

LECH TELLER

On the stratigraphy of beds younger than Ludlovian and the Silurian-Devonian boundary in Poland and Europe

ABSTRACT: The age of strata younger than Ludlovian is discussed. In the Polish and the European literature they are referred to the Silurian but at the same time they are incorrectly correlated with the typical Ludlow of England. In the writer's opinion these strata, being younger than Ludlovian, seem to deserve a separate name — the equivalent of a stage — whereas this stage should be included into the Silurian. The writer postulates that the Silurian-Devonian boundary be established in the top of the *Monograptus hercynicus* zone, and he suggests a revision of that boundary as established by R. I. Murchison.

INTRODUCTION

The correct determination of the stratigraphy of beds younger than Ludlovian throughout Europe, on the base of bio- or lithostratigraphic evidence, has lately aroused a great deal of interest. This is connected with the problem of the reconstruction of the Caledonian cycle of orogeny as well as with the recognition of criteria on which the Silurian-Devonian boundary could be conclusively established.

Controversial interpretations and concepts regarding the division of strata younger than Ludlovian and the Silurian-Devonian boundary are encountered in numerous papers dealing with these problems (Prager Arbeitstagung, 1960; Symposiums Band Bonn, 1962, etc.).

Many authors (A. J. Boucot, O. H. Walliser, H. Jaeger — Symposiums Band, 1962) suggest that on evidence provided by some groups of animals (brachiopods, trilobites, conodonts, fishes) the European beds younger than Ludlovian should be more closely associated with the Gedinnian; moreover they are inclined to include the Gedinnian into the Silurian. Such suggestions evidently undermine previous opinions on the Silurian-Devonian boundary.

The increasingly extended geological investigations in Poland have provided much valuable borehole material enabling the Polish geologists

to join the discussion on the above mentioned problems. The greater part of the material obtained from various parts of Poland during the last years has not as yet been thoroughly worked out. This impedes more detailed conclusions or the drawing up of accurate faunal inventories. Nevertheless, the descriptions that have already been prepared allow tentative inferences of a more general character. These will no doubt be useful to specialists in the above problems, both for the interpretation of their own achievements or the correlation of their sections with those from Poland.

A detailed stratigraphic analysis of beds younger than Ludlovian was carried out by the writer in 1961. This paper has not so far been published whereas additional facts have been established during the two past years and a comprehensive work on this subject was published by H. Tomczyk (1962). Hence, an attempt is here made to throw new light on the stratigraphy of beds younger than Ludlovian, and to convey the writer's views concerning the Silurian-Devonian boundary.

The most cordial thanks are due to Professor Dr. E. Passendorfer under whose guidance the paper has been prepared, for his continuous help and valuable suggestions.

Mrs. J. Humnicka has to be thanked for the English translation of the paper.

A HISTORICAL SKETCH OF THE STUDY OF STRATA YOUNGER THAN LUDLOVIAN IN POLAND

In Poland beds younger than Ludlovian are known from natural outcrops in the Holy Cross Mts. and the Sudety Mts. (Bardo and Kaczawa ranges). They have, moreover, been found in a number of boreholes in northern, eastern and southern Poland. So far their current stratigraphic definition is Upper Ludlovian and they are included into the Silurian.

J. Czarnocki (1919, 1936, 1942, 1957) and J. Samsonowicz (1916, 1934) were the first to investigate these strata while H. Tomczyk (1956, 1960) continued these studies with particular stress on their graptolite fauna. The present writer is interested in a but slightly known greywacke-shale series which he has been studying since 1955, whereas the non-graptolite fauna — chiefly trilobites — is being investigated by E. Tomczykowa (1957, 1958). In a paper published in 1962 H. Tomczyk gave a synthetic summary of the investigations undertaken by E. & H. Tomczyk, but other papers have also been published by them on this subject. In addition to the pre-war descriptions of the Sudety Mts. by German authors (E. Bederke 1924; F. Dahlgrün & L. Finck 1924; E. Dathe 1904 etc.) the Silurian stratigraphy of that area has been studied in the post-war period by J. Malinowska (1955) and L. Teller (1960a). Their

investigations have provided new information leading to the establishment of a more accurate stratigraphy of these beds.

The Chelm borehole, the first in which Silurian sediments have been reached, is described by L. Teller (1960b, 1961). Additional boreholes are being elaborated by H. Tomczyk and L. Teller. A synthesis of the stratigraphy of some boreholes has been published by Tomczyk (1962) but no detailed descriptions have as yet been made.

Important palaeontological investigations on the development of the borehole graptolite fauna are now being carried out by A. Urbanek (1960, 1963).

It may be expected that in the course of the next years further studies will contribute to the knowledge of these strata and provide interesting evidence for the establishment of a more detailed stratigraphy of the Silurian system.

LATEST DATA ON THE STRATIGRAPHY OF POLISH BEDS YOUNGER THAN LUDLOVIAN

In order to avoid misunderstandings the writer wishes to give first an accurate explanation of the term "strata younger than Ludlovian" in the meaning used here. It defines deposits occurring between the top of the *Monograptus formosus* zone and the top of the *M. hercynicus* zone. In relation to the section from England these deposits are the time-equivalent of the Downtonian (C. H. Holland, J. D. Lawson & V. G. Walmsley 1963).

In the Holy Cross Mts. this part of the section is developed as greywackes, greywacke silstones, sandstones, locally as limestones. J. Czarnocki (1936, 1942) distinguished these strata under the name of the Rzepin and the Bostów beds. The fauna they contain is represented chiefly by brachiopods, lamellibranchs, trilobites and other groups whose detailed descriptions will enable their correlation with other sections from Poland and outside of it. Fossils characteristic of these beds are quoted by H. Tomczyk (1962, p. 16-17) after E. Tomczykowa.

