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The Silurian biostratigraphy of Poland based on graptolites

ABSTRACT: The present state of knowledge of deposits of the Silurian system in Poland is reported, mainly on borehole data, while their biostratigraphy is based on graptolites. The descriptions of the Silurian deposits follow the regional subdivision of Poland into the particular structural units. The rich graptolite fauna they contain permits the whole Silurian system of Poland to be subdivided into zones. These have been defined according to the binding rules. A total number of 42 zones has been distinguished in the Polish Silurian. Out of these 12 belong to the Valentian, the youngest of them being separated into two subzones; 8 zones characterize the Wenlockian; 13 the Ludlovian, 4 of them forming one index horizon; 9 the Postludlovian, with one horizon which can be more accurately defined after its graptolite fauna has been worked out in greater detail. The standard subdivision of the Silurian system, including the Ludlovian, used in the present paper, follows the international rules. Deposits younger than the Ludlovian but older than the Gedinnian, without an officially recognized stratotype or name, are here referred to under the name of Postludlovian. The correlation of the Polish Silurian deposits with other, but only neighbouring areas, shows that the Polish profiles contain a complete stratigraphic sequence, particularly in the graptolite facies. Here and there it even passes into the Lower Devonian (Gedinnian) and this makes Poland a region of paramount importance in the study of the evolution of graptolite faunas.

INTRODUCTION

The increasingly extended prospecting undertaken by the Polish Geological Survey during the last decade has helped to clear up a number of problems in the field of structural geology concerning the deep substratum. Numerous boreholes have yielded rich material; its full description is, however, a timeabsorbing and strenuous task. This material contains Silurian profiles of deposits which are undoubtedly of great value. Even preliminary investigations have shown that this system is developed in Poland in a complete stratigraphic sequence, while its graptolite fauna is exceptionally abundant and allows a detailed subdivision. A number of new problems has also come forward concerning the paleogeography, stratigraphy, tectonics and facial conditions in the Silurian system of Poland and elsewhere.

The state of knowledge of the Silurian system in Poland, as presented by the writer, dates back to the middle of 1968. The data here given are based on the results of his own research studies, continued for over ten years, as well as on papers already published by himself or other authors, supplemented by archival material.

The biostratigraphy is based exclusively on the graptolite fauna whose analysis has led to the distinction of graptolite zones in agreement with the generally binding rules, The other fauna, also known from the various Silurian profiles of Poland, has been disregarded, since, so far, it is very fragmentarily worked out.

The standard subdivision of the Silurian system in Poland, used in the present paper, follows the international rules so as to facilitate more accurate correlation which has been carried out from the same aspect in relation to the adjacent areas.

The facial development and the paleogeography of the Silurian system in Poland are briefly discussed and the problem of the Silurian/Devonian boundary in Poland is presented.

All these problems could not be satisfactorily dealt with without the assistance and friendly co-operation of a number of persons.

The writer's most sincere thanks are due to Professor Dr. E. Passendorfer for the helpful suggestions concerning the lay out of the whole paper; Doc. Dr. A. Urbanek for the kind permission to make use of his still unpublished results of investigations of the Upper Ludlovian fauna, as well as for most helpful discussions on the graptolite fauna; Dr. K. Korejwo for successful co-operation in the elaboration of new materials and frequent discussions on the problems here considered; the Directors of the Geological Institute in Warsaw for the access to their archival materials; the Directors and geology staff of the Oil Research Survey for entrusting him with the elaboration of materials from some recent boreholes.

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HISTORICAL SKETCH OF SILURIAN INVESTIGATIONS IN POLAND

The history of the Silurian investigations in Poland may be split up into three periods. The first period covers the years between 1868 and 1913, i.e. from the discovery of this system in the Holy Cross Mts. by

Zejszner (1868), to the publication of a pertinent work by Czarnocki & Samsonowicz (1913). During that period, side by side with papers by Zejszner (1869), those by Gürich (1896, 1899), Siemiradzki (1886) and Sobolev (1900, 1911) supplied fresh evidence that added to the knowledge of the Silurian. This period, in principle consisting of pioneering exploration, is now only of historical importance, since the concept of the Silurian system was not then well defined, and some authors included into it also the Ordovician.

The second period, closely associated with the research work of Czarnocki and Samsonowicz, covers the years from 1913 to 1939. These two explorers have worked out not only the fundamental stratigraphy of the Silurian system but also the stratigraphy of the Paleozoic era in the Holy Cross Mts. In a number of publications (e.g. Czarnocki 1919a, b, 1927, 1936, 1938; Samsonowicz 1916, 1923, 1926, 1934) a synthesis was given of the stratigraphy and the tectonics of that area, while the Paleozoic strata of the Holy Cross Mts. were correlated with other European regions. Not much can now be added to the basic conclusions of these authors. Papers concerned with the neighbouring regions (Kozłowski 1929, Samsonowicz 1939) are also important for the knowledge of the Silurian stratigraphy.

The third period marks a growth in the research work of the Silurian. It started after the end of the second World War and still continues. Up to 1956, the investigations carried out by Czarnocki and Samsonowicz were also centred in the Holy Cross Mts. area. A paper by Czarnocki (1950) and a chapter in the Handbook on the Geology of Poland by Samsonowicz (1952) are important synthetic works on the Paleozoic of that region.

Since 1953, other writers are attracted by the Silurian deposits of the Holy Cross Mts.; among those most noteworthy are Tomczyk (1954, 1956, 1962a, b, c), Tomczykowa (1957, 1958, 1959, 1962a), Filonowicz (1963), Kowalczewski (1963, 1968a, b), Teller (1955), Dulski & Zagórski (1962). Their publications contain interesting information which more clearly define the Silurian stratigraphy and previous conclusions of Czarnocki and Samsonowicz.

Investigations on the stratigraphy and development of the Silurian deposits took a new turn as a program promoting the study of the subsurface structures in the Polish Lowlands was being realized. The first borehole (Chełm IG-1), drilled in 1956, revealed a 400 m deep profile of Upper Silurian deposits bearing a rich graptolite fauna. A preliminary report on the results of this boring was given by Tomczyk and Teller (1956), while a detailed description of that fauna was completed between 1956 and 1961 (Teller 1964a, Korejwo & Teller 1964). Since then up to now, Silurian deposits have been encountered in more than 90 boreholes and they have not, as yet, been completely worked out. The following authors have dealt with the stratigraphy, fauna and lithology of the Silurian system outside of the Holy Cross Mts.: Hajłasz (1967, 1968), Jaworowski (1964, 1965, 1966), Jaworowski & Modliński (1968), Teller (1960a, 1962a, c, 1964a, b, 1965, 1966, 1967, 1968a, b), Korejwo & Teller (1968); Teller & Korejwo (1968a, b, c d, e), Tomczyk (e.g. 1960a, 1962a, 1963a, b, 1964a, b, 1968a, b, c), Urbanek (1960, 1963, 1966), Witwicka (1967) and others.

A number of Silurian outcrops occur in the Sudetes which lie within the territory returned to Poland in 1945. Research work carried out by Malinowska (1955), Oberc (1953, 1957, 1966) and Teller (1959, 1960b, c, 1962b) in the Bardo Mts. supplied evidence in some cases directly contrary to the views advanced by the German geologists. The same applies to the Kaczawa Mts. area (Kornaś 1963; Jerzmański 1955, 1965, 1968), and to the Central Sudetes (Gunia & Wojciechowska 1964).

Boreholes in southern Poland (the Carpathian foredeep and the marginal area of the Silesia-Cracow basin) have also yielded interesting data concerning the stratigraphy and facial development of Silurian deposits there (Siedlecki 1962, Roszek & Siedlecki 1963, Tomczyk 1963a).

The above brief review of the post-war works shows the tremendous development of the investigations of the Silurian system in Poland. This is due mainly to the great abundance of new materials which attract the attention of many geologists.

THE SUBDIVISION OF THE SILURIAN SYSTEM IN POLAND

In order to present the subdivision of the Silurian system in Poland and its correlation with other European areas, it is necessary to give a brief review of the evolution of opinions on this problem in the course of the last ten years.

During that time a great number of European geologists were particularly attracted by the problem of the subdivision of Ludlovian deposits and of the Silurian/Devonian boundary. This interest may be put down to the great abundance of new material and the re-interpretation of earlier information. The subdivision of the Valentian and the Wenlockian seems to be the least or even not at all discussed. In result of the increasingly extended studies aiming at the correct subdivision of the Ludlovian and the Silurian/Devonian boundary, a number of papers, some of them containing controversial opinions, were published between 1958 and 1968. These problems were also broadly discussed at five international conferences held over the same lapse of time (Prague 1958, Bonn 1960, Rennes 1964, Calgary 1967 and Leningrad 1968).

There is lack of consistency among the various authors in their interpretation of the subdivisions of the Silurian, particularly of the Upper Silurian, in Poland. Consequentially this may lead to misinterpretations of the development of that system in Poland. The subdivision here presented is based on the rules and suggestions of the International Subcommission on Stratigraphic Terminology (1961). Its primary purpose is to draw up a set of generally binding rules for the subdivision of the Silurian system in Poland.

The Silurian, as the equivalent of the system in the chronostratigraphic classification, is being subdivided into two series, the lower and the upper. The lower series embraces two stages: the Valentian and the Wenlockian; the upper one the Ludlovian and the Postludlovian. The Ludlovian and Postludlovian stages are additionally divided into substages.

The smallest units characterizing the Silurian deposits are based on paleontological data. They are the graptolite zones which fit into the biostratigraphic classification. In most cases their subdivision follows the binding rules. A complete Silurian profile with its respective zones can be distinguished only on a compilation of fragmentary profiles from various boreholes situated in the epicontinental area.

Within the Holy Cross Mts. there are no graptolites in the upper part of the Ludlovian and throughout the Postludlovian. Hence, two series have been differentiated here. The term series is not used here in its current meaning in chronostratigraphy but refers to a complex of specifically developed strata. In lithostratigraphic classification, member would be its corresponding term as it is superior in rank to a bed.

The names of stages, the Postludlovian excepted, are used according to the rules of priority.

Valentian Stage

The Valentian was introduced by Lapworth (vide Jones 1921) for a clayey graptolite-bearing complex in southern Scotland. It is a counter name for Llandovery which is used by Murchison (vide Jones 1921) for a clay-sandy complex in Wales. Jones (1921) applies the name of Valentian exclusively to the graptolite facies of Scotland, that of Llandovery to the geosynclinal area of Wales.

In the Lower Silurian of Poland, the graptolite facies is predominant and Valentian is the correct name to be used for the lowermost stage of that system in Poland. The graptolite zones of Poland are correlated with those in Scotland where they have first been identified.

The Valentian stage thus understood is subdivided in Poland into 12 graptolite zones, one of them with two subzones. Akidograptus ascensus in the oldest zone, Spirograptus spiralis the youngest one.

Wenlockian Stage

In Elles' meaning (1900) the Wenlockian has its full equivalent in the Silurian of Poland and its differentiation is doubtless. It is characterized by eight graptolite zones, the base indicated by the Cyrtograptus insectus zone and the top by the Cyrtograptus lundgreni zone.

Ludlovian Stage

This was differentiated by Murchison (1833, 1835) chiefly on lithological data from profiles in the shelf facies of Wales. Up to 1959 the division of this stage into smaller lithostratigraphic units varied greatly with the different British authors. Since Wales had been recognized as the type area for Ludlovian deposits, the continental profiles were correlated to that area, though this was not always fully justifiable.

Holland, Lawson & Walmsley (1959) published a new subdivision of the Ludlovian deposits of England. The pertinent details were published by them in 1963. This subdivision is based on biostratigraphic data and follows the rules of the American Code of Stratigraphic Nomenclature (1961). The Ludlovian was raised to the rank of a series and subdivided into 4 stages (Eltonian, Bringewoodian, Leintwardinian and Whitcliffian) which were, in turn, subdivided into beds. This subdivision has been correlated with the basin facies of Wales for which Allender's et al. (1960) and Holland's (1962) division has been accepted. Doubtless, this new classification fits excellently into the shelly facies of south Wales. It is not, however, always possible to accept and use it for continental profiles because of the strong differences in the lithology and the development of fauna as compared with England.

In most of the Ludlovian profiles of the Continent, in Poland particularly so, the predominant facies is clayey-marly, containing a graptolite fauna, while other animal groups are subordinate. These profiles bear closer affinities with the basin facies than with the shelly facies of England, and this should be kept in mind when correlating them. Obviously, the above does not apply to continental profiles that are characterized by different facial development (for instance the Barrandian area, Podolia, the shelly facies of the East-European platform). Moreover, in a number of continental profiles the presence has been observed of Silurian graptolites which are absent above the Ludlovian in the type profile of England. A continuity of sedimentation to the Lower Devonian is also observable on the Continent. Neither has the characteristic Ludlow Bone Bed been ever found in the continental profiles. In Wales the Ludlow Bone Bed is regarded as the index Silurian/Devonian boundary horizon above which there is a change of facies into a terrestrial or lagoonal one.

Because of the difficulties encountered in the correlation of the Ludlovian deposits with the English type profile, regional subdivisions with local names were introduced on the Continent, thus increasing the intricacy of the problem.

The opinions of Polish stratigraphers concerning the division of the Upper Silurian have been gradually modified, too.

Czarnocki (1950) uses the tripartite division of the Ludlovian, including into the uppermost part of the Upper Ludlovian the Bostów beds from the Holy Cross Mts., whose Gedinnian age is today quite doubtless. Samsonowicz (1952) distinguished the Lower and the Upper Ludlovian. A part of the Downtonian was by him included into the Upper Ludlovian, another part into the Gedinnian.

The Tomczyks (1956—1962) also use the tripartite division, both for the Holy Cross Mts. and the epicontinental region. Tomczyk (1962a) has distinguished — not only within the Ludlovian — a number of beds which he correlated with the English division (Holland, Lawson & Walmsley 1959) interpreted after his own concept. His argumentation to justify the above separation of beds is, i.a., based on the lack in Europe of exactly defined boundaries between deposits of the Lower and the Upper Devonian, the Devonian and the Silurian, as well as between the Lower, Middle and Upper Ludlovian, moreover, on the lack of more accurate correlation of the British and Rhenish Silurian with the Bohemian Silurian.

Tomczyk thinks that the introduction of a Polish stratigraphic terminology for the Ordovician and the Silurian of Poland would be very helpful in subdividing these deposits and would permit closer correlation with the classic European profiles.

It is doubtful whether the introduction of a Polish terminology is justifiable. Moreover, Tomczyk's statement that accurate boundaries are lacking in the European profiles and that the Polish stratigraphic terminology will allow correctly to correlate different sections, seems incongruous.

The above author's division (Tomczyk 1962a) was based chiefly on lithological data. It does not follow the generally binding rules, to say nothing of a number of unclarified points and unjustifiable subdivisions as well as the incorrect use of the term bed. With this in mind, the present writer does not use here Tomczyk's subdivision of the Polish Silurian.

A different subdivision of the Polish Silurian, including the Ludlovian, was proposed by Tomczyk in 1968b. Silurian is divided into two series, the lower and the upper. Into the lower series he placed the Llandoverian and Wenlockian stages and also the Lower Ludlovian substage.

The last named subdivision is supposed to be the equivalent of the Eltonian, Bringewoodian and the lower part of the Leintwardinian stages (Holland, Lawson & Walmsley 1959).

Tomczyk's upper series of the Silurian system embraces the upper substage of the Ludlovian and a new Podlasie stage. The upper part of the Leintwardinian, the Whitcliffian and the Ludlow Bone Bed correspond to Tomczyk's Upper Ludlovian substage, while the Downtonian is regarded as the equivalent of the Podlasie stage. That author does not justify his subdivisions, hence, we do not know the criteria he used for the subdivision of the Ludlovian into two substages and for the inclusion of the Lower Ludlovian into the lower series.

Teller (1964a) included the Ludlovian stage into the Upper Silurian series, subdividing the former into a lower and an upper substage. The lower substage embraces the whole Ludlovian in its original meaning, while the upper corresponds to the Downtonian.

In result of new materials the writer has revised his views concerning the division of the Upper Silurian series (Teller 1964b).

At present the writer believes that the equivalent of the Ludlovian stage (whose base is represented by the Eltonian in the shelly facies and by the Lower Ludlow Graptolite Shales in the basin facies, while its top by the Whitcliffian and the Upper Ludlow Shelly Siltstones respectively) is represented in Poland by that part of the Upper Silurian series enclosed between the base of the Gothograptus nassa zone and the top of the Neocucullograptus kozlowskii zone. The top of the Ludlovian approximately also coincides with the appearance of *Monoclimacis ultimus* (Perner) and *Monograptus formosus* Bouček. The Ludlovian stage thus understood contains in Poland 13 graptolite zones, four of which jointly form one index horizon. This stage is, moreover, split up into 2 substages separated by the top of the Saetograptus leintwardinensis zone.

Postludlovian Stage

At the Prague Conference in 1958 (Prager Arbeitstagung 1960) the subdivision of the Upper Silurian was for the first time discussed in greater detail with the object of preventing the introduction of regional divisions and standardizing the subdivision itself. A bipartite subdivision was suggested for the Silurian of the mixed-Hercynian facies. The lower part, comprising the Valentian and the Wenlockian remained unmodified, while two new stages, the Budnan and the Lochkov, were proposed for the upper part. Their stratotypes were chosen in the Barrandian area. These two new stages were supposed to be the equivalent of the British Ludlovian and Downtonian. This would, however, contradict the Bristish division which regards the Downtonian as Lower Devonian. It was proposed to submit the above suggestions to the International Subcommission on Stratigraphic Terminology at the Copenhagen Congress in 1960.

In 1960, however, at another conference held in Bonn (Intern. Arbeitstagung 1962), new materials were presented showing that the proposed new Lochkov stage undoubtedly corresponded not to the Upper Silurian but to the Gedinnian. A number of paleontological arguments were also advanced in support of this theory.

An analysis of the brachiopod fauna of Podolia and Belgium led Boucot (1960) and Boucot & Pankiwskyj (1962) to conclude that the true Ludlovian is separated from the Gedinnian by a complex of deposits still showing a predominance of typically Silurian brachiopods but where the Gedinnian and younger forms are already present. Boucot called this complex the Skala, stressing that it is most certainly Postludlovian, i.e. Downtonian but still pre-Gedinnian.

Jaeger (1962) believed that *Monograptus hercynicus* Perner, which indicated the top zone of the Lochkov stage, might possibly reach the Siegenian.

Conodont (Walliser 1962) and trilobite (Alberti 1962) studies have also confirmed that the Lochkov ought to be associated not with the Silurian but with the Lower Devonian (Gedinnian). Solle (1964) on the other hand, confirmed the earlier suppositions of Schriel (1929) and Gaertner (1959) that brachiopods typical of the Lower Devonian occurred together with *Monograptus hercynicus* Perner.

A different concept was advanced by Nikiforova and Obut (1960) who suggested to include the Borshchov and the Chortkov Beds of Podolia into a separate stage which they called the Tywer. They looked on the Tywer as the youngest stage of the Silurian and correlated it with the Bohemian Lochkov, accepting the existence of a gap between the Ludlovian and the Downtonian of Great Britain. This concept was rejected by Ushatinskaya (1966), indeed, its authors now regard the Tywer as an equivalent of the Gedinnian (Nikiforova 1968).

At the Leningrad Conference in 1968, opinions, as to how to determine the top of the Silurian, were greatly convergent; the Lochkov was accepted as the time-equivalent of the Gedinnian; the division of the Upper Silurian series was not discussed.

Hence, the division of the Upper Silurian itself still remains an open question because the complex of deposits undoubtedly younger than the Ludlovian but older than the Gedinnian, already known on the Continent, cannot be correlated with the Upper Silurian of England unless the Downtonian be recognized as its time-equivalent. If, however, according to the faunal suggestions, this complex is older than the Gedinnian, it should be included into the Silurian.

In this case, the above complex of deposits should be separated into a new stage, equivalent of the Bohemian Budnan, the British Downtonian and only partly to Boucot's Skala.

In 1964, on the basis of Polish materials, the writer advanced his conception of a new stage which would embrace the sediments here discussed. The name of the stage was left an open question but its inclusion into the Silurian system was plainly stressed. The more important European profiles were also correlated (Teller 1964b) on the ground of this concept.

Another new stage, that called Podlasie, was introduced into the Polish literature by Tomczyk (1964a). For its stratotype he chose the Silurian profile from borehole Chełm IG-1, which has been worked out by the present writer (Teller 1960a, 1964a). This stage is recognized by Tomczyk as younger than the Ludlovian. In what the graptolite zones are concerned it is more closely related to the Barrandian Přidol Beds than any other European profiles. Its correlation with some of the European profiles makes Tomczyk suppose that in Podolia the Borshchov beds, or the so called Borshchov horizon, may be an equivalent of the Podlasie stage. The Jūra, possibly the Tilžę horizon, will be its equivalent in Lithuania. Nothing is said by that author about its equivalents in other European profiles.

The Podlasie stage, created by Tomczyk, is, however, unacceptable because of two important reasons:

a) the stratotype, i.e. the profile from borehole Chełm IG-1 did not exist at the time Tomczyk indicated it, because it had been completely broken up and only some very small fragments are still available;

b) no borehole may represent a stratotype since it does not comply with necessary requirements.

Since the existence of a complex of deposits younger than the Ludlovian is a fact confirmed not only in Poland, their tentative definition should warrant uncontroversial interpretation and correlation. In the present paper these deposits have been classified as Postludlovian which, in the chronostratigraphic classification, could correspond to uppermost Silurian stage. The subdivision of this unit in Poland is based on the graptolite fauna found in a score of boreholes. The lower boundary is indicated by the top of the Neocucullograptus kozlowskii zone, the top of the Monograptus angustidens zone being accepted as its upper boundary. A complete profile of these deposits was obtained in Poland by compiling the fragmentary profiles from several boreholes. Hence, the choice of a stratotype is not possible in Poland, but such a stratotype, based on a natural profile, may be established in another region. The Canadian profile of the Royal Creek, in the Youcon territory (Lenz 1966, 1967; Lenz & Jackson 1964) seems to be interesting from this point of view.

Evidently this may alter the proposed name of Postludlovian which is now only tentatively introduced by the writer since the final decision in this matter does not rest within his competence but that of the International Stratigraphical Commission.

Within the Postludlovian of Poland, 10 graptolite zones have so far been distinguished, but it is not excluded that their number will increase,

Chart 1

The subdivision of the Silurian system in Poland

System	Series	Stages	Substages	Graptolite Zones
SILURIAN	Upper	Postludlovian	Upper	43 — M. angustidens ↑ 35 — P. bugensius
			Lower	34 — M. formosus horizon
		Ludlovian	Upper	33 — N. kozlowskii ↑ 29 — B. bohemicus
			Lower	28 — S. leintwardinensis ↑ 21 — G. nassa
	Lower	Wenlockian		20 — C. lundgreni ↑ 13 — C. insectus
		Valentian		12 — S. spiralis ↑ 1 — A. ascensus

because the lower part of the deposits from the top of the Neocucullograptus kozlowskii zone to the base of the Pristiograptus bugensius zone has not yet been worked out and has, therefore, been tentatively created into a horizon. The top of this horizon separates the Postludlovian into a lower and an upper substage.

The subdivision of the Silurian system in Poland, as followed in this paper, is shown on chart 1.

SILURIAN AREAS IN POLAND AND THEIR LITHOLOGICAL-STRATIGRAPHIC CHARACTERISTICS

To present as clear as possible a picture of the lithology and stratigraphy of the Silurian system in Poland it seems recommendable to make a few concise remarks about the main tectonic units of Poland since they have had an important bearing on the formation and development of the Silurian deposits (fig. 1).

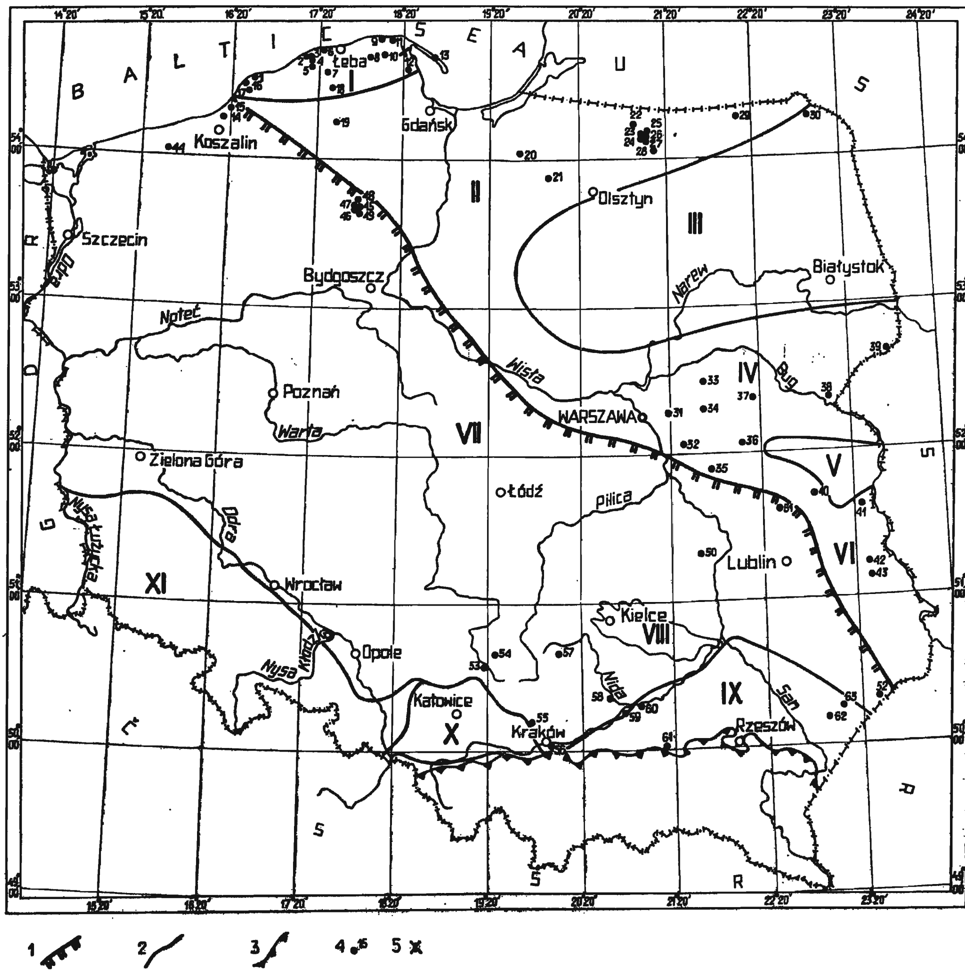


Fig. 1

Sketch map showing localization of boreholes in the structural units of Poland

1 probable tectonic boundary between the Precambrian and the Paleozoic platforms, *2* boundaries of structural units, *3* margin of the Carpathian overthrust, *4* boreholes specified in chart 2, *5* boreholes not localized owing to technical reasons but specified in chart 2, *I* Łeba elevation, *II* Peribaltic depression, *III* Mazury-Suwałki elevation, *IV* Podlasie depression, *V* Sławatycze horst, *VI* Bug depression, *VII* Paleozoic platform, *VIII* the Holy Cross Mts., *IX* Carpathian foredeep, *X* Silesian-Cracow basin, *XI* the Sudetes and fore-Sudetic monocline

Chart 2*

Silurian deposits obtained in boreholes

No.	Borehole	Top	Depth of the occurrence of the Silurian	Postludlovian	Ludlovian	Wenlockian	Valentian	Bottom
	ŁEBA ELEVATION							
1	Łeba 5	P	671.0–723.5	52.5				
2	Łeba 3	P	781.0–846.5	65.5				
3	Łeba 7	P	692.0–701.3	9.3				
4	Łeba 4	P	708.5–743.5	35.0				
5	Łeba 6	P	770.0–799.0	29.0				
6	Łeba 1	P	664.5–1273.4	608.9				
7	Łeba 2	P	875.0–915.5	40.5				
8	Salino IG-1	P	1078.0–1104.0	26.0				
9	Dębki IG-1	P	794.7–828.0	33.3				
10	Opalino IG-1	P	1008.6–1028.0	19.4				
11	Żarnowiec IG-1	P	839.5–1254.0	414.5				
12	Wejherowo IG-1	P	1126.7–1235.8	109.1				
13	Jastarnia IG-1	P	1125.0–1160.1	34.1				
X	[illegible] IG-1	P	944.3–971.6	27.3				
X	Chłapowo IG-1	P	961.2–1050.4	89.2				
X	Chłapowo IG-3	P	960.9–973.7	12.8				
X	Chłapowo IG-4	P	955.5–974.5	19.0				
X	Czarny Młyn IG-1	P	894.0–918.0	24.0				
X	Czarny Młyn IG-2	P	881.0–919.0	38.0				
X	Jastrzębia Góra IG-1	P	925.5–950.0	24.5				
X	Kłanino IG-1	P	930.5–955.0	25.0				
X	Kłanino IG-2	P	947.4–981.0	33.6				
X	Mieroszyno IG-2	P	951.9–971.0	16.1				
X	Mieroszyno IG-3	P	913.3–936.0	22.7				
X	Mieroszyno IG-4	P	944.6–980.0	35.4				
X	Mieroszyno IG-5	P	940.6–965.5	24.9				
X	Mieroszyno IG-6	P	980.9–1000.0	19.1				
X	Ostrowo IG-?	P	870.0–905.0	35.0				
X	Radoszewo IG-1	P	931.7–960.0	28.3				
X	Radoszewo IG-2	P	949.7–979.0	29.3				
X	Radoszewo IG-3	P	893.0–919.0	26.0				
X	Werblinia IG-1	P	988.0–1016.0	28.0				
X	Władysławowo IG-1	P	965.5–1000.0	34.5				
X	[illegible] IG-1	P	615.0–2545.0	total thickness 1930.0 m				●
	PERIBALTIC DEPRESSION							
14	Darłowo 2	P	1604.0–1615.9		11.9			
15	Darłowo 3	P	1277.9–1428.0		150.1			
16	Darłowo 4	P	617.0–3300.2	450?	1700?	200?	50?	
17	Darłowo 1	P	987.0–1052.1	65.1				
18	Lębork IG-1	P	1026.0–3253.0	896.0	1216.0	146.6	23.0	●
19	Bytów IG-1	P	1679.5–2969.5	751.0	539.4			
20	Pasłęk IG-1	P	1954.3–2638.0	156.2	392.0	59.0	20.0	●
21	Olsztyn IG-2	P	2142.0–2375.5		61.0	105.0	27.5	●
22	Bartoszyce IG-1	P	1487.0–1816.7		175.0	115.0	39.7	●
23	[illegible] 1	P	1533.3–1678.0			103.7	41.0	●
24	[illegible] 2	P	1498.0–1525.4				31.4	●
25	Kętrzyn 1	P	1480.0–1712.3		36.8	103.6	38.1	●
26	Kętrzyn IG-1	P	1477.9–1544.5			22.5	44.3	●
27	[illegible] 1	P	1481.0–1483.5				2.5	●
28	Klewno 1	P	1449.3–1457.7				8.4	●
29	Gołdap IG-1	P	1126.0–1427.0	143?	28?	92.0	12.0	●
30	Jezioro Okrągłe IG-1	P?	775.5–848.5			38.7	12.5	●
	PODLASIE DEPRESSION							
31	Okuniew IG-1	P	2275.0–2568.0		1179.0	70.0	18.0	●
32	Kołbiel 1	C	2400.0–2632.2	232.2				
33	Tłuszcz IG-1	P	1666.0–1963.8		176.0	85.0	34.8	●
34	Dobre 1	P	1837.0–2775.0	100?	740?	70?	40?	●
35	[illegible] 1	C	2195.0–3200.0		1005.0			
36	[illegible] IG-1	D	1360.9–2358.2	420.4	477.4	69.5	14.2	●
37	Sokołów Podlaski 1	P	1249.2–1715.3		369.1?	70?	30?	●
38	Mielnik IG-1	P	383.5–1120.0	486.5	230.0	40.0		●
39	[illegible] 1	J	370.3–464.6			94.3		
	BUG DEPRESSION							
40	Parczew IG-1	C	1001.0–1041.0			40.0		
41	Kaplonosy IG-1	C	446.2–718.0		230.0	42.0		
42	Sawin IG-1	C	1089.0–1181.5	75.9				
43	Chełm IG-1	D_1	1211.8–1607.4	395.6				
	PALEOZOIC PLATFORM							
44	Goczałkowice IG-1	D	4415.0–4416.6		1.6			
45	Stobno 1	P	2447.5–2530.3		82.8			
46	Stobno 2	D	3178.0–3190.0		12.0			
47	Stobno 3	D	2841.0–2950.0		109.0			
48	[illegible] 1	P	2463.0–3016.0				553.0	
49	[illegible] 3	D_1	2967.4–3044.5		77.1			
50	Ciepielów IG-1	D_1	2598.3–3000.0	401.7				
51	Kock IG-1	P	914.0–1010?	96.0				
52	Ruda Lubycka 1	D	1046.0–1890.0	844.0				
53	[illegible] IG-9	Z	150.0–500.0		350.0			
54	[illegible] IG-1	C?	lack of details					
55	[illegible] IG-1	C?	136.0–500.5			364.2		
56	[illegible]	J	322.0–395.0		73.0			
57	[illegible] IG-1	D	2068.5–2275.0			206.5		●
58	[illegible] 3	D	2824.5–3007.2		182.7			●
	CARPATHIAN FOREDEEP							
59	[illegible] 3	D	2729.4–2846.5		117.1			●
60	[illegible] 1	C	1356.5–1615.0		128.5	130.0		●
61	[illegible] 3	C	2860.0–2924.0				64?	●
62	[illegible] 1	J	1088.4–1096.4			8.0		●
63	[illegible] 1	?	1050.0–1255.0		100.0	60.0	45.0	

* Numbers in column 1 correspond to numbers in fig. 1. Boreholes marked with a cross could not be specified on fig. 1 owing to technical reasons. Continuous lines indicate obtained profiles; the figures above them refer to the thickness of particular members of the profile. Boreholes drilled by the Geological Institute marked IG — those by Oil Research Survey only numbered.

