Foraminifers and biostratigraphy of Upper Triassic and Lower Jurassic of the Slovakian and Polish Carpathians (plates 27-41)

Numerous benthonic foraminifer assemblages (comprising 104 species) were found in Upper Triassic-Lower Jurassic strata in the West Carpathians of Slovakia and Poland. A sequence of three foraminifer zones is recognized: *Triasina oberhauseri* Partial-range Zone (Norian), *Glomospirella friedli* and *Triasina hantkeni* Assemblage Zone (Rhaetian), and *Ophthalmidium leischneri* and *Ophthalmidium walfordi* Assemblage-Zone (Hettangian-?Sinemurian) — defining basal part of the Jurassic system in the Carpathians. This subdivision is correlated with standard ammonoid and conodont zonations. The studied foraminifer assemblages were related to lagoon areas and biostromal elevations in shelf zone with predominating carbonate sedimentation. Evolutionary trends in *Involutinidae* and *Ammodiscidae* in Late Triassic and Early Jurassic are analysed. In taxonomic composition and stratigraphic distribution the Triassic and Jurassic foraminifer assemblages of the West Carpathians do not differ from contemporaneous assemblages known from other parts of the Tethys Realm. The Lower Jurassic assemblage from West Carpathians displays some similarity to foraminifer assemblage known from epicontinental basin of north-western Europe.

Key words: Foraminifers, Upper Triassic — Lower Jurassic, Biostratigraphy, West Carpathians.
od równowieczowych zespołów z innych rejonów Tetydy. Ponadto zespół dolnojurajski z Karpat Zachodnich wykazuje pewne podobieństwo do równowieczowego zespołu z epikontynentalnego basenu północno-zachodniej Europy.

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INTRODUCTION

Marine Upper Triassic and Lower Jurassic strata exposed in the West Carpathians of Slovakia and Poland contain numerous biostratigraphically significant benthonic foraminifers. The 33 representative sections of the investigated strata in the Taticum, Fatricum, Hronicum and Silicicum have been measured and sampled in order to establish a vertical dis-
Fig. 1

a — profiles enclosing Upper Triassic deposits, b — profiles enclosing Upper Triassic and Lower Jurassic deposits, c — profiles enclosing Lower Jurassic deposits.
tribution of the foraminifers and associated biota (fig. 1). About 1,100 thin sections have been prepared, over 800 of which contained foraminifers. One hundred and four benthonic foraminifer species have been found in the investigated sequence. Of these, 79 are calcareous forms and 25 are agglutinated. Foraminifers are fairly common in the deposits of the Norovica and Fatra Formations (uppermost Triassic) and lower and upper limestones of Kopieniec Formation (Lower Lias).

The stratigraphic position of the Upper Triassic strata from the West Carpathians was determined by conodont studies (Mock 1971, 1975; Kozur and Mock 1974a; Gaździcki 1978a, b; Gaździcki et al. 1978, 1979a). This made possible the determination of the age of foraminifer-bearing samples and correlation of stratigraphic ranges of foraminifers in West Carpathians and other regions of the Tethys Realm.


The investigated foraminifer collections (thin sections) are housed in: Institute of Paleobiology of the Polish Academy of Sciences, Warszawa; Institute of Geology of the Slovak Academy of Sciences, Bratislava; Department of Geology and Paleontology of the Faculty of Natural Sciences J. A. Comenius University, Bratislava; and Institute of Geology of the Warsaw University, Warszawa.

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Abbreviations used:
GUSA V — Institute of Geology, Slovak Academy of Sciences, Bratislava
IGP — Institute of Geology, University of Warsaw, Warsaw
PFUK — Department of Geology and Paleontology, J. A. Comenius University, Bratislava
ZPAL — Institute of Paleontology, Polish Academy of Sciences, Warsaw
The studies on benthonic foraminifers of the Upper Triassic and Lower Jurassic of the West Carpathians were carried out on thin sections from samples carefully taken in individual sections (figs 1, 5-12). In the studied rocks, foraminifers are fairly common and relatively well-preserved. A great variability of sections of foraminifer tests made fairly accurate and reliable identifications (figs 5–12) possible. The studies covered about 1,100 thin sections (about 2.5 cm \( \times \) 3.0 cm in size), over 800 of which yielded foraminifers. The number of foraminifers in a thin section is ranging from a few to over 300, about 50 on the average. About 25,000 of various sections of foraminifer tests were analysed in detail, the majority of which was identifiable (see pls 31–41).

The thin section method is especially useful in studies on foraminifers of the family Involutinidae, fairly common in the Upper Triassic and Lower Jurassic and of high stratigraphic and paleogeographic value. Generic and specific identifications of involutinids are based on internal structure of the test, observable in thin sections. Even in the case of random orientation, two or three sections are sufficient for determination of structural type of a test.

It should be noted that the thin section method appeared highly successful and it becomes increasingly popular in studies on calcareous foraminifers, especially those occurring in hard carbonate rocks.

**GEOGRAPHIC AND GEOLOGIC SETTING**

Upper Triassic and Lower Jurassic rocks crop out in several place in the West Carpathians of Slovakia and Poland (fig. 1). They are highly variable in facies development, reflecting changes in sedimentary basin of the Carpathians at the turn of the Triassic and Jurassic. The changes are indicated by lateral variability and succession of rocks in individual paleotectonic-facies zones in the West Carpathians (fig. 2).

The present study covers outcrops of the relevant rocks in the Strážovská hornatina Mts., Malá Fatra Mts., Velká Fatra Mts., Nizke Tatry Mts., Tatra Mts., Slovenské rudohorie Mts., and Slovenský kras (see fig. 1). Thirty three sections of the investigated strata were measured and sampled in order to establish succession of facies and distribution of foraminifers and associated biota. A special attention was paid to rocks of the Fatra Formation and Kopieniec Formation in the Fatricum, Norovica Formation and Hybe Beds in the Hronicum, Bleskový prameň Lmst., and Zlambach Beds in the Silicicum and Lias of the Taticum in the Velká Fatra Mts., on account of the presence of very rich and highly diversified assemblages of benthonic foraminifers.

The studies recently carried out by Michalík et al. (1979), Gaździcki et al. (1979b), Gaździcki and Michalík (1980) and Michalík (1980) made possible lithostratigraphical subdivision of the Upper Triassic and Lower Jurassic sequences in the Fatricum and Hronicum in the West Carpathians (figs 3–4).

The Fatricum sequence was divided into four formal lithostratigraphic units: Carpathian Keuper Group and Fatra, Kopieniec and Janovky Formations, further subdivided into several informal members (see fig. 3). This sequence is about 200 m thick, ranging in age from Norian to Sinemurian (Gaździcki et al. 1979b).

The uppermost Triassic deposits of the Hronicum (Norovica Formation) are only fragmentarily preserved, as in several places they have underwent an erosion due to Early Kimmerian tectonic phase (Gaździcki and Michalík 1980, fig. 1). The Norovica Formation overlies the Hauptdolomit and underlies the Lower Lias crinoidal limestones (fig. 4). Three members are
Fig. 2

DISTRIBUTION OF FORAMINIFERS AND ASSOCIATED BIOTA

A detailed analysis of distribution of foraminifers and associated biota in deposits of the Upper Triassic and Lower Jurassic covers eight sections (figs 5–12) representing different paleotectonic-facies units in the West Carpathians (fig. 2). Sedimentary sequences and frequency distribution of foraminifers in the sections studied are given separately for Upper Triassic and Lower Jurassic.

Upper Triassic sequences

Foraminifers are especially numerous in rocks of the uppermost Triassic in the Fatricum, Hronicum and Silicicum but they are also present in the Tatricum in the Tatra Mts.

Tatricum. — The uppermost Triassic deposits of this unit in the Tatra Mts are developed either as clastic complex with plant remains (Tomanová Formation) or clastic-carbonate rocks with marine fauna (RADWAŃSKI 1968, MICHALÍK et al. 1976, MICHALÍK 1980). Foraminifers were found in clastic-carbonate complex in Mt. Kopieniec Starorobociarski section only (3), where they are represented by single, poorly preserved tests of the genus *Frondicularia*, occurring in sandy biomicrites. Moreover, RADWAŃSKI (1968) reported the presence of *Lenticulina*...
**U. TRIASSIC — L. JURASSIC FORAMINIFERS AND BIOSTRATIGRAPHY**

<table>
<thead>
<tr>
<th><strong>Formation</strong></th>
<th><strong>Age</strong></th>
<th><strong>Stratigraphic Units</strong></th>
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<tbody>
<tr>
<td><strong>Janovky</strong></td>
<td>SINEMURIAN</td>
<td>spotted limestones</td>
</tr>
<tr>
<td></td>
<td></td>
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</tr>
<tr>
<td><strong>Kopiľniec</strong></td>
<td>HETTANGIAN</td>
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<td></td>
<td></td>
<td>main claystones</td>
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<tr>
<td></td>
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<tr>
<td></td>
<td></td>
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<td><strong>Fatra</strong></td>
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</tr>
<tr>
<td></td>
<td></td>
<td>upper biostrome</td>
</tr>
<tr>
<td></td>
<td></td>
<td>barren interval</td>
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<tr>
<td></td>
<td></td>
<td>lower biostrome</td>
</tr>
<tr>
<td></td>
<td></td>
<td>basal beds</td>
</tr>
<tr>
<td><strong>Carpathian</strong></td>
<td>NORIAN (Sevatan)</td>
<td>upper dolomites</td>
</tr>
<tr>
<td><strong>Keuper</strong></td>
<td></td>
<td>main claystones</td>
</tr>
</tbody>
</table>

Fig. 3

Lithostratigraphic subdivision of the Upper Triassic and Lower Jurassic sequence of the Fatricum in the West Carpathians.

*sphaerica Kübler and Zwingli, Frondicularia woodwardi Howchin and Cornuspira* sp. from the Za Kiczerem Valley section but the latter are without any greater stratigraphic value.

*Fatricum.* — In that paleotectonic-facies unit, the Upper Triassic sequence is represented by the Carpathian Keuper Group and Fatra Formation (figs 2–3). Rocks of that age are cropping out in several places in the West Carpathians of Slovakia and Poland (fig. 1, see also Goetel 1917, Michálík 1973, 1974, 1977, 1978a, b, Gaździcki 1974, Gaździcki et al. 1979b). The sequence is here characterized in reference to the Mt. Veľká Furkaska section (17) in the Tatra
Crinoidal limestones of Lower Lias

HETTANGIAN

<table>
<thead>
<tr>
<th>FORMATION</th>
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<th>RHAETIAN</th>
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<tbody>
<tr>
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<td></td>
</tr>
<tr>
<td>Siwa Woda</td>
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<tr>
<td>Lower</td>
<td></td>
<td>?NORIAN</td>
</tr>
<tr>
<td>Hauptdolomit</td>
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<td>NORIAN</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CARNIAN</td>
</tr>
</tbody>
</table>

Fig. 4
Lithostratigraphic subdivision of the uppermost Triassic sequence of the Rhoricum in the West Carpathians.

Mts and Križna Valley section (12) in the Velká Fatra Mts (figs. 5–6). Foraminifers are exceptionally rare in rocks of the Carpathian Keuper Group, except for upper dolomites in the Mt. Velká Furkaska section (17). In that locality, numerous representatives of *Agathammina austroseapina* KRISTAN-TOLLMA NN and TOLLMA NN (pl. 37: 1–5), were found to occur along with single ostracodes in dolomitic matrix. Foraminifers were also found in the Lejowa Valley I section (18) in identical stratigraphic position. The findings are worth noting as these are first records of foraminifers in the Carpathian Keuper Group.

The overlying Fatra Formation comprises dark-gray compact organodetrital limestones with intercalations of loferitic dolomites, marls, and shales rich in faunal remains (figs 5–6, see also GOETEL 1917, GAZDZICKI 1974, MICHALIK and JENDREJÁKOVÁ 1978, MICHALIK 1978a, b). The Formation was subdivided into some informal lithostratigraphic units: basal beds, lower biostrome, barren interval, upper biostrome, and transitional beds (figs. 3, 5–6; see also MICHALIK et al. 1979, GAZDZICKI et al. 1979b).

Rich foraminifer assemblages comprising representatives of the families Ammodiscidae and Involutinidae mainly occur in lower and upper biostromes (see figs 5–6). In subordinate amount, there also occur Tetrataxidae, Miliolidae and Nodosariidae, whereas associations comprising the highest numbers of individuals are formed by *Glomospirella friedii* KRISTAN-TOLLMA NN (pl. 27:1), *Triasina hantkeni MAJZON* (pl. 27: 2, pl. 30:3, 5) as well as *Aulotortus tumidus* (KRISTAN-TOLLMA NN) (pl. 30: 1) and *Toelypmammin gregaria* WENDT (pl. 27: 1). The foraminifers were found in organodetrital limestones, mainly brachiopod-crinoid-coral biomicrites and biosparites (pl. 27: 1–2). Some predominance of the genera *Glomospira* and *Glomospirella* is noted in rocks containing admixture of detrital quartz.

In rocks of the Fatra Formation, foraminifers are most often accompanied by algae: *Thaummatoporella parvovesiculifera* (RAINERI) and *Aciculella* sp., corals: *Retiothylla cloathrata* (EMMRICH), *Astraeomorpha crassisepta* REUSS and *Phacelostyphillum robustum* RONIEWICZ, brachiopods mainly belonging to *Rhaetina gregaria* (SUESS) and *Zugmayerella uncinata* (SCHAF-
Detailed section of the Carpathian Keuper and the Fatra Formation (Upper Triassic) at the Velká Furkaska Mt., West Tatra Mts.; the section (17 in fig. 1) comprises lithology as well as frequency and distribution of foraminifers.

Lithology: 1 limestone, 2 sandy limestone, 3 nodular limestone, 4 oolitic limestone, 5 coral limestone, 6 brachiopod limestone, 7 Megalodon limestone, 8 gastropod limestone, 9 lamellibranch, 10 crinoid limestone, 11 organo-detrital limestone, 12 dolomite, 13 loferitic dolomite, 14 marl, 15 marly shale, 16 sandstone, 17 breccia, 18 belemnites, 19 erosion surfaces, 20 dislocations.

Total frequency of foraminifers: 1: 1-10 specimens, 2: 11-30 specimens, 3: 31-50 specimens, 4: 51-70 specimens, 5: more than 70 specimens in thin section from a given layer.

Distribution of foraminifers presenting number of specimens of a definite species or genus in thin section from a given layer: a — rare (1-5 specimens), b — frequent (6-25 specimens), c — abundant (more than 25 specimens).
Fig. 6
Detailed section of the Fatra Formation (uppermost Triassic) in the Kremnica Valley, Velka Fatra Mts. (12 in Fig. 1); explanations as for fig. 5.