The Żdanów beds, developed as varicoloured shales, locally intercalated with greywackes, are the time-equivalent of these beds in the Sudety Mts. In the top they contain thin intercalations of argillaceous and siliceous shales which so far have yielded graptolites from the two youngest zones, i.e. the *Monograptus praehercynicus* and *M. hercynicus* zones. No other fauna has been encountered in these beds.

Within the margin of the East-European platform (Tomczyk 1962) the facial development of these deposits differs from that observed in the two above named areas. In the platform they are represented almost exclusively by claystones bearing a rich graptolite fauna, side by side with an abundance of other fossils. These fossil remains have been found in boreholes, the most complete section being that from the

Chełm borehole. It is there palaeontologically documented from the zone of *Pristiograptus bugensius* to that of *Monograptus uniformis* (Teller 1961). The sections from borehole Ruda Lubycka and borehole Żebrak (Teller 1961, Tomczyk 1960, 1962) are less important in view of their poorly preserved fauna and incomplete development.

The above characteristics of beds younger than Ludlovian, though very synthetic, reasonably suggest that two separate lithofacial regions may be distinguished in Poland. One is an area with the predominance of clastic sediments (the Holy Cross Mts., and the Bardo Mts.), while an argillaceous facies dominates in the other area (Polish Lowland). The stratigraphy of the two regions is based substantially on different groups of animals (the Sudety Mts. excepted) and these beds have not so far been well correlated. Hence, the paramount problem here is the correlation of the beds of Rzepin and Bostów from the Holy Cross Mts. with their stratigraphic equivalents from the Polish Lowland, and with the Żdanów beds from the Bardo Mts.

The value of graptolites in determining the Silurian stratigraphy is commonly known, moreover the differentiated graptolite zones may be readily correlated over wide areas. The graptolite fauna obtained from the Chełm borehole is so abundant that by virtue of its description (Teller 1961) it was possible, for the first time in Poland, to differentiate not only zones that have been previously recorded from the Barradian basin, but several new ones, too. Hence, on the basis of the tectonically undisturbed section from the Chełm borehole it was possible to make a detailed stratigraphic division of the beds here considered. The division is documented by graptolites from the *Pristiograptus bugensius* zone — which is directly younger than the *Monograptus formosus* zone — up to the *M. uniformis* zone. Unfortunately this section is not comparable with the beds of Rzepin and Bostów as these contain hardly any graptolites that are such reliable correlation fossils. The sporadic finds from the Rzepin beds have a small stratigraphic value as the graptolites there are specifically unidentifiable owing to their poor state of preservation. Hence it is not the graptolite fauna but the non-graptolite fossils that must be taken into account here, in the first place brachiopods, trilobites and lamellibranchs as these groups are associated with graptolites in the Chełm borehole, and, moreover, they occur in considerable abundance in the beds of Rzepin and Bostów.

Brachiopods, though numerous in the beds of Rzepin and Bostów, need to be thoroughly worked out in order to become useful for correlation, possibly with other boreholes, as in the Chełm borehole they are inadequately preserved.

Trilobites are a group of great value for correlation. The following forms are mentioned from the Rzepin beds by H. Tomczyk (1962) after

E. Tomczykowa: *Proetus conspersus* (Ang.), *Calymene* cf. *beyeri* R. & E. Richter, *C. blumenbachii* Brong., *Homalonotus knightii* König., *Acaste* cf. *dayiana* R. & E. Richter, *Acastella spinosa* (Salter), *Scotiella samsonowiczi* E. Tom., and *S. opatowiensis* E. Tom. The forms mentioned from the Bostów beds are *Acastella tiro* R. & E. Richter, *Cyphoproetus rugosus* Bouček, *Digonus roemeri* (De Kon.) and *Treveropyge ebbae* (R. & E. Richter).

None of the Rzepin forms have been found in the Chełm borehole. The presence, however, in the Chełm borehole of the form *Monograptus uniformis* together with *Acastella tiro* is markedly significant. These two forms occur in the same core sample from the top part of the Silurian in the Chełm borehole at a depth of 1208.6-1209.9 m.

It seems a noteworthy fact that the side-by-side occurrence of these two forms at Chełm is the first ever reported from any part of the globe. No graptolites have as yet been obtained either from the Hüinghäuser beds of the Rhine province, which are the locus typicus of that form (R. & E. Richter 1954), or from the Bostów beds in Poland.

Two horizons have been distinguished in the Hüinghäuser beds (R. & E. Richter 1954). The lower one is characterised by the presence of the index fossil *Acaste* (*Acastella*) *heberti elsana*, the higher one by that of *Acastella tiro*. The underlying Köbbinghäuser beds do not, unfortunately, display an unbroken continuity with the overlying strata. This is due to the existence of a more closely indeterminate stratigraphic gap which is responsible for the inaccurate definition of the bottom of the Hüinghäuser beds. The Bredeneck beds that occur in the top of the Hüinghäuser beds are without major stratigraphic significance, although *Acastella tiro*? is mentioned from them by R. & E. Richter.

