GRAPTOLITES AND STRATIGRAPHY OF THE PŘIDOLI SERIES IN THE EAST EUROPEAN PLATFORM

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The paper revises the earlier information and updates the Přidolian biostratigraphy in the East European Platform as well as compares it to other areas. An improved zonal subdivision of the Přidoli in Chełm keysection is proposed and compared to the graptolite sequence in the type area of Barrandian. The stratigraphic significance of the *transgrediens* stock is demonstrated and the position of numerous low-diversity assemblages, dominated by *Linograptus*, is specified.

K e y w o r d s : Silurian, Přidoli, biostratigraphy, correlation.

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INTRODUCTION

The Přidoli Series was encountered within the Polish part of the EEP in the Chełm IG-1 borehole, in 1954–1955. The borehole was drilled in the Bug Depression, on the Uherka River, 1 km North of the town of the same name. Uppermost Silurian deposits were documented by graptolites and a rich benthic fauna. The faunas appear at a depth of 1207.7 m and continue to the total depth of the well at a depth of 1611.7 m.

It was the first borehole among those drilled by the Polish Geological Institute that revealed Silurian deposits in the Palaeozoic sedimentary cover of the EEP, and the second one in the history of that system's investigation in the area (DAHLGRÜN and SEITZ 1944).

The horizontal sediments, not folded during either the Caledonian or any other orogenic phase, represent a claystone facies with minor carbonate intercalations. They were deposited in the bathyal zone of the EEP slope and pass, without interruption, into the marine Lower Devonian of the Rhine facies (Gedinian). Preliminary stratigraphic conclusions based on the graptolite fauna encountered there were published by TOMCZYK and TELLER (1956). They showed that the graptolite and benthic faunas present in the sediments were typical of the Přidoli Formation of the Prague Basin, suggesting a close palaeogeographic affinity between the two areas. The sediments penetrated by the borehole were assigned, following PŘIBYL (1940), to the Middle Ludlow. The mis-correlation can be explained by the fact that, at that time, most of the stratigraphers engaged in the study of the Silurian, chiefly representatives of the British school, rejected a possibility of the presence outside the British Isles of muddy and carbonate series yielding graptolites and a benthic fauna that could be younger than the British Ludlow.

A detailed lithological and stratigraphic study of the Silurian from the Chełm IG-1 borehole section was published in a later paper (TELLER 1960) whereas the faunas, both graptolite (TELLER 1964) and benthic (KOREJWO and TELLER 1964), became the subject of separate later monographs.

In the stratigraphic part of the graptolite monograph (TELLER 1964), the Chełm IG-1 borehole section was regarded as coeval with the Upper Ludlow, which was a compromise with the generally accepted British subdivision rather than a definition of the true stratigraphic position of the series. It was not until the new subdivision of the Silurian System was accepted in 1984, officially establishing the Přidoli Series as the uppermost Silurian series entirely younger than the British Ludlow, that the proper stratigraphic position of the Chełm IG-1 section, a key-section for the Polish part of the EEP, was recognized.

Later (1960s–1970s), several additional boreholes were drilled in the Bug Depression. Characteristically, they revealed, below the marine Lower Devonian, a claystone complex containing graptolites of the late horizons of the Přidoli (boreholes: Busówno IG-1 1947.0–2890.0 m, Białopole IG-1 1577.5–1830.0 m, Terebin IG-1 1358.0–2648.0 m, Krowie Bagno IG-1 1850.0–2724.0 m, Strzelce IG-1 1424.0–1545.0 m, Strzelce IG-2 1732.5–1890.0 m, and Bachus 2133.0–2438.0 m, see TOMCZYKOWA 1988).

Still further East, in the Lublin Region, some wells, drilled below the marine Lower Devonian of the Rhine facies (Gedinian), encountered in stratigraphic continuity Přidoli graptolite – bearing claystones.

Boreholes drilled more to the North, in the eastern Podlasie Depression, penetrated Přidoli deposits of a somewhat different lithology, that being a widespread marly-limestone facies associated with the more shallow parts of the vast epicontinental basin (see p. 16 herein).

