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AN OUTLINE OF THE JURASSIC AND LOWER CRETACEOUS MICROBIOSTRATIGRAPHY OF THE KLIPPEN BELT OF THE WEST CARPATHIANS ON THE BASIS OF FORAMINIFERS

Abstract: The author gives an outline and perspectives of Jurassic and Lower Cretaceous microbiostratigraphy of the klippen belt concerning mainly the nodosariids (foraminifers). She tries to characterize foraminiferal associations in individual stages of the Jurassic and Lower Cretaceous and ecological and facial conditions of the klippen belt geosyncline.

Introduction

Jurassic and Lower Cretaceous biostratigraphy in the klippen belt as well as in other West Carpathian zones was up to the present based upon macrofossils (mainly ammonites — D. Andrusov 1938, 1945, 1959). Systematical investigation of the Jurassic and Lower Cretaceous foraminifers has not yet been made.

First records of outwashed Jurassic and Lower Cretaceous foraminifers in the klippen belt are known from the fiftieth years (E. Luczkowska 1952 in K. Birkenmajer 1963; E. Hanzlíková 1963; O. Pazdrowa 1963; V. Kantorová et J. Salaj [in D. Andrusov et E. Scheibner 1962]; M. Mišík 1961; V. Scheibnerová 1959, 1961). From the year 1961, J. Salaj has studied Lower Cretaceous microbiostratigraphy concerning mainly the Albian of the sub-Tatric series.

Beginning the year 1959, I dealt among others with a systematical collecting and study of micropaleontological material of Jurassic and Cretaceous beds of the klippen belt. I paid attention mainly to the localities with finds of ammonites. Unfortunately, I could not collect a microfauna in complete profiles due to unfavourable lithological conditions (predominating limestones). A study of microfauna in thin sections did not afford a suitable material for micropaleontological investigation.

Except for circumstances mentioned I assembled a quite considerable material which allowed to give principal micropaleontological characteristics of the sequences studied. I hope they will serve as a starting-point of a further study.

In the paper, I deal also with the Albian to show the gradual changes of foraminiferal assemblages towards planktonics.

Principal Characteristics of the Jurassic and Lower Cretaceous Foraminifers of the Area Studied

Jurassic and Lower Cretaceous sequences of the klippen belt of the West Carpathians are characterized by foraminiferal assemblages belonging to the families as follows: *Reophacidae, Ammodiscidae, Lituolidae, Textulariidae, Trochamminidae, Verneuilinidae, Valvulinidae, Ophthalmidiidae, Miliolidae, Nodosariidae, Polymorphinidae, Pleurostomellidae, Spirillinidae, Discorbidae, Epistominidae, Globigerinidae, Hantkeninidae, Glo-*

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borotaliidae, and Heterohelicidae. Representatives of *Nodosariidae, Discorbidae, Epistominidae, Globigerinidae* and *Globorotaliidae* families predominate (Tab. 1).

Foraminifers of the complexes studied we may divide in three groups:

1. Stratigraphically important species.
2. Species. stratigraphical value of which is up to the present not adequately known and studied in more complete profiles.
3. Long-ranged species without stratigraphical value.

In the first group one may place only a few species due to the absence of sufficient criteria on their stratigraphical value for the area studied. To this group belongs *Involutina liassica* (J o n e s) stratigraphical range of which was studied by M. M i š í k (1961), „*Anomalina*“ *matutina* F r a n k e, found in higher Lias of the Zázrivá klippen; nodosariid foraminifers such as are *Nodosaria metensis* T e r q u e m, *Nodosaria fontinensis* (T e r q u e m), *Nodosaria multicostata* (B o r n e m a n n), *Dentalina tenuistriata* (T e r q u e m) and *Geinitzina tenera pupa* (T e r q u e m). Nodosariids are represented by numerous species with a narrow stratigraphical range.

From among Lower Cretaceous species of *Gavelinella* and *Epistomina* genera and a majority of planktonic forms belong to this group.

The second group comprices predominating part of nodosariids. further ophthalmidiids, Polymorphinids, Valvulinids and Textulariids.

The third group is formed of representatives of *Ammodiscidae* family and some species of *Lenticulina* and *Nodosaria* genera.

Preservation of foraminifers dealt with is under influence of a degree of recrystallization. Morphological details are mostly wiped out, mainly in the case of stratigraphically older specimens.

Foraminiferal Characteristics of the Lias

The most complete material of foraminifers comes from Liassic sequence of the Kysuca series of the Zázrivá klippen. The sequence mentioned is formed of spotted marly limestones intercalated with spotted dark grey shales.

In lower parts of the Liassic sequence of the Zázrivá klippen, a microfauna was found characterized by the occurrence of *Involutina liassica* (J o n e s) and it corresponds to upper part of the Lower Lias. Except for the species mentioned there were found foraminifers: *Nodosaria fontinensis* (T e r q u e m), *Nodosaria metensis* T e r q u e m, *Nodosaria columnaris* F r a n k e, *Dentalina tenuicostata* (T e r q u e m), Dentalina vetustissima d'O r b i g n y, *Lenticulina radiata* (T e r q u e m), *Lenticulina inermis* (T e r q u e m), *Lenticulina inaequistriata* (T e r q u e m), *Lagena tenuicostata* F r a n k e, *Frondicularia sulcata* (B o r n e m a n n). The species were found at the place where D. A n d r u s o v (1931) found *Avicula (Oxytoma) inaequivalvis sinemuriensis* d'O r b i g n y, *Rhacophyllites quadrii* F u c i n i, *Ectoventrites purkynei* A n d r u s o v, *Arietites (Echioceras) raricostatus raricostatus* (v. Z i e t e n), *Arietites (Echioceras) raricostatus quenstedti* (C h a f h.) and *Oxynoticeras perneri* A n d r u s o v. This ammonite fauna corresponds to the Upper Sinemurian.

