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THE JURASSIC AND CRETACEOUS OF BACHOWICE (WESTERN CARPATHIANS)

(Plates XI—XXXII and 61 figures in the text)

SUMMARY

Abstract. Above the Senonian marls of the northern most element of the Sub-Silesian nappe one encounters numerous exotic blocks of crystaline, Paleozoic, Jurassic, and Cretaceous rocks. Distinguished among these blocks, on the basis of the quite abundant fauna, were the following: 1) sandstones of the Aalenian and Bajocian; 2) *Posidonomya* marls of the Bathonian; 3) variegated limestones of the Bathonian and Callovian; 4) crinoidal limestones of the Callovian and, perhaps, of the Lower Oxfordian; 5) pink, bluish, green, and yellow subcrinoidal limestones (see footnote on page 310) of the Middle Oxfordian and, perhaps, of the Upper Oxfordian; 6) green pelitic limestones of the Kimmeridgian; 7) white subcrystalline limestones, *Calpionella* limestones, and white subcrinoidal limestones of the Tithonian; 8) grey siltstones belonging probably to the Valanginian or Infravalanginian; 9) pink limestones with Globotruncanae and other planktonic Foraminifera and *Inocerami*; they belong to the Cenomanian, probably the Upper one, and the Turonian; 10) greenish limestones, belonging partly to the Turonian and representing in their main mass the Lower Coniacien; 11) white limestones, probably belonging to the Upper Coniacien; 12) red limestones, representing the Santonian and Campanian; 13) tuffites which were formed in consequence of eruptions between the Campanian and the Lower Eocene.

The Cretaceous limestones probably reposed in transgression on the Jurassic, containing, as they do, blocks and pebbles of the Tithonian and Kimmeridgian.

The Jurassic sediments belonged to the Mediterranean province, this being indicated by their fauna with a predominance of *Phylloceras* and *Lytoceras*. The calcareous sediments of the Cretaceous were also directly associated with the Carpathian geosyncline, being probably formed in some parts of the axial zone of the Flysch geosyncline. These formations must have been, towards the end of the Cretaceous, uplifted above the sea-level and, in consequence of a slump of the coastal cliffs or owing to a volcanic explosion, they were introduced into the sediments of the lowest Tertiary, where they constitute a deposit having the character of a colluvial deposit.

INTRODUCTION

Exotics in the Bachowice area were first reported by E. Tietze (1891) on the basis of information obtained from F. Bartonec. In his report, Tietze emphasized that the Jurassic limestones of Bachowice (originating, in his opinion, from a single stratigraphic member) correspond neither to the development of the Kruhel Jurassic, nor to the Jurassic of the klippes in the vicinity of Andrychów. In the Bachowice forest Tietze also found fragments of some violet-coloured rocks as to which, in spite of C. John's assistance, he was unable to express his opinion in favour of an arenaceous or tuffaceous rock.

Other authors endeavoured later to rediscover the exotics described by

T i e t z e; however, both W. S z a j n o c h a (1895) and T. F u r g a l s k i (1917) found no rocks whatever at the place denoted by T i e t z e.

When mapping the Wadowice sheet, the author frequently searched the stream-valleys in which, according to T i e t z e's description, the exotic rocks were to be found, but he could only ascertain that the ravines are occupied by a dense forest and that the barely trickling streams offer no outcrops. In the two streams, however, the author discovered small fragments of calcareous rocks and larger fragments of the violet-coloured rock described by T i e t z e, and in 1946, a larger block of white limestone with *Lytoceras*. Moreover, in 1947, in an exposure produced by the uprooting of a large tree, the author found in the clay a fragment of a pink limestone with the remains of *Inocerami*. In a thin slide this limestone revealed the mass occurrence of Globotruncanae. This induced the author to execute several artificial exposures in which he encountered Jurassic and Cretaceous rocks with a fauna. From 1948 to 1954, thanks to the financial assistance rendered by the State Geological Institute, the author was able every year to carry out extensive excavations, a dozen or more, from which several hundred small and large blocks of crystalline and sedimentary rocks were dug out. Most of the sedimentary ones were found to contain fossils and they supplied an interesting material, the elaboration of which enabled the author to ascertain that preserved in the Bachowice exotics are the remains of Jurassic and Cretaceous deposits demonstrating a development which is unknown elsewhere in the Carpathians.

I. GEOLOGICAL RELATIONS

The general geological conditions, under which the exotic rocks occur in the Bachowice forest, have been presented on the Wadowice sheet and in its accompanying text (K s i ą ż k i e w i c z 1951). The latter description is supplemented by detailed data obtained by means of excavations.

The forest lying to the south of the road leading from Kaniów towards Tłuczań is intersected by the valleys of several streams among which the easternmost one cuts in the deepest, forming a ravine that has a depth of more than 10 metres. In the latter stream the author encountered the largest number of exotic blocks, and in its ravine the principal exploratory excavations were carried out.

The above-mentioned area has a thick covering of loams (4—5 metres), and the streams form natural exposures neither in their beds, nor in the sides of the ravines. Consequently, in order to explain the mode of occurrence of the exotic blocks washed out by the streams, it was necessary to resort to the execution of artificial exposures (fig. 1). Within the area of the Bachowice forest more than 70 such exposures were made, not including the small excavations dug here and there throughout the forest in order to gain some indications concerning the character of the subsoil. Also executed were several shallow bore-holes by means of a hand-drill. In most cases the excavations had to be carried out to a considerable depth in order to penetrate through the cover of loams.

On the other hand, in many cases the abundantly occurring ground-water did not allow to attain a suitable depth.

On the basis of data obtained from the excavations and borings, and in reference to the survey presented in the Wadowice sheet, the geological relations in the area of the Bachowice forest and its nearest vicinity can be described as follows.

To the north of the road leading from Kaniów through the Bachowice forest towards Tłuczań there are natural outcrops of Middle-Eocene sandstones with nummulites and variegated shales dipping southward. To the south of the above-mentioned road, a thick cover of loams, exceeding 4 metres, completely conceals the older deposits. Excavations and borings revealed the following strata:

1. Gaize beds with bluish hornstones and spongiolites were exposed in excavation No. 73. They dip steeply to the south (70—80°); their strike runs NE. They are the oldest deposits in the area of the Bachowice forest (probably Albian).

2. To the south of the gaize strata runs a belt of marly shales, mostly green, sometimes also variegated. These shales contain a Senonian microfauna (cf. Explanatory text, Wadowice sheet, p. 64). The dip, determined in artificial exposures, is directed towards the S or SE.

3. Farther southward there is a belt of artificial exposures and bore--holes, encountered in which were mostly deposits of the Paleocene or Eocene. These are greenish, ash-grey, dark-grey, or even red clays, mostly non-calcareous ones. Moreover, in the same belt, in close association with the shales, encountered were intercalations of a deposit which may be defined as a colluvial breccia. It is composed of a grey-violet or dirty--reddish, soft arenaceous mass with nests of greenish, red, or black clays, or else irregular bands and nests of the above-mentioned mass alternate with, or are imbedded in, the greenish clays. The reddish arenaceous mass is a tuffaceous deposit, more or less decomposed. In this mass, or in the clays that accompany it, imbedded are numerous blocks and pebbles of rocks which are chiefly tuffaceous, and less numerous blocks and fragments of crystalline rocks (granites, basalts, melaphyres, etc.) and sedimentary ones (sandstones, limestones). The blocks of these rocks are not water--rounded, their surfaces have the character due to mechanical fragmentation, or of weathered surfaces with mineral elements (e. g., quartz grains) and fossils protruding through weathering. Only a small percentage of the blocks shows traces of being water-worn or forms true water-rounded pebbles; this pertains to the rather rare, large quartz grains imbedded in a tuffaceous breccia and its associated clays. The arrangement of the blocks is altogether chaotic; unnoticeable is any disposition according to their size or spatial orientation, this being, moreover, impossible of determination in consequence of the irregular shape of the blocks. These features indicate that the breccia, together with the blocks imbedded in it, is a colluvial deposit. Fig. 2 [1] illustrates the appearance of the latter deposit.

The calcareous rocks occurring in the breccia are frequently decoloured in an irregular fashion: dark rocks have streaks and nests of bright colours;

[1] Cf. Polish text.

coloured rocks, green and red ones, have streaks, small veins and nests which are yellow or white. Extraneous fragments imbedded in the rocks have borders of a different colour than that of the parent rock or the inclusions; such borders are usually brown, rust-coloured, or green. The latter features impart the impression as if the rocks were subjected to some kind of leaching or decolouration.

The breccia, situated and imbedded in loamy sediments, forms a water--carrying horizon, and consequently work therein was rendered difficult, inasmuch as at a small depth the breccia is water-logged.

The loams and argillaceous shales, imbedded in the breccia or directly associated with the latter, in most cases supplied no microfauna. Only in some outcrops either Senonian or Paleocene-Lower Eocene Foraminifera have been found by J. Liszkowa.

The rock most frequently occurring in the breccia is a dacitic tuff, numerous varieties of which were recently described by T. Wieser (1952). The tuff is encountered in lumps which are slightly rounded, or else in the form of angular blocks attaining a diameter of 2 metres and more.

In a few outcrops tuff occurs in the form of regularly disposed layers with a SW. — NE. strike and a SE. dip, imparting the impression of an intercalation in argillaceous beds which is more than 3 metres thick. In the decomposed tuff imbedded also are blocks of exotic rocks, and in one outcrop, imbedded in the decomposed tuff, are nests of a green loam containing a microfauna, the age of which was determined by Liszkowa to be Lower Eocene. In view of the fact that the Eocene was also determined microfaunistically in the nearest outcrops and bore-holes, one should ascribe an Eocene age to the tuff layers.

In the belt of Eocene deposits, encountered in several outcrops are coarse-grained, arkosic, non-calcareous sandstones, frequently conglomeratic, with large pebbles of quartzes; their beds do not exceed a thickness of 0.5 metres. They completely correspond to the type of Ciężkowice sandstones. They are accompanied by greenish shales.

Near the western boundary of the forest, discovered in excavations were red (in the field), marly loams containing numerous Globigerinae. This is the youngest member of the Eocene in the Bachowice forest; a Middle-Eocene or, perhaps, Upper-Eocene age may be ascribed to it.

4. To the SE. of the belt of Eocene deposits with exotics, again discovered in two bore-holes were marls of the Upper Cretaceous. On the latter basis, one may assume that the deposits with exotics occur in a narrow syncline bordered by deposits of the Upper Cretaceous (figs. 3 and 4).

Thus it may be considered that in the Bachowice forest we have Cretaceous deposits overthrust on the Eocene of the external Flysch, and overlaid by the Eocene which is wedged synclinally into the Upper Cretaceous. These Cretaceous deposits, comprising the Lower Cretaceous (Grodziszcze beds, gaize beds) and the Upper Cretaceous (green and variegated marls), together with their overlying Paleocene and Eocene with the exotics, form a scale belonging to the complex of the Sub-Silesian nappe. This scale, overlying the external Flysch and dipping underneath the following scale, the Woźniki Sub-Silesian one, constitutes the most external element of the Sub-Silesian nappe. It has been designated as the Bachowice scale (cf. M. Książkiewicz, 1951, pp. 213—214).

II. EXOTIC ROCKS

Apart from exotic crystalline rocks, exhaustively described by T. Wieser (1952), in the exotic series we have very numerous sedimentary rocks. Distinguishable among the latter are the following rocks, arranged according to their age determined by means of fossils, or their probable age:

1. Pre-Jurassic rocks

1. Black, strongly bituminous limestones. Only a single small block was discovered. They resemble the limestones of the Tournaisian stage in the vicinity of Cracow.

2. Reddish and reddish-violet limestones with lenticles of red hornstones. The limestones are pelitic, and in thin slides they display no organic texture. They bear a slight resemblance to the red limestones of the Visean stage in the Cracow district. Quite numerous.

3. Coarse-grained or fine-grained sandstones with numerous plant remains *(Stigmaria, Calamites, Cordaites)* and black shales with *Annularia*. These are rocks of the Upper Carboniferous; they occur rarely, the same as fragments of coal.

4. Thin-bedded, slightly bituminous, dark-grey or pink limestones, often with undulating stratification (Trias ? Carboniferous ?). Quite rare.

5. Reddish, quartzitic sandstones (Werfen ? Keuper ?). Only a single fragment was discovered.

2. Jurassic rocks

Bajocian

B1. Dark sandstones with ooids.

B2. Bluish sandstones with ooids and *Astarte*.

B3. Light-coloured sandstones, frequently conglomeratic, with numerous *Ostrea*, occasionally conglomeratic with a mass occurrence of *Ostrea* and *Avicula* (layers with *Avicula* and *Ostrea*).

B4. Dark-grey, fine-grained sandstones, generally without any fauna but with plant remains (fossil wood, plant detritus); sometimes with an abundant fauna occurring in nests.

B5. Sandstones and conglomerates with a mass occurrence of *Trigonia* (*Trigonia* layers).

B6. Fine-grained or coarse-grained sandstones, yellowish, limonitic, with a very numerous fauna.

B7. Black shales.

Bathonian-Callovian

Bt. Pink *Posidonomya* marls.
BtCa. Variegated limestones (grey, grey-yellow with greenish and pink streaks).
Ca. Red crinoidal limestones, closely associated with the former ones, and frequently forming intercalations within them.

Oxfordian

O1. Pink subcrinoidal[1] limestones.
O2. Bluish subcrinoidal limestones.
O3. Green subcrinoidal limestones.
O4. Yellow subcrinoidal limestones.

Kimmeridgian

K1. Yellow-greenish pelitic limestones.
K2. Greenish pelitic limestones.

Tithonian

T1. White subcrystalline limestones.
T2. Yellow *Calpionella* limestones.
T3. White *Calpionella* limestones.
T4. White subcrinidal limestones.
T5. Detrital limestones with oolites and *Crinoidea*.

Lower Cretaceous

V. Yellowish silstones (Lower Neocomian).
Ci. Dark clays (Upper Neocomian)?

Upper Cretaceous

Kr. Pink limestones and conglomerates (Cenomanian and Turonian).
Kz. Greenish limestones and conglomerates (Turonian, Coniacien).
Kb. White and cream-coloured limestones (Coniacien).
Kc1. Red limestones and conglomerates (Santonian-Campanian).
Kct. Dacitic tuffs (Campanian).
Kc2. Pink arenaceous limestones (Mastrichtian).

III. STRATIGRAPHY OF THE BACHOWICE JURASSIC

1. Aalenian and Bajocian

At Bachowice these stages are numerously represented by calcareous sandstones; their colour ranges from black to ash-grey, or almost white; nearly all of them contain numerous organic remains, and they are frequently filled with fossils. In view of the fact that the cementing

[1] In this work the author employs the term „subcrinoidal limestone" to designate a limestone containing scattered members of *Crinoidea*. The term „crinoidal limestone" is used by the author to denote a rock composed exclusively, or almost exclusively, of members of *Crinoidea*.

material underwent recrystallization, the sandstone rocks of Bachowice are very hard and it is extremely difficult to extract their fauna. The shells, moreover, are very often dissolved and completely leached, or else transformed into a clayey-limonitic substance which easily disintegrates.

The sandstone rocks of Bachowice can be arranged in six lithological types which, in general, are well characterized by their lithological properties and faunal contents.

Dark sandstones with ooids (B1)

They are fine-grained, dark-coloured, almost black when fresh, acquiring a bluish or greenish colour after weathering; then, also, the numerous ferrugineous ooids are more easily visible.

Essentially the rock is composed of quartz and an abundant calcitic cementing material (plate XI, fig. 1). The cementing material is so abundant that the quartz-grains do not come into contact with one another.

Organic remains, although numerous, are broken and but rarely preserved intact. However, even from these remains it is noticeable that the fauna is monotonous and composed of but two species:

Varamussium pumilum (Lam.)
Entolium spathulatum (Roem.).

The occurrence of the first species points to the Upper Aalenian (Dogger β), where this species is encountered in the greatest numbers. The presence of *Entolium spathulatum,* which first appears from the sowerbyi horizon, perhaps indicates the transition beds between the Aalenian and the Lower Bajocian.

This rock is rarely encountered among the exotics of Bachowice.

Bluish sandstones with ooids and *Astarte* (B2).

This rock resembles the previous one, but it has a lighter colour: bluish or greenish; the latter colour is secondary, resulting from weathering and leaching of the rock (removal of calcium carbonate). Ferrugineous ooids are considerably smaller and less frequent. The sandstone is composed of quartz grains imbedded in an abundant calcitic cementing material, so that the grains do not touch one another. The sandstone is well sorted.

The fauna is very numerous, but even in the large blocks the shells (*Ostrea* excepted) are dissolved and converted into a limonitic substance. The fauna consists exclusively of small bivalves:

Ostrea sp. — Fairly numerous
Cucullaea sp. — Numerous
Arca sp
Trigonia (Clavotrigonia) cf. *spinulosa* Young et Bird
Trigonia (Lyriodon) cf. *denticulata* Ag.
Trigonia sp. — Numerous
Astarte cf. *voltzii* Hoeninghaus
Astarte cf. *pulla* Roemer
Astarte cf. *depressa* Münster
Astarte minima Phill. — Numerous
Lucina sp.
Pholadomya murchisoni Sow.

On the basis of this scanty and very badly preserved fauna, it may be assumed that the bluish sandstones with the mass occurrence of *Astarte* correspond to the sowerbyi horizon, i. e., to the upper part of Dogger β.

A lithological resemblance to the dark sandstones (B1) is considerable, and the age of the blue sandstones is probably very close to that of the former; in any case the difference in age is very slight.

The rock is quite frequent at Bachowice, occurring occasionally in great blocks (diameter up to 2 metres).

Light-coloured sandstones (B3) and layers with *Avicula* and *Ostrea* (B3II)

These sandstones are of light colours, calcareous, very hard, mostly fine-grained, but also, frequently, conglomeratic. They occur quite numerously, being present almost in every excavation. They contain a very scanty fauna, while many blocks have none at all. Some blocks, lithologically similar, contain an abundant plant detritus. Small specimens of *Ostrea* are quite numerous in the blocks.

Determined were the following:

Avicula (Oxytoma) hersilia d'Orb.
Pseudomonotis echinata (Sow.)
Ostrea sp.
Astarte depressa Mstr.

All three determined species have a considerable vertical range (from the lower part of the Bajocian to the Lower Bathonian inclusively) and, on their basis, it is impossible to determine accurately the age of these rocks which are common at Bachowice. Their lithological resemblance to the layer with *Avicula* and *Ostrea*, with which they seem to be associated by transition deposits, indicate, however, that they must be of similar age; the age of the above-mentioned layer, on the other hand, can be determined as corresponding to the upper part of Dogger β or the lower part of Dogger γ. It is probable that in the profile of the Bachowice Jurassic the light-coloured sandstones formed a thick series in which the layer with *Avicula* and *Ostrea* formed an intercalation. When their colour becomes slightly darker, they also acquire a resemblance to the dark sandstones with *Dorsetensia* (B4), into which, perhaps, they did pass in their upper part.

The term „layer with *Avicula* and *Ostrea*" is assigned by the author to a conglomeratic, light-coloured sandstone, full of shells and impressions of Lamellibranchiata, chiefly *Avicula* and *Ostrea*. This is also a rock which has a calcitic cementing material and is composed of quartz and a very rare muscovite that is present in large scales. This deposit is quite well sorted. The quartz grains are of approximately equal size; most grains have a diameter of 0,25—0,3 mm. The rock also contains a quite considerable quantity of heavy minerals.

The fauna is abundant:

Avicula (Oxytoma) scarburgensis Rollier
Avicula (Oxytoma) cf. *münsteri* Bronn
Pseudomonotis echinata (Sow.). Very frequent, chiefly as casts.
Camptonectes lens (Sow.)

Varamussium pumilum (L a m.)
Entolium disciforme (S c h ü b l e r)
Entolium spathulatum (R o e m e r)
Ostrea cf. *obscura* S o w. — Very frequent.
Acanthothyris cf. *spinosa* (S c h l o t h.)
Pentacrinus sp.

Ostrea obscura is said to appear not lower than the Middle Bajocian, while *V. pumilum* does not pass higher than the lower part of the sauzei horizon (lower Dogger γ); on this ground it may be presumed that the layer with *Avicula* and *Ostrea* is older than the sandstones (B4) with *Witchellia romani*, and that it belongs to the Lower Bajocian, representing the highest part of Dogger β or the lower part of Dogger γ.

Dark fine-grained sandstones (B4)

This rock is a fine-grained one, very hard, calcareous, dark-grey, probably thick-bedded because it generally occurs in large blocks and displays no stratification. It is composed chiefly of quartz and an abundant, recrystallized, calcitic cementing material. It also contains some feldspar, quite a lot of muscovite, and rare biotite.

The rock is fine-grained, and the largest grains do not exceed 1 mm, while most of them have a diameter of ca. 0.2 mm.

Sandstones of the described type are comparatively rare at Bachowice, and usually they contain no fossils with the exception of wood fragments and fine plant detritus. Only a single block contained some fauna which occurred, as a matter of fact, in a nest, in a rock deprived of any other fossils. This nest, full of comparatively well preserved fossils, although mostly deprived already of shells, supplied the following forms:

Dorsetensia romani O p p.
Dorsetensia aff. *pulchra* B u c k m.
Dorsetensia sp.
Witchellia propinquans B a y l e
Witchellia cf. *eduardiana* d'O r b.
Avicula (Oxytoma) cf. *interlaevigata* Q u.
Pseudomonotis cf. *echinata* (S o w.)
Camptonectes cf. *lens* (S o w.)
Entolium spathulatum (R o e m.) — Frequent.
Entolium sp.
Gervillia cf. *acuta* S o w.
Ostrea cf. *obscura* S o w.
Modiola greppini R o l l i e r
Trigonia sp.
Astarte cf. *exarata* K o c h et D u n k e r
Lucina bellona d'O r b. — Fairly frequent.
Isocardia sp.
Pleuromya elongata M s t r.
Goniomya sp.
Abundant fossil wood and plant detritus.

The ammonites occurring in the above-mentioned sandstones (B4) point to the upper part of Dogger γ and the lower part of Dogger δ, particularly to the latter, i. e., to the Middle Bajocian or, in the division of the Bajocian into two substages, to the lower part of the Upper Bajocian.

Sandstones and conglomerates with *Trigonia* (B5)

Among fauna-containing sandstones of the Brown Jurassic, conspicuous at Bachowice are the sandstones in which there is a mass occurrence of large, well-preserved *Trigonia.* At Bachowice these rocks are rare, and they were encountered only in several places, in the form of large, tabular fragments. Their two varieties are distinguishable: a grey, coarse-grained and a greenish, fine-grained.

Conglomeratic sandstones with *Trigonia* (B5 I) are a very compact rock, separating along the *Trigonia* shells. Their colour is light-grey, and they are strongly calcareous. They have grains of unequal size, poorly sorted. The grain diameter attains a maximum of 6 mm; most grains have a diameter of 0.15—0.8 mm. Of all the sandstone rocks of the Brown Jurassic, this is the most coarse-grained one. Apart from quartz, small quantities of muscovite and biotite occur. The calcitic cementing material is so abundant that the quartz grains rarely touch one another (plate XI, fig. 2).

The fauna consists almost exclusively of large *Trigoniae* (the shells of which fill out the rock) and large *Gervilliae:*

Gervillia acuta Sow.
Gervillia sp.
Cucullaea cf. *aalensis* Qu.
Trigonia (Clavotrigonia) signata Ag. Frequent.
Trigonia (Clavotrigonia) goldfussi Ag.
Trigonia (Clavotrigonia) cf. *clavellulata* Strand.
Trigonia (Clavotrigonia) producta Lyc.(?)
Trigonia (Lyriodon) cf. *hemisphaerica* Lyc.

The determined *Trigoniae* have a large vertical range.

The fauna is not sufficient for an accurate designation of the age. It seems most probable that the *Trigonia* layers occurred as intercalations in sandstones B3 or B4, and they ought to be located either in the sauzei horizon or in the humphriesi horizon.

Greenish sandstones with *Trigonia* (B5 II) are fine-grained and calcareous. Their green colour is not derived from glauconite, which is altogether invisible, even in thin slides; it seems to be caused by the infiltration of iron compounds into the cementing material. The quantity of the latter is relatively small, so that the quartz grains contact one another. The diameter of the quartz grains attains a maximum of 1 mm, while most grains have a diameter ow 0.15—0.20 mm (61% by weight), so that the sandstone is well sorted.

The fauna is numerous and is composed chiefly of *Trigonia,* accompanied by representatives, also numerous, of the genera *Cucullaea* and *Lucina.* The state of preservation is quite good, but the shells are to a large degree dissolved.

Avicula (Oxytoma) hersilia d'Orb.
Gervillia sp.
Cucullaea subdecussata Mstr.
Cucullaea concinna Phill.
Cucullaea sp.
Astarte cf. *minima* Phill.
Trigonia (Clavotrigonia) cf. *signata* Ag.
Lucina bellona d'Orb.
Lucina zonaria Qu.

The fauna, therefore, is more diversified than in the conglomeratic sandstones but, nevertheless, unsuitable for a precise determination of the age. In any case, it may be assumed that the fauna is younger than those of sandstones B1—B4. Furthermore, when we take into consideration that the coarse-grained sandstone with *Trigonia* passes in one fragment into the fine-grained variety, one must presume that the two rocks were contiguous in the stratigraphic profile.

On the basis of the faunal assemblage of both varieties, one must assume that the *Trigonia* layer (or layers) was deposited in the upper part of the Bajocian (from the humphriesi horizon upwards) or in the Lower Bathonian (fusca horizon), although the mass occurrence of *Trigonia* rather indicates the Bajocian. If one may ground one's opinion upon the occurrence of *Tr. clavelluta*, it must be presumed that the *Trigonia* layers were deposited above the humphriesi horizon, i. e., in the middle part of Dogger δ.

Yellowish sandstones (B6)

Quite frequent at Bachowice are sandstones of a yellowish colour, occurring in small, tabular fragments. The colour of the fresh rock is unknown, inasmuch as unweathered fragments have not been found.

The sandstones are fine-grained (B6 I), but it is frequently noticeable that they pass into coarse-grained sandstones (B6 II); the latter probably formed intercalations in the former. The coarse-grained sandstones were also encountered in separate blocks. They are composed of quartz and quite numerous ferrugineous ooids imbedded in an abundant calcitic cementing material. In the fine-grained sandstones the quartz grains generally do not exceed a diameter of 0.4 mm, while most grains have a diameter ranging from 0.15 to 0.25 mm. These sandstones are quite well sorted.

The coarse-grained variety (B6 II) contains no ooids. The quartz grains attain a diameter of 1.5 mm, while most grains have diameters of 0.2—0.4 mm. This sediment is well sorted and the number of small grains is comparatively low. The calcitic cementing material is so abundant that the quartz grains do not touch one another.

The yellow sandstones have a tendency to split into slabs, several centimetres thick; their surfaces display numerous fossils, almost exclusively shells of Lamellibranchiata, disposed in parallel positions (plate XVIII, fig. 1). Most of the fossils are badly preserved, and their shells are mostly dissolved; consequently, the fossils chiefly occur in the form of casts.

The fauna was obtained from several blocks which, however, display no particular differences in their faunistic assemblage. The following forms occur here:

Sphaeroceras sp.
Belemnites sp.
Avicula (Oxytoma) münsteri Bronn.
Pseudomonotis echinata (Sow.)
Entolium spathulatum (Roemer) — Frequent.
Entolium disciforme (Schübler in Zieten)
Lima (Radula) duplicata Sow.
Gervillia acuta Sow. — Fairly frequent.
Ostrea cf. *planata* Qu.
Ostrea cf. *calceola* Ziet.
Arctostrea lub *Alectryonia* sp.
Trigonia (Clavotrigonia) signata Ag.
Tancredia donaciformis Lyc.
Cardium cf. *concinnum* Mor. Lyc.
Cardium cf. *incertum* Phill.
Astarte sp
Terebratula sp. — Loose valves.

On the ground of the foregoing fauna it may be assumed that the yellowish sandstones still belong to the Bajocian, probably to the upper one on account of the admixture of forms occurring already in the Bathonian. The presence of *Sphaeroceras*, belonging to the Upper Bajocian and the Bathonian, also supports such an interpretation.

Black shales (B7)

In some excavations black marly shales with thin sanstones and siderites have been found as lenses in green clays. According to J. Liszkowa they contain *Lenticulina quenstedti* (Gumb.) and associated microfauna which may be correlated with that of the *parkinsoni* zone.

Remarks concerning the Aalenian and Bajocian of Bachowice

It is probable that the rocks described above represent a quite complete series of the Bajocian, and that it lacks but a few members. The littoral or shallow-neritic character of the sediments causes the ammonite fauna to appear exceptionally; consequently, dating of the separate members is difficult. In any case, the Bajocian sediments, in spite of a certain lithologic monotony, display a faunistic differentiation which is probably a reflection of the great vertical differentiation. The conditions of sedimentation were, as a rule, quite constant, but their slight oscillations caused considerable faunistic alterations, the withdrawal of some assemblages of the lamellibranchiate fauna, and the appearance of others. A tentative sequence may be reconstructed as follows:

The first to be formed were arenaceous sediments with ferrugineous ooids (B1), but no typical oolites were yet produced. We do not know whether these were in fact the first sediments of the Jurassic transgression in the Bachowice area, or were they preceded by some other sediments, unknown to us. The grains of these sediments are small (figs. 5 and 6, and table 2); this together with the presence of ooids which usually are not formed during transgression, seems rather to indicate that the sandstones B1 were not a product of transgression, but that they were preceded by other sediments, probably coarse-grained ones. The thin-shelled pectines which occur in them, point to quiet waters, while their dark colour indicates that the aeration was not very good. These sediments were probably deposited at the passage of the Aalenian into the Bajocian.

As the aeration improved, the benthonic fauna increased and there took place an invasion of the genera *Astarte, Trigonia, Ostrea,* and, in a lesser degree, of other Lamellibranchiata (sandstones B2). The lamellibranchiate fauna has a tendency to occur in masses, in shoal-like quantities. This is probably the beginning of the Bajocian (sowerbyi horizon).

Deposited next are arenaceous sediments (B3) with a poor fauna composed chiefly of *Ostrea,* sometimes with an addition of a small number of *Astarte* and *Avicula,* without forming, however, any large accumulation of shells. At a certain moment, perhaps as the result of a shallowing of the sea by its being filled with sand, conditions were produced for the deposition of a layer with *Avicula* and *Ostrea.* The coarse grains, their good sorting, and a fairly well advanced mechanical abrasion of the grains, together with the faunistic assemblages, seem to show that the sediment is a barrier deposit, although not an eulittoral one, e. g., a barrier at a certain distance off-shore, washed by wave-motion of no great strength.

The deposition of arenaceous sediments with a poor fauna was continued, becauce the sandstones B3, which should be assigned to the romani horizon, as a rule have hardly any fauna. The rich fauna encountered in the latter sandstones, occurred in the form of a nest of chaotically arranged shells, and it probably owes its origin to some violent current which drove to one spot the shells of Lamellibranchiata and ammonites, plant detritus, and wood fragments. The organic assemblage of this occurrence is a heterogeneous one, produced by the conveyance of organisms from various environments to the spot of their thanatocenosis.

Different is the case with *Trigonia* layers. The thick shells of *Trigoniae* and *Gervilliae,* occurring in masses, have a parallel arrangement in the rock (with regard to one another) and are not crushed; the rocks which contain them are, therefore, fossil shell layers. The coarse-grained *Trigonia* layer was probably deposited on a barrier, while fine-grained layers, consisting of well sorted material, are sediments deposited in a slightly deeper zone, alongside a barrier, where the waves brought a finer material, leaving the coarser one on the barrier itself. This also manifests itself in the composition of the fauna which does contain Lamellibranchiata with thinner shells *(Cucullaea).*

The next deposit, B6, displays in relation to the previous ones a quite considerable change in its faunistic composition. *Trigonia* and *Astarte* withdraw into the background, and there now follows an invasion of numerous species, and in great numbers, of *Aviculae* and pectines. The faunistic composition is more diversified, although in some blocks one notices a tendency to produce shell layers of one species or genus (layers with pectines or *Avicula*). It is probable that the increase in the faunistic diversity is the result of a certain deepening of the sea. This took place towards the end of the Bajocian, or at the beginning of the Bathonian.

It may be assumed, therefore, that in the sediments of the Bachowice Bajocian there is noticeable a biostratigraphic and lithologic variability which is a reflection of the slow changes in the conditions of sedimentation. At first the sea is shallow, of a shallow-neritic character, with a tendency to form sublittoral barriers. These barriers are invaded by populations of Lamellibranchiata which in succession produce layers with the following: pectines, *Astarte, Avicula* and *Ostrea, Trigonia* and *Gervillia, Avicula.*

Between the periods when the above-mentioned layers were produced, there were intervals during which sands with a scanty fauna were deposited. Only towards the end of the Bajocian did the sea become slightly deeper. The deepening of the sea during the Bajocian is reflected in the sediments which gradually acquire lighter and lighter colours; the oldest sediments are almost black, while the youngest ones are yellowish.

2. Bathonian-Callovian

At Bachowice this stage is represented by deposits which supplied a scanty and uncharacteristic fauna; consequently, both their precise dating and their division is very difficult. Three lithological types are distinguishable here:

1. Pink *Posidonomya* marls (Bt)
2. Variegated limestones (BtCa)
3. Crinoidal limestones (Ca).

Pink and grey-pink *Posidonomya* marls (Bt)

These deposits occur in the form of small, flat, well-rounded fragments, encountered in red crinoidal limestones (Ca) that may be ascribed to the Callovian or the Lower Oxfordian. These fragments attain a size of 5—8 cm, with a thickness of several cm. The marls are hard, they effervesce strongly with HCl, their colour is pink, reddish, ash-grey; the surfaces of pebbles of these marls are sometimes coated with green efflorescences. They are full of *Posidonomya* which it is very difficult to isolate from the rock.