### Total frequency

- Glomospira sinensis
- Glomospira sp.
- Glomospirella faellis
- Glomospirella friedi
- Glomospirella parallela
- Polyommina gregaria
- Ammobaculites sp.
- Trochammina alpina
- "Tetrataxis" inflata
- "Tetrataxis" sp.
- Agathammina austroalpina
- Planinovolutes carinata
- Hodosaria sp.
- "Prondicularia woodwardi"
- Aulotortus communis
- Aulotortus goschel
- Aulotortus sinuoseum
- Aulococcyx tumidus
- Aulotortus sp.
- Aulococcyx permodisocoides
- Triasina hantkeni

**Zone**

**friedi and hantkeni**
HÄUTL) and pelecypods: *Chlamys winkleri* STOPPANI, *Lopha haidingeriana* (EMMRICH) and *Placunopsis alpina* WINKLER (comp. MICHALÍK and JENDREJÁKOVÁ 1978, GAŻDZICKI et al. 1979b, MICHALÍK et al. 1979).

Hronicum. — The uppermost Triassic deposits in the Hronicum of the West Carpathians are fragmentarily preserved (figs. 1–2). These are mostly light-grey, compact, organodetrital limestones resembling Dachstein Limestones. The sequence is assigned to the Norovica Formation (GAŻDZICKI and MICHALÍK 1980). Only in Hybe section (Hybe Beds), the uppermost Triassic...

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<table>
<thead>
<tr>
<th>Zone</th>
<th>Total Frequency</th>
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<td>12345</td>
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**Fig. 7**

Detailed stratotype section of the Norovica Formation (uppermost Triassic) at the Norovica Mt., Strážovská hornatina Mts. (22 in fig. 1); explanations as for fig. 5.
Detailed palynological section of the Norovica Formation (uppermost Triassic) at the Chochelowska Valley, West Tatra Mts. (Fig. 8)
Triassic strata are represented by dark limestones intercalated by marls and marly shales (Stache 1868, Michalík 1973, Gażdzicki et al. 1979). Sedimentary sequence and frequency distribution of foraminifers in Norovica Formation is presented in reference to Mt. Norovica section (22) in the Strážovská hornatina Mts (fig. 7) and Chocholowska Valley section (26) in the Tatra Mts (fig. 8). Foraminifers were found in both Siwa Woda Limestone and Mojtin Limestone Members (figs. 7–8).

In the Chocholowska Valley section (26), sandy biopelsparites of the Siwa Woda Limestone Member yield innumerable foraminifers identified as Glomospira sp., Trochammina alpina Kristan-Tollmann, Agathammina austroalpina Kristan-Tollmann and Tollmann, Nodosaria sp., and very rare Glomospirella friedli Kristan-Tollmann (fig. 8). Triasina hantkeni Majzón appears at the top of this member. It is worth to note that Triasina hantkeni co-occurs in the uppermost part of this member with stratigraphically important conodonts Misikella posthernsteini Kozur and Mock (see Gażdzicki 1978a, b; Gażdzicki and Michalík 1980). This is the first locality where these fossils so important for stratigraphy of the uppermost Triassic made their appearance.

Very rich foraminifer assemblages comprising representatives of the families Involutinidae and Ammodiscidae were encountered in crinoid-brachiopod oosparites of the Mojtin Limestone Member (figs. 7–8). Here the abundant associations of Triasina hantkeni Majzón (pl. 28: 2, pl. 30: 4) and Glomospirella friedli Kristan-Tollmann (pl. 28: 1) were also found. It should be noted that the frequency of involutinids in those rocks is incomparably higher than in the remaining uppermost Triassic sequences in the West Carpathians.

Besides the above mentioned conodonts Misikella posthernsteini Kozur and Mock, the fossils accompanying foraminifers (see figs. 7–8) most often include algae Aciculella sp., corals Phacelostylophyllum robustum Roniewicz, and Cyathocoeina schaafhaulli Winkler, brachiopods Rhaetina gregaria (Suess) and Zugmayerella uncinata (Schaafhäuttl), and pelecypods Atreta intusstriata (Emmrich), Rhaetavicula contorta (Portlock) and Placunopsis alpina Winkler (see Gażdzicki and Michalík 1980).

Hybe (25) is the best known locality of so called “Kössen Beds” in the Slovak Carpathians, a classical locality on account of its rich fauna (Goetel 1917, Kouteck 1927, Michalík 1973, 1975, 1976, 1977b). The Upper Triassic sequence is represented here (fig. 9) by Hauptdolomit of Carnian and Norian age, bedded light-grey Dachstein Limestone (Norian), and the Hybe Beds — consists of black limestones and marls with rich Rhaetian fauna.

In this sequence the following foraminifers were found (for location of samples see fig. 9).
Samples 1-3 (biopelmicrites) yielded:

- *Aulotortus* sp.
- *Aulotortus gaschei* (KOEHN-ZANINETTI and BRÖNNIMANN)

Samples 4-8 (mainly bioosparites) yielded:

- *Trochammina alpina* KRISTAN-TOLLMANN
- *Alpinophragmium perforatum* FLÜGEL
- *Agathammina austroalpina* KRISTAN-TOLLMANN and TOLLMANN
- *Miliolipora cuvillieri* BRÖNNIMANN and ZANINETTI
- *Nodosaria ordinata* TRIFONOVA
- *Aulotortus communis* (KRISTAN)
- *Aulotortus gaschei* (KOEHN-ZANINETTI and BRÖNNIMANN)
- *Aulotortus tumidus* (KRISTAN)
- *Triasina oberhauseri* (KOEHN-ZANINETTI and BRÖNNIMANN) (fig. 21a, b)
- *Aulococus permodicosoides* (OBERHAUSER)

Such association of foraminifers suggests the Norian (?Sevatan) (*Triasina oberhauseri* Zone) age of rocks bearing them.

Samples 9-12 (brachiopod-crinoid biosparite) yielded:

- *Glomospirella friedli* KRISTAN-TOLLMANN
- *Glomospirella pokornyi* (SALAJ)
- *Glomospirella parvella* KRISTAN-TOLLMANN
- *Trochammina alpina* KRISTAN-TOLLMANN
- *Tetrataxis inflata* KRISTAN
- *Agathammina austroalpina* KRISTAN-TOLLMANN and TOLLMANN
- *Miliolipora cuvillieri* BRÖNNIMANN and ZANINETTI
- *Planiinvoluta carinata* LEISCHNER
- *Nodosaria ordinata* TRIFONOVA
- *Lingulina aff. plackiensis* KRISTAN-TOLLMANN
- *Aulotortus communis* (KRISTAN)
- *Aulotortus gaschei* (KOEHN-ZANINETTI and BRÖNNIMANN)
- *Aulotortus tumidus* (KRISTAN-TOLLMANN)
- *Aulotortus sinusus* WEYNSCHENK
- *Triasina oberhauseri* KOEHN-ZANINETTI and BRÖNNIMANN
- *Aulococus permodicosoides* (OBERHAUSER)

The foraminifer association is indicative of the Rhaetian age — *Glomospirella friedli* and *Triasina hantkeni* Zone as defined here. However, it should be noted that one of the index fossils, *Triasina hantkeni* MAIZON, is still unknown from the Hybe section (see GAZDZICKI 1978b, GAZDZICKI et al. 1979a).

Hybe Beds yield rich assemblages of brachiopods, pelecypods, corals and echinoderms (GOETEL 1917, MICHALÍK 1973, 1975, 1976, 1977b). Moreover, ammonites *Arcestes* (*Rhaetites*) cf. *raeticus* CLARK and conodonts *Misikella posthersteinii* KOZUR and MOCK, were found in this sequence (ANDRUSOV 1934, MAJERSKÁ 1973).

Silicicum. — In this region, the uppermost Triassic is represented by Bleskový prameň Limestone and Zlambach Beds (fig. 2).

The Bleskový prameň Limestone forms lenses of grey crinoidal limestones above top part of the Furmanec Limestone near Drnava in Slovenský kras (fig. 10). These crinoid-coquinal limestones contain rich macrofaunal assemblages composed mainly of brachiopods, pelecypods and cephalopods (KOLLÁROVÁ-ANDRUSOVÁ and KOCHANOVÁ 1973, MELLO 1974).

The following foraminifers were found (sampling as shown in fig. 10).

- *Glomospirrella* sp.
- *Ammobaculites* sp. (pl. 36:14)
- *Tolypammina grayaria* WENDT
red nodular and crinoidal limestones
sample: BP-3

brecciated limestones with belemnites
sample: BP-2

dark-gray limestones
with lenses of crinoidal biosparite
samples: BP-1. 166/1, 166/2, 166/3-D₁, 166/3-D₂, 166/5-D₄ and Dr.

Fig. 10
Section of the Upper Triassic and Lower Jurassic deposits at Bleskový prameň, Slovenský kras (32 in fig. 1). Section adopted from MELLO and BYSTRICKÝ, 1973.

Trochammina alpina KRISTAN-TOLLMANN
Agathammina austroalpina KRISTAN-TOLLMANN and TOLLMANN
Planiinvoluta carinata LEISCHER
Ophthalimidium “carinatum” (LEISCHER)
Ophthalimidium cf. carpathicum (GAŻDZICKI) (pl. 37:11)
Ophthalimidium martanum (FARINACCI) (pl. 37:12)
Galeunella cf. tollmanni (KRISTAN) (pl. 37:15).
Milolipora cavillieri BRÖNNIMANN and ZANINETTI
Diplotrema sp.
Aulotortus communis (KRISTAN)
Aulotortus gaschei (KOHN-ZANINETTI and BRÖNNIMANN)
Aulotortus tenuis (KRISTAN)
Involutina turgida KRISTAN
Triasina hantkeni MAJZON
Auloconus permodiscoides OBERHAUSER
The presence of the species *Galeanella cf. tollmanni*, *Involutina turgida* and *Triasina hantkeni* indicates the Rhaetian age of Bleskovy prameň Limestone (*sensu* Gądzicki et al. 1979a).

The Malý Mlynský vrch is the best locality of Zlambach Beds in the Slovenský kras (figs. 1–2, see also Mock 1973). These deposits comprise grey marly pelmicrites and marly and sandy shales. Conodonts and holothurian sclerites are listed in Mock (1973) and Kozur and Mock (1974a, b). Cephalopods are represented here by the genus *Choristoceras*. The rocks range in age from the Norian (Sevatian) to Rhaetian (see Gądzicki et al. 1979a).

The following foraminifers were found:

- *Glomospirella cf. pokornyi* (Salaí)
- *Tolypanmina gregaria* Wendt
- *Trochammina alpina* Kristan-Tollmann (pl. 36:7)
- *Ammobaculites* sp.
- *Planinnovoluta carinata* Leischner
- *Agathammina austroalpina* Kristan-Tollmann and Tollmann
- *Agathammina? iranica* Zannetti, Brönnmann, Bozorgnia and Huber
- *Ophthalmidium “carinatum”* (Leischner)
- *Ophthalmidium carpathicum* (Gądzicki) (pl. 37:9–10)
- *Ophthalmidium marianum* (Farinacci)
- *Ophthalmidium triadicum* (Kristan)
- *Nodosaria* sp.
- *Austrocolomia cf. rhaetica* Oberhauser
- *Turrispirillina cf. minima* Pantić

In this sequence, involutinids are missing. This may be explained by differences in facies development.

**Lower Jurassic sequence**

Foraminifers are fairly numerous in Lias rocks of the Fatricum and Silicicum. They were also found in Lias sequences of the Tatricum in the Velka Fatra Mts and Tatra Mts.

*Tatricum.* — Lias rocks of that unit were studies in the Rúbaň Skala section (1), the Velka Fatra Mts (fig. 1, see also Sýkora 1975; Polak 1978). Here mainly crinoid biomicrites with foraminifer assemblages comprising *Involutina liassica* (Jones), *Trocholina umbo* Frentzen, numerous nodosariids (*Nodosaria, Frondicularia, Astacolus, and Lenticulina*), *Ophthalmidium leischneri* (Kristan-Tollmann), and *Ophthalmidium* sp. (pl. 29:1) occur. Attention should be paid to the presence of *Ophthalmidium leischneri* — the index fossil of *leischneri* and *walfordi* Zone (Hettangian – ?Sinemurian). This was the first locality in which that species made their appearance in the Tatricum region.

Foraminifers are accompanied by rich fauna of pelecypods including *Eopecten rollei* (StolticzkA), *Plagiostoma punctata* Sowerby, and *Entolium lunare* (Roemer), and brachiopods — *Lobothyris punctata* (Sowerby), *Spiriferina alpina* OppeL, and *Spiriferina pinguis* (OppeL), confirming the Hettangian — Sinemurian age of the rocks bearing them (see Sýkora 1975).

In the Tatra Mts. Lias rocks are known, among others from following outcrops: Mt. Bobrowiec (2), Mt. Kopieniec Starorobocianski (3), Mt. Dudziniec (4), and Kobyla Glowa crag (5) (fig. 1, see also Radwański, 1959; WójciK 1979, 1981). They are represented by sandy biopelsparites and crinoid biosparites. Foraminifers are very rare here, being represented by *Glomospira* sp. (pl. 39:14), *Textularia* sp. and nodosariids (*Nodosaria, Frondicularia, and Lenticulina*), which do not have a stratigraphic value.

*Fatricum.* — In this unit, the Lower Lias is represented by detrital rocks: marly shales and quartz sandstones with marly and limestone intercalations (Goetel 1917; Mišik 1964; Gądzicki 1975), assigned to the Kopieniec and Janovky Formations (fig. 3, see also Gądzicki et al. 1979b). The Kopieniec Fm. rests in sedimentary continuity on the Fatra Fm. It is subdivided into the following informal lithostratigraphic units: basal clastics, lower limestones, main claystones, and upper limestones (figs. 3, 11–12; see also Gądzicki et al. 1979b).
Detailed section of the Kopieniec Formation (Lower Liasia) at the Wielka Furtaka Mt., West Tatra Mts. (17 in Fig. 1).

---

**KOPIENIEC FORMATION**

<table>
<thead>
<tr>
<th>Basal clastics</th>
<th>Lower limestones</th>
<th>Main claystones</th>
<th>Upper limestones</th>
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**Fig. 11**

Explanations as for **Fig. 5**.

