over 500m. Representatives of Recent species of *Globorotalia* change depth zones even during their life. In early growth stages they live in the euphotic zone, while in late ontogeny they change to meso- or to bathypelagic depths. The same changes are assumed to have taken place in the case of Late Cretaceous keeled planktonic species and in the genus *Hedbergella*. Generally speaking, keeled planktonic species are replaced by *Hedbergella* at high latitudes and at the transition from oceanic to shallow or coastal areas (Douglas & Sliter 1966). This results in the development of particular Foraminifera provinces with differences in generic composition. However, it should be noted that the differences between foraminiferal assemblages of the Tethyan and the Boreal Provinces in the Late Cretaceous were mainly at the specific and not at the generic level.

In the Upper Cretaceous sediments of Poland the following genera of planktonic Foraminifera have been found: *Guembelitria, Guembelitriella, Heterohelix, Chiloguembelina, Pseudoguembelina, Pseudotextularia, Racemiguembelina, Planoglobulina, Globigerinelloides, Schackoina, Hedbergella, Praeglobotruncana, Rotalipora, Marginotruncana, Dicarinella, Helvetoglobotruncana, Whiteinella, Globotruncana, Archaeglobigerina, Globotruncanita, Rugoglobigerina, ? Abathomphalus* and *Globotruncanella* (Pożaryski & Witwicka 1956; Gawor-Biedowa 1972; Heller 1975; Peryt 1979). Some of these genera, for instance *Helvetoglobotruncana, Globotruncana, Racemiguembelina, Guembelitriella, Pseudoguembelina, Chiloguembelina* and *Pseudotextularia*, are represented only by a single species with innumerable individuals, and therefore their contribution to the foraminiferal spectrum is negligible. The dominant

genera are: *Hedbergella, Dicarinella, Marginotruncana, Globotruncana, Globigerinelloides, Heterohelix* and *Rugoglobigerina*. None of these above genera or their species are known to be restricted only to the Boreal Province. Only a few genera such as *Dicarinella, Globotruncana, Globotruncanita* and *Abathomphalus* have some species with a limited distribution, that is, restricted to the Tethyan Province. The genera less sensitive to changes in temperature have the maximum number of cosmopolitan species. They are respresented by at least one species in the Boreal assemblage, i. e. *Heterohelix, Planoglobulina, Globigerinelloides, Hedbergella, Marginotrucana, Whiteinella, Globotruncana* and *Archaeoglobigerina* (Sliter 1973; Douglas & Rankin 1969; North & Caldwell 1975; Norling 1973). It should also be noted that our knowledge of the distribution of Late Cretaceous nonkeeled species is notably poorer than that of the coeval keeled species. This is connected with their much slower rate of evolution, which has led to their limited attention in biostratigraphic studies. Until recently, studies of the warm-water, keeled species have mainly differentiated range zones and phylo-zones. The lack of keeled Foraminifera at higher latitudes, which are occupied mainly by cosmopolitan species much less sensitive to changes in temperature, has also had a limiting effect on stratigraphic studies based upon these Foraminifera. The need to introduce separate stratigraphic subdivisions for Tethyan and Boreal Provinces was pointed out by Scheibnerová (1971).
Studies of planktonic Foraminifera from the continuous Cenomanian-Maastrichtian profile of the Vistula river valley in Central Poland (Peryt 1979) have shown that in this section it is not possible to differentiate the range zones established on the basis of endemic Tethyan species (Fig. 3). The difficulties which arose in the construction of stratigraphic schemas were solved by using interval zones mainly, and by taking into consideration those cosmopolitan species which predominate in assemblages from higher latitudes but which are present in all the provinces. Such species facilitate long distance correlations.

