Cyclic-sedimentary Subdivision of the Rhaetian of the Polish Lowlands

by

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Summary. In the shallow, epicontinental Upper Triassic basin, which occupied vast parts of Polish Lowlands (Fig. 1), successive ingressions entering from the Alpine geosynclinal basin are marked. At the same time, paleotectonic modifications of the sedimentary basin, extensive and variable in time, took place. Cyclic changes of the diastrophism were of universal character, although not identical as to its content, and are reflected in the vertical lithological sequence of sediments, showing great regularity in their horizontal range at the same time. These changes also led to occurrence of local gaps, particularly numerous in the upper stage of the Upper Triassic — in the Rhaetian. The rhythmic sequence of marine and non-marine sediments is accepted as basic criterion for detailed stratigraphical division of the Rhaetian cycloths: RIJ, RIJ2, RIJ1 and RIJ3. The lithological characteristics of sediments, their structural pattern and vigorous development of terrestrial flora (Fig.3) typical for transition periods in stratigraphy of the Upper Triassic, enable us to assume that the upper boundary of the Rhaetian should be located between the cycloths RIJ and RL.

The deep boreholes recently drilled in the area of the Polish Lowlands revealed that the classic exposures and the previously known drilling profiles of epicontinental Rhaetian do not represent a complete stratigraphic succession.

The abundant well-logging material obtained within the research project of the Geological Institute, Petroleum Industry and Non-Ferrous Ore Industry of Poland made possible the attempt at a detailed subdivision of the Rhaetian in virtue of cyclic-sedimentary criteria, established on the most complete profiles from the region of Silesia and the eastern Sudetic forefield, and on their regional correlations in the Polish Lowlands. Concise results of this attempt are presented in the paper.

In consequence of the investigations performed it was found that the vertical position of certain previously known lithological units is — after establishment of complete correlations — different from that hitherto assumed. This is the case, for example, of the “Woźniki limestones” (Fig. 2, Pl. III, IV) and “Lisów breccia” (Fig. 2), previously discussed by Samsonowicz [27] and Różycki [25] and more recently by Znosko [34] and Szyperek [29].

A more detailed division of the Rhaetian was made by Różycki [26] for the region of Kujawy, Znosko [34] for the area between Cracow and Wieluń, and Dadlez [4—6] for Western Poland and
the Mazurian District. According to the views held at that time, these authors accepted the age of
Rhaetian deposits as Lower Jurassic.

In 1962, the International Colloquium in Luxemburg passed several regulations; one of them
including the Rhaetian developed in the German facies into the Triassic, as its uppermost stage;
moreover, the *Eupholetta gracilis* Horizon (the lowest part of the *Thaumatopterus schenkii* Zone
according to Troedsson [30]), should be considered as the lowermost zone of the Lower Jurassic.

The results of further studies revealed that the vertical range of the Rhaetian stage is still controver-
siual in the opinions of various authors (cf. [6, 11]). The lower boundary of the Rhaetian is basically
univocal and distinct. Many of the authors draw that boundary above the Upper Gypsum Level
within the Upper Gypsum Keuper (the German equivalent of that zone is “Heldburggips” [26, 11, 9]).

The upper boundary of the Rhaetian and the Rhaetian/Lower Jurassic boundary are still open
questions. Many authors from various parts of Europe have been discussing these problems (e.g.
[2, 3, 6, 9, 11, 14—16, 18, 20, 24, 28, 30—32]).