---

**Zone**

- Clomospira sp.
- Cycogyra liasina
- Cycogyra sp.
- Planiinvoluta marinata
- Ophthalmedium leischneri
- Ophthalmedium walfordi
- Ophthalmedium sp.
- Modosaria crispata
- Modosaria metensis
- Modosaria sp.
- Dentalina sp.
- Frondicularia pupiformis
- Frondicularia sp.
- Astaclus sp.
- Lenticulina sp.
- Involutina farinacciae
- Involutina liassica
- Trocholina umba
- Trocholina sp.
Fig. 12
Detailed section of the Kopieniec Formation (Lower Liassic) in the Strzyżewka Valley II, Tatra Mts. (21 in Fig. 11), exca-

Kopieniec Formation

basal clastics  lower limestones  main claystones  upper limestones

---

- Glycospira sp.
- Cyrtaspira sp.
- Planispira carinata
- Ophthalmodium leischneri
- Ophthalmodium walfordi
- Ophthalmodium sp.
- Nodosaria claviformis
- Nodosaria martensii
- Nodosaria nitidana
- Nodosaria sp.
- Dentalina sp.
- Frondicularia pupiformis
- Geinitzinita sp.
- Marginulinina sp.
- Antacolus sp.
- Lenticulina sp.
- Involutinella lissica
- Involutinella cf. turgida
- Involutinella sp.
- Trocholina umbo

leischneri and walfordi

Zone

Total frequency
The sedimentary sequence was characterized in reference to the Mt. Velká Furkaska (17) and Strážyska Valley II (21) sections in the Tatra Mts (figs. 11–12). Foraminifers are most common in lower and upper limestones of the Kopieniec Formation especially in crinoid-biomicrites (pl. 29:2), being represented by the families Miliolidae, Nodosariidae and Involutinidae. Here predominate *Ophthalmidium leischneri* (KRISTAN-TOLLMANN), *Ophthalmidium walfordi* HÄUSLER, *Involutina liassica* (JONES), *Involutina farinacciae* BRÖNNIMANN and KOEHN-ZANNETTI, *Trocholina umbo* FRENTZEN and nodosariids are fairly common (figs 11–12). The co-occurring fauna includes *Gryphea arcuata* LAMARCK and *Pentacrinus cf. tuberculatus* MILLER (see GAŻDZICKI 1975) as well as numerous ostracodes.

*Silicicum.* — In that unit, Lias rocks are known to occur in the Bleskovy prameii and Miglinc localities (fig. 1). In lower parts, they are represented by brecciated limestones with belemnites, passing upwards into red nodular and crinoidal limestones (fig. 10). Foraminifers mainly found in crinoidal biomicrites (pl. 29:3), include nodosariids (*Nodosaria, Lenticulina*, and *Geinitzinita*) and single *Semiinvoluta* sp. (pl. 39:1) and *Trocholina turris* FRENTZEN (pl. 39:7).

**TAXONOMIC COMPOSITION OF FORAMINIFER FAUNA**

One hundred and four foraminifer species have been found in the investigated Upper Triassic — Lower Jurassic sequences of the Tatricum, Fatricum, Hronicum and Silicicum in the West Carpathians of Slovakia and Poland. Of these, 25 are agglutinated forms and 79 are calcareous. The majority of the recorded species are well known from other areas of the Tethys Realm (see ZANNETTI 1976) and also from epicontinental basin of the north-western Europe (see FRANKE 1936, BROUWER 1969 and SCHLOZ 1972), and therefore they are not systematically characterized herein. The systematic part includes besides species recorded for the first time in the West Carpathians also taxa of disputable systematic position and those of correlative importance.

The majority of the investigated foraminifers are, however, figured here (pls 27–41) to show their variability and to facilitate further discussion.


**Upper Triassic**

In the studied Norian-Rhaetian rocks, 65 species were identified and assigned to 16 families and 29 genera. Calcareous forms predominate here (43 species), being accompanied by the agglutinated ones (22 species).

The Upper Triassic (Norian-Rhaetian) foraminifer assemblage comprises following taxa:

**Family Ammodiscidae** REUSS, 1862

*Ammodiscus multivolutus* REITLINGER, 1949 — pl. 31:3.
*Ammodiscus* sp.
*Glomospira simplex* HARLTON, 1928
*Glomospira tenuifistula* HO, 1959
*Glomospira* sp. — pl. 31:10.
Glomospirella amplificata KRISTAN-TOLLMANN, 1970
Glomospirella parallela KRISTAN-TOLLMANN, 1964
Glomospirella pokornyi (SALAI, 1967) — pl. 31:1-2, 4-5.
Glomospirella shengi Ho, 1959 — pl. 31:16.
Glomospirella sp. — pl. 31:6; pl. 32:7-8.
Tolypammina gregaria WENDT, 1969 — pl. 27:3; pl. 33:15; pl. 35:9; pl. 36:2-6.

Family **Lituolidae** de BLAINVILLE, 1825

Ammobaculites sp. — pl. 36:14, 16.

Family **Textulariidae** EHRENBERG, 1838

Textularia sp.

Family **Trochamminidae** SCHWAGER, 1877

*Trochammina* sp. — pl. 36:8.
?Trochammina* sp. — pl. 36:9.

Family **Caligellidae** REITLINGER, 1959

*Alpinophragmium perforatum* FLÜGEL, 1967

Family **Moravaminidae** POKORNÝ, 1951

*Earlandia* sp.

Family **Tetrataxidae** GALLOWAY, 1933

*Duotaxis birmanica* ZANINETTI and BRÖNNIMANN, 1975

"*Tetrataxis*" *inflata* KRISTAN, 1957 — pl. 36:11-12.
"*Tetrataxis*" *nana* KRISTAN-TOLLMANN, 1964
"*Tetrataxis*" sp. — pl. 36:10, 13.

Family **Endothyridae** BRADY, 1884

*Endothyra* sp.

Family **Fischerinidae** MILLET, 1898

*Agathammina? iranica* ZANINETTI, BRÖNNIMANN, BOZORGINA and HUBER, 1972
Family **Miliolidae** **Ehrenberg, 1839**

(*Ophthalmidium* KÜBLER and ZWINGLI was hitherto assigned to the family Nubeculariidae JONES 1875. However, studies on wall microstructure, the mode of coiling, length of chambers in relation to whorl, and geometry of chamber interior and peristome (PAZDRO 1971), permit to classify that genus along with *Palaeomiliolina* LOEBLICH and TAPPAN to the family Miliolidae EHRENBERG).

**Ophthalmidium** "carinatum" (LEISCHNER, 1961)


**Ophthalmidium cf. carpathicum** (GAŻDZICKI, 1979) — pl. 37: 11.

**Ophthalmidium marianum** (FARINACCI, 1959) — pl. 37: 12.

**Ophthalmidium triadicum** (KRISTAN, 1957)

**Ophthalmidium** sp. — pl. 11: 13–14.

Family **Milioliporidae** **BRÖNNIMANN and ZANINETTI, 1971**


**Miliolipora cuvillieri** BRÖNNIMANN and ZANINETTI, 1971

**Miliolipora** sp.

Family **Nodosariidae** **EHRENBERG, 1838**

**Nodosaria ordinata** TRIFONOVA, 1965

**Nodosaria** sp. — pl. 37: 8.


**Austrocolomia** cf. *rhaetica* OBERHAUSER, 1967

**Austrocolomia** sp.

**Lingulina** aff. *placklesensis* KRISTAN-TOLLMANN, 1970

Family **Variostomatidae** **KRISTAN-TOLLMANN, 1963**

**Diplotremina** sp. — pl. 37: 16.

**Variostoma** sp.

Family **Involutinidae** **BÜTSCHLI, 1880**

**Aulotortus communis** (KRISTAN, 1957) — pl. 33: 1.

**Aulotortus gaschei** (KOEHN-ZANINETTI and BRÖNNIMANN, 1968) — pl. 32: 9–16.

**Aulotortus impressus** (KRISTAN-TOLLMANN, 1964) — pl. 34: 4.

**Aulotortus pragsoideus** (OBERHAUSER, 1964)


**Aulotortus sinuosus** WEYNSCHENK, 1956 — pl. 28: 2; pl. 34: 2–3, 5, 7–12.

**Aulotortus tenais** (KRISTAN, 1957) — pl. 33: 9–11.

**Aulotortus tumidus** (KRISTAN-TOLLMANN, 1964) — pl. 30: 1, pl. 33: 3–8.

**Aulotortus** sp. — pl. 33: 2, 13–16; pl. 34: 6.

**Aulocomas permodiscoides** (OBERHAUSER, 1964) — pl. 30: 2, pl. 35: 1–6.

**Trocholina acuta** OBERHAUSER, 1964

**Trocholina crassa** KRISTAN, 1957

**Triasina hantkeni** MAJZON, 1954 — pl. 27: 2; pl. 28: 2; pl. 30: 2–6; pl. 35: 7–15.

**Triasina oberhaueri** KOEHN-ZANINETTI and BRÖNNIMANN, 1968 — fig. 21a, b
Family Planispirillinidae PILLER, 1978

?Semiinvoluta sp. — pl. 33:12.

Family indet.

Turrispirillina minima PANTIĆ, 1967

The families Ammodiscidae and Involutinidae predominate in number of both species and individuals in the above foraminifer assemblage, being represented by 15 and 14 species, respectively. A special attention should be paid to numerous associations of foraminifers: Glomospirella friedli KRISTAN-TOLLMANN (pl. 27:1, pl. 28:1), Glomospirella pokornyi (SALAJ) (pl. 31:1), Tolypammina gregaria WENDT (pl. 27:3), Aulotortus tumidus (KRISTAN-TOLLMANN) (pl. 30:1), and Triasina hantkeni MAJZON (pl. 27:2, pl. 30:2–6), locally of rock-forming importance. There are six species of the family Miliolidae represented by single individuals only. The family Fischerinidae is represented by three species of which Agathammina austroalpina KRISTAN-TOLLMANN and TOLLMANN is locally (in upper dolomites of the Carpathian Keuper Group) fairly common (pl. 37:1). The remaining families occur in subordinate numbers. It should be noted that the studied material does not comprise Semiinvoluta clari KRISTAN which was previously reported from the West Carpathians (Hybe and Červená Skala sections) by SALAJ (1976, pl. 1:5; 1977, pl. 5:8), SALAJ et al. (1967, pl. 6:1, 3) and GAŻDZICKI et al. (1979a). A thorough analysis of thin sections from Hybe has not confirmed these reports. The misidentified forms represent subaxial sections of Aulotortus tumidus (KRISTAN-TOLLMANN).

Lower Jurassic

In the studied Lias rocks, there were identified 39 taxa of the specific or generic rank. They are assigned to eight families and 16 genera. Calcareous forms predominate here (36 species), being accompanied by only three agglutinated taxa.

The Lower Jurassic (Hettangian — Pliensbachian) foraminifer assemblage comprises the following taxa:

Family Ammodiscidae REUSS, 1862

Glomospira sp. — pl. 39:14.

Family Textulariidae EHRENBERG, 1838

Textularia sp. — pl. 39:17.

Family Trochamminidae SCHWAGER, 1877

Trochammina sp. — pl. 39:15.

Family Fischerinidae MILLET, 1898

Cyclogyra liasina (TERQUEM, 1866)

Cyclogyra sp. — pl. 39:16.


Family **Miliolidae** Ehrenberg, 1839


*Ophthalmidium* martanum (Farinacci, 1959) — pl. 39:11.

*Ophthalmidium* walfordi Häusler, 1887 — pl. 40:13-16.

*Ophthalmidium* sp. — pl. 39:10, 13.

**Family Nodosariidae** Ehrenberg, 1838

*Nodosaria claviformis* TerqueM, 1866

*Nodosaria* cf. *claviformis* TerqueM, 1866

*Nodosaria* crispata TerqueM, 1866

*Nodosaria* metensis TerqueM, 1863


*Nodosaria* nitidana Brand, 1937


*Nodosaria* sp. — pl. 41:8.

*Nodosaria* sp. — pl. 41:9.

*Dentalina* sp.

*Frondicularia pupiformis* Häusler, 1881

*Frondicularia* sp. — pl. 41:6.

*Geinitzinita* sp. — pl. 41:5.

*?Geinitzinita* sp. — pl. 41:7.

*Marginulina* sp.

*Astacolus* sp. — pl. 41:10-12.

*Lenticulina* sp. — pl. 41:13-16.

**Family Involutinidae** Bütschli, 1880


*Involutina liassica* (Jones, 1853) — pl. 29:1; pl. 38:1-12, 15.


*Involutina* sp. — pl. 38:16.

*?Involutina* sp. — pl. 39:2.

*Trocholina* umbo Frentzen, 1941 — pl. 39:3-4.


*Trocholina* turris Frentzen, 1941 — pl. 39:7.

*Trocholina* sp. — pl. 39:5.

**Family Planispirillinidae** Piller, 1978

*Semiinvoluta* sp. — pl. 39:1.

In this assemblage the families Nodosariidae and Involutinidae predominate in number of both species and individuals, being represented by 17 and nine species, respectively. Nodosariids are markedly diversified. Best represented in number of individuals are the genera *Nodosaria* and *Lenticulina*. Among involutinids the most important and numerous are *Involutina liassica* (Jones) and *Trocholina umbo* Frentzen.

The family Miliolidae is represented by the genus *Ophthalmidium*. *O. leischneri* (Kristan-Tollmann) forms monotypic associations composed of large numbers of individuals and is locally of marked rock-forming value in the studied Lower Lias sequence. *Ophthalmidium*
walfordi Häusler, was so far known only from the epicontinental basin of the north-western Europe.

The families Fischerinidae (with four genera) and Ammodiscidae, Textulariidae, Trochamminidae and Planispirilllinididae (with one genus each) occur in subordinate numbers.

**EVOLUTIONARY TRENDS**

The character of evolutionary trends of Triassic and Early Jurassic families Involutinidae and Ammodiscidae is analysed in reference to variability in size and microstructure of test, number and arrangement of whorls and chambers as well as stratigraphic distribution in the studied sequences of the West Carpathians. Attention is also paid to evolutionary changes traceable in most important representatives of the genus *Ophthalmidium* Kübler and Zwingli.

**Involutinidae.** — The family comprises two-chambered forms consisting of spherical proloculus and tubular deuteroloculus, the coiling of which may be streptospiral, planispiral, oscillating or trochospiral. Segmentation of deuteroloculus first appears in the genus *Triasina* Majzón and development of umbilical masses composed of numerous pillars — in the genera *Involutina* TerqueM and *Trocholina* Paalzow. Wall structure is built of numerous aragonite crystal needles, another important feature (see Hohenegger and Piller 1977a, Piller 1978).

Involutinids, on account of similarities in wall structure and test morphology, should be regarded as derivatives of Paleozoic family Archaediscidae Cushman 1928. The genus *Permodiscus* Dutkevich in Czernysheva 1948 (fig. 13, see also Oberhauser 1964) may represent a direct ancestor of the earliest involutinids.