In the red crinoidal limestones containing the pebbles of these marls, one also encounters numerous fragments of calcareo-ferrugineous concretions which exceptionally are completely imbedded in the limestones but, as a rule, with traces of water-rolling or fragmentation. There is no doubt that the concretions occur on a secondary deposit in the crinoidal limestones. The concretions have the shape of small loaves or cakes and their diameter attains 15 cm. The nucleus of such concretions is formed by a calcareous pelite or a fine-crystalline calcite, while their crust is limonitic, with a distinct crusty concentricity and radial fissures. In rare cases, discovered in the concretions were the remains of ammonites (chiefly *Phylloceras*). The interior of the concretions frequently resembles the above-mentioned pink-grey marls; the joint occurrence of fragments of these concretions with fragments of marls on a secondary deposit in the crinoidal limestones, suggests that both the marl fragments and concretion fragments are derived from a common deposit, and that the concretions were washed out of the marls and imbedded in the crinoidal limestones. It may be assumed, therefore, that in the series of the Bachowice Jurassic there existed a series of *Posidonomya* marls with calcareo-ferrugineous concretions, and that the latter series was eroded during the deposition of the Callovian crinoidal limestones.

From the marls and concretions a very scanty fauna was obtained:

Phylloceras kudernatschi Hauer
Calliphylloceras disputabile Zitt.
Posidonomya alpina Gras. — In masses.

Stratigraphically, this fauna tells little. *Calliphylloceras disputabile* occurs in the Bathonian, Callovian, and Oxfordian; moreover, it is difficult to distinguish it from *C. demidoffi* Rousseau. *Posidonomya alpina* occurs from the Aalenian to the Callovian inclusively, but its mass occurrence rather points to the Bathonian similarly as *Ph. kudernatschi*. The fact that the marl pebbles occur in sediments which are probably Callovian, also indicates that the marls are rather older than the Callovian.

Variegated limestones (BtCa)

The latter term can be employed to designate a very common rock, probably the most frequent one, among the sedimentary exotics of Bachowice. The colour of the rock is yellowish or yellow-grey, with very irregularly running bands or streaks of a pink, red, or greenish colour. These streaks in some cases merge into the rock, in others they form narrow, sharply delimited, ramifying bands. Numerous veins of a dark-coloured calcite intersect the rock in various directions, occasionally forming such a dense pattern that the rock imparts the impression of being a breccia. The rock is a pelitic one; from its colour, hardness and odour alone, it is inferable that the rock contains a considerable admixture of clayey substances. Frequent in the rock are nests, lenticles, and clumps, sometimes bands or distinct layers composed of small, red-coloured *Crinoidea;* apart from these, single members of *Crinoidea* are scattered in the rock. In one of the blocks it was observable that the variegated limestone passes into the red crinoidal limestone described in the following subchapter.

Quite frequent in this rock are fragments of ferrugineous crusts, and even large fragments of calcareo-ferrugineous concretions of the type described above. However, it is easily observable in all cases that the latter concretions are extraneous bodies in the rock. This rock usually occurred in large fragments, some of which had a bulk of 2—3 m^3.

Traces of fauna are numerous. Cross-sections of fossils are visible on almost every fracture surface, chiefly ammonites, but also Gastropoda and Brachiopoda; however, apart from the Brachiopoda which are comparatively easy to isolate from the rock, it is impossible to extract the fossils. Upon being broken up, the rock, as a rule, splits across the fossils.

The microscopic texture of the variegated limestones (plate XI, fig. 3) is highly monotonous. Visible in thin slides is a calcareous pelite, only here and there recrystallized. The admixture of detrital quartz is slight (several grains per slide); the grains are fine, their diameter not exceeding 0.15 mm, but mostly much smaller (ca. 0.05 mm), and their shape is extremely angular. Besides the quartz grains, observable are *Crinoidea*, spines of echinoids, and sponge spicules, usually calcified. In some parts of the rock the number of sponge spicules rises very strongly; observable then, in a slide, is a skeleton of spicules linked up with one another, preserved in chalcedony (plate XI, fig. 4).

The variegated limestones, when dissolved in hydrochloric acid, give a quite considerable residue, amounting to ca. 12%. The residue is chiefly composed of clayey substances and a very small quantity of quartz-grains (ca. 2%).

The variegated limestones contain the following fauna:

Oppelia cf. *costata* R o e m.
Perisphinctes (Grossouvreia) curvicosta O p p.
Sowerbyceras cf. *subtortisulcatum* P o m p.
Phylloceras sp.
Rhynchonella trigonella R o t h p l e t z.
Rhynchonella subechinata O p p.
Rhynchonella cf. *kamiński* U h l.
Rhynchonella sp. ind.
Terebratula sp.
cf. *Neritopsis haueri* U h l.
Crossostoma sp.?
Turbo sp.
Remains of Crustacea and Gastropoda, fish teeth.

This fauna points to the Bathonian and Callovian. *Oppelia costata* is a form of the Upper Bathonian, while similar forms that could be taken here into consideration, belong to the Callovian. *Perisphinctes curvicosta* is a Callovian form, the same as *Sowerbyceras subtortisulcatum*. The determination of these forms, however, is not certain.

The Brachiopoda also indicate the Bathonian or Callovian. *Rhynchonella* belongs to the Callovian of the Alpine province: *Rh. subechinata* occurs in the beds of Klaus (Bathonian-Callovian); *Rh. kamiński*, described from the Pieniny Callovian, is closely related to *Rh. defluxa* O p p., also occurring in the beds of Klaus.

The above-mentioned forms were obtained from various blocks of the variegated limestones, and it is possible that this scanty fauna denotes that both the Upper Bathonian and the Callovian are represented in the variegated limestones of Bachowice.

Red crinoidal limestones (Ca)

A very hard, red crinoidal limestone is a common rock at Bachowice. Its colour occasionally becomes greenish or yellow, but only in the form of irregular nests and streaks. The limestone displays no lamination but it usually occurs in the form of slab fragments which attain a thickness of 2—3 dm, and it is probable that this rock formed beds of such thickness.

The rock is composed of closely packed members of *Crinoidea* which only in some places are imbedded in a red fine-pelitic limestone; usually they form with one another a compact mass. The crinoidal limestone contains numerous fragments of alien rocks, particularly of calcareo-ferrugineous concretions and marly *Posidonomya shales*. The fragments of the concretions are fist-sized or larger, occasionally the rock is full of them, but some blocks are almost completely deprived of them.

As mentioned above, in one large block there was observable the passage of the red crinoidal limestone into a variegated limestone. It was also noticeable in many blocks that rock of this type forms nests and streaks in the variegated limestone and, vice versa, streaks and even nests of the variegated limestone exist frequently in blocks of the crinoidal limestone.

Frequently the block surfaces are weathered and then observable are members and fragments of *Crinoidea*, isolated on the surface, while crinoid stems are encountered only exceptionally. The latter have mostly undergone complete disintegration. This fact, as well as the presence of numerous pebbles and fragments of extraneous rocks, indicate that the crinoidal limestones of Bachowice are an allochthonic deposit.

The red crinoidal limestone, after being dissolved in hydrochloric acid, leaves but slightly more than 10% (by weight) of undissolved substances. Of this residue, more than one-half belongs to fractions which are smaller than 0.1 mm; these consist of fine quartz dust, clayey substances, and ferrugineous ones. The larger fractions are composed of fragments of calcareo-ferrugineous concretions, rod-shaped or clumpy limonitic concretions, and quartz grains attaining a maximal diameter of 0.5 mm. Grains of such size are not frequent; on the other hand, much more numerous are grains with a diameter of 0.1—0.2 mm.

In thin slides one mostly observes *Crinoidea* imbedded in the cementing material of a fine-grained, mainly pelitic limestone (plate XI, figs. 5, 6). Foraminifera also occur.

The fauna of the red crinoidal limestones is extremely scanty:

Phylloceras sp. — Indeterminable young individuals or badly preserved ones
Rhynchonella orbignyana O p p.
Terebratula haasi R o l l i e r
Rhynchonella sp.
Terebratula sp.
Fish teeth.

In blocks of yellowish crinoidal limestones (red *Crinoidea* on a yellow background), the latter rocks are frequently associated in one block with the red crinoidal limestones. Discovered in such blocks was:

Rhynchonella cf. *kamiński* U h l.

The infrequent Brachiopoda of the red crinoidal limestones indicate the Callovian or Lower Oxfordian; *Rhynchonella orbignyana* is quoted from the Middle and Upper Callovian and the Lower Oxfordian (Nevisian). It is the same with *Terebratula haasi*.

On such a basis and on that of the association of crinoidal limestones with variegated ones which, as stated above, probably cover the Bathonian and Callovian, it may be assumed that the crinoidal limestones are also Callovian, but they may have been deposited also during the Lower Oxfordian.

3. Oxfordian[1]

The Oxfordian fauna at Bachowice is contained in variously coloured limestones which have the common feature that they always contain, in a greater or smaller quantity, *Crinoidea* members scattered in the rock, but they never become full-crinoidal limestones. The fauna which they contain, almost exclusively ammonitic, is in all varieties nearly identical.

Lithologically, four types of rocks are distinguishable: 1. pink limestones, 2. bluish limestones, 3. green limestones, 4. yellow limestones. In no block did the author observe passages between the types; however, if the rocks are strongly weathered and decoloured by weathering, they acquire a mutual resemblance.

Pink subcrinoidal limestones (O1)

Comparatively rare at Bachowice are pale-pink limestones with widely scattered *Crinoidea* which never form such concentrations of *Crinoidea* as in the variegated limestones. The *Crinoidea* members are small and usually white. Frequently encountered are large stems, some 15 cm long. The rock is composed of parts that are more calcified and cemented by means of a more marly limestone; consequently, it resembles nodular limestones. In some parts the limestone has a detrital aspect; the fine rock fragments, quite angular, are cemented by means of a calcerous substance of a slightly different colour. The weathered rock surface is rough, spongy, and sprinkled with quite numerous members of *Crinoidea*. In many places observable are irregular limonitic accumulations. In no case did the author notice lamination or bedding, and it may be presumed that the rock was thick-bedded.

After dissolving the rock in hydrochloric acid, the residue amounts to 7% only (by weight). Of the latter, only a small part (0,4%) corresponds to quartz fragments and grains exceeding 0.1 mm, and the remainder to clayey substances.

In thin slides it is visible that the rock is an organogenic deposit (plate XII, figs. 1—3). Frequently occurring in this rock are *Crinoidea* and probably the remains of other Echinodermata, sponge spicules, and Foraminifera from the *Cristellaria* group. Apart from this, we find in the rock many circular cross-sections of uncertain origin, filled with a radially arranged calcite; some of them may correspond to cross-sections of sponge spicules secondarily calcified, while others, to Radiolaria, also calcified. Frequent are the remains of shells (of ammonites). The organic remains are imbedded in a dark, fine-pelitic calcareous substance, only

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[1] After F. Trauth (1948) and other authors, the term Oxfordian is employed in the present work to designate the stage which includes the Nevisian, Argovian, Rauracian and Sequanian. According to the latter classification, the Callovian is terminated by the *Quenstedticeras lamberti* horizon (Divesian), while the Oxfordian begins with the *Cardioceras cordatum* horizon and reaches to the base of the *Idoceras planula* horizon; the latter is the beginning of the Kimmeridgian.

weakly recrystallized. Neither quartz nor other detrital minerals are visible in the rock.

The fauna in this rock is quite scanty; it is composed of young forms, but some individuals of *Phylloceras* and *Perisphinctes* attain relatively large dimensions:

Calliphylloceras (Holcophylloceras) zignoi (d'O r b.)
Sowerbyceras tortisulcatum (d'O r b.)
Taramelliceras cf. *kobyi* (C h o f f a t)
Perisphinctes (Properisphinctes) bernensis L o r i o l
Perisphinctes (Discosphinctes) cf. *jelski* S i e m.
Perisphinctes orbignyi L o r i o l
Perisphinctes sp.
Belemnites sp.

In this assemblage, the most frequent is *Sowerbyceras tortisulcatum*, but it occurs in small specimens.

In the variety of a slightly redder colour, apart from an abnormal specimen of *Perisphinctes* (?), discovered was only the following:

Sowerbyceras cf. *tortisulcatum* (d'O r b.)

On the basis of the fauna, it may be assumed that the pink subcrinoidal limestones belong either to the upper member of the *cordatum* horizon, or to the *transversarium* horizon.

It is probable that their pink colour indicates that they were deposited directly after the deposition of the red crinoidal limestones, and that they are immediately younger than the latter.

Bluish subcrinoidal limestones (O2)

This rock is similar to the previous one, but its colour is grey-bluish, passing into a greenish hue. *Crinoidea* are less numerous, smaller, usually also white. These limestones are harder, splintery, but with no tendency to form nodules. They occur, as a rule, in small fragments, not exceeding 0,25 m. On some fragments it is possible to see traces of the bedding surface. It seems that these rocks must have been thin-bedded, and that in the profile of the Bachowice Jurassic they represented no considerable thickness, because they are rare.

About 93% of the rock dissolves in hydrochloric acid. In the residue there is a great preponderance of clayey substances and quartz dust; only 2—3% consists of quartz grains greater than 0.1 mm.

In thin slides (plate XII, figs. 4—6) the rock texture is similar to that of the pink limestones. In the fine calcareous pelite, interspersed with very fine calcite crystals, imbedded are numerous organic remains; first of all, *Crinoidea;* next, numerous shell fragments filled with calcite; sponge spicules that occasionally predominate in some places and mostly are calcified; less numerous are the remains of spines of echinoids, also Foraminifera of the *Cristellaria* type, some of which are completely recrystallized. Some reticular textures may correspond to fragments of algae or stromatoporae.

The fauna of the bluish limestones is abundant. The fragments of these rocks were full of fossils which, as a rule, were easily extractable from the rock. This was exclusively an ammonitic fauna, composed of small specimens:

Calliphylloceras cf. *manfredi* (O p p.)
Calliphylloceras (Holcophylloceras) zignoi (d'O r b.)
Sowerbyceras tortisulcatum (d'O r b.) — Frequent.
Taramelliceras cf. *pichleri* (O p p.)
Cardioceras tenuiserratum (O p p.) N e u m.
Cardioceras sp. (ex aff. *cordatum* S o w.)
Perisphinctes (Properisphinctes) bernensis L o r. — Frequent.
Peltoceras (Pseudogregoryceras) neumayri J e a n n e t
Euaspidoceras cf. *perarmatum* (S o w.).

In this fauna the foreground is occupied, as to numbers, by *Sowerbyceras tortisulcatum;* the second place belongs to *Per. bernensis.*

This fauna points to the *P. transversarium* horizon. *Phylloceras,* occurring here in large numbers, has a great vertical range and no great stratigraphic importance; on the other hand, its abundance indicates that during the deposition of the bluish subcrinoidal limestones the influence of the Mediterranean province was very strong.

Greenish subcrinoidal limestones (O3)

This is a common limestone at Bachowice, although rarely found in large blocks; it was mostly encountered in fragments with a diameter of 20—30 cm. The colour of the rock is grey-greenish or yellow-green, spotted. The fracture is rough, associated with a tendency to form nodules. The rock seems to be more marly than the pink and bluish subcrinoidal limestones. In some blocks, the rock resembles more the bluish limestones, while in others it is more similar to the yellow subcrinoidal limestones; in small and weathered fragments, these rocks are distinguishable from each other with difficulty. *Crinoidea* are quite numerous in the rock, and frequently of large size, but mostly they are small, and brown or white.

In hydrochloric acid about 90% of the rock is dissolved. The residue chiefly consists of a clayey substance, while less than 1% corresponds to quartz grains and very rare sponge spicules. The quartz grains attain a maximal diameter of 0.3 mm.

In thin slides (plate XIII, fig. 4) the greenish limestones display a texture which is altogether similar to that of the bluish limestones. The principal constituents are: calcareous pelite, *Crinoidea,* sponges, remains of echinoids, and small Foraminifera.

The fauna is numerous, and is composed both of small and large specimens; the latter, however, are usually incomplete, and their extraction from the rock is difficult. It is exclusively a fauna of ammonites and belemnites; the latter, however, inasmuch as it is impossible to extract complete specimens from the rock, are indeterminable. The composition of the determined fauna is as follows:

Phylloceras cf. *douvillei* C h o f f a t
Calliphylloceras disputabile (Z i t t.)
Calliphylloceras (Holcophylloceras) cf. *zignoi* (d'O r b.)
Sowerbyceras tortisulcatum (d'O r b.)

Lytoceras sp. ind. (aff. *Thysannolytoceras adeloides* K u d.)
Taramelliceras sarasini (L o r.)
Taramelliceras (Proscaphites) anar O p p.
Perisphinctes (Properisphinctes) bernensis L o r.
Perisphinctes cf. *delgadoi* C h o f f a t.
Perisphinctes (Discosphinctes) lucingense F a v r e.

On the basis of the latter fauna, the greenish limestones must be considered as belonging to the *transversarium* horizon. They constitute, perhaps, a slightly younger member than the bluish limestones.

Yellow subcrinoidal limestones (O4)

Of this rock, only several small fragments were found at Bachowice, with a diameter not exceeding 25 cm. It is a yellowish, marly limestone, with numerous *Crinoidea* and fragments of echinoid spines. Crinoids are white or pink. The limestone is quite distinctly nodular, the ammonites being usually the centres of the nodules. The rock is full of the remains of ammonites that are usually broken or dissolved and also difficult to extract from the rock. The principal ammonite is *Phylloceras*; to a lesser degree, *Perisphinctes*.

In hydrochloric acid the rock dissolves in nearly 93%, while the residue consists almost exclusively of clayey substances; quartz grains are very rare and angular, with a diameter not exceeding 0.2 mm.

Quite distinctly noticeable in thin slides is the difference in relation to the subcrinoidal limestones described above (plate XIII, figs. 1—3, 5, 6). Apart from *Crinoidea*, we observe in the rock many cross-sections of echinoid spines, more numerous than in the varieties described previously. Sponge spicules disappear nearly altogether, while Foraminifera are more numerous and belong mostly to the *Cristellaria* type. The rocky background contains a larger quantity of non-crystalline pelite.

New elements appear in the fauna of the yellow limestones; first of all, Lamellibranchiata, absent in other types of limestone. The composition of this fauna is the following:

Calliphylloceras (Holcophylloceras) zignoi (d'O r b.)
Sowerbyceras tortisulcatum (d'O r b.)
Phylloceras sp. ind.
Trimarginites trimarginatus (O p p.)
Perisphinctes sp. — Not frequent.
Belemnites sp.
Cardium sp.
Astarte sp.
Fish teeth.

In this fauna the first position, quantitatively, is also occupied by *Phylloceras*. Stratigraphically, the fauna indicates little, inasmuch as *Phylloceras* species have a great chronological range, while *Trimarginites trimarginatus* occurs from the *transversarium* horizon to the *bimammatum* horizon inclusively. Characteristic is the disappearance of types occurring in the previously described limestones, ones that are exclusive for the lower horizons; this perhaps indicates that the yellow limestones are either the youngest member of the series of subcrinoidal limestones of the *transversarium* horizon, or that they are even younger and represent the *bimammatum* horizon.

It may be presumed, on the basis of the ammonitic fauna, that the subcrinoidal limestones of Bachowice, in their main mass, belong to the *transversarium* horizon, but that they probably descend also to the *cordatum* horizon at the bottom, while upwards they enter the *bimammatum* horizon. Thus, almost the entire Oxfordian *(sensu lato)* is represented by the latter. Such a sequence would explain the gradual change of colours, from the red colour of the crinoidal limestones of the Callovian and Lower Oxfordian, through the greenish hues, to the yellow limestones.

A full list of the fauna of the subcrinoidal limestones is given in Table 4 (p. 42 of the Polish text).

4. Kimmeridgian

Yellow-greenish (K1), greenish (K2), and grey (K3) pelitic limestones

The Kimmeridgian at Bachowice is represented by greenish pelitic limestones that are completely deprived of *Crinoidea* and relatively not very hard. Small calcareous ooids are observable here and there in the rock. Some limestones with identical properties have a more yellowish hue. The latter limestones occur in small fragments, exceptionally attaining a diameter of 25 cm; mostly they are small lumps of fist size or altogether little fragments. Some of these limestones were found loose in the Bachowice breccia, while others were extracted from conglomeratic limestones of the Campanian in which the greenish limestones, frequently containing some fauna, occur as pebbles and fragments.

The Kimmeridgian limestones are comparatively pure. After dissolving the rock in hydrochloric acid, the insoluble residue amounts to ca. 6% only. In this residue we have quartz in grains attaining a diameter of 0.2 mm, but usually smaller (0.1 mm) and, as a rule, angular; the principal constituents, however, are clayey substances and fine quartz dust.

In thin slides the greenish pelitic limestones (plate XIV, figs. 1, 2) display a pelitic background, imbedded in which are very rare calcite crystals coloured yellow by iron compounds; inserted in the above-mentioned background, there is quite a large number of long calcitic fibres containing a small channel and derived from sponges, as well as reticular algal structures with rectangular network. Small Foraminifera also occur. A similar texture is observable in thin slides prepared from the greenish-yellow limestones (K1) and the dark-grey pelitic limestones (K3); apart from some indeterminable belemnites and Oppelidae, they supplied no fauna. On account of the complete analogy in their microscopic texture (plate XIV, figs. 3, 4), these limestones must also be included in the Kimmeridgian.

In relation to the small number of blocks of the Kimmeridgian limestones and their insignificant dimensions, the fauna is abundant and it must be pointed out that almost every discovered fragment contained some faunal remains, although very badly preserved; the shells are dissolved, and only some fragments of the fossils are preserved in the rock. The list of the fauna is as follows:

Lytoceras polycyclum Neum.
Lytoceras cf. *orsini* Gem.
Lytoceras sp.
Phylloceras (Calliphylloceras) sp.
Sowerbyceras cf. *tortisulcatum* (d'Orb.)
Metahaploceras strombecki (Opp.)
Haploceras tenuifalcatum Neum.
Taramelliceras greenackeri (Moesch)
Idoceras cf. *sautieri* (Font.)
Ataxioceras cf. *stromeri* Wegele
Physodoceras ex aff. *uhlandi* (Opp.)
Lamellaptychus sp.
Avicula lacunosa Qu.
Indeterminable Lamellibranchiata *(Ostrea)*
Rhynchonella aff. *spoliata* Suess
Terebratula sp.
Fish teeth.

Apart from the latter, in the yellow-greenish pelitic limestones occurring as fragments in the Campanian limestones, the following were determined to exist:

Taramelliceras cf. *pseudoflexuosum* (Favre)
Taramelliceras cf. *trachynotum* (Opp.)

On the basis of the above-mentioned fauna, it may be assumed that the greenish pelitic limestones represent in the Bachowice Jurassic a complete series of the Kimmeridgian. Its lower part is represented by limestones containing *Ataxioceras stromeri,* and the upper one, by limestones with *Idoceras sautieri.* It is possible that the yellow-green limestones (K1) could have formed a transition member between the Oxfordian yellow limestones (O4) and the Kimmeridgian green limestones; on the other hand, the grey limestones (K3), on account of their colour, may be considered as the highest member of the Kimmeridgian, forming a transition to the light-coloured limestones of the Tithonian.

5. Tithonian

Rocks containing Tithonian fossils are quite common at Bachowice, being more frequent than Kimmeridgian ones, but less frequent than the Oxfordian limestones. All the rocks included herein, are light-coloured, white or white-yellow, and this distinguishes them from the other rocks, both Jurassic and Cretaceous. They occur in the form of blocks, usually angular or slightly rounded. More frequently than the other rocks, they are extracted from blocks of the Cretaceous limestones in which they are imbedded as fragments, pebbles, or even blocks of considerable size.

Among the Tithonian rocks of Bachowice, it is possible to distinguish several distinctly different lithological types, with diverse organic contents; this is proof that the Tithonian of the Jurassic series of Bachowice was composed of several lithological members, and probably stratigraphical ones too, the mutual relations of which, in spite of the quite abundant fauna, it is difficult to determine. The lithological members are as follows:

1) light-coloured subcrystalline limestones (T1),
2) yellow *Calpionella* limestones (T2),
3) white *Calpionella* limestones (T3),
4) white subcrinoidal limestones (T4),
5) white oolitic-crinoidal limestones (T5),
6) marly limestones (T6),
7) grey siltstones (V).

Light-coloured subcrystalline limestones (T1)

At Bachowice there is a rock which occurs quite frequently in the form of blocks attaining a diameter of 1/2 m. This rock is white-yellow or yellowish, sometimes with a greenish or ash-grey shade, very hard, with an even, fine-crystalline fracture. A fresh fracture glistens from numerous, very small crystals of calcite.

In a thin slide (plate XV, fig. 7) one can see that the rock is composed of a large number of finely divided sponge spicules and algae, calcified and agglutinated by means of a fine-grained cementing material consisting of a very finely crystalline calcite and a grey pelitic background. Besides the sponges, the remains of which in some parts make up more than 50% of the rock composition, there are some comparatively rare Foraminifera, still rarer and very fine discs of *Crinoidea*, and shell fragments. On the basis of its composition, the rock may be determined to be a sponge-limestone.

After dissolving the rock in hydrochloric acid, we obtain a small residue (6.8%) composed exclusively of a fraction smaller than 0.1 mm. Such dimensions are attained by a small number of quartz grains, while the remainder consists of clayey substances. This is the only limestone from Bachowice which contains no large quartz grains. In the residue no siliceous organisms are visible.

The fauna is composed almost exclusively of ammonite remains, while Brachiopoda and Lamellibranchiata are very rare. Fragments of *Lytoceras*, *Haploceras* and *Phylloceras*, frequently of large dimensions, are plentiful in these limestones. The following forms were determined:

Thysannolytoceras cf. *montanum* (O p p.)
Thysannolytoceras cf. *liebiegi* (O p p.)
Protetragonites quadrisulcatus (d'O r b.)
Lytoceras sp.
Calliphylloceras cf. *calypso* (d'O r b.)
Phylloceras sp.
Sowerbyceras cf. *tortisulcatum* d'O r b.
Haploceras elimatum (O p p.)
Aulacosphinctes pachygyrus U h l. (?)
Virgatosphinctes cf. *geron* (Z i t t.)
Perisphinctes sp. (*s. l.*)
Lamellaptychus beyrichi (O p p.)
Astarte sp.
Pygope diphya (C o l.)
Glossothyris bouei Z e j s z n.
Rhynchonella cf. *capillata* Z i t t.
Rhynchonella suessi Z i t t.

This is a typical fauna of the pelagic Tithonian, but a detailed determination of the age by means of this fauna is difficult, inasmuch as the above listed forms occur throughout the Tithonian; only *Lytoceras montanum is* restricted to the Lower Tithonian.

Grounding his opinion on the internal texture of the subcrystalline limestones containing, the same as the Kimmeridgian limestones, large quantities of sponges, the author presumes that the subcrystalline limestones were a member which was directly younger than the Kimmeridgian limestones and that they represent, in their main mass, the Lower Tithonian.

Calpionella limestones (T2, T3)

This rock is quite common at Bachowice, but it rarely occurs in blocks larger than 1/2 m; it is mostly encountered in small fragments of fist size, frequently imbedded in conglomerates and limestones of the Upper Cretaceous. Frequently the blocks of these limestones are fissured, and the fissures are filled by a pink limestone with Globotruncanae and *Inocerami.* Judging by the shape of the fragments, these limestones were thin-bedded; in any case, they were more thin-bedded than the subcrystalline limestones.

The limestone is pelitic, nearly lithographic, white (frequently snow-white) or yellowish, and it displays no granulation. Neither the weathered surfaces of these limestones display any structures isolated by weathering. In thin slides, on the other hand, it is observable that both the white limestones and the yellow ones are composed of an enormous quantity of small organisms, chiefly *Calpionella* occurring in masses (plate XV, figs. 1, 2; plate XVI), although in some slides they are present in small numbers. Apart from *Calpionella,* quite numerous are the remains of sponges and Echinodermata (*Crinoidea* and spines of echinoids), but they are very small; also present are large Foraminifera, rare Radiolaria, cross-sections resembling *Globochaete alpina* Lombard, and cross-sections probably corresponding to the spores of algae (*Thallophyta,* plate XVI, fig. 4). These numerous organic remains are imbedded in a grey pelitic mass.

The residue after dissolving the rock is relatively small. The residue after dissolving the white limestones amounts to ca. 6.5%; it is composed of an extremely small quantity of quartz-grains (0.1%) with dimensions of 0.1—0.3 mm and a low abrasion index. The main mass of the residue consists of a fraction smaller than 0.1 mm, chiefly clayey substances.

The yellow *Calpionella* limestones leave a still smaller residue after being dissolved (5.2%); it contains a small quantity of quartz grains larger than 0.1 mm (even 0.6 mm), usually well rounded.

The yellow *Calpionella* limestones (T2) were found only in one large block (1/2 m) and one small fragment. Nevertheless, they supplied quite an abundant fauna:

Lytoceras sp.
Phylloceras sp.
Calliphylloceras calypso (d'O r b.)
Calliphylloceras (Ptychophylloceras) cf. *semisulcatum* (d'O r b.)

Haploceras sp.
Berriasella cf. *oppeli* Kilian
Belemnites sp.
Rhynchonella cf. *zeuschneri* Zitt.
Rhynchonella sparsicosta Qu.
Rhynchonella aliformis Rollier
Glossothyris cf. *bouei* (Zejszn.)
Terebratula carpathica Zitt.
Terebratula bieskidensis Zejszn.
Waldheimia (Zeilleria) cf. *humeralis* (Roem).
Calpionella alpina Lor.
Calpionella elliptica Cadish.

The white limestones (T3), although considerably more frequent, supplied but a scanty fauna; on the other hand, the quantity of *Calpionella* which they contain seems to be greater in comparison with the yellowish limestones:

Perisphinctes sp.
Rhynchonella sparsicosta Qu.
Rhynchonella agassizi Zejszn.
Waldheimia (Zeilleria) cf. *humeralis* (Roem.)
Calpionella alpina Lorenz
Calpionella elliptica Cadish.

Cross-sections of ammonites in these limestones are not very rare, but their extraction is impossible.

The fauna of both types of limestone is a Tithonian one, but it contains no index forms with a short chronological range, such that would make possible a determination of the part of the Tithonian represented by the *Calpionella* limestones. It is possible that they are younger than the subcrystalline limestones.

White subcrinoidal limestones (T4)

These rocks belong to the rarest ones at Bachowice, and they occur in small fragments not exceeding 30 cm in diameter. The rock is white, compact, very hard, but of a heterogenous texture and quite a distinct tendency to become nodular; on a fresh fracture one observes nodules and fragments of a lighter-coloured limestone, cemented by a more marly substance. Quite numerous in the rock are the remains of *Crinoidea* and other echinoderms. In thin slides (plate XIV, figs. 5, 6) one sees abundant remains of organisms, chiefly *Crinoidea* and sponges, many benthonic Foraminifera from the *Cristellaria* group, and enigmatic star-shaped cross-sections which, perhaps, should be ascribed to the spores of algae (plate XIV, fig. 6). These remains, as well as the comparatively quite numerous quartz grains, are imbedded in a pelitic calcareous mass. The internal texture is similar, as a rule, to that of the *Calpionella* limestones, but the rock contains no *Calpionella*.

The rock contains many impurities, because the residue after dissolving the rock amounts to as much as 11%. Observable in the residue are large quartz grains (even up to 2 mm in diameter); nearly one-half of the residue (by weight) is made up of quartz grains which have a diameter of 0.1—0.8 mm and are angular. The remainder consists of quartz dust and clayey substances.

Judging from the shape of the fragments, the discussed limestones were thin-bedded; they may have occurred in slabs slightly exceeding 1 dm.

The collected fauna is scanty but, as already mentioned, this type of rock is rare and this chiefly explains the poverty of the fauna, inasmuch as some specimens were discovered in almost every rock fragment. The most numerous are Brachiopoda, while ammonites are preserved only as fragments that are difficult to extract from the rock. The list of the fauna is as follows:

Sowerbyceras cf. *tortisulcatum* (d'Orb.)
Taramelliceras sp. ind. (cf. *otreropleurum* Font.)
Taramelliceras sp.
Perisphinctes sp. (*s. l.*) ind.
Belemnites sp.
Rhynchonella capillata Zitt.
Terebratula simplicissima Suess
Waldheimia (Zeilleria) cf. *humeralis* (Roem.).

In this scanty fauna, *Rh. capillata* and *Terebr. simplicissima* indicate the Tithonian. The only tolerably preserved ammonite is indeterminable (*Taramelliceras* cf. *otreropleurum*?) and belongs to a group occurring in the Kimmeridgian and Tithonian.

The internal texture of these limestones, resembling that of the *Calpionella* limestones, perhaps indicates that these rocks lay close together in the profile of the Bachowice Tithonian. They may have formed an intercalation or intercalations among the *Calpionella* limestones, just as intercalations without *Calpionella* occur among *Calpionella* limestones in the Tithonian of Majorca (G. Colom 1948, p. 252). Neither is it out of the question that they are a younger member, while their increased quantity and the size of the quartz grains and the amount of clayey substances perhaps indicate a considerable shallowing of the sea during their deposition. This is also indicated by the nodular character of the limestones, readily produced by fragmentation of a partly consolidated sediment by wave action.

White oolitic-crinoidal limestones (T5)

Only one small piece of rock (diameter 1 dm) that could be thus determined, was found at Bachowice. The rock is ash-grey-greenish, hard, coarse-grained. Seen by the naked eye, the rock is composed of fine calcareous fragments or grains attaining a diameter of 2 mm. In a thin slide it is observable that the rock consists of rounded fragments of a dark-coloured limestone, concentrically built ooids, *Crinoidea*, and well-rounded quartz grains attaining a diameter of 0.5 mm; all these elements are agglomerated together by a light-coloured, coarsely crystalline, calcitic cementing material. In their interior the calcareous fragments contain bits of organic matter, fractions of shells, or Foraminifera, while some contain grains of organic structure, resembling *Globochaete alpina* Lombard. Foraminifera occur also in the cementing material. The rock texture bears a resemblance to some Stramberg limestones of the detrital type („calcaires graveleux"), in which the diverse calcareous particles, of detrital and oolitic origin, are cemented together by calcite. From the latter limestones it differs, to a certain degree, by the presence of *Crinoidea*, and also by its colour and general appearance; nevertheless, it could be one of the various types of the Stramberg limestones.

This limestone supplied no fauna, and it was included in the Tithonian solely on the basis of a certain analogy to the Stramberg limestones. Its extremely rare occurrence (only one small fragment) is proof that this limestone type played no important part in the composition of the Bachowice Tithonian. It may be that it formed only a thin intercalation or lenticle that was subordinate to the other Tithonian rocks, subcrystalline or *Calpionella* limestones, representing but an echo of a far-distant reef- or off-reef facies in the series of the Bachowice pelagic Tithonian.