The lower boundary of the Rhaetian and its correlation with Alpine Rhaetian facies were

The subdivision of the Rhaetian into the Lower (*Posterus*) and Upper (*Contorta*) Zones was
made by Kopik during his studies of the Polish Lowlands [11] and in the Holy Cross Mts [12]
with reference to German, Swedish and English palaeontological studies. This subdivision was based
on the occurrence of the pelecypod, *Unionites posterus*, and ostracods of the genus *Rhomboxythere*
in marine intercalations of the Lower Rhaetian. However, detailed ostracod zones were not distin-
guished [4, 11, 12]. The *contorta* Zone is not documented palaeontologically in Poland, because
neither the pelecypod *Rhaetavcica contorta* nor guide ostracods (except for *Boirida* sp. [4]) have
been found so far. The “Upper Rhaetian” deposits [11] were previously assigned by Dadlez and
Kopik [4] to the *Rhaetavcica contorta* Zone of the “Middle Rhaetian”. However, the microfaunal
assemblage of the Polish Lowlands listed by them [4, 7, 11, 12] occurs both in the *Unionites posterus*
and *Rhaetavcica contorta* Zones.

Will [32], who carried out studies of the area of NW Germany, makes use of palaeo-
ontological-lithological premises to present a detailed subdivision of the Rhaetian and a floristic
boundary between the Rhaetian and the Liassic.

In the Earth history, the time-span of the Upper Triassic is estimated at about
12 million years [3]. The most significant feature of epicontinental Keuper and Rhaetian
sediments is the stamp of continuous, enantiomorphic diastrophism, particularly
intensified during a few successive eo-Kimmeridgian phases.

The shallow epicontinental Upper Triassic basin occupied some parts of the
Polish Lowlands (Fig. 1) and German Lowlands and reached as far as Lorraine.
Successive ingressions from the Alpine geosynclinal basin are marked. At the same
time, paleoecological modifications of the sedimentary basin, extensive and variable
in time, took place. These changes resulted in a differentiation of sedimentary condi-
tions in various parts of the basin, including the formation of local gaps. Moreover,
the common scarcity of faunal fossils, particularly of guide fossils, make biological
subdivision and correlation with the Alpine region difficult to perform.

On the basis of lithofacial criteria, in the 1920’s and in later years, German authors
performed a detailed stratigraphic subdivision of clay-carboniferous and gypsum
Keuper, still valid and widely acknowledged.

Such subdivisions for the upper stage of the Upper Triassic were neither so detailed
nor so univocally understood (in the whole area of occurrence of epicontinental
Rhaetian, both in Poland and Germany). This is due to numerous stratigraphic
gaps in the vertical profile of the Rhaetian.
PLATE I

Photo 1. Core from borehole B-2. Depth — 1121 m; bottom part of the cyclothem R II. Graded sandstone, from coarse- to fine-grained, cross-bedded. Dip about 5°. (×1.0)

Photo 2. Core from borehole B-2. Depth — 1321 m; bottom part of the cyclothem R I. Dolomitic claystone with fine, parallel bedding with pelitic dolomite. Dip angle about 25°. (×1.0)
Photo 1, Photo 2. Core from borehole from the vicinity of Zawiercie. *Unioites posterus* in deposits of upper part of the cyclothem *R II*₂. (× 1.0)

Photo 3, Photo 4. Basal conglomerates of the cyclothem *R II*₁ from the region of the upper course of Warta river. (× 1.0)
PLATE III

Photo 1. Karst weathering of Woźniki limestones. Vicinity of Zawiercie. (× 0.20)
Photo 2. Woźniki limestone from the vicinity of Zawiercie. Fissures filled with quartz. (×1.0)
Photo 3. Syderitized Woźniki limestones from Poręba near Zawiercie. (× 1.0)
Photo 1. Macromnants of terrestrial flora occurring in Woźniki limestones. Well core from Poręba near Zawiercie. (× 0.5)

Photo 2. Woźniki limestone with algal remnants and burrowings. Vicinity of Zawiercie.

Photo 3. Stromatolites in Woźniki limestones. Vicinity of Zawiercie. (× 1.0)

Photo 4. Thin-bedded Woźniki limestone with ooids. Vicinity of Zawiercie. (× 1.0)
The subdivision of that stage presented in this paper is based (after Różysiński [26]) on the criterion of sequence of cyclic changes in sedimentary conditions of the basin.

Moreover, it was assumed that these changes were primarily connected with the cyclic course of diastrophism.