Figure 13 inferred evolutionary trends of Triassic and Early Jurassic Involutinidae Bütschli from the West Carpathians. Broken lines show probable evolutionary connections.

The first link in evolutionary lineages of involutinids is *Mesodiscus eomesozoicus* (Oberhauser) which appeared in the Scythian and persisted at least till the end of the Carnian (see Gądzicki et al. 1975, Piller 1978). That species is characterized by planispiral coiling which may help tracing its origin back to the genus *Permodiscus*.

More advanced forms, representing the genus *Aulotortus* Weynschenk, first appeared in the Middle Triassic (Anisian). They include *A. pragsoideis, A. sinuosus,* and *A. praegaschei*. The latter is characterized by the most primitive type of test, including streptospiral pattern of test structure, and *Aulotortus sinuosus* and *A. pragsoideis* — by planispiral coiling of deuteroloculus. It should be added here that *A. sinuosus* still displays marked oscillations within the last whorls (pl. 34:7-9). It seems that the above species have evolved from the genus *Mesodiscus* in the latest Scythian.

A marked acceleration in evolution and radiation of involutinids may be noted in the Upper Triassic (Norian-Rhaetian). This is reflected by appearance of numerous new species of the genus *Aulotortus* (see fig. 13), including *A. impressus, A. communis, A. tenuis,* and *A. tumidus*. The species are characterized by planispiral pattern of test structure but they differ markedly from one another in test shape and number and arrangement of whorls. In the Norian, there also appears the genus *Triasina*. That genus is represented by highly characteristic and, at the same time, very short evolutionary line *T. oberhauseri → T. hantkeni*. The appearance of segmentation of deuteroloculus represents a new element in evolutionary lineage of involutinids and further evidence for progress in their radiation (see fig. 13). The above mentioned forms presumably evolved from the genus *Aulotortus* (most probably from *A. pragsoideis*) in the Late Carnian.

In the Norian, trochospiral *Auloconus permodisoides* (Oberhauser) appears. These forms
may be also regarded as derivatives of the genus *Aulotortus* (most probably from the species *A. tumidus*).

The accelerated radiation of involutinids in the Norian-Rhaetian times has been followed by sudden extinction of all of them at the turn of the Rhaetian and Hettangian (= Triassic/Jurassic boundary), except for *A. sinuosus*. The crisis was also survived by a few other species of *Involutina* and *Trocholina*, which did not appear before the Late Rhaetian: e.g. *Involutina liassica*, *I. turgida*, *I. farinacea*, and *Trocholinaumbo*, known also from the Lias. The latter species are characterized by planispiral or trochospiral pattern of coiling and umbilical masses composed of numerous pillars. The appearance of pillars most probably is a new element in evolutionary line of involutinids. Both *Involutina* and *Trocholina* seem to represent derivatives of the genus *Mesodiscus*, from which they may have evolved at the turn of the Carnian and Norian.

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Fig. 14
Stratigraphic distribution and suggested evolutionary trends of most important Triassic representatives of the family *Ammodiscidae* Reuss, 1862 in the West Carpathians.
Ammodiscidae. — In analysis of that family, attention was mainly paid to the genera *Glomospira* Rzehak and *Glomospirella* Plummer. They are characterized by irregular and planispiral pattern of test structure and test consisting of proloculus and undivided planispirally enrolled tubular chamber. Walls are very finely agglutinated. The family is especially common in the Middle and Upper Triassic of the West Carpathians.

Stratigraphically significant Anisian foraminifers include *Glomospira densa* and *Glomospirella grandis* (see Salaj et al. 1967, Borza 1970, Belka and Gaździcki 1976), which are presumably derivatives of the genus *Ammodiscus* Reuss.

In the Ladinian-Carnian strata, Ammodiscidae are rather innumerable and of limited value, except for the representatives of *Glomospirella gemenica* and *G. kuthani* (fig. 14, see also Salaj 1976).

Similarly as in the case of Involutinidae, the evolution of Ammodiscidae became markedly accelerated at the turn of the Norian and Rhaetian. At that time, a marked radiation took place (fig. 14) and several new species appeared: *Glomospirella parallela*, *G. expansa*, *G. pokornyi*, and finally *G. friedli* (figs. 5–9, see also Michalík et al. 1979).

The above mentioned crisis at the turn of the Triassic and Jurassic affected also Ammodiscidae. All their species known from the Norian-Rhaetian sequences in the West Carpathians became extinct at the end of the Triassic and only innumerable *Glomospira* sp. are present in the Lower Lias (pl. 39:14).

Ophthalmidiinae. — The analysis of phylogenetic relations within this subfamily is markedly impeded by insufficient knowledge, especially in the case of Triassic forms. In the studied sections, this subfamily is primarily represented by individuals of the genus *Ophthalmidium* (fig. 15). The oldest representative of that genus in the West Carpathians is *Ophthalmidium chialing-chiagensis* (Ho 1959), first recorded in the Upper Scythian and known to be especially numerous in the Anisian (see Gaździcki and Zawidzka 1973, Salaj 1977, 1980). That taxon presumably evolved from representatives of the Paleozoic genus *Hemigordius* Schubert 1908 (see Zannetti and Brönnimann 1969). *Ophthalmidium tricki* (Langer 1968) and *O. exiguum* Köhn-Zaninetti 1968 are known from the Anisian-Ladinian, and the latter — also from the Lower Carnian (Gaździcki et al. 1978, Salaj 1980).

*Ophthalmidium* is fairly rare in the Upper Carnian-Lower Norian strata of the West Carpathians, becoming more common and therefore of higher stratigraphic value from the Middle Norian upwards. This is connected with appearance of new species: *O. carpathicum*, *O. triadicum*, *O. "carinatum"* and *O. martanum*, the last two known also from the Lower Lias (fig. 15).

In the studied foraminifer assemblages from the West Carpathians, *Ophthalmidium* begin to predominate from the lowermost Lias (Hettangian-Sinemurian) upwards. The association of *O. leischneri*, often accompanied by *O. walfordi*, are especially numerous. Upper parts of the Jurassic section display maximum development of the genus *Ophthalmidium* (see Pazdro-Wa 1958, Pazdro 1972).

The recognized evolutionary lineages of foraminifers are especially important for evaluating stratigraphic value of these microfossils and for better understanding of their taxonomy.

SEDIMENTARY ENVIRONMENT WITH REMARKS ON FORAMINIFERAL PALEOECOLOGY AND TAPHONOMY

In the West Carpathians, the richest associations of Upper Triassic-Lower Jurassic benthonic foraminifers were found in rocks of the Fatra and Norovica Formations, Hybe Beds, Skalka Limestone, Bleskový prameň Limestone and Kopieniec Formation. The rocks originated in relatively shallow marine environments. Such nature of the environments is evidenced by
Fig. 15
Stratigraphic distribution of most important representatives of the genus *Ophthalmidium* Kübler and Zwinglei, 1870 in Triassic and Lower Jurassic of the West Carpathians.

the wealth of ooids and oncoids as well as various skeletal fragments. Among the later, there are present both fragments of sessile (sponges, corals, brachiopods, pelecypods, and crinoids) and vagile benthonic forms (gastropods, ophiuroids, echinoids and starfishes (see Čepek 1970, Gazdzicki 1974, 1975, Michalík 1978b, Michalík and Jendrejáková 1978, Gazdzicki and Michalík 1980). Locally, foraminifers are the major microfaunal components of the communities (see pls. 27: 1–2, 28: 2, 29: 1–2, 30: 1–6). Algal coatings around bioclasts or foraminifers tests are common (pls. 27: 3, 29: 1–2, 38: 13–15), giving further support to deposition in photic zone under shallow-marine conditions (see Sellwood 1978). The abundance of calcarenites is typical of shallow subtidal zone with high agitation of waters (Heckel 1972). The general lithological character of the rocks reflects some significant facies changes, related to uplifting movements from the turn of the Triassic and Jurassic (Early Kimmerian phase). The movements resulted in marked decrease of depth of the sedimentary basin in relation to
that from the Late Triassic, some sea regression at the turn of the Rhaetian and Hettangian (not leading, however, to emergence of land), and predominance of clastic deposits in basal part of Lias sequence (figs. 11–12). A new marine transgression has begun at the beginning of the Jurassic (Hettangian-Sinemurian). It is reflected by numerous intercalations of carbonate rocks rich in marine fossils in Lower Lias clastic sequence (figs. 11–12, see also ČEPEK 1970, GAŻDZICKI et al. 1979b).

Ecological distribution of benthonic foraminifers was analysed on the basis of the best known succession of the Fatra Formation (see MICHALIK and JENDREJÁKOVÁ 1978, MICHALIK 1978a, b; GAŻDZICKI et al. 1979b). Foraminifers are here primarily limited to biostromal elevations and lagoons in shelf zone, characterized by marked predominance of shallow-water carbonate deposits (fig. 16). The foraminifers display a specific pattern of distribution and, therefore, they appear to be good facies indicators (see fig. 16).

The foraminifers are most common in areas of biostromal elevations (fig. 16), built by algae, sponges, corals, and brachiopods. The elevations are inhabited mainly by Involutinidae and Ammodiscidae. The representatives of the sessile genus Tolypammina, often encrusting coral colonies, are especially numerous in central parts of such elevations. They are sometimes accompanied by Alpinophragmium. The family Involutinidae is here mainly represented by the genera *Aulotortus*, *Auloconus*, and *Triasina*, most common in inner parts of the elevations and forming associations especially rich in individuals (pls. 27:2, 30:3, 5). It is worth to note that involutinids inhabiting that zone are characterized by massive structure, and large (about 1 mm in size) and relatively thick walled tests. Such features of tests may be explained by high water turbulence (see MURRAY 1973, BOLTOVSKOY and WRIGHT 1976). In the area of biostromal elevations, the representatives of the genera *Glomospira* and *Glomospirella* appear somewhat less frequent than involutinids.

Involutinids and ammodiscids also predominate in lagoon zones, characterized by marly and marly limestone facies. Here predominate representatives of the genera *Aulotortus*, *Glomospira* and *Glomospirella*. The last two genera are mainly found in lagoon zones affected by supply of terrigenic material of psammite size from neighbouring land areas (see BELKA and GAŻDZICKI 1976). Relatively smaller associations are formed by *Triasina*, *Auloconus*, *Trochamina*, “*Tetrataxis*” and nodosariids. Involutinids occurring in the lagoon zone are characterized by smaller and finer tests than those from the biostromal elevations (see pl. 30:1), which may be explained by less turbulent waters as well as lower availability of CaCO₃ (see GREINER 1974, DOUGLAS 1979).

Foraminifers are also locally recorded in rocks formed in hypersaline environments of the restricted shelf zone. In that zone, they are represented by associations of *Agathammina* (pl. 37:1) and *Glomospira* and *Glomospirella* (pl. 31:9), the only taxons capable to accomodate to the changed sedimentary conditions. Involutinids are completely missing in that environment (see SALAJ 1980).

It should be noted that common fluctuations in bathymetry and salinity, typical for sedimentary environment of the Fatra Formation (see MICHALIK 1980), were unfavourable for development of foraminifers. They are here somewhat impoverished in number of taxa and individuals in relation to foraminifers from rocks of the Norovica Formation (see GAŻDZICKI and MICHALIK 1980).

An interesting association of foraminifers is formed by *Involutina liassica*, *I. turgida*, *I. farinacciae* and *Trocholina umbo* in deposits of the Kopieniec Formation. The foraminifers are characterized by development of umbilical masses composed of pillars (see pl. 38:1–16). As stated above, the appearance of pillars is treated as a new element in evolutionary development of “post-Triassic” Involutinidae (BRÖNNIMANN and KOEHN-ZANINETTI 1969). It is highly probable that the appearance of pillars was similarly related to adaptation to new environmental conditions connected with a change in the sedimentary basin in the Early Lias (see GAŻDZICKI...
Ecologic distribution and frequency of the foraminifers in the lithofacies of the Fatra Formation (uppermost Triassic of the Krížna unit). 1 dolomite and marly dolomite; 2 marl and marly limestone with pelecypods and gastropods, sometimes sandy limestone; 3 skeletal limestone (calcarenite) with megalodonts and algae; 4 coral and sponge limestone; 5 brachiopod (Rhuetina) lumachelles; 6 crinoid limestone.

Frequency of foraminifers: a rare, b frequent, c abundant

Regeneration of tests is fairly rare in the studied foraminifer assemblages. The phenomenon appears most common in Lower Lias species *Ophthalmidium leischneri*. Individuals of that species, especially microspheric forms could easily loose outer whorl due to mechanical breakage on account of fine structure of their tests. Regeneration of tests damaged in that way is connected with reconstruction of one or two last chambers which, however, follow a different structure pattern than the preceding ones (see pl. 40:12).
Tests of many foraminifers (mainly involutinids) occurring in the studied rocks, especially in the Mojtin Limestone Member of the Norovica Formation, are often broken (pl. 28:2). The destruction took place during their post mortem transportation by local bottom currents. The co-occurring brachiopods and crinoids are also crushed (see pl. 28:2).

Foraminifer tests are often covered with onkolitic crusts (pls. 27:2, 30:5, 38:14), visible in thin sections as thin uniform envelopes (pl. 38:13) or thick irregular coatings (pl. 38:15). The origin of onkolitic crusts, envelopes and coatings is connected with the activity of blue-green algae (see Bathurst 1971). Algal crusts enveloping foraminifer tests from all sides, give evidence for movement of the tests on sea floor.

Foraminifer tests with oolitic coatings (pl. 30:4) have also been found. In that case, the tests acted as nuclei and the final shape of an ooid reflects that of the test (pls. 31:3, 38:16). Coatings of Girvanella Nicholson and Etheridge are less common. The algae either form overgrowths (pl. 33:16) or continuous coatings of foraminifer tests (pl. 35:7).

Some tests of large foraminifers of the genera Aulotortus and Triasina were found to provide a substratum for attachment of sessile foraminifers Tolypammina gregaria Wendt. Tolypamminas were not only inhabiting the surface of the large tests but they were also entering their interior, living in some chambers (see pls. 33:15, 35:9).

Diagenetic alternations often resulted in the deformation as well as recrystallization of foraminifer tests. Deformations of tests of Triasina hantkeni Majzón due to compaction were mainly recorded in marly limestones of the Norovica Formation (pls. 30:6, 35:8). Tests of foraminifers, mainly those of the family Involutinidae, more often display sparitization (pls. 27:2, 28:2, 30:1–3). Sparitization was usually progressing from the test center, inaccessible for micritic mud (see pls. 30:1–2, 35:12, 15). In some cases, the whole interior of the test is filled with sparite crystals (pls. 30:1–2, 35:6, 15). Advancing recrystallization may lead to obliteration of internal structure of foraminifer tests (see pls. 30:2–3, 35:15).