Higher, in marly spotted, dark grey shales, forming continued 1—3 m intercalations between limestones, a microfauna with no *Involutina liassica* (J o n e s) was found. It was composed of these species: *Ammodiscus* sp., *Valvulina* sp., *Ophthalmidium concentricum* (T e r q u e m et B e r t h e l i n), *Nodosaria* cf. *variabilis* T e r q u e m et B e r t h e l i n, *Nodosaria kuhni* F r a n k e, *Nodosaria fontinensis* (T e r q u e m), *Nodosaria metensis* T e r q u e m, *Dentalina tenuistriata* (T e r q u e m), *Dentalina* cf. *ve-*

tustissima d'O r b i g n y, *Dentalina subtenuicollis* F r a n k e, *Geinitzina tenera pupa* (T e r q u e m), *Lenticulina inermis* (T e r q u e m), *Marginulina prima* d'O r b i g n y, *Frondicularia sacculus* T e r q u e m and *Glandulina septangularis* B o r n e m a n n In this sequence, D. A n d r u s o v (1931) identified an ammonite *Harpoceras (Grammoceras) celebratum* (F u c i n i) and in marly spotted limestones, occurring in connection with the former shales, ammonites *Amaltheus (Amaltheus) margaritatus* M o n t f o r t and *Harpoceras (Arietites)* sp. ind. (together with V. J a n t s k y, see D. A n d r u s o v 1931, p. 34).

The top of the Kysuca series Lias with microfauna belongs to the Toarcian. Lithological character is closely allied to the latter horizons of the sequence studied. A species content of the latter was following: *Ammodiscus* sp. *Ophthalmidium concentricum* (T e r q u e m et B e r t h e l i n), *Nodosaria multicostata* d'O r b i g n y, *Nodosaria fontinensis* (T e r q u e m), *Nodosaria metensis* T e r q u e m, *Dentalina pseudocommunis* F r a n k e, *Dentalina* cf. *vetustissima* d'O r b i g n y, *Dentalina subtenuicollis* F r a n k e, *Geinitzina tenera pupa* (T e r q u e m), *Lenticulina subradiata* K a p t a r e n k o - Č e r n o u s o v a, *Lenticulina parallela* (R e u s s), *Lenticulina scalpta* F r a n k e, *Lenticulina polymorpha* (T e r q u e m), *Lenticulina semiincisa* (T e r q u e m et B e r t h e l i n), *Lenticulina acutiangulata* (T e r q u e m), *Lenticulina bicostata* (T e r q u e m et B e r t h e l i n), *Lenticulina d'orbignyi* (R o e m e r), *Marginulina prima* d'O r b i g n y (The two last species occur in abundance and characterize the whole assemblage).

In the Podbiel series, in red shales of the Toarcian of the Červený Kameň klippen near Podbiel (Orava) C. M. P a u l found a fauna revized by D. A n d r u s o v (1931), namely: *Nautilus* sp. ind. *Phylloceras nilssoni* (H é b.), *Lytoceras* sp. ind., *Hammatoceras (Hammatoceras)* sp. ind. *Hammatoceras (Haugia)* sp. ind., *Harpoceras (Hildoceras) bifrons* (B r u g.), *Coeloceras (Peronoceras) subarmatum* (Y.—B.) and *Coeloceras (Dactylioceras) communae* (S o w.). Near the place of the occurrence of the species mentioned a microfauna of a similar character aś that of the Kysuca series Toarcian was found.

Comparing assemblages described one may see following: the species *Involutina liassica* (J o n e s) occured only in the lowermos part of the Liassic sequence studied. *Ammodiscidae* family begin to occur in higher parts (second and third horizons), as well as *Ophthalmidiidae* family and a distinct species *Marginulina prima* and *Dentalina subtenuicollis*.

From among nodosariids only *Nodosaria fontinensis* (T e r q u e m), *Nodosaria metensis* T e r q u e m, and *Frondicularia sulcata* (B o r n e m a n n) occur in all Liassic horizons at the locality studied.