Grey shaly marls (T6)

Small fragments of a marly-shaly rock, of an ash-grey or ash-grey-creamy colour, are imbedded quite frequently in conglomerates and limestones of the Upper Cretaceous. These fragments are so fine that nearly all that can be said about them is that in thin slides they appear as a fine-grained, almost pelitic mass.

In a small fragment of this rock, imbedded in a pink limestone of the Upper Cretaceous, the author discovered a single specimen of an ammonite belonging, perhaps, to the species *Himalayites (Micracanthoceras)* cf. *microcanthus* (O p p.). This form indicates the Tithonian.

It is impossible to say what was the position of these shaly marls in the profile of the Bachowice Tithonian. They may have formed an intercalation or intercalations in the other Tithonian limestones, but it is also possible that they were the highest member of the Bachowice Tithonian, forming a transition to the next stage.

Grey-brown siltstones (V)

This rock is grey-brown, very fine-grained, with numerous fine particles of muscovite, non-calcareous, with a distinct tendency to split into slabs of 1 cm thickness. In thin slides, observable are only very fine grains of angular quartz, muscovite, and dark clayey substances. The author discovered only a single, small fragment of this rock, the size of a fist, but in this he found a *Lytoceras*:

Protetragonites quadrisulcatus (d'O r b.).

This form occurs both in the Tithonian and the Valanginian.

Encountered in the Bachowice Tithonian were limestone rocks with a rich world of micro-organisms (*Calpionella*, sponges, *Crinoidea*, etc.). The discussed siltstone displays such considerable differences in relation to the latter rocks that it seems very doubtful whether it could be subordinate to the limestone series. It must be sooner presumed that it already belonged to a separate series which in relation to the Tithonian rocks denotes a radical change in sedimentation. It is probable that this is already a manifestation of the alteration in sedimentation conditions at the transition of the Tithonian into the Cretaceous, and that the discussed rock was deposited already in the Infravalanginian or Valanginian, forming a deposit that corresponds to the lower marly shales of Cieszyn.

IV. FAUNA OF THE BACHOWICE JURASSIC

1. Fauna of the Aalenian and Bajocian[1]

Dorsetensia romani (Opp.). (Plate XVII, fig. 4). In spite of the poor preservation of the specimen, part of which is dissolved and filled with calcite, it seems that it can be assigned unreservedly to the above-quoted species. The diameter of the specimen amounts to 42 mm, the whorl height is nearly equal to the diameter of the umbilic. The section of the last-formed whorl is elongately oval, flanks flat, umbilical margin rounded. The keel is low, rounded and, as far as the state of preservation allows to judge, full. On the broken-off last-formed whorl, observable are ribs that are at first very flat and subsequently disappear, so that the terminal part of the whorl is covered only with delicate lines of growth which near the external side are curved forward. Dark sandstones (B4).

Dorsetensia aff. *pulchra* S. Buckm. (Plate XVII, fig. 1). Diameter of the specimen 165 mm (100%); height of the last-formed whorl 73 mm, (44.2%); thickness of the last-formed whorl 38 mm (23%); diameter of the umbilic 45 mm (27%). A large, quite well preserved specimen possessing the remains of its shell. This ammonite is quite strongly flattened, with feebly convex, nearly parallel flanks; the latter decline rather steeply towards the umbilic, but the umbilical border is rounded. The siphonal side is rounded and supplied with a strong „full" keel that is narrow and at first rounded, and then almost sharp on the ultimate part of the whorl. On both sides of the keel, visible are feebly marked, shallow furrows; on the terminal part of the whorl they flatten out. The flanks are adorned by delicate, flat, falciform riblets; near the external border of the whorl they curve strongly forward, producing an acute angle with the external border. This ornamentation is feebly marked on the shell, and still less on the cast, on which it is visible only when observing the specimen against the light. The dimensions of this specimen correspond quite well to the proportions quoted by Dorn (1935) for *D. complanata;* in the latter, for specimens with a diameter up to 50 mm, the whorl height ranges from 0.40 to 0.47%; thickness 0.23—0.28%, umbilic diameter 0.23—0.30%. The author's specimen, however, is larger than the specimens for which the above-mentioned proportions were quoted. Furthermore, the author's

[1] In the present work the paleontologic descriptions are intended to have but a documentary character for the stratigraphical part. Consequently, the full synonymy is not quoted, only the bibliographic position in which there is the most complete description and also, if available to the author, the publication in which the first description appeared. The works that served as a basis for making the determinations, are quoted in the Polish text.

specimen differs from *D. complanata* by its strongly developed keel which in *D. complanata* is less strongly developed than in *D. pulchra* and almost disappears on the living-chamber. In *D. pulchra* the umbilic is slightly smaller (23%), and the height is slightly smaller (40%), while the whorl thickness is the same. Another difference is the rounded periumbilical border which in *D. pulchra* forms an edge. Apart from this, the sculpture and the strongly developed keel make the specimen similar to *D. pulchra*. From the *Dorsetensia* group which includes *D. liostraca, tecta,* and *subtecta,* the specimen differs by the lack of a „hollow" keel and by a steeper outline of the whorl. It seems that the discussed specimen could belong to a form standing between *D. pulchra* and *D. complanata*. Dark sandstones (B4).

Witchellia cf. *eduardiana* (d'O r b.). (Plate XVII, fig. 3). Several whorl fragments of young and mature specimens belong, perhaps, to this species. In the young whorls, the width and height are equal, while the mature whorls are higher. The quite flat flanks are covered with strong riblets, near the external side strongly curved forward. Keel narrow, high; shallow furrows on both of its sides. The author's specimens belong to forms with quite strong evolution; this makes them more similar to B u c k m a n's specimens, as to which objections are raised by D o r n and others who question whether they really belong to d'O r b i g n y's species. Dark sandstones (B4): several fragments.

Witchellia propinquans B a y l e. (Plate XVII, fig. 2). This form has a quite wide umbilic, the whorls are slightly higher than wider, on the external side they have a full keel. The keel is quite wide, low, and rounded; noticeable on both of its sides are shallow furrows. On the flanks there are strong ribs, usually beginning with a protuberance on the umbilical border where they bifurcate; some ribs are single. Ribs straight, near the external border curving forward. Dark sandstones (B4): one specimen.

Pseudomonotis echinata (S o w.). (Plate XIX, fig. 5). The author possesses numerous specimens belonging to this species, and also specimens which probably belong here but cannot be determined with all certainty on account of the state of their preservation. The left valves are moderately dilated, covered with densely spaced riblets which are more or less distinctly covered with tubercles due to intersections with the lines of growth. The dimensions of the author's specimens oscillate within the following figures: height 8—22 mm, length 8—27 mm. Some of the strongly dilated specimens have less distinct tubercles on their riblets. Layer with *Avicula* and *Ostrea* (B3): quite numerous, left valves. Light-coloured sandstones (B3): one specimen of right valve. Dark sandstones (B4): one doubtful specimen. Yellow sandstones (B6): several left valves, mostly more strongly dilated than in the layer with *Avicula* and *Ostrea;* one specimen of right valve.

Avicula (Oxytoma) scarburgensis R o l l i e r. (Plate XVIII, fig. 6). This species differs from *Ox. münsteri* B r o n n by the presence of stronger lines running through the middle of the fields situated between primary riblets. It is thus stated at least by M. L i s s a j o u s (1923), in accordance with the description and drawing given by M o r r i s - L y c e t t, on the basis of which the species was established by Rollier. In Arkell's description of the original, the above-mentioned property is not stressed; to the contrary, the latter author states: „the absence of regularity in the arrangement of secondary and tertiary riblets, only irregular tertiaries being present..." Layer with *Avicula* and *Ostrea* (B3). Yellowish sandstones (B6).

Avicula (Oxytoma) münsteri Bron. (Plate XVIII, fig. 3). Quite numerous left valves, the dimensions of the largest being: length 15 mm, height 15 mm. Valves strongly convex, with a bent apex and covered with 12 strong riblets radiating from the apex; between the riblets, several fine striae, of which only the median one is more strongly marked. Layer with *Avicula* and *Ostrea* (B3): one specimen, not altogether certain. Yellow sandstones (B6).

Avicula (Oxytoma) hersilia d'Orb. Left valve, with an apex that is more acute than in the previous species, and somewhat less convex. Length 22 mm, height 20 mm. The riblets begin below the apex; consequently, the apical part is smooth. The riblets are weaker but more numerous than in the previous species, their number amounting to ca. 20; some of the riblets are finer and have the character of secondary ones. Light-coloured sandstones (B3): one specimen. Greenish sandstones with *Trigonia* (B5II): one specimen.

Avicula (Oxytoma) cf. *interlaevigata* Qu. Between strong riblets, wide fields; in the latter, only under a magnifying glass, one sees delicate longitudinal striae. Also observable are lines of growth, curving in the fields between riblets towards the apex. Dark sandstones (B4).

Camptonectes lens (Sow.). (Plate XIX, fig. 7). Valve feebly convex, covered with densely disposed riblets which frequently bifurcate and are distinctly dotted. In the lower part of the valve we also see lines of growth, strongly marked. Layer with *Avicula* and *Ostrea* (B3): one specimen.

Camptonectes cf. *lens* (Sow.). (Plate XIX, fig. 4). Apart from dense concentric lines, the valve has also densely disposed but less distinct radial striae. This is probably caused by the fact that the external integument of the valve is partly removed. It is not certain whether this specimen belong to *C. lens* (Sow.); it may be a different, similar species. Dark sandstones (B4).

Varamussium pumilum (Lam.). (Plate XIX, fig. 6). The left valve is covered with radiating delicate riblets that intersect the concentric, feebly noticeable lines of growth. The right valve, on the other hand, has more strongly marked concentring lines, while its radial striae, densely disposed, are visible but feebly. The auricles on the author's specimens are badly preserved or completely broken off. It is observable on one of the specimens (right valve) that the anterior auricle is longer and raised. Dark sandstones with ooids (B1): quite numerous. Layer with *Avicula* and *Ostrea* (B3): several specimens.

Entolium spathulatum (Roemer). (Plate XIX, figs. 1—2). Valves feebly convex, height exceeds width, auricles small, of almost equal size, developed slightly above the apex of the valve. Apical angle 90° or but slightly larger; in small and very large specimens less than 90^0, attaining even 80^0. Shallow furrows, disappearing towards the bottom, run from the apex along the flanks. The valve surfaces are covered with delicate, very regular, concentric lines. The species is common in the Brown Jurassic of Bachowice. Dark sandstones with ooids (B1). Light-coloured sandstones (B3): doubtful specimens. Layer with *Avicula* and *Ostrea* (B3): one specimen. Dark sandstones (B4): numerous small specimens. Yellowish sandstones (B6): quite numerous; here the largest specimens are encountered.

Entolium disciforme (Schübler in Zieten). (Plate XIX, fig. 3). The valve is circular, its height equals its width (e. g., 21 mm); it is very finely striated with concentric lines; apical angle ca. 110^0. Layer with *Avicula* and *Ostrea* (B3). Yellowish sandstones (B6): fragments mostly.

Lima (Radula) duplicata Sow. The valves are obliquely oval, covered with strong triangular riblets; between the latter, feeble single striae are visible. The number of riblets amounts to 25. According to Cossmann (1918), the typical *R. duplicata* from the Callovian has at least 28 riblets, older forms have less, while the Bajocian species *Radula* (Cossmann's *Plagiostoma*) *dicolpophorum* Cossm. has 20—22 riblets. The author's specimens, by their steep posterior border, resemble rather *R. duplicata*. Yellowish sandstones (B6): several specimens.

Gervillia acuta Sow. (Plate XVIII, figs. 1—2). The left valves have the following dimensions: length 76 mm, height 20 mm; 101 and 25 mm; 62 and 16 mm. Right valve: length 78 mm, height 20 mm. This form is common at Bachowice. The left valves are elongated, in their anterior part convex, flattened towards the back. The right valve is flatter. Dark sandstones (B4): one specimen, considerably damaged. Light-coloured sandstones with *Trigonia* (B5): very frequent but the better preserved specimens are rare, and some of the fragments may belong to a different species. Yellowish sandstones (B6): several well preserved specimens.

Ostrea cf. *obscura* Sow. In this species the author includes the numerously occurring, elongated and deformed valves which correspond quite well to Sowerby's drawings. Layer with *Avicula* and *Ostrea* (B3).

Ostrea cf. *planata* Qu. Flat, almost circular valve with concentric lines of growth and delicate radial riblets. Corresponds to Quenstedt's drawings. Yellowish sandstones (B6).

Ostrea cf. *calceola* Zieten. To this species, perhaps, belong one right and several left valves conforming quite well to the drawings of the above-mentioned author (and Quenstedt's also), but corresponding much less to Zieten's drawing. Yellowish sandstones (B6).

Modiola greppini Rollier. (Plate XVII, fig. 5). The well preserved shell, with both united valves, corresponds to Greppin's drawing and description. The valves are narrow, concave in their anterior part. Dark sandstones (B4): one specimen.

Cucullaea subdecussata Mstr. It differs from the similar *C. concinna* Phill. by its more elongated valve, lack of riblets in the anterior part of the valve, and presence of densely disposed, delicate radial striae which exist both on the umbones and the areola. Green sandstones with *Trigonia* (B5): two specimens.

Cucullaea concinna P h i l l. (Plate XIX, fig. 10). Included in this species may be two valves, one right, the other left; one of them is preserved in its entirety, the other partly. On the anterior part of their valve, both possess distinct riblets. One specimen also displays delicate radial striae between the riblets. Concentric lines of growth are more strongly marked in the lower part of the valve. The keel, quite acute in the upper part, flattens out towards the bottom. Greenish sandstones with *Trigonia* (B5).

Cucullaea cf. *aalensis* Q u. Included in this species may be a quite well preserved valve (a right one). Its sculpture consists of densely disposed radial striae intersecting, in the lower part of the valve, the strong concentric lines of growth. The shape and sculpture of this valve correspond to S c h m i d t i l l's drawing (and also Q u e n s t e d t's 1858), while its dimensions are somewhat different (length 25 mm, height 18 mm); moreover, a flattening of the umbo is not observable. Conglomeratic sandstones with *Trigonia* (B5).

Trigonia (Clavotrigonia) signata A g. (Plate XIX, fig. 8). This species is common in the arenaceous deposits of Bachowice, although but few specimens are preserved intact. It attains considerable dimensions, as is shown by the following examples: 1. length > 55 mm, height 35 mm (1 : 0.63); 2. length $\pm$ 60 mm, height 40 mm (1 : 0.66); 3. length 70 mm, height 53 mm (1 : 0.75). Most specimens are supplied with a thick shell, some have been preserved as casts or impressions of the external part of the shell. It is impossible to extract most of the specimens, because they adhere strongly with the external surface of their shells to the rock, at the same time splitting easily along their internal surface. Light-coloured conglomeratic sandstone (B5): full of shells belonging to this species. Greenish sandstones (B5): also quite numerous. Yellowish sandstones (B6): several specimens; here the shells are dissolved or changed into a limonitic substance.

Trigonia (Clavotrigonia) goldfussi A g. (Plate XIX, fig. 9). A single specimen, although the lower part of its valve is broken off, possesses all the properties which prove that it belongs to this species. The flank of the valve has a very characteristic, irregular ornamentation. On the valve we see tubercles of an irregular shape, usually elongated, running from the principal keel obliquely downwards. Near the keel, the rows of tubercles form an acute angle directed upwards; the following tubercles are scattered chaotically over the median part of the valve; near the anterior border, they again are disposed in a regular manner and, joining together, they form short ribs reaching the anterior border of the valve. Light-coloured sandstones with *Trigonia* (B5): one well-preserved specimen.

Trigonia (Clavotrigonia) clavellulata S t r a n d. On several badly preserved specimens, the sculpture corresponds to that of *Tr. signata,* but the apical angle is smaller (60^0). According to L e b k ü c h n e r, the latter property is sufficiently characteristic to distinguish the two related species. Light-coloured sandstones with *Trigonia* (B5).

Trigonia (Clavotrigonia) cf. *producta* L y c.? The single specimen has mostly the characteristics of *Tr. signata* but differs distinctly from it by the arrangement of the rows of tubercles on the flank of the valve. The first ribs are disposed concentrically around the apex, the following rows are bent, in the approximate middle of the valve, at an angle slightly exceeding 90^0 and are directed upwards, while in *Tr. signata* they run downwards or, at the most, horizontally forwards. The specimen is quite young and not very well preserved; consequently, its determination does not seem to be altogether certain. Light-coloured sandstones with *Trigonia* (B5): one specimen.

Trigonia (Clavotrigonia) cf. *spinulosa* Y o u n g et B i r d. A fragment of the areola and flank of the valve has characteristics which seem sufficient to determine the species, in spite of the fragmentariness of the specimen. The areola is limited by strongly tuberculated keels, and particularly the principal keel carries densely arranged, prominent tubercles which in specimens of the same size belonging to similar species are less conspicuous. The central keel divides the areola into two parts set at an angle to each other. The latter keel is composed of strong tubercles; its presence is the chief characteristic distinguishing this form from others. The flank is adorned with tuberculated ribs that are slightly upturned at the point where they encounter the principal keel. Apart from this, nothing can be said as to the course of the ribs, on account of the bad preservation of the specimen. Bluish sandstones (B2).

Trigonia (Lyriodon) cf. *hemisphaerica* L y c. The single very badly preserved specimen, the right valve of a *Trigonia* from the *costatae* group (L e b k ü c h n e r's *Lyriodon*), is barely sufficient to determine the species. The very densely disposed riblets, feebly depressed, and the relation of width to length in favour of the latter, seem to point to *Tr. hemisphaerica*. Light-coloured sandstones with *Trigonia* (B5).

Trigonia (Lyriodon) cf. *denticulata* A g. A fragment of the left valve has characteristics demonstrating that it belongs to the latter species. The quite well preserved areola is divided by a delicate furrow into two parts, of which the upper one is somewhat concave. Both are adorned with longitudinal denticulated riblets; on the upper part of the areola the teeth are smaller, and the whole gives the impression of a delicate meshwork; on the lower part the riblets have slightly coarser teeth, particularly the lowest ones, and running parallel to a longitudinal furrow, they imitate to a certain degree the existence of a central keel. The principal, prominent keel is partly destroyed in the available specimen. It is separated by a strong furrow from the valve flank which is covered with delicate ribs. This part of the specimen is, unfortunately, badly preserved, and the character of the costulation is not observable. The shape of the specimen corresponds more to *Tr. denticulata* than to the similar *Tr. costata* which is more triangular and higher. Bluish sandstones (B2).

Astarte cf. *voltzii* H o e n i n g h a u s. (Plate XVII, fig. 8). Several specimens correspond well to the drawings of Q u e n s t e d t and G o l d f u s s (plate 134, fig. 8), but not to those of R o e m e r (1836, plate VII, fig. 17); the latter are also quoted by B r a u n s in his list of synonyms. The outline is triangularly oval, the posterior border feebly curved, the anterior one slightly incised, the height is somewhat greater than the length (9 × 8 mm, 7 × 7 mm). Riblets numerous, steeper from the side of the apex; the intervals between the riblets are quite wide. Bluish sandstones with *Astarte* (B2): rare.

Astarte cf. *pulla* R o e m. (Plate XVII, fig. 6). Together with *A.* cf. *minima* the author encountered some small specimens that were more convex, covered with stronger but less numerous ribs (6—8), with a triangular outline, with the height exceeding the length. According to W e t z e l, the latter characteristics distinguish this form from *A. minima*. Replacement of the valves by limonite renders the determination more difficult. Bluish sandstones with *Astarte* (B2): rare.

Astarte cf. *minima* P h i l l. Some of the Bachowice sandstones are full of numerous casts or limonitized valves which may belong to the latter species. The specimens are small, the most frequent dimensions being: height 7 mm, length 7 mm; the apical part of the valve has a triangular outline. Riblets small, arranged densely. Bluish sandstones with *Astarte* (B2): very numerous. Greenish sandstones with *Trigonia* (B5): one specimen.

Astarte depressa M s t r. (Plate XVII, fig. 7). In relation to S c h m i d-t i l l's drawings, it is slightly elongated, becoming thus similar to Q u e n-s t e d t's drawing (1858, plate 67, fig. 33). The sculpture is composed of numerous concentric riblets that are delicate but sharply outlined and densely disposed. They are the strongest in the middle part of the valve, where also the intervals between them are larger; in the lower part of the valve and near the apex they are smaller and arranged more densely. Light-coloured sandstones (B3). Bluish sandstones with *Astarte* (B2): several doubtful specimens.

Astarte exarata K o c h et D u n k e r. (Plate XVII, fig. 9). To this species , probably, belongs a valve with a triangular shape, with a slight incision on the posterior side and a semicircular outline of the inferior border. Apex slightly curved backwards. Apical angle 90⁰. Lunula very narrow. Riblets 12, strong and markedly curved. Convexity of the valve small. Lines of growth between and on the riblets. Dark sandstones (B4).

Lucina bellona d'O r b. (Plate XVIII, fig. 4—5). The valves are quite strongly convex, adorned with delicate concentring riblets, between which one can observe still smaller striae. On some specimens, the riblets disappear towards the apex of the valve .The largest specimen has the following dimensions: length 52 mm, height 49 mm, thickness of one valve 13 mm. Dark sandstones (B4): several specimens. Greenish sandstones with *Trigonia* (B5): one specimen.

Lucina zonaria Q u. Valve moderately convex, covered with irregularly spaced, concentric riblets that are thin but sharply observable. Here and there between the riblets, one can see very weak lines of growth. Greenish sandstones with *Trigonia* (B5).

Tancredia donaciformis L y c. The specimen, slightly damaged in the termination of the anterior part, corresponds quite well to S c h m i d-t i l l's drawing. Yellowish sandstones (B6).

Protocardium cf. *concinnum* M o r. L y c. Included in this species could be a specimen with a considerably damaged valve, covered with fine, densely spaced, radial striae which intersect the more feebly marked concentric lines. The keel which separates the posterior field is less sharply marked than in the drawing of M o r r i s and L y c e t t. On another specimen, with an almost completely destroyed valve, the keel is marked sharply. Yellowish sandstones (B6).

Protocardium cf. *incertum* P h i l l. Yellowish sandstones (B6).

Pholadomya murchisoni S o w. (Plate XVII, fig. 11). The author has a complete specimen composed of both valves, with the following dimensions: length 43 mm, height 36 mm, thickness 26 mm. The characteristic sculpture consists of thick and irregular lines of growth, and of nine transversal, radially running riblets which, at their intersections with the lines of growth, are swollen into tubercles that are the strongest on the third, also strongest rib. The first rib is not tuberculated; the second one, in a barely perceptible manner. Dark-greenish sandstone with *Astarte* (B2): one specimen.

Pleuromya elongata (M s t r.) A g. (Plate XVII, fig. 10). Dark sandstones (B4).

Goniomya sp. Dark sandstones (B4).

Acanthothyris cf. *spinosa* S c h l. The inferior valve is covered with rounded riblets which dichotomize and carry spines that are arranged regularly in several rows. The number of riblets at the anterior margin amounts to 26. The length is equal to the height (8 mm). Layer with *Avicula* and *Ostrea* (B3).

Terebratula sp. The valves of *Terebratula* are numerous in the yellowish sandstones (B6) but they are always separated, abraded, and frequently broken. They probably belong to two species at least, but their determination is not possible. One of the specimens resembles most *T. ventricosa* H a r t m a n n.

2. Fauna of the Bathonian and Callovian

Phylloceras kudernatschi H a u e r. (Plate XX, fig. 13; fig. 7 in the text). Diameter of the specimen 42 mm (100%); height of the last-formed whorl 22 mm (52%); thickness of the last-formed whorl 18 mm (42%); diameter of the umbilic 6 mm (14%). The shell is covered with delicate striae, slightly curved forwards. The suture line (fig. 7 of the Polish text) with tripartite first saddle and the first lobe deeper than the siphonal lobe, corresponds well to the drawings of this species in literature. Pink marls (Bt) occurring as a fragment in the red crinoidal limestone (Ca): shell filled with the marl; one specimen.

Calliphylloceras cf. *disputabile* (Z i t t.): Fragments of casts with constrictions. Pink marls (Bt).

Sowerbyceras cf. *subtortisulcatum* P o m p. Diameter of the specimen 28 mm (100%); height of the last-formed whorl 14 mm (50%); thickness of the last-formed whorl 12 mm (43%); diameter of the umbilic 4 mm

(14%). With a certain reservation, the author includes in this species a damaged specimen. It is an ammonite with flat, almost parallel flanks, and a feebly rounded external side. Constrictions run straight from the umbilic towards the siphonal side. Near the external side they curve slightly backwards and then, curving forwards, cross the siphonal side. The straight course of the constrictions is the chief distinguishing feature of this species in relation to the very similar *S. tortisulcatum* (d'O r b.), in which the backward curvature is observable already in the middle of the flank. Variegated limestones (BtCa): one specimen.

Oppelia cf. *costata* J. R o e m. (Plate XX, fig. 14; fig. 8 in the text). Diameter of the specimen 38 mm (100%); height of the last-formed whorl 20 mm (52%); thickness of the last-formed whorl 10 mm (26%); diameter of the umbilic 7 mm (19%). The author possesses a single, well-preserved specimen. This ammonite is flat; it is supplied with a feebly noticeable but distinct keel and adorned on its flanks with flat ribs. The ribs are observable near the umbilic as weak striae directed forward; before reaching one-half of the flank height, they curve backward in a falciform manner, at the same time becoming wider and much more distinct. On the siphonal side they do not attain the keel; having become wider, they break off near the keel and are separated from the latter by a flat band. The number of perisiphonal ribs amounts to 30. In the proportions of the dimensions there is observable a conformity to the dimensions quoted by P a s s e n d o r f e r (1938) and by R o e m e r (e. g., variety *a*: diameter of the specimen 38.9 mm, height of the last-formed whorl 19.8 mm, thickness of the last-formed whorl 9.8 mm, diameter of the umbilic 7.5 mm). In relation to the dimensions quoted by L i s s a j o u s, the Bachowice specimen is samewhat thicker and it has a narrower umbilic. Of R o e m e r's varieties, variety *a* corresponds best: it is flat and its sculpture is not very strong. Variegated limestones (BtCa).

Perisphinctes (Grossouvreia) curvicosta (O p p.). (Plate XX, fig. 12). Diameter of the specimen 27 mm (100%); height of the last-formed whorl 8.5 mm (31%); thickness of the last-formed whorl 8.0 mm (30%); diameter of the umbilic 12 mm (44%). In this species the author includes, with reservations, one damaged specimen and several fragments. The flanks are slightly rounded, the same as the siphonal side. The irregularly spaced ribs ramify at one-half of the whorl height into 2 or 3 secondary riblets, the ramification either being a true one, or else secondary riblets intercalate between the primary ones. Before reaching the siphonal side, the secondary riblets curve backward. The number of primary riblets on the last-formed whorl amounts to 36. Here and there, observable are parabolic tubercles. Variegated limestone (BtCa).

Posidonomya alpina G r a s. (Plate XX, figs. 10, 11). This species does indeed occur in masses, nevertheless it was impossible to extract from the rock an intact specimen. The elongated shape of the valves distinguishes this species from *Pos. bronni* V o l t z. which has a more circular outline. By their costulation, the author's specimens are the most similar to figs. 4, 10, and 11 in G u i l l a u m e's work. Pink marls (Bt) occurring as water-rounded fragments in the crinoidal limestones (Ca): in masses.

Rhynchonella trigonella R o t h p l e t z. (Plate XX, fig. 3). The shell outline is triangular; the anterior margin forms the slightly rounded base of the triangle. The greatest width is near the base, and the greatest thickness near the beak. Both valves are the same, feebly convex, for the most part. Sinus and saddle do not exist; on the ventral valve there is only a slight depression, visible because the median riblet does not attain such a height as the adjacent ones do. The riblets are quite strong, slightly rounded, ten on each valve. The dimensions (length 11 mm, width 13.5 mm, thickness 6 mm) correspond to the proportions quoted by R o t h p l e t z (1886); on R o t h p l e t z's drawing slightly more riblets are shown than on the Bachowice specimen. Variegated limestones (BtCa): one specimen.

Rhynchonella subechinata O p p. (Plate XX, figs. 5 and 6). Three specimens bear the greatest resemblance to this species. In the two larger specimens the outline is triangular, with rounded corners at the anterior margin; beak sharpened. The smallest specimen has a subpentagonal outline. The ventral valve is more convex than the dorsal one, the latter being on one specimen quite considerably flattened. The anterior margin is straight; the frontal line on one specimen is slightly raised in the middle. The lateral sutures are almost straight, slightly curved towards the ventral side. The valves are covered with delicate riblets, more than 30 on each side. Some of the riblets are intercalated and do not reach the apex. Foramen small, deltidium invisible. The specimens are young, the largest one having a length of 13 mm and a thickness of 7 mm; the specimen being damaged, the width cannot be measured, but it is smaller than the height. The beak of the second specimen is broken off; in this specimen the length exceeds 10 mm, the width amounts to 10 mm, the thickness is 6 mm. Finally, the third specimen, with a subpentagonal outline, has the following dimensions: length 10 mm, width 10 mm, thickness 5 mm. This specimen corresponds best to fig. 9 in O p p e l's work (1863). The latter author quotes the following dimensions of the largest specimen: $21 \times 20 \times 12$ mm; so we see that the proportions are similar. Variegated limestones (BtCa).

Rhynchonella orbignyana O p p. (Plate XX, figs. 1 and 2). One well-preserved specimen conforms to the description, dimensions and drawing published by M o j s s e j e w (1934). The outline is almost pentagonal. The ventral valve has a quite wide and deep sinus which begins at a distance from the apex that is equal to one-third of the valve length. It is adorned with 11 ribs, three of which, broad and rounded, enter the sinus. The dorsal valve, more convex than the ventral one, has a feeble bulge and also 11 ribs, three of which, the strongest ones, run along the ridge of the saddle. The beak is slightly curved; underneath it one can see the deltidium. The lateral sutures are straight; the frontal suture, curved quite strongly upward. The width slightly exceeds the length; the distance between the greatest width and the anterior margin amounts to one-third of the length; the greatest thickness is approximately in the middle of the length. Dimensions: length 19 mm, width 21.5 mm, thickness 13 mm; they conform almost completely to the proportions quoted by M o j s s e j e w ($20 \times 23 \times 12.5$ mm). Apart from the described specimen, the author has one mature specimen which is damaged, and several young ones. The described form is very similar to *Rh. arolica* O p p.; it differs from the latter by the absence of dichotomy in the ribs. Particularly the young specimens, which are quite numerous at Bachowice, display a considerable resemblance to the above-mentioned form. Red crinoidal limestones (Ca): several specimens.

Rhynchonella cf. *kamiński* U h l. (Plate XX, fig. 7 and 8). Dimensions: length 12 mm, width 12 mm, thickness 6 mm. The greatest thickness is near the beak; the greatest width, near the front. Both valves are almost equally convex. The specimen corresponds relatively best to U h l i g's drawing from Babierzówka (1881) but with the difference that the median fold on the dorsal valve is more acute in the Bachowice specimen. The specimen from Babierzówka is also thicker (0.65 or 0.61 in U h l i g 1878, p. 656). A greater difference exists in relation to the dimensions quoted by U h l i g for a specimen described by him in 1878, on which the median fold of the dorsal valve is very feebly developed and almost flat. There is also a resemblance to the closely related *Rh. defluxa* O p p. from the beds of Klaus; the latter species has more acute folds but the number of its riblets is greater and it is thicker, although one of the specimens published by O p p e l (1863, plate VI, fig. 4) is more flat and has the same number of folds as the specimen from Bachowice. *Rh. kamiński* was described from the Callovian of the Pieniny Mountains. Variegated limestones. The block which supplied the specimen is ash-grey-yellow and differs somewhat from the yellowish or reddish limestones that predominate among the variegated limestones. On the fracture of the block one sees sections of ammonites with recrystallized interiors and also fragments of white lamellae of echinoderms, this being frequent in variegated limestones. In yellow limestones with numerous yellow and red crinoids (such limestones frequently form intercalations in the red crinoidal limestones), the author found a specimen of similar appearance but with still more rounded and flat bulges (Plate XX, fig. 7). It may be the same species or some closely related one.

Terebratula haasi R o l l i e r. (Plate XX, fig. 9). The outline is subpentagonal. The ventral valve is more strongly curved than the dorsal one; on the lower part of the quite flat dorsal valve one observes two inconspicuous folds reaching to the ends of the frontal line which, between them, is very slightly depressed. The beak is not very strong but markedly curved and with rounded areal edges. Dimensions: length 22 mm, width 18.5 mm (0.84), thickness 11.5 mm (0.52); this is within the limits of the considerable variability of this species. Red crinoidal limestones (Ca): one complete specimen and several fragments that perhaps belong here.

3. Fauna of the Oxfordian

Calliphylloceras (Holcophylloceras) zignoi (d'O r b.). (Plate XXI, fig. 1; fig. 9 in the text). Specimens belonging to this species *(Ph. mediterraneum* N e u m.) are numerous in the Oxfordian limestones at Bachowice. They conform completely to the descriptions of this frequent species, especially to the types described by P o p o v i c i - H a t z e g and to L oczy's variety A (Grundform). Red subcrinoidal limestones (O1): two specimens; a fragment of a large *Phylloceras* probably also belongs to this species. Bluish subcrinoidal limestones (O2): one specimen. Greenish subcrinoidal limestones (O3): one young specimen and one fragment. Yellow subcrinoidal limestones (O4): two specimens.

Calliphylloceras manfredi (Opp.). (Plate XXII, fig. 8; fig. 10 in the text). Slightly damaged cast. The flanks of the whorls are convex and attain their greatest thickness near the middle. The siphonal side is rounded. Umbilic quite wide. Five constrictions, almost radially arranged, run from the umbilic and become broader towards the siphonal side, which they cross with a slight forward curve. The proportions correspond to the dimensions quoted in literature for this species, the umbilic only being wider. It is characteristic that also Wójcik (1914) describes a greater width of the umbilic in a specimen from Kruhel in comparison with dimensions encountered in descriptions. Bluish subcrinoidal limestones.

Calliphylloceras disputabile (Zitt.). (Plate XXI, fig. 3). Diameter of the specimen 25 mm (100%); height of the last-formed whorl 15 mm (60%); thickness of the last-formed whorl 9 mm (36%); diameter of the umbilic 2 mm (8%). The shell is covered with delicate and densely spaced striae which run straight across the flanks and the siphonal side; they are more distinct in the external part of the whorl than in the periumbilical part. At regular intervals the striae are more prominent and thicker, and also slightly raised above the remaining ones. The umbilic is narrow, with gently rising walls. After removing the test, one observes constrictions on the cast, near the umbilic; they are feebly curved and do not reach the siphonal side. The suture line (fig. 11), in spite of the young age of the specimen, displays the characteristics of the species, as one may observe by comparing it with the drawing published by Jeannet. Green subcrinoidal limestones (O3): one specimen.