NE of a line roughly drawn from Koszalin across Bydgoszcz, S of Warsaw and NE of Lublin, as far as Rawa Ruska, we are dealing with a stabile unit of the Precambrian platform. It is an area which has not been folded by any Paleozoic or younger movements, but where these movements are registered as sedimentary lacunae or accumulated deposits of great thickness and specific facies. The old Paleozoic deposits here lie horizontally and their local dislocations may be connected with the fault tectonics which are reasonably referable to vertical movements that occurred either within the platform or along its marginal zone. The marked differences in the thickness of deposits of the particular systems or even stages of the older Paleozoic depend on the depth at which the crystalline substratum occurred, also on its morphology as well as the intensity of the vertical movements on the Platform itself and in its marginal zone. The same factors are largely responsible for the facial distribution in marine basins of this part of Poland.

The biostratigraphic and lithostratigraphic value of the sedimentary rocks on the Precambrian platform is very important, since it sometimes proves of the greatest help in tracing the full development cycle of deposits of a particular system or stage, as well as in correctly determining the biostratigraphy and evolution of the organic world.

South-west of the above mentioned line we encounter another structural unit, second in size, namely the Paleozoic platform. It was consolidated and jointed along a tectonic line to the Precambrian platform, during the Caledonian orogeny, and it consists of two structural stages.

Silurian deposits are associated only with the lower stage while the upper one represents the younger cover of the deposits. Besides considerable differences in thickness and lithological variability they are rather strongly tectonically disturbed and locally even metamorphosed. The fragmentary character of profiles that are, as a rule, obtained at great depths, hamper stratigraphic accuracy and correlation. The facial distribution of the Silurian deposits here was affected both by the development of the Caledonian geosyncline and the movements taking place in it.

These two structural units, extremely different in their development, cover more than 80 per cent of Poland's territory. The present state of knowledge concerning Silurian deposits in these units varies; it may be estimated by the number of boreholes where these deposits have been found until the middle of 1968. On the Precambrian platform there are 65 boreholes while on the Paleozoic platform only twenty (chart 2). If, moreover, the quality of the obtained material be also taken into account, differences in the extent of knowledge of the Silurian system in the two structural units will be readily seen. Obviously, this does not apply to the Holy Cross Mts. and to the Sudetes where Silurian deposits are encountered in natural outcrops.

In view of the fact that both in the Precambrian and in the Paleozoic platform most geographical regions are interlocked, the writer has based his structural division of Poland after that of Znosko (1966) and of Znosko & Pajchlowa (1968). In his opinion this division is perfectly logical, clearly expounded and adequately documented, at least in what concerns the development of the Silurian system.

Pożaryski's (1963) division seems more useful in the description of deposits from the Paleozoic platform cover than in that of the Paleozoic platform itself.

The subdivision of the Silurian is based on a standard classification code as has been discussed more at large in the preceding chapter.

Neither does it seem necessary to mention in detail the papers previously published on that problem, since the lithostratigraphic characteristic of the Silurian are required only for the more general consideration. Nonetheless, however, some type profiles must be taken into account and discussed in greater detail against the background of a given smaller unit (chart 3).

The Silurian in the East-European Precambrian platform

This vast structural unit is made up of a number of smaller units. They are (cf. fig. 1):

1) the Łeba elevation situated in the north-west, and representing the southern slope of the Baltic shield,

2) the Peribaltic depression, stretching equatorially,

3) the Mazury-Suwałki elevation, occupying the eastern part of the Precambrian platform within Polish territory,

4) the Podlasie depression, bordering in the south on the Mazury--Suwałki elevation,

5) the Sławatycze horst, partly separating the depression of Podlasie from the Bug depression,

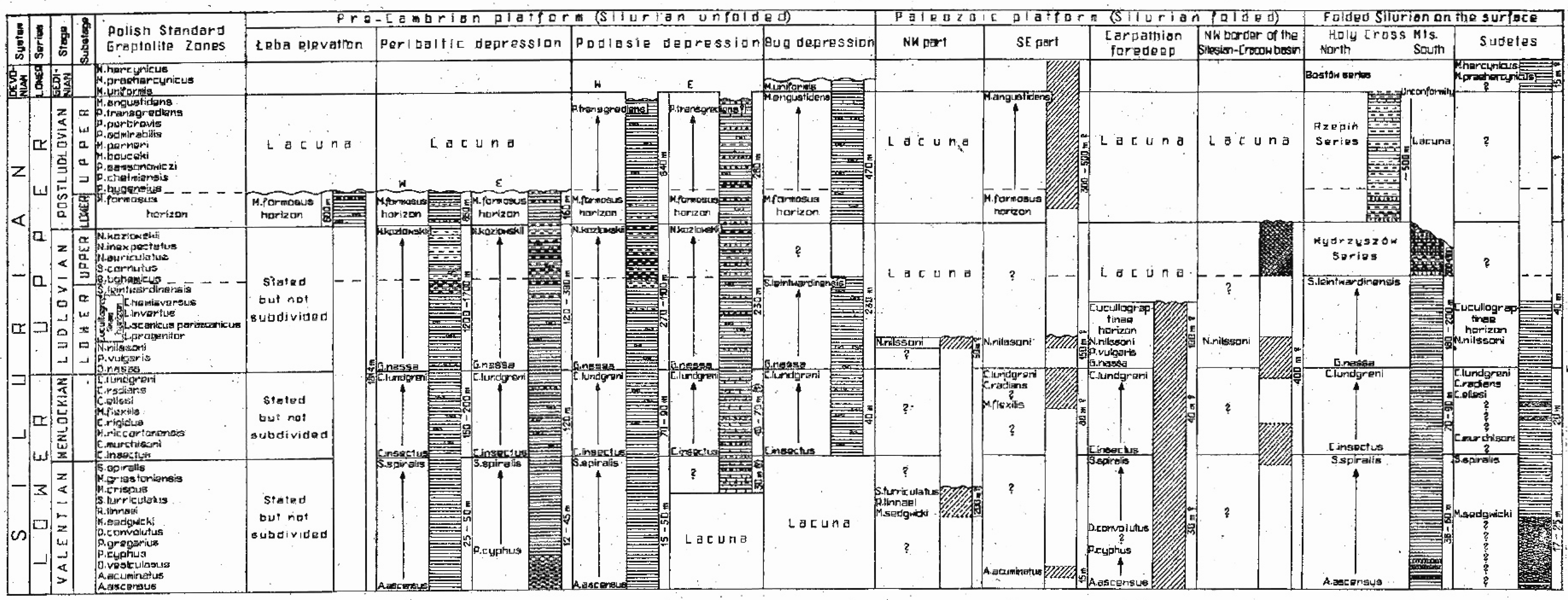
6) the Bug depression, situated in the SE periphery of the Precambrian platform.

The Mazury-Suwałki elevation and the Sławatycze horst are the only two among the above units where the presence of Silurian deposits has not as yet been observed.

They are represented in all the other units and their lithostratigraphic descriptions are given below.

Chart 3*

Correlation of the Silurian deposits in Poland on the basis of graptolite zones



* 1 limestones, 2 marly limestones, 3 nodular limestones, 4 mudstones, 5 siltstones, 6 marly and calcareous nodules, 7 sandstones, 8 greywackes, 9 conglomerates, 10 tillites, 11 tuffites.

The Łeba elevation

The Silurian deposits here were the first to be found in a borehole situated on the magnetic anomaly discovered in 1927/1928 by the German geologists (Dahlgrün & Seitz 1944).

During his visit to Berlin in 1958, the writer wanted to examine in the Museum of the Geologische Kommission the material preserved from that borehole. Samples from various depths contained *Monograptus* ex gr. *formosus* Bouček, which indicated that the whole complex could represent only the Upper Ludlovian. This conclusion was reached by the writer jointly with Tomczyk.

Tomczyk (1960b, table 2) shows, however, that the Silurian in borehole Łeba 1 corresponds to the Pristiograptus bugensius — Monograptus angustidens zones and he correlates this profile with that reached in Chełm IG-1, referring them both to the Middle Ludlovian.

After inspecting the material preserved from Łeba 1, Jaeger (1962) discovered at a depth of 715—746 m the presence of *Monograptus* cf. *bouceki* Přibyl, at 767.6 m that of *Monograptus* cf. *similis* Přibyl and at 831.8 m that of *Monograptus* aff. *formosus* Bouček. The last named form abounds between 1,267.7—1,273.4 metres. In his conclusions Jaeger states that the graptolites do not permit accurately to determine the age of the lower parts of the profile from that borehole, and that most probably the deposits reached there were not Ludlovian but younger in age.

In 1961, the writer paid another visit to East Germany, during which, after a reexamination of the preserved material he was able to conclude (Teller 1962c) that Silurian deposits from borehole Łeba 1 are an equivalent of a part of the series from boreholes Lębork IG-1 and Żebrak IG-1, encountered between the Saetograptus leintwardinensis and the Monograptus formosus zones.

The present state of knowledge of the Silurian in this area permits accurately to determine the stratigraphic position of the Silurian from borehole Łeba 1. It can be conclusively postulated that these deposits correspond to the lower part of the Postludlovian [1], i.e. to the M. formosus horizon.

Between 1961 and 1968, 34 boreholes were drilled on the Łeba elevation (fig. 1, chart 2). Silurian deposits, ranging in thickness from a few to several hundred metres, invariably underlie the Zechstein.

Most of these boreholes are in the eastern part of the Łeba elevation (Cetniewo IG-1, 3, 4; Chłapowo IG-1, 3, 4; Czarny Młyn IG-1, 2; Dębki IG-1; Jastarnia IG-1; Jastrzębia Góra IG-1; Karwia IG-1; Kłanino IG-1; Mieroszyno IG-2, 3, 4, 5, 6; Opalino IG-1; Ostrowo IG-1; Radoszewo IG-1,

[1] The ostracod fauna from this borehole has been worked out by Martinsson (1964) but without conclusive stratigraphic references.

2, 3; Salino IG-1; Skupowo IG-1; Wejherowo IG-1; Władysławowo IG-1), a few are in its central region (Łeba 1, 2, 3, 4, 6, 7; Żarnowiec IG-1) while only one (Łeba 5) is in the western part.

There is a lithological predominance of grey-greenish calcareous mudstones, with intercalations of marls and marly limestones, locally organodetrital. The dominant fossils are non-graptolithic, mainly brachiopods, pelecypods, gastropods, trilobites and ostracods. Graptolites are rare, but they are fairly good age-markers. The forms identified here (Teller 1966) are *Monograptus formosus* Bouček, *M. lebanensis* Teller, *Monograptus balticus* Teller, *Linograptus posthumus* (Richter) and *Pristiograptus dubius dubius* (Suess). Stratigraphically these deposits are most likely younger than Ludlovian and, similarly as in borehole Łeba 1, they represent the Postludlovian. No lower members of the Silurian have, so far, been reached in the Łeba elevation [2].

The character of the deposits and the fauna they contain suggest that, during the Upper Silurian, the Łeba elevation had been covered by sea, none too deep and with rather strongly differentiated sedimentary conditions of the neritic type. A regime of this kind will cause strong facial variability, even within a very small area, so it is not likely for a definite facies to have prevailed over a longer period and thus permit it to be traced over large areas [3].

The Peribaltic depression

The Silurian deposits, reached in a number of boreholes in the Peribaltic depression, have been investigated in some detail. The eastern part of this depression (in the Polish literature referred to as the Polish--Lithuanian depression or the Polish-Lithuanian syneclise) is raised in relation to the western part, while drillings on its southern slope, immediately under the Rothliegende pierced the Lower Silurian deposits in boreholes Jezioro-Okrągłe IG-1, Kętrzyn IG-1 (Tomczyk 1968b), Łankiejmy 1 and 2, Zawada 1, Klewno 1 (Teller 1967) and reached the Ordovician (Modliński 1967, Bednarczyk 1968).

Upper Silurian (Ludlovian) deposits occur in the axial part of the depression — as is shown in boreholes Bartoszyce IG-1 and Pasłęk IG-1

[2] In 1968 a new borehole (Żarnowiec IG-1) pierced the Silurian which occurs there at a depth from 829 to 2,645 m, being thus 1,814 m thick. This borehole is still being drilled and the exact results are not yet known. It may, however, be reasonably supposed that the complete Silurian profile is represented here (oral communication from Dr. A. Witkowski of the Geological Institute).

[3] Tomczyk (1968b) differentiated in this area a number of litho- and biofacies which have not, however, been observed by the present writer during his analysis of the available material.

(Tomczyk 1962a), Korsze 1 (Teller 1967), Olsztyn IG-2, even those of the Postludlovian — in boreholes Gołdap IG-1, Pasłęk IG-1 (fig. 1, chart 2).

Lithologically the Silurian is fairly well differentiated. In boreholes Łankiejmy 1, 2, Korsze 1, Zawada 1, Klewno 1 (Teller 1967), Olsztyn IG-1, Kętrzyn IG-1, Bartoszyce IG-1 (Jaworowski & Modliński 1968) the Lower Valentian is developed as nodular limestones of a pale-yellow, brownish colour. A dark-grey marly-clayey substance is found among the nodules. The fauna is extremely scarce. *Encrinurus* ex gr. *kiltziensis* Rosenst. and *Leonaspis* cf. *olini* Troeds. are reported by Jaworowski & Modliński (1968) from borehole Kętrzyn IG-1, while poorly preserved graptolite fragments have been detected by Professor R. Kozłowski in the material supplied to him by the writer from borehole Łankiejmy 1.

The limestones are overlaid by marly green mundstones with intercalations of black shales. The graptolites in the black shales indicate their Upper Valentian age — from the Pristiograptus cyphus zone to the Spirograptus spiralis zone (Tomczyk 1964a, 1968b; Teller 1967). The thickness of the Valentian deposits ranges from 12 to 45 metres.

The Wenlockian is very monotonously developed. It is represented by gray, locally calcareous, mudstones bearing a graptolite fauna from the Cyrtograptus insectus to the C. lundgreni zone (Tomczyk 1964a, Jaworowski 1965, Teller 1967). The Wenlockian deposits are up to 120 m thick.

The Ludlovian deposits are characterized by rather strong lithological variability. Side-by side with the grey mudstones there occur intercalations of siltstones, also of calcareous mudstones and lenses of marly limestones. The graptolite fauna is abundant and represents zones from the Gothograptus nassa to the Neocucullograptus kozlowskii (Tomczyk 1964a, Teller 1967).

The Postludlovian consists mainly of marly mudstones with calcareous intercalations. Besides graptolites, chiefly *Monograptus* ex gr. *formosus* Bouček, other fossils are encountered, too.

The somewhat intricate block tectonics of the substratum, embracing the network of equatorial and meridional faults, are responsible for the fact that pre-Zechstein erosion had affected the various Silurian members.

In the western part of the Peribaltic depression, the most complete Silurian profile has been reached, so far, in borehole Lębork IG-1, but Silurian deposits have also been found in boreholes Bytów IG-1 (Tomczyk 1964a), Darłowo 1, 2, 3 (Teller 1965) and quite recently in borehole Darłowo 4 (Teller 1968b).

The profile from borehole Lębork IG-1 is doubtless a typical one for this part of the depression, though that obtained recently from borehole Darłowo 4 is not without importance, in spite of the very inadequate coring, taken every 100 metres.

In borehole Lębork IG-1, the Valentian developed as black and dark-grey non-calcareous mudstones bearing fine dispersed pyrite and a graptolite fauna. The zones identified here are from the Akidograptus ascensus to the Spirograptus spiralis zone. The thickness of this stage is up to 25 metres. It seems, however, that the above figure does not give the actual thickness of Valentian deposits in this part of the depression. Fragments of *Spirograptus* sp. have been found in borehole Darłowo 4 at a depth from 3,249 to 3,255 m, also between 3,294 and 3,255 metres. Even these intervals stretch over 51 m and, moreover, neither the top nor the base of the Valentian can be accurately determined owing to the lack of data (Teller 1968b).

The Wenlockian deposits are represented by dark-grey, locally black, mudstones, with fine dispersed mica. The graptolite fauna is fairly abundant and well defines the zones of Cyrtograptus insectus to Cyrtograptus lundgreni. In borehole Lębork IG-1 the thickness of the Wenlockian is up to 148 m (Tomczyk 1964a), while in borehole Darłowo 4 it may be even 200 m (Teller 1968b).

The Ludlovian is developed as grey and light-grey mudstones. These are interbedded with grey siltstones and intercalated — chiefly in the upper part — with fine-grained sandstones up to a score or so centimetres thick. In the upper parts there are also intercalations of grey marly limestones. Mica is dispersed in great abundance among the siltstones and sandstones. Horizontal and cross lamination is quite distinct in some places. The fauna is fairly numerous though its state of preservation sometimes handicaps closer identification. All the zones are, however, represented, from the Gothograptus nassa to the Neocucullograptus kozlowskii. The latter was reached in borehole Darłowo 4 at a depth from 1,329.3 to 1,334.3 metres (Teller 1968b). According to Tomczyk (1964a) the thickness of this complex in borehole Lębork IG-1 is up to 1,907.3 m, but in the writer's opinion it is only about 1,200 m and does not exceed 1,700 m in the profile from borehole Darłowo 4.

The Postludlovian is represented by dark-grey mudstones, laminated with siltstones, and by siltstone and calcareous intercalations, while steel-grey silky intercalations of mudstones are fairly frequent in the top (borehole Darłowo 4). The graptolite fauna is abundant but not ubiquitous. Among the index forms are *Monograptus* ex gr. *formosus* Bouček, *M. formosus* Bouček and *Pristiograptus* ex gr. *dubius* (Suess), also *Linograptus* sp. It should be noted that calcareous intercalations, bearing a fauna of pelecypods, brachiopods, ostracods and sporadical trilobites, grow more numerous upwards.

In borehole Bytów IG-1 (Tomczyk 1962a) Upper Silurian deposits were not pierced down to a depth of 2,569.7 m, while stratigraphically their top represents the Postludlovian, and their lower part the Upper Ludlovian. In lithology they coincide with deposits from borehole Lębork IG-1.

In the westernmost part of the depression, the Silurian has been found in boreholes Darłowo 1, 2, 3 and 4 (Teller 1965, 1968b). The Silurian deposits, 65 m thick, reached in borehole Darłowo 1 resemble in lithology those found in boreholes of the Łeba elevation. They are developed as grey-greenish calcareous mudstones, with thin inercalations of marly limestones. The fauna is represented by *Pristiograptus* ex gr. *dubius* (Suess), also by fragmentary brachiopods, pelecypods and trilobites, probably referable to the Postludlovian.

In borehole Darłowo 2 only 12.5 m of grey and variegated (secondary colour) unfossiliferous mudstones were reached. They are stratigraphically indeterminate. A much thicker complex of gray-greenish siltstone-mudstone deposits was reached in the profile from borehole Darłowo 3. Its thickness is 150.5 m, while on the presence of *Bohemograptus bohemicus bohemicus* (Barr.) and *Pristiograptus* ex gr. *dubius* (Suess) they may be reasonably assigned to the upper part of the Ludlovian.

In borehole Darłowo 4, completed in 1968, the Silurian had not been pierced at a depth of 3,300.2 metres. The coring there was inadequate, hence the results obtained from that borehole are of little stratigraphic value. The lithology of the Silurian deposits here does not differ from those occurring in borehole Lębork IG-1, stratigraphically they represent the Upper Valentian, the Wenclockian, the Ludlovian and the Postludlovian. The boundaries between these stages and their thickness can hardly be determined even if geophysical measurements be taken into account.

The above description of the Silurian deposits from the western part of the Peribaltic depression clearly shows not only an increase in the thickness as compared with that, in the eastern part, but differences in lithology, too. A high per cent content of sandy material, horizontal and cross lamination, and large amounts of mica, reasonably suggest sedimentation in a shallow basin. The increase in thickness of the deposits and changes in character set in, roughly speaking, from the Saetograptus leintwardinensis zone. This is undoubtedly closely connected with events during the Caledonian orogeny whose presence has been confirmed in boreholes drilled along the NW margin of the Precambrian platform (Teller & Korejwo 1968b).

The Podlasie depression

In this unit various members of the Silurian have been found in the following boreholes: Okuniew IG-1, Tłuszcz IG-1, Kołbiel 1, Radzymin 1[4], Dębe Wielkie 1[4], Kock 4[4], Biała Podlaska 1[4], Dobre 1, Goździk 1[4], Sokołów

[4] The Silurian from these boreholes has not yet been throughly investigated as some of the boreholes are still being worked.

Podlaski 1, Żebrak IG-1, Mielnik IG-1, Krzyże IG-1 (fig. 1, chart 2). The descriptions of a number of boreholes have not yet been worked out, hence the picture of the facial development and stratigraphy of the Silurian system in this part of the Precambrian platform is far from complete. Such boreholes, however, as Żebrak IG-1 and Mielnik IG-1 provide sufficiently reliable lithological and stratigraphic information (Tomczyk 1958a, 1962a).

In borehole Żebrak IG-1, the lower part of the Valentian, resting on the Ashgillian, is developed as black graptolite-bearing mudstones. These grade upwards into dolomitic-calcareous mudstones intercalated by black shales. The Pristiograptus gregarius zone is the lowermost one reached here. Hence, several lowermost Valentian zones are missing. The thickness of the black shales does not exceed 14.2 metres. Overlying the well paleontologically defined Spirograptus spiralis zone there is a 70 m thick complex of grey, locally calcareous, mudstones bearing a fauna typical of the Wenlockian. The zones identified here are from the Cyrtograptus insectus through the Cyrtograptus lundgreni.

The lithological development of the Ludlovian to the Saetograptus leintwardinensis zone does not substantially differ from that of the underlying deposits. The deposits lying higher up, in addition to grey mudstones also contain siltstone and calcareous intercalations. Horizontal and cross lamination is very distinct and fairly abundant mica occurs on the bedding planes. *Bohemograptus bohemicus bohemicus* (Barr.) is the predominant graptolite here. In the writer's opinion, the thickness of the Ludlovian attains in the Żebrak IG-1 borehole about 275 metres.

The Postludlovian in the Żebrak IG-1 borehole does not differ in its lithological character from the lower part of the Ludlovian; it is about 650 m thick. Of the graptolite fauna *Monograptus formosus* Bouček occurs abundantly in the lower part, while zones first identified in borehole Chełm IG-1 (Teller 1964a) are said to be represented in the higher part. However, both, *Monograptus angustidens* Přibyl and *M. uniformis* Přibyl are absent (Tomczyk 1968c), *Pristiograptus transgrediens* Přibyl being the youngest form present here.

On the Silurian whose total thickness is 997.3 m conformably rest the Carboniferous deposits.

In the western part of the Podlasie depression (borehole Goździk 1), horizontally lying Silurian mudstones have not been pierced; the Ludlovian? underlies the Carboniferous at a depth of 2,195 m (borehole not yet completely described).

In borehole Kołbiel, a 232.2 m thick complex of grey-green mudstones, containing a rich non-graptolite fauna, was reached also below the Carboniferous. This complex is disturbed, the dips range from 15° in the top to 35° at the base. According to the Tomczyks (vide Karnkowski 1965) this profile is referable to the lowest stages of the Downtonian.

Borehole Okuniew IG-1, below the Zechstein (Areń 1967) reached a 1,293 m thick siltstone-mudstone complex with black shales intercalated by limestones at the bottom. All the Silurian stages are represented here, from the Valentian, 48 m in thickness, to the Wenlockian, 70 m, and the Ludlovian 1,175 m.

In borehole Tłuszcz IG-1 (Areń 1967), the Silurian, which underlies the Zechstein from a depth of 1,668 m to 1,963.8 m (295.8 m), is developed as graptolite-bearing mudstones. The complete profile of these deposits has been observed here. The Valentian, 34.8 m thick (Tomczyk 1962a) is that most completely developed. The Wenlockian represents all the graptolite zones, too, (85 m), while the Ludlovian (176 m) is well defined including the Saetograptus leintwardinensis zone.

In borehole Dobre 1 (Teller & Korejwo 1968d) the Silurian (900 m) was pierced below the Rothliegende. It is developed as dark-grey mundstones with siltstone and calcareous intercalations in the top. The presence has been observed of the Upper Valentian, the Wenlockian, the Ludlovian, and the Postludlovian. It is, however, hardly possible more accurately to establish the thicknesses of the particular stages because of inadequate coring.

Diabases have been observed too in the above profile. Neither the top nor the base of these diabases has been detected in the cores, hence their age cannot be more closely defined without additional studies.

In borehole Sokołów Podlaski 1 (Teller & Korejwo 1968e), the Silurian deposits occur between 1,249.2 and 1,715.3 m. Their lithology is identical with that of the deposits reached in other boreholes within this area. Stratigraphically, however, the Upper Valentian, the Wenlockian and the Ludlovian are all represented here. The top part of mudstones shows contact changes caused by the intrusion of the overlying magmatic rocks (diabases?) on which rests the Zechstein, faunistically well defined. The uppermost Ludlovian is probably absent from this profile; it may have been eroded as far as the top of the diabases. In this case the diabases may correspond to those observed in borehole Dobre IG-1.

In the eastern part of the Podlasie depression, Silurian deposits have been identified in borehole Mielnik IG-1 and Krzyże IG-4 (Tomczyk 1962a). In borehole Mielnik IG-1, light-grey, locally greenish, calcareous mudstones and marls, bearing a rich graptolite fauna, rest directly on the Ashgillian. The Valentian is absent while the Wenlockian, 40 m in thickness, starts from the Cyrtograptus insectus zone and ends with the Cyrtograptus lundgreni zone. The Ludlovian, which is over 230 m thick, contains a rich graptolite fauna. It was this very fauna which allowed Urbanek (1966, 1970) correctly to subdivide these deposits, also to distinguish a number of new zones. The uppermost part of the Silurian deposits here, over 250 m thick, is referable to the Postludlovian.

The lithology of the Silurian profile in borehole Krzyże IG-4 differs from all those described above. A 100 m thick complex of marly limestones, in places nodular-limestone-like, underlying the Jurassic, bears no fauna which could be regarded as a reliable age marker. Tomczyk (1962a) referred them to the Ludlovian, but in the writer's opinion it is not excluded that they may represent older members, i.e. the Wenlockian or even part of the Valentian.

The Silurian deposits, so far recorded from the Podlasie depression, clearly show that the thickness of the particular stages, specially of the Ludlovian and the Postludlovian, increases to the west. The same is observable in the eastern part of the Peribaltic depression lying on the north side of the Mazury-Suwałki elevation. In this respect the two tectonic units coincide very closely.

The stratigraphic lacunae observed at the base of the Silurian deposits and their occurrence on the various Ordovician members suggests the presence of the Taconian phase. On the other hand, the occurrence of various stratigraphic members of the Silurian below the Carboniferous, Permian and even Jurassic deposits, indicates that erosion had affected a part of the Upper Silurian, hence, a complete Silurian profile can hardly be expected in this region.

The Bug depression

The Silurian deposits in this unit were discovered in 1955 in borehole Chełm IG-1 (Tomczyk & Teller 1956, Teller 1960a) (fig. 1, chart 2). In this borehole, the Carboniferous is underlain by 400 m thick, horizontally lying, dark-grey calcareous mudstones with calcareous concretions and an 80 cm thick intercalation of dark organogenic limestone in the top part (between 1,257.0 and 1, 257.8 m). Thanks to the rich graptolite (Teller 1964a) and non-graptolite (Korejwo & Teller 1964) fauna there it was possible to differentiate not only several zones previously recorded from the Barrandian area only, but also some new zones. According to the information then available on the Silurian system of Europe, the whole section from this borehole was assigned to the Upper Ludlovian. Now, however, it should be regarded as Postludlovian in age, while its uppermost part, beginning at a depth of 1,211.8 m, may even be referred to the Lower Gedinnian because of the presence of *Acastella* cf. *tiro* Richter, a typically Gedinnian form (Korejwo & Teller 1964), side-by-side with *Monograptus uniformis* Přibyl.

In borehole Kaplonosy IG-1 (Tomczyk 1962a), Silurian sediments 272 m thick, developed as light-grey calcareous mudstones with concretions and intercalation of marly limestones, underlie the Lower Carboniferous and rest on the Ordovician. The graptolite fauna there made it possible to differentiate the Wenlockian from the Cyrtograptus insectus to the C. lundgreni zone, as well as the Ludlovian from the Gothograptus nassa to the Saetograptus leintwardinensis zone.

In borehole Sawin IG-1, only 76 m of grey calcareous mudstones probably Postludlovian in age, were reached. This age is suggested by the presence of *Monograptus formosus* Bouček. The whole profile is disturbed and the dips range from 20° to 55°, hence its true thickness probably does not exceed 50 metres.

Parczew IG-1 is the next borehole where Silurian sediments were encountered below the Carboniferous. They are represented by some 40 m of grey calcareous mudstones bearing a Wenlockian fauna. The lowermost Wenlockian horizons have not, however, been encountered.

The fragmentary Silurian profiles, reached in the four above boreholes, do not present a complete development of this system within this part of the Precambrian platform. It seems, however, that Valentian sediments are altogether absent here, and that the Silurian profile begins with the Wenlockian and ends with the Postludlovian, showing also continuity of sedimentation to the lowermost Devonian (Lower Gedinnian). This would then be the only such occurrence in the Precambrian platform.

The Silurian in the Paleozoic platform

This vast structural unit borders from the NE on the Precambrian platform, from the south on the Carpathian foredeep, the Carpathians and the Silesian-Cracow basin, from the SW on the Sudetes. It covers a large part of the Polish territory and is inadequately known, particularly in its central and western parts.

The Silurian deposits, so far found only in a dozen or so of boreholes (fig. 1, chart 2), are characterized not only by their development differing from that of the Precambrian platform but also by their strong tectonic disturbance, and the intensity of their folding. The Silurian was first identified in the SE part, in borehole Ruda Lubycka 1 where black clay shales, apparently 850 m in thickness, show strong tectonic disturbance and dips ranging from 10° to 80°. The actual thickness can hardly be established but most probably it does not exceed 400—500 metres. The picture is complicated by numerous slickensides and compressions. The mudstones have yielded a relatively abundant graptolite fauna together with a few pelecypods and columnals of crinoids. Tomczyk (1962a) report the occurrence in the above borehole of zones from the Pristiograptus ultimus to the Monograptus angustidens, though Tomczyk (1963a) does not mention the last zone but only *Pristiograptus transgrediens* Přibyl.

The graptolites from that borehole, worked out in 1961 (Teller 1964a), indicate some graptolite zones analogous with those found in borehole Chełm IG-1. The youngest zone here is the Pristiograptus admirabilis, while Monograptus formosus zone is the oldest one. All these forms indicate the Postludlovian.

In borehole Kock IG-1, situated in the Lublin depression, 200 m grey-greenish, slightly calcareous mudstones, showing strong tectonic disturbances, have been found under the Jurassic (Tomczykowa 1962b). The dips there range from 50° to 80°. In the top part, at a depth of 814 m, this author has observed the presence of *Acastella heberti elsana* Richter, also fragments of other trilobite genera, as well as brachiopods, pelecypods and ostracods. No graptolites were found down to the bottom of the borehole. According to Tomczykowa the top part is referable to the Lower Gedinnian, hence the lower parts might represent the Silurian, though there is no paleontological evidence to prove it.

Strongly tectonically disturbed Silurian deposits also occur in borehole Ciepielów IG-1 (Tomczyk 1968a). The M. angustidens zone was found there under the Gedinnian, at a depth from 2,598.3 to 2,677.9 metres. An angular unconformity occurs below this zone between 2,677.9 and 2,778.7 metres. *Pristiograptus ultimus* (Perner) and *Monograptus* ex gr. *formosus* Bouček are reported from a depth between 2,778.7 and 3,000 metres. All that complex from the above borehole, between 2,598.3 and 3,000 m is referable to the Postludlovian, but zones present both in Chełm and Ruda Lubycka with the exception of the M. angustidens are absent. They would fit into the part of the section of tectonic unconformity whose character has not yet been cleared up. A more detailed description of that borehole may elucidate a number of doubtful problems.

Within the NW part of the Paleozoic platform, folded Silurian deposits have been observed in five boreholes in the region of Chojnice (Teller & Korejwo 1968a, b, c). In four of them (Stobno 1, 2, 3 and Chojnice 3) the occurrence is noted of strongly crushed, slickensided and folded black mudstones. A fauna of graptolites and brachiopods, found in these mudstones, assigns them to the Lower Ludlovian (probably the Neodiversograptus nilssoni zone). In borehole Stobno 1 mudstones were found under horizontal Permian deposits and in the other boreholes they occur under horizontal Middle or Upper Devonian deposits.

Another Silurian member, much older and showing a different lithological development, was identified in borehole Lutom 1 (Teller & Korejwo 1968a). Alternating black mudstones and light-grey, mica-bearing siltstones unconformably underlie the Permian between 2,463 and 3,016 metres. Horizontal and cross lamination is frequent in the siltstones. The dips range from 30° to 90°. The graptolite fauna there reliably indicates the Middle Valentian age of these deposits. Only three zones have been defined: Spirograptus turriculatus, Rastrites linnaei and the top of Monograptus sedgwicki. It is hardly possible to determine the exact thickness of these deposits because of their strong tectonic disturbance, it does not seem, however, to be more than 200 metres.

In borehole Gościno IG-1 (Czermiński 1967) farther NW from the region of Chojnice, horizontal, faunally documented Devonian deposits are underlain by dark-grey, in places nearly black, phyllites, whose age has not been accurately determined, though Czermiński (1967) suggests the Lower Paleozoic (Silurian?) [5].