A. tiro occurs at Chełm in the bottom part of the *Monograptus uniformis* zone while the underlying *M. angustidens* zone is quite as well faunally documented — except for the absence of trilobites. Therefore, it may reasonably be inferred that the lower horizon of the Hüinghäuser beds — which, after R. & E. Richter contains the form *elsana* — corresponds to the *M. angustidens* zone, while the lower horizon with the form *tiro* corresponds to the *M. uniformis* zone. It is not excluded that *M. hercynicus*, the youngest graptolite zone, is the equivalent of the top part of the *tiro* horizon, though it may possibly also embrace the bottom of the Bredeneck beds.

The Bostów beds of the Holy Cross Mts. have not as yet been adequately subdivided, neither has a boundary been clearly fixed between the lower Rzepin beds and the overlying Klonów beds. This is undoubtedly due to the inaccessibility of these beds otherwise than through earth works. On the presence there of the form *Acastella tiro* they may be recognised as partly corresponding to the *Monograptus*

uniformis zone. The presence of the form *Cyphoproetus rugosus*, which has been described from an analogous graptolite zone of the Lochkov beds in the Barrandian basin, confirms this supposition.

In the writer's opinion there is hardly any conclusive evidence in support of E. & H. Tomczyk's (1962) hypothesis that

"deposits, containing faunal elements referable to horizons which overlie or underlie the Přidol beds, have been assigned to the Lochkov beds and to their Barrandian equivalents".

Moreover, the present writer is convinced that geologists who have personally inspected the Silurian sections in the Barrandian basin will not question the fact that the Lochkov beds overlie the Přidol beds.

An analysis of the occurrence of *Acastella tiro* shows that the Hüinghäuser beds as well as the Bostów beds may be the time equivalents of graptolite zones from the *Monograptus angustidens* to the *M. hercynicus* zone. Hence, the Rzepin beds being older, should correspond to the zone of *Pristiograptus bugensius* to *Pr. transgrediens* inclusively. As is already stated above, no trilobites have been encountered in these graptolite zones from the Chełm borehole. They do, however, contain a rich lamellibranchian fauna whose description has been given by K. Korejwo & L. Teller (1964). Indeed, some of the genera and species there are identical with those found by the above authors within the Rzepin beds. A more precise correlation of these beds with graptolite zones cannot be made before the collected fossil remains have been worked out.

AGE OF DEPOSITS BETWEEN THE *PRISTIAGRAPTUS BUGENSIUS* AND *MONOGRAPTUS HERCYNICUS* ZONES

The age determination of deposits occurring between the *Pr. bugensius* and *M. hercynicus* zones is another, as yet unsolved, question. In the foregoing chapter these deposits are dated as younger than Ludlovian, and they are said to be the time equivalent of the English Downtonian.

In the European literature, dealing with the Upper Silurian, all deposits bearing graptolites, or other Silurian-like faunas, have for a long time been correlated with the Ludlovian beds of England. It was not, indeed, until quite recently that new investigations revealed that the Ludlovian age had often been incorrectly assigned to younger deposits. A question thus arises whether these younger deposits are referable to the Silurian (since after R. I. Murchison (1835) the Silurian ends in the bottom of the Ludlow bone bed), or possibly to the Devonian. Some of the latest papers concerned with this problem are discussed below.

In England (C. H. Holland, J. D. Lawson & V. G. Walmsley, et al., 1962), it is currently held that the Silurian system as well as its Ludlovian stage — recently raised to the rank of series — (C. H. Holland, J. D. Lawson & V. G. Walmsley 1963) are to be interpreted according to R. I. Murchison's (1835) concept. Hence, beds younger than Ludlovian are assigned to the Downtonian, i.e. the Lower Devonian. The boundary between these two systems runs in the bottom of the Ludlow bone bed which may be readily traced in Wales only.

On evidence of the lower Gedinnian brachiopod faunas from Belgium and on descriptions of the Podolian fossils by R. Kozłowski (1929) and O. I. Nikiforova (1954), A. J. Boucot (1960, 1962) was led to infer that the Skała beds of Podolia are post-Ludlovian but pre-Gedinnian. In correlation with England they correspond to the Ludlow bone bed and the lower part of the Downtonian, while the beds of Borszczów and Czortków are referred by A. J. Boucot to the Gedinnian.

The sections from Kellerwald, Thuringia, Vogtland and Czechoslovakia, which have been found to contain the *Monograptus hercynicus* zone, are by H. Jaeger (1962) incorporated not only into the Gedinnian but even into the Middle Siegen of the Ardennes. According to that author the Lower Downtonian of England, being post-Ludlovian in age, corresponds to the *M. ultimus* — *M. uniformis* zones from the Barrandian basin, while the upper part of the Downtonian, the whole Dittonian, and the lower Breconian horizon with *Pteraspis dunensis*, are the equivalents of the *Monograptus praehercynicus* and *M. hercynicus* zone from Thuringia and Czechoslovakia. Jaeger regards the age of deposits younger than Ludlovian as an open question but he is in favour of placing the Silurian-Devonian boundary in the top of the *M. hercynicus* zone.

O. I. Nikiforova & A. M. Obut (1962) claim that the Skała beds of Podolia correspond to the whole Ludlow of England and suggest the introduction of a new stage for the beds of Borszczów and Czortków which are younger than Ludlovian. This Tyras stage, commonly assigned to the Silurian, is said to be the time equivalent of the Lochkov beds from Czechoslovakia. In relation to England it would represent a stratigraphic gap, not accurately defined by the above authors — above the Upper Ludlow and below the Downtonian. It seems probable that it is the Ludlow bone bed they had in mind.

R. Horny (1962) states that the beds of Kopanina coincide in age with the Ludlovian beds of England, while the beds of Přidol and Lochkov, being younger, correspond to the Downtonian. This is included into the Gedinnian, the latter being in turn incorporated into the Silurian.