Phylloceras cf. *douvillei* Choffat. (Plate XXI, fig. 4). The ribs are sharply marked, straight or slightly curved backward, strongly developed near the siphonal side, and disappearing on the flanks. The ribs disappear near the umbilic but not in a uniform manner; some of the ribs almost reach the umbilic, others become extinct below the middle of the flank, while still others come to an end at one-third of the distance from the siphonal margin. In *Ph. douvillei* the costulation is terminated in the upper one-third of the flank. The dimensions are quite similar to those of this species; the latter has a slightly greater whorl height and a relatively smaller umbilic. Green subcrinoidal limestones (O3).

Sowerbyceras tortisulcatum (d'Orb.). (Plate XXI, fig. 2). This is the most common fossil of the Bachowice Jurassic. Flattened flanks, a feebly rounded but wide siphonal side, and a broad umbilic are the characteristic features of this species. The dimensions correspond to this species, the ratio of the thickness of the last-formed whorl to its height exceeds, as a rule, 0.8, and on some fragments it equals 1. Pink subcrinoidal limestones (O1): several young specimens; in addition to this, one broken-off specimen has certain characteristics distinguishing it from other specimens of this species, i. e., a ridge on the siphonal side, bordering the constriction from the front; from the anterior side this ridge has a narrow and shallow furrow; this feature makes it similar to *Sowerbyceras protortisulcatum* Pomp. (cf. Neumann 1907, p. 12). Bluish subcrinoidal limestones (O2): numerous small specimens. Greenish subcrinoidal limestones (O3): numerous intact specimens and fragments of large specimens. Yellowish subcrinoidal limestones (O4): one large specimen and numerous small ones which in places fill up the rock.

Thysannolytoceras sp. ind. (ex aff. *adeloides* Kud.). (Plate XXI, fig. 8). The internal whorls are narrow and low; the last-formed whorl, which seems to be the living-chamber, is considerably thicker in relation to the internal whorls. The width of the whorl slightly exceeds its height. On the preserved remains of the valve observable are delicate striae and, at intervals, ridges. The sculpture, therefore, resembles that of *Thys. adeloïdes* (Kud.). By its proportions it also corresponds almost completely to the dimensions quoted by Popovici-Hatzeg (1905), while in relation to the specimen described by Passendorfer (1936) from the Bathonian of the Tatra Mountains it has a somewhat wider umbilic. *Lytoceras liebigi* Zitt. from the Tithonian is a form that is similar by its proportions, but it has a different sculpture and, being of considerably greater size, it is still chambered. The most similar is *Thys. adeloides* which occurs in the Bathonian and Callovian, but Gemmellaro (vide Choffat 1893, p. 18) quotes it also from the transversarium horizon of Sicily, while Roman (1924, p. 88) points out that the forms encountered in the Argovian are identical with the Callovian forms. Greenish subcrinoidal limestones (O3): one specimen and completely indeterminable fragments of *Lytoceras*.

Taramelliceras cf. *kobyi* (Choffat) (Plate XXI, fig. 9). Pink subcrinoidal limestones (O1).

Taramelliceras cf. *pichleri* (Opp.). (Plate XXII, fig. 6). In comparison with Dorn's (1931) drawing, the Bachowice specimen has slightly stronger riblets, and the geniculate flexure in the middle of the flank is more acute. The thickness of the riblets seems to correspond better to the drawing published by Maire (1928), plate II, fig. 7). Bluish subcrinoidal limestones (O2).

Taramelliceras sarasini (Lor.). (Plate XXII, fig. 7; fig. 13 in the text). The Bachowice specimen corresponds best to the drawing in Dorn's work (plate XV, fig. 6). Greenish subcrinoidal limestones (O3): one specimen.

Taramelliceras (Proscaphites) anar (Opp.). (Plate XXI, fig. 10; fig. 14 in the text). The single, quite well-preserved specimen corresponds to the descriptions and drawings of the authors quoted in the polish text, and to Oppel's type, reproduced by Roman (1938, plate XV, fig. 160). Greenish subcrinoidal limestones (O3): one specimen.

Trimarginites trimarginatus (Opp.) (fig. 15 in the text). Yellowish subcrinoidal limestones (O4).

Cardioceras aff. *cordatum* (Sow.). Fragment of a small whorl; the periumbilical part is destroyed. The specimen is so small and badly preserved that a determination of the species is impossible. The character of the costulation allows one to presume that the specimen belongs to *C. corda-*

tum or some closely related species. Bluish subcrinoidal limestones (O2): one specimen.

Cardioceras tenuiserratum (O p p.). (Plate XXI, figs. 6 and 7). Bluish subcrinoidal limestones (O2): three specimens. Greenish subcrinoidal limestones (O3): one specimen.

Perisphinctes (Properisphinctes) bernensis L o r. (Plate XXII, figs. 2 and 3; fig. 16 in the text). This form is quite common in the Oxfordian of Bachowice, conforming to Loriol's descriptions and drawings. The suture line also, which it was possible to trace only on a young whorl, has all the characteristics quoted by L o r i o l. In the Bachowice specimens the height is slightly larger than in the forms described by L o r i o l. Pink subcrinoidal limestones (O1): several specimens. Bluish subcrinoidal limestones (O2): numerously. Greenish subcrinoidal limestones (O3): one specimen.

Perisphinctes (Discosphinctes) cf. *jelski* S i e m. (Plate XXII, fig. 1). Conformity of the dimensions with N e u m a n n's Czetechowice specimen and the density of the costulation render the determination of this species a very probable one, in spite of the bad state of preservation. Pink subcrinoidal limestones (O1): one specimen.

Perisphinctes (Discosphinctes) lucingense (F a v r e). (Plate XXI, fig. 11: fig. 17 in the text). This *Perisphinctes*, with a comparatively high umbilic, a high whorl (whorl height almost equal to umbilic diameter), with a densely spaced and not very strong costulation (more than 50 ribs on one-half of a whorl), corresponds by its appearance and proportions to F a v r e's species. On the Bachowice specimen, the suture line is plainly visible and displays a sutural lobe which is as deep as the siphonal lobe; the first lateral lobe is shallower than the siphonal one, i. e., in accordance with N e u m a n n's statement. On the other hand, according to S i e m i r a d z k i (1894 and 1899), the siphonal lobe is as deep as the first lateral one, while the sutural lobe is considerably deeper. Apart from the fact that on account of corrosion some of the details are invisible, the aspect of the suture line in the Bachowice specimen is almost identical with D o r n's drawing. Greenish subcrinoidal limestones (O3): one specimen.

Perisphinctes orbignyi L o r. (Plate XXII, fig. 4). The specimen is preserved only fragmentarily, but there seems to be no doubt that it belongs to this species. It is a *Perisphinctes* with a wide umbilic, whorls higher than wider, flanks flat, covered with straight, strong, thin ribs which ramify near the siphonal side and cross the latter without changing direction. The umbilical wall is steep. Pink subcrinoidal limestones (O1).

Perisphinctes cf. *delgadoi* C h o f f a t. (Plate XXII, fig. 5). Only one side of the specimen is preserved. It is a feebly involute *Perisphinctes*, with whorls higher than wider; the umbilic equals one-half of the diameter. The ribs, 59 in number, are quite strong; on the last-formed whorl they bifurcate and, without changing direction, cross over to the siphonal side. The flanks of the whorls are weakly convex, and their umbilical wall is not very steep; they have an oval outline, becoming narrower towards the siphonal side, and their greatest thickness is below one-half of the height. Constrictions are present but shallow. On account of all of the above-mentioned characteristics and its dimensions, the author's specimen bears the strongest resemblance to *Per. delgadoi*, but the poor preservation of the specimen makes an accurate determination impossible. The rounded flanks distinguish this form from *Perisphinctes* belonging to the *orbignyi* group; one could take into account *Per. marnesiae* which has a wider umbilic and a tendency to trichotomy of the ribs. Greenish subcrinoidal limestones (O3): one specimen.

Peltoceras (Pseudogregoryceras) neumayri Jeannet. (Plate XXI, fig. 5). One young specimen completely corresponds to Neumayr's (1871) fig. 3 on plate XX. The internal whorls are smooth, and then strong single ribs appear, directed backwards; they disappear near the umbilic, and this, according to Neumayr, characterizes young specimens. The cross-section of the whorl is quadrate, with slightly rounded sides.

Neumayr determined his specimens, obtained from the Oxfordian of Stańkówka, as *Amm. transversarium* Quenstedt. Recently, however, Jeannet drew attention to the fact that the internal whorls of the Stańkówka specimens are smooth, in contrast with the sculptured young whorls of *Peltoceras* from the subgenus *Gregoryceras*. On such a basis, Jeannet considers Neumayr's form to be a different species, belonging to a separate subgenus. Bluish subcrinoidal limestones (O2): one specimen.

Euaspidoceras cf. *perarmatum* (Sow.). One young specimen belonging, perhaps, to this species. Bluish subcrinoidal limestones (O2).

4. Fauna of the Kimmeridgian

Lytoceras polycyclum Neum. (Plate XXIII, fig. 6). In spite of its fragmentariness, the specimen displays sufficient characteristics for determining its species. A characteristic feature of this species are the numerous, slowly widening whorls. The whorl height is equal to the width. The absence of constrictions distinguishes this form from the quite similar *L. quadrisulcatum* (d'Orb.). Greenish pelitic limestones (K2): one specimen.

Lytoceras cf. *orsini* (Gemmellaro). (Plate XXIII, fig. 4; fig. 18 in the text). With certain reservations, the author considers as belonging to this species a *Lytoceras* fragment in which are preserved the fragments of two whorls, partly covered with a shell. The whorls slightly adhere to one another: the external whorl is almost as high (19 mm) as it is wide (18 mm). The thin shell is covered with delicate striae, spaced at unequal intervals; they have a tendency to a backward deviation near the siphonal side. The constrictions observable on the cast are straight, flat and very feebly depressed. On the preserved shell-fragment it is visible that delicate low ridges correspond to the constrictions. The constrictions are spaced at large intervals from one another, and probably not more than four correspond to each whorl. The last-formed whorl expands quite rapidly; it is at least three times higher than the internal whorl which is in direct contact with it. The siphonal saddle and the first lateral one are dissected by deep lobes into two parts (fig. 18), each of which is also symmetrically dissected; the second lateral saddle, on the other hand, is dissected into two asymmetrical parts, bearing a resemblance to Favre's figure (plate VI, fig. 6b). The considerable difference in the height of the whorls that adhere directly to one another, the oval outline of the aperture, and the backward flexion of the striae on the shell, impart to the specimen the greatest resemblance to Gemmellaro's species. In the similar *L. quadrisulcatum* the evolution of the whorls is slower and the difference in whorl height is smaller. The constrictions in *L. quadrisulcatum* are also narrower and deeper. *L. municipale* Opp. has a wider aperture in relation to the height. Similar forms of the Lower Cretaceous have a larger number of constrictions. Greenish pelitic limestones (K2): one specimen.

Phylloceras (Calliphylloceras) sp. (fig. 18 in the text). Fragment of a cast with constrictions and a clearly visible suture line that is similar to the suture line of a *Phylloceras* from the *zignoi* or *polyolcum* group. It resembles the suture line of the latter species by the greater slenderness of its lobes and saddles, this being highly similar to the drawing published by Benecke (1865, plate VIII, fig. 2). The first saddle is bifoliate, the second one is trifoliate; in relation to the dimensions of the specimen (radius 20 mm), the suture line is strongly dissected. Greenish pelitic limestones (K2): one specimen.

Sowerbyceras cf. *tortisulcatum* d'Orb. Small specimen, with a diameter of only 15 mm. It has a quite wide umbilic and curved constrictions, characteristic of this species. Greenish pelitic limestones (K2): one specimen.

Haploceras tenuifalcatum Neum. (Plate XXIII, fig. 5). The author has only one-half of a whorl, with a diameter of 23 mm. It is a flat form, with almost completely parallel flanks, and an umbilic that is not very wide; the whorl height is almost twice greater than the thickness. On the perisiphonal part of the whorl, observable are delicate falciform riblets which in a still more delicate form, curved forward, pass across the narrow but rounded siphonal side. The suture line is invisible on the author's specimen. Greenish pelitic limestones (K2): one specimen.

Metahaploceras strombecki (Opp.). (Plate XXIII, fig. 3; fig. 20 in the text). The flank of the whorl is adorned with ribs running forward from the umbilic and bent at the middle of the whorl height, from where they run, curved but slightly backwards, towards the siphonal side. Near the siphonal side, the ribs become thicker, forming a longitudinal tubercle extended forward. Between the principal ribs, there are 5 or 6 smaller ones, very feebly marked; they disappear towards the umbilic. The same as the principal ribs, the secondary riblets do not cross the siphonal side which is rounded and smooth. The specimen corresponds to Quenstedt's and Loriol's drawings, but its dimensions are somewhat larger (whorl radius ± 35 mm); the intervals between the ribs are probably in consequence of this slightly larger than in the quoted drawings. Greenish pelitic limestones (K2): one specimen.

Taramelliceras greenackeri Moesch. (Plate XXIII, fig. 2). The specimen is only partly preserved, but characteristic. The flanks are flat, almost parallel; the siphonal side is rounded. The ornamentation is composed of falciform riblets which towards the siphonal side become much thicker and are terminated at the border of the siphonal side with strong swellings or distinct tubercles. Some of the riblets ramify. Across the middle of the siphonal side there runs a row of small tubercles, considerably weaker than the tubercles that terminate the ribs; some of the siphonal tubercles are slightly elongated longitudinally. The periumbilical part of the whorl, unfortunately, is not preserved. The specimen corresponds completely to L o r i o l's description and drawings, especially to figs. 2 and 2a which represent the original type of the species. The Bachowice specimen seems only to be slightly thicker, but this may be caused by the fact that the ventral side is split and pushed apart, while the fissure is filled with calcite. Greenish pelitic limestones (K2): one specimen.

Taramelliceras cf. *pseudoflexuosum* (F a v r e). (Plate XXIV, fig. 4). The delicate sculpture of this *Taramelliceras* corresponds best to F a v r e's descriptions and drawings, especially to those in his works concerning Voirons (1875, page 25, plate I, figs. 13—14) and the Freiburg Alps (1876, plate III, fig. 6); in the latter works the above-mentioned form is still described under the name of *A. (Oppelia) flexuosus* M s t r. Also similar to the discussed form is *T. trachynotum* (O p p.); it has a stronger sculpture and more elongated marginal and siphonal tubercles: this, however, is observable in mature forms, while the author's specimen represents a young whorl. Yellowish limestone (without crinoids), imbedded in a Cretaceous conglomerate. It is a small fragment, but similar limestones in larger fragments have a more distinctly greenish-yellowish colour and, consequently, the author includes this fragment in the yellow-greenish pelitic limestones (K1).

Taramelliceras cf. *trachynotum* (O p p.). Fragment of a whorl with a quite well preserved siphonal side. The riblets are slightly curved in the shape of an arc; some of them are terminated in pairs with a marginal tubercle. The siphonal tubercles are weaker than the marginal ones. In relation to *T. pseudoflexuosum* described above, the sculpture is more distinctly visible, but the specimen is also larger. It corresponds best to the forms published by L o r i o l and also by C h o f f a t (1893, page 25, plate XVII, figs. 1—3), much less to W e g e l e's drawings from the *bimammatum* horizon. Yellow-greenish limestone (K1) without crinoids, occuring as a pebble in the Campanian red conglomerates (Kr 5).

Idoceras cf. *sautieri* F o n t. (Plate XXIV, fig. 3; fig. 21 in the text). This ammonite is flat, feebly coiled, with a wide umbilic; the whorls are higher than wider, attaining their greatest thickness near the umbilical wall which descends almost perpendicularly towards the umbilic. The ribs are strong, rounded, and they bifurcate at approximately one-half of the whorl height; this division is not clearly marked because some ribs remain single, while secondary riblets are intercalated between them. At the siphonal side, which is rounded and somewhat flattened, the ribs become narrower and disappear, leaving on the siphonal side a smooth band that is several mm. wide. The suture line (fig. 21) is partly well visible on the specimen, the surface of which, having been subjected to strong corrosion, displays a wide external saddle. Both lobes, the siphonal one and the first lateral one, are almost of the same depth; the second lateral lobe is shallower and oblique. The siphonal saddle and the first lateral one are nearly of the same height, while the second lateral saddle is considerably smaller and inclined in a similar manner as the auxiliary saddles. The specimen corresponds best to the description, dimensions and drawings published by F a v r e for *Per. heimi*. F a v r e's species was united by S i e m i r a d z k i with *Per. sautieri* F o n t a n n e s. Green pelitic limestones (K2): one specimen and perhaps several fragments.

Ataxioceras cf. *stromeri* W e g e l e. (Plate XXIII, fig. 1). The specimen bears a very great resemblance to W e g e l e's description and drawing, with the difference that the Bachowice specimen is considerably larger; however, in W e g e l e's drawing (plate VII, fig. 4), the living-chamber is just beginning to develop. In spite of the differences in size, the dimensional proportions are in agreement. In W e g e l e's specimen, with a diameter of 106 mm, the umbilical width is 47%, whorl height 30%, whorl width 29%; the Bachowice specimen, with a diameter of 170 mm (it is, in fact, still larger, but the last-formed whorl of the specimen is cut short by the surface of the block from which the specimen was extracted), has an umbilical diameter amounting to 47%, whorl height 30%, while the whorl width (in the unilaterally preserved specimen) is approximately equal to the height. No other *Ataxioceras* displays such proportions. Green pelitic limestones (K2).

Physodoceras uhlandi (O p p.). (Plate XXIV, fig. 1). The cast of a large ammonite with one relatively well preserved side, displays the characteristic features of O p p e l's species: thick inflated whorls; rather narrow umbilic; on the flank of the whorl, approximately at one-third of the height, noticeable are flat tubercles, on the available specimen only partly visible on account of their damaging during the extraction of the latter; from each tubercle, two or perhaps three flat ribs run towards the siphonal side, disappearing almost completely when crossing the latter side. No ribs are observable running from the tubercles towards the umbilic, perhaps partly in consequence of the state of preservation; however, it is observable from W e g e l e's and L o r i o l's drawings and descriptions that on mature whorls internal ribs do not exist or are but very feebly marked. The umbilical wall is steep but rounded. Greenish pelitic limestones (K2).

Physodoceras ex aff. *uhlandi* (O p p.). (Plate XXIV, fig. 2; fig. 22 in the text). The author has a whorl fragment with a diameter of ca. 40 mm, with characteristic sculpture. The whorl width exceeds the height. The whorl flank is supplied with strong rounded tubercles; it is difficult to say whether these tubercles are the termination of the ribs running from the umbilic, inasmuch as the periumbilical side is strongly damaged. On the external side, which is moderately convex, feebly observable are flat rounded ribs, two (or three) of which issue from each lateral tubercle and cross the siphonal side. The suture line (fig. 22), visible only in part, displays properties characteristic of *Aspidoceras*. The saddles are wide and dissected by secondary lobes; the external saddle, which is dissected, is higher than the first lateral one. Greenish pelitic limestones (K2).

Avicula lacunosa Q u. (Plate XXIV, fig. 5). The author's specimens bear the greatest resemblance to *Monotis similis* M s t r in the work published by G o l d f u s s (1840, plate 120, fig. 9); O p p e l wishes to unite the latter species with *Av. lacunosa* Q u. A resemblance also exists to *Av. oscari* C a r t i e r (L o r i o l, 1881/2, plate XI, fig. 12, page 79), a species which is not well-defined and which differs from those mentioned above by the central placing of its umbones. Greenish pelitic limestone, slightly different from the other limestones of this type (K2).

Rhynchonella aff. *spoliata* S u e s s. (Plate XXIII, fig. 7). The ventral valve has a broken-off beak; the length, therefore, is probably greater than 16 mm and the indices somewhat too high. The shell is ovally pentagonal. The ventral valve has a flat sinus which begins at a distance from the beak that is equal to one-third of the length; the sinus, less depressed and more flat than in *Rh. spoliata*, merges into the slightly convex flanks of the valve. The dorsal valve is more strongly convex than the ventral one, and near the front it is raised. The lateral sutures are strongly curved towards the ventral valve; the frontal suture curves upward in a gentle arc. The surface is covered with delicate radial striae, joined at the very edge of the anterior margin by very short, fine riblets. Nearer the anterior margin, concentric lines of growth are more distinctly visible. *Rh. spoliata* almost always has a greater width than length (the quoted indices of width oscillate from 0.97 to 1.24, and an index below 1 is rather exceptional). The Bachowice specimen, therefore, is too long in relation to *Rh. spoliata*. It is also too thick, inasmuch as *Rh. spoliata* has an index of thickness amounting to 0.54—0.69. The Bachowice specimen cannot belong to *Rh. spoliata;* it belongs to some other, closely related species. Greenish limestones. The limestone containing the discussed shell differs somewhat from the pelitic limestones (K2); it is slightly crystalline, which makes it similar to the subcrystalline limestone (T1), differing from the latter by its colour.

5. Fauna of the Tithonian

Lytoceras (Thysannolytoceras) cf. *montanum* (O p p.). (Plate XXV, fig. 1; fig. 23 in the text). The specimen, with a diameter of 10 mm, represents the last-formed whorl; the internal whorls are not preserved. A considerable part of the whorl belongs to the living-chamber. The whorl height (ca. 32% of the diameter) is nearly equal to the width which cannot be measured on the specimen. The umbilic is large, its diameter amounting to ca. 48% of the diameter of the specimen. Such proportions and the absence of constrictions on the whorl, suggest that the specimen belongs to *Lyt. montanum*. The sutural line, which is clearly visible (fig. 23), gives no special indications for determining the species. The saddle apices lying on one line and the deeply incised siphonal lobe make it more similar to the sutural line of *Lyt. quadrisulcatum* (d'O r b.) than to that of *Lyt. montanum*. Light-coloured subcrystalline limestones (T1).

Lytoceras (Thysannolytoceras) cf. *liebigi* O p p. Several fragments may be considered as belonging to this species. Some of them belong to young specimens; the whorls are covered, at equal intervals, with straight delicate riblets between which still finer lines of growth are visible. The width of the whorls is distinctly greater than the height. These characteristics agree with those of *Lyt. liebigi* but young whorls of *Lyt. montanum* O p p. are indistinguishable; their riblets, however, are curved forwards.

The cast of a large fragment of a living-chamber, ca. 40 mm high and ca. 70 mm wide, perhaps also belongs to the same species. The transversal outline of the whorl corresponds to the outline published by Z i t t e l for *Lyt. liebigi* var. *strambergensis* (1868, plate 11). Light-coloured subcrystalline limestones (T1).

Lytoceras (Protetragonites) quadrisulcatum d'O r b. (Plate XXV, fig. 5). An ammonite with strong evolution and narrow whorls, with an almost circular cross-section. Characteristic constrictions exist on the last-formed whorl and on the one preceding it. On the better preserved specimen the diameter is 21 mm, umbilical radius 12.5 mm. Light-coloured subcrystalline limestones (T1): several fragments. Grey siltstones (V): one better preserved specimen.

Calliphylloceras calypso d'O r b. (Plate XXV, fig. 2; fig. 24 in the text). On the shell, the internal whorls of which are preserved, visible are four transversal furrows on the siphonal side, limited from the front by small ridges. The furrows are not extended to the flanks nor are they visible in the periumbilical part. Their presence induces the author to include the specimen in *Ph. calypso* (*Ph. silesiacum* O p p.), this being confirmed by the suture line (fig. 24) which is strongly dissected, with a tripartite first lateral saddle and a bipartite second saddle: this line agrees with the drawing published by Z i t t e l. Another specimen (plate XXV, fig .2) is a cast with traces of the shell. Visible are numerous constrictions that are straight or slightly curved in the middle of the flank. Light--coloured subcrystalline limestones (T1): several fragments of casts; one with a preserved shell perhaps belongs here. Yellowish *Calpionella* limestones (T2): one better preserved specimen.

Calliphylloceras (Ptychophylloceras) cf. *semisulcatum* d'O r b. A fragment of a *Phylloceras*, with a preserved shell, has on its siphonal side a ridge that rapidly disappears in the direction of the umbilic. In view of the fact that the flanks are quite strongly convex, one must exclude older forms of this group, also supplied with ridges on the siphonal side. White *Calpionella* limestone (T3).

Sowerbyceras cf. *tortisulcatum* d'O r b. A large fragment of a whorl with a characteristic constriction probably belongs to this species. White subcrinoidal limestones (T4).

Haploceras elimatum (O p p.). (Plate XXV, fig. 6; fig. 25 in the text). A quite well preserved specimen, almost completely deprived of its shell, corresponds closely to this species. The remains of the shell show that the form is a smooth one, with delicate lines of growth and insignificant ridges near the umbilic. The greatest thickness is in the lower part of the whorl; the siphonal side is wide and rounded. The suture line is well preserved. Fig. 25 demonstrates it at a height of 25 mm of the whorl. It displays the characteristics of the discussed species, i. e., siphonal saddle lower than the first lateral one; the siphonal saddle is dissected by a narrow lobe into two asymetrical parts, the perisiphonal one being higher; the first lateral saddle is also dissected into two unequal parts, the lower one of which (from the umbilical side) is higher and also asymetrically dissected. The first lateral lobe, which is tripartite, is deeper than the siphonal one. The second lateral saddle is not shown in the drawing because the cast, near the umbilic, is here damaged; this saddle is considerably lower than the first lateral one. Light-coloured subcrystalline limestones (T1): one complete specimen and several fragments. Yellow *Calpionella* limestones (T2): one speçimen of doubtful determination.

Haploceras sp. The state of preservation and the young age of the specimen make impossible its determination. It may be a young specimen of *H. elimatum*, or else *H. verruciferum* Meneghini, this being perhaps indicated by the completely flat flanks. Yellowish *Calpionella* limestones (T2).

Taramelliceras sp. ind. (cf. *otreropleurum* Fontannes). (Plate XXV, fig. 4). The badly preserved but very characteristic specimen (siphonal side damaged) is a fragment of a whorl with a height exceeding 34 mm. The whorl is high, narrow; its greatest thickness is approximately at one--half of its height. Umbilic very narrow. The sculpture, clearly visible, is composed of two kinds of costulation. At first, the riblets are very thin but flattened, farther on they become wide and flat. Some of the ribs begin on the edge of the umbilical wall; at this edge they frequently unite into pairs. The ribs, running from the umbilic, are directed slightly forward and insignificantly curved backwards (less in the lower part of the whorl, more in its upper part). Between the principal ribs, intercalated are secondary ones that begin approximately at the middle of the whorl height. Between two ribs beginning at the umbilical wall, intercalated most frequently is one secondary rib, sometimes two, and even three; when more than one secondary rib is intercalated between two primary ones, the secondary ribs begin at different distances from the umbilic. The secondary ribs never join the primary ones; they become sharper and are wedged in between the primary ribs. The umbilic is small, deep, and it has a sharp edge. By its characteristic costulation, the author's specimen bears a resemblance to *Oppelia otreropleura* Fontannes, described from the Upper Kimmeridgian; on the drawing of the latter, observable are ribs that have a geniculate curvature only in their middle, intercalated ribs that do not join the principal ribs, and also ribs that wedge out at various heights. In the younger part of the whorl, the principal ribs join together at the umbilic. White subcrinoidal limestones (T4).

Berriasella cf. *oppeli* Kilian. Damaged fragment of a whorl. The whorl height exceeds the width; the flank is slightly rounded, covered with straight, thin, sharply marked riblets that are either disposed radially, or inclined forwards; above one-half of the flank height, the riblets ramify into secondary ones; at the point of ramification there is a slight elevation of the principal riblet. The secondary riblets become thicker towards the siphonal side, where they are suddenly terminated by a narrow furrow. White *Calpionella* limestones (T3).

Himalayites (Micracanthoceras) cf. *microcanthus* (Opp.)? (Plate XXV, fig. 3). With reservations, the author includes in this species a small specimen with a diameter of only 15 mm. The whorls, with an almost circular cross-section, are covered with strong rounded ribs. At approximately one-half of the whorl height, most of the ribs ramify; at the point of ramification, there is a tubercular thickening; the secondary ribs, directed slightly forward, become somewhat wider on the siphonal side and are interrupted abruptly at the siphonal furrow which on the internal whorls is less distinct. The specimen was found in a small fragment of a light--coloured marly limestone (T6), imbedded in a pink limestone of the Upper Cretaceous.

Aulacosphinctes sp. (cf. *pachygyrus* U h l. ?). Fragment of an ammonite with internal whorls, resembling a *Perisphinctes*. A narrow furrow running across the siphonal side indicates that we have here some species belonging to the genus *Aulacosphinctes*. The sharply marked ribs divide into two in the perisiphonal part of the whorl; some of the ribs do not ramify; the whorl width exceeds the height. Distinct constrictions. Light--coloured subcrystalline limestones (T1).

Virgatosphinctes cf. *geron* (Z i t t.) With great reservations, the author includes in this species a large fragment of a whorl; its height considerably exceeds the width; the siphonal side is narrow and rounded. The whorl is covered with small, densely spaced riblets, most of which bifurcate at approximately one-half of the whorl height. The riblets are straight, slightly inclined forward. They cross the siphonal side without curves or interruptions. Light-coloured subcrystalline limestones (T1).

Lamellaptychus beyrichi (O p p.) T r a u t h. Light-coloured subcrystalline limestones (T1).

Rhynchonella capillata Z i t t. (Plate XXVI, fig. 4). In comparison with Z i t t e l's species, the Bachowice specimen has a somewhat higher width index (1.25, while in Z i t t e l's specimens the maximum is 1.16); apart from this, it corresponds to Z i t t e l's drawings and description. White subcrinoidal limestones (T4).

Rhynchonella sparsicosta Q u. (Plate XXVI, fig. 3). Yellow *Calpionella* limestones (T2): seven specimens.

Rhynchonella agassizi Z e j s z n. (Plate XXVI, figs. 11 and 12). In comparison with the forms from Rogoźnik, the Bachowice specimens are slightly wider and thicker. Yellow *Calpionella* limestones (T2): one of the larger specimens. White *Calpionella* limestones (T3): one small specimen and the ventral valve of another (plate XXVI, fig. 12). The latter has all the characteristics of the species, especially the plication of the straight frontal line in consequence of the presence of riblets which disappear just beyond the anterior margin; however, the lengths is 14 mm, and width amount to 13 mm (0.92), and thus the index of width is lower than 1, a thing that is not encountered in this species.

Rhynchonella cf. *zeuschneri* Z i t t. (Plate XXVI, fig. 2). The specimen conforms to Z i t t e l's description and drawings, in spite of certain dimensional differences which, however, are partly caused by deformation. Asymmetry, noticeable in Z i t t e l's species, is not observable in the Bachowice specimen. Yellowish *Calpionella* limestones (T2): two specimens.

Rhynchonella aliformis R o l l i e r. (Plate XXVI, fig. 10). In relation to the dimensions quoted by J a c o b and F a l l o t (1913), the Bachowice specimen is slightly thicker (0.7, while the index of thickness quoted by the above-mentioned authors amounts to 0.6), and the flanks are less elongated in a wing-like fashion. The wide and low sinus corresponds completely to the drawing published by Jacob and Fallot. Short, densely spaced riblets are observable close to the frontal line. Yellow *Calpionella* limestones (T2): three specimens.

Rhynchonella suessi Zitt. (Plate XXVI, fig. 1). Rounded pentagonal outline. Both valves are equally convex. Small foramen, clearly visible deltidium. On the ventral valve, the sinus is feebly inflected, but wide and distinct. The riblets are strong, rounded, and most of them dichotomize. These characteristics correspond well to Zittel's species, created for *Rh. lacunosa* var. *subsimilis* Suess. In relation to the form described by Mojssejew (1934), the Bachowice specimen is somewhat flatter. Subcrystalline limestones (T1): one specimen.

Glossothyris bouei (Zejszn.). (Plate XXVI, fig. 5). The dimensions of the specimen correspond almost completely to those of Zittel's specimen No. 3 from Rogoźnik (1870, p. 131). Besides this, the Bachowice specimen possesses all the characteristics of the species. Light-coloured subcrystalline limestones (T1): one specimen.

Waldheimia humeralis (Roem.). (Plate XXVI, figs. 6 and 7). In this species, the author includes specimens which resemble Loriol's figures (1876) in a greater degree than Roemer's figure (1836, plate XVIII, fig. 14) which is more elongated. The outline is pentagonal, with rounded corners. The ventral valve is strongly convex, with a strongly curved beak. The area is distinct, rounded from the side of the beak. The dorsal valve is less convex; its greatest width and greatest thickness are in the upper half. Visible trace of a median septum. The anterior margin is narrow, sharpened, almost straight. On the surface we see radial striae which are very delicate and widely spaced, and also concentric lines of growth, densely disposed. Yellow *Calpionella* limestones (T2). White *Calpionella* limestones (T3): large specimen.

Terebratula simplicissima Suess. (Plate XXVI, fig. 13). The shape is longitudinally oval, somewhat pentagonal; the ventral valve is slightly more convex than the dorsal one; the beak, although broken off, displays a quite strong flexion. The frontal suture is straight; the lateral sutures are almost straight, slightly depressed in the anterior part. The greatest width is somewhat below one-half of the length. The concentric lines of growth are strongly marked; the radial striae are very feebly visible. These characteristics agree with the description published by Suess (1858). There is also a resemblance to specimens of this species from Inwałd; they are only very slightly narrower and thinner. White subcrinoidal limestones (T4).

Terebratula carpathica Zitt. (Plate XXVI, fig. 8). The specimen corresponds completely to Zittel's description, while its proportions are within the dimensional bounds quoted by the latter author. The only difference consists in the fact that the greatest width lies clearly below one-half of the lenght, in consequence of which the upper part of the valve has a more triangular outline. Yellow *Calpionella* limestones (T2):

one specimen; three other specimens, which are damaged, also most probably belong to this species.

Terebratula bieskidensis Zejszner. (Plate XXVI, fig. 9). The outline is triangularly oval; the length exceeds the width; the beak is strongly bent; deltidium hardly visible; area absent. The lateral margins are obtuse; the anterior margin is sharpened. The sinus is low, asymmetric, raised, with gentle declivities. The lines of growth are strongly marked; delicate radial striae are also visible on the ventral valve. Yellow *Calpionella* limestones (V2): one specimen.