Strongly folded Přidoli sediments have also been penetrated further South of the Chełm IG-1 borehole, in the T.T. lineament zone, by the Ruda Lubycka well (TELLER 1964; TOMCZYK 1962). Beyond, but close to, the Polish state border, their presence has been reported in the Rava Russkaya borehole (SANDLER and GLUSZKO 1955).

When discovered, the Přidoli section in the Bug Depression was, next to that in the Prague Basin, only the second in the world. But with the course of time, thanks to wide-scale investigations conducted in various regions first in order to draw the Silurian/Devonian boundary, and then to introduce a new subdivision of the Silurian and to select the stratotype for the Přidoli Series, more and more sections were recorded where the Přidoli and Devonian age of the sediments was established on the basis of graptolites.

Within a fairly short time the presence of the Přidoli was proved for Canada (JACKSON and LENZ 1969; JACKSON *et al.* 1978; LENZ and JACKSON 1971; LENZ 1988, 1990), Australia (JAEGER 1967; JENKINS 1982; RICKARDS *et al.* 1992) Austria (JAEGER 1975; SCHÖNLAUB 1979) Germany (JAEGER 1959), Kazakhstan (MIKHAJLOVA 1971, 1976; BANDALETOV 1971; BANDALETOV *et al.* 1983; KOREN' 1983, 1986, 1989) Kirgystan (OBUT *et al.* 1968; RINENBERG 1965, 1973, 1985; KOREN' 1994), Podolia and Volhynia (TSEGELNJUK 1976a, b 1980, 1981, 1983), Morocco (WILLEFERT 1962), North America (BERRY and MURPHY 1975), France, Normandy (JAEGER *et al.* 1965), the Ural Mountains (KOREN' 1973).

However, a revision of the Přidoli graptolite fauna conducted by JAEGER (in KRIŽ *et al.* 1986) in the stratotype area, together with the new data obtained from that region by PŘIBYL (1983), the founder of the Přidoli Series zonal subdivision, have stimulated the present author to once again revise the Chełm graptolite fauna and to present an updated biostratigraphic subdivision.

THE ZONAL SUBDIVISION OF THE PŘIDOLI IN THE CHEŁM KEYSECTION

Most of the existing zonal subdivisions established on the basis of the graptolite fauna (TELLER 1964) are still valid (Fig. 1). This chiefly concerns the *samsonowiczi*, *chelmensis*, *bouceki*, *perneri*, *transgrediens*, and *angustidens* Zones. The base of the Series, however, requires some modification because of the revised taxonomy of two species (*Pristiograptus bugensius* and *P. aduncus*), which the present author assigns both to *Neocolonograptus lochkovensis*. The Series lower boundary has also been shifted to run through the bottom of a new, *ultimus* Zone, that is within the early Přidoli, and not through that of the *bugensius* Zone as was earlier suggested (Fig. 1).

The critical part of the section embraces the interval between 1601.5 and 1611.7 m (10.2 m). It yields at various depths the following graptolite species (Fig. 1):

1611.7–1608.5 m *Pristiograptus* ex.gr. *dubius* SUESS
1611.7–1607.4 m *Istrograptus transgrediens rarus* (TELLER)
1606.4–1601.5 m *Neocolonograptus ultimus* (PERNER)
1608.5–1607.4 m *Linograptus posthumus* (Reinhard RICHTER).

The highest form belongs to *P. dubius* s.l., a conservative lineage which persisted since the Wenlock. Its representatives appear abruptly at varying time intervals and in large numbers marking each time a population burst. Morphological differences between successive populations are, however, fairly small, and as such can be regarded as intraspecific variation. Therefore, in spite of the fact that the populations are distinctly separated from one another by representatives of other species, it would be hardly reasonable to classify each population as a separate species. Thus *P.* ex.gr. *dubius* has no stratigraphic significance and its presence can merely be recorded.