The present writer's suggestion concerning the age of deposits

discussed by him in 1961 is to tentatively regard it as Upper Ludlovian until this problem is definitely solved.

Beds that correspond to those of Rzepin and are enclosed between the bottom of the *Pristiograptus* cf. *fecundus* zone and the top of the *Monograptus angustidens* zone are by H. Tomczyk (1962) dated as Upper Ludlovian. He refutes the opinion of other geologists that the graptolite zones of *M. uniformis*, *M. praehercynicus* and *M. hercynicus* in Poland, Czechoslovakia, Thuringia and other areas occur above and are younger than the *M. angustidens* zone. Consequently that author places the Silurian-Devonian boundary in the top of the *M. angustidens* zone, i.e. "at the end of the occurrence of the last graptolites".

Even the above but brief review of the more important papers concerning the age of deposits younger than Ludlovian shows that a solution of this problem is very much needed.

With reference to the graptolite and non-graptolite sections in Poland, most particularly to that from the Chełm borehole, the present writer wishes to give here his opinion on this subject.

There is no doubt that the paramount prerequisite for the correlation of any beds is the correlation with the classic development area. Indeed, similarly as in the case of zoological nomenclature, a classic area has the right of priority. Wales is the classic area for the Ludlovian stage comprising the Eltonian, Bringewood, Leintwardine and Whitcliffe beds (or stages). Holland, Lawson & Walmsley's proposition to regard the Ludlovian as a series calls for recognition by an International Commission. The term Ludlovian stage was introduced by R. I. Murchison (1835) and the inclusion into it of younger or older deposits is contrary to binding regulations.

In the graptolite facies of Poland it is the *Gothograptus nassa* — *Monograptus formosus* zones that correspond to the Ludlovian stage thus conceived, in the non-graptolite facies it is the Wydrzysów beds of the Holy Cross Mts. and the lower part of the Żdanów beds in the Bardo Mts. Younger than the English Ludlovian are beds delimited by the graptolite zones of *Pristiograptus bugensius* and *Monograptus hercynicus* in the bottom and top respectively of the graptolite facies, the beds of Rzepin and Bostów in the Holy Cross Mts. and the remaining part of the Żdanów beds from the non-graptolite facies of the Bardo Mts. They cannot, therefore, be correlated with the Ludlow of England. They are the time equivalents of the Downtonian which — as already mentioned here — is currently regarded by English authors as Devonian. What age should, therefore, be assigned to beds younger than Ludlovian? The Devonian or the Silurian? The reply to this question is extremely complex and may vary depending on the area and the criteria we use.

If our speculations are based on sections with a predominance of

graptolite fauna we must admit that there are no sound reasons for subdividing the graptolite zones or for an artificial breaking up of the evolutionary line of this reliable group of fossils. In Poland a continuity of sedimentation has been found in a number of boreholes, from the zone of *Pristiograptus vulgaris* to at least that of *Monograptus boučeki* or *M. perneri* — in the Chełm borehole even to the *M. uniformis* zone. The particular genera and species are closely interlocked; above the *M. formosus* zone the graptolites still occur in great abundance and these younger graptolite zones cannot be referred to the Devonian. Hence, the graptolite fauna reasonably indicates that beds younger than the typical English Ludlovian, i.e. beginning with the *M. formosus* zone, are still referable to the Silurian and not to the Devonian. The same inferences may be drawn when analysing the Barrandian sections, even though these sections lack a continuity.

Other fossils in Poland, associated with graptolites, particularly brachiopods, lamellibranchs and trilobites, are more Silurian than Devonian in character. The appearance within the upper parts of these series of elements of the Gedinnian fauna does not provide conclusive evidence for its assignment to the Devonian. It is not excluded that beds in some areas (the Rhine province, Belgium) commonly referred to the Gedinnian still belong to the Silurian, though they yield no graptolite fossils.

Indeed, an analysis of the facial character — not only of the Polish deposits younger than Ludlovian — suggests their closer connections with the Silurian than with the Devonian, (e.g. continuity of the graptolite facies). Evidently the facial development depended on local conditions, the Caledonian orogeny that developed here being one of the decisive factors. Nevertheless, in areas not subjected to the Caledonian orogeny, distinct facial changes are not observable until the Upper Gedinnian.

Thus, the facial and faunal development in Poland and Europe indicate that younger deposits above the typical Ludlow beds certainly do not belong to the Devonian but still to the Silurian. At the same time they are the time equivalents of the Downtonian of England. Now, since on the basis of R. I. Murchison's Silurian-Devonian boundary the Downtonian is currently referred to the Devonian, the question arises whether this boundary is also correct with reference to European sections.

Another open question is the establishment of the stratotypical section of deposits younger than Ludlowian, and the choice of a name for this series of deposits. Some of the prerequisites for a stratotypical section are:

- 1) continuity of sedimentation between the younger and older deposits, also their marine facial development;

- 2) sufficient palaeontological documentation, not based on a single or a selected faunal group but on a whole faunal assemblage;
- 3) easy access to the section;
- 4) accurate correlation with other areas.

Obviously, the discovery of such a section is extremely difficult and it is hardly to be expected that any one section will meet the above requirements which the writer believes to be of utmost importance.