In consequence of a correlation of characteristic sets of beds and of drawings of successive paleogeographical maps it was found that various diastrophic changes were of common character, although not identical in their content, and were marked by changes in the vertical lithological sequence of deposits, showing at the same time a high regularity in their horizontal distribution. In most cases, these changes can be correlated with the area of the German Lowlands.

Fig. 1. Contemporary extent

In the subdivision proposed, paleotectonic cycles were applied to the time scale. By "paleotectonic cycle" is meant a complex of diastrophic changes, with up and down limitations in the time scale by the definite course of regional deformation of the basin and by accompanying climatic variations and sea-level changes.

In the scale of changes in lithologic character of the undergoing deposition, the "great cyclothem" corresponds to the time—span of one complete paleotectonic cycle. Here, great cyclothem is the term used to describe a sedimentary unit of the
BORE HOLE B-1

J_1

R III

R II_2

R II_1

R I_2

R I_1

Upper Gypsum Level in the Upper Gypsum Keuper
first order. The assumed criterion of differentiation of a single cyclothem is a sedimentary succession beginning with transgressive deposits and ending with regressive ones. It was noted that cyclothems based on such assumption repeatedly occur in the vertical profile of the Rhaetian (cf. Fig. 2), being differentiated among themselves by the order of magnitude of marine influences and their regional ranges. The term “cyclothem” will be further applied to sedimentary units of the second order, which begin with transgressive sediments, traceable in the whole basin. Also, in the whole basin, the rhythmical sequence of vertical changes is maintained, whereas faunal distribution is dependent on basin morphology.

Within the particular cyclothems also phantom links, i.e. such parts in which deposition did not continue or the sediment was thereafter removed, should be considered. Establishment of the size of a missing sedimentary section is only possible if still smaller sedimentary units will be distinguished within every cyclothem. Auxiliary terms applied for the third order of magnitude — span (marked with the letter “c” in Fig. 2), for the fourth — phase (“f” in Fig. 2), for the fifth — level (“p” in Fig. 2), and for the sixth order of magnitude — lithologic section.

It was noted that in the course of the Rhaetian, three paleotectonic cycles took place. During these cycles the epicontinental basin underwent structural modification and three large cyclothems marked with the symbols R I, R II and R III were deposited.

Higher intensifications of diastrophism of the three co-Kimmeridgian phases took place respectively: before R I, between R I and R II, and between R II and R III.

These phases were marked in the central parts of the basin by successive angular disconformities in the position of sediments (cf. B — 2, Pl. I, Photos 1 and 2), and in other parts of the basin by regional sedimentary gaps of various magnitude.

In the older lake cyclothem, R I, two cyclothems were distinguished — R I, and R I₂, (Table I, Fig. 2) similarly as in the middle great cyclothem R II, where cyclothems R II₁ and R II₂ were distinguished.

A generalized profile of a complete sedimentary sequence from the eastern Sudetic forefield (Borehole B — 1*), cf. Figs. 1, 2) is typical for cyclothems R I₁, R I₂, R II₁ and R II₂ of epicontinental Rhaetian.

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Fig. 2. Typical profile of complete sedimentary sequence, for cyclothems R I₁, R I₂, R II₁ and R II₂, given on the example of borehole B-1.

|   | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 |
| 1 | dolomite | 2 | limestone | 3 | dolomite claystone | 4 | limy calcic claystone | 5 | claystone | 6 | clotty claystone | 7 | claystone with allogenic clots | 8 | sandy claystone | 9 | claystone with sandstone intercalations | 10 | sandy clotty claystone | 11 | clayey sandstone | 12 | fine, medium and coarse-grained sandstones | 13 | conglomerate | 14 | gravel | 15 | breccia | 16 | coal | 17 | dips of beds | 18 | concentrations of secondary sulphates | 19 | carbonate, marly of siderite allogenic clots | 20 | glauconite | 21 | foraminifers | 22 | ostracods | 23 | “Woźniński limestones” | 24 | “Lisów breccia” | 25 | microsponges | 26 | bonebed | 27 | feldspar pebbles | 28 | quartz pebbles | 29 | detritus of carbonized plants |

* Rhaetian profile from borehole B — 1, in full name: 1 — KW Wieluń, was previously interpreted by Deczkowski [8], with reference to the stratigraphic subdivision of Dadlez [4] from Western Poland.
In order to make everyday use of these terms easier, additional names were given to them, either taken from geographical location of their best known profiles, or from traditional terms known from the literature and referred to typical lithological units, occurring within the cyclothsms (Table I).