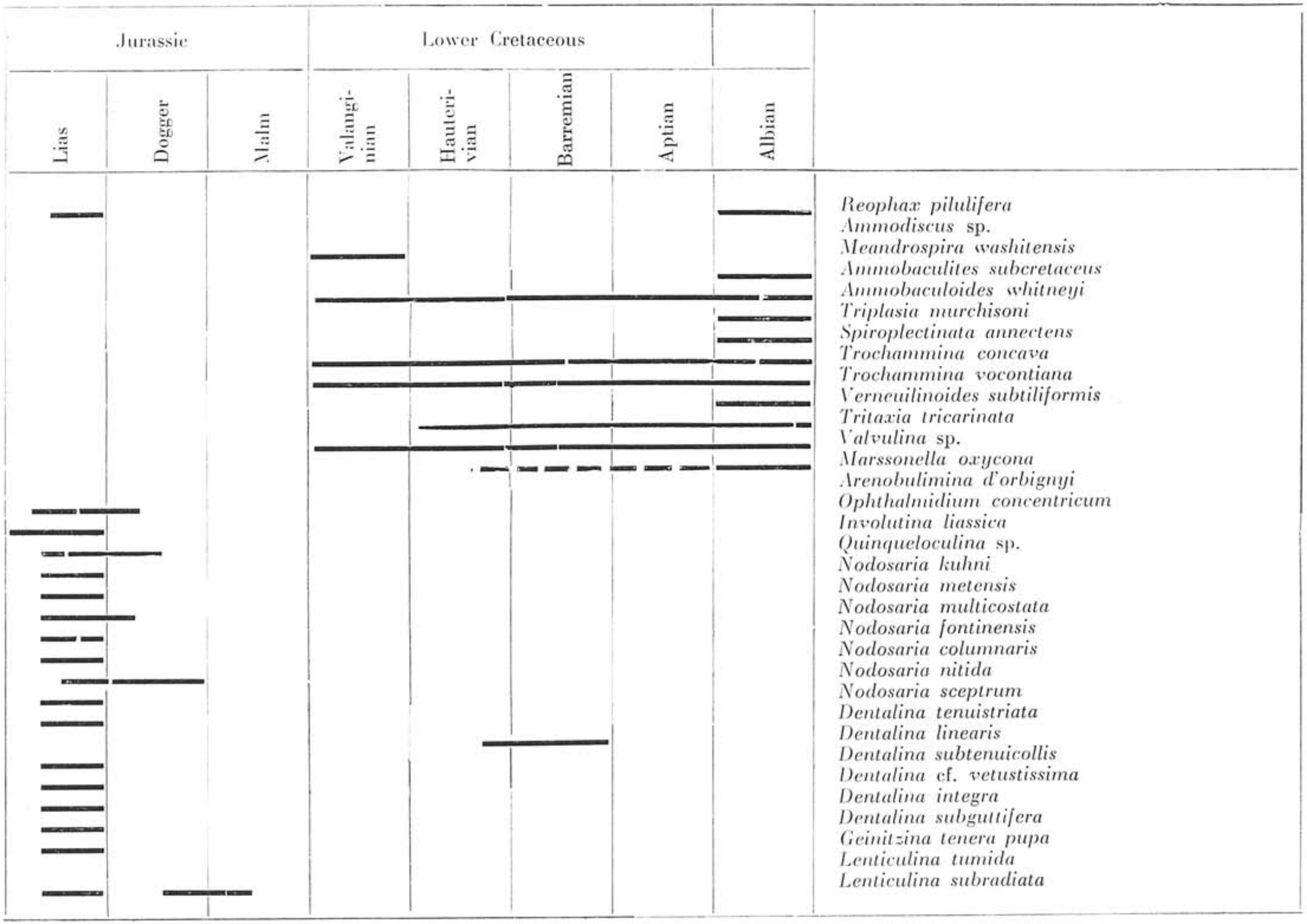
In the second and third horizons, we meet the species *Dentalina tenuistriata* (T e r q u e m), *Dentalina vetustissima* d'O r b i g n y and *Lenticulina inermis* (T e r q u e m).

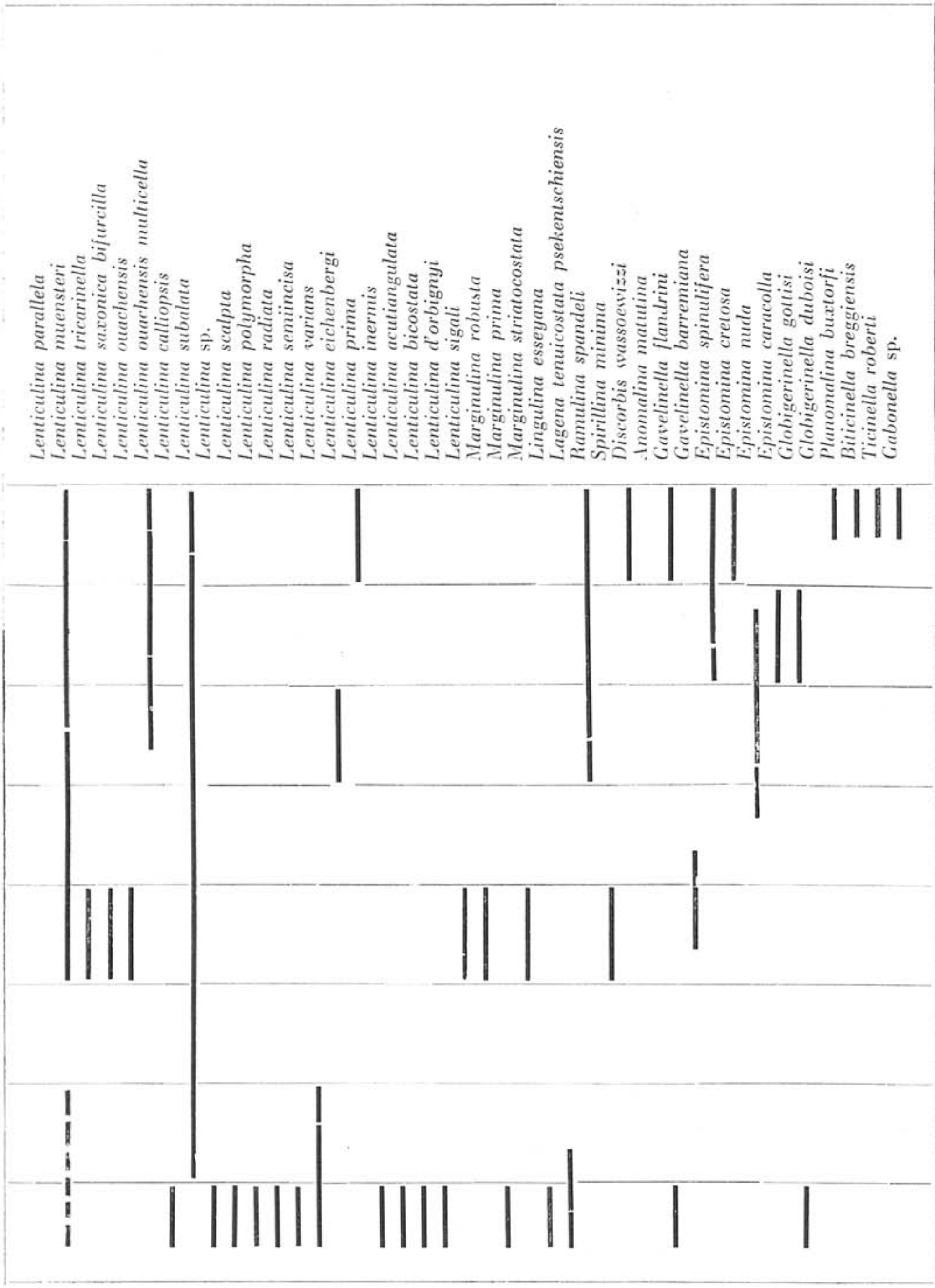
Nodosaria columnaris F r a n k e, *Lenticulina radiata* (T e r q u e m), *Lenticulina inaequistriata* (T e r q u e m) and *Lagena tenuicostata* F r a n k e were found only in the lowermost part of the sequence.