Distribution and Characteristics of Upper Cretaceous Faunas

Albian: An important Late Cretaceous marine transgression in Poland began as early as the Late Albian. The richest Foraminifera asemblages of that age have been found in marly deposits in the NW parts of the Mogilno Trough, as well as in the Lodz Trough and in the Fore-sudetic Monocline (Gawor-Biedowa 1972; Heller 1975). They include *Guembelitria cenomana, Heterohelix washitensis, Bifarina calcarata, Globigerinelloides bentonensis, Hedbergella planispira, H. infracretacea, H. simplicissima, H. hoterivica, Schackoina molinensis, S. cenomana cenomana* and *S. cenomana bicornis*. Also present are first representatives of the Cenomanian general *Rotalipora* and *Praeglobotruncana*. These genera, together with *Planomalina, Hedbergella, Schackoina* and *Globigerinelloides* have been considered by Douglas & Sliter (1966) to be widespread except at high latitudes. Of these genera only *Planomalina* is lacking in the Polish Lowlands. This genus seems to be limited to the warm-waters of the Tethys (Loeblich & Tappan 1961). The majority of species recorded in the Albian of the Polish Lowlands, as for example *Hedbergella simplicissima, H. hoterivica* and those of the genus *Schackoina*, are known from the Tethyan and from the Transitional Provinces. The remaining species of the genus *Hedbergella*, and *Globigerinelloides bentonensis*, are known from the Boreal Province (North & Caldwell 1975; Sliter 1973; Douglas & Rankin 1969). *Heterohelix washitensis* is extremely rare and *Guembelitria cenomana* is known only from the USSR and Poland.

Cenomanian: The Cenomanian planktonic Foraminifera assemblage is enriched relative to the Upper Albian by the maximum distribution of *Rotalipora* and *Praeglobotruncana*. The genus *Rotalipora* is represented by the species: *R.* ex gr. *cushmani, R. deeckei, R. appenninica* and *R. greenhornensis* in the Szczecin-Lodz-Miechow synclinorium and the Sudetic monocline (Gawor-Biedowa 1972), and by *R. cushmani* in the Marginal synclinorium, (where the genus *Schackoina* is absent). *Praeglobotruncana stephani* and *P. delrioensis* are, like the species of *Rotalipora*, characterized by a wide geographic distribution, but both do not extend beyond the northern boundary of the Transitional Province. The Cenomanian as well as the Upper Albian are characterized by an uniformity of faunas over vast areas. Typical Cenomanian Foraminifera associations from lower latitudes show a predominance of keeled species and a smaller contribution of hedbergellids. In Poland, a comparable number of keeled species and hedbergellids in the assemblages is observed from the Szczecin-Lodz-Miechow synclinorium, whereas in the Marginal synclinorium the hedbergellids dominate over the keeled species.

Lower Turonian: A sharp change in composition of foraminiferal assemblages is found at the Cenomanian/Turonian boundary. The genus *Rotalipora* disappears and the genus *Dicarinella* appears, represented by *D. imbricata, D. biconvexa biconvexa, D. biconvexa gigantea* and *D. longoriai*. Of these species, *D. imbricata* is characterized by a wide geographical distribution in the Tethyan and in the Transitional Provinces. *D. biconvexa* and *D. biconvexa gigantea*, hitherto known from the Tethyan region only (Western Carpathians) (Samuel & Salaj 1962), were recently recorded for the first time in the Marginal synclinorium (Peryt 1979). The distribution of *Helvetoglobotruncana helvetica* and *Heterohelix reussi* is similar to that of *Dicarinella imbricata. Whiteinella baltica*, initially recorded from the Boreal Province, appears to be also present in warmer regions (Hanzliková 1972; Herb 1974; Peryt 1979). The first representative of the genus *Marginotruncana*, the cosmopolitan species *M. marginata*, which is known from all foraminiferal provinces, also appears in the Lower Turonian. Other cosmopolitan species are *Hedbergella brittonensis, H. planispira* and *H. delrioensis* as well as two recently described species, *Hedbergella caspia* (Vassilenko) and *H. angolae* Caron.

Upper Turonian – Coniacian: The marked change in foraminiferal microfauna at the boundary of the Lower to the Upper Turonian is as sharp as that at the Cenomanian/Turonian boundary; however there is almost no faunal change at the Turonian/Coniacian boundary. The species appearing in the Upper Turonian are cosmopolitan and long-ranging, extending even into the Lower Santonian. The genus *Dicarinella*, common in the Lower Turonian, is represented by *D. imbricata*, which disappears not much above the base of the Upper Turonian. There is a rapid development of the genus *Marginotruncana*, here represented by 11 species. Three of them, *M. coronata, M. pseudolinneiana* and *M. marginata*, are also known from the Boreal Province (Douglas & Rankin 1969; Norling 1973). The remaining species are either relatively new and hence our knowledge of their distribution is limited (*Marginotruncana sinuosa* and *M. paraconcavata*), or, entirely new and determined at the generic level (often only known from single localities). The genus *Archaeoglobigerina* is represented by the cosmopolitan species *A. cretacea, A. blowi* and *A. bosquensis*.