Pygope diphya Col. (Plate XXVI, fig. 14). A large fragments of a flat shell with a broken-off apex is suitable for determining the species because the aperture is visible, situated high in relation to the dimensions. The specimen must have been a large one, inasmuch as the width amounts to 60 mm. Light-coloured subcrystalline limestones (T1): one determinable specimen and several fragments that probably also belong here.

Calpionella alpina Lorenz. (Plate XV, figs. 2 and 3; plate XVI, figs. 3—6). This species occurs numerously in typical forms. Maximal dimensions: length of the lorica 68 μ, width 58 μ. Yellow *Calpionella* limestones (T2): quite numerous. White *Calpionella* limestones (T3): numerous.

Calpionella elliptica Cadish. (Plate XV, figs. 2 and 3; plate XVI, figs. 3—6). Considerably rarer than the preceding one. Maximal length of the lorica 74 μ, width 42 μ. Visible on some sections is the sharpened aboral side. Yellow *Calpionella* limestones (T2): rare. White *Calpionella* limestones (T3): in small numbers.

V. REGIONAL POSITION OF THE BACHOWICE JURASSIC

1. Character of the sediments of the Bachowice Jurassic

It follows from the presentation of the lithological development and the character of the fauna contained in the Bachowice exotics that at Bachowice it is possible to reconstruct an almost complete sequence from the Aalenian or the lowest Bajocian to the Tithonian (table I). Each Jurassic stage, from the Aalenian to the Tithonian, is represented and documented faunistically. It may be that in this sequence certain gaps exist and that some members are lacking because either the rocks which represent them have remained undiscovered, or some members were not represented at all in the sequence of the Bachowice Jurassic. It is possible that some of the Jurassic members, if they were developed in the form of soft clayey or marly rocks, had no chances of being preserved under the conditions of deposition which gave the layers of the Bachowice exotics. It is also possible that the deposition of the Jurassic members, from the Aalenian to the Tithonian, did not continue without interruptions. The erosion and reworking of the *Posidonomya* shales, fragments of which are present in higher members, indicate that such a possibility existed at least once during the sedimentation of the Jurassic deposits of Bachowice. On the other hand, the lithological and petrographic similarities that are

Table I

STRATIGRAPHY OF THE BACHOWICE JURASSIC

Stage		Zone	Rock
BERRIASIAN		*Thurmannia boisseri*	Grey siltstones (V)
TITHONIAN	η	*Berriasella transitoria*	Marls (T6) White subcrinoidal limestones (T4) White Calpionella limestones (T3)
	ζ	*Waagenia beckeri*	Yellow Calpionella limestones (T2) White sub-cristalline limestones (T1)
KIMMERIDGIAN	ε	*Sutneria subeumela*	Grey pelitic limestones (K3)
	δ	*Aulacostephanus pseudomutabilis* and *Aspidoceras acanthicum*	
	γ	*Streblites tenuilobatus* *Sutneria platynota* *Idoceras planula*	Green pelitic limestones (K2) Green-yellow pelitic limestones (K1)
OXFORDIAN	β	*Oppelia litocera* *Peltoceras bimammatum*	Yellow sub-crinoidal limestones (O4)
	α	*Aspidoceras hypselum* *Peltoceras transversarium* *Cardioceras cordatum*	Green sub-crinoidal limestones (O3) Blue sub-crinoidal limestones (O2) Pink sub-crinoidal limestones (O1)
CALLOVIAN	ζ	*Quenstedtoceras lamberti* *Peltoceras athleta* *Reineckeia anceps*	Red crinoidal limestones (Ca)
	ε	*Macrocephalites macrocephalum*	Variegated limestones (BtCa)
BATHONIAN		*Oppelia aspidoides* *Oppelia fusca*	Posidonomya marls (Bt)
BAJOCIAN	δ	*Parkinsonia parkinsoni* *Cosmoceras garanti* *Cadomites humphriesi* *Dorsetensia romani*	Black shales (B7) Yellow sandstones (B6) Trigonia-sandstones (B5) Dark sandstones (B4)
	γ	*Otoites sauzei* *Witchellia laeviuscula* *Sonninia sowerbyi*	White sandstones and bed with Avicula and Ostrea (B3) Bluish sandstones with Astarte (B2) Dark oolitic sandstones (B1)
AALENIAN	β	*Ludwigia concava* *Ludwigia murchisoni*	
	α	*Lioceras opalinum*	

observable between the various members, e. g., between the Callovian and Oxfordian rocks (red crinoidal limestones and pink subcrinoidal limestones), between the Oxfordian and Kimmeridgian rocks (yellow subcrinoidal limestones and yellow-green pelitic limestones), and, finally, between the Kimmeridgian and Tithonian beds (grey pelitic limestones and light-coloured subcrystalline limestones), indicate that the sedimentation had been continuous. It may be assumed, therefore, that with small exceptions the Jurassic series of Bachowice, beginning with the Aalenian, is complete.

The Bachowice rocks make possible a reconstruction of a Jurassic sequence that has been hitherto known neither from the Flysch Carpathians, nor from the inner Carpathians, nor from their foreland. The sequence is highly differentiated, lithologically and stratigraphically, and simultaneously quite rich in fossils, when we take into consideration that almost every lithologically distinguished member contains a determinable fauna which frequently is even very abundant.

The sediments of the Bachowice Jurassic were at first shallow-water and arenaceous ones. From table 2 and figs. 5 and 6 (in the Polish text), it results that either the beds were quite well sorted as to coarse grains (e. g., sandstones B3II) or fine ones (e. g., sandstones B1, B6I), this being explainable by the action of wave-motion, or else the sediments were poorly sorted (e. g., sandstones B4, B2), being probably deposited below the wave-base. The shoal-like character of the occurrence of Lamellibranchiata also seems to indicate the sublittoral character of the sediments. One may suppose, therefore, that during the Bajocian there was an alternating succession of barrier deposits and shallow-neritic ones, and that the sea attained no great depth. The sea-coast at this time must have been somewhere near, as testified by the frequently coarse-grained character of the deposits and the abundant organic detritus. The lack of deposits with graded bedding also points to shallow-water conditions of sedimentation.

In the Bathonian, the *Posidonomya* marls indicate that there was a considerable deepening of the sea, attaining a bathyal depth. Unknown are deposits that could be considered as a transition between the arenaceous Bajocian and the shaly-marly beds of the Bathonian. Indeed, perhaps here some member is lacking which on account of its lithological properties had no chances of being preserved in the aggregate of exotic rocks. If they were clays or soft marls, they could have been abraded during deposition. Perhaps some of the dark or black shales occurring in small fragments and containing no fauna, represent the sediment of this period. On the other hand, it is easy to imagine that the Bathonian-Callovian variegated limestones could have been deposited immediately after the *Posidonomya* marls. They probably denoted, in relation to the marls, a shallowing of the sea; the depth, at which they were deposited, could not have been great, as testified by the quite strong admixture of sand and silt in the limestones (table 7 in the Polish text) and, to a certain degree, by the character of their fauna (Gasteropoda). A shallowing of the sea was still more strongly marked during the deposition of the red crinoidal limestones that are, undoubtedly, an allochthonous deposit, reworked by wave-action and deposited, in any case, close to the wave-base. It was during this period, probably, that there followed a partial emergence of the existing area of sedimentation, and erosion of the older deposits; proof of this are the pebbles and fragments of *Posidonomya* marls occurring in the crinoidal limestones.

The shallow-water deposits from the later part of the Callovian and the beginning of the Oxfordian gave place to deposits of a deeper sea; as such one must consider the varicoloured series of the subcrinoidal limestones. The latter limestones are, as a rule, quite pure; they contain a poor benthonic fauna, while their ammonitic fauna is more abundant than in the Bathonian-Callovian limestones. The tendency to nodularity, noticeable in these limestones, may be proof that the deposits undergoing consolidation were still agitated by wave-action, but the fauna with a great predominance of *Phylloceras* and *Oppelidae* points to a deeper sea. The environment of sedimentation of these deposits can be designated as a deep-neritic one.

It must be accepted that there was a still more distinct deepening of the sea in the Kimmeridgian and, particularly, in the Lower Tithonian, during the deposition of the subcrystalline limestones which are a deposit of a deeper and open sea, as testified by their fauna composed, first of all, of *Phylloceras, Lytoceras* and *Haploceras*. The period of deposition of the *Calpionella* limestones begins, on the other hand, with a tendency to a shallowing of the sea, at first progressing very slowly and marked by the appearance of a large number of Brachiopoda and an increase in the quantity of quartz, and subsequently by the appearance of Crinoidea and large quartz grains in the white subcrinoidal limestones. The shallowing of the sea attains its culmination in the presumable Valanginian, and the calcareous deposits of the Jurassic change into silt deposits.

By arranging the Jurassic rocks of Bachowice in the order of their determined or probable age, and by comparing their content of calcium and terrigenous substances, there is observable a gradual increase in the content of calcium carbonate from the Callovian to the Kimmeridgian--Lower Tithonian, and subsequently a decrease of the above-mentioned content. It is presumable that this is a reflection of changes in depth and in distance from the shore.

Beginning with the *Posidonomya* marls, numerous individuals of *Phylloceras* appear in the fauna of the Bachowice Jurassic; they are later joined by *Lytoceras*. This proves that the sea of Bachowice, from the Bathonian at least, had a good connection with the southern sea. This connection is maintained throughout the period of deposition of the Jurassic rocks of Bachowice; especially in the Kimmeridgian and Tithonian, these rocks contain a fauna of a markedly Mediterranean type.

2. Comparison of the Bachowice Jurassic with that of other regions

The regional position of the Bachowice Jurassic demands, first of all, a comparison of its development with that of the Jurassic occurring within the Flysch zone (fig. 26). The Jurassic occurs at Kruhel, in klippes near Andrychów, in Moravia, and in several places in the Eastern and Roumanian Carpathians.

Apart from Bachowice, Kruhel Wielki near Przemyśl is the only place at which, in one point, there exists an accumulation of rocks from various Jurassic members, although even there the Jurassic series is not so complete as it is at Bachowice. Among the exotic blocks of Kruhel, Wójcik

(1914) distinguished the Bathonian, Callovian, (Lower) Oxfordian, Sequanian, and Tithonian.

Kruhel, the same as Bachowice, lies near the border of the Carpathians. However, as far as their relation to the Flysch is concerned, the blocks of Kruhel are situated in a different, more external Flysch unit, i. e., in the Skole nappe, while the Bachowice blocks are imbedded in deposits of the Sub-Silesian nappe which, in relation to the Skole nappe, is higher and more internal unit.

There is also a marked difference in the age of the Flysch member in which are imbedded the exotic blocks. At Bachowice the blocks are encountered in deposits of the Paleocene and Lower Eocene, in which they undoubtedly arrived in consequence of sedimentary processes, and not tectonic ones. At Kruhel the situation is less clear and seems to be more complicated. Indeed, in Wójcik's (1907) opinion, the exotic blocks are supposed to be imbedded in clays of the Oligocene (according to the microfauna described by the latter, one would rather say now: Upper Eocene), but in Rabowski's (1928) opinion the exotic rocks of Kruhel are associated with layers of the Upper Cretaceous and, together with the latter, have been pushed on top of, and pressed into, the „Oligocene" deposits. The quarries at Kruhel are now overgrown to such a degree that it is impossible to observe the conditions which exist there, but it seems to be certain that the Jurassic rocks are inserted, partly at least, in the Inoceramian beds, composed of conglomerates, sandstones, and marls containing *Globotruncana conica*. It appears that the rocky outcrops may be an eroded klippe, covered transgressively by the Upper Senonian, in a similar manner as the Jurassic klippes near Andrychów (Książkiewicz, 1951).

By comparing the lithological development of the various members of the Kruhel Jurassic with those of the Bachowice Jurassic, it can be ascertained that, in spite of an approximately similar age of the deposits, there is in fact between them not a single lithological member in common. According to the description published by Wójcik (1914), the following rocks are encountered in the Jurassic of Kruhel:

1. Light-grey, hard but brittle, highly fine-grained quartzitic sandstone. This rock has no counterpart in the calcareous sandstones of Bachowice, the latter being not only calcareous, but also mostly dark or yellow-rusty. The above-mentioned sandstones occur at Kruhel and Lubeń (near Rzeszów), and contain an abundant lamellibranchiate fauna preserved in the form of casts, thus resembling the conditions at Bachowice.

2. Yellowish arenaceous oolite, „here and there composed mostly or even almost exclusively of shell fragments and cemented by means of an oolitic marl". Rock of this type is absent at Bachowice; some sandstones do indeed contain ooids, but even the most oolitic yellow sandstone (B6), usually full of shell remains, displays great differences in relation to Wójcik's description.

3. Whitish or light-grey, bedded or nodular „marly limestone". Here and there it contains quite abundant remains of echinoderms (echinoids and Crinoidea), and it could be compared with the crinoidal and subcrinoidal limestones of Bachowice, but the latter are highly varicoloured and never white or grey.

4. Reef-limestone (Stramberg limestone). This rock, the most common one at Kruhel, does not occur at Bachowice at all.

The foregoing comparison was carried out on the basis of Wójcik's lithological descriptions which, as a matter of fact, are quite laconic. The author paid several visits to Kruhel for the purpose of obtaining some comparative material. In the present state of the old quarries, which are densely overgrown, the author did not succeed in finding an abundant material. The author rediscovered there neither the quartzitic sandstones, nor the oolites; on the other hand, apart from the Stramberg limestone, which is the principal rock of Kruhel and forms there an uncovered large klippe, and the calcareous conglomerates, also quite common, the author managed to find the following: 1) yellowish limestone with Crinoidea, perhaps corresponding to Wójcik's rock No. 3; 2) pink arenaceous--oolitic rocks with Crinoidea, which do not correspond to Wójcik's descriptions; 3) white detrital limestones, very similar to limestones occurring in the so-called „limestones of Plattenkalk type" from the Middle and Upper Oxfordian in the Cracow region. In any case, at Kruhel the author encountered not a single rock resembling the Bachowice rocks.

By comparing the Jurassic fauna of Bachowice with that of Kruhel in the various members, one can ascertain considerable differences.

The fauna of the quartzitic sandstone from Kruhel and Luben was determined by Wójcik as belonging to the Bathonian; the calcareous sandstones of Bachowice belong to the Aalenian and Bajocian. The faunistic differences are considerable; only four forms occur in common. As a matter of fact, the fauna of the Bachowice sandstones is much more abundant; it is composed of 42 forms determined as to species, while the Kruhel Bathonian consists of 19 species. The Bachowice sandstones have only one species in common with the Kruhel oolite designated by Wójcik as the Bathonian and, partly, Callovian. Comparing the fauna of the *Posidonomya* marls and variegated limestones of Bachowice, determined as belonging to the Bathonian and Callovian, with the Bathonian and Callovian of Kruhel, not a single form occurring in common is discovered. The lithofacial difference between these deposits is so great that a faunistic similarity cannot be expected to exist.

Even when comparing rocks of the Oxfordian, of one age and lithofacially similar, no great resemblances are discovered. A more accurate comparison is difficult on account of the quantitative incommensurability of the fauna at both places: the Kruhel Oxfordian supplied 81 forms, and the Bachowice Oxfordian, only 20 species. However, if we exclude Brachiopoda, sponges, etc., and take into consideration only ammonites, the disproportion becomes greatly reduced: against 20 ammonites from Bachowice, there are 37 from Kruhel, but only 5 species occur in common. Further features that distinguish the Bachowice Oxfordian from the Kruhel Oxfordian are the complete absence of Lamellibranchiata and Gastropoda, and the almost complete absence of Brachiopoda.

Comparing the fauna of the highest members of the Jurassic of Bachowice and Kruhel, one can discover, in spite of their equal age, very considerable differences. The fauna of the Tithonian Stramberg limestone of Kruhel is much richer than the pelagic fauna of Bachowice. Wójcik determined 221 species and varieties from Kruhel; the determinable fauna of the Tithonian limestones of Bachowice consists of only 25 species. At Kruhel, among 221 forms there are but 6 ammonites; at Bachowice, among 25 species there are 13 ammonites. This fact alone testifies to the difference in the character of the fauna. This difference stands out still better when one considers that in the Tithonian the Kruhel fauna is composed of 72 species of Gastropoda and 71 species of Lamellibranchiata, while in the Bachowice fauna the author discovered but a single species of Lamellibranchiata and only a few casts of Gastropoda. In the Tithonian of Kruhel there are 29 Brachiopoda, in that of Bachowice, 12; however, only one species occurs in common.

Such considerable differences are the result, of course, of diverse environments: at Kruhel we observe a typical shallow-water fauna, living alongside reefs, with a large quantity of thick-shelled Lamellibranchiata (*Diceras luci* D e f r.) and Gastropoda of the genera *Nerinea* and *Itieria;* Cephalopoda, particularly ammonites, form its insignificant admixture; in the Tithonian of Bachowice we have a fauna of the open sea, with ammonites and *Calpionella.*

It must be stated, therefore, that considerable lithological, facial, and faunistic differences exist between the Jurassic of Bachowice and that of Kruhel. In all, the deposits of Kruhel are much shallower than those of Bachowice.

The nearest occurrence of the Jurassic, in relation to Bachowice, are the klippes in the vicinity of Andrychów. In these klippes only the Tithonian occurs, with which we are acquainted chiefly through Z e j s z n e r's works. Facially, lithologically and, to a large degree, faunistically, it corresponds to the Tithonian of Stramberg, on the one hand, and to that of Kruhel, on the other. As regards the Tithonian of the Andrychów klippes, one may repeat, therefore, what has been said concerning the relation of the Tithonian of Bachowice to that of Kruhel; it is a deposit that differs very strongly from the Tithonian of Bachowice. It is probable, moreover, that the Tithonian of the Andrychów klippes was deposited directly on a crystalline base, while the Bachowice Tithonian forms the termination of a series of Jurassic deposits which begin in the Bajocian at least.

A further locality which must be taken into consideration is a Jurassic klippe at Leśna near Żywiec, discovered by S. S o k o ł o w s k i and marked as „Dogger-Malm" on the map (1953) which he prepared in a scale of 1 : 300 000; this klippe, unfortunately, has not been hitherto described in literature, nor has it been elaborated faunistically. The klippe is built of yellowish arenaceous crinoidal limestones, containing numerous Brachiopoda; it seems on their basis that the latter limestones might represent the upper part of the Dogger and perhaps, at most, the Lower Oxfordian. If so, they might represent an equivalent of the red crinoidal limestones of Bachowice, most probably deposited much nearer the shore. In any case, the deposit is lithologically different in comparison with the appropriate rocks at Bachowice.

The klippe at Leśna occupies a different position with regard to the Flysch than does the Jurassic of Bachowice. It is situated between the upper Cieszyn shales at the bottom, and the lower Cieszyn shales and Cieszyn limestones at the top; it is, therefore, thrust-sheet of the Silesian nappe, the same as the Andrychów klippes. Consequently, both the klippe at Leśna and the Andrychów klippes must be associated tectonically with the more internal region of the Carpathians.

To the same tectonic region belongs also the klippe at Stramberg, situated, the same as the Andrychów klippes, near the margin of the Silesian nappe. In the Bachowice Tithonian there is no equivalent for the well-known Stramberg Tithonian, divided into several facies (coral-, spongite-, coral-*Diceras*, and echinoderm facies).

The Tithonian is also developed in Moravia in the klippes of the Pavlovské Kopce (Pollauer Berge), and in Lower Austria, in the Nikolsburg-Ernstbrunnen klippes. Both chains of klippes form one zone. The Tithonian is developed in a slightly different manner than at Stramberg. M. F. Glaessner (1931) distinguished here an older section and a higher-lying one; the former, designated as the Klentnitzer beds, is developed as grey marly limestones with hornstones and oolites, and as algal limestones; the higher-lying section is composed of white limestones, also differing from the Stramberg limestones, and they are designated as „Ernstbrunner Kalk". The fauna consists of numerous Lamellibranchiata, Brachiopoda, and corals; it also contains ammonites, chiefly *Phylloceras*, *Lytoceras* and *Perisphinctes*, in a large degree common with the Stramberg fauna (Vetters, 1905). Apart from the Tithonian elements, Upper--Kimmeridgian ones are also said to be included in the fauna, according to L. E. Spath (vide Glaessner, 1931, p. 3).

Basing his opinion on the descriptions of numerous writers, the author must state that it is difficult to discover any resemblances whatever between the Tithonian of Bachowice and that of the klippes in Lower Austria or of the Pavlovské Kopce.

The klippes of the Pavlovské Kopce and of Lower Austria occur in the so-called Sub-Beskidy zone composed of beds that are an equivalent of the Krosno beds (Auspitzer Sch., Ždanice beds) and Menilite shales. The tectonical position of these beds is not clear, and it is difficult to say whether they can be considered as an equivalent of the Krosno beds of the Sub-Silesian series, or of some higher-lying unit. In any case, they lie in the foreland of the Magura nappe.

Associated with the latter nappe in Moravia are the numerous occurrences of the Jurassic which together present a quite complete sequence of the Jurassic. These are the blocks and klippes occurring in the vicinity of Koryczany.

The author, unfortunately, was unable to become personally acquainted with the above-mentioned Jurassic deposits that are so important for comparing with the ones at Bachowice. However, thanks to the great kindness of Dr L. Čepek of the Vladny Vybor pro Geologie and Dr J. Kalašek of the Brno Section of the Geological Institute of Czechoslovakia, the author obtained a collection containing almost all of the Jurassic rocks of the Moravian Carpathians.

The oldest member of the Jurassic in this zone is the Middle Lias (Rzehak, 1903, 1904; Oppenheimer, 1906) at Lukoweczek, developed as dark limestones with Crinoidea, containing *Amaltheus costatus* and *A. margaritatus*. The fauna especially the Brachiopoda, corresponds to the Lias δ of Franconia. The upper member is composed of dark, calcareous, arenaceous shales and shaly sandstones occurring near Koryczany and containing *Perisphinctes* cf. *ybbsensis* J ü s s e n, *Oppelia* from the *fusca* group, and *Posidonomya alpina*. This occurrence was discovered by O p p e n h e i m e r (1906). Three species of *Phylloceras* occurring in this deposit point to the Mediterranean character of the fauna. The *Posidonomya* marls of Bąchowice, in spite of lithological differences, could be an equivalent of the above-mentioned deposits with regard to age and, to a certain degree, facially.

The next member of the Jurassic in the Moravian Carpathians occurs at Czetechowice, and it has been described by many authors, such as N e u m a y r (1871), U h l i g (1903), and especially N e u m a n n (1907). In the Czetechowice klippe there are light-grey, subcrystalline, nodular limestones, covered with red nodular limestones (with numerous young individuals of *Phylloceras*); slightly younger than the latter, are the light--coloured, red-spotted or yellow-spotted limestones that in N e u m a n n's times had been already completely exploited and were known to him only from collections. The Czetechowice klippe supplied the richest fauna of the Mediterranean Lower Oxfordian. The lower-lying limestones contain a fauna of the *cordatum* and *perarmatum* zone with a large quantity of *Perisphinctes*, *Peltoceras*, and *Phylloceras*; the *transversarium* zone is probably also represented here, while in the higher members there are forms which, according to N e u m a n n, point to the *bimammatum* zone, or even to the lowest Kimmeridgian.

Lithologically, the Czetechowice limestones do not resemble the rocks of the Bachowice Oxfordian. A distant resemblance is noticeable only in the red limestones which could be compared with the pink subcrinoidal limestones of Bachowice. On the other hand, certain faunistic analogies do exist. In common with the Czetechowice fauna are almost all the Bachowice species of *Phylloceras* and *Perisphinctes* (with the exception of *Per. bernensis* which is absent at Czetechowice), while *Taramelliceras* is lacking at Czetechowice; to the contrary, at Bachowice there is an almost complete lack of *Cardioceras*. Such differences might, to a large degree, be the result of the fact that at Czetechowice the *cordatum* zone is represented above all, while at Bachowice, it is the *transversarium* zone. Of the 18 ammonites of the Bachowice Oxfordian, 10 of them are represented in the Czetechowice fauna. W ó j c i k (1914), comparing the Oxfordian fauna of Kruhel with that of Czetechowice, presumed that there was a close association between them; the Bachowice Oxfordian, displaying certain associations with Czetechowice on the one hand and with Kruhel on the other, can be considered as an intermediate member between these far-distant points; perhaps the fauna of Czetechowice communicated with that of Kruhel by way of Bachowice.

The youngest members of the Jurassic in the Moravian Carpathians are known from Holy Kopec where A n d r u s o v (1932) discovered the existence of light-grey limestones with *Calpionella alpina*, and from Kurowice, long known for its white litographic limestones with Tithonian species of *Aptychus* (A n d r u s o v, 1933). To the Tithonian also belongs the light-yellow limestone with *Lytoceras sutile* O p p. from Strażowice (O p p e n h e i m e r, 1916), as well as the *Calpionella* limestones from Wigantice. Lithological and facial resemblances exist between the *Calpio-*

nella limestones of Bachowice and those of Holy Kopec, while rocks of the Kurowice type are unknown at Bachowice.

Summing up the comparisons between the Jurassic of Koryczany and that of Bachowice, it can be stated that certain analogies do exist, although it is absolutely impossible to speak of a complete similarity between the two localities. Apart from the *Calpionella* limestones, no rock from Bachowice has a similar equivalent in the members of the Koryczany Jurassic. The existing analogies in the development of the Bathonian, Oxfordian and Tithonian are associated with the fact that the Jurassic of Koryczany and Bachowice was deposited in a deeper sea than the Jurassic of Kruhel, of the Silesian klippes (Stramberg, Andrychów, Leśna), or of the klippes of the Pavlovské Kopce and Lower Austria.

The Tithonian of Kurowice passes upward into marly-shaly rocks with intercalations of limestones containing Neocomian *Aptychi*. If the supposition were correct that the Bachowice Tithonian was overlain by Neocomian deposits, one would have to accept an additional analogy with the Koryczany zone. It must be also pointed out here that in the latter zone Oppenheimer (1916) discovered also a higher member of the Cretaceous in the non-Flysch facies in the form of dark limestones with *Parahoplites bigoureti*, occurring in the conglomerates from Strażowice.

Probably to the same zone as the Jurassic occurring near Koryczany, belong the rare outcrops of the Jurassic that are associated with the Ultrahelvetian Flysch of the Eastern Alps, which forms a prolongation of the Magura Flysch. These are red clayey limestones with *Peltoceras transversarium* (Qu.) and *Perisphinctes polygyratus* Rein. from Gross-Weil (Bavaria), considered by Trauth (1948) to be a thrust-sheet of the Ultrahelvetian Flysch. To the same zone belong the outcrops of limestones with *Aptychus* in the vicinity of the lake Schlier (Kimmeridgian-Tithonian), and also the Upper-Jurassic red limestones injected with diabases, occurring as exotics in the Lower Eocene of southern Bavaria, as well as the small klippes of Stollberg (Wienerwald), composed of limestones and marls (red, green, and grey ones), with *Aptychi* pointing to the Kimmeridgian-Tithonian-Neocomian. With no personal acquaintance with the lithological type of the above-mentioned deposits, it is difficult to make a definite statement concerning any analogies with the Bachowice rocks, but the descriptions in literature (compiled by Trauth, 1948) give no grounds for suspecting that such analogies could be far-reaching.

Farther westward, the Jurassic in the Bregenzer Wald, belonging to the Helvetian zone of the Eastern Alps, ought to be taken into consideration when searching for analogies for the Bachowice Jurassic in Jurassic outcrops associated with the Alpine-Carpathian Flysch belt. This is the northernmost occurrence of the Jurassic in the Eastern Alps, and it is known from the works published by Mylius (1911). The oldest member of this Jurassic is composed of marly shales (Callovian), covered with calcareous breccias of the Lower and Middle Oxfordian with a dwarf ammonitic fauna (*Perisphinctes bernensis* Lor., *Oppelia heimi* Lor.). The main mass of the Jurassic series of the Bregenzer Wald consists of a thick--bedded dark-grey limestone („Aue Kalk") which in its highest part contains an Upper-Tithonian fauna with *Perisphinctes transitorius* Opp., *Pygope diphya* (Col.), *Calpionella alpina*, etc. The presence of *Calpionella*, with a simultaneously small quantity of Brachiopoda, resembles rather the Bachowice type of the Tithonian and not the Stramberg type, although lithologically the „Aue Kalk", according to its descriptions, does not resemble the Bachowice Tithonian limestones.

It seems, in any case, that the Helvetian Jurassic of the Bregenzer Wald can be considered as deposited in a deeper zone in comparison with the klippes of Lower Austria, and consequently as comparable with the Jurassic of Bachowice.

At the top, the Tithonian „Aue Kalk" is overlain by dark or yellowish shaly marls representing the Lower Neocomian. This, too, would be a certain conformity with Bachowice and Kurowice.

In the Flysch zone of the Eastern Carpathians there are some rare Jurassic outcrops; of these, the klippes at Krasna (V e t t e r s, 1905) and Iwanówka, lying near the edge of the Carpathians, contain the Tithonian (and perhaps some lower members) in the Stramberg facies, while the klippes of the Czarnohora Mountains represent a separate type of deposits. These klippes, discovered one after another by H a u e r (1859), Z a p a ł o w i c z (1886), Ś w i d e r s k i (1937), and S u j k o w s k i (1938), have been very little investigated and neither their age, nor their tectonic position have been explained in detail, but their occurrence within the Flysch proves that Jurassic deposits existed in the substratum of the Flysch basin in the Eastern Carpathians. From the description published by Z a p a ł o w i c z (whose fossils were determined by N e u m a y r) and from the data supplied by later authors one can obtain a general notion regarding the composition of the above-mentioned klippes. It is chiefly the Tithonian that occurs there, developed as white limestones (the western klippe Szesa) or white and red ones with *Rhynchonella capillata* (the eastern klippe Szesa), or chocolate-brown, partly white and partly red limestones with *Phylloceras* cf. *silesiacum* O p p. = (*calypso* d'O r b.) from the klippe Pietros, and the light-coloured limestone klippes Bałtacuł with *Aspidoceras* sp. (Tithonian). From the area between Pietros and Howerla, A n d r u s o v (1936) describes light-grey limestones with *Calpionella alpina*, but these limestones also contain oolites, and some of the limestones, according to A n d r u s o v, are to be similar to the Stramberg limestones. Also represented here is a red nodular limestone with *Aspidoceras, Lytoceras* and *Aptychus* (the klippe Kierniczny in the valley of the Czarny Czeremosz), compared by Z a p a ł o w i c z with the Czorsztyn limestone, and a light-grey and dark-red limestone of the klippe Szczawnik with an abundance of *Phylloceras*, determined by Ś w i d e r s k i (1936) and pointing to the Callovian or to the neighbouring stages of the Jurassic.

From the descriptions of these rocks and from the lists of fossils, one can draw the conclusions that represented here is a Jurassic series including several stages and that the facies of this Jurassic has a bathyal character, perhaps with a certain shallowing of the sea in the Tithonian. This deep-water character resembles the Jurassic of Bachowice and that of Koryczany. A characteristic feature of these outcrops is the association of Jurassic (and Triassic) rocks with volcanic ones, thus resembling the conditions existing at Bachowice. The western klippe Szesa, discovered by H a u e r, is said to be composed of melaphyre („diorite"), imbedded in which are calcareous rocks; at several other places the melaphyre occurs together with Jurassic rocks (the eastern klippe Szesa and the klippes: Pietros, Batłacuł, Regieski; cf. also the profile running through the klippes in Sujkowski's work, 1938, fig. 10, p. 73). The klippe of Szczawnik consists of tuffs, inserted in which are Callovian ammonites.

The age of the volcanic rocks of the Czarnohora klippes has not been established, but it is certain that the melaphyres and tuffs are younger than the Tithonian.

The Jurassic of the Pieniny Mountains manifests but a distant similarity to the Bachowice series. Of the lithological types, common to both is only the red crinoidal limestone which, however, is of Bathonian age in the Pieniny Mountains, while at Bachowice it is Upper-Callovian. The reddish nodular limestones of the Bachowice Oxfordian display but a distant resemblance to the Czorsztyn limestones. The fauna, on the other hand, has many elements in common; this pertains, particularly, to the Oxfordian, because at Bachowice there are 7 ammonites common to the fauna of the *transversarium* zone of the Pieniny, Kimmeridgian, and also to the Tithonian; nearly all the ammonites and Brachiopoda of the Bachowice Tithonian occur in the Pieniny Tithonian. Faunistically, the Bachowice Tithonian bears a stronger resemblance to the Pieniny Tithonian than to that of Stramberg or Kruhel. This is proof of similar facial conditions and good communication between the Bachowice sea and the Pieniny sea.

Finally, to terminate the comparisons between the Bachowice Jurassic and that of its nearest neighbourhood, one must also consider the Cracow Jurassic which lies the closest, at a distance of only 5 kilometres. In spite of this close neighbourhood, it must be stated that in the Bachowice Jurassic not a single lithological element is encountered as to which one could at least say that it is a reflection of some type of the Cracow Jurassic. This fact induces one to conclude that the Bachowice Jurassic could not have been deposited near its present place of occurrence. The sea-basin in which it was deposited must have been situated far to the south and it could not have been in direct communication with the basin of the Cracow Jurassic.

3. Paleogeography of the Jurassic within the Flysch Carpathians

A paleogeographic reconstruction of the Jurassic which underlies the Flysch is extremely difficult on account of the fragmentariness of the Jurassic exposures in the Flysch belt. The Jurassic in this belt is never *in situ*, but it occurs as klippes or blocks of uncertain origin. Either tectonically or sedimentarily, and most frequently in both manners, the klippes and blocks were translocated to their present position. In some cases, volcanic forces also played a certain part in localizing the Jurassic rocks. The true distribution of the Jurassic deposits can be established only after taking into consideration the consequences of the compression of the Carpathian Mountains. The extent of the dislocations caused by this compression is known to us only in a general outline. Consequently, all attempts of reconstruction are doomed in advance to be uncertain and hypothetical.

Such attempts have been made by Wójcik (1914), Nowak (1927), and Andrusov (1930). The discovery of the almost complete series of the Middle and Upper Jurassic at Bachowice, makes possible a modification and supplementing of the latter attempts.