FORAMINIFER BIOSTRATIGRAPHY

The zonation of Upper Triassic and Lower Jurassic strata was carried out in reference to the results of studies on foraminifer successions in 33 sections in different tectonic units of the West Carpathians (fig. 1). The recognized evolutionary lineages and the rates of evolutionary changes in test morphology of representatives of the families Involutinidae and Ammodiscidae and the subfamily Ophthalmidiinae permit to separate a few stratigraphically important species and to use them in establishing relatively precise zonation. A sequence of three foraminifer zones — Triasina oberhauseri (Norian), Glomospirella friedli and Triasina hantkeni (Rhaetian), Ophthalmidium leischneri and Ophthalmidium walfordi (Hettangian — ?Sinemurian) Zones — is recognized as the first appearance and extinction of individual species in the sections studies is taken into account (figs. 5–12). Lower boundaries of the above zones are defined by first appearance of their index species. The above subdivision represents at the same time a revision of those previously proposed by Salaj (1969a, 1977) and Gazdzicki (1974, 1977).

**Triasina oberhauseri Zone**

Partial-range Zone; Norian (sensu Kozur 1972, 1980)

**Definition.** — Interval with zonal marker, from its first occurrence to the first occurrence of Triasina hantkeni or Glomospirella friedli.

**Type locality.** — Hybe (section 25, layers 4–8), Nizke Tatry Mts (Czechoslovakia). — see fig. 9.
Foraminifer biostratigraphy of the uppermost Triassic and lowermost Jurassic in the West Carpathians.

**Remarks.** — **SALAJ** (1977) differentiated the *Semiinvoluta clari* and *Triasina oberhauseri* Assemblage-Zone in Middle Norian (Alaunian) strata. However, the forms assigned to *Semiinvoluta clari* by **SALAJ** (1976, pl. 1:5, 1977, pl. 5:8) and **GAZDZICKI et al.** (1979a) appeared to be misidentified and the majority of them represent the species *Aulotortus tumidus*. There is no evidence for the presence of *Semiinvoluta clari* in the Norian of the West Carpathians and, consequently, it cannot be used as index fossil.

It was also found that the stratigraphic range of *Triasina oberhauseri*, the other zonal marker, comprises the Lower Norian (Lacian) — lowermost Rhaetian interval and this species is a direct ancestor of *Triasina hantkeni*. This gives support to differentiation of *Triasina oberhauseri* Partial-range Zone in the Norian. It should be noted that *Triasina oberhauseri* was also found in samples from Norian Dachstein Limestone of Bakony Forest in Hungary, kindly supplied by Prof. E. Végh-Neubrandt.

**Geographic distribution.** — Czechoslovakia (**SALAJ** 1976, **GAZDZICKI et al.** 1979a), Hungary (**GAZDZICKI**, this paper), Austria (**KOEHN-ZANINETTI** and **BRÖNNIMANN** 1968), USSR (**Efimova** 1974), Turkey (**ZANINETTI** 1976), China (**HE YAN** 1980).

**Glomospirella friedli** and **Triasina hantkeni** Zone

Assemblage Zone; Rhaetian *(sensu** Kozur** 1973, see also** GAZDZICKI et al.** 1979a)*

**Definition.** — The range of this zone is defined by stratigraphic ranges of the species *Glomospirella friedli* and *Triasina hantkeni*. This zone is also characterized by the association of index fossils with *Glomospirella pokornyi* (only on lower part of the zone).

**Type locality.** — Mt. Velká Furkaska (section 17, layers 317–404), Tatra Mts (Czechoslovakia). — see fig. 5.
Remarks. — On the basis of foraminifer microfauna, the Rhaetian was divided into the Lower — the pokornyi and friedli Zone, and the Upper — the hantkeni Zone (Salaj 1969a, 1977; Gądzicki 1974, 1977). However, further detailed analysis of stratigraphic distribution of foraminifers in sections of the uppermost Triassic in the West Carpathians has shown that the index fossil, Glomospirella friedli, is present in both lower and upper parts of the Rhaetian (figs 5–8), whereas the index fossil of the Upper Rhaetian, Triasina hantkeni, already appears in the lowermost Rhaetian. These findings preclude the use of the above mentioned subdivision of the Rhaetian and, therefore, the previously proposed pokornyi and friedli Zone and hantkeni Zone are here treated as a single, Glomospirella friedli and Triasina hantkeni Assemblage Zone, comprising the whole Rhaetian Stage in the West Carpathians.


Ophthalmidium leischneri and Ophthalmidium walfordi Zone

Assemblage Zone; Hettangian — ?Sinemurian

Definition. — The range of this zone is defined by stratigraphic ranges of the species Ophthalmidium leischneri and Ophthalmidium walfordi. The zone is also characterized by an association of the index fossils and Involutina liassica, Involutina farinacciae and Trocholina umbo.

Type locality. — Mt. Velká Furkaska (section 17, layers 414–442), Tatra Mts. Czechoslovakia) — see fig. 11.

Remarks. — In the West Carpathians, the basal part of the Hettangian and, therefore, the base of the Lias are defined by the first appearance of Involutina liassica (see Salaj 1969a). That species is, however, inconvenient as index fossil as its range straddles the Rhaetian/Hettangian boundary, extending from upper part of the Rhaetian through the Jurassic up to the Lower Cretaceous (Kristan 1957, Radoičić 1962, Piller 1978). That is why the author (Gądzicki 1974, 1977) has proposed to single out “Vidalina” leischneri Range Zone in Lower Lias of the Tatra Mts. According to newly obtained data on Lower Lias sections of the West Carpathians (figs. 11–12), Ophthalmidium leischneri occurs together with Ophthalmidium walfordi, hitherto known from coeval rocks of epicontinental basin in north-western Europe only (Franke 1936, Wood and Barnard 1946). Be this the case, the distinction of the Ophthalmidium leischneri and Ophthalmidium walfordi Assemblage Zone should make it possible to correlate Lias sections of the Tethys Realm and those of epicontinental basin in the north-western Europe. This also indicates that the lower boundary of this zone delineates the boundary between the Triassic and Jurassic in the West Carpathians. It should be added that upper boundary of that zone is still poorly defined as a detailed analysis of higher stratigraphic members is till missing in the region studied.

Geographic distribution. — Czechoslovakia (Gądzicki, this paper), Poland (Gądzicki, 1974, 1975), Austria (Leischner 1961, Kristan-Tollmann 1962, Papp and Turnovsky 1970),

STRATIGRAPHIC CORRELATION

Foraminifer zonation of the uppermost Triassic in the West Carpathians has been correlated with orthostratigraphic ammonoid zonation of the Norian and Rhaetian sensu KOZUR (1973, 1980), concordant with the GÜMBEL's (1861) subdivision (fig. 18, see also GAŻDZICKI ET AL. 1979a). Triasina oberhauseri Zone, as interpreted above, extends from Mojsisovicsites kerri Zone to Cochloceras suessi Zone (Norian). Glomospirella friedli and Triasina hantkeni Zone may be correlated with ammonoid Choristoceras haueri and Choristoceras marshi Zones (Rhaetian) and its extent corresponds to that of the conodont Misikella posthernsteini Zone (GAŻDZICKI 1978a, b; GAŻDZICKI ET AL. 1979a). In turn, the extent of Lower Lias Ophthalmidium leischneri and Ophthalmidium walfordi Zone corresponds to that of the ammonoid Psiloceras planorbis Schlotheimia angulata and presumably Arietites bucklandi Zones (Hettangian — ?Sinemurian); (GAŻDZICKI ET AL. 1979b, see also KRISTAN-TOLLMANN 1962).

<table>
<thead>
<tr>
<th>STAGE</th>
<th>RHAETIAN</th>
<th>HETTANGIAN</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>LOWER</td>
<td>UPPER</td>
</tr>
<tr>
<td>Ammonoid zones</td>
<td>Choristoceras haueri</td>
<td>Choristoceras marshi</td>
</tr>
<tr>
<td>Conodont zones</td>
<td>Misikella posthernsteini</td>
<td></td>
</tr>
<tr>
<td>Foraminifer zones</td>
<td>Glomospirella friedli and Triasina hantkeni</td>
<td></td>
</tr>
</tbody>
</table>

Fig. 18
Stratigraphic correlation of the ammonoid, conodont and foraminifer zones in the Rhaetian and Hettangian of the Alpine-Carpathian region. For stratigraphic comments see GAŻDZICKI ET AL. 1979a.

REMARKS ON CHRONOSTRATIGRAPHIC BOUNDARIES

The foraminifer zonation given above makes it possible to single out the following stages: Norian (Triasina oberhauseri Zone), Rhaetian (Glomospirella friedli and Triasina hantkeni Zone), and Hettangian — ?Sinemurian (Ophthalmidium leischneri and Ophthalmidium walfordi Zone). At the same time, it makes possible reanalysis of the question of stratigraphic boundaries between Carnian and Norian, Norian and Rhaetian and Rhaetian and Hettangian (= Triassic/Jurassic boundary) in the West Carpathians.

Carnian/Norian boundary. — The boundary is passing in the interval delineated from below by the last occurrence of Glomospirella kuthani (SALAJ), index fossil of the kuthani Zone sensu SALAJ (1969a, 1977), and from above — by first appearance of Triasina oberhauseri KOEHN-ZANINETTI and BRÖNNIMANN, index fossil of the oberhauseri Zone sensu GAŻDZICKI (this paper).
Strata of the Carnian age are out of scope of this paper so it should be noted that in the West Carpathians they are dated by several foraminifers including *Glomospirella kuthani* (Salaj, Mesodiscus eomesozoicus (Oberhauser), Aulotortus praegaschei (Koehn-Zaninetti), Lamelliconus biconvexus (Oberhauser), I. procerus (Liebus), Pachyphloides klebelsbergi (Oberhauser), and P. oberhauseri Sellier de Civrieux and Desseuvage (see Salaj 1969a, 1977; Salaj and Jendrejáková 1967; Salaj et al. 1967; Jendrejáková 1973, Gażdzicki et al. 1978).

Norian/Rhaetian boundary. — Lower boundary of the Rhaetian Stage is defined by the first appearance of *Glomospirella friedli* or *Triasina hantkeni* (see figs. 5–10). The underlying strata are of the Norian (Sevatian) age. The boundary is passing within the Carpathian Keuper or Fatra Formation in the Fatricum and within the Norovica Formation in the Hronicum (fig. 2).

Rhaetian/Hettangian boundary. — In the sections studied (figs. 5, 11–12), the uppermost layer yielding index fossils of the Rhaetian, *Glomospirella friedli* or *Triasina hantkeni*, and the lowermost layer with index fossils of the Hettangian — ?Sinemurian, *Ophthalmidium leischneri* or *O. walfordi*, are separated by a series of clastic deposits without any foraminifers, 10 to 15 m thick. The Rhaetian/Hettangian boundary (= Triassic/Jurassic boundary) in the West Carpathians is drawn within this series, interpreted as the correlation error interval.

**DIACRONISM OF THE LITHOSTRATIGRAPHIC UNITS**

A detailed biostratigraphic zonation of the Upper Triassic and Lower Jurassic of the West Carpathians, established on the basis of foraminifers, shows that boundaries of the Carpathian Keuper, and Fatra and Kopieniec Formations in the Fatricum and Norovica Formation in the Hronicum are diachronous and they cannot be used as time lines (figs 2, 5–10). Upper part of the Carpathian Keuper Group in the sections Mt. Velká Furkaska (section 17) and Lejowa Valley I (section 18), widely assumed to be of the Carnian-Norian age (Sokołowski 1959, Kotalński 1963, 1979), was found to be of the Rhaetian age (Gażdzicki et al. 1979b). Sedimentation of rocks of the Fatra and Norovica Formations was recently shown to begin as early as the Late Norian (Gażdzicki and Iwanow 1976, Gażdzicki and Michałek 1980) whereas the Kopieniec Formation began to originate not before the Rhaetian (friedli and hantkeni Zone) on the Štefanský žlab section (19) and even not before the Hettangian — ?Sinemurian (leischneri and walfordi Zone) in the Mt. Velká Furkaska section (18). This disappearance of carbonate facies of the Fatra Formation and development of clastic facies of the Kopieniec Formation in the Carpathian sedimentary basin in Late Triassic and Early Jurassic times prove an increasing regression related to uplifting movements of the Early Kimmerian phase. In the West Carpathians, the movements began in the Rhaetian (friedli and hantkeni Zone) and their maximum activity was marked in the Early Lias (leischneri and walfordi Zone).

**PALEOGEOGRAPHIC DISTRIBUTION**

In the Late Triassic and Early Jurassic, geographic distribution of benthonic foraminifer faunas, mainly comprising representatives of the families Involutinidae, Ammodiscidae, and Miliolidae, was controlled by facies pattern.

In the analysis of the distribution, attention should be paid to Involutinidae. Representatives of that family form associations comprising large numbers of individuals in Triassic rocks. The occurrence of such associations appears clearly related to areas of lagoons and biostromal elevations in shelf zones, where a carbonate sedimentation was prevailing.

The analysis of distribution of Upper Triassic facies in Europe and North Africa (fig. 19)
has shown that shallow-water carbonate facies, characterized by the wealth of sponge, corals, brachiopods, pelecypods, and echinoderms, fairly well coincides with areas of occurrence of involutinids (fig. 20). According to paleogeographic distributions (Smith and Briden 1977, figs. 12, 25, 51, see also Michalík 1978a, fig. 1), such shallow-water carbonate facies of the Upper Triassic were related to shelf areas, mainly those of the northern coast of the Tethyan Ocean. Therefore, the distribution of involutinids in the uppermost Triassic of the Tethys is found to coincide with that of the shallow-water facies (fig. 20). It follows that for the late Triassic, involutinids are a sensitive paleogeographic indicator for the Tethys Realm.

Fig. 19

Present distribution of the Late Triassic facies in Europe and North Africa (arrow indicates the area investigated in the present paper): 1 continental facies (red beds); 2 evaporite facies with main halite deposits (vvv); 3 shallow-water carbonate facies (platform carbonates with more or less subsidence); 4 deeper water facies (Hallstatt Limestone and related facies). (Adopted from Bosellini and Hsü, 1973, figs 1–3).