Santonian: The first species of true globotruncanids *Globotruncana lapparenti* and *G. linneiana* appear at the beginning of the Santonian, soon followed by *G. fornicata*, and later, in the uppermost Santonian, by *Globotruncana obliqua*. The former three are known from the

Tethyan and the Transitional Provinces as well as from the Boreal Province (Brotzen 1942; Sliter 1973). Also recorded in this stage are cosmopolitan species of the genera *Archaeoglobigerina, Marginotruncana* and *Heterohelix,* all of which are continuous from the proceeding stage.

Campanian: Successive species of true globotruncanids appear in the Campanian: *Globotruncana arca*, which is the best known and a cosmopolitan species, then *G. churchi* and *G. nothi*. The latter two are regarded by Sliter & Douglas (1963) as endemic species, restricted to the Campanian-Maastrichtian of the west coast of America. However *G. churchi* has also been found in Bulgaria (Vaptzarova 1975), Poland (Peryt 1979) and in Austria (erroneously identified as *G. arca* by Ibrahim 1976). The geographic distribution of *G. nothi* is also much wider, as it has been recorded from Bulgaria (Vaptzarova 1974), Moravia (Hanzlikovà 1972), Poland (Peryt 1979) and from New Guinea (Owen 1973). The remaining species of *Globotruncana* occuring in the Campanian of Poland, i. e. *G. ventricosa, G. pessagnoi, G. plummerae* and *G. bulloides*, are warm-water forms and are known from both the Tethyan and the Transitional Provinces. A rapid development of the genus *Globigerinelloides* took place at the boundary of the Lower to the Upper Campanian. This is reflected by the appearance of 4 species, of which the first three are represented by very numerous individuals i. e. *Globigerinelloides multispinus, G. volutus, G. prairiehillensis* and *G. yaucoensis. G. multispinus* has the widest geographic range and it is known from many localities in all of the provinces. The remaining species of the genus *Globigerinelloides* are known only from warmer provinces. The species of the genus *Heterohelix* are cosmopolitan in general, except the species *H. ventilabrelliformis* and *H. planata* which occur only in the Transitional Province.

Maastrichtian: A rapid and striking development of the genus *Rugoglobigerina* occurs in the Maastrichtian. *R. pennyi* and *R. milamensis* appear in the Lower Maastrichtian accompanied by *R. rugosa*, which is also known from the Upper Campanian. In the Boreal Province the genus *Rugoglobigerina* is represented by the species *R. pilula* (Sliter 1973); the remaining species are limited to the Tethyan and Transitional Provinces. In the upper part of the Lower Maastrichtian these species are accompanied by *Globotruncanita elevata, Racemiguembelina powelli, Globotruncana patelliformis, Pseudotextularia deformis* and *Planoglobulina brazoensis. Planoglobulina acervulinoides* is also known only from the Boreal Province (Sliter 1973). All of these forms (except the species of the genus *Rugoglobigerina*) and the globotruncanids disappear at the end of the Lower Maastrichtian. In the Upper Maastrichtian the genera *Rugoglobigerina, Heterohelix, Globigerinelloides* and *Guembelitria* dominate; the majority of their species are known only from the Tethyan and Transitional Provinces, except for a few cosmopolitan species of the genus *Heterohelix*.

The Middle and Upper Maastrichtian of the Tethyan Province are characterized by species such as *Globotruncanita gansseri, Abathomphalus intermedius* and *A. mayaroensis*. The lack of these species in the Polish sequences might be the consequence of their limitation to warm and tropical waters. Although, *A. mayaroensis* has also been found in the uppermost Maastrichtian of Denmark (Berggren 1962), its presence in such high latitudes might be explained as a result of a Gulfstream-like palaeocurrent which could transport species living in tropical waters far to the north.

Douglas (1972) explained the presence of Maastrichtian warm-water faunas occurring at latitudes higher along the Atlantic coast, as compared to the Pacific coast of America, by palaeocirculation systems similar to those today. Studies on the distribution of Recent planktonic Foraminifera (Bé & Tolderlund 1971) have shown a general shift of the latitudinal pattern close to continents. A similar effect of oceanic currents on the distribution of foraminiferal faunas, in the northern Pacific Late Cretaceous was found by Sliter (1972).