On the basis of the data hitherto available, the Jurassic occurring in the Flysch Carpathians can be divided into the following groups (fig. 26 and table II):

I. Słoboda zone. The most external Jurassic zone associated with the most external Carpathian unit, is the Jurassic that is marked by the presence of limestone pebbles in the Słoboda conglomerates (Lower Miocene) of the Eastern Carpathians. These pebbles are derived chiefly from the Stramberg limestone; Czarnocki (1934), however, supposes that also present here is the Sequanian developed as white and yellowish dolomitic limestones, considered previously to be Triassic and containing corals and *Trigoniae*. Czarnocki stresses that the above-mentioned limestones contain fragments and pebbles of green phyllites, and supposes that the transgression of the Jurassic took place directly on the green rocks. A similar conclusion is arrived at when one considers the conditions existing in the klippe at Krasna (Bukowina); according to Vetters (1905), in the mantle of the Jurassic klippe one encounters conglomerates with green rocks. On the basis of the composition of the Słoboda conglomerates, it can be assumed that a ridge existed here, built of green phyllites, probably of Pre-Cambrian age, covered with the remains of the older Paleozoic (the Silurian discovered by Czarnocki) and also perhaps of the younger Paleozoic, analogically to the structure of the Dobrodgea massif which, according to Zuber's old conception, is continued in the above-mentioned ridge. This ridge was probably inundated partly by the sea during the Sequanian-Tithonian. To the north of it there was a narrow sea-bay extending as far as Niżniów and the upper Bug River, with a shallow-water facies, or a lagoonish one (J. Samsonowicz 1952), of the Kimmeridgian-Bononian. The ridge of green rocks, separating the two seas, was prolonged into the Paleozoic massif of northern Dobrodgea, at present almost completely deprived of the Jurassic with the exception of fragments wedged in near the Pecineaga-Camena dislocation which separates the zone of green rocks from the folds of the higher Paleozoic in northern Dobrodgea. In contrast with the Jurassic of central Dobrodgea, the above-mentioned Jurassic is composed only of limestones of the Upper Malm (Simionescu 1912), i. e., in a similar manner as in the Słoboda ridge.

II. Kruhel zone. This zone has been distinguished on the basis of the composition of the exotics from Kruhel Wielki, Węgierka, and the vicinity of Rzeszów. In this zone we encounter the Bathonian, Callovian, Oxfordian (with the Sequanian), and Tithonian. The latter is developed in the facies of the Stramberg limestone; perhaps the Kimmeridgian also, in part at least, is developed in this facies, as Wójcik (1914, p. 237) supposes. Transgression in this zone was begun in the Bathonian; the basement consisted of deposits of the young Paleozoic (Devonian, Carboniferous), covered by the Triassic. The crystalline foundation of this zone is unknown; it could have consisted of deeply submerged green rocks.

The continuation of this zone in the Eastern Carpathians is unknown, but in all probability the Jurassic of central Dobrodgea must belong to this

Tabela II

THE JURASSIC OF THE FLYSCH CARPATHIANS

	Słoboda zone	Kruhel zone	Dębica zona	Bachowice zone	Silesian Klippes	Pavłovske (Pollauer) Klippes	Czetechovice zone
TITHONIAN	Limestones of the Stramberg type	Reef limestones of the Stramberg type	Limestones of the Stramberg type	Marls White subcrinoidal limestones Calpionella limestones White sub-crystalline limestones	Stramberg limestones Limestones with silex	Ernstbrunner Kalk Klentnitzer Schichten	Marly shales Kurovice limestones Calpionella limestones (Holy Kopec)
KIMMERIDGIAN				Green limestones			
OXFORDIAN		Marly limestones		Sub-crinoidal limestones			Nodular limestones of Cetechovice
CALLOVIAN		Oolites		Red crinoidal limestones	Sandy crinoidal limestones		Grey crinoidal limestones of Holy Kopec
BATHONIAN		Quartzitic sandstones		Variegated limestones Posidonomya marls Black shales Calcareous sandstones			Posidonomya shales
BAJOCIAN							
AALENIAN							
LIAS							Black limestones

zone. The Jurassic of central Dobrodgea is composed of the Upper Callovian, Oxfordian (with the Sequanian), Kimmeridgian, and Tithonian. The lower stages have a middle-European character (S i m i o n e s c u 1909, 1927), while the Kimmeridgian and Tithonian have a Mediterranean and reef-character, i. e., similarly as at Kruhel. In relation to Kruhel, transgression in the Dobrodgea area came later: in the Upper Callovian. If we take into consideration the fact that outside the zone of the Słoboda-Dobrodgea green rocks the Jurassic is altogether lacking or it does not occur until the Kimmeridgian or Bononian of southern Podolia, it becomes clear that the Jurassic transgression, which brought a middle-European fauna to Dobrodgea, could have come to Dobrodgea only by way of the Carpathians, i. e., by way of the Kruhel zone which, indeed, has the lower members of its Jurassic developed in a middle-European type.

III. D ę b i c a z o n e. To the south of Tarnów, Dębica, and Ropczyce, there is a zone in which in conglomerates of the Upper Cretaceous and Paleocene we encounter crystalline rocks, phyllites, Carboniferous limestones, bituminous coals, and very numerous limestones of the Stramberg type. The age of these limestones has not been accurately established and it is possible that they might also represent Jurassic members that are lower than the Tithonian, but in any case it seems that here the Jurassic series is less complete than in the Luboń-Kruhel zone, and perhaps here it was chiefly the Tithonian which transgressed directly on an older substratum.

IV. B a c h o w i c e z o n e. Proceeding farther westward, near the border of the Carpathians we encounter the Jurassic of Bachowice. Here the series is considerably more complete than in the previous zones; the Jurassic begins with the Aalenian, the Bajocian is arenaceous, from the Bathonian the deposits are mostly of a bathyal or deep-neritic character, the Tithonian is pelagic. The Bachowice series could not have been a local development of the Jurassic; its completeness and deep-water character testify that the distribution of such deposits must have been extensive. Up to the present moment, however, we know of no deposits that could be identified with the development of the Bachowice Jurassic. Following the course of the Sub-Silesian zone, containing the remains of the Bachowice Jurassic, nowhere within the Carpathians do we encounter any deposits of the Jurassic. Not until we come to the Czarnohora zone, do we discover remains of the Jurassic; here the Callovian is bathyal, while the Tithonian is rather of a deep-neritic character (*Calpionellae)*, and so the type of the deposits resembles Bachowice. Still farther to the south-east, after a long interval, the Jurassic occurs in the zone of conglomerates of the Middle Cretaceous in the vicinity of Teleajen (headwaters of the rivers Jalomita and Buzau), where F i l i p e s c u (1937) discovered klippes of *Calpionella* limestones (with *Calpionella alpina, elliptica*, and *carpathica)*. F i l i p e s c u considers these limestones to be the remains of a cordillera which supplied material to the Albian conglomerates of Zaganul. The tectonic position of these beds indicates their internal situation in the structure of the Carpathians, the fact being that the Tithonian klippes of Teleajen belong to the „nappe interne" which is an overthrust on the external nappe containing variegated marls of the Senonian. These marls, in the Teleajen area, lie between the Eocene-Oligocene Flysch limiting them from the east and the

Cretaceous of the internal nappe which is overthrust on the variegated marls. If these marls, as is highly probable, correspond to the Senonian variegated marls of the Polish Carpathians, we must conclude that the *Calpionella* Tithonian of the Zaganul conglomerates is associated with a unit which occupies a position comparable with the Silesian nappes.

One must stress here a very characteristic fact, also discovered by Filipescu (1938) in the basin of the upper Buzau, i. e., not far from Teleajen. In the foreland of the Carpathian nappes, the internal one of which includes the klippes of the *Calpionella* Tithonian, one encounters salt diapires; some diapires, in their mantle, contain blocks of exotic rocks, such as granites, quartzites, green shales, and chiefly grey-bluish limestones. In these limestones, occurring in the form of enormous blocks, at Badila, apart from numerous corals, Brachiopoda, algae, and *Nerineae*, Filipescu discovered also *Perisphinctes* and *Calpionella alpina*. The latter, establishing the Tithonian age of the above-mentioned limestones, occurs in this reef assemblage exceptionally and is proof of influences exerted by the neighbouring *Calpionella* region. On the basis of these two occurrences of the Jurassic in Muntenia, it can be assumed that in a section carried out along the Braszów-Buzau line in the Carpathian geosyncline, in the Tithonian there existed in the east a zone of crystalline rocks on which was deposited the reef Tithonian (Badila) belonging to Słoboda zone; much farther to the west was the zone of pelagic Tithonian that is observable at present in the Teleajen region. Between the two, there must have existed the Jurassic Kruhel zone, connecting central Dobrodgea with the Jurassic sea of Poland by way of Kruhel. The latter zone must be concealed deep beneath the external nappes of the Roumanian Flysch. The zone of Teleajen with the pelagic Tithonian lies to the west of Kruhel zone, the same as Bachowice lie more internally in relation to zone Słoboda-Dębica. It may be supposed, therefore, that the *Calpionella* limestones of Bachowice and Teleajen belonged to the same pelagic zone of the Tithonian, underlain according to Preda (1941) by Oxfordian radiolarites and Middle Jurassic sandstones.

V. Zone of the Silesian klippes. United under this name are the occurrences of the Jurassic that are associated more or less directly with the Silesian series of the Western Carpathians. Included here, first of all, are the klippes in the vicinity of Andrychów, which lie, as a matter of fact, just below the Silesian nappe, but are covered with the non-Silesian Upper Cretaceous. The klippe of Stramberg has a quite similar position, being overthrust on the upper Cieszyn shales and, together with the latter, on the „subbeskidisches Alttertiär" (Leicher 1931) which probably belongs to the Sub-Silesian nappe. Finally, the third Jurassic klippe that ought to be included here, is the klippe at Leśna (Sokołowski 1954), wedged into the Cieszyn series of the Silesian nappe and forming, together with the latter, an overthrust on the Sub-Silesian nappe of the Żywiec tectonic window. The stratigraphic inventory of the above-mentioned klippes does not present a complete series (Upper Dogger, Tithonian), and most probably some of the members are lacking. The oldest member of this zone represents the Upper Dogger, but probably the Jurassic did not begin everywhere so low. In the Andrychów klippes the Tithonian reef-limestone occurs in association with crystalline rocks, contains blocks of crystalline rocks, and it seems certain that this limestone was deposited directly on a crystalline basement. It is presumable, therefore, that the klippes of Andrychów and Stramberg ought to be considered as a prolongation of the Słoboda zone towards the west, and that they have their origin in the northern margin of the Jurassic geosyncline of the Carpathians, where the Tithonian was developed in the reef facies. Such was the opinion upheld by A n d r u s o v (1931) in his tentative paleogeography of the Carpathian Jurassic. The Bachowice Jurassic, however, occurs in a more northern tectonic unit and it must have its origin in a zone lying to the north of the belt of the Andrychów klippes. The Jurassic of these klippes and the Stramberg Jurassic were deposited to the south of the sedimentation zone of Bachowice. Such an opinion is confirmed by the distribution of exotics in the Flysch series. In the Silesian nappe, from the Skawa eastward, in the Istebna beds of the Silesian nappe one encounters numerous pebbles of Stramberg limestones, occurring in association with pebbles of crystalline rocks. The Lower Cretaceous of the Sub-Silesian nappe also contains many blocks of Stramberg limestones in thrust-scales lying to the south of the Sub-Silesian thrust scale with the Bachowice Jurassic. The Stramberg exotics in the Silesian series can be traced far to the east, between the Skawa and the San. Farther eastward, almost all the Cretaceous members contain pebbles of a Jurassic of the Stramberg type; conglomerates of the Grodziszcze beds (Hauterivian-Barremian), of the lower Lgota sandstones (Aptian) and of the lower Godula sandstones (Albian), contain in many places, frequently in great numbers, pebbles of the Stramberg limestones. Therefore, in the neighbourhood of the basin in which were being deposited the Cretaceous beds of the future Silesian nappe, in progress was the erosion of a massif built of crystalline rocks covered directly with reef-limestones of the Tithonian; members older than the Tithonian were either non-existent, or else they played an insignificant part. Such relations resemble Dębica zone, but the latter lay to the north of the Bachowice zone, with a more complete and pelagic Jurassic; this zone was bordered from the south by the zone of Silesian klippes.

The association of this „internal" Stramberg zone, opposed to the „external" Stramberg zone, with the Silesian basin is also confirmed by the fact that the lower Cieszyn shales contain small reefs of the Stramberg type (dark limestones with corals) which are still a reflection of the slowly declining reef-sedimentation of the Tithonian. A considerable part of the internal region of the Stramberg reefs was subjected after the Tithonian to submersion and to transformation into the sedimentation basin of the Silesian series.

It is a highly characteristic fact that the Istebna beds which to the east of the Skawa contain many Stramberg exotics (B u r t a n 1933, K s i ą ż k i e w i c z 1951), contain none in the Beskid Mały and Beskid Śląski, as already pointed out by W. S z a j n o c h a (1922). The external parts of the Magura nappe in the Western Carpatians, in spite of an abundant exotic material, also contain no Stramberg limestones. The latter are not encountered in conglomerates until we reach the internal part of the Magura zone (on the Cracow meridian: on the Jordanów-Osielec-Stryszawa line). This suggests, therefore, that in the Western Carpathians there existed an area which was not covered transgressively by the Jurassic. This area was situated to the south of zone V and it could have formed a quite extensive island, bordered by reefs of the Stramberg Tithonian from the north and from the south (zone Va, marked by the occurrence of pebbles of the Stramberg limestones in the internal Magura zone). This island can be designated as the Silesian island. It is a zone with no Jurassic cover (Vb). It must be pointed out that Nowak (1927) also, in his paleogeographic reconstruction of the „Malm", accepted the view that a large part of the Western Carpathians was the dryland. It is difficult to say at present, how far eastward extended the zone without the Jurassic. Much farther to the east, one could accept its counterpart in the Marmaros massif. The latter massif was perhaps during certain periods even completely submerged by the Jurassic sea, but in the Tithonian it was partly emerged, forming a portion of the Transilvanian mainland (Macovei-Atanasiu 1931) or a zone of shoals (Vc) where reef-limestones resembling the Stramberg limestones could have been developed in places (Andrusov 1936, p. 97).

VI. Zone of the Pavlovské Kopce, and the klippes of Lower Austria. In this zone we encounter the Tithonian and perhaps also the Kimmeridgian developed in the form of the Klentnitzer beds and limestones designated either as „Ernstbrunner Kalk", or as Stramberg limestone; the presence of granitic blocks near the klippes (Waschberg) seems to prove that the Tithonian (perhaps the Kimmeridgian) transgressed in this zone directly on a crystalline substratum. The tectonic position of the above-mentioned klippes is not altogether clear; however, especially after Glaessner's work (1931), it must be assumed that the klippes are not autochthonous but closely associated with the Flysch and translocated together with the latter. This Flysch may correspond to the Sub-Silesian Flysch, but in any case it is more external than the Magura Flysch. Having accepted such a view, one must assume that the above-mentioned klippes are not a prologation of the Stramberg klippe, but that they belong to a more external sedimentation zone of the Jurassic. This would perhaps explain the differences in the development of the Tithonian of the klippes in comparison with the Stramberg Tithonian; these differences were recently stressed by Trauth (1948) who simultaneously emphasized that they belong to diverse tectonic units. Considering that the Tithonian of the klippes belongs to the „external" Stramberg belt, and that the Tithonian of Stramberg belongs to the internal belt, it must be accepted that the zone of klippes in Lower Austria and in the Pavlovské Kopce corresponds by its position to the Słoboda zone.

In both zones the highest members of the Jurassic transgressed directly on a crystalline basement.

VII. Czetechowice zone. The klippes near Koryczany represent a quite complete series of the Jurassic, composed of the Middle Lias, Bathonian, Oxfordian (and perhaps the Lower Kimmeridgian), and Tithonian. The Bathonian, Oxfordian, and Tithonian are of a bathyal or deep-neritic character. All these occurrences are associated with the Magura nappe, and they must be pushed back quite far to the east or south-east to find the place where these beds were deposited. Nothing, however, indicates that between this zone and that of the Pavlovské Kopce there existed any intermediate type, and it must be assumed that the deeper zone of the

Czetechowice Jurassic was adjacent, from the east, to the littoral zone of the Jurassic of the Pavlovské Kopce and Lower Austria. To the east this trough probably ran south of the Silesian island fringed by the internal Stramberg reefs; the klippe of Wigantice is the only trace of the course of the latter trough. However, it must be also accepted that this trough must have been connected with the Bachowice trough by ramifying into two arms encircling the Silesian island. Only by means of the northern ramification could the Aalenian and Bajocian sea from the Liassic trough of Lukoweczek invade the Bachowice region. The southern ramification probably ran far eastward, and somewhere in the Central or Eastern Carpathians it rejoined the northern (Bachowice) ramification to form a single trough; in this trough was perhaps deposited the Jurassic of the Czarnohora klippes.

VIII. Pieniny klippes zone. The zone of deposition of the Pieniny Jurassic was situated to the south of the Cetechowice trough and its eastward prolongation towards the Czarnohora Mountains. It is not the aim of the present work to discuss the question whether the Jurassic of the Pieniny Mountains was separated by means of a ridge from the Czetechowice trough and its prolongation. Perhaps such a ridge did exist during certain periods and it could have been the place of origin of the detrital admixtures in the rocks of the Czorsztyn Dogger, but at other times it was marked only as a zone of shoals along which was deposited the Czorsztyn facies.

On the basis of such a review of the Jurassic occurrences in the area of the Flysch Carpathians, the development of the Jurassic transgression in the latter area can be tentatively presented in the following manner.

At the beginning of the Jurassic, the whole area formed the land. The sea, which during the Rhetic invaded the subtatric region, in the Lower Lias probably did not pass northward of the Pieniny trough. During the Middle Lias, the sea invaded the Czetechowice trough (fig. 27). It is difficult to say whether this transgression came from the west, from the Jura-Swabian basin, or was it the result of a gradual spreading of the Mediterranean sea which in the Lias occupied already a considerable part of the High-Tatric region of the Tatra Mountains and probably flooded the whole Pieniny trough. Rzehak (1904, p. 151) stresses the faunistic analogies between the Lukoweczek Lias and the Franconian basin, but these analogies may be so great on account of the fact that in both cases we have shallow-water deposits of a very similar facies; faunistic differences between the Central European region and that of the Mediterranean sea are not marked until we come to the deeper facies. It is rather difficult to assume a transgression directly from the west in view of the universally accepted fact that the Regensburg gateway was not forced until the Bajocian.

In the Bajocian (fig. 28), the sea invaded the Bachowice trough. The Bajocian transgression, which deposited the arenaceous beds of Bachowice, could have come only from the west, i. e., from the Czetechowice trough, the fact being that nowhere in the foreland do we know of any marine deposits in the immediate neighbourhood of the Carpathians, and in the Cracow area the transgression coming from the north did not arrive till the Bathonian or Callovian.

In the Bathonian (fig. 29), the sea in the Bachowice-Czetechowice trough became so much deeper that *Posidonomya* beds of a bathyal type could be deposited. During this period, by means of the southern ramification of the Czetechowice trough, the sea probably extended far eastward, inasmuch as the bathyal facies of the Callovian in the Czarnohora klippes indicates that the sea must have existed in this area already before the Callovian. At the same time the foreland sea, coming from the region situated between the Cracow area and the Holy Cross Mountains (Góry Świętokrzyskie), invaded the Kruhel zone. This transgression probably joined neither the Bachowice trough, nor the sea of the Eastern Carpathians, inasmuch as the fauna of these regions has too little elements in common.

In the Callovian (fig. 30), the sea of the Kruhel zone attained Dobrodgea, initiating a series of deposits displaying great faunistic and lithological analogies with the epicontinental Jurassic of Central Europe (absence of *Phylloceras* and *Lytoceras,* rare *Oppelidae,* numerous *Perisphinctes*, sponge facies; cf. Simionescu 1909 and 1927). The Kruhel-Dobrodgea sea of the Callovian at this time does not seem to have been connected yet with the sea of the Bachowice trough and its prolongation in the Eastern Carpathians, inasmuch as the rich *Phylloceras* fauna of the latter zone is unnoticeable in the faunistic assemblage of the Kruhel Callovian. On the other hand, the Bachowice trough must have had a free connection with the southern sea, with which it displays extensive faunistic relations.

In the Oxfordian (fig. 31), however, a connection must have been accomplished between the Bachowice trough and the Kruhel trough, and this made possible, as demonstrated by Wójcik (1914), an interchange between the mediterranean province and Central-Europe. It is probable that the connection of the Carpathian sea, or of its most external Bachowice-Kruhel trough, with the sea of southern Poland was accomplished rather in a region lying nearer Kruhel than Bachowice, inasmuch as the lithological influence of the foreland facies is noticeable in the Kruhel area and not at Bachowice. The Bachowice trough must have been separated from the sea of the Cracow Jurassic by means of some barrier; the eastern part of this barrier was not submerged until the Tithonian, while in the Oxfordian it was probably free from the sea as far as the meridian of Dębica or Ropczyce. It is possible, on the other hand, that farther westward, somewhere in Moravia, there did exist another connection between the Carpathian sea (Czetechowice trough) and the sea that towards the close of the Callovian, after breaking through the Regensburg gateway, invaded the area of Brno (Brünn). The acceptance of such a connection would explain the fact that the Oxfordian of Brno possesses more species of *Phylloceras* (and even one *Lytoceras*) than any other epicontinental Oxfordian in Central Europe. The rich *Cardioceras* fauna could have also penetrated by means of this connection, in the opposite direction, into the Czetechowice trough.

In the Kimmeridgian (fig. 32), the conditions in the Carpathian area underwent no great changes, but the connection with the foreland sea became more difficult on account of a noticeable regression in the foreland; nevertheless, it did exist as proved by the presence of Franco-

Swabian and Alpine forms (*Aspidoceras* from the *uhlandi* group, *A. acanthicus, Simoceras,* etc.) in the Kimmeridgian of central Poland (M i c h a l s k i 1907, P r e m i k 1926). The Kimmeridgian sea of the northern Carpathians, the deposits of which are hitherto known only from Bachowice, at this time must have been connected with the sea of the Eastern Alps; the latter sea, in the Kimmeridgian and Tithonian, had a free connection with the sea of the Franco-Swabian basin, separated solely by shoals in which *Diceras* limestones were formed (B r i n k m a n n 1953, p. 182). On the other hand, the connection by way of Brno, where the Jurassic is terminated with the Astartian, between the sea of Poland and the Franco-Swabian basin, existed no more. The uplifting movements in the foreland are contrasted by the subsidence in the Carpathian area; in the zone of the Lower-Austrian klippes, the Kimmeridgian seems to transgress directly on a crystalline basement; the same, perhaps, is also valid in relation to the Słoboda zone where already the highest Oxfordian (the Sequanian of C z a r n o c k i 1934) initiated a transgression on the zone of green rocks.

In the T i t h o n i a n (fig. 33), the Jurassic transgression in the northern Carpathians attains its culmination. The sea inundates many regions, such as the zones of Słoboda, Stramberg-Andrychów, Lower Austria, etc. Of the extensive mainland area in the Western Carpathians, only the Silesian island remains. This negative movement of the above-mentioned area is probably associated with the subsidence of the Vindelician range in the foreland of the Alpine geosyncline. The separation from the northern seas is at this time complete, and this probably favours the enormous development of the reefs that grow up along the northern shores of the Carpathian sea, forming a belt of external reefs (Ernstbrunn, Pavlovské Kopce, Dębica, Węgierka, Kruhel, Słoboda zone, Dobrodgea) and the shores of the Silesian island (Stramberg, Andrychów, etc.), thus building the internal reefs. Between the island reefs and the reefs of the external shore, deposited are the ammonitic and *Calpionella* limestones of Bachowice, marking the pelagic zone. A similar zone of the pelagic Tithonian extends to the south of the Silesian island; the two zones, perhaps joined in the east, form a belt of the pelagic Tithonian, the remains of which are observable in the klippes of Teleajen.

The subsidence in the Carpathian area is opposed by a reverse movement in the foreland. There the sea retreats to the trough of central Poland, but both in the Kimmeridgian and now a part of the Podolian platform becomes submerged. It is possible that the arm of the sea stretching towards southern Podolia, was connected with the sea which submerged the ridge of green rocks in the Słoboda zone. This connection perhaps, which was probably of very short duration, was the route of penetration from the northern sea for the boreal forms *(Aucella)* discovered long ago by A b e l (1889) in the klippes of Lower Austria.

VI. STRATIGRAPHY OF THE BACHOWICE CRETACEOUS

1. Lower and Middle Cretaceous

As already mentioned, the youngest rock of the Jurassic assemblage at Bachowice are the marly siltstones with *Lytoceras quadrisulcatum* d'O r b., which display such a great lithological difference in relation to the Tithonian rocks that one might suspect them to be rocks deposited after some radical change in the conditions of sedimentation. Such a change is perceptible in the Western Carpathians at the boundary of the Jurassic and Cretaceous; consequently, it is presumable that the siltstones belong to the lowest members of the Cretaceous, i. e., to the Berriasian. They would thus be a counterpart of the lower Cieszyn shales.

We are unable to say how long the sedimentation of the above-mentioned siltstones lasted and what beds were deposited after the deposition of the siltstones in the basin in which were formed the deposits of the Bachowice Jurassic. A frequent Cretaceous rock at Bachowice are Upper Cretaceous limestones containing pebbles and fragments of rocks of the Jurassic, Tithonian, and Kimmeridgian. From this fact the conclusion might be drawn that the Upper Cretaceous transgressed directly on rocks of the Upper Jurassic. It the later members were deposited after the Jurassic, they were completely or almost completely removed by erosion preceding the Upper Cretaceous, or else they were eroded by the transgression of the Upper Cretaceous. In the latter case this would be possible if the deposits of the Lower Cretaceous were suitably soft and erodible. This is highly probable in view of the fact that the siltstones, which initiate the possible Cretaceous series, are a very soft deposit.

Unfortunately, there are no available paleontological documents to prove that deposits of the Lower Cretaceous are present in the exotic series of Bachowice. Deposits exist, however, which can be suspected of having a Lower Cretaceous age. In the Bachowice breccia have been discovered some fragments of papery black clayey shales, similar to the Wierzowice shales (Barremian). They occurred, however, very rarely, in small fragments, and their washing revealed no microfauna. Also discovered were pieces of clayey siderites, similar to the ones that occur in Lower Cretaceous beds of the Flysch. It is possible, however, that these siderites derive from some beds of the Middle Jurassic.

It is particularly interesting that apart from the shales suspected of belonging to the Wierzowice beds and the siderites, we encounter in the exotic series of Bachowice no rocks of Flysch character; especially striking is the lack of sandstone rocks. Flysch sandstones, if they existed above the Bachowice Jurassic, would have much greater chances of being preserved during the erosion caused by the Upper Cretaceous transgression, than the soft shaly deposits. Consequently, if any Lower Cretaceous deposits did exist here, they had, similarly as the grey siltstones, a non-Flysch character.

2. Upper Cretaceous

Of common occurrence at Bachowice is a calcareous rock, most frequently of a pink colour, less often green or white, containing numerous remains of *Inocerami,* while in thin slides it frequently displays a mass occurrence of *Globotruncanae* and *Globigerinae*. In almost all of these rocks one encounters fragments of Jurassic rocks, white *Calpionella* limestones and subcrystalline limestones of the Tithonian, and green pelitic limestones of the Kimmeridgian; these rocks occur both in the form of pebbles and angular fragments. This indicates that during the deposition of the Upper Cretaceous limestones, the Jurassic rocks protruded above the sea level; the coastal erosion probably caused a destruction of the Jurassic rocks, and the introduction of their more or less rounded and unweathered fragments into the deposits of the Upper Cretaceous sea.

The age of these rocks was determined chiefly on the basis of *Globotruncanae* because the latter occur in masses and in every rock fragment. *Inocerami* also served to establish the age, but they are not numerous and usually badly preserved. Their determination was undertaken by F. Mitura who reported the results of his study in a separate publication (Ann. Soc. Geol. Pol., in preparation).

The colour of the Upper Cretaceous limestones of Bachowice gives no indication of their age; pink limestones are mainly of Turonian age, but some limestones of the same colour have a Cenomanian fauna; green limestones are either Turonian or younger. The red and green limestones probably occurred alternately in the sequence of the Bachowice Cretaceous; even in a single rock fragment it is frequently observable that the colours pass one into another. On the basis of the lithological properties and the fauna, the following members of the Upper Cretaceous limestones are distinguishable (beginning with the types containing the oldest fauna):

1. Pink limestones (Kr1).
2. Pink limestones with large pebbles of Tithonian white limestones (Kr2).
3. Older green limestones (Kz1).
4. Pink limestones with large *Inocerami* (Kr3).
5. Pink limestones without large pebbles of Tithonian limestones and without large *Inocerami* (Kr4—5).
6. Green limestones (Kz2).
7. White or yellow-white limestones (Kb).
8. Red limestones (Kc1).
9. Arenaceous pink limestones (Kc2).

It must be emphasized that apart from their colour, the enumerated rock types manifest no macroscopic lithological differences, and also that they differ in no manner within a type characterized by a common colour, e. g., the pink limestones Kr1, Kr2 and Kr5 are not distinguishable from one another macrocospically; the same pertains to the green limestones Kz1 and Kz2 which, regardless of their different age, have the same appearance.

All the distinguished types of Bachowice limestones always contain an admixture of fragments of Jurassic rocks, frequently in such quantity that the rock becomes a conglomerate with an abundant calcareous cementing material. The white limestones (Kb) contain the smallest quantity of such an admixture.

Pink limestones (Kr1, Kr2, Kr3, Kr4, Kr5). These rocks are hard, compact, fine-grained, of a light-pink colour that sometimes passes into a dark-pink one; in some fragments observable is a passage of the colour into a green one. In the granular fracture of the rock it is noticeable that in the background of a lighter colour are imbedded darker fragments of organic origin, imparting to the rock its granular aspect. The above-mentioned darker fragments are plates of echinoderms, finely divided fibres of *Inocerami*, and Foraminifera visible even to the naked eye, distinguishable by their colour as dark points. Moreover, observable in the rock are larger fragments of the shells of *Inocerami* and Brachiopoda.

In thin slides (plate XXVII, figs. 1, 3, 4, 5) one perceives that the rock is composed almost exclusively of organic remains. Prominent in the foreground are Foraminifera, chiefly Fissurines, *Globotruncanae*, and *Globigerinae;* in smaller numbers one encounters *Gümbelinae* and, very infrequently, benthonic Foraminifera belonging to the genera *Robulus, Marsonella*, or *Verneuillina*. In different slides the above-mentioned forms occur in various proportions, and even in a single slide they change from place to place, but usually the most numerous are *Globotruncanae* and Fissurines. The latter are often the principal element of the rock (plate XXVII, fig. 1). Fissurines (also called oligostegines) are organisms of obscure systematic position. The sections visible in thin slides of the Bachowice limestones are circular or elliptical, and they correspond to the drawings of Colom, Castany, and Delga (1953, p. 529), representing *Fissurina ovalis* (Kauf.). Only some of the sections with two chambers are referable to *Oligostegina laevigata* Kauf. *Globotruncanae* occur in all slides, frequently as the principal element, but in some slides they give place to *Inoceramus* fibres or Fissurines. The second component element, besides planktonic Foraminifera, are the fibres of *Inocerami*. Finally, the third organic constituent of the discussed rocks are the remains of echinoderms (crinoidal plates, echinoid spines); they are less numerous than planktonic Foraminifera, but only in few slides are they absent; also in but few slides do they occur as the principal element of the rock (plate XXVII, figs. 3 and 4).

On the average, more than one-half of the rock is composed of organic remains.

Of the inorganic constituents, only quartz and fragments of Tithonian limestones are distinguishable. Among the limestone fragments, determinable are subcrystalline limestones (T1) and white *Calpionella* limestones (T3), and also, less frequently, limestones of the Kimmeridgian (K1, K2). Quartz occurs in relatively small quantities, and in some slides it is absent. Its largest grains attain a diameter of 0.35 mm; such large grains, however, are rare and, in spite of such size, badly rounded. The most frequent are grains with a diameter of 0.10—0.15 mm.

As regards such impurities as quartz and clayey and ferruginous substances, the pink limestones are comparatively pure; the residue, after dissolving the rock, does not exceed 9%.

The pink limestones were not, perhaps, thick-bedded (1—2 dm), or else the thicker beds were easily split into slabs.

The *Globotruncana* fauna is very rich and consists of many species, some of which occur in masses, while others only accessorily. The Foraminifera were washed out of the pink limestones by employing glauber salt; consequently, the determination of the *Globotruncanae* is based both on material isolated from the rock, and on axial sections obtained in thin slides.

The following assemblages are distinguishable in the *Globotruncana* fauna of the pink limestones:

1. *Gl. apenninica* (R e n z)
   Gl. helvetica B o l l i
   Gl. renzi G a n d o l f i
   Gl. stephani G a n d o l f i
   Gl. cf. *turonica* B r o t z e n

This assemblage is composed exclusively of single-keeled *Globotruncanae,* the first of which occurs very numerously. (Plate XXVIII, fig. 5). and 6).

Striking is the complete absence of double-keeled *Globotruncanae* from the *lapparenti* and *marginata* groups which occur abundantly in the following assemblages.

Rocks containing such an assemblage are extremely rare at Bachowice; this assemblage was discovered only in a few fragments of limestones.

The assemblage points to the Cenomanian; it is identical with the assemblage quoted by B o l l i (1944) from the Upper Cenomanian of the Helvetian Cretaceous in the Alps.

2. *Globotruncana* cf. *apenninica* R e n z
   Gl. lapparenti coronata B o l l i. Fairly numerous
   Gl. lapparenti lapparenti B o l l i
   Gl. lapparenti angusticarinata (G a n d o l f i). — Fairly numerous
   Gl. lapparenti bulloides (V o g l e r). — Rare
   Gl. marginata R e u s s

Such an assemblage occurs in pink limestones containing large blocks of Tithonian limestones (Kr2). On account of the presence of *Gl.* cf. *apenninica,* this assemblage must be considered as an older one; it probably indicates a very low Turonian.