Only in the second part there were found *Nodosaria* cf. *variabilis* T e r q u e m et B e r t h e l i n, *Nodosaria kuhni* F r a n k e, *Geinitzina tenera pupa* (T e r q u e m), *Frondicularia sacculus* T e r q u e m and *Glandulina septangularis* B o r n e m a n n.

The third horizon contained only a minute amount of species common in two lower horizons. The majority of assemblage was formed of different species: *Lenticulina subradiata* K a p t a r e n k o - Č e r n o u s o v a, *Lenticulina parallela* (R e u s s), *Lenticulina scalpta* F r a n k e, *Lenticulina polymorpha* (T e r q u e m), *Lenticulina semiincisa* (T e r q u e m et B e r t h e l i n), *Lenticulina acutiangulata* (T e r q u e m), *Lenticulina*

Table 1. Stratigraphical distribution of the most important foraminifers in the Jurassic and Lower Cretaceous of the klippen belt




Lenticulina parallela
Lenticulina muensteri
Lenticulina tricarinella
Lenticulina saxonica bifurcilla
Lenticulina ouachensis
Lenticulina ouachensis multicella
Lenticulina calliopsis
Lenticulina subalata
Lenticulina sp.
Lenticulina scalpta
Lenticulina polymorpha
Lenticulina radiata
Lenticulina semiincisa
Lenticulina varians
Lenticulina eichenbergi
Lenticulina prima
Lenticulina inermis
Lenticulina acutiangulata
Lenticulina bicostata
Lenticulina d'orbignyi
Lenticulina sigali
Marginulina robusta
Marginulina prima
Marginulina striatocostata
Lingulina esseyana
Lagena tenuicostata psekentschiensis
Ramulina spandeli
Spirillina minima
Discorbis wassoewizzi
Anomalina matutina
Gavelinella flandrini
Gavelinella barremiana
Epistomina spinulifera
Epistomina cretosa
Epistomina nuda
Epistomina caracolla
Globigerinella gottisi
Globigerinella duboisi
Planomalina buxtorfi
Biticinella breggiensis
Ticinella roberti
Gabonella sp.

bicostata (T e r q u e m et B e r t h e l i n), *Lenticulina d'orbignyi* (R o e m e r), *Lingulina esseyana* D e e c k e, *Lagena tenuicostata psekentschiensis* M a m o n t o v a and *Frondicularia* sp.

Except for formerly mentioned, I must point out that mainly in higher horizons there are abundant ostracods (smooth types), in some samples predominating.

Foraminiferal Characteristics of the Dogger

Dogger microfauna found in the klippen belt corresponds mainly with lower parts of this stage (Aalenian). The best preserved and richest in species microfauna was found in the Murchisonae beds of the Czertezik series. At the Litmanová locality, in great number there were found these species: *Quinqueloculina* sp., *Lenticulina subalata* (R e u s s), *Lenticulina varians* (B o r n e m a n n), *Lenticulina d'orbignyi* (R o e m e r), *Lenticulina muensteri* (R o e m e r), *Patellinella* sp., *Lagena tenuicostata psekentschiensis* M a m o n t o v a a *Epistomina nuda* T e r q u e m.