In the southern part of the Paleozoic platform, Silurian deposits occur in borehole Jaronowice IG-1, Strożyska-5, also in the N and NE margins of the Silesia-Cracow basin.

In borehole Jaronowice IG-1 (Jaworowski, Jurkiewicz & Kowalczewski 1967), at a depth between 2,068.5 and 2,274.9 m, dark grey partly siliceous mudstones — towards the base finaly intercalated by lydites and limestones, and containing calcareous laminae of siltstone — underlie deposits of indeterminate age (Lower Devonian? — Silurian?). The latter occur between sediments undoubtedly Lower Devonian and Silurian in age. The dips there range from 10° to 15°, and between 15° and 20° only at the base. The graptolite fauna of the bottom part of the deposits suggests the Lower Valentian, that of the higher part the Wenlockian. The only paleontologically defined zones are, however, Monograptus flexilis, Cyrtograptus radians and Cyrtograptus lundgreni. The Silurian deposits here rest on the Upper Tremadocian.

Black calcareous mudstones, apparently 182.7 m thick, bearing a graptolite fauna, have been reached in borehole Strożyska 5 (Bednarczyk, Korejwo, Łobanowski & Teller 1968) under the Lower Devonian and above the Upper Ashgillian. The dips here are between 10° and 20°. The graptolithic assemblage assigns the mudstones to the Lower Ludlovian — the Neodiversograptus nilssoni zone.

The Silurian deposits, occurring in the N and NE margin of the Silesia-Cracow basin, were the latest to be identified (Siedlecki 1962). In boreholes Mrzygłód IG-1, 6, 8 and 9, also Kotowice IG-1 and Będło IG-1, drilled in the fifties, a complex of grey uncalcareous, clayey-siliceous shales, with intercalation of dark-grey and black siltstones, was reached at a relatively small depth below the Triassic or the Carboniferous. The whole complex is rather strongly silicified, contains numerous crystals

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[5] In this phyllite Dr. K. Lendzion found a tentaculite which Hajłasz (1967) identified as *Tentaculites* sp., without, however, any closer age determination. The present writer is inclined to agree with Czermiński, because in Fisher's (1962) opinion the family Tentaculitidae does not make its appearance before the Lower Silurian (Valentian) and becomes extinct in the Frasnian. Since the Devonian age of the phyllite is unacceptable, it can be no other than Silurian.

of pyrite and is intersected by intrusions of diabases and of quartz porphyries. The dips range from 40° to 60°.

Initially, on the plant remains found in borehole Mrzygłód IG-8 (Ekiert 1957), the above complex had been referred to the Upper Carboniferous. The graptolites in borehole Mrzygłód IG-9, found by Siedlecki (1962) in the top part of these deposits between 162 and 175 m, reliably suggest the Lower Ludlovian age (upper part of the *Neodiversograptus nilssoni* zone). Lower down, under the diabase and quartz-porphyry intrusions, the deposits, though unfossiliferous, are supposed by Siedlecki to be the equivalent of the lowermost Ludlovian or even the Wenlockian.

In other boreholes of that region (Mrzygłód IG-1 and Kotowice IG-1) a complex of deposits consisting of light-grey-greenish, sericitic-chloritic, phyllite-like shales was differentiated by Siedlecki (1962). They contain intercalations of sandstones and greywackes. The whole complex is uncalcareous and intersected by veins of quartz or calcite, while contact changes are observable at the boundaries of the intrusions. On analogies with the Holy Cross Mts. and with the Sudetes, Siedlecki is inclined to regard these deposits as equivalents of the Middle or Upper Ludlovian.

In borehole Bębło IG-1 (Siedlecki 1962), probably under the Carboniferous, there are strongly silicified dark-grey and black mudstones and shales which may possibly represent the Wenlockian or even the Valentian.

In the light thrown by that undoubtedly important discovery a revision has been made of the analysis of deposits occurring between 322—395 m in the pre-war borehole Kraków-Dąbie where olive-green sericite shales (phyllites) were found under the Jurassic. All these sediments are unfossiliferous, they dip at an angle of 25°. Rutkowski (1930) believed them to be Carboniferous while Różycki (1953) was the first correctly to suggest their Silurian age. On the basis of new material, obtained from boreholes Mrzygłód IG-1, 6, 8, 9, Bębło IG-1 and Kotowice IG-1, it seems reasonable to accept their Silurian age, as has already been stressed by Siedlecki (1962).

The clastic sediments from boreholes Łapczyca 2, Batowice 1, Mikluszowice 1 and Wola Kalinowska 1, not faunally defined, have, likewise, been recognized as Lower Ludlovian (Łydka, Siedlecki & Tomczyk 1963, Roszek & Siedlecki 1963). These authors based their assignment chiefly on the lithological resemblance with deposits, faunally well defined, from borehole Kleczanów in the eastern part of the Holy Cross Mts. This led the above authors to far-fetched tectonic conclusions. In the present writer's opinion it is hardly possible to judge if these conclusions are quite correct and whether the age of the sediments under consideration coincides with that of deposits from borehole Kleczanów. These doubts may be justified by the great distance separating the two regions as well as by the intricate structure of the Paleozoic platform in this part of Poland.

The fragmentary Silurian profiles, not always well faunally defined, so far observed in the various parts of the Paleozoic platform, show off the obstacles encountered in correlating and interpreting the development of this system over so vast an area. It seems beyond doubt that the sedimentary cycle of the Silurian deposits was connected here with the range and development of the Caledonian geosyncline and that this had an all important bearing both on the character of the sediments and the extent of their tectonic disturbance.

The Silurian in the substratum of the Carpathian foredeep

The presence of Silurian deposits in this foredeep was first recorded in 1958 and since then they have been reached in the following boreholes: Doliny 1, Uszkowce 1, Mędrzechów 1, Czarna-Pilzno 3 and Niwki 3 (fig. 1, chart 2).

The most complete Silurian profile was obtained in borehole Doliny 1 (Tomczyk 1962a, 1963a) where, below the Jurassic, between 1,050 and 1,253 m, a complex of black, muddy-siliceous shales, a. 200 m thick, has been pierced. It contains a graptolite fauna reliably indicating the presence of the lowermost Valentian, from the Akidograptus ascensus to the Pristiograptus cyphus zone. Higher up there occur greenish dolomitic-calcareous mudstones, interbedded by black shales which contain graptolites from the Demirastrites convolutus to the Spirograptus spiralis zone of the Upper Valentian.

The Wenlockian is represented by dark-grey laminated mudstones containing the index graptolite forms from the zones Cyrtograptus insectus, C. rigidus, C. radians and C. lundgreni. In view, however, of incomplete coring, it may be reasonably supposed that the remaining zones of that stage are present, too.

The top of the Silurian is developed as grey, partly calcareous mudstones bearing a fauna which indicates the presence of zones from the Pristiograptus vulgaris to the lower part of the Lobograptus scanicus parascanicus of the Lower Ludlovian.

The dips of the deposits range from 10° to 20°, hence the observed thickness is an apparent one and the true thickness may be approximately 150—170 metres.

In borehole Uszkowce 1 (Tomczyk 1962d, 1963a), below the Jurassic and above the Upper Ordovician, at a depth between 1,088.4 and 1,096.4 m, only 8 m of dark-grey mudstones was reached. They contain a fauna reliably indicating the Cyrtograptus insectus zone of the Lower Wenlockian. The dips here vary strongly and range from 15° to 40° [6].

In the profile of borehole Mędrzechów, the Silurian occurs below the Carboniferous and above the Arenigian, at a depth from 1,550 to 1,811 m (Tomczyk 1958b, 1963a). It consists of grey calcareous mudstones containing a few marly limestone intercalations. In the top part of the profile, at a depth from 1,550.2 to 1,556.5 m, the presence has been noted of silty-sandy calcareous deposits bearing analogies to the bottom parts of the greywacke-shale series in the Ludlovian from the Holy Cross Mts.

The graptolite fauna encountered in the above profile supplies evidence for the presence of the Wenlockian, from the Cyrtograptus insectus to the Cyrtograptus lundgreni zone, and also of the Lower Ludlovian — from the Gothograptus nassa to the Neodiversograptus nilssoni zone. The whole is strongly disturbed and contains numerous tectonic slickensides and compressions, with dips varying from 20° to 40°.

In borehole Niwki 3, at a depth from 2,792.4 to 2,818.2 m disturbed complex of dark-grey, nearly black mudstones, with dips up to 40°, was found under the Lower Devonian and above the supposed Ordovician (Korejwo & Teller 1968). The graptolite fauna there indicates the Neodiversograptus nilssoni and the Lobograptus scanicus parascanicus zones of the Lower Ludlovian.

Czarna-Pilzno 3 is one of the last boreholes where the Silurian has so far been found in the substratum of the Carpathian foredeep. Dark-grey and black mudstones have been reached there under the Carboniferous at a depth of 2,860 metres. The meagre graptolite fauna they contain does not date them more accurately except for suggesting the Wenlockian and the Lower Ludlovian age. The mudstones are disturbed and their dips range from 20° to 40°.

The above characteristics of Silurian deposits, so far observed in the substratum of the Carpathian foredeep, show that they represent only fragmentary profiles relatively uniform developed. The most complete profile occurs in the south-eastern part, in borehole Doliny 1 where the presence of Valentian, Wenlockian and Lower Ludlovian deposits has been noted. In the other boreholes the Silurian deposits rest on various member of the Ordovician, indicating a major sedimentary lacuna connected with the Taconian phase of the Caledonian orogeny. The folding of the Silurian deposits including those of the Lower Ludlovian, shows

[6] Moryc (1961) states that the Silurian also occurs in profile II (borehole Uszkowce 4 — the writer's note) where, in a grey marly limestone intercalation, found among mudstones, Pachucki (*in* Moryc 1961) had identified *Monograptus testis* Barr., *Encrinurus punctatus* Wahl., *Chonetes striatella* Dalm., *Plectodonta* cf. *mariae* Kozł. and *Sowerbyella* cf. *transversalis* Dalm. In that author's opinion the above fauna suggests the uppermost Wenlockian. Tomczyk (1962a) however, doubts that fact believing that the Silurian is absent from that borehole and that the Tertiary is underlain directly by the Lower Ashgillian.

that they were affected by the Caledonian orogeny. The long-lasting post-Silurian erosion — locally reaching as far as Jurassic (Karnkowski & Głowacki 1961) had probably removed a large part of these deposits. Hence, even the profile in borehole Doliny 1 does not fully reflect the thickness and the sedimentary conditions prevailing in the Upper Silurian basin.

The Silurian on the surface

The Holy Cross Mts.

The Silurian deposits that occur on the surface in the Holy Cross Mts. have always been and still continue to be attractive to a large group of specialists.

The stratigraphic foundations of that system, laid down by Czarnocki (1919a, b, 1936, 1942, 1950) and Samsonowicz (1916, 1934, 1952), have been confirmed thanks to the recent detailed studies (Tomczyk 1954, 1956, 1962a, b, c; Teller 1955; Tomczykowa 1957, 1958, 1959, 1962a, b, c; Ryka 1957; Pawłowska 1961; Dulski & Zagórski 1962; Filonowicz 1963; Kowalczewski 1963, 1968a, b; Teller & Kowalczewski 1968).

The stratigraphy of the Silurian in the Holy Cross Mts., established after long years of research work, constitutes a basis for the study of other areas in Poland, and has been confirmed in numerous boreholes. Regretfully, no monographs of the fauna from the Holy Cross Mts. have so far been published, and this leaves many of problems unsolved, especially in what the upper part of the Silurian is concerned. Investigations in this field, started by the writer and Dr. K. Korejwo, had to be interrupted so that the rich, partly elaborated, material is still awaiting description.

According to Czarnocki (1950) the geology of the Holy Cross Mts. is strongly differentiated. Distinct differences in the facial and tectonic development, particularly of the old Paleozoic sediments, have suggested to Czarnocki the separation of this area into two regions, each displaying a different evolution. They are the Łysogóry geosynclinal region in the north, and the Kielce anticlinal region in the south. The boundary between them, on the whole runs south of the Łysogóry fold and it is tectonic in character.

Łysogóry region (northern)

The Silurian here occurs on the northern side of the main fold within the extensive Wilków syncline. The full profile of these deposits is paleontologically defined showing their continuous transition into the Gedinnian.

The Valentian is developed as black graptolite shales with a fauna that suggests the presence of the Akidograptus ascensus to the Spirograptus spiralis zones.

In the Lower Valentian stratigraphic gaps have been noted in some places, and also the absence of the lowermost graptolite zones, sometimes up to the Orthograptus vesiculosus zone. Local changes in facies have also been observed. Black shales are replaced by greenish siltstones and mudstones with fine intercalations of black graptolite shales. This indicates the presence of the Taconian phase. The total thickness of the Valentian does not probably exceed 60 metres.

The Wenlockian and Lower Ludlovian are characterized by the uniform sedimentation of grey, sometimes calcareous, mudstones with syngenetic calcareous concretions, mostly in the top. Their rich graptolite fauna made it possible to distinguish the Wenlockian zones from the Cyrtograptus insectus including the Cyrtograptus lundgreni. In the Lower Ludlovian, the paleontologically defined zones are those from Gothograptus nassa to Saetograptus leintwardinensis. The thickness of that series attains a. 250 metres.

Above the Saetograptus leintwardinensis zone there is a distinct change in the mode of sedimentation. Graptolite-bearing mudstones are replaced by a complex of olive-green and pale brown siltstones and greywackes. This complex, containing a meagre and poorly preserved fauna, particularly so at the base, has been called the Wydrzyszów series[7] by Czarnocki (1942). Its stratigraphic position is not faunally well defined, since the sporadic graptolite fauna it yielded is so poorly preserved that it does not allow specific identification, while the other rare fossil represents species having a wide vertical range. Nevertheless, the Wydrzyszów series undoubtedly represents the Upper Ludlovian. Its thickness may be only approximately determined, but it is fairly great and attains a. 1000 metres.

On this series conformably rests a rock complex with a strongly differentiated lithology which Czarnocki (1942) calls the Rzepin series. It is developed as olive, sometimes cherry-coloured and greenish shales, calcareous greywackes, also as grey limestones represented by lenses with fauna. At the top there even occur light-cherry-coloured limestones, up to 2.5 m thick. The fauna is relatively rich and has been encountered in all lithological types. It contains corals (Różkowska 1962), pelecypods, gastropods, brachiopods, ostracods, trilobites etc. This series is younger than Ludlovian but older than Gedinnian and ought to be regarded as an equivalent of the Postludlovian. It is difficult to establish the boun-

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[7] In the Polish literature it is a current practice to refer to the Wydrzyszów and the Rzepin series as beds; the present writer does not think this name to be correct but believes that the earlier name of series given by Czarnocki (1942, 1950) should be used.

dary of the Wydrzyszów/Rzepin series, hence the top part of the former and the base of the latter may be either Ludlovian or Postludlovian. The thickness of the Rzepin series does not probably exceed 500 m. The Gedinnian, containing a typical fauna of trilobites, brachiopods and other fossils, conformably rests on the Rzepin series.

Our present knowledge of the Silurian from the Łysogóry region suggests that the deposits there have a monoclinal northward dip (35° to 40°) and that they had not been folded until the Variscan orogeny.

Kielce region (southern)

The Kielce region consists of two principal elements: the Kielce-Łagów synclinorium and the Chęciny-Klimontów anticlinorium, both of which embrace several minor elements and, as a whole, present a rather complicated picture.

The Silurian deposits here are not distributed over so large an area as in the Łysogóry region and their occurrence areas are of rather limited size. The most complete development has been traced in the Bardo syncline (profile of the Prągowiec ravine) which lies in the central part of the Chęciny-Klimontów anticlinorium.

The Valentian consists at the base of muddy-siliceous shales with thin intercalations of black lydites, grading upwards into mudstones and siltstones with sandy intercalations, while black graptolite-bearing shales occur still higher up. The Akidograptus ascensus zone, also some Lower and Upper Valentian zones are paleontologically defined. Lithological variability and the absence of some zones indicate the Taconian phase. The Valentian deposits here are a. 25—30 m in thickness.

The Wenlockian is represented by black calcareous graptolite-bearing shales with calcareous concretions in the top part. All the Wenlockian zones have been found here, from the Cyrtograptus insectus to C. lundgreni (Tomczyk 1962a), with a total thickness of a. 70 metres.

In the Lower Ludlovian the type of sedimentation resembles that in the Wenlockian; the graptolite fauna reliably indicates the presence of zones from the Gothograptus nassa throught the Saetograptus leintwardinensis (Tomczyk 1962a, Teller & Kowalczewski 1968). At the base of the Ludlovian there occur olive-coloured calcareous mudstones containing trilobites, pelecypods and brachiopods (Tomczykowa 1958). The total thickness of the Lower Ludlovian complex is a. 160—180 metres.

An abrupt change in the sediments sets in above the mudstone complex: a greywacke-silty series makes its appearance and develops as a thick complex, by Czarnocki (1919a) called the Niewachlów greywackes. In their lower part they are conglomeratic or coarse-grained, while upwards they grade into finer-grained deposits with shale intercalations. In the conglomeratic part, fragments of other sedimentary rocks as well as the detritus of extrusive rocks are fairly common. The fauna here is very meagre and poorly preserved. The thickness of the series ranges from 300 to 1,300 m; stratigraphically it corresponds to a large part of the Wydrzyszów series in the northern region.

In the Bardo syncline, diabases intersecting various graptolite zones occur at the boundary of the graptolithic mudstones and the Niewachlów greywackes. They have been traced in both limbs of the Bardo syncline; their thickness ranges from 12—25 m (Ryka 1957, Kowalczewski 1968a). At some points we are even dealing with two veins separated by shales — the lower one is thicker than the upper. Clastic Lower Devonian (?Siegenian or Emsian) deposits rest unconformably on the greywackes.

The base of the Silurian in the Kielce region does not always represent the Valentian, only here and there it begins with the Wenlockian. As a rule it rests on various members of the Ordovician. In some places the Silurian deposits wedge into Cambrian or Ordovician sediments and form thrust folds (Czarnocki 1950). It is also noteworthy that, in the western part of the Kielce region, the Silurian is represented by more fragmentary profiles and its total thickness is considerably less than in the east. This is applicable in a large measure ot the greywacke complex.

In the Kielce region the Silurian deposits are characterized not only by greater diversity of the development and bigger stratigraphic lacunae than those in the Łysogóry region but they are markedly more disturbed, too, and moreover, unconformably underlie the Lower Devonian. This would indicate differences in their evolution and stronger tectonic activity as compared with the region of Łysogóry. The development of the Lower Valentian deposits in the Kielce region was strongly affected by the Taconian phase while the whole of the Silurian was folded during the Ardennian phase of the Caledonian orogeny. This is indirectly reflected in the Wydrzyszów and Rzepin series farther north.

Outside of the Holy Cross Mts. four Silurian occurrence areas are known in the north and the south. In the north they have been found in the Bronkowice and Wydrzyszów folds, at the locality Czerwona Góra, while in the south they have been encountered in the Zbrza fold.

The highest parts of the Wydrzyszów series, partly also the Rzepin series, crop out in the Bronkowice fold. An abundant fauna has been yielded by these two series.

In the Wydrzyszów fold there are the same stratigraphic members with an equally abundant fauna. Moreover, the two folds are characterized by rather complicated tectonics expressed by numerous faults and compressions.

At Czerwona Góra, the uppermost members of the Rzepin series as well as fragments of the Gedinnian, emerge within the Triassic. The tectonics there have not as yet been accurately worked out.

In the south, the Silurian deposits are not the only ones found in the Zbrza fold, where black siliceous shales with clay intercalations occur nearer to the base. The graptolite fauna reasonably suggests the presence of zones from the Akidograptus acuminatus to the Pristiograptus gregarius. On these, in tectonic contact, rest graptolithic shales of the uppermost Valentian and nearly all the zones of the Wenlockian. Ludlovian deposits have not been found. The whole Silurian is strongly disturbed and intersected by numerous faults. Compressions and refoldings are noted, too.

The Sudetes Mts.

In the Sudetes, Silurian deposits are known since long ago, and they have attracted the attention of numerous geologists (Dathe 1904; Bederke 1924; Dahlgrün & Finckh 1924; Finckh 1932; Finckh, Meister, Fischer & Bederke 1942; Oberc 1953, 1957; Malinowska 1955; Teller 1960b, c, 1962b). In the Bardo Mts., the Silurian belongs to those members of the older Paleozoic rocks which have not undergone metamorphic changes and, therefore, contain a fauna that is an excellent and reliable age marker. In the Kaczawa Mts., on the other hand, the Silurian is metamorphosed and the fossils it yields are usually very poorly preserved, impeding the correct determination of the sequence of beds.

The Bardo Mts.

Silurian deposits occur here only in a very few outcrops and are strongly disturbed. The two best outcrops are the Żdanów profile and that in Mt. Łopianka near Wilcza. At Żdanów, Valentian, Wenlockian and Ludlovian deposits are well paleontologically defined; at Mt. Łopianka only the Valentian and the Wenlockian (Malinowska 1955; Teller 1960b, 1962b). In the other profiles only fragments of the various members of this system are observable.

The Valentian is developed at the base as a basic conglomerate a. 0.5 m thick, on which rest variegated clay shales grading upwards into black lydites with layers up to 40 cm thick. These layers thin out to the top and are finely intercalated by black clay shales bearing a very badly preserved graptolite fauna. The lydites are overlain by siliceous shales interbedded with clay shales, and thin lydite laminae. Phosphorite concretions are frequent. Zones from the Monograptus sedgwicki to the Spirograptus spiralis are well defined. It is hardly possible to determine the true thickness of the Valentian because the profiles are strongly tectonically disturbed, but probably it varies from 17 to 25 metres.

The Wenlockian is represented chiefly by black clay shales, interbedded with black siliceous shales. Green siliceous unfossiliferous shales are subordinate and so are the intercalations of brown tuffites, from a few to some 35 cm in thickness. The graptolite fauna here indicates the presence of zones from the Cyrtograptus murchisoni to C. lundgreni. The total thickness of the Wenlockian does not exceed 20 metres.

The Ludlovian exhibits stronger lithological differentiation. It is developed as green, yellow or black, often siliceous, shales. The fauna is rather meagre and defines only the lower zones including the Lobograptus scanicus parascanicus zone. Unlike the lower members, the stratigraphy of the Ludlovian has not been fully clarified, largely owing to the intricate tectonics in this area.

Other graptolites have also been obtained from the Bardo Mts. until recently they have been regarded as the youngest ones and indicating the top of the Silurian. They are *Monograptus praehercynicus* Jaeger, *Monograptus microdon silesicus* Jaeger (cf. Jaeger 1959), *M.* cf. *hemiodon* Jaeger and *M. hercynicus* Perner (cf. Teller 1960c). At present these forms have been referred to the Gedinnian and this has additionally complicated the stratigraphy of the Upper Silurian in this region.

The Kaczawa Mts.

In this area the Silurian is strongly folded and displays rather high metamorphism caused by orogenic processes. The fauna, mainly graptolithic, is inadequately preserved. It is known from a very few sites only, reported in papers by Jerzmański (1955) and Kornaś (1963) but it has allowed to define the Lower and the Upper Silurian.

The Valentian is developed as lydites and siliceous shales containing subordinate intercalations of clay shales. The zones identified here are those from the Demirastrites convolutus to the Spirograptus spiralis (Kornaś 1963). The lowest Silurian zones have not so far been defined but it is reasonable to suppose here the presence of deposits representing the lowest Valentian.

The Wenlockian is similarly characterized by siliceous and siliceous-clay shales bearing a graptolite fauna which indicates the presence of all the Wenlockian zones. The thicknesses of the Valentian and Wenlockian here have not been determined owing to the fragmentary nature of the profiles and the strong folding of beds.

The youngest Silurian members probably occur in the western part of the Kaczawa Mts., but only the Neodiversograptus nilssoni zone (Jaeger, 1964a, b) has so far been identified here. In lithology the Ludlovian deposits do not differ from the underlying Wenlockian one.

Monograptus hercynicus Perner which, as has already been mentioned, represents the Gedinnian, was found by Jaeger (1964a, b) [8].

Both the lower and the upper parts of Silurian deposits from the Bardo and the Kaczawa Mts. resemble closely in lithology, differing distinctly from other Polish regions already described. In its small thickness, not exceeding 100 m and in a specific type of development, the Silurian deposits here seem to resemble more closely some areas outside of Poland than any region in Polish territory.

THE POLISH SILURIAN GRAPTOLITE ZONES

General remarks

The biostratigraphy of Silurian deposits is based chiefly on graptolites. This group of fossils shows a strong specific and generic differentiation, occurs in great masses in the rocks, and has a wide geographical distribution. These are all conditions favourable to correlation with other profiles.

The first standard classification, based only on the above group of fossils, was drawn up by Elles (1900) for the Ludlovian, by Wood (1900) for the Wenlockian and by both these authors for the whole Silurian (Elles & Wood 1913). In the latter work, 21 graptolite zones were distinguished in the Silurian. Out of these 10 characterize the Valentian, 6 the Wenlockian, 5 the Ludlovian. This subdivision has been accepted by the majority of stratigraphers dealing with the Silurian biostratigraphy.

As studies progressed, the above classification was extended to include a much greater number of graptolite zones, particularly so in the Ludlovian. One of the reasons is the fact that in Great Britain the graptolite facies ends with the Saetograptus leintwardinensis zone while on the Continent it persisted much longer, in places reaching even to the Lower Devonian.

Studies on the Silurian graptolite faunas on the Continent kept pace with those in Great Britain, but their development varied in the different countries. They developed first and foremost in Czechoslovakia thanks to the works of Barrande (1850) and Perner (1897), also Perner & Kodym (1919), in the thirties continued by Bouček and Přibyl. The two last na-

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[8] Jaeger has revised some old material, probably found by Peck in 1865 and which is now preserved in the collections of the Natural History Museum at Görlitz. They come from the railway cut near Lubań.

med authors have presented in their publications (e.g. Bouček 1931a, b, c, 1932, 1933, 1953, 1960a, b; Přibyl 1940a, b, 1941a, b, 1942a, b, 1943, 1948, 1957) a much more comprehensive stratigraphic division of the Silurian from the Barrandian area into graptolite zones than that worked out in Great Britain.

Přibyl differentiated 15 zones in the Valentian but he does not distinguish the three lowest ones, i.e. Akidograptus ascensus, A. acuminatus and Orthograptus vesiculosus. A more complete description is given by Bouček (1953) who distinguishes 15 Valentian zones as well as a number of subzones and beds. He justifies this subdivision by the presence either of new species or by the concentration of one form in a definite stratigraphic position. Moreover, that author ascribes a great importance to the evolutionary stages of the Valentian graptolite fauna (Bouček 1960b). The difference between the subdivision of Přibyl (1948) and that of Bouček (1953) consists in that the latter author distinguishes three lowermost zones. If this is taken into account in Přibyl's (1948) subdivision, the number of his zones will increase to eighteen.

Within the Wenlockian deposits Bouček (1933) distinguishes 11 zones, most of them based on cyrtograptids, but his papers published in 1953 and 1960b mention 12 zones. The same number is mentioned by Přibyl (1948) and it increases to 13 when Horny (1962) places the Gothograptus nassa zone in the Wenlockian.

Since graptolites younger than the Saetograptus leintwardinensis zone have been identified in the Barrandian area, the Ludlovian stage is very accurately subdivided by Přibyl (1941a, b) and Bouček (1960b), also by Horny (1962). In the Barrandian area these authors distinguish as many as 14 zones, out of which the 3 youngest ones now certainly represent the Gedinnian. The division of the Ludlovian from the Barrandian area into zones has not as yet been fully clarified, so that further modifications are not excluded, as may i.a. be supposed from the Polish profiles. The question arises whether the whole division of the Silurian, varying with the Czechoslovakian authors, is correct and whether the zones that have been distinguished by them are really index horizons as is currently accepted.

The progress of studies on the stratigraphy and graptolite fauna in Poland started some ten years ago. Regretfully, a full description of the Silurian fauna, particularly of the Valentian and the Wenlockian, has not as yet been worked out in spite of the great abundance of materials. Studies on the Ludlovian and Postludlovian deposits are slightly more advanced but likewise not yet fully completed.

With a few exceptions Tomczyk (e.g. 1962a, 1968c) distinguishes in the Polish Silurian the same zones as those of the Czechoslovakian authors; for the Ludlovian he mentioned as many as 19 zones, i.e. considerably more. Papers by that author, however, lack a more complete justification of his subdivisions, moreover, the interpretation of the various zones seems somewhat arbitrary, sometimes even inaccurate.

The Silurian graptolite fauna, so far identified in Poland, is discussed in the present chapter. Sufficient evidence is yielded by it to distinguish well defined graptolite zones, while those which the writer does not regard as perfectly certain are eliminated, though they had been previously introduced into the literature. Material from outcrops or boreholes investigated by the writer, as well as data from the literature, in some cases even unpublished information were used as a basis in analysing this problem. The zones distinguished in Poland have been compared with those established in Czechoslovakia and Great Britain.

Other European profiles have been disregarded in view of their mostly incomplete development. Neither have profiles outside of Europe been considered, because of their great distance and owing to the presence of numerous endemic species which would obscure the picture here presented.

The distinction of the Silurian graptolite zones was based first and foremost on the generally binding rules, established by the International Subcommission on Stratigraphic Terminology (1961). In that meaning this is the first comprehensive concept of a biostratigraphic division of the Silurian in Poland, based on graptolites.

A complete specification of the Silurian graptolite fauna of Poland, so far identified, showing its vertical range and the defined zones, is given in charts, separately for every stage.

Valentian (Llandovery)

By far the greatest part of the Valentian deposits, both on the Precambrian and the Paleozoic platforms, as well as in the Holy Cross Mts. are clayey; subordinately clayey-siliceous, marly or calcareous. The last named type is confined to the Lower Valentian and it is associated with the neritic zone of the Mazury-Suwałki elevation. On the other hand, the predominance of the clayey-siliceous sediments is characteristic of the Sudetes. In their lower part there is a fairly thick series of lydites which grade upwards into siliceous shales interbedded by clays. Marly and clastic deposits have been found sporadically in some profiles and they occur only as rather thin intercalations. Graptolites are the predominant, in principle, the only fauna. The few brachiopods, trilobites and pelecypods, are of small stratigraphic value. An analysis of the graptolite fauna has led to the distinction of the following zones (chart 4).

Akidograptus ascensus Zone

This zone complies with the requirements for an acrozone and it should be treated as the lowermost one, beginning the Silurian profile in Poland. The following forms occur in the faunal assemblage here: *Akidograptus ascensus* (Nich.), *Diplograptus modestus modestus* Lapw., *D. modestus diminutus* Elles & Wood, *Glyptograptus persculptus* (Salt.), *Climacograptus medius* Törnq., *C. scalaris normalis* Lapw., *C. scalaris miserabilis* Elles & Wood.

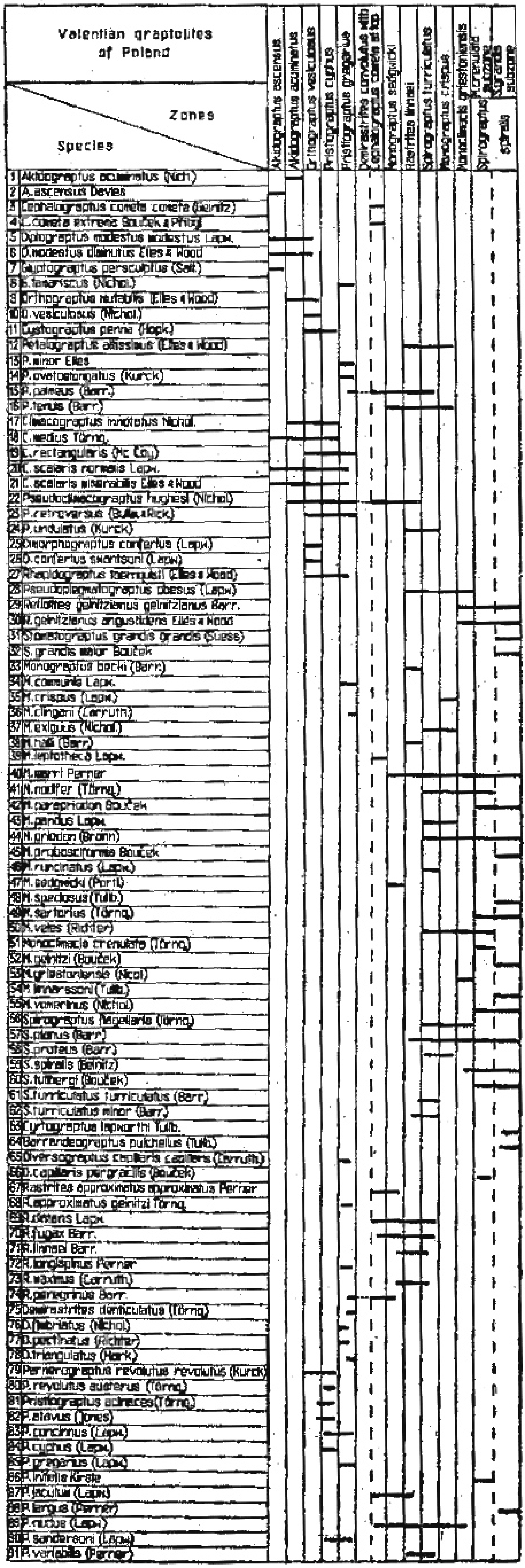
All the above forms have also been found in the Barrandian area (Bouček 1953) and in Great Britain (Davies 1929). This zone is, therefore well paleontologically defined, and permits extensive correlation.