The extinction of the globotruncanids at the end of the Lower Maastrichtian in Poland has been previously explained by climatic cooling (Witwicka 1958). This seems, however, unsubstantiatable, as the Lower Maastrichtian globotruncanid assemblage comprises cosmopolitan forms such as *Globotruncana arca*, *G. linneiana* and *G. lapparenti*, known also from cooler regions such as Sweden and Canada (Brotzen 1942; Sliter 1973). However, almost all species recorded from the Upper Maastrichtian in Poland show a rather warm-water affinity, and are known only from Tethyan and Transitional Provinces. The extinction of these forms seems more easily explicable as a result of shallowing of the basin. This seems to be supported by the heterohelicid-rugoglobigerinid-globigerinelloid-hedbergellid microfauna. Sliter (1972) showed that heterohelicid-hedbergellid diversity increased in shallower waters, which would then suggest that they are more tolerant to environmental changes than globotruncanids.

At the end of the Cretaceous and particularly in the early Paleocene, an amelioration of climate took place. The Montian reflects an invasion of the Polish Lowlands by assemblages of warm-water benthonic Foraminifera via the Paris basin (Marie 1937), the Mons basin (Pożaryska & Szczechura 1968, 1970; Szczechura & Pozaryska 1971), from West Germany (Indans 1965), and via East Germany (Kiesel 1970). During Montian time, when planktonic Foraminifera were almost completely absent, Boreal, cosmopolitan and warm-water forms can be differentiated on the basis of benthonic microfaunas. It should be noted that the differentiation into these Provinces was first accomplished in Western Europe, where marly and organo-detrital (so-called Tuffeau) facies developed in the Late Maastrichtian. The assemblage of warm-water benthonic Foraminifera is restricted to this Tuffeau facies in the Late Maastrichtian and the Early Paleocene. Its most characteristic forms are: *Discorbis marginata*, *Epistomaria bundensis*, *E. rimosa*, *Rotorbinella mariei*, *R. papillata*, *R. montiana*, *Rotalia saxorum*, *R. trochidiformis*, *Pararotalia tuberculifera*, *Thalmannita pomeraniana*, *Bildia reinholdi*, *Glabratella polonica*, *Baggatella aenigmatica*, *Schlosserina asterites*, *Vacuovalvulina keijzeri* and *Anomalina minor* (Pl. 2).

In central Europe this assemblage appears somewhat later than in Western Europe, and reaches Poland in the Montian. Its presence is always connected with the development of calcareous, organo-detrital Tuffeau facies, which comprises reef like sediments in the shallow and warm sea of the Transitional Province. Sediments of this type were deposited in this sea from the beginning of the Late Maastrichtian in Belgium to the Montian in Poland.

The intensity of Laramide orogeny was variable in the Alpine region. In areas more strongly affected by the movements, glauconitic and marly sands were deposited, while in less affected areas more calcareous or organo-detrital deposits of the Tuffeau or pisolitic limestone type were formed. The former sediments are typical of the Montian of the Boreal Province in the areas of Denmark, Sweden, NE Poland and the European parts of the USSR, and the latter of the Transitional Province in relatively limited areas of western and central Europe. Planktonic Foraminifera are extemely scarce in these two provinces and are represented by globigerinids. The whole area of Paleocene deposits in Europe can be divided into a region where *Globigerina*-like forms dominate, and a region where keeled and angulated planktonic Foraminifera predominate (Szczechura & Pożaryska 1976). The former region comprises both Boreal and Transitional Provinces, while the latter corresponds to the Tethyan Province. An analogous distribution pattern is shown by Recent planktonic Foraminifera (Phleger 1960).

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Explanation of plates

Plate 1

Some warm-water Upper Cretaceous planktonic Foraminifera from Central Poland (Peryt 1979).