Together with the assemblage mentioned, except for shells of *Posidonia alpina* G r a s (fossilized in pyrite) there were determined rare specimens of *Cenoceras lineatus* (S o w.) and mediterranean types of ammonites (E. S c h e i b n e r 1963): *Ptychophylloceras. tatricum* (P u s c h), *Ptychophylloceras chonomphalum* (V a c e k), *Calliphylloceras connectens* (Z i t t e l), *Lytoceras rubescens* (V a c e k), *Lytoceras rasile* (D u m), *Lytoceras* sp. and westand middle European types: *Ludwigia murchisonae* (S o w.), *Ludwigia obtusiformis* (B u c k m.), *Brasilia bradfordensis* (B u c k m), *Graphoceras concavum formosum* (B u c k m.), *Graphoceras V-scriptum* (B u c k m.), *Graphoceras casta* (B u c k m.), *Graphoceras robustum* (B u c k m.), *Graphoceras tenuis* (B u c k m.), *Hyperlioceras discites* (w a a g e n). The fauna listed characterizes three top subzones of the Lower Bajocian (Aalenian), namely murchisonae, bradfordensis and concavum zones. Moreover, *Hyperlioceras discites* is an index species of the lowermost subzone of the Middle Bajocian — discites subzone (according to E. S c h e i b n e r 1964).

In the same beds, at the same locality (Litmanová), E. H a n z l í k o v á (1963) identified the follwing species of foraminifer *Lenticulina (Robulus) münsteri* (R o e m.), *Citharina* sp. and *Epistomina* cf. *ornata* (R o e m.). East of Jarabina locality, in the flych Aalenian sequence E. H a n z l í k o v á (1959) found *Lenticulina (Astacolus) brückmanni* M j a t l j u k, *Lenticulina varians* (B r o n), *Lenticulina prima* (B i e l e c k a et P o z a r y s k i) and *Lenticulina münsteri* (R o e m e r).

In the Posidonia marls near Zázrivá locality, I found *Ammodiscus* sp., *Nodosaria fontinensis* T e r q u e m, *Nodosaria nitida* T e r q u em, *Lenticulina inaequistriata* T e r q u e m, and *Lenticulina muensteri* (R o e m.).

Foraminiferal Characteristics of the Malm

The Malm sequences of the majority of klippen series and developments is mainly composed of green and red radiolarites and radiolarite limestones of deep-water character. Locally, between radiolarite beds fine siliceous shales occur in of some cm thick layers. Characteristic occurrence of these rocks is in the quarry before Trstená (Orava). Except for numerous Radiolarias of various types (predominantly *Spumellaria*, less *Nassellaria*), there was found *Lenticulina tumida* M j a t l j u k in these shales. The species is characteristic for the Middle Kelloway to Oxford (it corresponds to the assumed age of the radiolarites). Scarce specimens of the species mentioned were quite corroded which may serve as evidence of redeposition of it from shallower parts of the basin.

Foraminiferal Characteristics of the Valanginian

Valanginian microfauna of the Tethyan region and west-European areas has some common signs with Jurassic microfauna. The main part of the Valanginiam assamblages is formed of nododsarids as in the Jurassic, although there occur different species of the family mentioned. Other families are less important in assemlbages of this stage of the Lower Cretaceous and representatives of Globigerinidae are absolutely absent.

The most common species occurring in the Valanginian of the area studied are: *Ammodiscus* sp., *Trochammina concava* Chapman, *Meandrospira?washitensis* Loeblich et Tappan, *Dentalina linearis* (Roemer), *Lenticulina tricarinella* (Reuss), *Lenticulina incurvata* (Reuss), *Lenticulina saxonica bifurcilla* Bartenstein et Brand, *Lenticulina* sp., *Lenticulina ouachensis* (Sigal), *Lenticulina calliopsis* (Reuss), *Lenticulina subalata* (Reuss), *Lenticulina eichenbergi* Baretnstein, *Lenticulina sigali* Bartenstein, Bettenstaedt et Bolli, *Lenticulina subalatiformis* Dain, *Marginulina striatocostata* (Reuss), *Vaginulina gibbosa* (Terquem), *Vaginulina recta* (Reuss), *Pseudoglandulina* sp., *Spirillina minima* Schacko, *Gavelinella barremiana* Bettenstaedt, *Globorotalites bartensteini intercedens Bettenstaedt*.

These species were found at the locality southwest of Myjava (a quarry near a road, Kysuca series). The other locality rich in Valanginian foraminifers is in the cut of a road from Považská Bystrica to Beluša. However, position of the last occurrence is up to the present not clear.

The main part of species occuring in the Valanginian has a wider stratigraphical range and therefore is quite difficult to divide more detailly this stage only on the basis of foraminifers.

Foraminiferal Characteristics of the Hauterivian

Microfauna of the Hauterivian has many common features with that of the Valanginian. Therefore it is very difficult and in many cases impossible to distinguish these two stages only on the basis of microfauna (foraminifers). There are but some species found only in assemblages younger than Valanginian, namely *Discorbis wassoewizzi* Djaffarova—Agalarova and *Epistomina caracolla* (Roemer) which were not found in Valanginian assemblages. Unfortunately, we have only rare localities where together with a microfauna also ammonites or other macrofossils occur. In the klippen belt of the West Carpathians, there are two localities which may be regarded as of Hauterivian age: Členkovec northwest of Nové Mesto nad Váhom and a part of Lower Cretaceous complex of the Červený Kameň klippen (near Podbiel, Orava). In the latter klippen, D. Andrusov (1945) quotes *Holcodiscus (Spitidiscus) incertus* (d'Orbigny) from shales with the following microfauna: *Glomospira pusilla* (Geinitz), *Trochammina concava* Chapman, *Clavulina* sp., *Nodosaria sceptrum* Reuss, *Dentalina linearis* (Roemer), *Lenticulina* sp., *Lenticulina muensteri* (Roemer), *Lenticulina tricarinella* (Reuss), *Lenticulina incurvata* (Reuss) *Lenticulina ouachensis* (Sigal), *Lenticulina calliopsis* (Reuss), *Lenticulina subalata* (Reuss), *Lenticulina eichenbergi* Bartenstein et Brand, *Lenticulina* sp., 2. *Marginulina striatocostata* (Reuss), *Vaginulina recta* Reuss, *Tristix insignis* Schacko, *Gyroidina* sp., *Gavelinella barremiana* Bettenstadt, *Epistomina caracolla* (Roemer) and *Epistomina* sp.