The next in line, *Istrograptus transgrediens rarus* (TELLER), is represented by a dozen or so clearly distinctive specimens. Their diagnostic feature is a beak-like first theca made up of two elaborated lateral lobes whilst the remaining thecae are all straight, of the *dubius* type. The ancestors of this subspecies can probably be found among Přidolian pristograptids. With a high degree of probability we can posit that

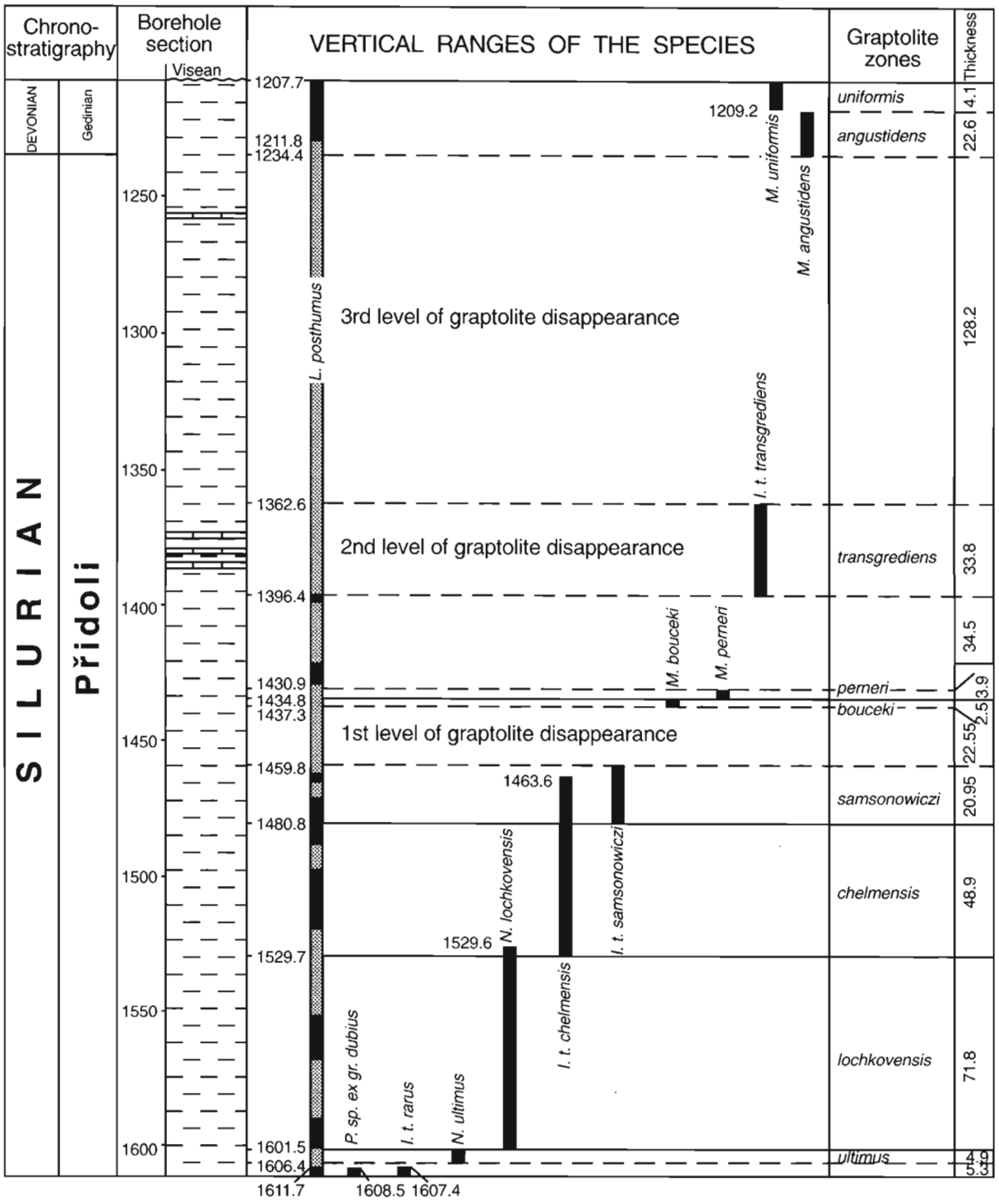

Fig. 1
Vertical ranges of the Pridoli monograptids within the Chełm IG-1 wellcore and suggested zonal subdivision.