Within the Barrandian basin, in spite of the apparent continuity of sedimentation, sections of this series display considerable stratigraphic gaps. In Thuringia, on the other hand, there is no reliable palaeontological documentation of the complete section of beds younger than Ludlovian because the ochre limestone does not as a rule contain any index fossils. Neither can the Downtonian section in England be taken into account because it does not represent typically marine deposits and is but poorly palaeontologically documented. In Poland, continuity of sedimentation of marine deposits does occur in the Łysogóra area of the Holy Cross Mts., but detailed palaeontological descriptions of that region are still lacking and, moreover, the exposures in that series are rather poor. Neither do boreholes in the Polish Lowland meet the necessary requirements.

In the writer's opinion the Podolian section is the only one that merits being taken into consideration. A detailed palaeontological description of that section is, however, needed, particularly because following the hints of Professor R. Kozłowski (oral communication) graptolites have recently been discovered in the Borszczów beds.

Sections from Arctic Canada or Australia may possibly also be reliable, but our knowledge of these regions is still inadequate.

The selection of a suitable section and of a name for the series between the Ludlovian and the Devonian is, therefore, an open question. The writer thinks that it calls for international discussion with the cooperation of all interested specialists.

SILURIAN-DEVONIAN BOUNDARY

In many European Silurian areas (England, Germany, Czechoslovakia, U.S.S.R., Poland), the Silurian-Devonian boundary is not accurately established and correlation is very difficult. Doubtless, this is due to local facial development of the border beds as well as to the fauna they contain.

English investigators accept the boundary established by R. I. Murchison. It is based on the well defined and widely spread "Ludlow bone bed" which constitutes the bottom of the Downtonian. In correlation with the European continent, however, this boundary seems somewhat uncertain and its reliability may cause hesitations:

1. No equivalents of the "Ludlow bone bed" have so far been found anywhere in Europe, hence there are no points for correlation.

2. There is no certainty as regards continuity of sedimentation between the underlying Whitcliffe beds and the overlying Downtonian. Perhaps the Ludlow bone bed represents only a fragment of a series of deposits that were denuded prior to the deposition of the Downtonian. A stratigraphic gap of a more closely indeterminate duration may, therefore, exist between the Ludlow and the Downtonian.

3. The facial change itself that occurred between the Ludlow-Downtonian boundary cannot provide conclusive evidence for the determination of the Silurian-Devonian boundary since this change was caused by the Caledonian orogeny. In other European areas this orogeny may not have occurred at all or its activity may have been so limited that it caused no observable changes. The Holy Cross Mts. may be cited as an example. In the eastern part of that area the change of the graptolite facies into the greywacke-shale facies occurs already in the *Lobograptus scanicus* zone, while in the western part it occurs above the *Saetograptus leintwardinensis* zone (H. Tomczyk 1956). No facial change is, however, observable in the Polish Lowland; sedimentation of the graptolite shales continued throughout the Ludlovian as well as in younger beds.

The criteria used for determining the Silurian-Devonian boundary in England are probably correct for Wales, they cannot, however, be taken into account for other European sections. In the writer's opinion the typically Silurian character of beds younger than Ludlovian speaks in favour of a revision of the boundary that was established for England by R. I. Murchison.

The aim of the 1958 conference in Prague was primarily to establish the Silurian-Devonian boundary on the basis of sections from the Barrandian basin. All the participants in that Conference agreed that this boundary should be placed in the top of the Lochkov beds, i.e. in the uppermost occurrence range of *Monograptus hercynicus* which is the youngest graptolite zone. The above concept of the Silurian-Devonian boundary was followed with satisfactory results in the correlation of sections within Europe and outside of it. This is attributable to the presence in a number of sections — sometimes very distant — of *M. hercynicus*, a reliable index fossil. Moreover, this form terminates the evolutionary line of *Graptoloidea* and this animal group does not appear again.

Three variants of the Silurian-Devonian boundary were advanced at the Bonn conference in 1960. One coincides with that accepted at the Prague Conference, another one is based on the top of the *Monograptus ultimus* zone, the third either on the top or the bottom of the

Chart

A correlation chart of the Ludlovian and younger strata with those
Tabela korelacyjna ludlowu i warstw młodszych od ludlowu oraz

System	Stages (Piętro)	Poland (Polska)			England (Anglia)
DEVONIAN (DEWON)	?	Platform area (Obszar platformy)	Holy Cross Mts. (Góry Świętokrzyskie)	Bardo Mts. — Sudeten (Sudety—Góry Bardzkie)	Welsh Borderland (Walia)
		?	Klonów beds (Warstwy klonowskie)	?	Ditton
SILURIAN (SYLUR)	?	? ? <i>Monograptus uniformis</i> <i>M. angustidens</i> <i>Pristiograptus transgrediens</i>	Bostów beds (Warstwy bostowskie)	<i>Monograptus hercynicus</i> <i>M. praehercynicus</i>	DOWNTON
		<i>Pr. perbrevis</i> <i>Pr. admirabilis</i> <i>Monograptus perneri</i> <i>M. boučeki</i> <i>Pristiograptus samsonowiczi</i> <i>Pr. chelmiensis</i> <i>Pr. bugensis</i>	RZEPIN BEDS (WARSTWY RZEPiNSKIE)	ŻDANÓW BEDS (WARSTWY ŻDANOWSKIE)	
LUDLOVIAN (LUDŁOW)		<i>Monograptus formosus</i> ? <i>Saetograptus leintwardinensis</i> <i>Pristiograptus tumescens</i> <i>Lobograptus scanicus</i> <i>Neodiversograptus nilssoni</i> <i>Pr. vulgaris</i>	Wydrzyszów beds (Warstwy wydrzyszowskie)	?	Ludlow bone bed
				<i>Lobograptus scanicus</i>	Whitcliffe Leintwardine Bringewood Elton