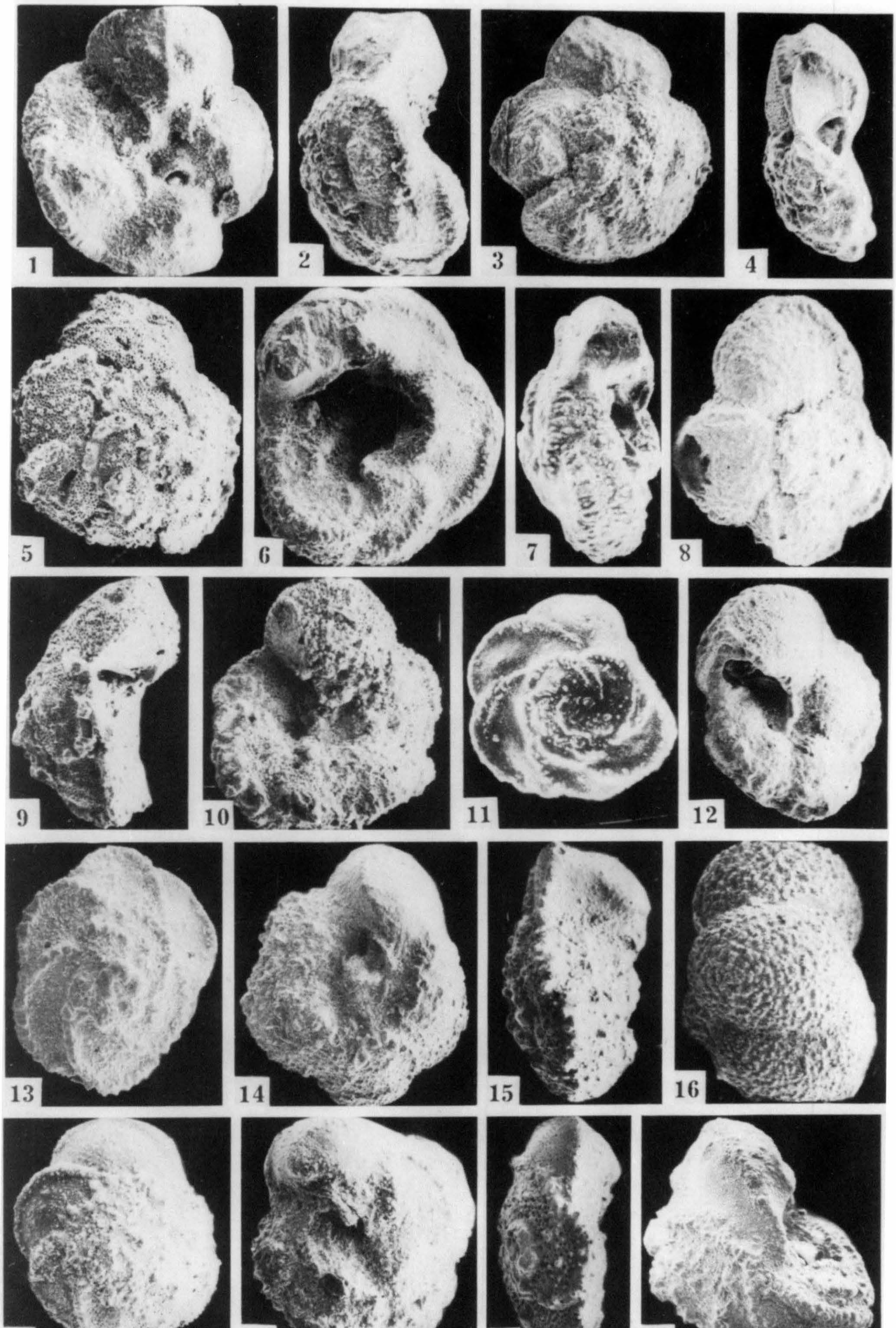
Fig. 1, 2, 3: *Rotalipora cushmani* (Morrow), x 90.
Fig. 4, 8, 12: *Dicarinella longoriai* Peryt, x 100.
Fig. 5, 9, 10: *Praeglobotruncana hilalensis* Barr, x 100.
Fig. 6, 7, 11: *Marginotruncana sinuosa* Porthault, Fig. 6, 7 x 85, Fig. 11 x 65.
Fig. 13, 14, 15: *Globotruncanita elevata* (Brotzen), x 90.
Fig. 16: *Rugoglobigerina rotundata* Brönnimann, x 110.
Fig. 17, 18, 19: *Globotruncana pessagnoi* Longoria, x 100.
Fig. 20: *Globotruncana patelliformis* Gandolfi, x 75.