I. t. rarus gives rise to the *transgrediens* phylogenetic stock, which, in the Chełm IG-1 section, is represented by at least three further distinct populations (cf. p. 73).

Neocolonograptus ultimus (PERNER) is the most important form encountered at a depth of 1606.4–1601.5 m (Fig. 1). It marks the *ultimus* Zone which is here no more than 4.9 m thick, a small zonal thickness not dissimilar to that found in the Mielnik IG-1 section – 3.4 m (URBANEK this volume p. 168). It should, however, be noted that the Chełm IG-1 *ultimus* Zone may be even thicker given the section's

location on the EEP slope and, moreover, it may also embrace some of the uncored interval at a depth between 1601.5 and 1599.9 m.

Putting aside all the uncertainties, it is clear that the *ultimus* Zone of the Chełm IG-1 section is at least 4.9 m thick and that it is the oldest Přidoli zone established there on a faunal basis. Whether the part of the section between 1611.7 and 1606.4 m (4.3 m) is also part of the *ultimus* Zone or whether it already belongs to the *parultimus* Zone, remains an open question.

The above interval of the section also contains *Linograptus posthumus* (Reinhard RICHTER) (1608.5–1607.4 m) (1.1 m). This species occurs discontinuously throughout the entire section of the series drilled (Fig. 1), displaying short periods of mass occurrence discussed below.

The interval of 1599.9–1529.6 m (70.3 m) (Fig. 1) features a mass occurrence of *Neocolonograptus lochkovensis* (PŘIBYL) showing different astogenetic stages. This form, highly characteristic and typical of that part of the Přidoli Series, shows great intraspecific variation, a fact which originally led to its division into two separate species, *P. bugensius* and *P. aduncus*, included in the *bugensius* Zone (TELLER 1964). The *lochkovensis* Zone was proposed as early as 1960 (TELLER 1960), but, as now recognized, both its stratigraphic position and species identification were erroneous.

Having revised the identifications, the author has assigned all the forms of *bugensius* (1599.9–1529.6 m) and *aduncus* (1573.5–1530.5 m) to *Neocolonograptus lochkovensis* PŘIBYL. In this way, the *lochkovensis* Zone, whose boundaries are marked by the first appearance of the index species at a depth of 1599.9 m and by its disappearance at a depth of 1529.6 m, has been recognized in the Chełm IG-1 section as having a thickness of 70.3 m.

Within the vertical range of the index species there are two intervals with mass occurrences of *L. posthumus* (Reinhard RICHTER), at a depth of 1599.0–1589.0 m (10 m) and 1573.3–1549.4 m (23.9 m), respectively (Fig. 1).

In the Mielnik IG-1 boring, URBANEK (this volume) subdivides the *lochkovensis* Zone into the lower, *branikensis* Subzone and the upper, *lochkovensis* Subzone. The two are separated by *Monograptus (Dulebograptus) trimorphus* TSEGELNJUK. This subdivision is not recognizable in the Chełm IG-1 section (see the discussion following the description of the *lochkovensis* Zone).

At the top of the *lochkovensis* Zone, at a depth of 1529.7 m, appears a highly distinctive elongated and slim form whose first two thecae are beak-like and the rest represent the *dubius* s.l. type. That form, described (TELLER 1964) as a *P. chelmensis*, marks a separate zone at depths 1529.7–1480.8 m (48.9 m). At the top, it is replaced by a much broader and more robust form with at least the first three thecae beak-like, identified (TELLER 1964) as *P. samsonowiczi* and marking another independent zone at depths 1480.8–1459.85 m (20.95 m) (Fig. 1).

In the course of a recent revision, the author now recognizes that both of these species belong to the *transgrediens* morpho-type and has instead formed two sequential subspecies of *I. t. transgrediens* out of them, namely *I. t. chelmensis* and *I. t. samsonowiczi* (Fig. 1).