(Tabela) 1

of the Silurian-Devonian boundary, interpreted by L. Teller

warstw granicznych między sylurem a dewonem w interpretacji L. Tellera

Czecho-slovakia (Czecho-słowacja)	Germany (Niemcy)			Soviet Union (ZSRR)	France (Francja)
Barrandian	Sauerland and Siegerland (Nadrenia)	Thüringia and Vogtland (Turyngia i Vogtland)	Kellerwald	Podolia (Podole)	Ardennes (Ardeny)
Dvorec-Prokop beds	Bredeneck Schichten	Tentaculithen-knollenkalk	Erbsloch Schiefer	Old Red	Psamites de Liévin
<i>Monograptus hercynicus</i> Lochkov beds	Hüinghäuser Schichten	<i>Monograptus hercynicus</i> Obere Graptolithen-schiefer	<i>Monograptus hercynicus</i> Obere Steinhorn Schichten	CZORTKÓW BEDS (WARSTWY CZORTKOWSKIE)	Schistes de Mericourt
Přidoli beds	Köbbinghäuser Schichten	OCKERKALK	Untere Steinhorn Schichten	BORSZCZÓW BEDS (WARSTWY BORSZCZOWSKIE)	Couches de Broucort Calcaire d'Angres
KOPANINA BEDS		Untere Graptolithen-schiefer		SKAŁA BEDS (WARSTWY SKALSKIE)	Calcaire de Liévin

Saetograptus leintwardinensis zone. The two last concepts seem hardly acceptable for reasons as follows. In a paper by the present writer (Teller 1961) it was pointed out that the distinction of the *Monograptus ultimus* zone was not justifiable because its vertical distribution in Poland is too wide and its occurrence noted from the *Saetograptus leintwardinensis* to the *Monograptus formosus* zone, inclusively. Moreover, one should take into account that — as stressed by the writer in 1961 — the boundary of the Kopanina and the Pridol beds is very problematic. The lack of continuous sedimentation within the border beds, and the presence there of a stratigraphic gap was already confirmed by Horny (1962). Should we accept that the top of this zone represents the Silurian-Devonian boundary the latter would be the time equivalent of R. I. Murchison's boundary which the writer supposes barely acceptable for correlation in the European sections.

The writer also thinks that the third Bonn variant cannot be taken into account because according to that concept the upper part of the English Ludlow — the Whitcliffe beds (stage) as well as their time equivalent in Europe — would have to be included into the Lower Devonian. The *Saetograptus leintwardinensis* zone would obviously be very useful in correlation since this form occurs practically in all the Silurian sections of Europe, but so does also do *Monograptus hercynicus* (England excepted).

On evidence of the Silurian sections in Poland, both from the Holy Cross Mts. and from the Lowland region, the writer thinks that the most justifiable Silurian-Devonian boundary would be that based on the top of the *M. hercynicus* zone.

M. hercynicus has not been found in the Holy Cross Mts., but in the Bostów beds the occurrence is noted of *Acastella tiro*, in the Chełm borehole associated with the *Monograptus uniformis* zone. Hence, the upper part of the Bostów beds may correspond to the *M. hercynicus* zone, while their top may represent the Silurian-Devonian boundary. This is also reasonably suggested by the change of the argillaceous facies into an arenaceous one, and it seems justifiable to accept that, beginning with the predominance of the arenaceous facies we are dealing with the Devonian. The youngest graptolite form known from boreholes is *M. uniformis* while *M. hercynicus* has never been recorded during drilling. We do not know much about the transition in the Polish Lowland of the Silurian into the Devonian, but it seems reasonable to suppose that it would also be accompanied by a distinct change of facies.

The Bardo Mts. are the only area in Poland where *M. hercynicus* has been found, but the younger deposits are absent there.

In spite of the previously mentioned doubts aroused by the Polish sections the writer believes that the top of the *M. hercynicus* zone presents

the most reliable basis for the establishment of the Silurian-Devonian boundary, and he agrees with those authors who are inclined to place this boundary in the top of the *M. hercynicus* zone.

In the interpretation of the border beds between the Silurian and the Devonian of Poland E. & H. Tomczyk (1962) claim that *M. angustidens* is the last representative of the *Graptoloidea*. This concept is based on the determination by H. Tomczyk, below the *Monograptus formosus* zone in the Zebrak borehole, of such forms as: *M. uniformis*, *M. hercynicus*, *M. microdon* and *M. microdon silesicus*. In Czechoslovakia, Thuringia and the Bardo Mts., however, these forms occur invariably above the *M. angustidens* zone. The above authors make many critical remarks as to the correctness of the stratigraphy of most of the Upper Silurian sections in Europe. They are in favour of establishing the Silurian-Devonian boundary in the top of the *M. angustidens* zone. The present writer thinks that problems connected with the correct establishment of the Silurian-Devonian boundary call for discussion at international conferences, with the active cooperation of the interested specialists.

In chart 1 the writer gives his interpretation of the correlation of the border beds between the Silurian and the Devonian, and the correlation of the graptolite zones *Pristiograptus bugensis* — *Monograptus hercynicus* in Poland, and their time equivalents in other European areas.