Plate 2

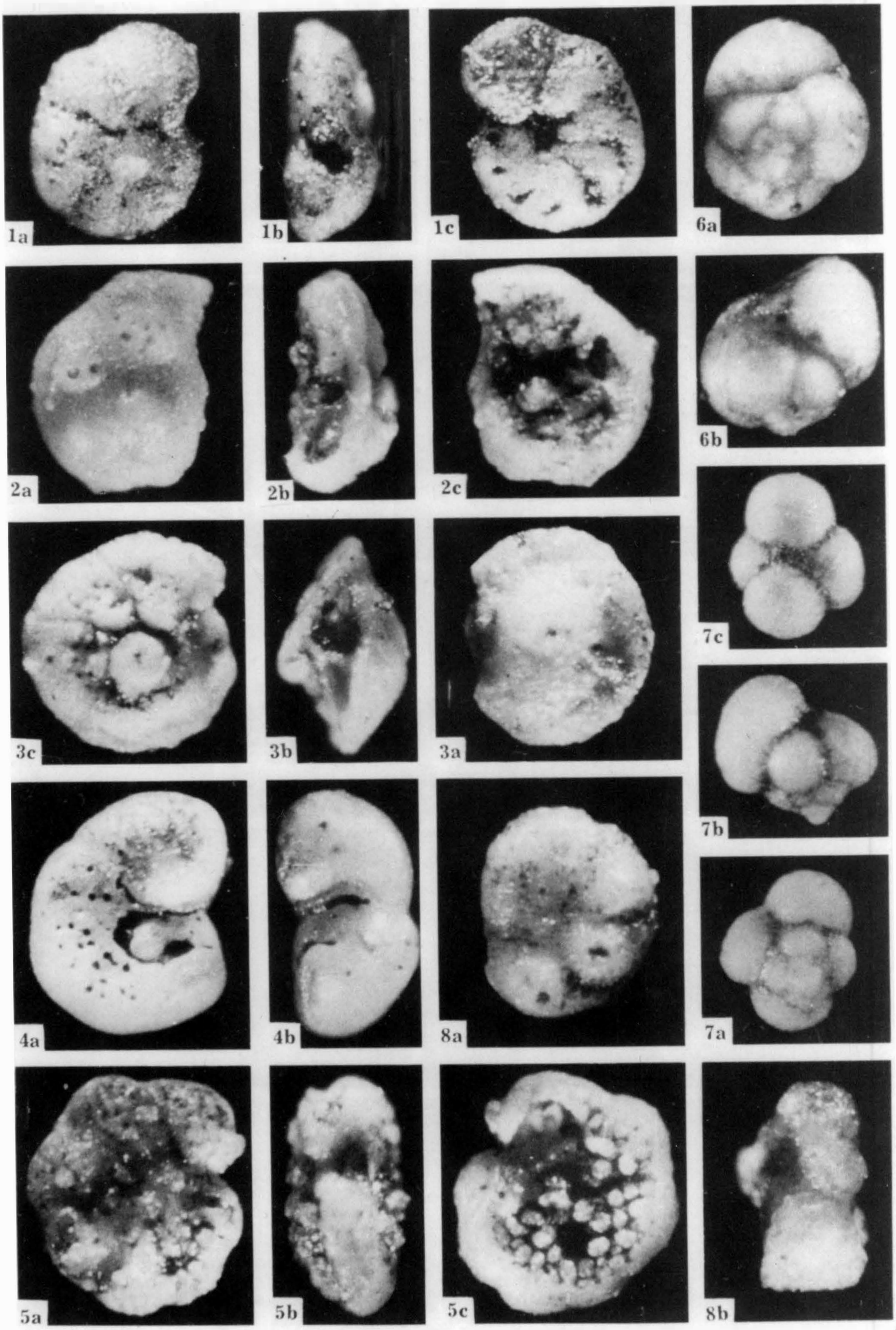
Some warm-water Foraminifera from the Montian Transitional Province of Europe (Pożaryska & Szczechura 1968, 1970).

Fig. 1: *Anomalina umbilicata costata* Pożaryska & Szczechura, x 200.
Fig. 2: *Rotorbinella montiana* Pożaryska & Szczechura, x 150.
Fig. 3: *Rotalia saxorum* d'Orbigny, x 100.
Fig. 4: *Anomalina minor* Pożaryska & Szczechura, x170.
Fig. 5: *Rotorbinella mariei* (van Bellen), x 250.
Fig. 6: *Glabratella polonica* Pożaryska & Szczechura, x 150.
Fig. 7: *Globigerina kozlowskii* Brotzen & Pożaryska, x 100.
Fig. 8: *Rotorbinella papillata* Pożaryska & Szczechura, x 280.
All specimens from the Montian, cored by the Pamietowo borehole, near Chojnice, Pomerania, Poland.

Plates



The Late Cretaceous and Paleocene Foraminiferal "Transitional Province" in Poland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