Tomczyk (1962a, 1968c) recognizes that *Glyptograptus persculptus* (Salt.), found in the profile of borehole Lębork IG-1 is characteristic of the lowermost Silurian zone of Poland. In his opinion this form occurs together with *Climacograptus scalaris normalis* Lapw. and *C. scalaris miserabilis* Elles & Wood. The differentiation of this zone does not, however seem justifiable because *Glyptograptus persculptus* (Salt.) is known from the uppermost Ordovician (Dicellograptus anceps zone) and it occurs in Poland as well as in Great Britain (Davies 1929), together with *Akidograptus ascensus* (Nich.) which does not pass from the Ordovician. *Glyptograptus persculptus* (Salt.) is cited by Elles and Wood (1913) also from the Akidograptus acuminatus zone, and with an interrogation mark even from the Orthograptus vesiculosus zone. Thus it is a form with a relatively great vertical range (from the Upper Ordovician to at least the Akidograptus acuminatus zone) and it can hardly be regarded as an index form of an independent lowermost Silurian zone. The Glyptograptus persculptus zone is not known in Czechoslovakia, while Davies (1929) distinguishes it in Great Britain.

Akidograptus acuminatus Zone

This is a zone faunally well defined in Poland and readily distinguishable, moreover, it may be regarded as the equivalent of an acrozone. A typical assemblage is indicated by the following forms: *Akidograptus acuminatus* (Nich.), *Diplograptus modestus modestus* Lapw., *D. modestus diminutus* Elles & Wood, *Orthograptus mutabilis* (Elles & Wood), *Climacograptus innotatus* Nich., *C. medius* Törnq., *C. scalaris normalis* Lapw., *C. scalaris miserabilis* Elles & Wood, *Pseudoclimacograptus* cf. *hughesi* (Nich.). All these forms are likewise known from an analogous zone in the Barrandian area (Bouček 1953), while in Great Britain (Elles & Wood

Chart 4


Valentian graptolites of Poland
Zones
Species
Akidograptus ascensus
Akidograptus acuminatus
Orthograptus vesiculosus
Pristiograptus cyphus
Pristiograptus gregarius
Demirastrites convolutus with Cephalograptus cometa at top
Monograptus sedgwicki
Rastrites linnaei
Spirograptus turriculatus
Monograptus crispus
Monoclimacis griestoniensis
Monoclimacis crenulata
Spirograptus spiralis
M. crenulata subzone
S. grandis subzone
1 Akidograptus acuminatus (Nich.)
2 A. ascensus Davies
3 Cephalograptus cometa cometa (Geinitz)
4 C. cometa extrema Bouček & Přibyl
5 Diplograptus modestus modestus Lapw.
6 D. modestus diminutus Elles & Wood
7 Glyptograptus persculptus (Salt.)
8 G. tamariscus (Nichol.)
9 Orthograptus mutabilis Elles & Wood
10 O. vesiculosus (Nichol.)
11 Cystograptus penna (Hopk.)
12 Petalograptus altissimus (Elles & Wood)
13 P. minor Elles
14 P. ovatoelongatus (Kurck)
15 P. palmeus (Barr.)
16 P. tenuis (Barr.)
17 Climacograptus innotatus Nichol.
18 C. medius Törnq.
19 C. rectangularis (Mc Coy)
20 C. scalaris normalis Lapw.
21 C. scalaris miserabilis Elles & Wood
22 Pseudoclimacograptus hughesi (Nichol.)
23 P. retroversus (Bulman & Rick.)
24 P. undulatus (Kurck)
25 Dimorphograptus confertus (Lapw.)
26 D. confertus swanstoni (Lapw.)
27 Rhaphidograptus toernquisti (Elles & Wood)
28 Pseudoplegmatograptus obesus (Lapw.)
29 Retiolites geinitzianus geinitzianus Barr.
30 R. geinitzianus angustidens Elles & Wood
31 Stomatograptus grandis grandis (Suess)
32 S. grandis major Bouček
33 Monograptus becki (Barr.)
34 M. communis Lapw.
35 M. crispus (Lapw.)
36 M. clingani (Carruth.)
37 M. exiguus (Nichol.)
38 M. halli (Barr.)
39 M. leptotheca Lapw.
40 M. marri Perner
41 M. nodifer (Törnq.)
42 M. parapriodon Bouček
43 M. pandus Lapw.
44 M. priodon (Bronn)
45 M. proboscisformis Bouček
46 M. runcinatus (Lapw.)
47 M. sedgwicki (Portl.)
48 M. speciosus (Tullb.)
49 M. sartorius (Törnq.)
50 M. veles (Richter)
51 Monoclimacis crenulata (Törnq.)
52 M. geinitzi (Bouček)
53 M. griestoniensis (Nicol)
54 M. linnarssoni (Tullb.)
55 M. vomerinus (Nichol.)
56 Spirograptus flagellaris (Törnq.)
57 S. planus (Barr.)
58 S. proteus (Barr.)
59 S. spiralis (Geinitz)
60 S. tullbergi (Bouček)
61 S. turriculatus turriculatus (Barr.)
62 S. turriculatus minor (Barr.)
63 Cyrtograptus lapworthi Tullb.
64 Barrandeograptus pulchellus (Tullb.)
65 Diversograptus capillaris capillaris (Carruth.)
66 D. capillaris pergracilis (Bouček)
67 Rastrites approximatus approximatus Perner
68 R. approximatus geinitzi Törnq.
69 R. distans Lapw.
70 R. fugax Barr.
71 R. linnaei Barr.
72 R. longispinus Perner
73 R. maximus (Carruth.)
74 R. peregrinus Barr.
75 Demirastrites denticulatus (Törnq.)
76 D. fimbriatus (Nichol.)
77 D. pectinatus (Richter)
78 D. triangulatus (Hark.)
79 Pernerograptus revolutus revolutus (Kurck)
80 P. revolutus austerus (Törnq.)
81 Pristiograptus adinaces (Törnq.)
82 P. atavus (Jones)
83 P. concinnus (Lapw.)
84 P. cyphus (Lapw.)
85 P. gregarius (Lapw.)
86 P. initialis Kirste
87 P. jaculum (Lapw.)
88 P. largus (Perner)
89 P. nudus (Lapw.)
90 P. sandersoni (Lapw.)
91 P. variabilis (Perner)

1913) there occur, moreover, *Dimorphograptus confertus swantsoni* (Lapw.), *D. elongatus* Lapw. and *D. erectus* Elles & Wood.

The Akidograptus acuminatus zone may be readily correlated with other European profiles.

Orthograptus vesiculosus Zone

This zone has been distinguished in Poland on the basis of the following assemblage: *Diplograptus modestus modestus* Lapw., *D. modestus diminutus* Elles & Wood, *Orthograptus mutabilis* (Elles & Wood), *O. vesiculosus* (Nichol.), *Cystograptus penna* (Hopk.), *Climacograptus innotatus* (Nichol.), *C. medius* Törnq., *C. rectangularis* (Mc Coy), *C. scalaris normalis* Lapw., *C. scalaris miserabilis* Elles & Wood, *Pseudoclimacograptus hughesi* (Nichol.), *P. retroversus* (Bulman & Rickards), *Dimorphograptus confertus confertus* (Nichol.), *D. confertus swantsoni* (Lapw.), *Rhapidograptus toernquisti* (Elles & Wood), *Pernerograptus revolutus* (Kurck).

The above assemblage is likewise characteristic of an analogous zone in the Barrandian area (Bouček 1953) and in Great Britain (Elles & Wood 1913). As presented above it should be treated as the acrozone of *Orthograptus vesiculosus* (Nichol.).

Between the zone Akidograptus acuminatus and Orthograptus vesiculosus, Tomczyk (1962a, 1968c) places the Diplograptus modestus subzone. This form is known in Poland and in the Barrandian area (Bouček 1953) from the Akidograptus ascensus to the Orthograptus vesiculosus zone; in Great Britain (Elles & Wood 1913) from the Akidograptus ascensus to the Pristiograptus cyphus zone. In the Barrandian area this subzone is not distinguished by Bouček (1953) or Horny (1962), while in England it was differentiated as an independent subzone and placed above Akidograptus acuminatus by Jones (1921). On the other hand, Elles and Wood (1913) regard as one zone the Orthograptus vesiculosus and Diplograptus modestus zones. In the division of Curtis (1961) the zone Diplograptus modestus is replaced by the Monograptus atavus zone, the Orthograptus vesiculosus zone by the Monograptus acinaces zone. In what rules are concerned, the Diplograptus modestus subzone does not compley with any requirements warranting its differentiation, hence, the present writer does not distinguish it in the Polish Valentian profile.

Pristiograptus cyphus Zone

In Poland this zone belongs to those faunally well defined. It is characterized by numerous forms common to the Barrandian area (Bouček 1953) and to Great Britain (Elles & Wood 1913, Jones 1921) where it is known, too. Its index assemblage contains: *Cystograptus penna* (Hopk.), *Climacograptus innotatus* Nichol., *C. medius* Törnq., *C. rectangularis* (Mc Coy), *C. scalaris normalis* Lapw., *C. scalaris miserabilis* Elles & Wood, *Pseudoclimacograptus hughesi* (Nichol.), *P. retroversus* (Bulman & Rickards), *Rhapidograptus toernquisti* (Elles & Wood), *Pernerograptus revolutus revolutus* (Kurck), *P. revolutus austerus* (Törnq.), *Pristiograptus acinaces* (Törnq.), *P. atavus* (Jones), *P. concinnus* (Lapw.), *P. cyphus* (Lapw.), *P. sandersoni* Lapw. Its characteristic feature is the appearance of the first pristiograptids among which *Pristiograptus cyphus* (Lapw.) is an index form complying with the requirements for an acrozone.

Pristiograptus gregarius Zone

In Poland this zone may be distinguished on its index form as well as on the whole assemblage, but its separation into subzones, as was done by Elles & Wood (1913), is hardly possible. Tomczyk (1962a, 1968c) postulates the presence of two subzones, i.e. Demirastrites fimbriatus and Demirastrites triangulatus. Above these he places Pristiograptus gregarius as an independent zone. Such an interpretation does not, however, seem correct, because these two subzones are embraced by the Pristiograptus gregarius zone and do not constitute independent underlying subzones.

In Czechoslovakia, Přibyl (1948) replaces the subzones by three zones: Demirastrites pectinatus (according to Přibyl & Münch, 1942, *Demirastrites pectinatus* Richter is a synonym of *Graptolites fimbriatus* Nicholson), Demirastrites triangulatus and Rastrites approximatus, without distinguishing the Pristiograptus gregarius zone. On the other hand, Bouček (1953) mentions the Demirastrites pectinatus and the Demirastrites pribyli zones. At the base of the former he places the *Demirastrites triangulatus* (Hark.) bed. In a brief diagnosis of the species *Demirastrites pribyli*, Bouček (1953, p. 14) states that it closely resembles *D. triangulatus* (Hark.), the only observable difference being a more arcuate rhabdosome and more widely spaced thecae which never coalesce at the base. Even these slight differences, however, must raise doubts as to the correctness of the creation of a new species and its use as an index form of a zone which is supposed to replace the D. triangulatus subzone. On the other hand, Bouček (1953) cites the presence of numerous representatives of *Demirastrites triangulatus* (Hark.) from the Pristiograptus gregarius zone.

In a later paper (Bouček 1960b), the bed containing *D. triangulatus* (Hark.) is raised to the rank of a zone, while the P. gregarius zone is not distinguished, similarly as in Přibyl (1948).

Curtis (1961) replaces the P. gregarius zone by the Monograptus triangulatus, Diplograptus magnus and Monograptus leptotheca zones. Thus the problem of the Pristiograptus gregarius zone is not yet accurately defined either in the Polish profile or elsewhere. The writer's analysis of materials (Teller 1967) from several boreholes in the eastern part of the Peribaltic depression has reliably indicated that the Pristiograptus gregarius zone itself is easily distinguishable. Moreover, the presence of two lower subzones: Demirastrites fimbriatus and Demirastrites triangulatus may be reasonably supposed. At present, however, their separation lacks accuracy, although both these forms are characterized by an extremely narrow vertical range. In view of the uncertain position in the Polish profile of index forms of the subzones, it seems safer to distinguish only the Pristiograptus gregarius zone, without separating it into subzones.

The following assemblage has been distinguished in Poland: *Glyptograptus tamariscus* (Nichol.), *Petalograptus minor* Elles, *P. ovatoelongatus* (Kurck), *P. palmeus* (Barr.), *Climacograptus rectangularis* (Mc Coy), *C. scalaris normalis* Lapw., *C. scalaris miserabilis* Elles & Wood, *Pseudoclimacograptus hughesi* (Nichol.), *P. retroversus* (Bulman & Rickards), *Rhapidograptus toernquisti* (Elles & Wood), *Monograptus communis* Lapw., *M. clingani* (Carruth.), *Diversograptus capillaris* (Carruth.), *Rastrites approximatus geinitzi* Törnq., *R. longispinus* Perner, *R. peregrinus* Barr., *Demirastrites denticulatus* (Törnq.), *D. fimbriatus* (Nichol.), *D. pectinatus* (Richter), *D. triangulatus* (Hark.), *Pristiograptus concinnus* (Lapw.), *P. gregarius* (Lapw.), *P. sandersoni* (Lapw.).

Demirastrites convolutus Zone

In the Silurian profile of Poland this zone is not well defined because its index species has not as yet been found.

In the Barrandian area (Bouček 1953, 1960b; Přibyl 1948), similarly as in Great Britain (Elles & Wood 1913), this zone is well developed. Bouček (1953) has even distinguished at its base a bed with *Monograptus millepeda* (Mc Coy) and two overlying subzones: Pristiograptus leptotheca and Petalograptus folium. In 1960b, however, that author mentions only two subzones. In Great Britain (Elles & Wood 1913) in the top of the Demirastrites convolutus zone, there is a bed with *Cephalograptus cometa* (Geinitz).

To the species *Cephalograptus cometa* (Geinitz) Tomczyk (1962a, 1968c) assigns the rank of an index form of the zone bearing that name. This species actually occurs in the top of a non-graptolite layer between the Pristiograptus gregarius and Monograptus sedgwicki zones (borehole

Zawada 1), i.e. of a layer which is the stratigraphic equivalent of the Demirastrites convolutus zone.

In Great Britain, *Cephalograptus cometa* (Geinitz) characterizes also the top of that zone and in this respect it resembles the Polish profile. In Czechoslovakia the C. cometa zone is unknown because this form is included in the index assemblage of the Demirastrites convolutus zone.

In the writer's opinion the absence in Poland of *Demirastrites convolutus* (Kurck) should not impede the distinction of the zone, because in the Polish profiles there occurs a layer which is its stratigraphic equivalent and in whose top *C. cometa* (Geinitz) is present. On the other hand, the separation by Tomczyk of the C. cometa zone does not seem justifiable because in other profiles this form as a rule characterizes the top part of the Demirastrites convolutus zone.

The assemblage so far reported from the Polish D. convolutus zone is very meagre. It contains the following forms: *Cephalograptus cometa* (Geinitz), *Petalograptus palmeus* (Barr.), *Pseudoclimacograptus hughesi* (Nichol.), *Monograptus* cf. *leptotheca* Lapw., *Rastrites approximatus* Perner, *R. distans* Lapw., *R. fugax* Barr., *R. peregrinus* Barr., *Pristiograptus jaculum* (Lapw.), *P. nudus* (Lapw.).

Monograptus sedgwicki Zone

This is one of the well defined zones in Poland and it may be regarded as the equivalent of the acrozone of the index form whose vertical range is restricted to that zone. Moreover, it can be readily correlated both with Czechoslovakia (Bouček 1953, 1960b), Great Britain (Elles & Wood 1913, Jones 1921) and other regions. The great abundance of the genus *Rastrites* does not facilitate its differentiation. The characteristic assemblage of this zone is as follows: *Petalograptus palmeus* (Barr.), *P. tenuis* (Barr.), *Pseudoclimacograptus hughesi* (Nichol.), *Monograptus marri* Perner, *M. sedgwicki* (Portl.), *Rastrites approximatus* Perner, *R. distans* Lapw., *R. fugax* Barr., *R. linnaei* Barr., *R. maximus* (Carruth.), *R. peregrinus* Barr., *Pristiograptus jaculum* (Lapw.), *P. nudus* (Lapw.).

Rastrites linnaei Zone

In the Silurian profile of Poland this zone is distinguished with some difficulty. By Tomczyk (1962a) it is distinguished only within the eastern part of the Peribaltic depression, while in his last paper (1968c) he suggests that *Rastrites maximus* (Carruth.) is its characteristic form, too. Bouček (1953) distinguishes two subzones within the Rastrites linnaei zone: Petalograptus palmeus as the lower and Petalograptus hispanicus as the upper one. In 1960, only one zone, that of Rastrites linnaei, is differentiated by the above author. Horny's (1962) differentiation is analogous and thus the two authors go back to Přibyl's concept (1948).

Elles and Wood (1913) do not mention that zone at all, though its characteristic form is known in Great Britain already from the M. sedgwicki zone. Jones (1921) on the other hand, suggests the zone Monograptus halli as an equivalent of the Rastrites linnaei zone. Curtis (1961) accepts Jones proposition but above the M. halli (Barr.) zone he distinguishes and independent Rastrites maximus zone.

In Poland, *Rastrites maximus* (Carruth.) and *R. linnaei* Barr. have been encountered together but in the lower Monograptus sedgwicki zone as well as in the upper Spirograptus turriculatus zone. Other species present in the assemblage of the R. linnaei zone also occur in the Spirograptus turriculatus zone or pass from the underlying zone. There are others, however, which appear for the first time in the Spirograptus turriculatus zone. Among these are: *Monograptus pandus* Lapw., *M. priodon* (Bronn), *M. veles* (Richter), *M. exiguus* (Nichol.), *M. nodifer* (Törnq.), *M. runcinatus* (Lapw.). Hence that part of the profile where *R. linnaei* Barr. and *R. maximus* (Carruth.) occur together in great numbers but where the forms mentioned above as well as *Monograptus sedgwicki* (Portl.) and *Spirograptus turriculatus turriculatus* (Barr.) are missing, may be regarded as equivalent of the R. linnaei zone. Not in every profile, however, are the prevailing conditions so favourable, and then an exact definition of the R. linnaei zone may be impeded. It should be stressed too, that the index species does not fulfill all the conditions required to regard this zone as an acrozone. This very species does, however, attain its epibole within the accepted interval.

The index assemblage here is: *Petalograptus altissimus* (Elles & Wood), *P. palmeus* (Barr.), *P. tenuis* (Barr.), *Pseudoclimacograptus hughesi* (Nichol.), *P. undulatus* (Kurck), *Pseudoplegmatograptus obesus* (Lapw.), *Monograptus becki* (Barr.), *M. halli* (Barr.), *M. marri* Perner, *Spirograptus planus* (Barr.), *S. turriculatus minor* (Barr.), *Rastrites distans* Lapw., *R. fugax* Barr., *R. linnaei* Barr., *R. maximus* (Carruth.), *Pristiograptus jaculum* (Lapw.), *P. nudus* (Lapw.), *P. variabilis* (Perner).

Spirograptus turriculatus Zone

This zone is restricted to the vertical range of the index form and it can be readily defined in Poland. Neither are any difficulties encountered in its correlation with other European profiles, because of the close similarity in their assemblage.

Two subzones have been distinguished here by Bouček (1953). The lower one is indicated by the index form, the upper one by *Monograptus runcinatus* (Lapw.). In a later paper (Bouček 1960b), however only the zone is mentioned by that author, similarly as was done by Horny (1962). From the base of the S. turriculatus zone, Elles & Wood (1913) mention a bed with *Rastrites maximus* (Carruth.). But this opinion is not shared either by Jones (1921) nor by Curtis (1961) who distinguish only the S. turriculatus zone.

The following species occur within the characteristic assemblage of this zone: *Petalograptus altissimus* (Elles & Wood), *P. palmeus* (Barr.), *P. tenuis* (Barr.), *Pseudoclimacograptus undulatus* (Kurck), *Pseudoplegmatograptus obesus* (Lapw.), *Monograptus exiguus* (Nichol.), *M. marri* (Perner), *M. nodifer* (Törnq.), *M. pandus* Lapw., *M. priodon* (Bronn), *M. runcinatus* (Lapw.), *M. veles* (Richter), *Spirograptus flagellaris* (Törnq.), *S. planus* (Barr.), *S. proteus* (Barr.), *S. turriculatus turriculatus* (Barr.), *S. turriculatus minor* (Barr.), *Rastrites distans* Lapw., *R. fugax* Barr., *R. linnaei* Barr., *R. maximus* (Carruth.), *Pristiograptus nudus* (Lapw.), *P. variabilis* (Perner).

Monograptus crispus Zone

This zone is undoubtedly defined in Poland by its index form. It is also reliably defined in profiles of the Barrandian area (Bouček 1953) and of Great Britain (Elles & Wood 1913, Jones 1921, Curtis 1961). A most characteristic feature of this zone is the complete absence of the genus *Rastrites*, whose last representatives occur in the underlying zone. The typical assemblage contains: *Petalograptus altissimus* (Elles & Wood), *P. tenuis* (Barr.), *Pseudoplegmatograptus obesus* (Lapw.), *Monograptus crispus* (Lapw.), *M. exiguus* (Nichol.), *M. marri* Perner, *M. nodifer* (Törnq.), *M. pandus* Lapw., *M. priodon* (Bronn), *M. veles* (Richter), *Spirograptus planus* (Barr.), *S. proteus* (Barr.), *Pristiograptus nudus* (Lapw.).

Monoclimacis griestoniensis Zone

This zone, similarly as the underlying one, is readily distinguishable in the Upper Valentian profile of Poland, being indicated by the vertical range of the index species. It is also well defined in the Barrandian area (Bouček 1953, 1960b; Horny 1962) and in Great Britain (Elles & Wood 1913, Jones 1921, Curtis 1961). The graptolite assemblage is relatively poor but genus *Petalograptus* is missing altogether while two new genera make their appearance: *Retiolites* and *Monoclimacis,* facilitating its definition. The typical assemblage contains i.a.: *Pseudoplegmatograptus obesus* (Lapw.), *Retiolites geinitzianus geinitzianus* Barr., *R. geinitzianus angustidens* Elles & Wood, *Monograptus marri* Perner, *M. nodifer* Perner, *M. priodon* (Bronn), *M. veles* (Richter), *Monoclimacis griestoniensis* (Nicol), *Spirograptus flagellaris* (Törnq.), *S. planus* (Barr.), *S. spiralis* (Geinitz), *Pristiograptus nudus* (Lapw.).

Spirograptus spiralis Zone

This zone should be regarded as the youngest one in the deposits of the Polish Valentian. It may be separated into two subzones: the lower, Monoclimacis crenulata and the upper, Stomatograptus grandis. In the uppermost Valentian of Poland the three following zones are distinguished by Tomczyk (1962a, 1968c) from the bottom upwards: Monoclimacis crenulata, Spirograptus spiralis and Stomatograptus grandis. This division is analogous with that of Bohemia introduced by Bouček (1953). In the top part of the Monoclimacis crenulata zone this author has also distinguished a bed with *Spirograptus curvus* (Manck) and three subzones in the Spirograptus spiralis zone. From the bottom upwards they are: Monograptus parapriodon, M. anguinus and Monoclimacis geinitzi. At the base of the Stomatograptus grandis zone, moreover, he distinguishes a bed with *Monograptus probosciformis* Bouček. In a paper published in 1960b Bouček retained only the three subzones of the S. spiralis zone, while Horny (1962) mentions the zones only, omitting the subzones.

In Great Britain (Elles & Wood 1913) the Valentian deposits end with the Monoclimacis crenulata zone, though *S. Spiralis* (Geinitz) and an assemblage resembling that in Czechoslovakia and Poland have been rocognized in several profiles. *Stomatograptus grandis* (Suess) does not occur in Great Britain. The M. crenulata zone is treated by Jones (1921) as well as by Curtis (1961) as the youngest one of the Valentian.

An analysis of the occurrence of the particular species within the three zones of Czechoslovakia and Poland as well as within the profile of Great Britain reasonably suggests that the vertical range of such forms as *Retiolites geinitzianus geinitzianus* Barr., *R. geinitzianus angustidens* Elles & Wood, *Monograptus marri* Perner, *M. parapriodon* Bouček, *M. priodon* (Bronn), *M. veles* (Richter), *Monoclimacis vomerinus* (Nichol.), *Spirograptus planus* (Barr.), *S. spiralis* (Geinitz), and *S. tullbergi* (Bouček) embraces all the three zones so far distinguished by Tomczyk (1962a, 1968c). Hence, the presence of only one of the mentioned species, or even of all of them, impedes the correct determination of one of the three currently accepted zones; the S. spiralis zone excepted. At present, a correct definition of the Monoclimacis crenulata zone or of the Stomatograptus grandis zone calls for the identification not only of these two index species but likewise of several other forms which occur exclusively in one of these two zones and are encountered in the S. spiralis zone. In the absence from the profile of index species, and the presence of other forms characterizing as assemblage typical of the three currently accepted zones, a correct definition of one of them is hardly possible. Therefore, the distinction of only one Spirograptus spiralis zone with two subzones: Monoclimacis crenulata and Stomatograptus grandis, seems more justifiable. Such a division would, on the one hand, eliminate possible misinterpretations, especially in fragmentary profiles, on the other hand it would facilitate correlation with other European profiles where the situation is very much the same. This concept of the S. spiralis zone in the Upper Valentian profile of Poland may authorize its recognition as the equivalent of an acrozone, even though the index form itself appears already in the top part of the M. griestoniensis zone but disappears in the S. grandis subzone.

The graptolite assemblage typical of the Spirograptus spiralis zone is as follows: *Retiolites geinitzianus geinitzianus* Barr., *R. geinitzianus angustidens* Elles & Wood, *Monograptus marri* Perner, *M. nodifer* (Törnq.), *M. parapriodon* Bouček, *M. priodon* (Bronn), *M. sartorius* (Törnq.), *Monoclimacis vomerinus* (Nichol.), *Spirograptus planus* (Barr.), *S. spiralis* (Geinitz), *S. tullbergi* (Bouček).

Besides those just mentioned, forms typical of the Monoclimacis crenulata subzone are: *Monoclimacis crenulata* (Törnq.), *Diversograptus capillaris pergracilis* (Bouček), *Pristiograptus initialis* Kirste. For the Stomatograptus grandis subzone the typical forms are: *Stomatograptus grandis grandis* (Suess), *S. grandis maior* Bouček, *Monograptus probosciformis* Bouček, *M. speciosus* (Tullb.), *Monoclimacis geinitzi* (Bouček), *M. linnarssoni* (Tullb.), *Cyrtograptus lapworthi* Tullb., *Barrandeograptus pulchellus* (Tullb.), and *Pristiograptus largus* (Perner).

The division of the Valentian deposits of Poland, here presented, is based mainly on fauna, so far identified. Its elaboration has not as yet been undertaken, therefore, future modifications of the division are not excluded. The particular zones have, however, been discussed according to the generally binding rules. Hence, each one has been analogously defined and based on the same criteria. The zones, so far distinguished by Tomczyk (1962a, 1968c) were not always adequately defined, and did not always comply with the requirements of the biostratigraphical classification, therefore, some of them will either have to be integrated or eliminated.

Wenlockian

The deposits of this stage are characterized in the Polish profiles by fairly uniform development and are represented chiefly by a clayey complex. Calcareous intercalations occur only in the top part. A somewhat different facies is encountered in the Sudetes. Shales predominate there, interbedded by siliceous shales with tuffite intercalations.

An extremely rich graptolite fauna permits a fairly accurate subdivision of this stage into zones and its correlation with other European profiles, especially those of Czechoslovakia and Great Britain (chart 5). The non-graptolite fauna occurs chiefly in the top layers and it is without any great biostratigraphic value.

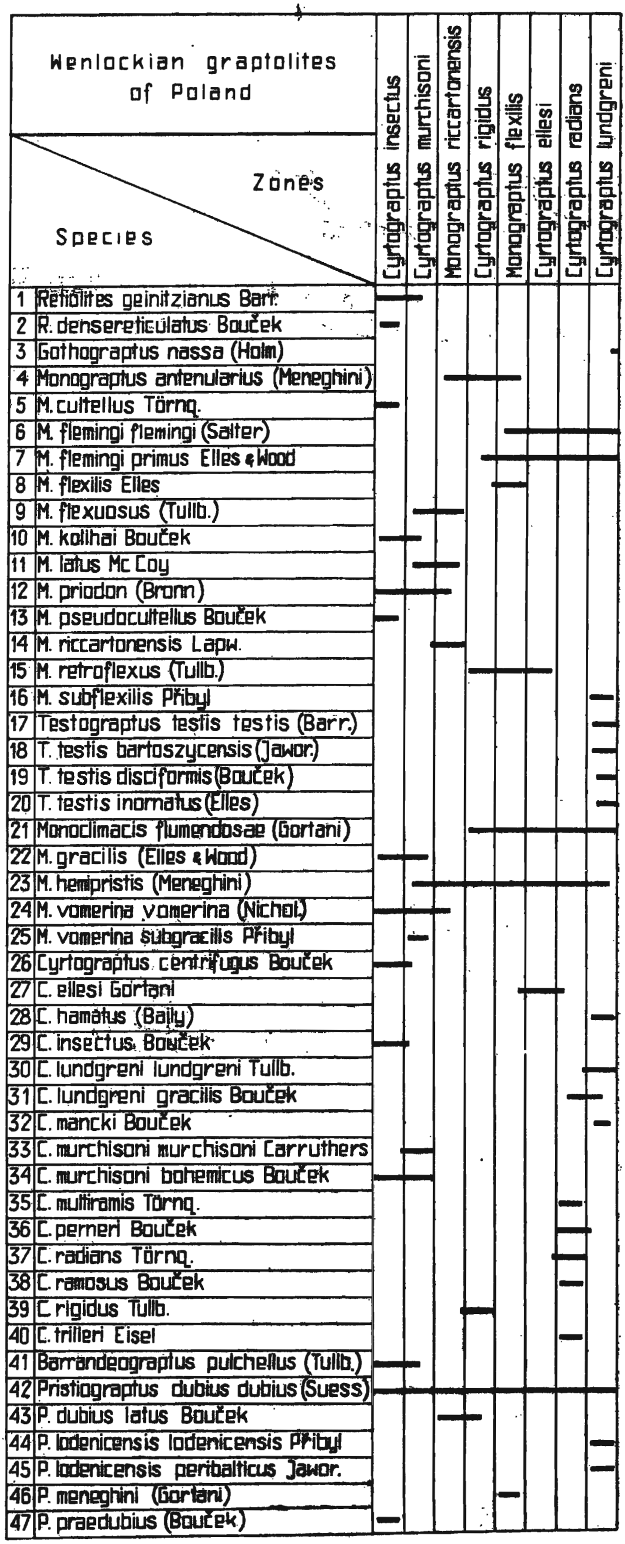
Cyrtograptus insectus Zone

This zone may be regarded as the oldest one in the Wenlockian deposits of Poland. It is well faunally defined; Tomczyk (1960b) distinguished it, too. In his later papers that author (Tomczyk 1962a) considers Cyrtograptus murchisoni to be the lowermost zone. In Great Britain it is currently accepted (Elles & Wood 1913, Pringle & George 1948, Evans 1961, Warren 1964) that *C. murchisoni* Carruth. represents the base of the Wenlockian. Strachan (1964) mentions that *Cyrtograptus insectus* Bouček and *Cyrtograptus centrifugus* Bouček have been found together in the south of Scotland and in the Lake District, but he makes no suggestions to differentiate a C. insectus zone in Great Britain. Rickards (1967) is the first to distinguish the C. centrifugus zone as the lowermost one, at the same time stating that *C. insectus* Bouček reaches to the middle of the C. murchisoni zone. From the C. centrifugus zone of Great Britain, Rickards (1967) describes a number of new forms, not one of which has so far been reported from the Polish profiles.

In Czechoslovakia, the C. murchisoni zone has been currently recognized as the lowermost Wenlockian zone (Přibyl 1948) and zones characterized by such forms as *C. centrifugus* Bouček and *C. insectus* Bouček were supposed to overlie the C. murchisoni zone. Bouček (1953, 1960b) established the correct sequence by placing these two zones below C. murchisoni.

In Poland (Teller 1967) *C. insectus* Bouček occurs together with *C. centrifugus* Bouček, but the latter form interlocks with *C. murchisoni* Carruth. in the base of the zone, while *C. insectus* Bouček is reported only from the base of Wenlockian deposits. *C. insectus* Bouček, being a species limited in its vertical range, may be regarded as an index form of the Cyrtograptus insectus acrozone. This requirement is not fulfilled by *C. centrifugus* Bouček.