FINAL CONCLUSIONS

The speculations in this paper concerning the age of strata younger than Ludlovian, and the establishment of the Silurian-Devonian boundary may be summed up as follows:

1. The term "Ludlovian stage" should be used in the meaning determined by R. I. Murchison.
2. Strata younger than Ludlovian but older than Lower Devonian are closely connected with the Silurian both faunally and lithologically.
3. A new name in the rank of stage is needed for these beds, to be determined on the basis of a selected stratotypical section.
4. This stage should be included into the Silurian system.
5. A revision of the present Silurian-Devonian boundary in England is thought recommendable, with the suggestion to shift it upwards at least to the top of the Downtonian.
6. A revision is also believed necessary of the stratigraphy of beds at present referred to as Lower Gedinian and assigned to the Devonian, because they need not all be Gedinian in age but may belong to the Silurian.

7. It is thought correct to place the Silurian-Devonian boundary in the top of the *Monograptus hercynicus* zone because other variants of this boundary impede the correlation of the particular Silurian sections in Europe and outside of it.

*Institute of Geological Sciences
of the Polish Academy of Sciences
Stratigraphic Laboratory
Warszawa 22, Al. Żwirki i Wigury 6
Warszawa, October 1963*

SELECTED BIBLIOGRAPHY

- BEDERKE E. 1924. Das Devon in Schlesien und das Alter der Sudetenfaltung. — Fortschr. Geol. & Pal., H. 7. Berlin.
- BOUCOT A. J. 1960. Lower Gedinian Brachiopods of Belgium. — Mém. Inst. Géol. Univ. Louv., t. XXI. Louvain.
- CZARNOCKI J. 1919. Stratygrafia i tektonika Gór Świętokrzyskich. Stratygrafia i tektonika staropaleozoicznych utworów Gór Świętokrzyskich (kambr, sylur, dewon dolny). — Prace TNW, nr 28. Warszawa.
- 1936. Przegląd stratygrafii i paleogeografii dewonu dolnego Gór Świętokrzyskich (Überblick der Stratigraphie und Paläogeographie des Unterdevons im Polnischen Mittelgebirge). — Spraw. P.I.G. (C.-R. Séanc. Serv. Géol. Pol.), t. VIII, z. 4. Warszawa.
- 1942. Silur im S-ty Krzyż Gebirge. — Arch. Państw. Inst. Geol. Warszawa.
- 1957. Geologia regionu Łysogórskiego (Geology of the Łysogóry region). — Prace I.G. (Trav. Inst. Géol. Pol.) XVIII, t. II, z. 3. Warszawa.
- DAHLGRÜN F. & FENCKH L. 1924. Ein Silurprofil aus dem Warthaer Schiefergebirge in Schlesien. — Jb. Preuss. Geol. L.-A. Bd. 44. Berlin.
- DATHE E. 1904. Erläuterungen zur Geologischen Karte von Preussen und benachbarten Bundesstaaten. Lieferung 115, Blatt Neurode. Berlin.
- HOLLAND C. H., LAWSON J. D. & WALMSLEY V. G. 1963. The Silurian rocks of the Ludlow district, Shropshire. — Bull. Brit. Mus. (Nat. Hist.) Geol., vol. 8, no. 3. London.
- HORNY R. J. 1962. Das mittelböhmisches Silur. — Geologie, Jahr. 11, H. 8, S. 873-916. Berlin.
- 2 Internationale Arbeitstagung über die Silur/Devon-Grenze und die Stratigraphie von Silur und Devon, Bonn — Bruxelles 1960. Symposiums Band. 1962. Stuttgart.
- KOREJWO K. & TELLER L. 1964. Upper Silurian non-graptolite fauna from the Chełm borehole (eastern Poland). — Acta Geol. Pol., vol. XIV/2. Warszawa.
- KOZŁOWSKI R. 1929. Les Brachiopodes Gothlandiens de la Podolie Polonoise. — Palaeontologia Polonica, vol. I. Warszawa.
- MALINOWSKA L. 1955. Stratygrafia gotlandu Gór Bardzkich (Stratigraphy of the Gothlandian of the Bardo Mountains). W: Z badań geologicznych na Dolnym Śląsku, t. I (In: Some geological researches in Lower Silesia, v. I). — Biul. I.G. (Bull. Inst. Géol. Pol.) 95. Warszawa.
- MURCHISON R. I. 1835. On the Silurian system of rocks. — Lond. and Edinb. Phil. Mag., 7. London.