The assemblage listed is very similar to Valanginian one, from which only in the presented representatives of the genus *Epistomina* are some differences. A new feature is the appearance of this genus.

Foraminiferal Characteristics of the Barremian

Barremian sequences in the klippen belt have very unfavourable lithological character from a view of a collecting of micropaleontological material. The most common are complexes of limestones with scarce interbeds of hard, frequently sandy shales. Therefore, occurrences of Barremian microfauna are very rare as well as those with Barremian ammonites. Microfaunistic criteria for distinguishing this stage in the klippen belt are up to the present not reliable.

On the whole, Barremian assemblages are of a similar character as those of the Hauterivian or Valanginian. There are some slight differences in discorbids. I have not yet found representatives of the genus *Hedbergella* in this stage.

At the locality south of the settlement U Holičov, Rudina klippen near Žilina and Červený Kameň klippen near Podbiel (Orava), there was found the following microfauna, regarded as Barremian: *Tritaxia pyramidata* Reuss, *Lenticulina incurvata* (Reuss), *Lenticulina ouachensis* (Sigal), *Lenticulina calliopsis* (Reuss), *Lenticulina subalata* Reuss, *Lenticulina eichenbergi* Bartenstein et Brand, *Discorbis wassoewizzi* Djaffarova-Agalarova, *Gavelinella* cf. *complanata* Reuss, *Gavelinella* sp., *Gavelinella* cf. *flandrini* Moullade, *Gavelinella barremiana intercedens* Bettenstaedt and *Epistomina caracolla* Roemer.

In connection with the assemblage mentioned, there was found *Barremites cf. charrieri* (d'Orbigny) D. Andrusov 1945) in the Červený Kameň klippen.

From the data mentioned is clear that only on the basis of foraminifers it is very difficult to distinguish Valanginian, Hauterivian and Barremian. At some localities, there were found in various amounts ostracods. The further study of them will show their stratigraphical value.

Foraminiferal Characteristics of the Aptian

Occurrences of Aptian microfauna are quite rare, due to unfavourable lithological character of Aptian sequences (predominating limestones or sandy limestone). From these rocks it is impossible by current micropaleontological methods to obtain isolated specimens, suitable for further study. Aptian limy shales of the Kysuca series afforded the best material.

Aptian microfauna is characterized by the presence of typical Lower Cretaceous types of foraminifers: *Lenticulina muensteri* (Roemer), *Lenticulina ouachensis* (Sigal), *Lenticulina crepidularis* (Roemer), further representatives of the genus *Epistomina: Epistomina ornata* (Roemer),*Epistomina cretosa* Ten Dam, of the genus *Gavelinella Gavelinella* cf. *complanata* (Reuss) *Gavelinella barremiana* Bettenstaedt. Except for these species, less important are agglutinated foraminifers belonging to the genera *Ammodiscus*, *Glomospira* and *Trochammina*.

In the Aptian of the klippen belt as well as of other Tethyan areas we meet representatives of *Globigerinidae* and *Globorotaliidae* families which give younger character to associations of the Aptian. Very numerous are minute individuals of the genus *Hedbergella*. *Globigerinella duboisi* Chevalier and *Globigerinella gottisi* Chevalier. These species make very often a main part of Aptian assemblages.

Representatives of *Nodosariidae* family are less important comparing with older stages of the Lower Cretaceous. More abundant are mainly epitsominids and discorbids, the most important constituents of Aptian assemblages.

Foraminiferal Characteristics of the Albian

During the Aptian and Lower Albian the representation changed towards *Discorbidae, Globigerinidae* and *Epistominidae* families. *Nodosariidae* family is much less important, although it takes a part in shallower associations.

Occurrence of well preserved Albian complexes are quite numerous in the klippen belt. From among best localities I have to note a profile of the Rudina klippen, the most complete section of the Kysuca series. Lithologically, there occur grey'spotted marly shales, very characteristic for the Albian on a whole. Benthonic species of the Lower and Middle Albian are mostly composed of these species: *Trochammina concava* Chapman, *Ammobaculites subcretaceus* Cushman et Alexander, *Lenticulina prima* d'Orbigny, *Lenticulina muensteri* (Roemer), *Ramulina spandeli* (Paalzow), *Dentalina subguttifera* Bartenstein, *Spirillina minima* Chacko, *Discorbis* cf. *wassoewizzi* Djaffarova-Agalarova, *Gavelinella flandrini* Moullade, *Gavelinella* cf. *complanata* (Reuss), *Epistomina spinulifera* (Reuss), and *Epistomina cretosa* Ten Dam.