The studied Norian-Rhaetian foraminifer assemblages of the West Carpathians (in the Fatra and Norovica Formations, Hybe Beds, Skalka Limestone and Bleskový prameň Limestone) are very similar to contemporaneous assemblages in other parts of the Tethys Realm in both taxonomic composition and stratigraphic succession of individual associations. The similarities are not confined to assemblages from neighbouring areas in the Alpine Europe (Gaździcki 1974, Zaninetti 1976, Salaj 1980), being equally high in other parts of the Tethys Realm: from Rif Mts. in Morocco to Calamian Islands of Philippines as well as Papua New
The investigated Lower Lias foraminifer assemblages from the West Carpathians (mainly those from the Kopieniec Formation and from the Tatricum in the Velká Fatra Mts.) also do not differ from contemporaneous assemblages of the Tethys Realm in specific composition or stratigraphic distribution. Lower Lias foraminifers characterized by vast geographic distribution, especially in the Tethys Realm. They are known from Hungary (FULOP 1976), Lower Austria (KRISTAN-TOLLMANN 1962, FUCHS 1970, PAPP and TURNOVSKY 1970), Northern Limestone Alps (LEISCHNER 1961, FABRICIUS 1966, TOLLMANN 1976), Haute-Savoie (ZANINETTI 1977a) Southern Alps (CITA 1965, COUSIN and NEUMANN 1971, TSAMANTOURIDIS 1971), Apen-

Fig. 20

Geographic distribution of Involutinidae in the uppermost Triassic deposits of the Tethys Realm
1 Alpine Europe (GAZDZICKI 1974, ZANINETTI 1976); 2 Rif Mts., Morocco (RAOUlt 1962); 3 Djebel Fkirine, Tunisia (SALAJ and STRANK 1970); 4 Taurus Mts., Turkey (BRÖNNIMANN et al. 1970); 5 Caucasus Mts., Soviet Union (EFIMOVA 1974); 6 Alborz Mts., Iran (ZANINETTI et al. 1972); 7 Kuh-e-Nayband Mts., Iran (BRÖNNIMANN et al. 1972); 8 Wardak Mts., Afghanistan (LYS and MARIN 1973); 9 Samana Suk, Pakistan (ZANINETTI and BRÖNNIMANN 1975); 10 Pamir Mts. Soviet Union (DRONOV et al. 1982); 11 Kyaukme-Longtawkno area, Burma (BRÖNNIMANN et al. 1975); 12 Yunnan, China (Ho YEN and Hu LAN-YING, 1977); 13 Hoang Mai, Vietnam (LIEM 1966); 14 Si Sawat, Thailand (KEMPER et al. 1976); 15 Kodiang, Malaysia (GAZDZICKI and SMIT 1977); 16 Busuanga, Calamian Islands, Philippines (FONTAINE et al. 1979); 17 Gurumugl, Papua New Guinea (GAZDZICKI in preparation)

1 Recently the assemblage of Norian involutinids Aulotortus gaschei, A. sinuosus and Triasina oberhauseri was found (GAZDZICKI and REID in press) to be also present in the North America (Lime Peak, Yukon, Canada).

The foraminifer assemblage from the Kopieniec Formation (Hettangian — ?Sinemurian) of the West Carpathians also somewhat resemble those of the "Oolithebank" in the Baden-Wuerttembergian Hettangium, representing typical epicontinental deposits (Schloz 1972). The above similarities may be also traced within Lower Lias sequences in other parts of the north-western Europe (see Franke 1936, Wood and Barnard 1946, Drexler 1958 and Brouwer 1969).

The record of the species Ophthalmidium walfordi Häusler, hitherto known from the Lower Lias of the epicontinental basin of the north-western Europe only (Issler 1908, Franke 1936, Wood and Barnard 1946), in the Tatra Mts. is of interest. From the Lower Lias of the two sedimentary basins are also known some other species including Involutina liassica, Trocholina umbo and numerous representatives of family Nodosariidae (see Brouwer 1969).

Taking into account the present state of knowledge of Lower Lias foraminifers, it may be stated that they occur both in geosynclinal and epicontinental basins at those times.

At the same time the presented data indicate that the environmental conditions prevailing in the Carpathian geosyncline and epicontinental basin of the north-western Europe were quite similar during the Early Lias, which was undoubtedly determined by the existence of effective marine connections between those basins. This point of view is further supported by earlier observations of Goetel (1917), who emphasized a marked resemblance of the sandstone with Cardinia from the Tatra Mts and Lower Lias sandstones of Swabia in petrological characteristic and composition of faunal assemblages.

**FINAL REMARKS**

The benthonic foraminifers of Upper Triassic and Lower Jurassic seem to be good environmental indices for shelf areas of the Tethyan Ocean. Their wide geographic distribution, mass occurrence and relatively high rate of evolution, give them significant stratigraphic value.

The Involutinidae, Ammodiscidae and Miliolidae are most common in the sequences studied. Their distribution was related to extensive shelf areas with predominating carbonate sedimentation. Ammodiscidae, most common in onshore zones characterized by supply of psammitic terrigenous material were the exception.

A special stratigraphic value is attributed to the Involutinidae and Ammodiscidae as their evolution during Late Triassic underwent marked acceleration. Fast species alternation permits to use them for relatively precise zonation.

A major part of involutinids became extinct at the Rhaetian/Hettangian (= Triassic/Jurassic) boundary and only some of them are present in Lias and younger strata. From the base of the Lias (Hettangian-Sinemurian) upwards, the analysed foraminifer assemblages begin to display predominance of Ophthalmidiinae, the peak in development of which took place already in the Jurassic.

The mass occurrence of the foraminifers, particularly in the Upper Triassic, results in their high stratigraphic value comparable with that of cephalopods and conodonts, i.e. the groups giving the basis for biostratigraphy of that epoch.

The intercorrelation of the proposed foraminifer zones with standard cephalopod and conodont zones makes possible the use of foraminifers in local, regional, and intercontinental stratigraphic correlations, especially in those parts of the Tethys Realm where the cephalopods and conodonts are scarce or absent.
SYSTEMATIC PALEONTOLOGY

Suborder Textulariina Delage and Hérouard, 1896
Superfamily Ammodiscacea Reuss, 1862
Family Ammodiscidae Reuss, 1862
Subfamily Ammodiscinae Reuss, 1862
Genus Glomospirella Plummer, 1945

Glomospirella friedli Kristan-Tollmann, 1962
demend. Brönnimann and Zaninetti, 1970
(pl. 27:1; pl. 28:1; pl. 31:1–6)

Material. — Over 1,000 fairly well preserved specimens in thin sections.


Dimensions of the test (in μm)

<table>
<thead>
<tr>
<th></th>
<th>pl. 32:2</th>
<th>pl. 32:3</th>
<th>pl. 32:4</th>
</tr>
</thead>
<tbody>
<tr>
<td>diameter</td>
<td>440</td>
<td>400</td>
<td>580</td>
</tr>
<tr>
<td>thickness</td>
<td>360</td>
<td>320</td>
<td>340</td>
</tr>
<tr>
<td>diameter of the proloculus</td>
<td>—</td>
<td>50</td>
<td>50</td>
</tr>
</tbody>
</table>

Remarks. — The specimens of Glomospirella friedli, very numerous and particularly well-preserved in the uppermost Triassic of the West Carpathians, make some important conclusions possible. The studied forms (pl. 6:1–6) are characterized by test outline ovate in axial and oblique sections and circular in the equatorial. A special attention should be paid to the mode of coiling of test. Central part of test is streptospirally coiled and it comprises 6 to 8 whorls (pl. 32:2–4). It is followed by elements of sigmoidal coiling, passing into planispiral, comprising four whorls at the average (pl. 32; 1–3). Wall microstructure of tests which escaped recrystallization is very finely agglutinated and, sometimes, incrusted with single crystals of pyrite. The above features clearly evidence that the forms belong to the genus Glomospirella Plummer. It should be noted, however, that Hohenegger and Piller (1975) and Piller (1978) interpreted Glomospirella friedli as a synonym of Aulotortus gaschei (Koehn-Zaninetti and Brönnimann), taking into account identify of the mode of coiling and wall microstructure of recrystallized tests. The mode of coiling is similar but, nevertheless, some differences remain. Planispiral part is well-developed in Glomospirella friedli and rarely visible in sections of Aulotortus gaschei, comprising about four and usually less than two whorls, respectively. Umbilical masses, typical of involutinids, are well developed in Aulotortus gaschei and missing in Glomospirella friedli. Walls of tests of the former often display perforation (see pl. 32:9–10), whereas those of Glomospirella friedli are imperforate.

It should be admitted, however, that the tests of the two species are difficult to separate when recrystallized, which may explain the above viewpoint of Hohenegger and Piller. When the material is well preserved as in the present case, it may be easily shown that the species are separate and assignable to two different families, Ammodiscidae and Involutinidae.
The marked similarity in size, shape, and mode of coiling of these species is an excellent example of advanced homeomorphy.


*Glomospirella pokornyi* (Salaj, 1967)  
(pl. 31:1–2, 4–5)

1967. *Angulodiscus pokornyi* Salaj: 128, pl. 6 : 4a, b (in Salaj *et al.*).

**Material.** — About 200 specimens in thin sections.

**Association.** — Most often with *Glomospira* sp., *Glomospirella friedli*, *G. parallela*, *Glomospirella* sp., *Trocchammina alpina*, *Agathammina austroalpina*, "*Tetradactylus inflata*", *Nodosaria* sp., "*Frondicularia woodwardi*", *Diplocreminia* sp.; occasionally with *Aulotortus communis*, *A. sinuosus*, *A. tumidus*, *Auloconus permodiscoides*, and *Triasina hantkeni*.

**Description.** — as given by Salaj (*in Salaj *et al.* 1967).

Dimensions of the test (in μm):

<table>
<thead>
<tr>
<th>pl. 31:2</th>
<th>pl. 31:4</th>
<th>pl. 31:5</th>
</tr>
</thead>
<tbody>
<tr>
<td>diameter</td>
<td>410</td>
<td>440</td>
</tr>
<tr>
<td>thickness</td>
<td>80</td>
<td>80</td>
</tr>
</tbody>
</table>

**Remarks.** — The species described was originally assigned by Salaj (*in Salaj *et al.* 1967) to *Angulodiscus* (Kristan 1957, which is treated by Piller (1978) as a junior synonym of *Aulotortus Weynschenk* 1956.

The analysis of representatives of this species from the uppermost Triassic of the West Carpathians has shown that their test walls are very finely agglutinated. This, along with the arrangement of whorls in both axial and equatorial sections (pl. 31:1–2, 4–5) is typical of the genus *Glomospirella* Plummer 1945.
It should be also noted that the specimens from the Norian-Rhaetian of the Northern Limestone Alps, assigned to *Aulotortus pokornyi* (Salaj by Pillér (1978, pl. 11:1-7), do not match the diagnosis of that species, differing mainly in having a calcareous wall. These forms would be best assigned to *Aulotortus communis* (Kristan 1957).


This species was also reported from the Rhaetian of the Eastern Atlas Mts. in Tunisia (Salaj and Stranik 1970).

---

Suborder *Miliolina* Delage and Hérouard, 1896  
 superfamily *Miliolacea* Ehrenberg, 1839  
 family *Miliolidae* Ehrenberg, 1839  
 subfamily *Ophthalmidiinae* Wiesner, 1920  
 genus *Ophthalmidium* Kübler and Zwingli, 1870  
 *Ophthalmidium carpathicum* (Gaždzicki, 1979)  
 (pl. 37:9-10)


**Material.** — Fifteen specimens in thin sections.

**Association.** — With *Glomospira* sp., *Glomospirella* sp., *Trochammina alpina*, *Agathammina austroalpina*, *Ophthalmidium “carinatum”*, *Nodosaria ordinata*, *Austrocolomia* sp. and *Diplotremina* sp.

**Description.** — as given by Gaždzicki (in Gaždzicki et al. 1979a).

Dimensions of the test (in µm):  

<table>
<thead>
<tr>
<th></th>
<th>pl. 37:9</th>
<th>pl. 37:10</th>
</tr>
</thead>
<tbody>
<tr>
<td>diameter</td>
<td>350</td>
<td>360</td>
</tr>
<tr>
<td>thickness</td>
<td>60</td>
<td>70</td>
</tr>
<tr>
<td>diameter of the proloculus</td>
<td>40</td>
<td>—</td>
</tr>
</tbody>
</table>

**Remarks.** — *Ophthalmidium carpathicum* differs from the remaining Upper Triassic — Lower Jurassic species of *Ophthalmidium* Kübler and Zwingli in constriction between central part and the ultimate whorl, especially well visible in axial section (pl. 37:9-10). The constriction may be responsible for breaking-off of the ultimate whorls as the representatives of that species are often found incomplete, i.e. represented by proloculus and two inner whorls only (see pl. 37:11). It should be noted that the forms devoid of the ultimate whorl are very close to megalospheric forms of the species *Ophthalmidium “carinatum”* (Leischner 1961) = *Involutina carinata* Leischner 1961 (see Leischner 1961, pl. 2:15a-c) known from the uppermost Triassic and Lower Lias of Northern Limestone Alps.

In accordance with the suggestions of Wernli (1972) and Decrouez et al. (1978), the species is here assigned to *Ophthalmidium* Kübler and Zwingli 1870 on account of its multilocular test structure, and not to *Vidalina* Schlumberger 1900, characterized by bilocular structure and not known from rocks older than the Late Cretaceous.

**Occurrence.** — West Carpathians Slovenský kras, section: 31 — Malý Mlynský vrch Mt.: Upper Norian (Sevatian); 32 — Bleskový prameni: Rhaetian (*friedli* and *hantkeni* Zone).
Ophthalmidium leischneri KRISTAN-TOLLMANN, 1962
(pl. 40:1-12)

1976. Ophthalmidium leischneri (KRISTAN-TOLLMANN); ZANNETTI: 144, pl. 7:14-16 (with synonymy).
1977. “Vidalina” leischneri (KRISTAN-TOLLMANN); GAŻDZICKI: 94, pl. 3:9-12, 16 (with synonymy).

Material. — Over 500 well-preserved specimens in thin sections.

Association. — Most often together with Ophthalmidium walfordi, Involutina liassica, I. turgida, I. farinacciae, Trocholina umbo, and nodosariids (Astacolus, Nodosaria, Frondicularia and Lenticulina), occasionally with Trochammina sp. and Planinvoluta carinata.

Description. — as given by KRISTAN-TOLLMANN (1962).

Dimensions of the test (in μm):

<table>
<thead>
<tr>
<th></th>
<th>pl. 40:1</th>
<th>pl. 40:5</th>
<th>pl. 40:8</th>
</tr>
</thead>
<tbody>
<tr>
<td>diameter</td>
<td>200</td>
<td>210</td>
<td>270</td>
</tr>
<tr>
<td>thickness</td>
<td>80</td>
<td>80</td>
<td>—</td>
</tr>
<tr>
<td>diameter of the proloculus</td>
<td>50</td>
<td>—</td>
<td>30</td>
</tr>
</tbody>
</table>

Remarks. — Large populations of Ophthalmidium leischneri, found in analysed Lower Lias rocks, permit to recognize megalo- and microspheric forms. The former, biconvex in axial section (pl. 40:1-2), with 3-5 chambers and proloculus about 50 microns in size on the average, are less common here than the latter, with depressed umbilical masses (pl. 40:5-6), 7-8 chambers, and proloculus about 30 microns in size.