The above two zones also contain three intervals featuring a mass occurrence of *L. posthumus* (Reinhard RICHTER). They lie at depths 1518.2–1497.1 m (21.1 m), 1486.1–1471.0 m (15.1 m), and 1466.8–1465.4 m (1.4 m).

At depths of 1459.8–1437.3 m (22.5 m), only benthic faunas were encountered. It is the first of the three barren, nongraptollitiferous intervals in the section.

The interval between 1437.3 and 1434.8 m (2.5 m) contains a well-defined species, *Monograptus bouceki*, constituting the eponymous zone. Towards the top, *M. bouceki* gives way to *M. perneri* which occupies the interval between 1434.8–1430.9 m. (3.9 m) and marks a distinct and well-defined eponymous zone (Fig. 1). Both zones were originally established in the Prague Basin (PŘIBYL 1940) and have subsequently been recognized in other sections of the world. They constitute reliable correlation markers for this part of the Přidoli Series.

Above the *perneri* Zone, two intervals with *L. posthumus* (Reinhard RICHTER) have been recorded, lying at a depths of 1427.5–1420.8 m (6.7 m) and 1398.5–1396.4 m (2.1 m), respectively. The narrow interval, 1418.9–1419.5 m (0.6 m), yields a proximal fragment of a *Monograptus* rhabdosome showing a preserved sicula and three thecae. In their morphology, the thecae closely resemble those of *M. hornyi* JAEGER, a species described by JAEGER in KRIŽ *et al.* (1986) from the Prague Basin and having about the same stratigraphic position there.

The interval between 1396.4 and 1362.6 m (33.8 m) (Fig. 1) contains an abundant graptolite complex representing various astogenetic forms belonging to the *transgrediens* morphotype. The present author (TELLER 1964) earlier described, within this complex, three new species, *P. separabils, P. admirabilis*, and

P. perbrevis, and also typical forms of *P. transgrediens* (s.s.). Two of the species, *P. admirabilis* and *P. perbrevis*, not unlike the type form, were then considered index species. Following the present revision, those new species distinguished at the time are now all re-assigned to *Istrograptus transgrediens transgrediens* (PERNER) because they represent only different developmental stages of the type form. Thus the *transgrediens* Zone has become increased to include the above interval, its total thickness now being 33.8 m.

Above the *transgrediens* Zone, up to a depth of 1234.4 m (128.2 m), the section yields no graptolites. Benthic faunas, however, are rather abundant (KOREJWO and TELLER 1964), while at a depth of 1257.8–1257.0 m (0.8 m) there is a limestone layer containing orthocones, bivalves, and conodonts indicative of the uppermost Přídoli – the *eosteinhornensis* conodont Zone (WOLSKA 1969).

Still higher up, between the depth of 1234.4 m and the erosional boundary with the Visean at 1207.7 m (26.7 m), graptolites were again encountered, together with a highly abundant benthic fauna (KOREJWO and TELLER 1964). Among the graptolites are several specimens belonging to *Monograptus angustidens* PŘIBYL (1234.4–1211.8 m) (22.6 m) and one of *M. uniformis* PŘIBYL (1209.2–1209.0 m) (0.2 m) in association with *Acastella* cf. *tiro* R.E. RICHTER, pointing to an early Gedinian age for this part of the section. The Silurian (Přídoli)/ Lower Devonian (Lochkovian) boundary can be tentatively drawn in the Chełm IG-1 section at a depth of 1234.4 m, that is at the first appearance of *M. angustidens*. This species also marks the eponymous zone, which is here about 22.6 m thick (1234.4–1211.8 m) (Fig. 1), while the youngest *uniformis* Zone is represented only by 4.1 m of sediments (1211.8–1207.7 m).

The *angustidens* Zone features mass occurence of linograptids, for the ninth time in this section. Their accumulations occur between the depths of 1227.8–1212.0 m (15.8 m).

There are three nongraptolitiferous intervals in the Chełm IG-1 section, at depths 1459.85–1437.3 m (22.55 m), 1430.9–1396.4 m (34.5 m), and 1362.6–1234.4 m (128.2 m).