3. *Gl. lapparenti lapparenti* B o l l i
   Gl. lapparenti coronata B o l l i
   Gl. lapparenti cf. *inflata* B o l l i
   Gl. globigerinoides B r o t z e n

   Or a very similar assemblage:

   Gl. lapparenti cf. *inflata* B o l l i
   Gl. lapparenti angusticarinata (G a n d o l f i)
   Gl. marginata R e u s s
   Gl. globigerinoides B r o t z e n

Such assemblages were ascertained to exist in a very small number of fragments of pink limestones. They are considerably rarer than assemblage No. 2 or the following assemblages. The limestones containing these assemblages, lithologically displaying no differences in relation to the limestones with assemblage No. 1, are designated by the symbol Kr3. Assemblage No. 3 indicates a low Turonian, as testified by the presence of *Gl. lapp. inflata.*

4. *Gl. lapparenti lapparenti* B o l l i
   Gl. lapparenti tricarinata (Q u e r e a u). — Very numerous
   Gl. lapparenti angusticarinata (G a n d o l f i)
   Gl. lapparenti coronata B o l l i

Gl. marginata R e u s s
Gl. cf. *turonica* B r o t z e n

This assemblage occurs in pink limestones containing shells of *Inocerami* determined by M i t u r a as follows:

Inoceramus cuvieri S o w.
Inoceramus cuvieri var. *haani* J. B o e h m.
Inoceramus inaequivalvis S c h l ü t e r
Inoceramus annulatus G l d f.

The first two *Inocerami* indicate the In. lamarki zone (higher Lower Turonian); the third *Inoceramus* may also have its origin in the same zone, or in the immediately higher one, i. e., the Scaphites geinitzi zone.

The presence of such forms as *Gl.* cf. *turonica* and *Gl. lapp. angusticarinata* in the assemblage of *Globotruncanae,* indicates the Lower Turonian, although the latter of the two is also quoted from higher up. The limestones containing this assemblage are designated Kr 4.

5. *Gl. lapparenti lapparenti* B o l l i
Gl. lapparenti tricarinata (Q u e r e a u)
Gl. lapparenti bulloides (V o g l e r)
Gl. marginata R e u s s
Gl. globigerinoides B r o t z e n.

In some samples the latter assemblage is joined, very rarely, by:

Gl. ventricosa W h i t e (non B r o t z e n).

Noticeable in this assemblage is the characteristic disappearance of forms occurring in the previous assemblages, such as *Gl. lapp. angusticarinata, Gl. lapp. coronata,* and *Gl.* cf. *turonica*; on the other hand, besides *Gl. lapp. lapparenti* and *Gl. lapp. tricarinata,* which occurred in the previous assemblages, one encounters here *Gl. lapp. bulloides* and *Gl. ventricosa.* Disregarding the latter form, which is very rare and in most samples absent, assemblage No. 5 is the one that is most frequently encountered in the pink limestones. These limestones are designated as Kr 5.

In the limestones containing the above-mentioned assemblage, discovered were *Inocerami* determined by M i t u r a as follows:

Inoceramus apicalis W o o d s
Inoceramus inconstans rotundatus F i e g e.

Of these *Inocerami,* the first one occurs from the In. labiatus zone to the Sc. geinitzi zone; the second one characterizes the schloenbachi zone, i. e., the highest Turonian.

On the basis of the *Globotruncanae,* ascertainable is the lack of forms belonging to the Lower Turonian; such an assemblage as No. 5, however, can occur both in the Upper Turonian and in the Coniacien, and even in the Lower Santonian. The only thing that can be said concerning it, is that it contains no forms of the Upper Senonian. The *Inocerami* offer here an important indication, pointing to the Turonian; of particular importance is the presence of *In. inconstans rotundatus,* indicating the highest Turonian.

The main mass of the pink limestones seems to have been formed by the ones containing assemblage No. 5. They represented the Upper Turonian.

On the basis of the assemblages of *Globotruncanae* and *Inocerami*, it can be stated that the pink limestones represent the Cenomanian and Turonian; moreover, in all probability, all members of the Turonian are represented in these limestones.

Green limestones (Kz 1, Kz 2). These rocks are light-green, hard, fine-grained or pelitic. The colour sometimes changes into almost white with a barely perceptible green shade, while in some places a pink colour also appears. The green (leptochloritic) substance is localized on the cracks and fissures, and it imparts then a strong green colour to the rocks. The same as in the pink limestones, both on a fresh fracture and on a weathered surface one observes very numerous organic remains: small Crinoidea, fragments of echinoid spines, Foraminifera, and fibres of *Inocerami*. Also frequent are bits of shells of *Inocerami;* moreover, one encounters in this rock small Brachiopoda and fish teeth. In almost every piece of rock one observes more or less rounded fragments of Tithonian limestones, chiefly light-coloured subcrystalline limestones (T1) and, considerably less often, *Calpionella* limestones (T3); also encountered are fragments of marly-shaly limestones (T6) and fragments of limonitic crusts, probably having their origin in weathered siderites, and large grains of quartz.

In thin slides (plate XXVII, fig. 2 and 6) the picture of the texture of the green limestones is almost identical with the microscopic aspect of the pink limestones. Fissurines occur frequently in masses, *Globotruncanae* also, while *Globigerinae* are less numerous; other Foraminifera, such as *Gümbelina*, *Robulus* and *Verneuillina*, are very rare. Of inorganic constituents, visible is quartz occurring in angular or feebly rounded grains. The greatest diameter of the quartz-grains amounts to 0.3 mm. but most of the grains have a diameter of ca. 0.15 mm. The residue after dissolving the rock amounts to ca. 8.7%; 8.4% are fractions smaller than 0.15 mm, while larger quartz grains form only an insignificant percentage.

The green limestones are somewhat less numerous at Bachowice than the others; their blocks never attain large dimensions (diameter ca. 20—30 cm), they are never rounded, having most frequently the shape of thick slabs. It seems that the green limestones were arranged in beds, 10—30 cm thick.

The fauna of the green limestones is composed of *Inocerami* present in small numbers (their remains are less numerous than in the pink limestones), quite numerous but small *Terebratulae* (belonging perhaps to two or three species), and, above all, planktonic Foraminifera occurring in masses.

Distinguishable here are two different assemblages of *Globotruncanae*.

1. The older assemblage consists of the following forms:

Gl. cf. *turonica* Brotzen
Gl. stephani (Gandolfi)
Gl. marginata (Reuss)
Gl. lapparenti lapparenti Bolli
Gl. cf. *rosetta* Carsey.

Disregarding the latter form, we can include the assemblage among the older ones of the pink limestones containing *Gl.* cf. *turonica*. The presence of *Gl. stephani* suggests, by comparison with the Helvetian Cretaceous, that this assemblage may be ascribed to the lowest Turonian. It is possible that the green limestones (Kz 1), containing assemblage No. 1, formed an intercalation in the lower part of the sequence of the Bachowice limestones, probably between the limestones Kr 2 and Kr 3 (cf. table III). Such a conclusion would seem to be opposed by the presence of *Gl.* cf. *rosetta*, but this form was discovered only in a few specimens and its significance is highly uncertain; it is usually quoted from the Senonian, but American authors state that it occurs still lower.

2. The younger assemblage of *Globotruncanae*, with small exceptions always encountered in the green limestones, is composed of the following forms:

Gl. lapparenti bulloides (Vogler)
Gl. lapparenti lapparenti Bolli — Fairly numerous
Gl. lapparenti tricarinata (Quereau) — Very numerous
Gl. globigerinoides Brotzen — Not frequent
Gl. marginata (Reuss) — Numerous.

This assemblage of *Globotruncanae*, therefore, is identical with the one occurring in the pink limestones. Such an assemblage may occur both in the Upper Turonian and the Coniacien. The age of the green limestones is established more accurately by two *Inocerami* determined by F. Mitura and indicating the Lower Coniacien:

Inoceramus kleini G. Müller
Inoceramus umbonatus Meek.

Also discovered in the green limestones was a tooth of *Ptychodus mammilaris* Ag.

It follows from the above-mentioned data that the main mass of the green limestones (Kz 2) represented the Lower Coniacien in the sequence of the Bachowice limestones, while the intercalations of the green limestones in the pink ones could have also occurred lower down.

White limestones (Kb). These rocks occur rarely; they are of a cream-white or white colour, spotted with iron compounds, and they are encountered in slab-like fragments, about 1 dm thick. Apart from their colour, these limestones resemble the pink and green ones; their fracture is granular and they are hard. They contain small fragments of Upper-Jurassic limestones, in much smaller quantities than the pink and green limestones did. The quantity of quartz in these rocks is also very small. These rocks are very pure. The residue, after dissolving the rock in hydrochloric acid, amounts to 2.9% only.

In thin slides (plate XXVIII, fig. 2) it is visible that the rock is composed almost exclusively of fissurines; *Globotruncanae* and the remains of *Inocerami* are comparatively not frequent, while other Foraminifera are absent. The remains of echinoids occur occasionally, while quartz is encountered in very rare, fine, angular grains.

The fauna is very poor, but the principal reason therefore may be the very rare occurrence of this rock. The author did not succeed in finding any determinable *Inoceramus*; discovered were only some small *Terebratulae* and a tooth of *Ptychodus* cf. *mammilaris* A g.

The microfauna is also poor in contrast with the other varieties of limestone, excluding, of course, the fissurines. The following assemblage of *Globotruncanae* occurs in these limestones:

Gl. lapparenti tricarinata (Q u e r e a u)
Gl. lapparenti lapparenti B o l l i
Gl. ventricosa W h i t e (non B r o t z e n)
Gl. marginata (R e u s s)
Gl. arca C u s h m.

The latter, as a matter of fact, occurs in rare specimens, and it is the only new element in comparison with the assemblage of limestones Kz 2 and Kr 5. *Gl. ventricosa*, represented here quite numerously, occurs chiefly in the Coniacien (it is also encountered lower down); *Gl. arca* occurs chiefly in the Senonian. Taking into consideration that fissurines disappear near the Coniacien-Senonian boundary, it is presumable that the white limestones still belong to the Coniacien and represent its upper part.

B r i c k - r e d l i m e s t o n e s (Kc 1). At Bachowice these rocks are not so frequent as the pink and green limestones, but they are more frequent than the white limestones. They occur both in small fragments and in large blocks with a diameter of 1/2 m. In comparison with the other Upper Cretaceous limestones of Bachowice, they contain more fragments of Kimmeridgian limestones.

The colour of these limestones is pale red or pink, but it is different from that of the pink limestones; especially in a wet state the red colour becomes stronger. The aspect of the limestones is also different from that of the previously described limestones; granularity on the fracture exists no more, and the rock imparts the impression of being a pelitic limestone.

The microscopic texture (plate XXVIII, figs. 1, 3, 4) is different in comparison with the previously described limestones. Striking, above all, is the almost complete disappearance of fissurines; only rare and atypical sections could be ascribed to them. It is perhaps their lack which causes the absence of granularity in the rock, observable in the other Upper Cretaceous limestones of Bachowice. Fibres of *Inocerami*, on the other hand, continue to be numerous, the same as *Globotruncanae* which in some places occur in masses; *Globigerinae* are also quite frequent. Quartz is mostly absent, but if it does occur, it attains relatively large dimensions (up to 0.4 mm); quite many of the quartz grains have a diameter of 0.25 mm.

The residue insoluble in hydrochloric acid amount to 7.5% and is composed of quartz grains mostly with a diameter that is smaller than 0.1 mm.

The different internal texture of the rock causes it to behave differently under the action of glauber salt; in contrast with the other limestones, no *Globotruncanae* could be isolated from the red limestones. Their determination is based on axial sections in thin slides.

A similar texture exists in small fragments of the limestones imbedded in blocks of tuffs, the presence of which was discovered by T. W i e s e r (1952). In the available material (plate XXIX, figs. 1—2), these fragments have sharp, irregular outlines and attain small dimensions (diameter of

1—2 cm). Both the colour and the microscopic texture of these fragments is identical with those of the red limestones; most probably, therefore, we have here fragments which mechanically, perhaps still in a state of incomplete diagenesis, were introduced into volcanic ashes.

The fauna of the red limestones and conglomerates is composed of quite numerous but small *Terebratulae, Terebratula* cf. *carnea* Sow., *Terebratula* sp. sp., *Terebratulina* sp.) and small *Exogyra* sp.

In the microfaunistic assemblage of *Globotruncanae,* great differences exist in comparison with the assemblages of the pink, green, and white limestones. Striking, above all, is the appearance of biconvex or conical types of *Globotruncanae,* absent in the previous assemblages.

In the red limestones (Kc 1) we have the following assemblage of *Globotruncanae:*

Gl. cf. *fornicata* Plummer. — Fairly numerous
Gl. arca Cushm. — Fairly numerous
Gl. cf. *conica* White. — Rare
Gl. lapparenti lapparenti Bolli. — Not very frequent
Gl. lapparenti tricarinata (Quereau). — Not very frequent
Gl. marginata Reuss. — Not very frequent.

The presence of *Gl. arca* and *Gl. fornicata* indicates that it is the Senonian, probably a high Santonian or even the Lower Campanian. The lack of forms that are typical of the Campanian and Mastrichtian, rather indicates that it cannot be more than a low Campanian.

The presence of *Terebratula carnea* Sow. also points to a Campanian age.

In the fragments of limestones contained in the tuffs (Kct), it was possible to determine the following:

Gl. arca Cushm.
Gl. cf. *globigerinoides* Brotzen
Gl. lapparenti lapparenti Bolli
Gl. lapparenti tricarinata (Quereau)
Gl. cf. *leupoldi* Bolli.

The latter form points to the Campanian.

The presence of calcareous fragments with Campanian *Globotruncanae* in the tuffs indicates that the Bachowice tuffs were formed in the Campanian or after the latter. The nests with a Lower Eocene fauna, occurring in the tuffs, testify that they continued to be formed until the Lower Eocene.

Arenaceous brick-red limestone (Kc 2). Already at first glance this rock differs from the previous ones, inasmuch as it contains a large quantity of quartz grains attaining a diameter of 4 mm. Apart from the quartz, noticeable are numerous fragments of Kimmeridgian green limestones and less frequent fragments of Tithonian limestones. Rare fragments of sandstones also occur.

In this slides (plate XXIX, figs. 3 and 4) the difference in relation to the other Cretaceous limestones is still more noticeable. Quartz dominates, occupying frequently more than 30% of the slide area. Frequent are fibres and fragments of *Inocerami,* echinoid spines, and benthonic Foraminifera, while *Globotruncanae* are very rare and seem to belong to one species only. Representatives of the genera *Gümbelina* and *Globigerina* are also very rare, and fissurines are lacking altogether. Glauconite occurs in rare grains.

Neither from this rock, the same as from the previous one, did the author succeed in isolating any Foraminifera .Determined in slides was only *Globotruncana* cf. *stuarti* (L a p p.), occurring very rarely and in sections that are not very typical.

The latter *Globotruncana* indicates the Campanian or Mastrichtian. Nothing more can be said concerning the age of this rock with the exception that the arenaceous limestone has an appearance that makes it very similar to the red limestones (Kc 1), and that it probably is of similar age; it must, therefore, be suspected of a Campanian age, rather than Mastrichtian.

On the basis of the strongly arenaceous character of the rock, it is presumable that the arenaceous limestones (Kc 2) were deposited in a sea receiving a large quantity of terrigenous material; the conditions for the development of the plankton must have been considerably worse than they were during the deposition of the other limestones of the Upper Cretaceous at Bachowice. It is possible that the land, near which the calcareous deposits were formed, was subjected at this time to a strong emergence, or else the sea became very much shallower; in the latter case, the deposition of the arenaceous red limestones could have been followed by a complete regression, and the latter limestones would be the last member of the Upper Cretaceous limestones at Bachowice.

The above-mentioned deposits, uplifted above the sea level towards the end of the Cretaceous, were eroded by the sea, and they could have been introduced into the deposits of the Paleocene or Lower Eocene sea.

3. Review of the stratigraphy of the Upper Cretaceous of Bachowice

On the basis of the fauna, especially the *Globotruncanae* (table IV) that occur in all types of limestones, and partly the *Inocerami,* it is possible to present an approximate reconstruction of the sequence of beds in the profile of the Cretaceous, the remains of which exist in the deposits of exotics at Bachowice.

The oldest member (table III) is composed of pink limestones (Kr). The microfauna which they contain proves that their deposition started in the Cenomanian, probably in the upper one, and continued without interruption troughout the Turonian, up to the base of the Coniacien. The *Inocerami* which they contain indicate various members of the Turonian; the forms that occur here are characteristic of the *In. lamarki, Sc. geinitzi,* and *In. schloenbachi* zones, but there are also forms which may occur in the *labiatus* zone. *Globotruncanae* in the pink limestones form several diverse assemblages, the oldest of which is composed exclusively of single-keeled *Globotruncanae,* while the youngest consists exclusively of double-keeled forms; an intermediate position is occupied by mixed assemblages, composed of double-keeled forms with an admixture of single-keeled forms. It is certain, however, that the deposition of the pink limestones at least

Table III

STRATIGRAPHY OF THE BACHOWICE CRETACEOUS

	Rocks	Globotruncanae	Inocerames[1]
MASTRICHTIAN	Brick-red sandy limestones (Kc2) Brick-red limestones (Kc1)	*cf. stuarti, cf. globigerinoides*	
CAMPANIAN		*lapparenti lapparenti, lapp. tricarinata, marginata, ventricosa, arca, cf. fornicata, cf. leupoldi, cf. globigerinoides, cf. conica*	
SANTONIAN			
CONIACIEN	White limestones (Kb)	*lapparenti lapparenti, lapp. tricarinata, marginata, ventricosa, arca*	
	Green limestones (Kz2)	*lapparenti lapparenti, lapp. bulloides, lapp. tricarinata, marginata, globigerinoides*	*umbonatus, kleini*
TURONIAN	Pink limestones (Kr5)	*lapparenti lapparenti, lapp. bulloides, lapp. tricarinata, marginata, globigerinoides, ventricosa*	*rotundatus, apicalis*
	Pink limestones (Kr4)	*cf. turonica, lapp. angusticarinata, lapp. coronata, lapp. lapparenti, lapp. tricarinata, marginata, globigerinoides*	*cuvieri, cuv. var. haani, inaequivalvis*
	Pink limestones (Kr3)	*lapp. inflata, lapp. angusticarinata, lapp. coronata, lapp. lapparenti, lapp. tricarinata, marginata, globigerinoides*	
	Green limestones (Kz1)	*stephani, cf. turonica, lapp. lapparenti, marginata, cf. rosetta*	
	Pink limestones (Kr2)	*cf. apenninica, lapp. angusticarinata, lapp. coronata, lapp. lapparenti, lapp. tricarinata, marginata, globigerinoides, (helvetica)*	*(annulatus)*
CENOMANIAN	Pink limestones (Kr1)	*apenninica, stephani, renzi, helvetica, cf. turonica*	

[1] determined by F. Mitura

once gave place to the deposition of the green limestones (Kz 1) with a Lower Turonian microfauna.

The Coniacien is represented by the green limestones (Kz 2) with *Inocerami* of the Lower Coniacien; the assignment of the white limestones (Kb) to the Upper Coniacien is based on scantier evidence; this assignment is dictated by the fact that the white limestones still contain fissurines which become extinct in the Lower Senonian, while their assemblage of *Globotruncanae* is essentially like the one that dominates in the Upper Turonian and the Coniacien.

The Santonian is not well expressed in the limestone series of Bachowice; the red limestones (Kc 1) with numerous *Gl. arca* ought to be assigned rather to the Lower Campanian. It is difficult to say whether the Santonian is represented in the red limestones together with the Campanian, or are Santonian rocks for some reason lacking; it does not seem probable, however, that this lack should be caused by emergence and erosion. One must rather suppose that the Upper Cretaceous limestones of Bachowice are a continuous series of deposits.

The Campanian (and perhaps the Upper Santonian) is represented in the red limestones (Kc 1); it is probably the Lower Campanian. The higher part of the Campanian (or perhaps the Mastrichtian) is represented by the arenaceous limestones (Kc 2). The deposition of tuffs and tuffites probably ought to be ascribed to this period, i. e., to the Upper Campanian or Mastrichtian (Wieser 1952, Książkiewicz and Wieser 1953). It is probable that the eruptions, which were active in the formation of the above-mentioned tuffs, lasted until the Lower Eocene.

It is evident from the foregoing remarks that the limestone series of Bachowice represents the Upper Cenomanian, Turonian, Coniacien, and

Table IV

GLOBOTRUNCANAE OF THE BACHOWICE CRETACEOUS

	Pink limestones (Kr1)	Pink limestones (Kr2)	Green limestones (Kz1)	Pink limestones (Kr3)	Pink limestones (Kr4)	Pink limestones (Kr5)	Green limestones (Kz2)	White limestones (Kb)	Red limestones (Kc1)	Fragments of red limestones in tuffs (Kct)	Red sandy limestones (Kc2)
Glob. stuarti (Lapp).											○
Glob. conica White									○		
Glob. fornicata Plummer									○		
Glob. leupoldi Bolli										○	
Glob. arca Cushm.								●	●	●	
Glob. ventricosa White						●		●	●		
Glob. globigerinoides Brotzen		●		●	●	●	●			○	○
Glob. rosetta Carsey			○								
Glob. marginata (Reuss)		●	●	●	●	●	●	●	●		
Glob. lapparenti tricarinata (Quereau)		●			●	●	●	●	●	●	
Glob. lapparenti lapparenti Bolli		●	●	●	●	●	●	●	●		
Glob. lapparenti bulloides Vogler		●				●	●				
Glob. lapparenti coronata Bolli		●		●	●						
Glob. lapparenti angusticarinata Gandolfi		●		●	●						
Glob. lapparenti inflata Bolli				●							
Glob. turonica Brotzen	○		○		○						
Glob. renzi Gandolfi	●										
Glob. helvetica Bolli	●										
Glob. stephani Gandolfi	●		●								
Glob. apenninica Renz	●	○									

a part of the Senonian. The deposition of the limestones was begun in the Upper Cenomanian and was terminated in the Upper Campanian or Lower Mastrichtian. It is probable that the deposition of the Upper Cretaceous limestones was begun in consequence of a Cenomanian transgression on a previously uplifted, eroded, and resubsiding ridge, built of the Jurassic and perhaps the Lower Cretaceous. During the Upper Cretaceous the above-mentioned ridge did not become completely submerged; parts of it must have remained above the water-level, because throughout the Cenomanian-Campanian a detritus of the Upper Jurassic limestones was being continuously introduced into the calcareous deposits. It is also probable that eroded initially was the uppermost part of the Jurassic (the Tithonian, especially the *Calpionella* Tithonian), and subsequently the erosion penetrated deeper and deeper because there are more fragments of Tithonan rocks in the older members of the Cretaceous, while in the younger members there is a predominance of Kimmeridgian rocks.

It follows from the character of the Upper Cretaceous limestones at Bachowice that they were deposited near a coast built of Jurassic rocks. This coast was probably of a cliff character, and the nearby sea was presumably quite deep. Detritus produced by wave-erosion and by rockfalls from steep coastal cliffs fell into the sea; a poorly rounded and badly sorted material slumped into deeper waters. Attention must be paid to the unusual development of the plankton of the Upper Cretaceous limestones at Bachowice, especially in view of the fact that nowhere in the adjacent regions (cf. the following chapter) do we encounter such a development. Two possible explanations come to mind. The ridge, near which were deposited the Bachowice limestones, could have occupied such a position in the sea that it formed a barrier for warm currents which coming from the west, probably from the Alpine region, carried an abundant plankton. This plankton could have been held up near the shores, if their configuration were suitable, and close to the above-mentioned ridge masses of the plankton sank to the bottom. The other explanation takes into account ascending currents, arising near a coast exposed to the wind. If the Jurassic ridge had a latitudinal position or one that was almost such, with a predominance of west or north-west winds which in these geographical latitudes must be accepted also for the Cretaceous period, in the deep waters adjacent to the ridge on its windward side there could have existed the constant upwelling of deep-lying water, caused by a pushing of the sea-level towards the east or south-east by the west wind; this caused an ascending current of deep-lying waters that were rich in nourishment.

4. Regional position of the Bachowice Cretaceous

The position of the Bachowice Cretaceous is altogether exceptional. Nowhere in the Carpathians do we know of any deposists that could be identified therewith, although deposits of Cenomanian-Mastrichtian age in the Carpathians are developed well and in a diverse manner. Neither in the Cretaceous series of the Carpathian foreland do we encounter any rocks that are similar to the Upper Cretaceous limestones of Bachowice.

The development of the Bachowice limestones, covering a large period of time, i. e., almost all of the Upper Cretaceous, and with a pelagic fauna, indicates that the deposits could not have been local ones, developed in some small bay or as a lenticle subordinate to other deposits. Such a type of deposit as the limestone with a rich plankton must have had a considerable depositional area.

Regionally the nearest deposits are the variegated marls of the Sub-Silesian series, occurring at Bachowice in the immediate substratum of the exotic-bearing series. Lithologically, these marls or marly shales are altogether different from the hard limestones of Bachowice, but they have common colours: red and green ones. Of the fauna, only the microfauna can be taken into consideration on account of the absence of a large fauna in the variegated marls; the microfauna of both series displays considerable differences: the variegated marls contain mostly a mixed assemblage of Foraminifera with a large number of agglutinated forms and, in general, most frequently with a predominance of benthonic forms; only in some places of this series does there exist a predominance of planktonic forms. Of the latter, *Globotruncanae* occur in common; in the variegated marls they are encountered in large numbers but they are never so numerous as in the Bachowice limestones. Many forms of *Globotruncanae* occur in common: *Gl. lapparenti lapparenti, Gl. lapparenti coronata, Gl. lapparenti tricarinata, Gl. marginata, Gl. rosetta, Gl. arca, Gl. fornicata,* etc. (cf. Książkiewicz 1949); a close comparison, however, is difficult, inasmuch as an abundant fauna of *Globotruncanae* does not appear in the Sub-Silesian marls until the Campanian, i. e., when the sedimentation of the Bachowice limestones was coming to an end. The Bachowice fauna of *Globotruncanae,* therefore, is generally older than the fauna of the variegated marls. The noticeable differences are due at least partly to the difference in age. In any case, comparing assemblages of one age, i. e., Campanian ones, it must be stated that *Gl. marginata* is rare in the Sub-Silesian marls, while at Bachowice it is common.

Gl. marginata is a form that is supposed to characterize, above all, the epicontinental sea of Europe, while *Gl. lapparenti* is characteristic of the seas of the Alpine province; and indeed, *Gl. marginata* is almost absent in the Apennines and the Alps, being mentioned neither by Bolli 1944, nor Cità 1948, or Noth 1951, while it is quite frequent in the Cretaceous of the foreland. Accepting this as correct, one must assume that the Bachowice assemblage of *Globotruncanae* to a much greater degree reflects the influence of the foreland sea than does the assemblage of the Sub-Silesian marls.

In spite of the observable differences, there is no doubt that the Upper Cretaceous limestones must have been deposited in the same basin as the Sub-Silesian marls, or near this basin. They occur reworked, immediately in the upper part of the marls; although they are encountered in a deposit with a distinct slump character, there are no grounds for assuming that they were transported a long distance. The geochemical character of the basin in which both deposits were formed is perhaps expressed in imparting similar colours to both types of deposits.

On the other hand, taking into account the influence of the foreland sea, expressed in the abundance of *Gl. marginata* in the Bachowice limestones, it must be assumed that the deposition zone of the Bachowice limestones lay to the north of a similar zone of the Sub-Silesian marls.

Progressing in the latter direction, we encounter Upper Cretaceous deposits in the Cracow area. The Bachowice Cretaceous has one feature in common with the Cracow Cretaceous: the transgressive relation to the Jurassic substratum. In both regions the Cenomanian initiates the transgression of the Cretaceous. However, at Bachowice we most probably have an uninterrupted series of deposits from the Cenomanian up to the Campanian at least, while in the Cracow Cretaceous the oscillations of the sea manifest themselves as several interruptions, discovered by P a n o w (1936). The lithological development in both areas differs; only some of the Turonian limestones of the Cracow area bear a lithological resemblance to the Coniacien white limestones of Bachowice. On the other hand, absent in the Cracow area are the red and green colours that dominate in the Cretaceous of Bachowice. The fauna does not differ very much: in the Bachowice Turonian there is a lack of the echinoids and *Rhynchonellidae* that are frequent in the Cracow Turonian; some of the *Inocerami* occur in common; the *Globotruncana* fauna is, in general, different, inasmuch as in the Cracow Turonian there is a predominance of *Globotruncanae* from the group of *Gl. marginata,* while *Globotruncanae* from the *lapparenti* group, the dominant ones at Bachowice, are rarer if one may judge on the basis of the available materials and microscopic photographs published by A l e k s a n d r o w i c z (1954), inasmuch as *Globotruncanae* of the Cracow Turonian have not been elaborated. In some Turonian limestones of the Cracow area, also noticeable is a fissurine fauna that is common, as a matter of fact, in the Turonian of the foreland. Considerable differences are noticeable in the microfauna of the Senonian; *Globotruncanae* in the Cracow Senonian occur subordinately in relation to other Foraminifera (L i s z k a 1953).

Taking into consideration the above-mentioned data, it must be stated that the sea, in which were deposited the Bachowice limestones, was in some sort of communication with the Cretaceous sea of the Cracow area. Undoubtedly, however, this communication did not consist in a direct passage of the Bachowice sea into the Cracow sea; these seas were separated from each other either by still another zone of deposition, or by a land barrier, and they communicated with each other by way of some roundabout route.

At a comparatively small distance from the Bachowice Cretaceous, lies nowaday the Upper Cretaceous of the Andrychów klippes. In a similar manner as the Bachowice Cretaceous, it lies transgressively on the Jurassic. This, however, is the only analogy. Lithologically, the white marls and limestones with hornstones of the Andrychów klippes do not correspond at all to the Bachowice limestones, in relation to which, as a matter of fact they are younger on the whole (Campanian-Mastrichtian; K s i ą ż k i e w i c z, 1951). The foraminiferal fauna, very abundant and chiefly calcareous in the Andrychów Cretaceous, contains incomparably more benthonic forms, but the *Globotruncana* plankton is also quite abundant *(Gl. lapparenti lapparenti, Gl. lapparenti tricarinata, Gl. arca, Gl. caliciformis, Gl. rosetta).* Striking is the absence of *Gl. marginata* which evidently did not penetrate into the more internal areas of the Carpathian geosyncline.

A comparison with the Cretaceous of the Istebna and *Inoceramus* beds can be disregarded, because in both cases the deposits are completely different and of a Flysch character. On the other hand, one must also take into consideration the Upper Cretaceous covering transgressively the Jurassic of the Lower-Austrian klippes. According to Glaessner (1931), the lowest member of this Cretaceous consists of the „Klementer Schichten“ that begin with a conglomerate and are composed of green sandstones with *Inocerami* of the Upper Turonian *(In. cuvieri, In. latus, In. inconstans)* and with *Scaphites* cf. *geinitzi.* The higher-lying member of the Cretaceous in the above-mentioned area consists of arenaceous marls with *Belemnitella mucronata,* known since the times of Suess. This shows that regardless of the analogy in the transgressive disposition, there is no lithological analogy.

Searching for calcareous deposits of Cretaceous age in the Flysch zone, limestones are encountered only at one place apart from Bachowice, i. e., in a calcareous klippe discovered by K. Pożaryska at Łukawica, in the river-basin of the Czeremosz, and described by Sujkowski (1938). It is a white-grey limestone with *Globigerinae* and *Globotruncana* cf. *apenninica* (?). Neither macroscopically (on the basis of rock specimens inspected by the author in the collections of the Geological Institute in Warsaw), nor microscopically (absence of fissurines) does this limestone resemble the Cenomanian or any Cretaceous rock of Bachowice.

It is difficult to say anything certain concerning the mutual relation of these far-distant Upper Cretaceous calcareous rocks that do not correspond to each other lithologically, belong to different tectonic units, and are only ones in the extensive Flysch area of the Carpathian zone; however, one cannot exclude the possibility that the limestones of Bachowice and Łukawica were deposited in one common zone with non-Flysch sedimentation, situated within the Flysch sea. In fact, it is probable that the calcareous zone of Bachowice, adjacent to the zone of the variegated marls, extended together with the latter zone along the middle of the Flysch sea, dividing this sea longitudinally into two zones with Flysch sedimentation (Książkiewicz, 1953).

The course of the „variegated“ zone with a non-Flysch type of sedimentation in the Upper Cretaceous is particularly well observable in the Central Carpathians (fig. 34). To the north of this zone lies the external zone of sedimentation of *Inoceramus* beds, together with a region of baculite marls with strong lithological and faunistic influences of the foreland. To the south of the axial zone lay the sedimentation zone of Istebna beds; to the south this zone bordered, in some manner hitherto unknown to us, upon a zone with sedimentation that again has the character of *Inoceramus* beds. All the above-mentioned sedimentation zones exist between the meridian of Tarnów in the west and the meridian of Przemyśl in the east, within the Carpathian geosyncline.

Proceeding now to the east and west of the Central Carpathians, we notice that the above-mentioned zones run obliquely in relation to the presumed borders of the geosyncline. Consequently, in the East Carpathians the internal zones disappear; it seems, however, that the „axial“

zone of the Central Carpathians does have its counterpart in the Roumanian Carpathians, although for a long distance, between the San and the Trotus, it does not come anywhere to the surface. On the other hand, towards the west it is the external zone that disappears. It is not known whether this disappearance, on the meridian of Cracow, is not caused solely by tectonical agencies; it is possible that a prolongation of the *Inoceramus* zone in this region lies deep beneath the surface, concealed underneath overthrusts of the Carpathian nappes, but still farther westward, especially in Moravia, it seems certain that the external *Inoceramus* zone of the Central and East Carpathians does not possess its counterpart, and that the Frydek marls belong rather to the sedimentation zone of the variegated marls. Perhaps only the Upper Cretaceous of the Lower-Austrian klippes forms a counterpart of the external *Inoceramus* zone. The relations in Moravia are too uncertain to say anything positive concerning the course of the axial zone with variegated marls. Variegated marls are unknown in this area but the discovery, by Grill (1945), of red shales with an Upper Cretaceous microfauna in the region of the Pavlovské Kopce, is an indication that in this area too exists the variegated facies of the Upper Cretaceous, with a still uncertain zonal position. Farther westward, variegated marls are encountered in Helvetic tectonic windows of the Eastern Alps, underneath an overthrust of the Ultrahelvetic (= Magura) Flysch: such windows were first discovered by Richter (1929) in Bavaria, and most recently by Prey (1948) in Upper Austria. Here the variegated marls are considered to be a prolongation of the Helvetic zone of Switzerland.