- NIKIFOROVA O. I. 1954. Stratigrafija i brachiopody silurijskich otłożenii Podolii. - Trudy Vsies. Nauč.-Isl. Geol. Inst. Moskva.
- Prager Arbeitstagung über die Stratigraphie des Silurs und des Devons (1958). 1960. Praha.
- RICHTER R. & E. 1954. Die Trilobiten des Ebbe-Sattels und zu vergleichende Arten (Ordovizium, Gotlandium-Devon). — Abh. Senck. Nat. Ges., 488 Frankfurt.
- SAMSONOWICZ J. 1916. Kambry i kambrosylur Gór Świętokrzyskich (On the Cambrian rocks of the St. Cross Mountains, Poland). — Spraw. TNW (C.-R. Séanc. Soc. Sc. et Lettr. de Varsovie), IX. Warszawa.
- 1934. Objasnienie do arkusza Opatów (Explication de la feuille Opatów). — Biul. P.I.G. (Bull. Serv. Géol. Pol.) 1. Warszawa.
- TELLER L. 1960a. Poziom *Monograptus hercynicus* z warstw żdanowskich w Górach Bardzkich (*Monograptus hercynicus* zone from the Żdanów beds of the Bardo Range — Sudeten). — Acta Geol. Pol., vol. X/3. Warszawa.
- 1960b. Wyniki wiercenia w Chełmie, Sylur (Results obtained in borehole Chełm (Lublin Upland), Silurian). W: Z badań podłoża Polski, t. VI (In: Investigations of the substratum structures of Poland, v. VI). — Biul. I.G. (Bull. Inst. Géol. Pol.) 165. Warszawa.
- 1964. Graptolite fauna and stratigraphy of the Ludlovian deposits from the Chełm borehole (Eastern Poland). — Studia Geol. Pol., vol. XIII. Warszawa.
- TOMCZYK H. 1956. Wenlok i ludlow w synklinie kieleckiej Gór Świętokrzyskich (Wenlock and Ludlow in the Kielce syncline of the Święty Krzyż Mts.). — Prace I.G. (Trav. Serv. Géol. Pol.), t. XVI. Warszawa.
- 1960. Atlas geologiczny Polski. Zagadnienia stratygraficzno-facjalne. Z. 4. — Sylur (Geological Atlas of Poland. Stratigraphic and facial problems. Fasc. 4 — Silurian). Inst. Geol. Warszawa.
- 1962. Problem stratygrafii ordowiku i syluru w Polsce w świetle ostatnich badań (Stratigraphic problem of the Ordovician and Silurian in Poland in the light of recent studies). — Prace I.G. (Trav. Serv. Géol. Pol.), t. XXXV. Warszawa.
- TOMCZYKOWA E. 1957. Trylobity z łupków graptolitowych wenloku i dolnego ludlowu Gór Świętokrzyskich (Trilobites from graptolitic shales of the Wenlock and Lower Ludlow of the Święty Krzyż Mts.). — Biul. I.G. (Bull. Inst. Géol. Pol.) 122. Warszawa.
- 1958. Fauna z łupków graptolitowych syluru niecki bardziańskiej Gór Świętokrzyskich (Fauna from Silurian graptolitic shales of the Bardo basin in the Święty Krzyż Mts.). — Kwartalnik Geol., t. 2, z. 2. Warszawa.
- URBANEK A. 1960. An attempt at biological interpretation of evolutionary changes in graptolite colonies (Próba interpretacji biologicznej zmian ewolucyjnych w koloniach graptolitów). — Acta Palaeont. Pol., vol. V/2. Warszawa.
- 1963. On generation and regeneration of cladia in some Upper Silurian Monograptids (O rozwoju pewnych górno-sylurskich Monograptidae). — Ibidem, vol. VIII/2.

L. TELLER

**UWAGI O STRATYGRAFII WARSTW MŁODSZYCH OD LUDLOWU
ORAZ O GRANICY MIĘDZY SYLUREM A DEWONEM W POLSCE I W EUROPIE**

STRESZCZENIE: Omówione zostało zagadnienie wieku warstw młodszych od ludlowu, które zarówno w literaturze polskiej jak i europejskiej uważane są za sylurskie, lecz błędnie koreluje się je z typowym ludlowem Anglii. Zdaniem autora, warstwy te jako młodsze od ludlowu winny otrzymać odrębną nazwę, która byłaby równoznaczna z pojęciem piętra, a piętro to powinno zostać włączone do syluru. W odniesieniu do granicy sylur-dewon, autor wypowiada się za przeprowadzeniem jej w stropie poziomu *Monograptus hercynicus*, proponując jednocześnie rewizję granicy sylur-dewon, ustalonej przez R. I. Murchisona.

W pracy omówione zostało zagadnienie wieku warstw młodszych od ludlowu, które zarówno w literaturze polskiej jak i europejskiej uważane są za sylurskie.

Autor, w oparciu o profile graptolitowe Niżu Polskiego oraz niegraptolitowe Gór Świętokrzyskich, dochodzi do wniosku, że warstwy od poziomu *Pristiograptus bugensius* do *Monograptus hercynicus* włącznie nie mogą być paralelizowane z ludlowem Anglii, lecz że są one znacznie młodsze i stanowią odpowiednik czasowy downtonu. Dla warstw tych, jako młodszych od ludlowu a starszych od dewonu dolnego, autor proponuje utworzenie odrębnego piętra, w oparciu o wybrany profil stratotypowy. Piętro to — zdaniem autora — winno być włączone do syluru. Nazwę piętra i wybór profilu autor pozostawia otwartą, podkreśla jednak, że profile Polski i Europy, z wyjątkiem profilu Podola, nie spełniają wymaganych warunków profilu stratotypowego.

W pracy omówione zostało również znaczenie dla stratygrafii i paralelizacji profilów syluru współwystępowania formy *Acastella tiro* z *Monograptus uniformis* na jednej płaszczyźnie rdzenia w wierceniu Chełm, stwierdzone po raz pierwszy w Polsce.

Ponadto autor poddaje dyskusji zagadnienie granicy sylur-dewon, stojąc na stanowisku, że winna ona być przeprowadzona w stropie poziomu *M. hercynicus*, podobnie jak to przyjmuje szereg innych badaczy. Autor wyraża zdanie, że dotychczasowa granica sylur-dewon w Anglii, ustalona przez R. I. Murchisona, winna być poddana rewizji, przy czym wydaje się, że należy ją przesunąć ku górze, co najmniej do stropu downtonu. Autor proponuje również rewizję stratygrafii warstw, które w chwili obecnej określane są jako dolnożedyńskie i zaliczane do dewonu.

W załączonej tabeli korelacyjnej ludlowu i warstw młodszych od ludlowu autor interpretuje ważniejsze profile syluru w Polsce i Europie w świetle własnej koncepcji.

Zakład Nauk Geologicznych PAN
Pracownia Stratygrafii
Warszawa 22, Al. Żwirki i Wigury 6
Warszawa, w październiku 1963 r.