Chart 5



Wenlockian graptolites of Poland
Zones
Species
Cyrtograptus insectus
Cyrtograptus murchisoni
Monograptus riccartonensis
Cyrtograptus rigidus
Monograptus flexilis
Cyrtograptus ellesi
Cyrtograptus radians
Cyrtograptus lundgreni
1 Retiolites geinitzianus Barr.
2 R. densereticulatus Bouček
3 Gothograptus nassa (Holm)
4 Monograptus antenularius (Meneghini)
5 M. cultellus Törnq.
6 M. flemingi flemingi (Salter)
7 M. flemingi primus Elles & Wood
8 M. flexilis Elles
9 M. flexuosus (Tullb.)
10 M. kolihai Bouček
11 M. latus Mc Coy
12 M. priodon (Bronn)
13 M. pseudocultellus Bouček
14 M. riccartonensis Lapw.
15 M. retroflexus (Tullb.)
16 M. subflexilis Přibyl
17 Testograptus testis testis (Barr.)
18 T. testis bartoszycensis (Jawor.)
19 T. testis disciformis (Bouček)
20 T. testis inornatus (Elles)
21 Monoclimacis flumendosae (Gortani)
22 M. gracilis (Elles & Wood)
23 M. hemipristis (Meneghini)
24 M. vomerina vomerina (Nichol.)
25 M. vomerina subgracilis Přibyl
26 Cyrtograptus centrifugus Bouček
27 C. ellesi Gortani
28 C. hamatus (Baily)
29 C. insectus Bouček
30 C. lundgreni lundgreni Tullb.
31 C. lundgreni gracilis Bouček
32 C. mancki Bouček
33 C. murchisoni murchisoni Carruthers
34 C. murchisoni bohemicus Bouček
35 C. multiramis Törnq.
36 C. perneri Bouček
37 C. radians Törnq.
38 C. ramosus Bouček
39 C. rigidus Tullb.
40 C. trilleri Eisel
41 Barrandeograptus pulchellus (Tullb.)
42 Pristiograptus dubius dubius (Suess)
43 P. dubius latus Bouček
44 P. lodenicensis lodenicensis Přibyl
45 P. lodenicensis peribalticus Jawor.
46 P. meneghini (Gortani)
47 P. praedubius (Bouček)

To the characteristic assemblage here belong: *Retiolites geinitzianus* Barr., *R. densereticulatus* Bouček, *Monograptus cultellus* Törnq., *M. kolihai* Bouček, *M. priodon* (Bronn), *M. pseudocultellus* Bouček, *Monoclimacis gracilis* Elles & Wood, *M. vomerina* (Nichol.), *Cyrtograptus centrifugus* Bouček, *C. insectus* Bouček, *C. murchisoni bohemicus* Bouček, *Barrandeograptus pulchellus* (Tullb.), *Pristiograptus dubius dubius* (Suess) and *P. praedubius* (Bouček).

Cyrtograptus murchisoni Zone

This is a zone well faunally defined and readily distinguishable in Poland (Teller 1967). It is also easily correlated with other European profiles where it is without hesitation interpreted as the acrozone of *C. murchisoni murchisoni* Carruth. This applies to Great Britain (Elles & Wood 1913, Evans 1961, Warren 1964, Rickards 1967) as well as to Czechoslovakia (Bouček 1953, 1960b; Horny 1962). The assemblage characterizing the C. murchisoni zone in Poland consists of: *Retiolites geinitzianus* Barr., *Monograptus flexuosus* (Tullb.), *M. kolihai* Bouček, *M. latus* Mc Coy, *M. priodon* (Bronn), *Monoclimacis gracilis* (Elles & Wood), *M. hemipristis* (Menegh.), *M. vomerina* (Nichol.), *M. subgracilis* Přibyl, *Cyrtograptus centrifugus* Bouček, *C. murchisoni murchisoni* Carruth., *C. murchisoni bohemicus* Bouček, *Barrandeograptus pulchellus* (Tullb.) and *Pristiograptus dubius dubius* (Suess).

In Czechoslovakia, Bouček (1931b, c, 1932) distinguished above the C. murchisoni zone the Monograptus firmus zone whose differentiation is based only on this single species which apparently occurs en masse in a one metre thick layer. The assemblage listed by that author does not in any way differ from that typical of the lower zone. In the Polish profile, in spite of the complete development of the Wenlockian deposits, the writer (Teller 1967) did not succeed to find *M. firmus* Bouček though he did identify several typically Bohemian species both in the underlying and the overlying zone. It seems that the zone differentiated by Bouček (1931b, c, 1953, 1960), is only of a local value and that at present it is hardly possible to distinguish it in the Polish profile.

Monograptus riccartonensis Zone

This zone is indicated by the vertical range of the index form not only in the Wenlockian profile of Poland but also in those of other European countries. In Poland it has been distinguished by Tomczyk (1962a, 1968c); in Czechoslovakia by Přibyl (1948), Bouček (1953, 1960b), Horny (1962); in Great Britain by Elles (1900), Elles & Wood (1913), Pringle & George (1948), Evans (1961), Warren (1964) and Rickards (1967).

The typical assemblage of that zone (Teller 1967) is as follows: *Monograptus antenularius* (Meneghini), *M. flexuosus* (Tullb.), *M. latus* Mc Coy, *M. priodon* (Bronn), *M. riccartonensis* Lapw., *Monoclimacis hemipristis* (Meneghini), *M. vomerina* (Nichol.), *Pristiograptus dubius dubius* (Suess) and *P. dubius latus* Bouček.

Above the M. riccartonensis zone Tomczyk (1968c) distinguishes the Pristiograptus dubius latus subzone, without stating within which zone it occurs. This subzone is omitted in that author's earlier paper of 1962a. Its differentiation is based only on four species: *M. antenularius* (Menegh.), *Monoclimacis hemipristis* (Menegh.), *Pristiograptus dubius dubius* (Suess) and *P. dubius latus* Bouček. Each of them is found both in the overlying and underlying deposits. This applies also to the index form. Obviously, the above is no conclusive evidence even for determining a subzone, and the present writer's investigations do not confirm Tomczyk's supposition. In an analogous stratigraphic position, Bouček (1953, 1960b) also distinguished the Pristiograptus dubius dubius zone, but he does not define it in any of his papers.

The species Pristiograptus dubius (Suess) is an extremely conservative form; it is characterized by an unusually great vertical range and has not, as yet, been adequately studied. An en masse appearance of this species has been observed in various graptolite zones from the Middle Wenlockian through the Postludlovian, not only in the Polish profiles but also in those of other areas. Were everyone of these occurrences taken as conclusive evidence for an independent zone or subzone, there would be ground for the differentiation of several of them.

Hence, Tomczyk's (1960a, 1962a, 1968c) differentiation of the independent P. dubius latus zone within the Wenlockian profile of Poland does not seem justifiable.

For the same reasons, Rickard's (1967) differentiation in the profile of North England of the M. antenularius zone (said to correspond to the P. dubius latus zone of Poland and to the P. dubius dubius zone of Czechoslovakia) is likewise thought insufficiently grounded. The form *M. antenularius* (Mengh.) passes from the M. riccartonensis zone reaching as far as the C. linnarssoni zone, while the associated species are known from the overlying as well as the underlying deposits.

Cyrtograptus rigidus Zone

This zone is well defined on its index form and on the whole typical assemblage. Within the Wenlockian profile of Poland it is distinguished by Tomczyk (1962a, 1968c) as the Cyrtograptus symmetricus zone. This is not correct because as early as in 1922 Gortani claims that this species, described by Elles (1900), is conspecific with *C. rigidus* Tullb., described by Tullberg (1883). This has also been confirmed by Bouček (1933).

The C. rigidus zone is also differentiated in Czechoslovakia (Přibyl 1948; Bouček 1931a, 1933, 1953, 1960b; Horny 1962), while in Great Britain it is cited under the old name by Pringle & George (1948) and Warren (1964). Evans (1961), however, calls it by the correct name, while Rickards (1967) has established a new local zone for the North of England only, i.e. the Monograptus flexilis belephorus zone, supposed to be an equivalent of the C. rigidus zone.

The graptolite assemblage in the Polish profile (Teller 1967) is as follows: *Monograptus antenularius* (Meneghini), *M. flemingi primus* Elles & Wood, *M. retroflexus* (Tullb.), *Monoclimacis flumendosae* (Gortani), *M. hemipristis* (Meneghini), *Cyrtograptus rigidus* Tullb., *Pristiograptus dubius dubius* (Suess), *P. dubius latus* Bouček. It allows good correlation with other European profiles.

Monograptus flexilis Zone

This is in Poland the equivalent of the English Cyrtograptus linnarssoni zone. The species *Cyrtograptus linnarssoni* Tullberg has not as yet been recorded from Poland, but the graptolite assemblage with *Monograptus flexis* Elles is practically identical with the English zone. The M. flexilis zone was first distinguished by Bouček (1933) because the form on which it is defined in Great Britain has not so far been found in Czechoslovakia. The assemblage found in Poland consists of the following species: *Monograptus antenularius* (Meneghini), *M. flemingi flemingi* (Salter), *M. flemingi primus* Elles & Wood, *M. flexilis* Elles, *M. retroflexus* (Tullb.), *Monoclimacis flumendosae* (Gortani), *M. hemipristis* (Meneghini), *Cyrtograptus ellesi* Gortani, *Pristiograptus dubius dubius* (Suess), *P. meneghini* (Gortani).

Cyrtograptus ellesi Zone

This is an equivalent of the Cyrtograptus rigidus zone as currently accepted in the old British classification. The species described by Elles (1900) and Elles & Wood (1913) as *Cyrtograptus rigidus* Tullb. was revised by Gortani (1922), who showed that it differed from Tullberg's form (1883) and gave it the new name *ellesi*. In the earlier papers of British authors this zone is still called C. rigidus (Pringle & George 1948, Warren 1964), but Evans (1961) and Rickards (1967) call it by the correct name. Tomczyk (1962a) distinguished this zone under its correct name, but in

1968c he mentions the old specific name. The Cyrtograptus ellesi zone is not known in Czechoslovakia. The graptolite assemblage found in the Polish profiles (Teller 1967) is nearly analogous with that of England. It is represented by: *Monograptus flemingi flemingi* (Salter), *M. flemingi primus* Elles & Wood, *M. retroflexus* (Tullb.), *Monoclimacis flumendosae* (Gortani), *M. hemipristis* (Meneghini), *Cyrtograptus ellesi* Gortani, *Pristiograptus dubius dubius* (Suess).

Cyrtograptus radians Zone

In the Wenlockian profile of Poland, two additional zones: Cyrtograptus perneri and C. radians are distinguished by Tomczyk (1962a) above the C. ellesi zone but below the C. lundgreni zone. In 1968c this author characterizes both of them by two species. The lower zone is said to be indicated by *Cyrtograptus perneri* Bouček and *C. ramosus* Bouček, the upper zone by *Cyrtograptus radians* Törnq. and *Cyrtograptus multiramis* Törnq. This would reasonably suggest that they are both regarded by Tomczyk as cenozones.

The above zones were first differentiated in the Barrandian area by Bouček (1933) and placed by him in the following order, going from the bottom: Cyrtograptus ramosus, C. perneri and C. radians.

Bouček and Přibyl (1953) when discussing the occurrence of *Cyrtograptus ramosus* Bouček state that within the profile of Male Chuchle in the Barrandian area this form was associated with numerous *Cyrtograptus perneri* Bouček, *Monograptus flemingi flemingi* (Salter), *Monoclimacis flumendosae* (Gortani), *M. hemipristis* (Meneghini) and *Pristiograptus pseudodubius* Bouček. Since in this profile *C. perneri* Bouček has been found in great abundance, the above authors do not distinguish here an independent C. ramosus zone, but a C. ramosus-C. perneri zone. In the Tmané profile of the Barrandian area, the species *C. ramosus* Bouček is said to occur together with *Monograptus retroflexus* (Tullb.), *Monoclimacis flumendosae* (Gortani), *Monograptus flemingi flemingi* (Salter), *Pristiograptus pseudodubius* Bouček and also *Cyrtograptus perneri* Bouček. This latter form, is, however, less frequent, which made Bouček & Přibyl (1953) to differentiate here only the C. ramosus zone. At the end they mention, however, that the differences between the species *C. ramosus* Bouček and *C. multiramis* Törnq. are not great, hence, they may be related, while *C. ramosus* Bouček may even be a subspecies of *C. multiramis* Törnq. Obviously, the distinction itself of the C. ramosus zone arouses doubts which grow in importance with the knowledge that the definition of the index species is not very accurate.

Neither has the question of the Cyrtograptus perneri zone been cleared up. Bouček (1933) reports the presence of that form from several profiles and states that its vertical range is considerable. It appears just above *Monograptus flexilis* Elles and persists as far as the upper parts of the C. radians zone. In the Male Chuchle profile of the Barrandian area (Bouček & Přibyl 1953) this form was found in the following assemblage: *Cyrtograptus ramosus* Bouček, *Monograptus flemingi flemingi* (Salter), *Monoclimacis hemipristis* (Meneghini), *Pristiograptus pseudodubius* Bouček. A little higher up in this profile and less often it is associated with *Cyrtograptus radians* Törnq., *C. multiramis* Törnq., *C. lundgreni lundgreni* Tullb., *C. lundgreni gracilis* Bouček, *Pristiograptus pseudodubius* Bouček and *P. dubius dubius* (Suess). If it is accepted that the C. perneri zone is the equivalent of an acrozone then it may be regarded as well defined, but if so, there will be no space left for the C. ramosus and C. radians zones. On the other hand, if that part of the profile between the C. ellesi and C. lundgreni zone were discussed as a cenozone, not one of the three zones distinguished by Czechoslovakian authors would prove acceptable. If the term zone would have an arbitrary meaning, i.e. the index species plus the assemblage, then Cyrtograptus perneri may be regarded as the index form for a given fragment of the profile, even if it interlocks with other species. Difficulties will, however, be always encountered in the accurate definition of the C. perneri zone. The assemblage is hardly typical and analogous with the overlying C. radians zone, while several forms even pass from the underlying zone.

The writer's investigations and observations of this fragment of the Wenlockian profile from the Holy Cross Mts. (Zbrza anticline, Bardo-Stawy) and from the Sudetes, also borehole material, particularly from the eastern part of the Peribaltic depression, all reasonably suggest that such a detailed subdivision as that of Tomczyk (1962a, 1968c) is scarcely possible. The whole graptolite assemblage overlying the Cyrtograptus ellesi zone is uniform and *Cyrtograptus perneri* Bouček, as a rule, occurs together with *Cyrtograptus radians* Törnq. On the other hand, such species as *Cyrtograptus multiramis* Törnq. and *Cyrtograptus ramosus* Bouček, are without value because of their inadequate description which needs to be revised and worked out. In the writer's opinion that part of the Wenlockian profile enclosed between the Cyrtograptus ellesi and Cyrtograptus lundgreni zones can be most readily defined on the basis of the *Cyrtograptus radians* Törnq. This species is namely so characteristic that it is readily identifiable and arouses no doubts. Moreover, its vertical range is limited to that interval and, therefore the C. radians zone may be regarded as an acrozone. The graptolite assemblage, which characterizes the C. radians zone in Poland, is as follows: *Monograptus flemingi flemingi* (Salter), *M. flemingi primus* Elles & Wood, *Monoclimacis flumendosae* (Gortani), *M. hemipristis* (Meneghini), *Cyrtograptus ellesi* Gortani — in the bottom part only — *Cyrtograptus lundgreni gracilis* Bouček, *C.* cf. *multiramis* Törnq., *C.* cf. *ramosus* Bouček, *Cyrtograptus radians* Törnq., *C.* cf. *trilleri* Eisel, *C. perneri* Bouček, *Pristiograptus dubius dubius* (Suess).

The Polish C. radians zone corresponds to the C. ramosus, C. perneri and C. radians zones of Czechoslovakia. Correlation with Great Britain is extremely difficult because not one of these three zones is known there. It is noteworthy that, in the U.S.S.R. Obut, Sobolevskaya & Bondarev (1965), also Obut (1960) distinguish only the C. radians zone and correlate it with the Cyrtograptus ellesi zone of Great Britain.

Cyrtograptus lundgreni Zone

This zone is well defined in the Wenlockian profile of Poland. It is distinguished by Tomczyk (1962a, 1968c) while Jaworowski (1965) has worked it out in greater detail on the basis of material from two boreholes: Bartoszyce IG-1 and Gołdap IG-1, situated in the eastern part of the Peribaltic depression. Jaworowski's results very slightly deviate from those obtained by the writer (Teller 1967) from a complete profile in borehole Zawada 1.

A most striking observation is the extinction in the top part of this zone of nearly all the graptolites so far predominant in the Wenlockian. This is a very common symptom and it has not, as yet, been clarified. The only forms that persist into the Ludlovian is *Pristiograptus dubius dubius* (Suess), a very conservative species, also *Gothograptus nassa* (Holm) which makes its first appearance in the top of the Cyrtograptus lundgreni zone and occurs en masse in the base of the Ludlovian.

The typical assemblage found in a number of Wenlockian profiles of Poland is as follows: *Gothograptus nassa* (Holm), *Monograptus flemingi flemingi* (Salter), *M. flemingi primus* Elles & Wood, *M. subflexilis* Přibyl, *Testograptus testis testis* (Barr.), *T. testis bartoszycensis* (Jaw.), *T. testis disciformis* (Bouček), *T. testis inornatus* (Elles), *Monoclimacis flumendosae* (Gortani), *M. hemipristis* (Meneghini), *Cyrtograptus hamatus* (Baily), *C. lundgreni lundgreni* Tullb., *C. lundgreni gracilis* Bouček, *C. mancki* Bouček, *C.* cf. *trilleri* Eis., *C. perneri* Bouček and *Pristiograptus dubius dubius* (Suess).

The writer recognizes the Cyrtograptus lundgreni zone as the youngest one for the Wenlockian deposits, and in its top he places the Wenlockian/Ludlovian boundary. This interpretation coincides with that of Jaworowski (1965) and of the English authors (Elles 1900, Wood 1900, Elles & Wood 1913, Pringle & George 1948, Evans 1961, Warren 1964, Rickards 1967), but differs from the concept of Tomczyk (1962a, 1968c) and of Bouček (1953, 1960b). These two authors accept the Testograptus testis zone as the youngest one. Judging from the index value which Tomczyk and Bouček assigned to *Testograptus testis testis* (Barr.) its vertical range must be greater than that of *Cyrtograptus lundgreni lundgreni* Tullb. This is not, however, the case in the Polish profiles, as was correctly observed by Jaworowski (1965) and as confirmed by the writer's investigations (Teller 1967). In the profile of borehole Zawada 1, *Testograptus testis testis* (Barr.) makes its appearance at a depth of 1,562 m and it is associated with *Cyrtograptus lundgreni lundgreni* Tullb. as far as the top of the Wenlockian, i.e. 1,533 m. In other — not continuously cored boreholes (Sokołów Podlaski 1, Korsze 1, Dobre 1) — these two forms were always found together. Hence, this occurrence is not local but usual and, in obeyance to the binding rules, it is safer to distinguish the C. lundgreni zone, regarded as the acrozone of this form, than to differentiate a zone non complying with the binding conditions.

The T. testis zone may obviously be treated as an acrozone but then the Cyrtograptus lungreni zone loses its priority. Both species comply with the requirements for a cenozone but then the zone must be indicated on the basis of both species.

If the two species are to be discussed from the point of view of their maximum development and occurrence in the stratigraphic profile (i.e. their epibole), it is seen that the evolutionary maxima overlap, too. Hence, a dual name should be used again, but then the bottom as well as the top of the C. lundgreni zone would be characterized by other forms.

On the basis of investigations carried out in the Silurian profiles of Thuringia, Jaeger (1959) inferred that, in the top part of the Wenlockian, there occur in principle only two species: *Pristiograptus dubius dubius* (Suess) and *Gothograptus nassa* (Holm), and that *Pristiograptus vulgaris* (Wood) is the first typically Ludlovian form. *P. dubius dubius* (Suess) occurs together with it, moreover, at the base the presence is also noted of *G. nassa* (Holm) as well as of other retiolites and of *Monograptus deubeli* Jaeger. The mass occurrence of the species *P. dubius dubius* (Suess) and *G. nassa* (Holm) was called by Jaeger (1959) the dubius-nassa Interregnum and was included into the Wenlockian. He does not assign to the term Interregnum the rank of a zone, as is occurrently used, but places the Wenlockian/Ludlovian boundary in the top of this layer. In support of his concept Jaeger also discusses other European profiles (in Poland, Great Britain and Czechoslovakia), and gives his results obtained from erratic boulders, affirming that such an Interregnum may be differentiated everywhere. In another paper (Jaeger 1964c), besides retaining his term dubius-nassa Interregnum he also distinguishes the Monograptus deubeli zone at whose base he places the Wenlockian/Ludlovian boundary. The above zone is formed by reducing the top of Interregnum and the base of the vulgaris zone. In support of this view he mentions several facts from other profiles, in. al. from Poland and states that he had observed the presence both of the dubius-nassa Interregnum and of M. deubeli Jaeger within the profile of the Prągowiec ravine in the Holy Cross Mts.

The present writer, however, never succeeded to find this characteristic form *M. deubeli* Jaeger, in spite of his repeated and careful searching in the bottom of the Prągowiec profile. In 1964 and 1965 the rock material from the base of that profile was again very thoroughly examined but *M. deubeli* Jaeger was not encountered. This led to the conclusion that Jaeger's dubius-nassa Interregnum corresponds to the Gothograptus nassa zone by the present writer referred to the Lower Ludlovian. The last species is encountered from the top of the Wenlockian, but its mass occurrence is noted in the olive-green calcareous mudstones associated with *Pristiograptus dubius dubius* (Suess). *Pristiograptus vulgaris* (Wood) makes its appearance already in the top parts of the zone.

A re-interpretation of this situation, on the ground of the binding rules, would show that the Gothograptus nassa zone indicates the epibole of this species, while its assignment to the Ludlovian may be based even on the complete absence of Wenlockian species among the associated forms. After this concept the Wenlockian/Ludlovian boundary should occur below the observed maximum occurrence of *Gothograptus nassa* (Holm). This would mean the extinction of *C. lundgreni lundgreni* (Tullb.) and of *T. testis testis* (Barr.).

Horny (1962) distinguishes the C. lundgreni, T. testis and G. nassa zones in the uppermost Wenlockian of the Barrandian area. This is a perfectly new concept as compared not only with the works of other authors (Bouček 1960b, Přibyl 1948), but also with his own papers. In order to justify the inclusion of the G. nassa zone into the Wenlockian, Horny (1962, p. 892) mentions the lack of new elements among the graptolite fauna and the typically Wenlockian character of the other fauna, particularly of the trilobites. However, only a few lines farther down, but again on pages 901—903, Horny states that new trilobite forms make their appearance in the uppermost Wenlockian (T. testis and G. nassa zones) while several older forms die out and other degenerate. We are dealing here with a slight inconsequence, hence the inclusion of the G. nassa zone into the Wenlockian is not persuasive.

Ludlovian

The deposits of this stage show a distinctly dual type of development. In its lower part they occur as graptolite mudstones here and there calcareous and containing limestone concretions. Marly mudstones dominate only in the more shallow-water parts of the Silurian basin, along with an increase in the calcium carbonate content. The clayey facies, on the whole monotonous, changes abruptly in the top of the Lower Ludlovian and is replaced by a muddy-siltstone one, accompanied by an increase in the thickness. The last named type of sediments dominate on the Precambrian platform, in the western part of the Peribaltic depression and the western part of the Podlasie depression. Analogous facial changes are also traceable in the Holy Cross Mts., where graptolite mudstones are replaced by greywackes.

On the other hand, in the Ludlovian profile of the Sudetes, the predominant facies continues to be clayey with subordinate siliceous intercalations. A distinct change in the facies does not set in before the Lower Devonian.

Facial changes caused by tectonic events are responsible for the complete disappearance of graptolites from certain areas, e.g. Great Britain, the Holy Cross Mts., while in other regions (Czechoslovakia, the Polish Lowland) they seem to thrive though the conditions must have deteriorated. Hence, it is not surprising that the subdivision of the Ludlovian of the various countries into graptolite zones differs in details and that a generally acceptable classification has not as yet been established.

The standard classification of the Ludlovian deposits of Great Britain into graptolite zones, as established by Wood (1900), has not undergone any cardinal modifications. The first recent attempts to re-interpret this subdivision suggest that its bottom part, i.e. the Pristiograptus vulgaris zone, may still represent the Wenlockian and not the Ludlovian (Bassett & Shergold 1967, Holland et al. 1967), while Strachan (1964) even includes this zone into the Wenlockian. The English literature does not contain any works giving a more comprehensive analysis of the Ludlovian graptolite fauna of Great Britain or of the graptolite zones established by Wood (1900).

On the Continent this problem is somewhat different and its growing attractiveness started but a few years ago. The English division, accepted during so many years, has proved to lack precision and arouses more and more doubts. For example, during a long time, the Czechoslovakian authors did not separate the Neodiversograptus nilssoni zone from the Lobograptus scanicus zone (Přibyl 1943, Bouček 1936), while the Pristiograptus tumescens zone was placed by them above the Saetograptus leintwardinensis primus zone. Neither was the Pristiograptus vulgaris zone distinguished there (Bouček 1936; Přibyl 1942a, 1948) later on Horny (1955) and Bouček (1960b) were the first to separate the Neodiversograptus nilssoni zone from the Lobograptus scanicus zone, while Bouček (1960b) and Horny (1962) also introduce the Pristiograptus vulgaris zone as the oldest one for the Ludlovian deposits. There is no change, however, in the position of the Pristiograptus tumescens zone which is placed above the Saetograptus leintwardinensis primus zone both by Přibyl (1948) and by Bouček (1960b). Horny (1962) was the first to advance another interpretation by suggesting the presence in the Czechoslovakian profile of a stratigraphic gap between the Saetograptus fritschi linearis and the Pristiograptus ultimus zones.

Opinions differed concerning the division of the Ludlovian deposits in Germany where Eisel (1899—1900, 1903), regarded his 20-th zone, out of all those he created, as the equivalent of nearly all (five) zones of Great Britain. The correct sequence is given by Jaeger (1959). It agrees with that of Great Britain as far as the Labograptus scanicus zone, above which occurs the Saetograptus fritschi linearis zone overlain by the Pristiograptus dubius ludlowensis zone. In his revision of the Thuringian profile, Jaeger (1964c) differentiates in the bottom of the Ludlovian a new Monograptus deubeli zone, above which occur, in the order here stated, the Pristiograptus vulgaris, Neodiversograptus nilssoni, Lobograptus scanicus, Saetograptus leintwardinensis, Saetograptus fritschi linearis and Pristiograptus dubius thuringicus zones. Moreover, that author also suggests to replace the Neodiversograptus nilssoni zone by the Colonograptus colonus zone, and the Lobograptus scanicus and Pristiograptus tumescens zones by the Saetograptus chimera zone.

Jaeger's (1964c) concept was discussed by Urbanek (1966) who showed that Jaeger's arguments are but partly justifiable and do not provide a full solution to the problem of dividing the Ludlovian into zones. It can namely be seen on faunal evidence from borehole Mielnik IG-1 that the Saetograptinae group, said to replace the well studied Cucullograptinae group, is not adequately known and that its evolutionary stages are far more complicated than as they are presented by Jaeger. Urbanek also discusses with Jaeger the form *Pristiograptus tumescens* (Wood).

The present writer's opinion concerning Urbanek's (1966) suggestions is stated elsewhere. In what Jaeger's propositions are concerned it seems that his intentions were primarily of a practical nature, i.e. that first and foremost he strove to make the newly suggested subdivision of the Ludlovian suitable to biostratigraphy, while evolutionary criteria were second in importance. If this was that Jaeger had actually in mind, it must be regarded as correct because every biostratigraphic division should be based on readily identifiable species characterized by a given vertical range. The group selected by Jaeger, is, however, inadequately known, and this is plainly stressed by Urbanek.

On the other hand, when dealing with the problem concerning the role of *Pristiograptus tumescens* (Wood) as an index form for the zone, it is noted that Jaeger's observations are confirmed only by the earlier investigations of other authors. The establishment of zones, based on the very poorly dubius group, is certainly to no purpose. This is admitted by Jaeger, too, but in spite of this view point he acts inconsequentially when differentiating in the Thuringian profile, above the Saetograptus fritschi linearis zone, the Pristiograptus dubius thuringicus zone. This is not said in the text of his paper but it is shown in a table (Jaeger 1964c, p. 28).

An analysis of the Ludlovian subdivision into graptolite zones on the basis of the Polish profiles, and our present knowledge of their fauna, lead to an inference that the problems there by involved are more complicated than it is supposed. Tomczyk (1956) mentions five Ludlovian zones identical with those of Great Britain, the lowermost one being distinguished by him as Gothograptus nassa-Pristiograptus vulgaris. The present writer (Teller 1964a) likewise distinguishes only five English zones, accepting the Pristiograptus vulgaris zone as the lowermost one. Tomczyk (1962a) mentions a greater number of zones in the order here followed, from bottom to top: Gothograptus nassa, Pristiograptus vulgaris, Pristiograptus dubius, Pristiograptus gotlandicus, Neodiversograptus nilssoni, Lobograptus scanicus, Pristiograptus tumescens, Saetograptus leintwardinensis and Pristiograptus ultimus. He also gives an analogous interpretation in later papers but modifies it (Tomczyk 1968b, chart 2) on the ground of results obtained by Urbanek (1966). The Lower Ludlovian, regarded by him as the equivalent of the Eltonian, Bringewoodian, partly the Leintwardinian, is supposed to be characterized by the following zones and subzones: Gothograptus nassa, Pristiograptus vulgaris, Pristiograptus dubius (subzone), Pristiograptus gotlandicus, Neodiversograptus nilssoni, Lobograptus progenitor, Lobograptus scanicus parascanicus, Cucullograptus pazdroi (subzone), Cucullograptus hemiaversus and Saetograptus leintwardinensis. The new zones were introduced here by Urbanek (1966), with the reservation, however, that their distinction for stratigraphic reasons, in practice may prove very inconvenient. Some difficulties, can, namely, be encountered in identifying index species in a compressed state of preservation, moreover, the newly established zones may be regional in character, and be different enough to serve for standard stratigraphy. Another subdivision, based on saetograptids, was simultaneously suggested by Urbanek. In present writer's opinion, however, that concept ought to be treated rather as an argument for discussion with Jaeger than as a proposition. Urbanek, namely distinctly stresses our inadequate knowledge of that graptolite group and thinks that in the future new evolutionary data will be obtained.

Without going into details (cf. Urbanek 1966) it seems that the proposed new zones are based on reliable paleontological evidence and on a profile with a complete sequence of beds. Hence, these zones may be accepted without hesitation; their practical use, however, for standard biostratigraphy, would be greatly handicapped by the extreme scarcity of material well enough preserved to offer a clear picture of all the details needed for a correct definition of the species and subspecies described by Urbanek.

The above division must, moreover, be confirmed in profiles from other boreholes in order to warrant correctness in the established sequence of zones, and to prove that the division is not regional, this not being excluded by the author himself.

On the other hand, Urbanek's statements concerning the strong differentiation of the Ludlovian graptolite fauna, and its inadequate knowledge, are of real value. This has, namely an indirect bearing on the present difficulties connected with the correct division of the Ludlovian into zones.

Though the knowledge of the graptolite fauna of Poland is far more advanced than that of any other region, yet it is most difficult to define the middle part of the Ludlovian profile embracing — according to the current classification — the Lobograptus scanicus, Pristiograptus tumescens and Saetograptus leintwardinensis zones. The maximum development and differentiation of the Cucullograptinae may be noted in that interval. Since this part of the profile is well paleontologically defined and since Urbanek's distinction of the zones follows the binding rules, his classification seems reasonably acceptable. Practically, however, as has already been mentioned, it cannot serve its purpose. The practical solution of this problem calls, therefore, for a settlement by compromise.

The present writer suggests as a clue to that solution the fusion, under the name of the Cucullograptinae horizon, of Urbanek's (1966) zones Lobograptus progenitor, L. scanicus parascanicus, L. invertus and Cucullograptus hemiaversus. This does not coincide with the full vertical range of the above subfamily, hence it does not correspond with Urbanek's Cucullograptinae range zone. This concept seems justifiable on other grounds, too. In the profile of borehole Mielnik IG-1, between the L. scanicus parascanicus and L. invertus zones there is a 15 m gap from which both these species are absent and only *L. expectatus* Urbanek and (at the base) *C. pazdroi* Urbanek have been found. Another gap, even though of 5 m only, occurs between the Lobograptus invertus and Cucullograptus hemiaversus zones, and still another one, of 10 m, between the Cucullograptus hemiaversus and the Cucullograptus aversus zones. The lack of continuity in the sequence of Urbanek's zones does not, by any means, render their differentiation less plausible. This problem should, evidently, be cleared up because, in the Silurian, species traditionally acceptable as index forms interlock at the base with the index species of the preceding zone and at the top with the index species of the next zone.

The present Saetograptus leintwardinensis zone, based on a species known from many profiles, hence readily correlated, might be retained instead of Urbanek's Cucullograptus aversus zone and C. aversus rostratus subzone. As is currently accepted, the presence of *Saetograptus leintwardinensis* (Hopk.) is limited to the interval which roughly coincides with the Cucullograptus aversus zone and the C. aversus rostratus subzone, though, in borehole Mielnik IG-1, the two last species reach somewhat higher up (Urbanek 1966). The en masse occurrence of *Bohemograptus bohemicus bohemicus* (Barr.) above the S. leintwardinensis zone provides additional reliable evidence.

The base of the S. leintwardinensis zone may be established in the top of the *Lobograptus cirrifer* Urb., i.e. of a form readily identifiable even in a compressed state of preservation.

The above concept of the Saetograptus leintwardinensis zone should be tentatively accepting pending the elaboration of the Saetograptinae. It is, namely, not excluded that this group, if not completely at least partly, will serve biostratigraphic purposes better than some Cucullograptinae species on which Urbanek had based his division.

As has been more at large discussed in the chapter on the division of the Silurian system, the present writer does not end the Ludlovian stage with the S. leintwardinensis zone but includes therein the five new zones distinguished by Urbanek (1970). They are the Bohemograptus bohemicus, B. cornutus, Neolobograptus auriculatus, Neocucullograptus inexpectatus and Neocucullograptus kozlowskii zones. The new zones are far more readily distinguishable than the lower ones, based on the Cucullograptinae, and data available from the literature suggest that they occur not only within the Polish profiles.

Neocucullograptus inexpectatus (Bouček) has been described from the Barrandian area by Bouček (1932) but its position in the profile was incorrectly interpreted. This species had even been accepted by Přibyl (1948) as a synonym of *Lobograptus scanicus* (Tullb.). The identification of this species by Urbanek in a definite stratigraphic position, and its recognition as the zone index fossil reasonably suggest its occurrence in an analogous horizon of the Barrandian area. The problem of the Bohemograptinae is very much the same; a number of specimens was collected by the writer in 1962, during a trip with Profesor B. Bouček from the Čertove Schody profile in the Barrandian area. Most regretfully the accurate stratigraphic position of these forms has not as yet been definitely established by the Czech explorers.