Not until we come to the latter zone do we encounter beds that more than any others are comparable to the Bachowice limestones. The Upper Cretaceous of the Helvetic Alps is composed of Seewerkalk limestones of Cenomanian-Turonian-Lower Coniacien age, covered with shales and marls (Seewerschiefer, Amdener Schichten, Leistmergel, Wangschichten) representing the upper members of the Upper Cretaceous, to the Mastrichtian inclusively. The Seewerkalk limestone is, as a matter of fact, light-grey, but part of it (Lower Turonian and Upper Cenomanian) is red, while the aspect of its internal texture is identical with that of the Bachowice limestones; it is composed chiefly of fissurines *(Fissurina ovalis), Globigerinae, Gümbelinae,* and very numerous *Globotruncanae*. The large fauna of the Seewerkalk limestones is similar to the fauna of the Bachowice limestones (*Inocerami* mostly indeterminable and small, but also *In. cuvieri, Terebratulae,* fish teeth). Regardless of the unquestionable differences, it must be admitted that the Bachowice limestones, by their age, lithology, microscopic texture, and fauna, resemble most the Seewerkalk limestones of the Helvetic series in the Alps.

It seems that the remains of the Helvetic series, occurring in windows of the Flysch zone of the Eastern Alps in the form of variegated marls, have their counterpart, probably in many respects quite considerably altered, in the zone of various variegated and grey marls of the Carpathian Upper Cretaceous. As explained above, the Bachowice limestones are associated, as far as their regional position is concerned, with the variegated series. It is highly probable, therefore, that in the Carpathians the Bachowice limestones are a counterpart of the Seewerkalk limestones in the Alps. Nowadays the Bachowice limestones are known solely as exotics. Their facial type indicates that they could not have been a local deposit; their distributional area, at least in the West Carpathians, must have been of considerable extent. It is probable that in some part of the sedimentation zone of the Senonian variegated marls, the latter could have been underlain by the Bachowice limestones, representing in their main mass the Cenomanian-Turonian-Coniacien.

It is not an easy matter to determine the position of the sedimentation area of the Bachowice limestones within the Carpathian geosyncline, but there is no doubt that this area must have been situated far from their present position. The Bachowice exotics were dragged to their present position by overthrust movements. The extent of the overthrust of the Sub-Silesian nappe in the Carpathians is unknown; the visible extent amounts to several kilometres, but by stretching the folds and pushing apart the Flysch scales, and by taking into account the extent of the overthrust of the Silesian nappe, which underneath itself and at its front shoved the Sub-Silesian series northward, the place of deposition of the Bachowice limestones must be put back at least 30 kilometres to the south. The latter figure is a minimal one, resulting from the geometry of the Carpathian overthrusts. If we also take into consideration the facial and provincial differences between the Bachowice Cretaceous and the Cretaceous of the Cracow foreland, and also the differences between the Bachowice Jurassic (near which was deposited the Bachowice Cretaceous) and the Jurassic of the Cracow area, we must arrive at the conclusion that the deposition area of the rocks observable in the Bachowice exotic series, at present less than 5 kilometres distant from the foreland, was situated tens of kilometres farther southward.

VII. GLOBOTRUNCANAE OF THE BACHOWICE CRETACEOUS

Globotruncana apenninica Renz[1]. (Plate XXX, figs. 10, 11 and 13; fig. 35 in the text). Numerous axial sections correspond well to the drawings published by Bolli. The outline is biconvex; in large forms it is often dorsally conical. All the chambers have only one keel.

Isolated specimens are very few in number and, unfortunately, the umbilical side is obstructed with rock. Consequently, invisible in the sutures are the apertures that would decide that the sections belong to the subgenus *Rotalipora* which includes *Gl. apenninica*. The discussed sections, however, occur in company with other single-keeled forms, usually associated with *Gl. apenninica*, so that it seems certain that the above-mentioned sections do belong to the latter species. On very large specimens it is observable that the keel disappears on the last chamber. Pink limestones (Kr1): numerous. Pink limestones (Kr2): the few sections of a single-keeled *Globotruncana* can be ascribed to the discussed species only with great reservations. The species concerned might just as well be *Gl. sigali* Reichel.

Globotruncana stephani Gandolfi. (Plate XXX, figs. 12 and 14; fig. 36 in the text). The section displays a single keel in the internal

[1] Reference given in the Polish text.

whorls; the section passing through the last-formed whorl intersects a chamber with rounded walls that have no keel. Usually only the last chamber in the section is rounded, but occasionally the chamber of the last whorl, lying on the opposite side, also displays a rounded shape and the absence of a keel; this indicates that more than one chamber of the last-formed whorl loses its peripheral keel. Several specimens were also isolated, but in a bad state of preservation. In consequence of the lack of a keel on the last chambers, the discussed *Globotruncana,* when isolated, gives the impression of being a *Globigerina.* Pink limestones (Krl): numerous. Green limestones (Kzl): the rare sections have internal chambers that are more rounded than in the forms obtained from the pink limestones. It could be a form similar to *Gl. alpina* B o l l i or *Gl. turonica* B r o t z e n, if the latter forms would lose their keels on the last chambers.

Globotruncana renzi G a n d o l f i. (fig. 37 in the text). Sections of a small *Globotruncana* that in its internal whorls has two keels, and in the last-formed whorl, only one with a visible tendency in these specimens to become extinct. Largest diameter ca. 0.3 mm. The author did not succeed in isolating the above-mentioned form. Pink limestones (Krl): very rare and not very distinct sections.

Globotruncana helvetica B o l l i. (Plate XXX, fig. 17; fig. 38 in the text). Axial sections display a dorsal side that is completely or almost completely flattened; on the other hand, from the ventral side the chambers are rounded; on the border of the dorsal side there is a more or less distinct keel. The rare isolated specimens, seen from their ventral side, bear a complete resemblance to *Globigerinae.* In some specimens it is observable that on the external whorls the keel becomes extinct and the chambers are rounded or only slightly flattened from the top. The axial sections correspond completely to B o l l i's drawings and description. Pink limestones (Krl): quite numerous.

Globotruncana cf. *turonica* B r o t z e n. (Plate XXXII, figs. 15—18; figs. 39 and 39a in the text). The rare sections display a *Globotruncana* with strongly dilated chambers, with axial sections that are circular or elliptical. Both the internal and external whorls possess a single keel that is not very distinct. Some sections, with chambers that are less rounded, resemble *Gl. alpina* B o l l i; as to the latter, R e i c h e l (1949, p. 608) does not exclude the possibility that they might belong to the species *Gl. turonica.* Observable on some sections (plate XXXII, fig. 18) are numerous protuberances on the external wall of the chambers, this also being a characteristic of *Gl. turonica.*

The author managed to isolate but a single specimen (fig. 39a) which perhaps corresponds to the sections visible in thin slides. On the ventral side, badly exposed as a matter of fact, it is observable that the aperture of the penultimate chamber is located in the suture. Pink limestones (Kr 1): one specimen. Green limestones (Kz 1): not numerous. Pink limestones (Kr 4): rare.

Globotruncana lapparenti B r o t z e n. This species is abundantly represented at Bachowice in almost all of its varietes or subspecies described from the Alps. Its principal characteristic is the strong curvature of the chambers and sutures on the ventral side in the direction of the test involution.

Globotruncana lapparenti inflata Bolli. (Plate XXXI, figs. 4 and 5; fig. 40 in the text). This subspecies was established by Bolli on the basis of axial sections in which the last chamber has no keels. At Bachowice this form was discovered only in one fragment that was too small for isolating the tests. The axial sections are highly characteristic; the internal chambers have two keels, the last chamber in the section is rounded, without keels, and thin-walled, in accordance with Bolli's drawings. The walls of the internal chambers in Bolli's drawings are convex, not parallel and not rectangular; in the Bachowice material two types are observable: one type has internal chambers that are more rounded, while the other type has rectangular chambers. This suggests that the former variety might be referable to *Gl. marginata,* and the latter one to *Gl. lapparenti.* Noticeable in both these species is a tendency to a disappearance of the keels as an individual gets older, and it might be suspected that what we have here is not so much a separate subspecies as an anomaly in individual development. Striking, in any case, is the fact that such anomalous forms occur in masses in one rock, and are altogether absent in other rocks. Pink limestones (Kr 3): numerous.

Globotruncana lapparenti angusticarinata (Gandolfi). (Plate XXXI, figs. 1, 2, 3, 6; figs. 41 and 42 in the text). The test is biconvex: both sides are almost equally raised in a flatly conical manner. The pearled keels lie so close to one another that the band between the keels either does not exist, or is very narrow. The lower keel passes over to the periumbilical side, where it is quite strongly marked. When the band between the keels is wider, the form resembles the subspecies *Gl. lapp. tricarinata.* Another subspecies, *Gl. lapp. coronata,* is very similar as far as the arrangement of the keels is concerned, but it is flatter. Pink limestones (Kr 2): numerous. Pink limestones (Kr 3). Pink limestones (Kr 4).

Globotruncana lapparenti coronata Bolli. (Plate XXXI, fig. 17—18; figs. 43 and 44 in the text). The complanation of the test and its elongation in the equatorial plane makes it easily distinguishable from the similar *Gl. lapp. tricarinata.* Pink limestones (Kr 2): quite numerous. Pink limestones (Kr 3 and Kr 4): not very numerous.

Globotruncana lapparenti lapparenti Bolli. (Plate XXXI, figs. 7, 8, 9; figs. 45 and 46 in the text). This form is frequent at Bachowice, although it is not so numerous as *Gl. lapp. tricarinata.* Pink limestones (Kr 2): not numerous. Green limestones (Kz 1): not numerous. Pink limestones (Kr 3): not very numerous. Pink limestones (Kr 4 and Kr 5): quite numerous. Green limestones (Kz 2): not numerous. White limestones (Kb): not numerous. Red limestones (Kc 1): not numerous, in sections that are not very typical.

Globotruncana lapparenti tricarinata (Quereau). (Plate XXXI, figs. 10, 11, 12; figs. 47 and 48 in the text). The test is flattened more from the bottom, or else it is feebly biconvex, with a wide umbilic. The chamber walls are not so parallel to one another as they are in *Gl. lapp. lapparenti,* and the band between the keels is also narrower. The lower keel, passing over on the periumbilical margin, becomes strongly marked, this being particularly well observable in axial sections. As a rule, the dimensions are larger than in *Gl. lapparenti lapparenti*. Forms exist that deviate from the type of this subspecies. Some forms have a flat ventral side and a slightly conical dorsal side; there are also forms with slightly curved chamber-walls. With reservations, the author also includes in this subspecies the section in fig. 16 of plate XXXI, representing an enormous *Globotruncana* (diameter 1.2 mm), the internal whorls of which have the section of *Gl. lapp. tricarinata*, while the external whorls are different, with convex chamber-walls and converging keels, the same as in *Gl. lapp. coronata*. At Bachowice this *Globotruncana* is the most common one. Pink limestones (Kr 2): quite numerous. Pink limestones (Kr 4 and Kr 5): very numerous. Green limestones (Kz 2): very numerous. White limestones (Kb): quite numerous. Red limestones (Kc 1): quite numerous. Also in fragments of limestones in tuffs (Kct).

Globotruncana lapparenti bulloides (V o g l e r). (Plate XXXI, figs. 13, 14, 15; fig. 49 in the text). The axial sections of this form published by B o l l i (1944, 1951) might arouse doubts whether they do not belong to *Gl. marginata*. *Gl. lapp. bulloides* is said to have sutures on the ventral side curved forwards; this feature, however, is not visible on an axial section. B o l l i (1951) gives no drawings of forms isolated from the rock, and he shows only axial sections; on the other hand, he makes reference to the drawings published by C u s h m a n (1946, p. 150, plate 62, figs. 1 and 2), which are to represent *Gl. marginata* R e u s s. However, in the quoted drawings the sutures do not run radially but arc-like; consequently, Bolli considers this form as belonging to the subspecies *Gl. lapp. bulloides*. In the Bachowice material, of quite frequent occurrence are double-keeled *Globotruncanae* with a ventral side that is typical of the species *Gl. lapparenti* but the chambers are spherical, the same as in *Gl. marginata*. Undoubtedly, therefore, what we have here is the subspecies *Gl. lapp. bulloides*. In axial sections it is quite difficult to distinguish this form from *Gl. marginata*. This is facilitated, however, by the presence of a „third" periumbilical keel (plate XXXI, figs. 13—15), distinctly visible on many sections. In *Gl. marginata* such a keel is absent, and it must be pointed out that on some of B o l l i's sections it is also absent, this suggesting that the sections are those of *Gl. marginata*. Pink limestones (Kr 5): quite numerous. Also Kr 2. Green limestones (Kz 2): not very numerous.

Globotruncana ventricosa W h i t e (C u s h m.). (Plate XXX, fig. 1; figs. 50 and 51 in the text). This species was established by C u s h m a n (1946) who raised the variety *Gl. canaliculata* var. *ventricosa* White to the rank of a species. Previously, with White's variety as the basis, B r o t z e n (1936) did the same, but Brotzen's forms, with biconvex chambers, belong to the *marginata* group [1]. The upper surface of *Gl. ventricosa* is completely flat, while from the ventral side the chambers are convex and conical, and simultaneously elongated more or less towards the involution. The num-

[1] *Gl. ventricosa* from the Istebna beds, determined by the author (Książkiewicz, 1949) after Brotzen, belongs to the group of *Gl. marginata* R e u s s.

ber of chambers in the last-formed whorl amounts to 6 or 7. The sutures on the dorsal side are disposed almost perpendicularly in relation to the preceding whorl; the sutures on the ventral side are straight or slightly oblique. The two keels are pearled at first; the band between the keels is perpendicular to the equatorial plane, occasionally on the last chamber it runs obliquely. This interval between the keels is quite large, but in some specimens it narrows down quite considerably. The lower keel, running into the suture, on some specimens is invisible on the umbilical margin, while on other specimens it is visible and borders the chambers around the umbilic. This conforms to Mornod's description, according to whom the periumbilical keel is not always visible. In the drawings of various authors, the matter is presented variously: in those published by Cità (1948) and Cushman (1946) who gives a copy of White's drawing, the keel is visible, while in the forms described by Carbonnier (1952) from the Upper Cenomanian, it is not visible. The aperture has lip at the base of the last chamber. Pink limestones (Kr 5): rare. White limestones (Kb): quite numerous. Red limestones (Kc 1): rare.

Globotruncana marginata (Reuss) Thalm. (Plate XXXII, figs. 1—14; figs. 52—55 in the text). This species, described by Reuss in a not very clear manner, in accordance with subsequent authors is distinguishable from other *Globotruncanae* chiefly by its rounded, spherical, or elliptical chambers, two keels that are not very strong, and straight sutures on the ventral side. Moreover, the umbilic is narrow, the chambers are disposed more or less obliquely in relation to one another, and from the dorsal side they are slightly flattened. In axial sections this species can be mistaken for *Gl. lapparenti bulloides* if the section of the test of the latter form does not pass accurately through the periumbilical keel. The band between the keels is narrower in *Gl. marginata,* and it is not straight, as it is in the entire *lapparenti* group, but rounded. This species has no particular stratigraphic value, occurring as it does from the Lower Turonian to the Mastrichtian inclusively, but its principal frequency coincides with the Turonian, Coniacien, and Lower Senonian. In the Bachowice material this species occurs very abundantly, and after *Gl. lapparenti tricarinata* it occupies the second position as to quantity. It is easily observable, however, that in this species there exist a quite considerable variability, and a more detailed study might lead to a division of this species into several groups, subspecies, or varieties in a similar manner as in the species *Gl. lapparenti.* Distinguishable here, at any rate, are the following types:

1. Chambers of the external whorl: elliptical section; in the internal whorls: circular or feebly elliptical section (fig. 52: 2; fig. 54: 2, 3, 4; plate XXXII, figs. 6, 7, 11, 12). These forms can be probably considered as the central group of the discussed species *(marginata marginata).*

2. Chambers with internal and external whorls with a circular section (fig. 52: 1; fig. 54: 1, 5, 6, 7; plate XXXII, figs. 1—5). On account of the shape of the chambers, this type could be designated as *marginata bulloides.* These forms resemble *Gl. globigerinoides* Brotzen, but they differ by having thick-walled chambers and keels that are stronger and spaced more widely. Young individuals of this group are sometimes difficult to

distinguish from the internal whorls of the first group (cf., e. g., drawings 4 and 6 in fig. 54). Dimensions usually smaller than in the first group.

3. Chambers with elliptical section, but keels running close together and merging into a single keel on the external whorls (fig. 52: 3; fig. 54: 8; plate XXXII, figs. 8—10). On account of the analogy to a similar developmental tendency in the species *Gl. lapparenti*, this group could be designated as *marginata angusticarinata*. It corresponds to the type presented by Franke (1928; p. 192, plate XVIII, fig. 9).

4. Chambers elliptical, keels on the external whorl disappearing altogether (fig. 55). This form is flattened from both sides more strongly than the other groups.

5. Dorsal side more strongly flattened than in all the above-mentioned groups (fig. 53). In axial sections it may be impossible to distinguish this form from *Gl. ventricosa*.

The distinguished types occur together; type 4 was discovered only in red limestones (Kc 1). The most frequent form is the typical one. Pink limestones (Kr 2): not numerous. Green limestones (Kz 1): not numerous. Pink limestones (Kr 3): not numerous. Pink limestones (Kr 4, Kr 5): numerous. Green limestones (Kz 2): numerous. White limestones (Kb): not very numerous. Red limestones (Kc 1): quite numerous.

Globotruncana globigerinoides Brotzen. (Plate XXX, figs. 2 and 3, figs. 56 and 57 in the text). This *Globotruncana* resembles a *Globigerina (Gl. cretacea)*, but at the peripheries of its chambers it has two delicate keels running close together. Number of chambers in the last-formed whorl: 5—6; they are spherical or almost so, and thin-walled; umbilic narrow. In axial sections this form can be easily mistaken for *Gl. marginata*, especially for forms of the *bulloides* type (e. g., plate XXXII, fig. 2). Pink limestones (Kr 3, Kr 5): rare. Green limestones (Kz 2): rare. Red limestones (Kc 2): several sections of a small *Globotruncana* with considerably thicker walls than in *Gl. globigerinoides* perhaps belong here.

Globotruncana cf. *rosetta* Carsey. (Plate XXX, fig. 16). Several axial sections display double-keeled internal chambers, while the external chambers are either double-keeled and single-keeled, or only single-keeled. The dorsal side is strongly flattened, from the ventral side the chambers are conically shaped. The author did not succeed in isolating these forms; moreover, it must be pointed out that hitherto no author has published an axial section of this form, and it is unknown whether it does indeed possess double-keeled internal chambers. Furthermore, considerable doubts exist concerning the relation of *Gl. rosetta* to *Gl. arca, leupoldi*, and others (cf. Hamilton 1953, p. 233, and Subbotina 1953, p. 198). Greenish limestones (Kz 1): infrequent sections.

Globotruncana arca Cushm. (Plate XXX, figs. 4, 5, 6; figs. 58 and 59 in the text). Tests of this species were not isolated from the Bachowice material, but quite numerous sections make possible an identification of this form in thin slides. In vertical sections this species displays a narrow band between the keels, inclined towards the centre or the vertical axis of the test, differing thus from the quite similar section of *Gl. lapp. tricarinata*, and also from that of *Gl. fornicata* which it resembles by the fact that its dorsal side is also more strongly convex in comparison with the ventral side. It attains quite considerable dimensions, some sections exceeding 0.8 mm. For the purpose of comparing sections with a test, shown in fig. 58 is a large specimen of *Gl. arca* obtained from grey marls of the Sub-Silesian series in the neighbouring locality of Zygodowice. White limestones (Kb): very rare. Red limestones (Kc 1): quite numerous; also several sections in fragments of limestones encountered in tuffs.

Globotruncana cf. *fornicata* P l u m m e r. (Plate XXX, figs. 7—9; fig. 60 in the text). Quite numerous sections with a convex dorsal side and an almost flat ventral side; the band between the keels is quite high and only slightly inclined in relation to the axis of the section. Regardless of the difference in the height and inclination of the band between the keels in the axial section, the discussed species is difficult to distinguish from *Gl. arca* if the test is not isolated, inasmuch as the difference between these two species consists chiefly in the strongly elongated chambers in the last-formed whorl of *Gl. fornicata*; consequently, the determination is not altogether certain. Red limestones (Kc 1): quite numerous.

Globotruncana leupoldi B o l l i. (Plate XXX, fig. 15). The axial section displays double-keeled internal whorls; on the last chamber visible in the section (perhaps in the last several chambers of the last-formed whorl), there is only a single keel. The dorsal side is more strongly convex than the ventral one. The author possesses only one section that is quite similar to B o l l i's figures, but the determination cannot be considered as altogether certain. It must be pointed out that T i l e v supposes that *Gl. leupoldi* might be an anomalous *Gl. arca*. Fragments of red limestones (Kct) imbedded in tuffs: one specimen.

Globotruncana cf. *conica* W h i t e. (fig. 61 in the text). Several not very good sections of the conical form with a flat base correspond to the section published by T i l e v. Red limestones (Kc 1): not numerous.

Globotruncana cf. *stuarti* (L a p p.). (Plate XXX, fig. 18). A few axial and equatorial sections suggest that it is this species. In the equatorial sections it is visible that the outline is not lobate, as in other *Globotruncanae*, but circular, and the section of the chambers is rectangular. The axial sections are either biconvex or the dorsal side is flattened. The keel is single in all whorls. Arenaceous red limestones (Kc 2): not numerous.

VIII. ORIGIN OF THE STRATUM WITH EXOTICS

Exotic rocks are common in the Flysch. They occur in conglomerates as usually well-rounded elements, and in clays in which pebbles are inserted loosely. Exotic-bearing beds can be traced, as a rule, for long distances.

The exotics at Bachowice have a completely different form of occurrence. Well-rounded rocks are lacking almost altogether. The blocks are mostly badly rounded, and most frequently without any traces of mechanical abrasion. Their surfaces are not smoothed, as in other Carpathian exotics, but they bear the distinct stamp of weathering, they are porous, rough, uneven; either the harder elements (e. g., quartz or organic remains) are isolated by weathering or else we encounter fresh-looking surfaces of mechanical fractures.

Carpathian exotics occurring in conglomerates can be traced for long distances in certain stratigraphic horizons. On the other hand, as regards the Bachowice exotics, this is not so. Apart from their occurrence at Bachowice, extending some 700 metres, in spite of a quite good knowledge of the neighbouring areas, nowhere did the author discover any deposits of exotics that could be considered as corresponding to those occurring at Bachowice. Moreover, the rocks encountered in the Bachowice exotics occur nowhere else, in no other assemblage of Carpathian exotics. This applies especially to the Jurassic and Cretaceous rocks, but also in a large degree to igneous rocks. On the other hand, in other exotic-bearing beds of the Carpathian Flysch, the particular rocks types occur in various outcrops over large areas.

All this is proof that the manner of occurrence of the Bachowice exotics is something exceptional, and that the deposit with the exotics must have been formed in some exceptional fashion, different from the one that produced the exotic-bearing beds of the Carpathian Flysch or at least their great majority.

The exotic-bearing beds of the Carpathian Flysch, as we may suppose on the basis of the hitherto available data, were produced by the transport of material derived from the erosion of coasts or brought by rivers and deposited in deeper waters lying farther off-shore, with the assistance of strong currents or slumps originating on the slopes of littoral embankments and producing either turbidity currents or subaqueous mudflows. In all these cases we have a redeposition of material abraded by fluvial transport or coastal erosion.

The lack of abrasion in the blocks, their dimensions, their weathered surfaces, and the characteristics of the occurrence of the exotics at Bachowice, indicate that the manner of their deposition must have been different.

Two possibilities of explaining the manner in which these exotics were produced come to mind.

As the first alternative hypothesis it might be accepted that the deposit with exotics is a littoral one, the blocks being produced not as the result of the mechanical action of surf and abrasion, but by the breaking-off, from the coastal cliffs, of slightly weathered great rock-masses that fell straight into deep water, and not into the zone of wave-action. Such rock-masses could have been broken up when falling or as the result of hitting the bottom. The tuff-breccia, in which the exotic blocks of Bachowice are usually encountered, could be the product of an abrasive reworking of Upper Cretaceous tuffs by marine wave-action. It could have been deposited both at the shore and slightly deeper. Into this deposit fell rock blocks from the cliffs together with weathered talus. Some blocks could have fallen on a clayey sea-bottom, others on a „tuffite" bottom, while still others reached the zone of wave-action, where they became rounded. Slumping movements of a sea-bottom burdened with accumulating blocks could have caused subaqueous slipping and intermixing of the material.

The coast at which the above-mentioned process took place, probably could not have extended a long distance; it would be otherwise difficult to explain the fact that the occurrence of the exotics is restricted to a small area. One might rather assume that at the transition of the Cretaceous into the Tertiary, as the result of Laramian movements, a small island emerged at a distance of at least 40 kilometres to the south of the present position of the exotics, and its shores were gradually cut away by the waves of an Early Tertiary sea. All that remained of this island at a certain stage of its liquidation by the sea, was a marine haystack built of a complete series represented by the Bachowice exotics, i. e., a crystalline basement, the Carboniferous, Jurassic, and Cretaceous. Undercut by waves, the haystack finally crashed into the sea and was scattered over a small area of the sea-bottom, producing thus a deposit of exotics.

This explanation has its weak points; it is difficult to accept that sea-abrasion eliminated the material so thoroughly that almost no abraded rocks remained, the only product of abrasion being a tuff-breccia; incomprehensible is the fact that the sea, having reworked such a quantity of tuff material, simultaneously produced such a small amount of pebbles.

The hypothesis discussed above can be opposed by another which refers to the unquestionable association of exotics rocks with volcanic ones. As already mentioned several times, the exotics are imbedded in a tuff-breccia or in tuffs. It is presumable that the latter breccia is not the product of coastal erosion and abrasion, but volcanic dust mingled with clays and silts of the sea-bottom. It could have been produced as the result of an enormous mudflow (so-called lahar) that flowed down into the sea and, burdening the deposits of the latter at a place where the configuration of the bottom was suitable, caused a submarine slump. This mudflow could have transported from the land a quantity of detritus and talus that was thus introduced into deep waters.

Building up the latter hypothesis, we can imagine the following course of events that gave rise to the deposit of the Bachowice exotics. Towards the end of the Campanian or after the Campanian, volcanic activity was commenced in a sea in which were deposited the Upper Cretaceous limestones of Bachowice. The volcanic activity had in this period, as determined by Wieser (1952), a submarine character; spilites and dacite tuffes were its product. Towards the end of the Cretaceous, in consequence of Laramian movements, the Upper Cretaceous deposits, together with their Jurassic base and crystalline basement, were uplifted in the form of an island probably a small one. On this island there was an active volcano which produced the tuffs that are observable in the tuffite bed (or beds) encountered in the Bachowice area already in association with Early Tertiary deposits.

Some violent eruption brought about the flow of volcanic dust which slid down a declivity into the sea, together with the detritus of older tuffs, and with the talus and blocks of rocks belonging to the volcanic substructure that was shaken by the explosion; burdened with the conveyed material, the sea-bottom slumped and the volcanic material, the blocks and detritus were intermixed with the clayey deposits of the sea-bottom. Involved in this movement were also the tuffite beds and the underlying marly deposits of the Upper Cretaceous; only in such a manner are we able to explain the existence of bands of Upper Cretaceous marls mingled with Early Tertiary marly clays.

It may be that the above-mentioned volcanic eruption caused a disappearance of the „mystery island", the remains of which, in consequence of the eruption were buried in the deposits of the Sub-Silesian basin. Due to his cataclysm, introduced into the Carpathian Flysch were rocks that nowhere else had a chance of deposition into the sediments of the Carpathian sea.

IX. CONCLUSIONS

The examination of the exotic series of Bachowice makes possible a reconstruction of a geological structure that at present does not occur at the surface, and also a reconstruction of its history. This structure existed within the Carpathian geosyncline.

The reconstruction is based on fragmentary material, rendered incomplete by an intricate geological history and probably incompletely extracted from the deposit. Nevertheless, this material is sufficiently abundant and so extremely interesting that the author cannot restrict himself to its description alone; an attempt should be made to reconstruct, in time and space, one of the most amazing phenomena in Carpathian geology.

The extraordinariness of this phenomenon consists in the following facts.

The cristalline basement on which were deposited the sedimentary series of Bachowice was different from the crytalline basement that can be reconstructed from other occurrences of Carpathian exotics. This follows clearly from W i e s e r's work (1952); he states that only in the exotics of the Sub-Silesian series exist certain analogies to the Bachowice tonalites.

The Jurassic, an almost complete sequence of which can be reconstructed from the Bachowice exotics, is different both from the foreland Jurassic and any Jurassic whatever that is known in the Carpathians.

The limestone Cretaceous of Bachowice has no counterpart in any deposits of the Carpathians or their foreland.

The characteristics of the rocks of the crystalline basement, as well as those of the Jurassic and Cretaceous rocks, are such that in no case could they be local deposits; their distributional area must have been extensive.

So much more astonishing is the fact that with the exception of tuffites, no rock of the Bachowice type has been discovered anywhere else in the Carpathian Flysch.

The above-mentioned facts are proof that in the geological history of the Carpathians certain processes came into being and brought about a complete disappearance from the surface of deposits, the existence of which would not even be suspected if it were not for their remains in the Bachowice exotics.

The crystalline basement of Bachowice was probably covered directly by the Lower Carboniferous and subsequently by the Upper Carboniferous. Very little is known of the history that followed the Carboniferous and preceded the Jurassic; it is possible that the Bachowice area was submerged for a certain time by the Trias sea.

Beginning with the Aalenian, marine deposits were formed. A gradual deepening of the sea, with certain oscillations and even interruptions, lasted throughout the Middle and Upper Jurassic, attaining its culmination in the Kimmeridgian and Lower Tithonian. In a trough bordered on both its sides by lands edged with coral reefs in the Tithonian there is produced a specific series of deposits of the Bachowice Jurassic. In the Lower Cretaceous a shallowing and emersion takes place, prior to the Cenomanian or earlier.

It is not known of what character was the above-mentioned emersion. Perhaps it was only some phenomenon that was synorogenic with the Austrian stage, but it is also possible that it was an uplift associated with a folding movement. In the latter case it would be easier to understand that the bathyal series was subjected to emersion.

One way or the other, emerged before the Cenomanian was a Jurassic ridge that must have formed a cordillera within the Carpathian geosyncline. This cordillera was situated at a distance of at least 40 kilometres from the present northern border of the Carpathians.

In the Cenomanian the Bachowice cordillera became again partly submerged. Troughout the Upper Cretaceous, on the Jurassic beds that were continuously eroded and that supplied the Cretaceous sea with detritus and pebbles, deposited were Upper Cretaceous limestones with a facies which was completely different from any other occurrences of the Upper Cretaceous in the Carpathians. The type of deposits with variegated colours has an Alpine character (Seewer Kalk, couches rouges), and in the foraminiferal fauna rich in planktonic elements there is a predominance of influences of warm southern seas.

The Upper Cretaceous limestones are deposited until the Campanian, or even the Mastrichtian, producing most probably a continuous series of deposits. In the Campanian, volcanic action is in evidence, at first of a submarine character. It is possible that directly on the Bachowice limestones were deposited variegated marls of the highest Senonian in the same facies that existed in the Sub-Silesian basin which was situated somewhere in close neighbourhood. In the latter basin the variegated marls lie on Flysch deposits that are lacking in the Bachowice series. The currents carrying the clastic material which produced the Flysch did not perhaps penetrate into these parts of the basin, and consequently in the Bachowice series there is a complete lack of the Flysch. It is known from elsewhere that a zone with a non-Flysch character of its deposits run along the middle of the Flysch geosyncline, beginning with the Albian or Cenomanian (K s i ą ż k i e w i c z, 1949, 1952). It is possible that some parts of this axial zone were free from Flysch deposits also in the Lower Cretaceous.

The termination of sedimentation in the limestone series of Bachowice was probably associated with a complete submersion of the Jurassic cordillera. Its existence probably caused the abundant flourishing or the retention of a current-borne plankton. The disappearance of the cordillera brought about a change in the conditions of sedimentation.

At the transition of the Cretaceous into the Tertiary, the cordillera reappears. It may be that its reappearance was marked only by the emersion of a small volcanic island, and not, as previously, by the appearance of an extensive ridge causing the sedimentation of calcareous deposits. Marine abrasion or, as is more probable, a powerful explosion brought about a disappearance of the ephemeral island. However, due to the island's emersion, the rich inventory of geological deposits of the zone from which the island emerged could be recorded in the rocky talus that was introduced into the Early Tertiary deposits of the Sub-Silesian series.

During the Tertiary compression of the geosyncline, not all of its sedimentary contents were caught up in folds and nappes in such a manner as to become observable at the surface in consequence of subsequent erosion. Planes of shearing and stripping-off were formed at the base of the Lower Cretaceous, and the masses underlying these planes remained deep below, and were not drawn into folding masses. Consequently, only exceptionally does the Jurassic enters the Flysch structures. The Bachowice Jurassic, deposited in a deep trough, had smaller chances of being included within surface folds than the Jurassic adhering to elevated parts of the substratum, such as the Jurassic of Stramberg, Inwałd, or Kruhel. Not being sheared off from the substratum, it remained deep below and far to the south, while the Flysch masses deposited still farther south could be sheared off and translocated far northward. The same fate was shared by the Bachowice Cretaceous, accreted directly to the Jurassic substratum and not separated from the latter by any clayey deposits that would facilitate stripping off.

One more agency could have participated in causing that the Jurassic--Cretaceous series was not included in the Carpathian folds. These deposits, as explained above, were deposited in the axial zone, free from Flysch sedimentation. During the compression of the geosyncline, the deposits of this zone were probably drawn deep down and not pushed upwards like the neighbouring Flysch deposits that were forced one on the other from the borders of the narrowing geosyncline. The deep-lying substratum of the axial zone, together with the crystalline basement and its overlying Bachowice Jurassic and Cretaceous, was thus „swallowed" and concealed underneath the charriage-borne masses of the stripped off Flysch masses.

If it were not for the course of events, at the transition of the Cretaceous into the Tertiary, that produced the colluvial bed with exotics, there would be no way of knowing what was the aspect of the substratum and deposits of the axial zone in the Flysch geosyncline of the Carpathians. The exotics of Bachowice shed a beam of light on the problem concerning the substratum and they indicate that the paleogeography and evolution of the „Flysch" geosyncline in the Carpathians was more complicated than might be supposed on the basis of facts known only from the surface structure of the Flysch Carpathians.

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