The division of epicontinental Rhaetian proposed, and a comparison with the actually applied subdivisions of the Rhaetian by various authors are presented in Table I.

The third and youngest upper paleotectonic Rhaetian cycle was marked with the symbol R III. It is a significant, although different from the two older ones, element of the development of the Rhaetian basin on the platform. After completion of cyclothem R II 2 sedimentation, further, pre-Liassic modification of the structural frame took place. This phase of diastrophism in the area of Polish Lowlands was not found to be accompanied by a marine impulse. Within cyclothem R III, corresponding to “Lower Beds with Triletes” [32], nonmarine facies are dominant and their lithological character still has many “Upper Triassic” features.

The idea of stratigraphic divisions based on the criterion of cyclic rhythm of non-marine sedimentation was elaborated by S.Z. Różycki [26] for establishing a detailed stratigraphy of the Rhaetian and Liassic in the area of southern Kujawy.

The profile of the “Upper Klodawa series” [26] determined lithofacially, presents a complete and typical development of cyclothem R III. Correlation of a detailed

### TABLE II

<table>
<thead>
<tr>
<th>S.Z. Różycki 1958</th>
<th>Subdivision into cyclothsms 1971</th>
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<tbody>
<tr>
<td><strong>Cycle III:</strong></td>
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<td>Ksawerów Series</td>
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<td>RI.</td>
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<td>D</td>
<td>Ksawerów Cyclothem</td>
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<td>A</td>
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<td><strong>Cycle II:</strong></td>
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<tr>
<td>Upper Klodawa Series</td>
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<tr>
<td>D</td>
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<td>C</td>
<td>R III</td>
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<td>B</td>
<td>Klodawa Cyclothem</td>
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<td>A</td>
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<td><strong>Cycle I:</strong></td>
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<td>Lower Klodawa Series</td>
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lithostratigraphic subdivision according to S.Z. Różycki, together with the proposed subdivision into cyclothem is given in Table II.

Successive intensification of diastrophism, which took place at the completion of deposition of cyclothem R III definitely ended the existence of the sedimentary basin with Upper Triassic structural frame in the Polish Lowlands.

Deposition of sediments belonging to the limnic cyclothem marked with symbol “RL” and corresponding to the “Upper Beds with Trilobites” [32], was preceded by a regional erosion.

The most complete known development of cyclothem RL is represented by a detailed lithofacial profile of the “Ksawerów series” from southern Kujawy, given by S. Z. Różycki [26].

Sediments of cyclothem RL already exhibit features typical of the Lower Jurassic. Clay rocks of dark-gray and brown-black colour predominate. The structural pattern of sediments RL is quiet and generally flat, with rare traces of slickenside, and similar in tectonic style to that of the overlying horizons sediments of the Liassic. Thickness of that cyclothem in up to a few scores of meters in Northern Poland and up to 180 m in the Szczecin synclinorium. Sediments RL are rich in floral macrofossils and palynologically documented by assemblages of characteristic megaspores and microspores in some regions.

Biostratigraphical remarks

Changes in the organic assemblages during the Rhaetian took place in a way harmoniously connected with changes in configuration of the basin accompanying climatic fluctuations. The general outline of vertical ranges of animal and plant organisms, depending on ecological laws which are different in water basins and on land surrounding those basins, is given on Fig. 3. Various hemeras are listed on the basis of the data collected from the literature [1, 2, 13—20, 22, 28, 30, 32, 33] for selected most characteristic fossils of the Rhaetian.

Transgressive-marine impulses are marked in sediments by common and abundant occurrence of foraminifers of the genera Variostoma and Diplotremina, among others.