Single equatorial sections (pl. 40:8, 10), clearly showing internal structure of test, fully confirm assignment of that species to Ophthalmidium KÜBLER and ZWINGLI.


This species was reported from the Lower Lias of Northern Limestone Alps (LEISCHNER 1961), substratum of the Vienna Basin (KRISTAN-TOLLMANN 1962), Haute-Savoie (ZANNETTI 1977), Southern Alps (CITA 1965, TSAMANTOURIDIS 1971), Karavanken Mts. (RAMOVŠ and REPŠEK 1970), Croatia (GUŠČIĆ 1975) and from Taurus Mts. (BRÖNNIMANN et al. 1970).

Ophthalmidium walfordi Häusler, 1887
(pl. 40:13-16)

1887. Ophthalmidium walfordi Häusler: 192, pl. 6:7-11.
1936. Ophthalmidium walfordi Häusler; FRANKE: 122, pl. 12:16.
1946. Ophthalmidium walfordi Häusler; WOOD and BARNARD: 91, fig. 6.

Material. — Forty specimens in thin sections.

Association. — Mainly with Ophthalmidium leischneri, Involutina liassica, I. turgida, I. farinacciae, Trocholina umbo, Nodosaria sp., and Lenticulina sp.

Description. — as given by Häusler (1887).

Dimensions of the test (in μm):

<table>
<thead>
<tr>
<th></th>
<th>pl. 40:13</th>
<th>pl. 40:14</th>
<th>pl. 40:16</th>
</tr>
</thead>
<tbody>
<tr>
<td>diameter</td>
<td>360</td>
<td>440</td>
<td>360</td>
</tr>
<tr>
<td>thickness</td>
<td>40</td>
<td>50</td>
<td>—</td>
</tr>
<tr>
<td>diameter of the proloculus</td>
<td>25</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

Remarks. — Ophthalmidium walfordi differs from the remaining representatives of the genus Ophthalmidium KÜBLER and ZWINGLI in specific development of the last chamber. The chamber is straight and markedly diverges from the planispiral part of the test (pl. 40:16),
and its length is most equal to diameter of the planispiral part (pl. 40:13–15). The recorded number of chambers ranges from seven to eight.

A characteristic final chamber, initiating the development of the linear series of chambers, suggests attachment of that species to foreign bodies during its life.


Hitherto known from the Lias of the epicontinental basin of north-western Europe (ISSLER 1908, FRANKE 1936, WOOD and BARNARD 1946). This is the first record of that species not only from the Carpathians but from the whole Tethys Realm.

**Ophthalmidium** sp.

*(pl. 37:13–14)*

**Material.** — Seven specimens in thin sections.

**Association.** — *Glomospira* sp., *Trochammina alpina*, “*Tetrataxis* inflata” and *Triasina hantkeni*.

**Description.** — Test lenticular in outline in axial sections (pl. 37:13–14), somewhat elongate, with well-marked neck. Chambers, 5–7 in number, spirally coiled; the last two chambers comprise a major part of the test, forming the outer whorl. Proloculus circular, located in the center of the test. Aperture terminal, with distinct prominent lip. Variability in size of individuals is fairly high.

**Dimensions of the test (in μm):**

<table>
<thead>
<tr>
<th></th>
<th>pl. 37:13</th>
<th>pl. 37:14</th>
</tr>
</thead>
<tbody>
<tr>
<td>diameter</td>
<td>200</td>
<td>490</td>
</tr>
<tr>
<td>thickness</td>
<td>70</td>
<td>180</td>
</tr>
<tr>
<td>diameter of the proloculus</td>
<td>30</td>
<td>—</td>
</tr>
</tbody>
</table>

**Remarks.** — Test outline and internal structure match well the diagnosis of the genus *Ophthalmidium*. However, the specimens are poorly preserved, sections innumerous, and variability in size is fairly high which makes specific identification hazardous.

**Occurrence.** — West Carpathians (Tatra Mts., sections: 17 — Velká Furkaska Mt., 26 — Chocholowska Valley): Rhaetian (*friedli* and *hanthkeni* Zone, the conodont *posthernsteini* Zone).

Suborder **Involutilina** HOHENEGGER and PILLER, 1977

Superfamily **Involutilinacea** BÜTSCHLI, 1880

Family **Involutilinidae** BÜTSCHLI, 1880

Genus **Aulotortus** WEYNSCHENK, 1956

*Aulotortus gaschei* (KOEHN-ZANINETTI and BRÖNNIMANN, 1968)

*(pl. 32:9–16)*

1976. *Involutilina gaschei* (KOEHN-ZANINETTI and BRÖNNIMANN); ZANINETTI: 159, pl. 9:13–15 (with synonymy).
1978. *Aulotortus friedli* (KRISTAN-TOLLMANN); PILLER: 55, pl. 8:3–8, pl. 9:1–16.

**Material.** — About 200 specimens in thin sections.

**Association.** — Most often with involutilinids (*Aulotortus sinuosus*, *A. tenuls*, *A. tumidus*, *A. communis*, *Auloconus permodiscoides*, *Triasina hantkeni*, *T. oberhauseri*); and sometimes
with *Glomospira sinensis*, *Glomospirella friedli*, *G. parallela*, *Tolypammina gregaria*, *Trochammina alpina*, "*Tetra taxis*" *inflata*, *Agathammina austroalpina* and "*Frondicularia woodwardi*".

**Description.** — as given by KOEHN-ZANINETTI and BRÖNNIMANN (1968) and ZANINETTI (1976).

Dimensions of the test (in μm):

<table>
<thead>
<tr>
<th></th>
<th>pl. 32:9</th>
<th>pl. 32:13</th>
<th>pl. 32:16</th>
</tr>
</thead>
<tbody>
<tr>
<td>diameter</td>
<td>440</td>
<td>760</td>
<td>720</td>
</tr>
<tr>
<td>thickness</td>
<td>260</td>
<td>—</td>
<td>480</td>
</tr>
</tbody>
</table>

**Remarks.** — *A. gaschei* appears to be a homeomorph of *Glomospirella friedli* (comp. p. 145) differing from the latter by streptospiral coiling of the first 6–8 whorls (pl. 32:9–16) which are obscured by the outer, planispirally coiled whorls. It differs clearly from *G. friedli* in the presence of umbilical masses and somewhat in test size (about 700 μm and 500 μm on the average, respectively). Moreover, the representatives of *A. gaschei* studied are characterized by calcareous wall sometimes displaying perforation (pl. 32:9–10). *Aulotortus gaschei* differs from its direct ancestor, *A. praegaschei* KOEHN-ZANINETTI, known from the Ladinian-Carnian, in planispirally coiled outer whorls.


**Genus Involutina** TERQUEM, 1862

*Involutina liassica* (JONES, 1853)

(pl. 29:1; pl. 38:1-12, 15)

1969. *Involutina liassica* (JONES); KOEHN-ZANINETTI: 82, figs 22–24 (with synonymy).

**Material.** — Over 100 specimens in thin sections.

**Association.** — *Involutina turgida*, *I. farinacea*, *Trocholina umbro*, *Ophthalmidium leischneri*, *O. walfordi*, *Planinvoluta carinata*, *Trochammina* sp. and nidosariids (*Astacolus*, *Frondicularia*, *Lenticulina* and *Nodosaria*).

**Description.** — as given by KOEHN-ZANINETTI (1969) and PILLER (1978).

Dimensions of the test (in μm):
Remarks. — *I. liassica* is characterized by umbilical masses composed of numerous pillars (pl. 38:7–8). The appearance of pillars is a new element in evolution of Involutinidae, typical of the so-called “post-Triassic” involutinids. The dimorphism is clearly marked in this species. Megalospheric forms (pl. 38:5, 15) are characterized by large proloculus (about 100 μm in diameter) and, usually, three whorls, and the microspheric — by almost twice smaller proloculus (about 60 μm in diameter) and up to 6 whorls. This species was previously recorded in the Lias of the West Carpathians by Mišk (1961). It should be noted, however, that the form figured as *Involutina cf. liassica* from Dachstein Limestone of Muránska planina by Mišk (1961, pl. 30:2) does not display features typical of this species (e.g. pillars are almost completely missing) and it most probably represent *Aulotortus communis* (Kristan).


**Genus Triasina Majzón, 1954**

*Triasina hantkeni* Majzón, 1954

(27:2; pl. 28:2; pl. 30:2–6; pl. 35:7–17)


Material. — Over 1000 specimens in thin sections; locally forming very large, rock-forming accumulations.

Association. — Most often with involutinids (*Auloconus permodiscoides*, *Aulotortus communis*, *A. gaschel*, *A. impressus*, *A. pragooides*, *A. sinuosus*, *A. tenuis* and *A. tumidus*); also with *Glomospira sinensis*, *Glomospirella friedli*, *Glomospirella parallela*, *Tolypamminagregaria*, “Tetrataxis” *inflata*, *Ophthalmidium* sp., “*Frondicularia woodwardi*”, *Nodosaria* sp. and *Diplotrema* sp.

Description. — as given by Majzón (1954) and Piller (1978).

Dimensions of the test (in μm):  

<table>
<thead>
<tr>
<th></th>
<th>pl. 35:10</th>
<th>pl. 35:12</th>
<th>pl. 35:14</th>
</tr>
</thead>
<tbody>
<tr>
<td>diameter</td>
<td>760</td>
<td>1,000</td>
<td>1,500</td>
</tr>
<tr>
<td>diameter of the proloculus</td>
<td>90</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Remarks. — *Triasina hantkeni* is a well known species which makes it easy to be identified in thin sections. It is primarily characterized by segmentation of deuteroloculus, well visible in sections (pl. 35:9–12). The segmentation of deuteroloculus is a new element in evolution of
Late Triassic involutinids. About 7 to 8 whorls were recorded. *T. hantkeni* was previously reported from the West Carpathians by *Salaj et al.* (1967) and *Gaździcki* (1970).


*Triasina oberhauseri* Koehn-ZanINETTI and BRÖNNIMANN, 1968

(fig. 21a, b)

1968. *Triasina oberhauseri* Koehn-ZanINETTI and BRÖNNIMANN: 1, pl. 1:1–2, fig. 1.

**Material.** — Five specimens in thin sections.

**Association.** — Co-occurring with *Aulotortus communis, A. gaschei, A. sinuosus, A. tumidus, Auloconus permidoscoideus, Tolypammina gregaria* and *Nodosaria* sp.

**Description.** — as given by *Koehn-ZanINETTI* and *BRÖNNIMANN* (1968).
Dimensions of test (in \( \mu m \)):

<table>
<thead>
<tr>
<th></th>
<th>fig. 21a</th>
<th>fig. 21b</th>
</tr>
</thead>
<tbody>
<tr>
<td>diameter</td>
<td>440</td>
<td>360</td>
</tr>
<tr>
<td>thickness</td>
<td>320</td>
<td>280</td>
</tr>
</tbody>
</table>

**Remarks.** — The tests of *Triasina oberhauseri* (fig. 21a, b) studied are almost identical with representatives of this species from the Upper Norian of Northern Limestone Alps (KOEHN-ZANINETTI and BRÖNNIMANN 1968, fig. 1). The Carpathian specimens are characterized by 3–5 whorls and an underdeveloped segmentation of deuteroloculus best visible in the case of the last whorls.

It is worth to note that *Triasina oberhauseri*, first described by KOEHN-ZANINETTI and BRÖNNIMANN (1968), represents a transitional form between involutinid *Aulotortus pragsoides* and *Triasina hantkeni*, the existence of which has been earlier inferred by OBERHAUSER (1964, fig. 1) in this theoretical analysis. It should be also noted here that the existence of such transitional form gives support to the allocation of *Triasina* in the family Involutinidae BÜTSCHLI. The form recently described and figured as *Triasina hantkeni* MAJZON from the Upper Norian (“Maantang” Formation) of Sichuan (China) by HE YAN (1980, pl. 73:11), displays underdeveloped segmentation of deuteroloculus, so it is assigned here to *Triasina oberhauseri* KOEHN-ZANINETTI and BRÖNNIMANN, 1968.

**Occurrence.** — West Carpathians (Nizke Tatry Mts., section: 25 — Hybe); Upper Norian (Sevatian) (*oberhauseri* Zone).

*T. oberhauseri* is also known from the Norian of Bakony Forest (GAŻDZICKI unpublished), Caucasus Mts. (EFIMOVA 1974) and from the Upper Norian of Northern Limestone Alps (KOEHN-ZANINETTI and BRÖNNIMANN 1968, KOEHN-ZANINETTI 1969), Tauros Mts. (BRÖNNIMANN et al. 1970) and Sichuan province of China (HE YAN 1980).

**Genus Auloconus PILLER, 1978**

*Auloconus permodiscoides* (OBERHAUSER, 1964) (pl. 30:2; pl. 35:1-6)


**Material.** — Over 200 well preserved specimens in thin sections.

**Association.** — Commonly with *Triasina hantkeni*, *Aulotortus sinuosus*, *A. communis*, *A. gaschei*, *A. impressus*, *A. tenuis*, *Tolypammina gregaria*; sometimes with *Glomospira* sp., *Glomospirella friedli*, *G. parallela*, *“Tetrataxis” inflata*, *Ophthalmidium* sp., and *“Frondicularia woodwardi”*.

**Description.** — as given by OBERHAUSER (1964) and PILLE (1978).

Dimensions of the test (in \( \mu m \)):

<table>
<thead>
<tr>
<th></th>
<th>pl. 35:1</th>
<th>pl. 35:4</th>
<th>pl. 35:5</th>
</tr>
</thead>
<tbody>
<tr>
<td>diameter of the base</td>
<td>560</td>
<td>840</td>
<td>760</td>
</tr>
<tr>
<td>height</td>
<td>280</td>
<td>560</td>
<td>680</td>
</tr>
</tbody>
</table>

**Remarks.** — The specimens studied are characterized by conical shape with rounded apical part and elongate base in axial (vertical) sections (pl. 35:1–6). Trochospiral coiling; number of whorls usually ranging from 6 to 8. These features, along with the lack of pillars, well match the diagnosis of *Auloconus permodiscoides*. One of the specimens figured (pl. 35:3), displaying not more than three whorls, may represent a megalospheric form. Some of the specimens studied are low-trochospirally coiled, except for planispiral coiling of first 2–3 whorls.
Such features bring them closer to the genus *Aulotortus*. This gives support to the interpretation of trocholinids as trochospirally coiled involutinids (see OBERHAUSER 1964, KOEHN-ZANINETTI 1969, and GUŠIĆ 1975).