A plankton is represented by the species: *Hedbergella infracretacea* (Glassner), *Globigerinella* sp. Hedbergelles come also to the Upper Albian, in the klippen belt characterized almost exclusively by planktonic assemblages with *Ticinella roberti* (Gandolfi), first rotalipores: *Rotalipora ticinensis alpha* (Gandolfi), and *Rotalipora ticinensis tipica* (Gandolfi). Further very important species of the Upper Albian are: *Biticinella breggiensis* (Gandolfi) and *Planomalina buxtorfi* (Gandolfi). The benthos of the Upper Albian is very similar to that of the Lower Albian — i. e. mainly epistominids and discorbids.

The microfauna of the Albian (mostly Upper) belongs to the best distinguishable. From time to time there occur some discerpances in stratigraphical evaluation of some species (mainly *Ticinella roberti* [Gandolfi]) in literature, but if comparing with a macrofauna is always clear very constant occurrence of the species mentioned in the Upper Albian over the Mediterranean area, including the area studied. One may say the same about *Biticinella breggiensis* (Gandolfi) and *Planomalina buxtorfi* (Gandolfi) which do not occur lower than in the upper part of the Albian (rather higher).

Some Notes to Ecological and Facial Features of the Jurassic and Lower Cretaceous of the Klippen Belt of the West Carpathians

E. Scheibner (1964) has divided the Pienidy geosyncline to three principal parts representing large blocks divided themselves by dislocations forming the Pieniny lineament. These blocks (or areas) have uniform but specifical paleogeographical and facial development. They are as follows: northern intrageanticlinal (where deposited sequences of the Czorsztyn series and some of transitional developments), central intrageosynclinal (Kysuca—Branisko and Pieniny series replacing themselves) and southern intrageanticlinal (Klape Haligovce and exotic series) areas. In transitional areas, transitional developments were deposited between the mentioned principal areas.

Studiing the ecological relations, I was limited by material to the Lias of the intrageosynclinal area (Kysuca series), Lower Dogger of the northern intrageanticlinal area (Czertezik and Czorsztyn series) and intrageosynclinal area (Kysuca series), Upper Dogger Lower Malm of the intrageosynclinal area (Kysuca series and Podbiel development). The Lower Cretaceous of mainly intrageosynclinal area and the Albian of almost all paleogeographical areas afforded comparatively more abundant material.

Very rich benthonic microfauna occurs in the Lias, mainly in the facies of spotted marly limestones and shales of the Kysuca series. It is represented mainly by nodosariids. Unfortunately, they do not reflect enough the ecological conditions. We may distinguish here three groups of assemblages. In the first group (the lowermost horizon in the profile of the Lias of the Zázrivá klippen), *Involutina liassica* (J o n e s) is a very distinct element. This species occurs at other places (M. M i š í k 1961) in association with shallow-water organisms (in organoclastic facies). The second group and also the third one (in the profile higher) have analogical composition in regard to nodosariids. More distinct difference is a lack of *Involutina liassica* (J o n e s). This species is in a certain sense replaced by numerous individuals of the genus *Ammodiscus*. One may see increasing number of representatives of this genus in higher parts of the profile of the Zázrivá klippen studied.

The mentioned may perhaps serve as evidence of gradual deepening of the facies of spotted marly limestones and shales. However, it may be caused also by other reasons.

Assemblages of mainly lower parts of the Liassic profile studied are being composed of abundant ostracods which up to the present have not yet been a matter of my study.

The facies of spotted marly shales and limestones according to D. A n d r u s o v (1959) represents probably an equivalent of the Recent terrigenous blue mud which was deposited in open sea (not very deep) with considerable rate of sedimentation of organic material. In consequence of this in a certain depth reducing environment originated in a sediment. Less convenient explanation of the origin of this facies in the Central West Carpathians is frequently quoted opinion about hydrogene sulhpide infestion of a certain water layer above the sea-floor. This opinion is supported by the absence of benthonic fauna. However, according to my results, the benthonic fauna (and also microfauna) is characteristic for this facies, even if a macrofauna of cephalopods (ammonites and belemnites) and lamellibranchs [*Posidonia alpina* (G r a s) — this species very probably planktonic, at least in juvenile stages] does not afford evidence about the character of environment.

In the klippen belt, not only in the Upper Lias but also in the Lower Dogger, we meet rock sequences with higher content of bituminous materials. As I have mentioned, in publications dealing with the Central West Carpathians, the authors suggest the origin of these sequences in „euxinic“, not ventilated, or little ventilated environment; they very frequently speak about a saturation of hydrogene sulphide. However, the benthonic microfauna (mentioned yet at the other place) was found in the Upper Liassic marls („Fleckenmergel“ facies) and also in the Lower Dogger shales (Murchisonae and Posidonia beds). The benthonic fauna (mainly gastropods) is less numerous, but together with the benthonic microfauna may serve as evidence against the existence of environment saturated by hydrogene sulphide.

The question of bituminous sequences is up to the present not adequately solved. An amount of bituminous material in a sediment depends on that of transported organic material and of its proportion to anorganic material which was not oxydized during transport and sedimentation, and deposition of anorganic material is quick, reducing conditions originate in a sediment. Reducing environment influences the diagenetic processes which lead to the origin of a deposit rich in bituminous material and mainly pyrite. Surrounding water, however, need not be saturated by hydrogene sulphide. It is so only in the case when deposition of anorganic material is not intensive and does not cover the organic material. The latter decays in the water at the bottom and not in a sediment as in the first case.