The confirmed occurrence of the new zones in some Polish boreholes, as well as the presence of some zones in the Bohemian profile, have allowed their better definition than that of the lower zones, so that they are acceptable on safer grounds.

With reference to the problems discussed above, the following graptolite zones are distinguished by the writer in the Ludlovian profile of Poland (chart 6).

Gothograptus nassa Zone

This zone occurs in the bottom part of the Ludlovian and it is characterized by an extremely meagre assemblage consisting of the following forms: *Gothograptus nassa* (Holm), *Pristiograptus dubius dubius* (Suess), in the top also *Pristiograptus vulgaris* (Wood). The index species makes its appearance already in the Upper Wenlockian but its epibole becomes distinct not earlier than above the Cyrtograptus lundgreni zone. The Gothograptus nassa zone is not known in the Silurian profile of Great Britain, while in the Bohemian area (Horny 1962) and the German (Jaeger 1959, 1964c) profiles it is placed in the Wenlockian (compare the C. lundgreni zone).

Pristiograptus vulgaris Zone

Similarly as the lower one, this zone contains an extremely poor assemblage represented by: *Spinograptus spinosus* (Wood), *Plectograptus macilentus* (Törnq.), *„Retiolites" wimani* Eis., *Pristiograptus dubius dubius* (Suess), *P. vulgaris* (Wood) in the upper part also *P. gotlandicus* (Perner). It is differentiated in the British (Wood 1900) as well as in the Bohemian (Horny 1962) profiles, and can be readily correlated. Above the P. vulgaris zone, Tomczyk (1962a, 1968c) distinguishes the Pristiograptus dubius subzone and the Pristiograptus gotlandicus zone. Both these forms belong to the *dubius* group which is inadequately studied and, therefore, cannot serve as index forms in the differentiation of independent zones (comp. p. 442).

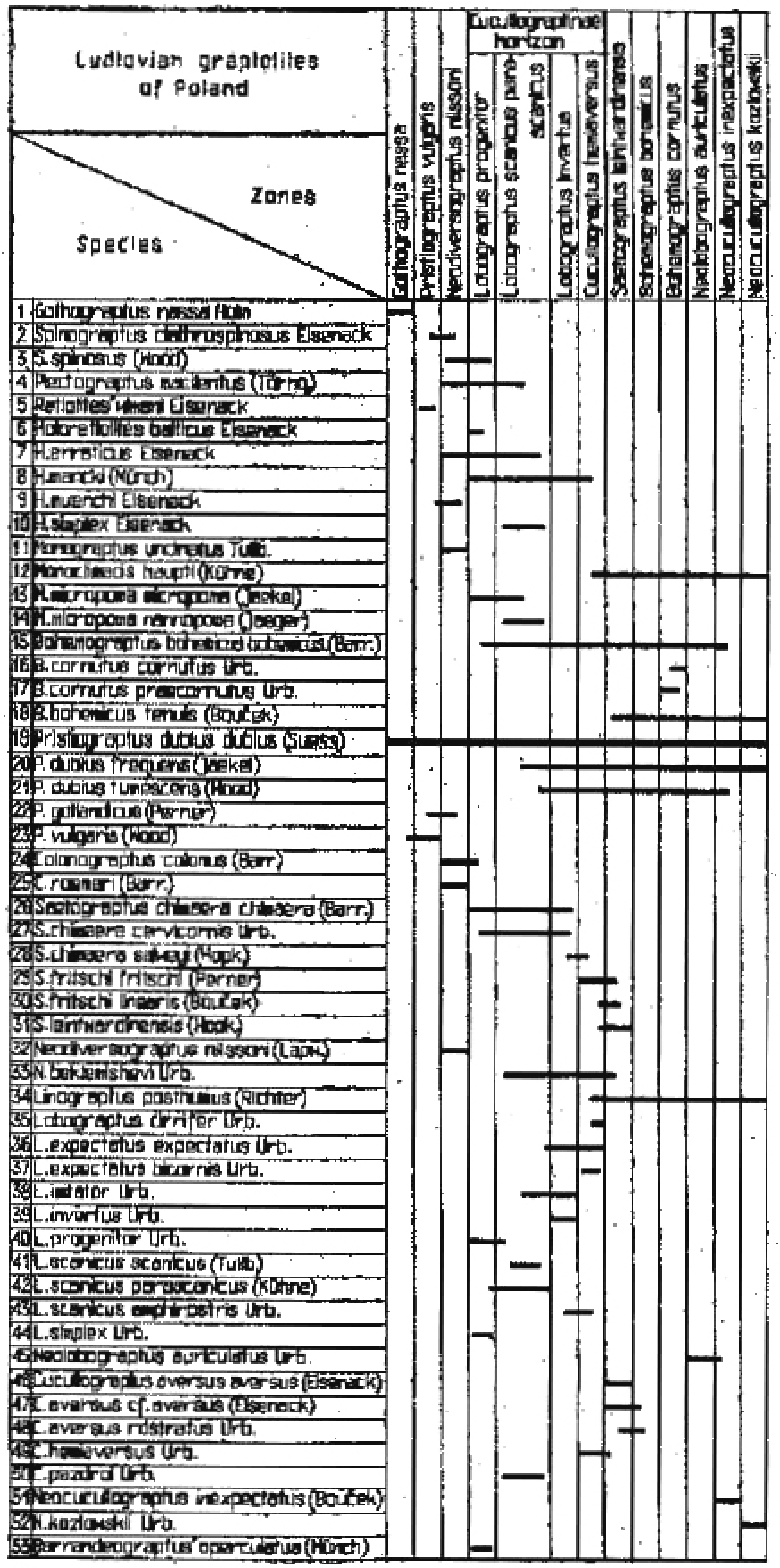
Neodiversograptus nilssoni Zone

This zone is excellently defined in all the Ludlovian profiles of Poland and may be regarded as the acrozone of this species. Its most typical assemblage is represented by: *Spinograptus clathrospinosus* Eis., *Spin. spinosus* (Wood), *Plectograptus macilentus* (Törnq.), *Holoretiolites erraticus* (Eis.), *H. muenchi* Eis., *Monograptus uncinatus* Tullb., *Bohemograptus bohemicus bohemicus* (Barr.), *Pristiograptus dubius dubius* (Suess), *P. gotlandicus* (Perner), *Colonograptus colonus* (Barr.), *C. roemeri* (Barr.), *Neodiversograptus nilssoni* (Lapw.).

Colonograptus colonus (Barr.) and *Monograptus uncinatus* Tullb. belong to the characteristic forms of this zone.

A similar assemblage defines this zone in the profiles of Bohemian

Chart 6


Ludlovian graptolites of Poland
Zones
Species
Gothograptus nassa
Pristiograptus vulgaris
Neodiversograptus nilssoni
Cucullograptinae horizon
Lobograptus progenitor
Lobograptus scanicus parascanicus
Lobograptus invertus
Cucullograptus hemiaversus
Saetograptus leintwardinensis
Bohemograptus bohemicus
Bohemograptus cornutus
Neolobograptus auriculatus
Neocucullograptus inexpectatus
Neocucullograptus kozlowskii
1 Gothograptus nassa Holm
2 Spinograptus clathrospinosus Eisenack
3 S. spinosus (Wood)
4 Plectograptus macilentus (Törnq.)
5 Retiolites? Eisenack
6 Holoretiolites balticus Eisenack
7 H. erraticus Eisenack
8 H. manckii (Münch)
9 H. muenchi Eisenack
10 H. simplex Eisenack
11 Monograptus uncinatus Tullb.
12 Monoclimacis haupti (Kühne)
13 M. micropoma micropoma (Jaekel)
14 M. micropoma nannopoma (Jaeger)
15 Bohemograptus bohemicus bohemicus (Barr.)
16 B. cornutus cornutus Urb.
17 B. cornutus praecornutus Urb.
18 B. bohemicus tenuis (Bouček)
19 Pristiograptus dubius dubius (Suess)
20 P. dubius frequens (Jaekel)
21 P. dubius tumescens (Wood)
22 P. gotlandicus (Perner)
23 P. vulgaris (Wood)
24 Colonograptus colonus (Barr.)
25 C. roemeri (Barr.)
26 Saetograptus chimaera chimaera (Barr.)
27 S. chimaera cervicornis Urb.
28 S. chimaera salweyi (Hopk.)
29 S. fritschi fritschi (Perner)
30 S. fritschi linearis (Bouček)
31 S. leintwardinensis (Hopk.)
32 Neodiversograptus nilssoni (Lapw.)
33 N. beklemishevi Urb.
34 Linograptus posthumus (Richter)
35 Lobograptus crinitus Urb.
36 L. expectatus expectatus Urb.
37 L. expectatus bicornis Urb.
38 L. imitator Urb.
39 L. invertus Urb.
40 L. progenitor Urb.
41 L. scanicus scanicus (Tullb.)
42 L. scanicus parascanicus (Kühne)
43 L. scanicus amphirostris Urb.
44 L. simplex Urb.
45 Neolobograptus auriculatus Urb.
46 Cucullograptus aversus aversus (Eisenack)
47 C. aversus cf. aversus (Eisenack)
48 C. aversus rostratus Urb.
49 C. hemiaversus Urb.
50 C. pazdroi Urb.
51 Neocucullograptus inexpectatus (Bouček)
52 N. kozlowskii Urb.
53 Barrandeograptus? operculatus (Münch)

area (Bouček 1936; Přibyl 1940a, 1942a, 1943, 1948) also in that of Great Britain (Wood 1900; Elles & Wood 1913; Rickards 1965, 1967), as well as in several other profiles of Europe and outside of Europe. Hence, this is an acrozone of paramount importance in correlation.

Cucullograptinae horizon

It contains the four following graptolite zones distinguished by Urbanek (1966) from bottom upwards: Lobograptus progenitor, L. scanicus parascanicus, L. invertus and Cucullograpus hemiaversus whose descriptions are given below.

Lobograptus progenitor Zone

This zone defines the lower part of the horizon. The index species belongs to the oldest, today known, representatives of the subfamily Cucullograptinae and begins its evolutionary line. Other associated forms are: *Spinograptus spinosus* (Wood), *Plectograptus macilentus* (Törnq.), *Holoretiolites balticus* Eis., *H. erraticus* Eis., *H. mancki* (Münch), *Monoclimacis micropoma* (Jaekel), *Bohemograptus bohemicus bohemicus* (Barr.), *Pristiograptus dubius dubius* (Suess), *Colonograptus colonus* (Barr.), *Saetograptus chimaera cervicornis* Urbanek, *Lobograptus progenitor* Urbanek, *L. simplex* Urbanek and *„Barrandeograptus" operculatus* (Münch).

Lobograptus scanicus parascanicus Zone

It is conspicuous among the other Ludlovian zones by its very rich assemblage containing: *Plectograptus macilentus* (Törnq.), *Holoretiolites erraticus* Eis., *H. mancki* (Münch), *H. simplex* Eis., *Monoclimacis haupti* (Kühne), *M. micropoma micropoma* (Jaekel), *M. micropoma nannopoma* (Jaeger), *Bohemograptus bohemicus bohemicus* (Barr.), *Pristiograptus dubius dubius* (Suess), *P. dubius frequens* (Jaekel), *P. dubius tumescens* (Wood), *Saetograptus chimaera chimaera* (Barr.), *Saetograptus chimaera cervicornis* Urbanek, *Neodiversograptus beklemishevi* Urbanek, *Lobograptus expectatus* Urbanek, *L. imitator* Urbanek, *L. progenitor* Urbanek, *L. scanicus scanicus* (Tullb.), *L. scanicus parascanicus* (Kühne) and *Cucullograptus pazdroi* Urbanek.

Lobograptus invertus Zone

In the profile of borehole Mielnik IG-1 (Urbanek 1966) this zone is delimited from the underlying one by a gap of 15 m and by another gap of 5 m from the overlying zone. It is, so to say, suspended in a profile with a normal sequence, and future investigations will probably show whether this species interlocks with zone index forms at the base as well as at the top. Its assemblage contains: *Holoretiolites mancki* (Münch), *Monoclimacis haupti* (Kühne), *Bohemograptus bohemicus bohemicus* (Barr.), *Pristiograptus dubius dubius* (Suess), *P. dubius frequens* (Jaekel), *P. dubius tumescens* (Wood), *Saetograptus chimaera chimaera* (Barr.), *S. chimaera cervicornis* Urbanek, *S. chimaera salweyi* (Hopkin.), *S. fritschi* (Perner), *Neodiversograptus beklemishevi* Urbanek, *Lobograptus expectatus* Urbanek, *L. imitator* Urbanek, *L. invertus* Urbanek, *L. scanicus amphirostris* Urbanek.

Cucullograptus hemiaversus Zone

This zone is arbitrarily accepted as the top of the Cucullograptinae horizon. The top of the zone is indicated by *Lobograptus cirrifer* Urbanek. The following forms characterize the zone: *Holeretiolites mancki* (Münch), *Monoclimacis haupti* (Kühne), *Bohemograptus bohemicus bohemicus* (Barr.), *Pristiograptus dubius dubius* (Suess), *P. dubius frequens* (Jaekel), *P. dubius tumescens* (Wood), *Saetograptus chimaera salweyi* (Hopkinson), *S. fritschi* (Perner), *Neodiversograptus beklemishevi* Urbanek, *Linograptus posthumus* (Richter), *Lobograptus cirrifer* Urbanek, *L. expectatus expectatus* Urbanek, *L. expectatus bicornis* Urbanek, *L. scanicus amphirostris* Urbanek, *Cucullograptus hemiaversus* Urbanek.

The four graptolite zones, discussed above, which indicate the Cucullograptinae horizon, are based in Poland on the fauna found in the profile of borehole Mielnik IG-1 (Urbanek 1966). This horizon which, in its old broad concept, embraces a part of the top of the Neodiversograptus nilssoni zone, the L. scanicus and the Pristiograptus tumescens zones, is readily traceable in nearly all the profiles of Poland. The question now arises whether the concept here presented will be confirmed in the other European profiles (Barrandian area, Great Britain, Germany) whose re-examination in this respect is thought necessary in the writer's opinion. On the presence in the European profiles of genera and species which also occur in the assemblage of the Polish zones, it may be reasonably supposed that also the Cucullograptinae are subject to changes resembling those observed by Urbanek.

Saetograptus leintwardinensis Zone

The definition of this zone and the purposefulness of its tentative retainment have been discussed on p. 452. The following forms occur in its assemblage: *Monoclimacis haupti* (Kühne), *Bohemograptus bohemicus bohemicus* (Barr.), *B. bohemicus tenuis* (Bouč.), *Pristiograptus dubius dubius* (Suess), *P. dubius frequens* (Jaekel), *P. dubius tumescens* (Wood), *Saetograptus fritschi fritschi* (Perner), *Saetograptus fritschi linearis* (Bouč.), *S. leintwardinensis* (Hopk.), *Linograptus posthumus* (Richter), *Cucullograptus aversus aversus* (Eisenack), *C. aversus rostratus* Urbanek, *C. hemiaversus* Urbanek.

Bohemograptus bohemicus Zone

According to Urbanek (1970) this zone is indicated by the epibole of the index species which makes its first appearance already in the N. nilssoni zone and becomes finally extinct in the top of the Neocucullograptus kozlowskii zone, i.e. in the top of the Ludlovian. Beginning from the S. leintwardinensis zone a variability is observable within the species *B. bohemicus bohemicus* (Barr.), producing several characteristic subspecies. In the zone here considered, the index form occurs en masse, though this has not been noted throughout the vertical range of this species. According to Urbanek, the following forms are encountered in the assemblage characterizing this zone: *Monoclimacis haupti* (Kühne), *Bohemograptus bohemicus bohemicus* (Barr.), *B. bohemicus tenuis* (Bouč.), *Pristiograptus dubius dubius* (Suess), *P. dubius frequens* (Jaekel), *P. dubius tumescens* (Wood), *Linograptus posthumus* (Richter), *Cucullograptus aversus* cf. *aversus* (Eisenack), *C. aversus rostratus* Urbanek.

Bohemograptus cornutus Zone

Urbanek (1970) separates this zone into two subzones: the lower, B. cornutus praecornutus and the upper, B. cornutus cornutus subzone. In the writer's opinion such a subdivision is not really necessary because the two subzones are based on one and the same species and are, moreover, characterized by the same assemblage. According to the above concept this zone is treated as the acrozone of the species *cornutus*. The absence of Cucullograptinae is one of the typical features, while the assemblage is analogous with that present in the underlying zone. According to Urbanek it consists of: *Monoclimacis haupti* (Kühne), *Bohemograp-*

tus bohemicus bohemicus (Barr.), *B. bohemicus tenuis* (Bouček), *B. cornutus cornutus* Urbanek, *B. cornutus praecornutus* Urbanek, *Pristiograptus dubius dubius* (Suess), *P. dubius frequens* (Jaekel), *P. dubius tumescens* (Wood), *Linograptus posthumus* (Richter).

Neolobograptus auriculatus Zone

This zone may be regarded as an equivalent of the acrozone of the index species. According to Urbanek (1970), the characteristic assemblage, which strongly resembles the underlying one, is represented by: *Monoclimacis haupti* (Kühne), *Bohemograptus bohemicus bohemicus* (Barr.), *B. bohemicus tenuis* (Bouč.), *Pristiograptus dubius dubius* (Suess), *P. dubius frequens* (Jaekel), *P. dubius tumescens* (Wood), *Neolobograptus auriculatus* Urbanek and *Linograptus posthumus* (Richter).

Neocucullograptus inexpectatus Zone

It complies with the requirements for an acrozone; its assemblage according to Urbanek (1970) consists of: *Monoclimacis haupti* (Kühne), *Bohemograptus bohemicus bohemicus* (Barr.), *B. bohemicus tenuis* (Bouč.), *Pristiograptus dubius dubius* (Suess), *P. dubius frequens* (Jaekel), *P. dubius tumescens* (Wood), *Neocucullograptus inexpectatus* (Bouček) and *Linograptus posthumus* (Richter). Moreover, Urbanek (1970), has distinguished some varieties within the species *Neocucullograptus inexpectatus* (Bouček) and *Linograptus posthumus* (Richter).

Neocucullograptus kozlowskii Zone

In the writer's opinion, this zone ought to be regarded as the youngest one in the Ludlovian stage. Its assemblage displays distinct impoverishment; according to Urbanek it is represented by *Monoclimacis haupti* (Kühne), *Bohemograptus bohemicus tenuis* (Bouček), *Pristiograptus dubius dubius* (Suess), *P. dubius frequens* (Jaekel), *Neocucullograptus kozlowskii* Urbanek and *Linograptus posthumus* (Richter).

The top of the above zone is accepted by the writer as an arbitrary Ludlovian/Postludlovian boundary. This supposition is based on the following data:

a) distinct impoverishment of the fauna, similar to that observable on the Wenlockian/Ludlovian boundary,

b) complete disappearance of the genus *Bohemograptus*, a very characteristic Ludlovian form,

c) extinction of the Cucullograptinae; *N. kozlowskii* Urbanek being probably their last representative,

d) the persistance above the Ludlovian of three species only: *P. dubius frequens* (Jaekel), *Monoclimacis haupti* (Kühne) and *Linograptus posthumus (Richter)*. Out of these *P. dubius frequens* (Jaekel) retains its conservative characters, *M. haupti* (Kühne) probably initiates a new species „*Monoclimacis*" *ultimus* (Perner), while *L. posthumus* (Richter) persists, without substantial changes, as far as the Lower Devonian,

e) the appearance above *N. kozlowskii* Urbanek of new Monograptidae species i.a. of several mutations of *Monograptus formosus* Bouček, which have not, as yet, been fully worked out.

The above facts are easily traceable in Poland within every profile fully developed in the graptolite facies.

The youngest Ludlovian zones and their characteristic assemblages here considered, occurring above the leintwardinensis zone, allow the first accurate division of this fragment of the Silurian system in Poland. Although the presence of these zones in other profiles (Barrandian area) is not excluded, their correlation is now hardly possible.

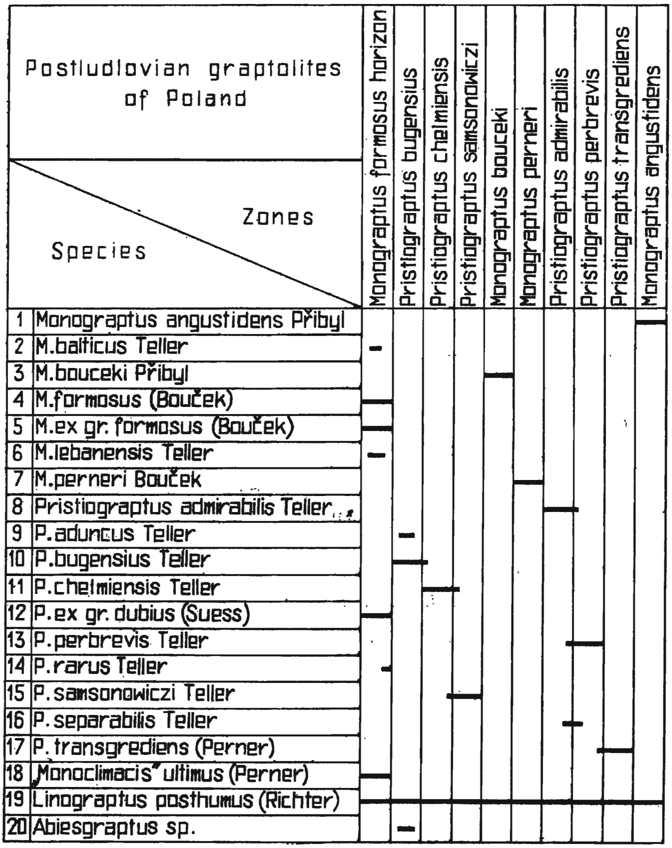
Postludlovian

At their base the deposits of this stage are developed as mudstones interbedded by siltstones. Marly limestone intercalations are fairly common in the shallower parts of the basin. Towards the top sedimentation grows more uniform with the predominance of mudstones, partly calcareous. Concretions of marly limestones as well as intercalation of organogenic limestones are frequent, too. Graptolites are the dominant fauna; they are recorded in great abundance from several boreholes (Teller 1960a, 1964a, 1966). Side by side, especially in the calcareous intercalations, the presence has been noted of trilobites, ostracods, pelecypods, gastropods, cephalopods, conodonts and brachiopods (Korejwo & Teller 1964, Witwicka 1967).

A variegated complex consisting of mudstones, intercalated by calcareous greywackes, is well developed in the Holy Cross Mts. Calcareous concretions are present, too, with limestone intercalations in the top parts. A rich non-graptolite fauna is encountered throughout that complex.

The Postludlovian biostratigraphy is based on graptolites, borehole Chełm IG-1 being the basic profile in the top part. Its lower part has not as yet been fully worked out (chart 7).

Chart 7



The subdivision of that stage (from bottom to top) is as follows:

Monograptus formosus Horizon

This horizon is confined to the vertical range of the species *M. formosus* Bouček, and its base indicates the Ludlovian/Postludlovian boundary. Its top, on the other hand, overlaps with the bottom of the Pristiograptus bugensius zone.

The presence, besides *M. formosus* Bouček, of several new species, so far not yet worked out but which may in future prove very helpful in detailed classification, reasonably suggests to recognize the lower part of the Postludlovian as a horizon. On the other hand, the distinction of a zone acceptable as the acrozone of *M. formosus* Bouček would hardly give a true picture of the present situation.

The following forms have been hereto recorded from the above horizon: *Monograptus balticus* Teller, *M. formosus* Bouček, *M.* ex gr.

formosus Bouček, *M. lebanensis* Teller, *Pristiograptus* ex gr. *dubius* (Suess), *P. rarus* Teller, „*Monoclimacis*" *ultimus* (Perner), *Linograptus posthumus* (Richter).

M. formosus Bouček was described from the Barrandian area; it occurs there in the Pristiograptus ultimus zone which indicates the base of the Přídoli beds (Přibyl 1941a). In the Polish profiles „*M.*" *ultimus* (Perner) is associated with *M. formosus* Bouček but throughout its vertical range. There seems, however, to be no plausible reason to distinguish in Poland the „M." ultimus zone; this zone in the Barrandian area represents only a very small fragment of the Polish M. formosus horizon (Teller 1964a).

Monograptus formosus Bouček is, moreover, known from some boreholes in Lithuania, located in the eastern part of the Peribaltic depression (Paškevičius 1963), also in Volhynia (Krandievsky et al. 1968), Bulgaria (Spassov 1960), Kazakhstan (Apollonov et al. 1968), Central Asia (Obut et al. 1968), Morocco (Willefert 1963) and Normandy (Jaeger, Doré & Philippot 1965). Quite recently, Jackson (written communication) has reported a similar form in an analogous stratigraphic position in Canada (Royal Creek profile).

Tomczyks (1961) and Tomczyk (1962a, p. 65 et al.) state that among the forms encountered at the bottom of the vertical range of *M. formosus* Bouček, he has identified: *Monograptus microdon silesicus* Jaeger, *M. microdon* Richter, also species from the „uncinatus" group — *Monograptus uniformis* Přibyl, *M. praehercynicus* Jaeger and *M. hercynicus* Perner.

All the above species are, however, known from other profiles of Europe or outside Europe, also from Poland, but in considerably younger layers, above the Monograptus angustidens zone.

Tomczyk claims that in Poland as well as in other parts of the globe, *Linograptus posthumus* (Richter) is the only species occurring above the Monograptus angustidens zone, other graptolites being absent. This led Tomczyk (1962a) to incorrect stratigraphic conclusions.

Jaeger (1962), Bouček & Horny (1964), also Teller (1964b) all disagree with the above concept.

Nevertheless, Tomczyk (1968a, p. 141—142) adheres to his original interpretation and justifies it by new arguments based on the Silurian profile from borehole Ciepielów IG-1. His arguments contradict, however, the results obtained not only by the writer (Teller 1960a, 1964a, b; Korejwo & Teller 1964) but also those of many other authors (Přibyl 1941a; Bouček 1966; Jaeger 1959, 1962; Hollard & Willefert 1961; Willefert 1962, 1963; Koreń 1967, 1968; Lenz 1966; Bouček et al. 1967; Berry 1967; Philip 1967; Nikiforova et al. 1967). Since, moreover, Tomczyk's arguments are not based on any reliable evidence, the present writer must again express his opinion on this problem.

1) Tomczyk (1962a, 1968a) has not as yet figured or described any

of species he has identified as *Monograptus uniformis* Přibyl, *M. praehercynicus* Jaeger, *M. hercynicus* Perner, *M. microdon microdon* Richter and *M. microdon silesicus* Jaeger. Neither did he publish any other facts in support of his supposition respecting the absence of the here named species above the M. angustidens zone. He confined himself to very general speculations concerning the evolution of graptolites (Tomczyk 1962a), at the same time depreciating the arguments advanced by other authors.

2) Tomczyk (1968a) denies the correctness of the identification of *M. uniformis* Přibyl from borehole Chełm IG-1 (Korejwo & Teller 1964) postulating that it is *Monograptus angustidens* Přibyl. He assigns great importance to differences in the state of preservation of graptolites from mudstones as compared with those from limestones. The rhabdosome figured in pl. XXI, fig. 3a, b, by Korejwo & Teller (1964) is normally compressed and not preserved in half relief. Moreover, it does not come from a limestone, as is suggested by Tomczyk, but from a calcareous mudstone.

3) Tomczyk (1968a) claims that the absence of *M. uniformis* Přibyl in a 143.5 m thick fragment of core above the M. angustidens zone in borehole Ciepielów IG-1 provides reliable evidence to exclude the occurrence of the former above the latter. The question here arises whether the M. angustidens zone is really well defined in borehole Ciepielów IG-1 and whether the index species is correctly identified by Tomczyk, because his paper does not contain any documentation. Moreover, from the profile of the above borehole, Tomczyk (1968a, p. 141) mentions two intervals with *M. angustidens* Přibyl. One at a depth of 2,648—2,675 m (27 m) from which he reports *M.* cf. *angustidens* Přibyl; the other at 2,605—2,615 m (10 m) with *M. angustidens* Přibyl, said to occur en masse. These two intervals are separated by 33 m of deposits containing only *Linograptus* sp. Even if *M. angustidens* Přibyl had been correctly identified in both cases, the absence of *M. uniformis* Přibyl from borehole Ciepielów IG-1, above the M. angustidens zone, cannot evidently prove its absence in general above the last named zone throughout Poland, and still more so throughout the world. The limited diameter of all boreholes, apparently not taken heed of by Tomczyk, may be quoted to illustrate his argumentation.

4) The results from borehole Nl_3 in the Sahara desert, worked out by Willefert (1962, 1963), are accepted by Tomczyk as evidence for the presence of *Monograptus formosus* Bouček together with *M. uniformis* Přibyl as well as younger forms which he (1962a, 1968a) calls the „uniformis" group.

The present writer took his opportunity to have this problem cleared up. The „uniformis" group, as understood by Dr. Willefert, does not coincide with the concept of *M. uniformis* Přibyl. The latter occurs in borehole Nl_3 between 2,702.5 and 2,732 m in association with *M. hercynicus* Perner and *M. praehercynicus* Jaeger, while a form resembling *M. uniformis* Přibyl (which Dr. Willefert does not identify with *M. uniformis* Přibyl but possibly with the „uniformis" group) occurs lower down in borehole Nl_3, together with *M. formosus* Bouček. Except for its outer appearance, this form has nothing in common with the typical form from which it is much older.

5) Tomczyk postulates (1968a) that *Acastella tiro* R. & E. Richter from borehole Chełm IG-1 represents the young stage of a new species of the genus *Acastella,* said to occur in borehole Ciepielów IG-1, above as well as below the M. angustidens zone. This prove might be acceptable if Tomczyk had given both a description of the new species and had figured its successive evolutionary stages. The correctness of the identification of the specimen from borehole Chełm IG-1 (Korejwo & Teller 1964) as *Acastella tiro* R. & E. Richter has been confirmed by Dr. Alberti during a discussion with the present writer, when Dr. Alberti emphasized that the specimen here considered is very typical.

6) Tomczyk's concept (1968a) that the base of the M. uniformis zone is not acceptable as an index horizon in the correlation of Silurian deposits in Europe obviously contradicts the opinions of all European and non-European explorers, Tomczyk excepted. This was stressed at the 1967 Conference at Calgary and again in 1968 at Leningrad.

According to the present knowledge of the Upper Silurian graptolite fauna in Poland, it may be reasonably accepted that, within the vertical range of the species *Monograptus formosus* Bouček, there are other genera and species, outwardly resembling the forms *M. uniformis* Přibyl or *M. microdon* Richter, but which cannot be identified with species occurring much higher up in the stratigraphic sequence. Most likely, these are new species, possibly even new genera, as was correctly suggested by Tomczyk (1962a). Such species, however, as *M. uniformis* Přibyl, *M. microdon silesicus* Jaeger, *M. praehercynicus* Jaeger, *M. hercynicus* Perner, and also *Pristiograptus atopus* Bouček, *Monograptus yukonensis* Jackson & Lenz, are not Silurian but already belong to representatives of the Lower Devonian, and occur above the M. angustidens zone.

Tomczyk's conclusions (1962a, 1968a) drawn on mis-identified fauna, suggest lack of documentation and, therefore, authorize the present writer to neglect them in the study of the Upper Silurian stratigraphy of Poland.

Pristiograptus bugensius Zone

This zone is the acrozone of the index form. It is characterized by an extremely meagre assemblage represented by *Pristiograptus aduncus* Teller, *P. bugensius* Teller, *Linograptus posthumus* (Richter) and

Abiesgraptus sp. It has been recognized in several Polish boreholes. Obut et al. (1968) have recorded it from Central Asia, while quite recently it is reported by Jackson (written communication) from Canada.

Pristiograptus chelmiensis Zone

This zone should be recognized as an acrozone. Its characteristic assemblage contains besides *Linograptus posthumus* (Richter) also *Pristiograptus bugensius* Teller at the base, as well as *P. chelmiensis* Teller and *P. samsonowiczi* Teller in the top. It has been recognized in several Polish boreholes; Obut et al. (1968) have recorded it from Central Asia, while Jackson (written communication) reports it from Canada.

Pristiograptus samsonowiczi Zone

This is an acrozone of the index species. The only forms found here are *Pristiograptus chelmiensis* Teller — encountered at the base only — *P. samsonowiczi* Teller and *Linograptus posthumus* (Richter). This zone has been recognized in several Polish boreholes.

Monograptus bouceki Zone

This is a zone that may be readily defined and should be recognized as the acrozone of *Monograptus bouceki* Přibyl which occurs here in association with *Linograptus posthumus* (Richter) only. It has been found in several boreholes.

Přibyl (1941a) was the first to define it in the Barrandian area. Jaeger, Doré & Philippot (1965) report it from Normandy, while Obut et al. (1968) found it in Central Asia.

Monograptus perneri Zone

It is an acrozone, similarly as the underlying one. *Linograptus posthumus* (Richter) is the only other form found there besides the index species *Monograptus perneri* Bouček. In the Barrandian area, it was distinguished by Přibyl (1941a) from the Přidoli beds. Tomczyk (1962a et al.) mentions the two last zones in a reversed order, while in his paper published in 1968b they are fused into one binominal zone. The correct sequence of these zones has been more at large discussed previously by the present writer (Teller 1964a). The Monograptus perneri zone is also known from Kazakhstan (Apollonov et al. 1968) and from Central Asia (Obut et al. 1968).

Pristiograptus admirabilis Zone

This zone has been defined on the vertical range of the index form. Its assemblage contains *Pristiograptus separabilis* Teller, *Pristiograptus admirabilis* Teller and *Linograptus posthumus* (Richter), as well as *Pristiograptus perbrevis* Teller in the top part. So far, besides in the profile from borehole Chełm IG-1 this zone has also been found in the profile of borehole Ruda Lubycka (Teller 1964a).