**Genus Trocholina PAALZOV, 1922**

*Trocholina umbo* FRENZEN, 1941

(Pl. 39:3–4)


**Material.** — Twenty specimens in thin sections.

**Association.** — Commonly with *Involutina liassica*, *I. turgida*, *I. farinacciae*, *Ophthalmidiun leischneri*, *O. walfordi*, *Nodosaria* sp., *Aastacolus* sp., and *Lenticulina* sp.

**Description.** — as given by FRENZEN (1941) and PILLER (1978).

Dimensions of the test (in μm):

<table>
<thead>
<tr>
<th></th>
<th>Pl. 39:3</th>
<th>Pl. 39:4</th>
</tr>
</thead>
<tbody>
<tr>
<td>diameter of the base</td>
<td>300</td>
<td>280</td>
</tr>
<tr>
<td>height</td>
<td>130</td>
<td>120</td>
</tr>
</tbody>
</table>

**Remarks.** — The specimens studied are characterized by a conical shape with markedly rounded apical part in axial (vertical) sections (pl. 39:3–4), deuteroloculus markedly semitubular in shape (pl. 39:3), trochospiral coiling and a number of discernible whorls equalling 4–6, so they fully match the diagnosis of *Trocholina umbo*.


*U. TRIASSIC – L. JURASSIC FORAMINIFERS AND BIOSTRATIGRAPHY*

**Trocholina turris** FRENTZEN, 1941  
(pl. 39:7)

1975. *Trocholina turris* FRENTZEN; GUŠTČ: 25, pl. 8:1–7 (with synonymy).  

**Material.** — Four poorly preserved specimens in thin sections.  
**Association.** — *Nodosaria* sp., *Lenticulina* sp., *Astacolus* sp., and *Ophthalmidium* sp.  
**Description.** — as given by FRENTZEN (1941) and PILLER (1978).

**Dimensions of the test (in μm):**

<table>
<thead>
<tr>
<th>pl. 39:7</th>
</tr>
</thead>
<tbody>
<tr>
<td>diameter of the base</td>
</tr>
<tr>
<td>height</td>
</tr>
</tbody>
</table>

**Remarks.** — *T. turris* was identified is single subaxial and oblique sections only. The preservation is unsatisfactory because of an advanced recrystallization (sparitization) of tests but, nevertheless, high trochospiral coiling (pl. 39:7) and whorl number equalling 6–8 make the assignment of the specimens to *T. turris* possible. This species was hitherto unknown from the Carpathians.

**Occurrence.** — West Carpathians (Slovenský kras, section: 32 — Bleskov prameň): Pliensbachian.


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**Family Planispirillinidae** PILLER, 1978  
**Genus Semiinvoluta** KRISTAN, 1957  
*Semiinvoluta* sp.  
(pl. 39:1)

**Material.** — Two specimens in thin sections.  
**Association.** — *Nodosaria* sp., *Lenticulina* sp., *Geinitzinita* sp., and *Ophthalmidium* sp.  
**Description.** — Test consisting of proloculus and planispirally coiled deuteroloculus with umbilical depression on one side. In axial (vertical) sections (pl. 39:1), whorls are symmetrically crescent, with rounded ends. Number of whorls ranges from 4 to 5. Wall calcareous.

**Dimensions of the test (in μm):**

<table>
<thead>
<tr>
<th>pl. 39:1</th>
</tr>
</thead>
<tbody>
<tr>
<td>diameter</td>
</tr>
<tr>
<td>maximum thickness</td>
</tr>
</tbody>
</table>

**Remarks.** — The form studied is most close to *Semiinvoluta* sp. 2 described by GUŠTČ (1975, pl. 11:1–3) from the Lias of Medvednica Mt., Northern Croatia.

**Occurrence.** — West Carpathians (Slovenský kras, section: 32 — Bleskov prameň): Pliensbachian.
REFERENCES


— 1975. Genus Rhaetina Waagen, 1882 (Brachiopoda) in the uppermost Triassic of the West Carpathians. — Ibidem, 26, 1, 47-76.


U. TRIASSIC — L. JURASSIC FORAMINIFERS AND BIOSTRATIGRAPHY


WOJCIK, K. 1979. Sedymentacja i wykształcenie facjonalne liasu wierchowego w otoczeniu Doliny Chocholowskiej (unpublished report; Graduate paper MSc. Archiwum Instytutu Geologii Podstawowej UW).


EXPLANATION OF PLATES 27-41

PLATE 27

1. Abundant foraminifers Glomospirella friedli KRISTAN-TOLLMANN in coral-crinoid-brachiopod biomicrite. Tatra Mts., Lejowa Valley 1 (section 18, sample 49); Fatra Formation, upper biostrome; Rhaetian, ZPAL F. XXVIII/18-49.
2. Foraminifer biosparite with *Triasina hantkeni* Majzon. Tatra Mts., Velká Furkaska Mt. (section 17, sample 338); Fatra Formation, lower biostrome; Rhaetian. ZPAL F. XXVIII/17-338.
3. Biosparrudite composed of pelecypod and gastropod debris with oncolitic envelopes and sessile foraminifers *Toly­pammina gregaria* Wendt. Velká Fatra Mts., Dedošova Valley (section 11, sample 3); Fatra Formation, lower biostrome, GUSA V 268/3.

**PLATE 28**

1. Numerous foraminifers *Glomospirella friedli* KRISTAN-­TOLLMANN in crinoid-brachiopod-pelecypod biosparite. Stráž­žovská hornatina Mts., Norovica Mt. (section 22, sample 25); Norovica Formation, Mojtin Limestone Member; Rhaetian. GUSA V N/25.
3. Biosparrudite composed of pelecypod and gastropod debris with oncolitic crusts; ooids and rare foraminifers *Aulo­tortus sinuosus* WYNSCHENK, “*Tetrataxis* inflata KRISTAN and *Ophthalmidium* sp. are also visible. Slovenské rudo­horie Mts. (Muránska planina), Skalka (locality 30, sample 1); Dachstein Limestone; Rhaetian. ZPAL F. XXVIII/30-1.

**PLATE 29**

1. Foraminifer assemblage enclosing *Involutina liassica* (JONES), *Nodosaria* sp., *Frondicularia* sp., *Astacolus* sp., *Lenticulina* sp. and *Ophthalmidium* sp. seen in crinoid bionicrite. Velká Fatra Mts., Rúbaň Skala (locality 1, sample 9718); Lias of the Tatricum in the Velká Fatra Mts., Sinemurian. PFUK 9719.

**PLATE 30**

2. Obliteration of internal structure through recrystallization in *Triasina hantkeni* MAJZON, *Aulotortus sinuosus* WYNSCHENK and *Auloconus permodiscoides* (OBERHAUSER). Strážovská hornatina Mts., Těstie (section 24, sample 23); Morovica Formation, Mojtin Limestone Member; Rhaetian. GUSA V T/23.
3. Various stages of progressing recrystallization (sparrytization) of *Triasina hantkeni* MAJZON tests. Tatra Mts., Lejowa Valley (section 18, sample 17); Fatra Formation, lower biostrome; Rhaetian. ZPAL F. XXVIII/18-17.
4. Tests of foraminifers *Triasina hantkeni* MAJZON with oolitic coatings (arrowed) in biosparite. Strážovská hornatina Mts., Norovica Mt. (section 22, sample 15); Norovica Formation, Mojtin Limestone Member; Rhaetian. GUSA V N/15.
5. Numerous tests of foraminifers *Triasina hantkeni* MAJZON with onkolitic envelopes (arrowed). West Tatra Mts., Velká Furkaska Mt. (section 17, sample 338); Fatra Formation, lower biostrome; Rhaetian. ZPAL F. XXVIII/17–338.

6. Compactional deformation of *Triasina hantkeni* MAJZON tests (arrowed) in marly limestone. Tatra Mts., Wielka Sucha Valley (locality 27, sample 2); Norovica Formation, Mojtíž Limestone Member; Rhaetian. ZPAL F. XXVIII/27–2.

All × 10

**PLATE 31**


**PLATE 32**

1. Foraminifer biomicrite with *Glomospirella friedli* KRISTAN-TOßMANN. Lejowa Valley I (section 18, sample 49). Fatra Formation. Rhaetian. ZPAL F. XXVIII/18–49. × 30.

2-4. *Glomospirella friedli* KRISTAN-TOßMANN; 2 — equatorial section, 3 — axial and equatorial sections, 4 — oblique section. Lejowa Valley I (section 18, sample 49). Fatra Formation. Rhaetian. ZPAL F. XXVIII/18–49. × 80.


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**PLATE 33**


8. *Aulotortus tumidus* (Kristan-Tollmann), subaxial section. Široka Valley (section 8, sample 5). Fatra Formation. Rhaetian. GUSAV 062/5. × 65.


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**PLATE 34**


Norovica Formation, Rhaetian

All \( \times 40 \)

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**PLATE 35**


4. *Auloconus permodiscoides* (OBERHAUSER), subaxial section. Chocholowska Valley (locality 26, sample II-5). Norovica Formation. Rhaetian. ZPAL F. XXVIII/26-II-5. \( \times 50 \).


7. *Triasina hantkeni* MAJZON. Test encrusted by *Girvanella*. Chocholowska Valley (locality 26, sample II-5). Norovica Formation. Rhaetian. ZPAL F. XXVIII/26-II-5. \( \times 50 \).


10 — Norovica Mt. (section 22, sample 13). Norovica Formation. Rhaetian. GUSAV N/13. \( \times 65 \).

11 — Chocholowska Valley (section 26, sample 5a). Norovica Formation. Rhaetian. ZPAL F. XXVIII/26-5a. \( \times 75 \).

12 — Lejowa Valley II (locality 28, sample II-6). Norovica Formation. Rhaetian. ZPAL F. XXVIII/28-II-6. \( \times 50 \).

13 — Velká Furkaska Mt. (section 17, sample 338). Fatra Formation. Rhaetian. ZPAL F. XXVIII/17-338. \( \times 40 \).

14 — Norovica Mt. (section 22, sample 20). Norovica Formation. Rhaetian. GUSAV N/20. \( \times 30 \).

15 — Trstie (section 24, sample 23). Norovica Formation. Rhaetian. GUSAV T/23. \( \times 30 \).

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**PLATE 36**

1. *Planiinvoluta carinata* LEISCHNER, vertical section. Chocholowska Valley (section 26, sample 8). Norovica Formation Rhaetian. ZPAL F. XXVIII/26-8. \( \times 80 \).


17. *Ammobaculites* *rhaeticus* KRISTAN-TOlLMANN, axial section. Třísté (section 24, sample M-21). Norovica Formation. Rhaetian. GUSA V T/M-21. × 56.

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**PLATE 37**


8. *Nodosaria* sp., axial section. Velká Furkaska Mt. (section 18, sample 388). Fatra Formation. Rhaetian. PFUK 352/388. × 120.


12. *Ophthalmidium martanum* FARINACCI, subaxial section. Bleskový prameň (section 32, sample 166/2). Limestone of Bleskový prameň. Rhaetian. ZPAL F. XXVIII/32-166/2. × 120.


1-2. *Involutina liassica* (Jones), axial sections, microspheric forms. Ružán Skala (locality 1, sample 9719). Lias of the Tatricum in the Velká Fatra Mts. Sinemurian. PFUK 9719. 1 — x 80, 2 — x 70.


7-8. *Involutina liassica* (Jones), oblique sections. Ružán Skala (locality 1, sample 9720). Lias of the Tatricum in the Velká Fatra Mts. Sinemurian. PFUK 9720. 7 — x 80, 8 — x 90.


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**PLATE 40**

*Ophthalmidium leischneri* (Kristan-Tollmann)

1. axial section, megaspheric form. Velká Furkaska Mt. (section 17, sample 421). PFUK 352/421. × 150.

2. axial section, megaspheric form. Lejowa Valley I (section 18, sample L-8). ZPAL F. XXVIII/18-L-8. × 150.

3. axial section, Strážyska Valley I (section 20, sample S2b). ZPAL F. XXVIII/20-S2b. × 150.

4. axial section, Strážyska Valley I (section 20, sample S2). ZPAL F. XXVIII/20-S2. × 150.

5. axial section, microspheric form. Strážyska Valley I (section 20, sample S3). ZPAL F. XXVIII/20-S3. × 150.

6. subaxial section, microspheric form. Strážyska Valley I (section 20, sample S2b). ZPAL F. XXVIII/20-S2b. × 150.

7. oblique section, megaspheric form. Lejowa Valley I (section 18, sample L-8). ZPAL F. XXVIII/18-L-8. × 150.

8. equatorial section. Lejowa Valley I (section 18, sample L-8). ZPAL F. XXVIII/18-L-8. × 150.

9-10. subequatorial sections, Lejowa Valley I (section 18, sample L-8). ZPAL F. XXVIII/18-L-8. × 150.

11. axial section; a specimen with attached foreign test. Strážyska Valley I (section 20, sample S2b). ZPAL F. XXVIII/20-S2b. × 150.

12. axial section: a specimen with regenerated last chamber (arrowed), situated asymmetrically to the foregoing chambers. Strážyska Valley I (section 20, sample S2b). ZPAL F. XXVIII/20-S2b. × 150.

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**Ophthalmidium walfordi** Häusler


15. subaxial section. Strážyska Valley I (section 20, sample S2a). ZPAL F. XXVIII/20-S2a. × 100.


All from Kopieniec Formation. Lias (Hettangian-Sinemurian)

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**PLATE 41**


A. GAŻDZICKI: U. TRIASSIC—L. JURASSIC FORAMINIFERS AND BIOSTRATIGRAPHY
A. Gazdzicki: J. Triassic - L. Jurassic Foraminifers and Biostratigraphy
A. GAŻDZICKI: U. TRIASSIC - L. JURASSIC FORAMINIFERS AND BIOSTRATIGRAPHY
A. GAŻDZICKI: U. TRIASSIC—L. JURASSIC FORAMINIFERS AND BIOSTRATIGRAPHY
A. GAŻDZICKI: U. TRIASSIC — L. JURASSIC FORAMINIFERS AND BIOSTRATIGRAPHY
A. GAŻDZICKI: U. TRIASSIC — L. JURASSIC FORAMINIFERS AND BIOSTRATIGRAPHY
A. GAŻDZICKI: U. TRIASSIC — L. JURASSIC FORAMINIFERS AND BIOSTRATIGRAPHY
A. Gaździcki: U. Triassic—L. Jurassic Foraminifers and Biostratigraphy