All these phenomena are influenced also by the presence or absence of sea currents.

More complete assemblages of Dogger foraminifers are known from dark bituminous shales, the so-called Murchisonae beds of the Czertezik series (northern intrageanticlinal area). It is interesting that 50 % of the assemblage is formed of other groups than nodosariids. Representatives of Epistominidae *(Epistomina nuda* Terquem) and Milliolidea *(Quinqueloculina* sp.) one may regard on the basis of comparison with data given by authors studiing ecology of both Recent and fossile foraminifers as indicators of a shallower facies. In the Posidonia beds of a similar age (Kysuca series), quite rich microfauna of foraminifers characterized among others by numerous representatives of *Ammodiscus* was also found.

During the Middle Dogger the intrageosynclinal area deepened, a sequence of the Posidonia beds was replaced by the super-Posidonia beds. Very typical is a change of sponge microfacies to sponge-radiolarian (E. Scheibner 1964).

A deepening of the Pienidy geosyncline at the end of the Dogger and a shallowing in the Malm is a diachronic process which began earlier in the intrageosynclinal than in the intrageanticlinal areas. This process is gradual as shows a symmetry of lithofacies in some transitional developments. One may see the following sequence of lithofacies: lower nodular limestones, red radiolarites, green radiolarites, red radiolarites and upper nodular limestones (K. Birkenmajer 1963).

Locally, between radiolarites and limestones of this type, thin intercalations of shales occur with various types of radiolarias. At the locality (a quarry) near Trstená (Orava) in such shales (between radiolarites and radiolarite jaspers), except for numerous radiolarias, *Lenticulina tumida* Mjatljuk and other undeterminable nodosariids were found. It is known that radiolarian rocks need not origin only in a deep-water environment, however, in one case mentioned I have some reasons to suggest that these radiolarites originated in relatively deep environment, thought we cannot compare them with the Recent abyssal deposits. It is necessary to stress rather their pelagicity. As evidence of a deep-water origin of the radiolarites studied may serve the following features: symmetricity of distribution of facies, a lack of coarse-clastic terrigenous fragments and a lack of benthonic fauna. The macrofauna of these beds is composed of aptichi exclusively.

In the intrageanticlinal areas, mainly organoclastic limestones occur. In thin sections from these rocks, there are many benthonic foraminifers.

A distinct shallowing in the whole Pienidy geosyncline manifested from the Kimmeridge. It is in connection with synorogenic neocimmerian movements which took place most distinctly in the northern intrageanticlinal area. At the end of the Malm and Lower Cretaceous, also in the intrageosynclinal and southern intrageanticlinal areas, sedimentation settled, the sequence of the Biancone facies deposited. Sedimentation in the northern intrageanticline was strongly influenced by neocimmerian movements. Mainly organoclastic limestones originated, and frequent are sedimentary gaps, hard-grounds and submarine erosion (K. Birkenmajer 1963).

From the biancone facies a pelagic microfauna composed of tintinnoid infusorias, coccolites, stomiosphaeres and radiolarias is well known. Locally, in the upper part of the sequence benthonic foraminifers occur with more than 60 % of nodosariids. Very characteristic are mainly sculptured types of the genera *Marginulina* and *Lenticulina,* although the intensity of ornamentation is far from that in epicontinental forms.

Hauterivian microfauna of shallower types of the Kysuca series is of similar composition. However, very distinct are representatives of the genera *Gyroidina, Discorbis* and *Gavelinella,* and on the other hand *Epistomina.* Discorbids prefer deeper waters; epistominids one may regard as shallower elements of the Albian and Aptian.

At the end of the Lower Cretaceous, a part of the southern intrageanticlinal area emerged; in shallower facies, sequences of organoclastic limestones originated as well as in the High Tatric area. Shallowing of environment has manifested in increasing amount of the benthos and on the other hand in the presence of shallower types of foraminifers. Shallower facies are rich in representatives of the genus *Epistomina* which appear and take a part in assemblage everywhere where became shallowing and sequences of sandy shales originated.

At the beginning of the Middle Cretaceous, sedimentation in the Pienidy geosyncline became quite settled except for the southern intrageanticline. There deposited mainly sequences of marls, marly shales, aleuroliths, marly limestones characterized by pelagic microfauna of globigerine-like foraminifers and radiolarias (globigerine-radiolarian beds of K. Birkenmajer 1957) which are frequently in rock-forming amount. In the northern intrageanticlinal area, these rocks of pelagic character are sometimes in transgressive position.

Emergion of the southern intrageanticline influenced a deposition in adjacent areas; they have a flysch character, frequently with intercalations of exotic conglomerates.

Pelitic components of the flysch sequences come rich in assemblages with predominant benthonic foraminifers. The microfauna has a similar composition as we have observed in the Aptian. Very characteristic is prevailing of some species mainly of the genera *Haplophragmoides* and *Haplophragmium*, *Anomalina*, *Discorbis*, *Gyroidina*, *Gavelinella* and *Epistomina*. On the whole, these assemblages are characteristic of not very deep sea, although far not all elements mentioned are distinctly shallow-water.

Very important task in the sediments of the mentioned types plays a redeposition of microfauna and also of whole fragments and blocks of older rocks. One must take this in account reconstructing the paleogeographical and paleoecological conditions.

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