Pristiograptus perbrevis Zone

So far, this zone has been distinguished in no other boreholes except Chełm IG-1. Its meagre assemblage consists of *Pristiograptus perbrevis* Teller, *P. separabilis* Teller, *P. transgrediens* (Perner) in the top, and *Linograptus posthumus* (Richter).

Pristiograptus transgrediens Zone

This is an acrozone and besides *P. transgrediens* (Perner) it contains only *Linograptus posthumus* (Richter). Přibyl (1941a) was the first to distinguish it in the Barrandian area. More recently it has been recorded from Thuringia (Jaeger 1964c), Normandy (Jaeger, Doré & Philippot 1965) while quite lately Jackson (written communication) has reported it from Canada.

Monograptus angustidens Zone

This is the last graptolite zone of the Silurian system in Poland. Its top also indicates the Silurian/Devonian boundary. It is an acrozone and besides *M. angustidens* Přibyl, the only other form it contains is *Linograptus posthumus* (Richter). The index form was for the first time distinguished by Přibyl (1941a) in the Barrandian area, but recently also in Podolia and the Ural (Koreń 1967, 1968).

The graptolite horizon and the graptolite zones of the Polish Postludlovian represent today the most complete Upper Silurian sequence of Central Europe. Until recently it was known only from the Barrandian area and was regarded as the type profile. The research studies undertaken in Poland have, however, resulted in a more detailed subdivision of the Postludlovian and, what is still more important, some of the new Polish zones have also been recently distinguished in Canada and Central Asia. This corroborates the writer's (Teller 1964a) supposition about the existence of stratigraphic gaps in the Barrandian area. Therefore, a re-examination of both, the Kopaniny beds and the Přídoli beds, now seems indispensible for the clearing up of the above problem. The need for such studies is stressed by the discovery by Bouček (1966) — even though in much younger layers — of *Monograptus yukonensis* Jackson & Lenz, a form described from Canada from a profile where Jackson has lately found some Polish Postludlovian zones. Hence, it does not seem excluded that some Polish zones are also present in the Barrandian area.

Other faunas, recently encountered in Poland within the zones P. bugensius — M. angustidens, are nearly identical with those known from the Barrandian area (Korejwo & Teller 1964). These finds have considerably helped in the correlation of the Rzepin series which contain no graptolites.

Younger graptolites, until lately referred to the Silurian, have been found in Poland above the M. angustidens zone, i.e. *Monograptus uniformis* Přibyl in borehole Chełm IG-1 (Korejwo & Teller 1964), in the Sudetes *Monograptus hercynicus* (Perner), *M. hemiodon* Jaeger (Teller 1962) and *Monograptus microdon silesicus* Jaeger (Jaeger 1959). Today these forms have been assigned already to the Gedinnian.

THE CORRELATION OF THE POLISH SILURIAN WITH ADJACENT AREAS BASED ON GRAPTOLITES

The Silurian deposits of Poland, subdivided on the basis of recognized and defined graptolite zones, may be readily correlated with such profiles from adjacent areas (Scania, Latvia, Lithuania, the Barrandian area, Thuringia) where the division of the Silurian system is likewise based on graptolites. As a rule, no essential difficulties are encountered during the work of correlation, as far as the Saetograptus leintwardinensis zone, in the Barrandian area and in Thuringia even including the Postludlovian. Above this zone a change of facies is noted in most of the European profiles; the graptolites cease to be the index forms and grow less frequent. Such facial changes are observable in Poland, too. A complete absence of the graptolite fauna above the S. leintwardinensis zone has been noted only in the Holy Cross Mts., both in the Wydrzyszów and the Rzepin series. Within the Precambrian platform, also in the SE part

Chart 8

Correlation of the Polish Silurian with some European regions

Stratum	Series	Stage	Substage	POLAND: Lowland	POLAND: Holy Cross Mts. North	POLAND: Holy Cross Mts. South	POLAND: Sudetes	SWEDEN Scania /Regnéll 1960/	U S S R: Latvia /Ulst 1964, Gailite 1964/	U S S R: Lithuania /Kaljo, Paškevičius 1963, 1965/	U S S R: Ukraine /Nikiforova 1964/	BOHEMIA Barrandian area /Bouček et al. 1966, 1968; Kříž 1962/	EAST GERMANY Thuringia /Jaeger 1964/	GREAT BRITAIN /Holland et al. 1963, Jones 1921, Curtis 1961, Straw 1930, Richards 1967/
DEVONIAN	LOWER	GEDINNIAN		M.uniformis	Bostów beds	Siegenian	M.hercynicus M.praehercynicus	Lack of deposits	Lack of deposits	Stoniškiai horizon	Tiverian stage: Ivanie, Chortkov, Borshchov M.uniformis	Lochkov: M.hercynicus M.praehercynicus M.uniformis	M.hercynicus M.praehercynicus M.uniformis	Dittonian
SILURIAN	UPPER	DOWNTONIAN	UPPER	M.angustidens P.transgrediens P.perbrevis P.admirabilis M.perneri M.bouceki P.samsonowiczi P.chelmiensis P.bugensis	Rzepin Series	Lack of deposits	?	Öved-Ramsåsa Series / Öved-Ramsåsa Group: Lack of deposits Division 4 Öved sandstone Division 2-3	Lack of deposits Jūra horizon	Tilžė horizon Jūra horizon	Skala horizon	BUDŇANIAN, Přídolí beds: M.angustidens P.transgrediens ? ? M.perneri M.bouceki ? ? ? M.formosus and "M." ultimus	Upper graptolite shales: P.transgrediens Ocker limestone	DOWNTONIAN: Red Downtonian Temeside shales Downton Castle sandstone
			LOWER	M.formosus horizon				Division 1 Bjärsjölagård limestone and shale	Minija horizon M.formosus?	Minija horizon M.formosus				Ludlow bone-bed
		LUDLOVIAN	UPPER	M.kozlowskii M.inexpectatus S.auriculatus B.cornutus B.bohemicus	Wydryszów Series		?	Colonus Series / Colonus shale: ?	Pagegiai horizon	Pagegiai horizon	Malinovtsy horizon	? M.inexpectatus ? ? ? S.fritschi linearis	P.dubius thuringicus S.fritschi linearis	LUDLOVIAN: Shelly: Whitcliffian; Basin: U. Ludlow shelly siltstones
			LOWER	S.leintwardinensis S.hemiaversus L.invertus L.scanicus L.progenitor N.nilssoni P.vulgaris G.nassa (graptolite horizon)	S.leintwardinensis G.nassa		L.scanicus N.nilssoni ? ?	L.scanicus N.nilssoni ? ?	P.tumescens L.scanicus N.nilssoni P.vulgaris	L.scanicus N.nilssoni P.vulgaris G.nassa? | Neris and Verkné horizons Birštonas horizon		Kopanina beds: L.scanicus N.nilssoni P.vulgaris G.nassa	S.leintwardinensis L.scanicus N.nilssoni P.vulgaris with P.deubeli P.dubius – G.nassa	Shelly: Leintwardinian Bringewoodian Eltonian; S.leintwardinensis P.tumescens L.scanicus N.nilssoni P.vulgaris; Basin: Leintwardine beds L. Ludlow shelly siltstones L. Ludlow Graptolitic shales
	LOWER	WENLOCKIAN		C.lundgreni C.radians C.ellesi M.flexilis C.rigidus M.riccartonensis C.murchisoni C.centrifugus	C.lundgreni C.insectus		C.lundgreni C.radians C.ellesi ? ? ? C.murchisoni	Cyrtograptus Series / Cyrtograptus shale, Flemingi beds: T.testis C.perneri C.rigidus M.riccartonensis C.murchisoni; Retiolites beds	C.lundgreni C.radians | T.testis C.perneri M.flexilis M.riccartonensis C.murchisoni	T.testis C.radians M.flexilis M.riccartonensis C.murchisoni | Paprieniai horizon	Ustje horizon Mukshe horizon	WENLOCKIAN: T.testis C.radians C.perneri-C.rameus M.flexilis C.rigidus M.riccartonensis C.murchisoni C.insectus P.dubius M.firmus C.centrifugus	T.testis C.lundgreni C.radians M.flexilis C.murchisoni	WENLOCKIAN: C.lundgreni C.ellesi C.linnarssoni C.rigidus M.riccartonensis C.murchisoni C.centrifugus
		LLANDOVERIAN		S.spiralis M.griestoniensis M.crispus S.turriculatus R.linnaei M.sedgwicki D.convolutus P.gregarius P.cyphus O.vesiculosus A.acuminatus A.ascensus	S.spiralis A.ascensus		S.spiralis M.griestoniensis M.crispus S.turriculatus R.linnaei M.sedgwicki ? ? ? ? ? ?	Rastrites Series / Rastrites shale: S.spiralis M.discus M.turriculatus M.runcinatus M.sedgwicki C.cometa, P.folium M.triangulatus M.revolutus P.extenuatus A.acuminatus ?	S.spiralis M.crispus S.turriculatus M.sedgwicki D.convolutus D.triangulatus P.cyphus Limestone	S.spiralis M.griestoniensis M.crispus S.turriculatus R.linnaei M.sedgwicki P.gregarius Nodular limestone | Svenčionys horizon	Kitaigorod horizon	Liten beds, LLANDOVERIAN: S.spiralis S.grandis M.crenulata M.griestoniensis M.crispus S.turriculatus R.linnaei M.sedgwicki D.convolutus D.pribyli D.pectinatus D.triangulatus P.cyphus O.vesiculosus A.acuminatus A.ascensus	Lower graptolite shales: M.spiralis with M.crenulata M.griestoniensis M.crispus M.turriculatus R.linnaei M.sedgwicki D.convolutus with C.comata P.gregarius with D.triangulatus P.cyphus O.vesiculosus A.acuminatus	LLANDOVERIAN: UPPER: M.crenulata M.griestoniensis M.crispus S.turriculatus R.maximus with M.halli M.sedgwicki; MIDDLE: D.convolutus with C.comata at top M.leptotheca D.magnus P.cyphus; LOWER: M.atavus and M.acinaces A.acuminatus G.persculptus

of the Paleozoic platform, the graptolite fauna still predominates and in some places it has persisted up to the Lower Devonian inclusively.

The Polish graptolite zones have been compared either with analogous zones or with deposits which are their time eqivalents in the various profiles. The Silurian profile of Podolia has also been correlated because of its importance for Middle Europe, even though its lithological equivalents are missing in Poland. Indirect stratigraphic connections are, however, traceable. The correlation of the Silurian deposits of Poland with analogous sediments of Great Britain has for its primary purpose to prove the close connections of the latter not only with the Polish area but also with the European areas here discussed (chart 8).

Valentian (Llandovery)

Both, the deposits and the fauna of this stage show close connections with Scania, Latvia, Lithuania, the Barrandian area, Great Britain and Thuringia.

In Scania (Regnéll & Hede 1960) the Valentian is represented by the Rastrites shales and the lower part of the Cyrtograptus shales. Akidograptus acuminatus is the lowermost zone noted there. It corresponds to an analogous zone in the Polish profile. The Rastrites extenuatus zone is the equivalent of the Orthograptus vesiculosus zone, while the Monograptus revolutus zone should be accepted as the equivalent of the Pristiograptus cyphus zone in Poland.

The Monograptus triangulatus zone corresponds to the Polish Pristiograptus gregarius zone, while the Petalograptus folium and Cephalograptus cometa zones are to be correlated with Demirastrites convolutus. The Rastrites linnaei, Monograptus crispus and Monoclimacis griestoniensis zones have not been distinguished in Scania. They are replaced by the Monograptus turriculatus and Monograptus discus zones. The top of the Valentian is indicated, as in Poland, by the Spirograptus spiralis zone which is included in Scania into the base of the Cyrtograptus shales.

In Latvia (Ulst 1964; Gailite 1964; Gailite, Rybnikova & Ulst 1967) the base of the Valentian, as far as the Pristiograptus cyphus zone, while in Lithuania as far as the Pristiograptus gregarius zone (Paškevičius 1963, 1965) is developed as limestones and marls without a graptolite fauna. Moreover, in some places, there is a minor sedimentary gap between the Ordovician and the Silurian. An analogous situation has been observed in some Polish boreholes in the eastern part of the Peribaltic depression. Hence, it may be reasonably accepted that these deposits are synchroneous and correspond with the zones from Akidograptus ascensus to Pristiograptus cyphus or even Pristiograptus gregarius. Higher up, the limestone complex is replaced in Poland as well as in Latvia and Lithuania by greenish mudstones intercalated with black shales.

In Latvia the zones Rastrites linnaei and Monoclimacis griestoniensis have not been defined.

In Lithuania, on the other hand, zones from P. gregarius to S. spiralis are included into the Švenčionys horizon. The Demirastrites convolutus and R. linnaei zones are not here paleontologically defined.

The Valentian deposits of Latvia and Lithuania closely resemble those in the eastern part of the Peribaltic depression in Poland where the presence of the D. convolutus zone is indicated only by *Cephalograptus cometa* (Geinitz) while *R. linnaei* Barr. is missing.

The Valentian deposits of Poland may be most closely correlated with those of the Barrandian area (Bouček 1953, 1960b; Horny 1962), Thuringia (Jaeger 1964c) as well as with the British profiles (Elles & Wood 1913, Jones 1921, Curtis 1961). Zones analogous with those of Poland occur in the above profiles; the slight differences consist in that some of the zones are defined on the ground of other species.

In Czechoslovakia this applies particularly to the zone P. gregarius which is separated there into three zones characterized by the species *Demirastrites triangulatus* (Hark.), *D. pectinatus* (Richter) and *D. pribyli* Bouček. The top of the Valentian in Czechoslovakia is likewise divided into three separate zones, while in Poland they embrace only one, the Spirograptus spiralis zone, with two subzones.

In Thuringia all the zones have been defined analogously as in Poland, with the exception of the lowermost Akidograptus acuminatus zone; in details they resemble closely those in Poland.

The Valentian graptolite zones of Great Britain, listed by Curtis (1961) represent the complete profile of deposits. Some of them, are, however, based on different index species than in Poland, but even then they may be satisfactorily correlated with the time equivalents of the Polish Valentian. The oldest Polish zone has its correspondent in the English Glyptograptus persculptus zone. The Polish Orthograptus vesiculosus zone corresponds to two English Monograptus atavus and Monograptus acinaces zones. Some difficulties are encountered with the Pristiograptus gregarius zone to which may correspond the three English zones: Monograptus triangulatus, Diplograptus magnus and Monograptus leptotheca. Out of these three index forms only *D. triangulatus* (Hark.) occurs in Poland, strictly within the P. gregarius zone. *D. magnus* Lapw. has not, so far been reported from Poland while *M. leptotheca* (Lapw.) has been found together with *Cephalograptus cometa* (Geinitz). The index species of the Demirastrites convolutus zone has not as yet been found in Poland but one part of the profile is its time-equivalent.

No doubts arise in the correlation of the Monograptus sedgwicki zone; the Monograptus halli and Rastrites maximus zones, overlying it the English profile, correspond to the Polish Rastrites linnaei zone. he top of the Valentian deposits in Great Britain is characterized by the Monoclimacis crenulata zone whose Polish correspondent is the Spirograptus spiralis zone.

In the tripartite division of the Valentian in southern Scotland into the Lower and Upper Birkhill and the Gala Group we are dealing with another problem. The subdivision of the Birkhill which has been based on the separation of the zones, is merely arbitrary. Jones (1921) divides the Birkhill even into three parts. On the other hand, the separation of the Gala Group is better grounded because it is based not only on graptolites but also on lithological differences. Except for some minor lithological differences in its lower part, the Polish Valentian profile is represented mainly by black mudstones. Its subdivision cannot coincide with that in South Scotland.

The tripartite division of the Llandovery of Wales is justified by unconformities, though this is also merely an arbitrary problem. Such unconformities are missing in the Valentian of Poland, although their existence within the Caledonian miogeosyncline on the as yet poorly known Paleozoic platform (profile of borehole Lutom 1) is not excluded.

In Podolia, the base of the Silurian system is represented by the Kitaigorod horizon. Nikiforova (1968) compares this horizon with the standard graptolite sequence of the U.S.S.R. and supposes that it corresponds to the zones from Pristiograptus gregarius through Spirograptus spiralis. Hence, the equivalents of the lowermost zones are missing here, similarly as has been observed in the eastern part of the Polish Peribaltic depression.

Graptolites of the Valentian and of younger Silurian members have been found also in boreholes of western Volhynia (Krandievsky 1962, 1968; Krandievsky, Ishchenko & Kiryanov 1968). The descriptions of that fauna, so far published, are so vague and lacking in clarity that they can hardly be used for correlation.

Wenlockian

The Wenlockian deposits of Poland and of the correlated areas are characterized by the most stabile sedimentary conditions within the Silurian profile.

In Scania (Regnéll & Hede 1960) the Wenlockian is represented by the Cyrtograptus shales whose base consists of the Retiolites beds. These are overlain by the Flemingii beds. The bottom part of the Retiolites beds still belong to the Valentian, while their top is indicated by the Cyrtograptus murchisoni zone corresponding to the Polish zone. The lowermost Cyrtograptus insectus zone is not distinguished here. The Flemingi beds are characterized by three zones of which Monograptus riccartonensis is the lowermost, while Cyrtograptus carruthersi [9] and Testograptus testis indicate the top. The lowermost zone is an equivalent of the Polish zone, while the top zones may be regarded as correspondents to the Cyrtograptus lundgreni and Cyrtograptus radians zones of Poland. The Cyrtograptus rigidus zone, indicating the middle part of the Flemingi beds, probably embraces not only the Polish Cyrtograptus rigidus zone, but also the Monograptus flexilis and Cyrtograptus ellesi zones (Nilsson 1946, Regnéll & Hede 1960).

In Latvia (Ulst 1964; Gailite 1964; Gailite, Rybnikova & Ulst 1967) the Cyrtograptus insectus zone is not known from the base of the Wenlockian. The higher Cyrtograptus murchisoni and Monograptus riccartonensis zones have been recognized there, as in Poland. Neither is the Cyrtograptus rigidus zone distinguished there, but this form is present in the assemblage of the younger Monograptus flexilis zone which corresponds to the same zone in Poland. It is believed to be overlaid by the Cyrtograptus perneri and Testograptus testis zones. In Latvia the latter one is divided into two subzones, Cyrtograptus radians and C. lundgreni. Regretfully there is no reliable evidence to prove that the Cyrtograptus ellesi zone of Poland is an equivalent of the Cyrtograptus perneri zone of Latvia, while the T. testis zone of Latvia corresponds to the two youngest zones of Poland. This incomplete correlation of the Wenlockian zones of Latvia with those of Poland is not due to the absence of a complete profile within the area under consideration, but may be caused by a marked impoverishment of the graptolite fauna.

A very similar situation is observed when correlating the Polish Wenlockian profiles with those of Lithuania (Paškevičius 1963, 1965). The Wenlockian deposits are included into the Paprieniai horizon and the only differences from the Latvian profile is the lack of the Cyrtograptus perneri zone and the separation of the Cyrtograptus radians and Testograptus testis zones into independent one.

The Polish Wenlockian zones are most readily correlated with the Barrandian area and with the British profile. In the Barrandian area (Bouček 1960b, Horny 1962) there occur all the equivalents of the Polish zones as well as several others not confirmed in the Polish profile. The interpretation of the Wenlockian/Ludlovian boundary, however, differs markedly; in the Barrandian area (Horny 1962) the Gothograptus nassa zone characterizes the top of the Wenlockian, while in Poland it begins the Ludlovian.

All the zones distinguished in the British profile (Wood 1900, Evans 1961, Rickards 1967) have their equivalents in Poland, the only

[9] According to Bouček (1933) the species *Cyrthograptus carruthersi* Perner is synonymous with *C. perneri* Bouček which occurs within the Cyrtograptus radians zone of the Polish profile.

differences being the presence in England of the Cyrtograptus linnarssoni zone instead of the Monograptus flexilis zone of Poland, and in the absence of the Cyrtograptus radians zone. The base of the Wenlockian is indicated by the Cyrtograptus centrifugus zone, while the top, similarly as in Poland, by the Cyrtograptus lundgreni zone.

Correlation with Thuringia (Jaeger 1964c) is but partly possible because of the absence there of a number of zones recognized in Poland. The top of the Wenlockian, indicated by the dubius-nassa Interregnum, correponds to the Polish Gothograptus nassa zone included into the Ludlovian.

In the Podolian profile, Nikiforova (1968) regards the Muksha and Ustie horizons as equivalents of the Cyrtograptus murchisoni — Testograptus testis zones. This coincides fully with the Polish profile, except that the base of the Wenlockian in Poland is indicated by the Cyrtograptus insectus zone which is unknown in the standard graptolite sequence of the U.S.S.R.

Ludlovian

The Ludlovian deposits in Poland represent today the most complete and most satisfactorily subdivided profile of that stage on a world-wide scale. Its recognized zones allow a relatively exact correlation with the adjacent regions, including the Saetograptus leintwardinensis zone.

In Scania (Regnéll & Hede 1960) the Polish Ludlovian zones have their equivalents in the Colonus shales where only the Neodiversograptus nilssoni and the Lobograptus scanicus zones have been defined. The last one, as well as the Pristiograptus tumescens zone, is correlated by the present writer in all the profiles here discussed with the Cucullograptinae horizon. The upper part of the Colonus shales is not, however, well defined and it is not certain whether they are of the same age with the zones from Saetograptus leintwardinensis to Neocucullograptus kozlowskii, though this cannot be altogether excluded.

In Latvia (Ulst 1964; Gailite 1964; Gailite, Rybnikova & Ulst 1967) all the zones, Gothograptus nassa excepted, may be correlated with the Polish profile including the Cucullograptinae horizon. Above this the Pagėgiai horizon has been distinguished; it may be the equivalent of the Polish zones from Saetograptus leintwardinensis through Neocucullograptus kozlowskii.

The Ludlovian/Postludlovian boundary may be established in the top of the above horizon.

Correlation with Lithuania (Paškevičius 1963, 1965) is very much the same; the Lithuanian zones G. nassa?-Lobograptus scanicus are closely comparable with analogous zones in Poland. They are placed there in the Birštonas and Verknė horizons, while the Neris horizon, occurring higher up, may be already the equivalent of the Polish S. leintwardinensis zone. The uppermost Pagėgiai horizon occupies an analogous stratigraphic position in relation to the Polish profile as it does in Latvia.

In the Barrandian area (Bouček 1960b, Horny 1962), the profile of the Polish Ludlovian has its equivalent in the Kopanina beds which can be readily correlated including the S. leintwardinensis zone. Higher up, however, the occurrence of stratigraphic gaps is possible but not absolutely certain (Horny 1962), because the Neocucullograptus inexpectatus zone is present there.

The lower part of the Ludlovian profile of Thuringia (Jaeger 1964c) is represented by the upper part of the lower graptolite shales with the zones from dubius-nassa Interregnum through S. leintwardinensis. This part is a full equivalent of the Polish zones. Above the S. leintwardinensis zone, the ochre limestone is present and the Ludlovian/Postludlovian boundary occurs within it. The change of the clay facies into a limestone one in Thuringia coincides with analogous changes in Poland which are observable above the same graptolite zone.

In the shelly facies of Wales (Holland, Lawson & Walmsley 1959, 1963) the Eltonian, Bringewoodian and Leintwardinian are the equivalents of the Polish zones from G. nassa to S. leintwardinensis while the Whitcliffian may be correlated with the zones from Bohemograptus bohemicus to Neocucullograptus kozlowskii.

In the basin facies of Wales, the Polish zones from G. nassa to S. leintwardinensis have their equivalents in the Lower Ludlow graptolithic shales, Lower Ludlow shelly siltstones, Leintwardinensis and Lauensis beds while the Upper Ludlow shelly siltstones are the equivalents of the upper Polish zones. The top of the Ludlow Bone Bed horizon probably indicates the Ludlovian/Postludlovian boundary.

Owing to a revision of the fauna and the discovery of *Monograptus uniformis* Přibyl at the base of the Borshchov horizon (Koreń 1967, 1968) the biostratigraphical subdivision of the Podolian profile has recently undergone substantial changes. According to the new concept (Nikiforova 1968) the Malinovtsy and Skala horizons represent the Ludlovian. When comparing this area with the Polish profile it may be supposed that only the Malinovtsy horizon corresponds to the whole Ludlovian, while the Skala horizon is younger.

Postludlovian

This stage is represented in Poland by a complete profile of deposits and its greater part has been accurately subdivided (Teller 1964a) on graptolites. Its lower part, included by the present writer into the Monograptus formosus horizon, is the only one not yet completely worked out.

The deposits of this stage also occur in the areas here discussed but their correlation on graptolite zones is possible only in the Barrandian area. For some regions (Latvia, Lithuania), however, the Monograptus formosus horizon is of great value. In Scania (Regnéll & Hede 1960) the Öved Ramsåsa Group corresponds to a certain — now indeterminate — part of the Postludlovian. Within Division 1, distinguished there, the presence has been noted of graptolites whose state of preservation does not permit closer identification. The uppermost part of the deposits from this group has been eroded while the Lower Devonian is completely missing. Hence, a closer correlation with the Polish profile is not possible.

In Latvia (Ulst 1964; Gailite 1964; Gailite, Rybnikova & Ulst 1967) and in Lithuania (Paškevičius 1963, 1965) the Minija horizon, containing *Monograptus formosus* Bouček, may reasonably be correlated with the Polish Monograptus formosus horizon. In Latvia and Lithuania, the Jūra horizon corresponds to the middle part of the Postludlovian, while in Lithuania the Tilže horizon corresponds to the upper part of the Postludlovian. In Latvia, there are no deposits above the Jūra horizon, while in Lithuania the Tilže horizon is overlaid by the Lower Devonian deposits.

In the Barrandian area (Přibyl 1941a, Bouček 1960b, Horny 1962) the equivalents of the Postludlovian are the Přidoli beds from which are known only some equivalents of the Polish zones (comp. p. 461). The bottom part of these deposits is indicated by the „M." ultimus zone. This zone is not differentiated in Poland because of the great vertical range of this species and its occurrence together with *Monograptus formosus* Bouček. The „M." ultimus zone may only have a local character and it only partly corresponds to the Polish M. formosus horizon. On the other hand, such zones as M. bouceki, M. perneri, P. transgrediens and M. angustidens are fully confirmed in the Polish profile. The top of the Postludlovian corresponding to the top of the Silurian system, is indicated by the base of the Monograptus uniformis zone in Poland as well as in the Barrandian area.

In Thuringia, a great part of the ochre limestones as well as the lower part of the upper graptolite shales contain the Pristiograptus transgrediens zone (Jaeger 1964c). Similarly as in the Barrandian area and in Poland the top of the Postludlovian is indicated by the base of the M. uniformis zone.

In Great Britain the Postludlovian is represented by the Downtonian whose age varies with the different English authors (Boucot 1960; Straw 1962; Walmsley 1962; Holland, Lawson & Walmsley 1963; Tarlo 1964; Holland 1965; Earp 1967; Potter 1968).

In Podolia, however, because of the presence at the base of the Borshchov horizon (Koreń 1967, 1968) of the Monograptus uniformis zone which indicates the Lower Gedinnian, the underlying Skala horizon ought to be referred to the Postludlovian.

The correlation of the graptolite zones of Poland with those in the adjacent areas shows that the deposits of the Valentian, Wenlockian and Ludlovian, including the S. leintwardinensis zone, display close affinities and have their full equivalents. The difficulties that impede correlation of the upper parts of the Ludlovian and the Postludlovian result from an abrupt change in the sedimentary conditions which set in during the Upper Silurian, and for which the mountain-building movements of the Caledonian orogeny are fully responsible.

PALEOGEOGRAPHY AND FACIAL ZONES IN THE SILURIAN BASIN OF POLAND

During the Silurian, the Polish territory was occupied by a marine basin which had persisted since the Ordovician. This basin, consisting of two distinct zones, the epicontinental and the geosynclinal, had convenient communication routes with Western and Eastern Europe.

The epicontinental zone covered the whole Precambrian platform; within the Polish territory it passed into the geosynclinal zone, roughly along a line from Koszalin in the NW to Rawa Ruska in the SE. This line probably also indicates the present boundary of the Precambrian platform within the Polish territory (cf. fig. 1).

In what concerns the stratigraphy and the development of the Silurian deposits, the epicontinental zone is now that more adequately known. The Ordovician sedimentary cycle, characterized throughout the epicontinental zone by the predominance of sandy-marly-calcareous deposits, is shallow-neritic in character. A similar character of sedimentation persisted in some regions of Poland (the Łeba elevation, the Mazury-Suwałki elevation) until the lowermost Silurian, somewhere up to the Pristiograptus cyphus or Pristiograptus gregarius zone. The calcareous sediments laid down in the above regions were more shallow-water in character than those of the Upper Ordovician. They are represented almost exclusively by nodular limestones, up to 25 m thick.

In the axial parts of the depressions (western parts of the Peribaltic and the Podlasie depressions), the basin deepens and the facies changes into a more clayey one, while the sea floor slightly oscillates, chiefly above the Pristiograptus cyphus or the Pristiograptus gregarius zones. These oscillations are marked by intercalations of green calcareous mudstones occurring within black graptolite-bearing shales. Beginning with the upper part of the Valentian, sedimentation grows uniform and greenish mudstones containing chiefly graptolite plankton, predominate. The Lower Valentian rests conformably on the Ordovician, but very often, especially in the eastern part of the present Peribaltic syneclise, there is an erosional unconformity between the uppermost Ordovician and the lowermost Valentian. In the eastern parts of the present Podlasie and Bug depressions, Valentian deposits are missing, while the Lower Wenlockian rests directly on the Ordovician.

The Taconian phase of the Caledonian orogeny is probably responsible for the Lower Valentian oscillations, as well as for the erosional unconformity between the Ordovician and the Valentian (fig. 2). Sedimentary conditions attain their complete stability during the Wenlockian

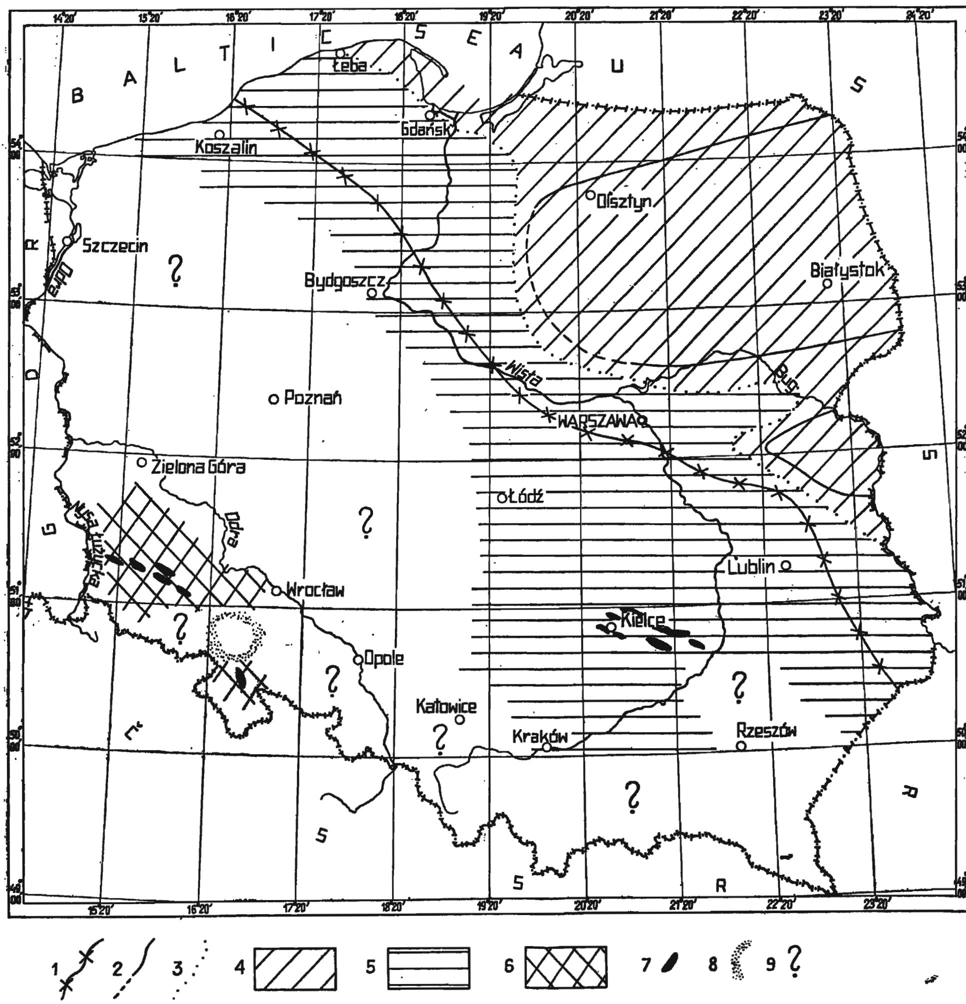


Fig. 2

Paleogeographic map of the Lower Valentian

1 probable boundary of the epicontinental and geosynclinal zones, *2* boundary of the observed range of deposits, *3* probable boundary of the range of facies, *4* limy-marly facies, *5* clayey facies, *6* siliceous-clayey facies, *7* deposits on the surface or those under a thin Quaternary cover, *8* probable boundary of areas mostly denuded, *9* lack of data and persist until the Lower Ludlovian, as far as the Saetograptus leintwardinensis zone. Mudstones, bearing a rich graptolite fauna, are the only deposits laid down in the gradually deeping basin throughout the epicontinental zone in Poland. In the shallower parts embracing the present Mazury-Suwałki depression as well as the eastern parts of the Podlasie the Peribaltic and the Bug depressions, the occurrence is noted of muddy-marly deposits with calcareous intercalations, while syngenetic

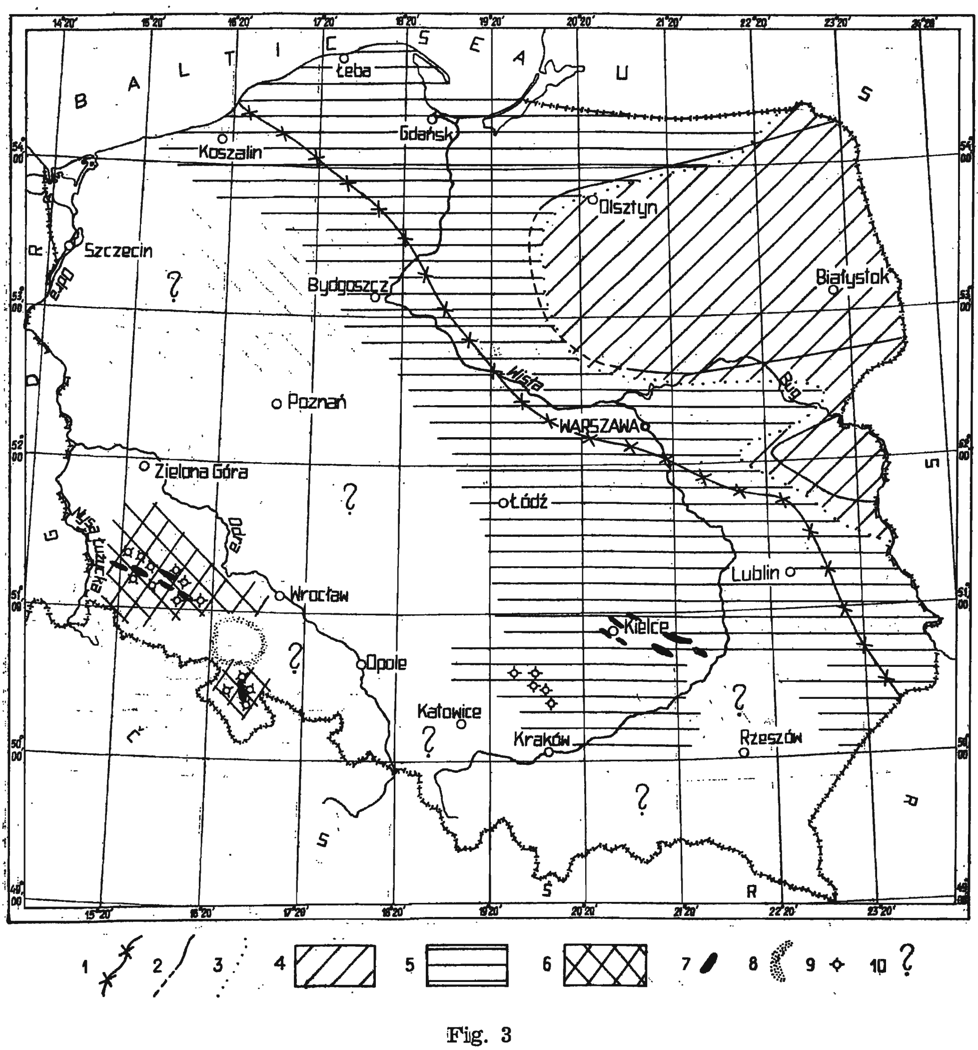


Fig. 3

Paleogeographic map of the Upper Valentian, Wenlockian and Lower Ludlovian

1 probable boundary of the epicontinental and geosynclinal zones, *2* boundary of the observed range of deposits, *3* probable boundary of the range of facies, *4* limy-marly facies, *5* clayey facies, *6* siliceous-clayey facies, *7* deposits on the surface or those under a thin Quaternary cover, *8* probable boundary of areas mostly denuded, *9* signs of Caledonian magmatism, *10* lack of data nodules of marly limestones (Langier-Kuźniarowa 1967) are quite common. On the whole, the thickness of the deposits decreases to the east from ca. 350 m in the western part of the Peribaltic depression to ca. 120 m in its eastern part and to about 150 m in the eastern part of the Podlasie depression (fig. 3).