Gradual transition to brackish and lagunal environment is marked by development of ostracods of the genera Notocythere [32] = Rhombocythere [1] and Darwinula.

Transitional periods, i.e. corresponding to decline of regression and outset of another marine ingression, are characterized by the greatest intensification in the development of terrestrial plant communities. Micro- and megaspores are the best indicators here. Successive climatic fluctuations and changes determine their vertical individual and quantitative development.

The first large group of microspores* (Fig. 3) is represented by numerous genera and species; only the most common are listed. This group existed from the decline of the Gypsum Keuper, through the whole of the Rhaetian, and became almost completely extinct at the beginning of the Lower Jurassic, i.e. during cyclothem RL corresponding to the Upper Beds with Trilobites.
The second group of microspores ** (Fig. 3) is represented on the diagram by two characteristic species. They appear in the cyclothem R I, and achieve main development in RL, becoming extinct in the *Thaumatopteris schenki* Zone.

Megaspores, a few guide species of which are listed on Fig. 3, appear in R II, thrive during RL and partly pass to the *Thaumatopteris schenki* Zone.

Macroflora is represented by pteridosperm *Lepidopteris ottonis* (Goepert) Schimper (Fig. 3), and occurs in sediments of cyclothsms R II 1–2 and R III, and was not recorded above the top of the Beds with *Triletes*.

<table>
<thead>
<tr>
<th>Vertical range</th>
<th>Biostratigraphy</th>
<th>Microflora</th>
<th>Flora</th>
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<tr>
<td></td>
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<td>Foraminifers</td>
<td>Ostracods</td>
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<td>UGL</td>
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**Fig. 3**

Microfauna: foraminifers — gen. *Varikostoma* and *Diplomorina*; ostracods — gen. *Notocythere* and *Darwinula*.


Flora: *Lepidopteris ottonis* (Goepptre) Schimper

UGL — Upper Gypsum Level of the Upper Gypsum Keuper

The growing — from the cyclothem R I 2 — evolutionary transforming floral association, reaches its maximum at cyclothem RL and thereafter rapidly becomes extinct in the Liassic a.

The moment of extinction of this association was recognized by a number of Scandinavian authors as an upper boundary of the Rhaetian [2, 10, 15]. In Poland this view is shared by T. Marcinkiewicz, in results of her studies on megaspores [18].

Observations of plant hemeras in the whole of epicontinental Upper Triassic reveal that the development of floras begins usually below the sedimentary boundary of sediments, main intensification of the development falls to the transition between two lithostratigraphical units, and the occurrence of indicative flora still continues in the lowermost parts of the younger unit, already above sedimentary boundary.
Thus it may be assumed that, by analogy to older subdivisions, also this boundary based on floral indices may be located at the beginning of maximal development of floral association, i.e. between R III and RL and not at the moment of its final extinction, i.e. at the base of the *Thaumatopteris schenki* Zone.

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Содержание. В мелком эпиконтинентальном позднеприазовом бассейне, охватывающем значительную часть Польской низменности (фиг. 1), отмечаются очередные ингрессии, поступающие из альпийской геосинклинали. Одновременно происходила существенная и дифференцированная во времени палеотектоническая перестройка седиментационного бассейна. Циклические изменения диастрофизма отличались повсеместностью и хотя по содержанию не тождественные, они отражались в вертикальном изменении литологической последовательности отложений, сохраняя при этом выдержанность горизонтального распространения. Эти изменения привели к образованию локальных перерывов, особенно часто наблюдаемых в верхнем ярусе верхнего триаса, в рэте. Ритмически-циклическая последовательность морских и неморских отложений является основой детального стратиграфического подразделения, предлагаемого в настоящей работе для рэта циклами R I, R II и R III. Литологические особенности отложений, их структурная позиция, развитие континентальной растительности (фиг. 3), характерное для переходных моментов в стратиграфии верхнего триаса, обусловливает проведение верхней границы рэта между циклами R III и RL.