Within the Saetograptus leintwardinensis zone, possibly just above it, mainly in the deeper parts of the epicontinental zone of Poland, the mudstone facies changes distinctly into a silty-muddy one and this is accompanied by an increase in thickness up to and even more than one thousand metres. The silty-muddy facies is chiefly confined from the Saetograptus leintwardinensis to the Neocucullograptus kozlowskii zones, but here and there it also overlaps the base of the Monograptus formosus horizon. The territory occupied by this facies covers the western part of the Peribaltic depression, as far as Pasłęk, and the western part of the Podlasie depression. The deposits that are the stratigraphic equivalents of the eastern parts of the two depressions just mentioned, are developed in a muddy-marly-limy facies.

The deposition of mudstones and marls is closely connected with the development of the geosynclinal zone. The period of uniform sedimentation lasted from the Upper Valentian until the Lower Ludlovian, and was characterized by lack of orogenic activities. It was followed by greater intensity of the mountainbuilding movements in the Caledonian geosyncline existing in the forefield of the Precambrian platform where the old-Paleozoic deposits had been folded up to and including the Lower Ludlovian. These folding resulted in a narrowing of the Silurian basin within the geosyncline, but the narrowing affected only the folded and uplifted areas. In some parts of the geosyncline, the sedimentation of Silurian deposits continued through the Gedinnian and their folding and emersion took place in the final phase of the Caledonian orogeny, i.e. during the Erian phase.

No regression or sedimentary break is observable during the Upper Ludlovian within the epicontinental zone. The emersed Caledonian externides are the alimentary area of their foredeep. This was subsiding rather rapidly and being filled up with material from the near-by land. The period of maximum erosion of the externides and of the accumulation of sediments in the foredeep occurs during the Upper Ludlovian, resulting in a siltstone-mudstone facies (fig. 4). At the close of the Ludlovian, with decreasing rate of erosion, sedimentation in the adjacent basin becomes stabilised. In the top of the Silurian deposits of the epicontinental zone, muddy sediments are again predominant in the deeper parts. An increase is noted in the carbonate content of deposits in the neritic zone which stretches over the same areas as during the Lower Silurian. The latter type of sedimentation continued within this area up to and including the Lower Devonian (Gedinnian).

No Silurian deposits, younger than the Monograptus formosus horizon, have so far been encountered in the Łeba elevation or in the Peribaltic depression within the Polish territory. In the Podlasie and the Bug depressions, the situation is somewhat different, since the presence has been observed of sediments younger than the Monograptus formosus horizon. In borehole Żebrak IG-1, the youngest adequately defined zone

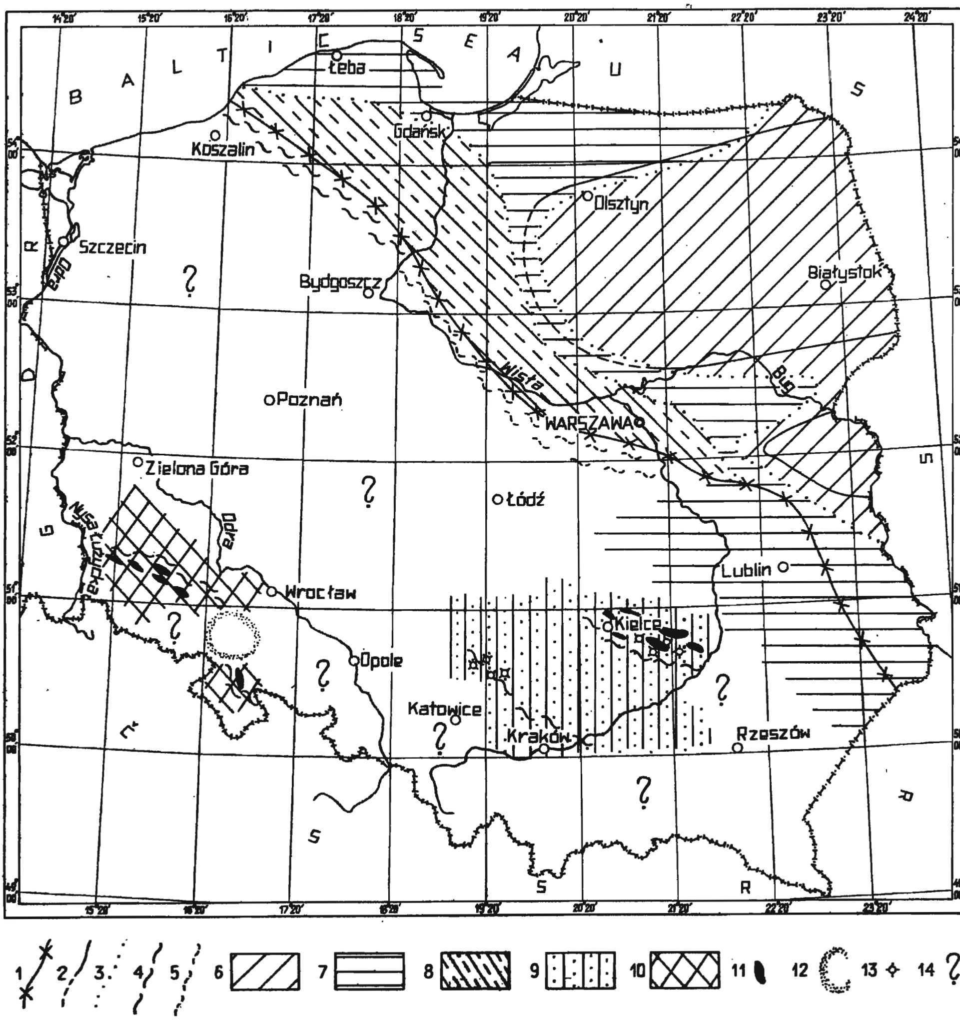


Fig. 4

Paleogeographic map of the Upper Ludlovian

1 probable boundary of the epicontinental and geosyclinal zones, *2* boundary of the observed range of deposits, *3* probable boundary of the range of facies, *4* zone of observed Caledonian foldings (Ardenian phase), *5* zone of probable Caledonian foldings, *6* limy-marly facies, *7* clayey facies, *8* silty-clayey facies, *9* clastic-greywacke facies, *10* siliceous-clayey facies, *11* deposits on the surface or those under a thin Quaternary cover, *12* probable boundary of areas mostly denuded, *13* signs of Caledonian magmatism, *14* lack of data i.e. Pristiograptus transgrediens, occurs below the Carboniferous, in borehole Mielnik IG-1 it underlies the Zechstein, while in borehole Chełm IG-1 the Carboniferous is underlaid by the Monograptus uniformis zone. This zone characterizes the lowermost Gedinnian and it is underlain in sedimentary continuity by Monograptus angustidens, i.e. the youngest Silurian zone.

The presence within the Podlasie and the Bug depressions of the uppermost Silurian members, as well as of the Gedinnian in the mudstone facies, reasonably suggest the occurrence of analogous deposits in the NW part of the Precambrian platform, too. These must have been eroded because the Zechstein sea directly overflooded the Silurian deposits (fig. 5). The presence of higher Silurian deposits than those observed in the area here considered is corroborated by the fauna found in pebbles of a transgressive Zechstein conglomerate (Kummerov 1944, Krömmelbein 1958, Martinsson 1964).

A sedimentary break of such long duration (Upper Silurian — Zechstein) is, however, hardly acceptable because it must have led to a much deeper erosional incision into the Silurian deposits than that which has been observed. It rather seems that the Silurian deposits of that part of the epicontinental zone here considered must have twice been subjected to erosion. The first of these erosional processes, rather short-lasting, may have occurred after the Gedinnian as the final effect of the activity of the Caledonian orogeny. This may have been responsible for a partial removal only of the Gedinnian sediments, possibly also the uppermost Postludlovian. It was followed by the Devonian transgression and the marine regime continued into the Lower Carboniferous. The second emersion, lasting until the Lower Permian, may have occurred after the Lower Carboniferous in result of events connected with the Variscan orogeny. And not only the post-Silurian cover was stripped off by this erosion, but also the Upper Silurian deposits, as far as the Monograptus formosus horizon.

The present Mazury-Suwałki elevation was overflooded during the Upper Silurian and also — after a brief emersion — during the Devonian and the Carboniferous. It formed one unit with the Peribaltic, the Podlasie and the Bug depressions. The uplifting of the Mazury-Suwałki elevation did not take place until the Lower Carboniferous, and its morphological picture closely resembled that of today. It was then that the present Bug depression was separated from the Podlasie depression by the Sławatycze horst which was partly denuded of its older deposits (Lendzion 1962; Suveizdis 1963, 1968; Znosko 1965; Żelichowski 1968). This event suggests greater intensity of the vertical movements and disjunctive tectonics.

The marine basin, then covering the epicontinental zone within the Polish territory, had convenient connections with the neighbouring areas.

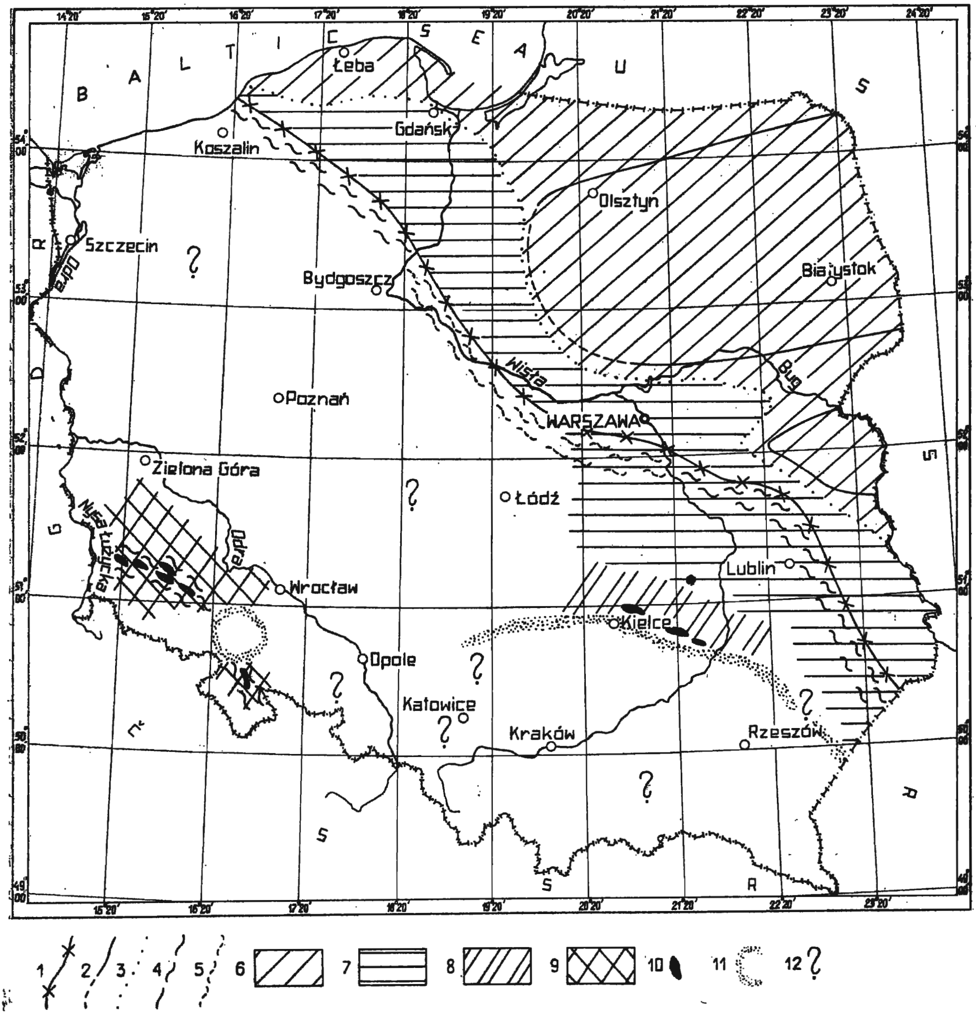


Fig. 5

Paleogeographic map of the Postludlovian

1 probably boundary of the epicontinental and geosyclinal zones, *2* boundary of the observed range of deposits, *3* probable boundary of the range of facies, *4* zone of observed Caledonian foldings (Erian phase), *5* zone of probable Caledonian foldings, *6* limy-marly facies, *7* clayey facies, *8* clayey-silty-limy facies (Rzepin Series), *9* siliceous-clayey facies, *10* deposits on the surface or those under a thin Quaternary cover, *11* probable boundary of areas mostly denuded, *12* lack of data

To the north and the north-east it stretched as far as the Baltic shield. Its range is indicated by the Silurian deposits in the Islands of Bornholm and Gotland (Hede 1942, Regnéll & Hede 1960), also in Estonia (Kaljo & Sarv 1966; Kaljo 1967, 1968), Latvia (Gailite 1964; Gailite, Rybnikova & Ulst 1967) and Lithuania (Paškevičius 1958, 1959, 1960, 1963, 1965), as well as by the sediments now covering the Baltic sea bottom (Martinsson 1960). To the east and south-east the epicontinental sea stretched across Western White Russia (Golubtsov & Makhnach 1961) and Western Volhynia (Krandievsky, Ishchenko & Kiryanov 1968), as far as Podolia, partly invading the Ukrainian shield.

The greater part of the above basin was relatively shallow, the neritic type of sedimentation prevailed, only some regions with a distinct tendency to subsidence were characterized by bathyal sedimentation. The deepest zones of the basin are in the NW, partly in the SE of Poland, and throughout the Silurian they tend to immersion. This is reflected by the great thickness of the Silurian deposits and their uniform development in the mudstone facies. A plausible explanation is here offered by the transition of the epicontinental basin — SW of the line from Koszalin to Rawa Ruska — into a geosynclinal basin where a changed regime set in and the prevailing conditions were different.

The geosynclinal zone, which covered the remaining area of Poland, is at present rather inadequately known. Its existence is confirmed by Silurian surface deposits in the Holy Cross Mts. and the Sudetes, as well as by the fragmentary profiles obtained from boreholes situated in the geosynclinal zone. The Silurian cycle of sedimentation here was affected by the varying conditions prevailing in the Caledonian geosyncline.

Along the deeply immersed SW margin of the Precambrian platform existed a Caledonian miogeosyncline where sedimentation of the Flysch type was taking place. Old Paleozoic sediments of great thickness, chiefly represented by mudstones with siltstone intercalations, were deposited here.

During the last years, reliably documented deposits of the Ordovician as well as of the Lower and Upper Silurian have been obtained from several boreholes in the Koszalin-Chojnice region (Dadlez 1967; Teller & Korejwo 1967, 1968a, b, c; Modliński 1968), as well as farther NW outside Poland, i.e. in the Island of Rügen (Franke 1967, Jaeger 1967). All these deposits are strongly folded and possibly also overthrust onto the Precambrian platform. Phyllites, probably Silurian in age (Czermiński 1967) underlie even the Devonian south of Koszalin.

In SE Poland, folded Postludlovian mudstones of great thickness have been encountered in borehole Ruda Lubycka IG-1 (Tomczyk 1962a, Teller 1964a) as well as in borehole Rawa Ruska (Sandler & Glushko 1955, Sandler 1965, Gurevich 1963) just beyond the Polish frontier. Folded Upper Silurian deposits are, moreover, known from borehole Kock IG-1 (Tomczykowa 1962b) and borehole Ciepielów IG-1 (Tomczyk 1968a). The tectonics in borehole Kock IG-1, is however, rather complicated because the borehole is situated within a tectonic horst, hence it cannot be quite certainly determined whether the disjunctive post-Caledonian tectonics or the fold tectonics of the Caledonian orogeny are responsible for the folding of the Silurian sediments. Znosko (1965), however, admits only the latter concept.

The presence of folded Silurian deposits in this part of Poland likewise suggests the existence here of a Caledonian miogeosyncline which had, however, persisted much longer here than in the North-East. The folding of the Koszalin-Chojnice region did not occur later than during the Ardennian phase. This is reliably indicated by the change in the character of the deposits which had been observed in the western parts of the Peribaltic and the Podlasie depressions, above the Saetograptus leintwardinensis zone (Znosko 1963, 1964, 1965; Dadlez 1967; Korejwo & Teller 1968b). Younger members of the Silurian or of the Gedinnian are, however, encountered within the geosynclinal zone of SE Poland, affected by the final events of the Caledonian orogeny, i.e. the Erian phase. Hence, it may be inferred that in this part of Poland, similarly as on the Precambrian platform, the Silurian cycle of sedimentation continued until the Lower Devonian. Neither can the occurrence of Ardennian fold movements within this area be altogether excluded. They did not necessarily cause complete emersions, possibly only a short break in sedimentation, followed again by the deposition of mudstones.

In the Holy Cross Mts., the Silurian, as far as the Lower Ludlovian, is developed in the mudstone facies. Only during the Valentian do intercalations of siliceous shales occur there, while siltstone and sandy intercalations or interbeddings are encountered in the region of Kielce. A change into a greywacke-shale facies throughout the Holy Cross Mts., at the boundary of the Lower and Upper Ludlovian, indicates young Caledonian diastrophism (Czarnocki 1919a, 1927, 1936, 1950; Samsonowicz 1926, 1934, 1952; Tomczyk 1962a; Znosko 1963, 1964, 1965). The Lower Devonian (Emsian), unconformably resting on the folded Upper Ludlovian, reasonably suggests the occurrence of the Ardennian phase in the region of Kielce, as well as a major sedimentary gap. This is likewise confirmed by subsequent Upper Silurian magmatism (Kowalczewski 1968a). In the Łysogóry region, the greywacke-shale facies grades upwards into a muddy one with limy intercalations. We are dealing here with a complete sequence of the Silurian deposits and a continuous transition into the Gedinnian.

The development of Silurian deposits in the substratum of the Carpathian foredeep is analogous with that in the region of Kielce. The occurrence of the particular members of that system below various younger members (Devonian-Jurassic) suggests a long duration of the erosional processes that affected the Silurian sediments (Karnkowski & Głowacki 1961, Tomczyk 1963a, Teller & Korejwo 1968b).

A 200 m thick greywacke-conglomerate complex, attained in boreholes Mikluszowice IG-1, Batowice IG-1, Łapczyca IG-2 is by Łydka, Siedlecki & Tomczyk (1963) believed to be a synorogenic sediment of the Cracovian phase which they distinguished and suppose to be older than the Ardennian phase. The above named complex indicates a near-by alimentary area in the south and this is confirmed by borehole Rzeszotary 2 (Burtan 1962) and other boreholes from the Bielsko-Andrychów region (Konior 1968).

Znosko (1965) connects the Silurian from both, the Holy Cross Mts. and the substratum of the Carpathian foredeep with a miogeosynclinal area, while he detects an eugeosyncline below the overthrust Carpathians.

The mudstone deposits of the Lower Ludlovian and the clastic-greywacke sediments of the Upper Ludlovian (Roszek & Siedlecki 1963, Siedlecki 1962), encountered in the eastern and north-eastern margins of the Silesia-Cracow depression, indicate not only a change in the facies but also the presence in this region of young Caledonian foldings.

Both in the Bardo and the Kaczawa Mts. of the Sudetes, the Silurian deposits display a distinctly geosynclinal character and locally, well expressed initial volcanism (Oberc 1966). Tectonically they are rather strongly disturbed and they have all — at various times and to a varying extent — been affected by the folding movements of the Caledonian orogeny. A more accurate reconstruction of these movements as well as of the Silurian sedimentary cycle is greatly hampered owing to the interlocking of younger tectonics with the older pattern.

It is hardly possible to make any statements concerning the nature of the Silurian deposits covered by younger sediments (Devonian-Quaternary) of great thickness, to the NW of the line Warszawa-Częstochowa, bacause just now that region is inaccessible for technical reasons.

As may be seen from the observations here presented, only a very inadequate picture can be given of the paleogeography and facial development of the Silurian deposits within the geosynclinal zone. There are no doubts, however, concerning the folding of the Silurian deposits by the young Caledonian movements, chiefly during the Ardennian and the final Erian phase. This is confirmed by the diastrophism and Upper Silurian volcanism of the Holy Cross Mts., as well as those of the substratum of the Carpathian foredeep and the diastrophism of the western parts of the Peribaltic and the Podlasie depressions. According to the data now available, the Taconian phase was marked by local shallowings or emersions and it lacked a fold-like character. Although Oberc (1966) accepts Taconian foldings within the geosyncline of the Kłodzko and Bardo regions, his suppositions do not coincide with the investigations of the present writer (Teller 1962a).

Today there are no doubts as to the existence of an eastern branch of the Caledonides which has been suggested by many explores (see

Znosko 1963) and which has now been confirmed in several boreholes in the Koszalin-Chojnice region (Dadlez 1967, Teller & Korejwo 1968b), as well as in SE Poland (Czermiński & Znosko 1967).

SILURIAN/DEVONIAN BOUNDARY IN POLISH PROFILES

The boundaries delimiting geological systems are among the most controversial problems in the geological literature. The problem of the Silurian/Devonian boundary is likewise one of those most widely discussed. During the last decade it has gradually become of paramount importance, so much so that five symposiums were organized to deal with this subject. The opinions expressed at the first conference in Prague (Prager Arbeitstagung 1960) suggested to place the Silurian/Devonian boundary in the top of the Monograptus hercynicus zone, its index form being then supposed to be the last representative of that animal group. Views contrary to this concept (Nalivkin, Gaertner — vide Prager Arbeitstagung 1960) were declared as lacking conclusive evidence.

Three concepts concerning the Silurian/Devonian boundary were advanced at the 1962 Symposium at Bonn; one coincided with that accepted in Prague, another one suggested placing this boundary in the top of the Monograptus ultimus zone, the third one at the base or the top of the Saetograptus leintwardinensis zone (Intern. Arbeitstagung 1962). Geologists from Great Britain, who attended the Bonn Conference, were all of the opinion that the top of the Ludlow Bone Bed in the stratotype profile of Wales should continue to indicate the Silurian/Devonian boundary (Walmsley, Shirley, Straw, Holland, Lawson — vide Intern. Arbeitstagung 1962). Other view expresses at Bonn (Boucot & Pankiwskyj 1962, Jaeger 1962, Walliser 1962) suggest that both the brachiopod and the conodont faunas confirm the Gedinnian or even the Lower Siegenian age of *Monograptus hercynicus* Perner.

The latter concept gains ground with the publication of further evidence (Alberti & Hollard 1963; Berry 1964, 1965; Teller 1964b; Walliser 1964, 1966), while the finds of graptolites younger than *M. hercynicus* Perner depreciate the earlier opinions on the vertical range of that group of fossils (Jackson & Lenz 1963, Legrand 1964, Planchon 1964, Bouček 1966).

Discussions at Rennes (Colloque 1965) were confined to the correlation of the basic facial regions, no suggestions were made concerning the Silurian/Devonian boundary.

At the Symposium at Calgary (Report 1968) the prevailing opinion was that the Silurian/Devonian boundary ought to be placed at the bottom of the Monograptus uniformis zone, additional paleontological evidence being brought forward in support of this concept (Abushik; Berry; Bouček, Chlupač & Horny; Lenz; Maximova; Nikiforova, Predtechensky & Abushik; Philip; Stukalina — vide International Symposium 1967).

Analogous views were expressed at the 1968 Symposium at Leningrad (Abstracts 1968) where the need was stressed of further more detailed investigations which would permit to define and select a stratotype profile for the Silurian/Devonian boundary.

Among the British authors there is a tendency to have the Silurian/ /Devonian boundary shifted upwards (Allen & Tarlo 1963, Tarlo 1964, Holland 1965, Earp 1967, Potter 1968).

A number of other authors have published their views on this problem; these either coincide with or closely resemble the concepts accepted at Leningrad (Bouček, Horny & Chlupač 1966; Přibyl & Vaněk 1968; Sokolov & Polenova 1968; Halfin 1968). The growing interest, now being taken in the problem of this Silurian/Devonian boundary, has led to results that were perhaps initially unexpected but have certainly suggested some clues to an objective solution.

In Poland, the problem of the Silurian/Devonian boundary is gaining ground as new materials are obtained while the evolution of opinions resembles that in other countries (Teller 1959, 1960b, 1964a, b, 1968; Tomczykowa & Tomczyk 1961; Tomczyk 1962a, 1968b).

Tomczyk (1962a, 1962b) is the only one to postulate that graptolites, the genus *Linograptus* excepted, do not pass into the Devonian. He places the Silurian/Devonian boundary in the top of the Monograptus angustidens zone, while such forms as *Monograptus uniformis* Přibyl and *M. hercynicus* Perner are referred by that author to the Monograptus formosus horizon.

The boundary beds are traceable in very few Polish profiles, namely in three boreholes: Chełm IG-1, Ciepielów IG-1 and Kock IG-1. Of the two other profiles where these beds are observed, one is situated in the Łysogóry region of the Holy Cross Mts., the other one in the Sudetes.

In borehole Chełm IG-1 (Teller 1964a, b, Korejwo & Teller 1964) there is a continuity of sedimentation from the Silurian to the Devonian, in the graptolite facies; the boundary is indicated by the base of the M. uniformis zone which is underlain by the Monograptus angustidens zone, the youngest one in the Silurian system. *M. uniformis* Přibyl occurs in association with *Acastella tiro* R. & E. Richter. Strictly speaking this is the only one, paleontologically well define profile, though the boundary itself may be regarded by some authors with a certain amount of hesitation.

On the basis of materials from Podolia, Koreń (1967) suggests that *M. angustidens* Přibyl may possibly be a subspecies of *M. uniformis* Přibyl. In borehole Chełm IG-1, these two forms are readily distinguishable and they differ sufficiently to justify their specific separation (Teller 1964a, Korejwo & Teller 1964).

In borehole Ciepielów IG-1 the Silurian/Devonian boundary has been placed in the top of the M. angustidens zone at a depth of 2,598.3 m, because higher up the presence of trilobites (Tomczyk 1968b) and of tentaculites (Hajłasz 1968) indicates the Gedinnian age of the deposits. The situation in this borehole is not fully cleared up, hence there are some doubts whether the boundary has been correctly placed (comp. also p. 461).

Neither has the boundary been accurately established in borehole Kock IG-1 (Tomczykowa 1962b). No graptolites have been encountered here, while *Acastella heberti elsana* R. & E. Richter is the only form suggesting the Gedinnian age of the sediments between the depth of 810 and 814 metres. Owing to the lack of reliable paleontological evidence it is hardly possible to establish whether the underlying deposits, down to a depth of 1010 m, represent the uppermost Silurian or still the Gedinnian.

In the Holy Cross Mts. the Silurian/Devonian boundary is indicated by the base of the Bostów beds which, together with the Rzepin series, were referred to the Devonian both by Czarnocki (1936) and later on by Samsonowicz (1952). The Gedinnian age of the Bostów beds is confirmed by Tomczykowa (1962b) when she reported a number of trilobite species known from the Huinghäuser beds in the Rhine Province (R. & E. Richter 1954). Owing to the lack of outcrops between the Bostów beds and the Rzepin series, it is hardly possible to trace the boundary.

We meet with the same difficulties in the Sudetes where the accessible profiles are strongly tectonically disturbed (Teller 1959, 1960c). In spite of the lack of paleontological evidence testyfying to the presence in this area of the uppermost Silurian, a continuity of sedimentation from the Silurian to the Devonian may be reasonably supposed in the graptolite facies. This may be likewise indicated by the occurrence of *Monograptus hercynicus* Perner observed in the Bardo Mts. (Teller 1960c) and in the western Sudetes (Jaeger 1964a, b).

The facts here presented throw a light on the difficulties encountered in the search for a solution of the Silurian/Devonian boundary problem in Poland. However, the data now available reliably confirm the current opinion that this boundary should be placed at the base of the M. uniformis zone (Teller 1968a). Moreover, it may be reasonably expected that future borehole material will help satisfactorily to solve this problem in Poland, too.

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BIOSTRATYGRAFIA SYLURU POLSKI W OPARCIU O GRAPTOLITY

(Streszczenie)

W pracy omówiono dotychczasowy stan znajomości osadów systemu sylurskiego w Polsce, głównie na podstawie danych z wierceń oraz przedstawiono ich biostratygrafię w oparciu o faunę graptolitową. Charakterystyka osadów sylurskich ujęta została regionalnie, zgodnie z wyróżnianymi na obszarze Polski jednostkami strukturalnymi, dla strefy epikontynentalnej i geosynklinalnej. Bogata fauna graptolitowa pozwala rozpoziomować cały system sylurski w Polsce na zony, które zgodnie z przyjętymi regułami zdefiniowane zostały po raz pierwszy. Łącznie w osadach syluru polskiego wydzielono 42 zony, w tym dla walentu 12, spośród których najmłodsza rozbita jest na dwie podzony; dla wenloku 8; dla ludlowu 13, w tym cztery ujęte są w jeden przewodni horyzont; dla postludlowu 9 oraz jeden horyzont, mogący ulec dokładniejszemu rozpoziomowaniu po szczegółowym opracowaniu fauny graptolitowej. Przyjęty w pracy schemat podziału systemu sylurskiego aż po piętro ludlow włącznie, nawiązuje do ustaleń międzynarodowych. Osady młodsze od ludlowu a starsze od żedynu, nie posiadające formalnie swego stratotypu ani też nazwy, ujęte zostały w pracy pod nazwą postludlow. Przeprowadzona korelacja osadów sylurskich Polski z innymi, lecz tylko blisko położonymi obszarami wykazała, że profile polskie charakteryzują się pełnym następstwem stratygraficznym szczególnie w facji graptolitowej. Przechodzi ona nawet miejscami do dolnego dewonu (żedynu), co stawia Polskę w rzędzie ważnych regionów dla studiów nad rozwojem fauny graptolitowej w środkowej Europie. Paleogeografia systemu sylurskiego jak i rozwój facji wskazują nie tylko na ścisłe związki z obszarami przyległymi, lecz również na przebieg zjawisk natury tektonicznej. Przyjęta granica sylur/dewon jest zgodna z przyjmowaną obecnie w literaturze światowej.

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