The first interval, 1459.85–1437.3 m (Fig. 1) has yielded some representatives of benthos and not a single graptolite fragment (KOREJWO and TELLER 1964). The second, 1430.9–1396.4 m, features only two population bursts of *L. posthumus* (Reinhard RICHTER) assemblages, and a fairly abundant benthic fauna. What we observe here is a distinct diversity decrease leading to the domination by a single species. This becomes even more conspicuous due to the fact that at a depth of 1437.3–1430.9 m (6.4 m) the first two nongraptolitiferous intervals are separated by a sudden appearance of cryptic elements (URBANEK 1993), namely *M. bouceki* and *M. perneri*. Being markers of separate graptolite zones, both of them occupy the same stratigraphic position in many sections all over the world, which confirms the global nature of this phenomenon.

The third nongraptolitiferous interval, 1362.6–1234.4 m (Fig. 1), contains benthic fauna alone, but the interval is preceded by 23.8 m of claystones displaying the presence of numerous *I. t. transgrediens* (1386.4–1362.6 m). This species belongs to a rather well-established phylogenetic line, confined to the Přídoli. It does not cut across the tentatively drawn Silurian/Devonian boundary, which in the Chełm IG-1 section is marked by the first appearance of *M. angustidens* superseded by *M. uniformis*. Both the species, associated with the *uncinatus* group appearing here after a fairly long break, can be described as typical immigrants. It is *L. posthumus*, which reappears in great numbers after a long absence, that alone can be regarded as a surviving species. In the final stage of its occurrence, *L. posthumus* undergoes a limited radiation giving rise to a new genus *Abiesgraptus*.

The distribution of *L. posthumus* (Reinhard RICHTER) should also be briefly summarized. It appears in the Chełm IG-1 vertical section as many as nine times (Fig. 1), each appearance being expressed as a population burst. Five from among the nine outbursts were short-lived (in terms of geological time): (1608.5–1607.4 m, 1599.0–1589.0 m, 1465.4–1466.8 m, 1427.5–1420.8 m, and 1398.5–1396.4 m), whereas the remaining four: 1573.4–1549.4 m, 1518.2–1497.1 m, 1486.1–14771.0 m, and 1227.8–1212.0 m lasted much longer. Not unlike *P. dubius, L. posthumus* belong to surviving species comprising a relic assemblage (URBANEK 1993). Limited radiation occurs not earlier than in the Lochkovian, although the Chełm IG-1 section has yielded, at a depth of 1553.95–1553.5 m one specimen which might have been a precursor of the above changes (TELLER 1964).

A comparison with other areas. — Graptolitiferous deposits of the Přídoli Series have been encountered in many sections throughout the world. But outside the Prague Basin, the series is most complete in Poland (TELLER 1964, 1966, 1969, 1987).

Prague Basin. — This region contains well-developed sequences of the Přídoli Series, and it is here that the stratotype (Požary section) was established (KRIŽ *et al.* 1986, 1989). The graptolite sequence as set up by PŘIBYL (1940, 1983) was only slightly altered by JAEGER in KRIŽ *et al.* (1986) but these changes

made less clear the subdivision functioning for many years, especially in as far as the *lochkovensis* Zone and the *transgrediens* Interzone are concerned.

As the Chełm IG-1 section displays all the major graptolite zones, with the only exception of the *parultimus* Zone in the bottom, the correlation of its Přidoli Series with that of the Prague Basin is fairly easy. It was made for the first time as early as 1956 (TOMCZYK and TELLER 1956), while a detailed correlation dates from 1964 (TELLER 1964). The current revision of the material from the Chełm IG-1 section has revealed some differences as compared with JAEGER's subdivision (in KRIŽ *et al.* 1986).

The lack of the *parultimus* Zone in the Chełm IG-1 section is compensated for by its presence in the nearby Mielnik IG-1 section (URBANEK this volume, p. 166). The younger *ultimus* Zone is in the Chełm IG-1 section rather thin (4.9 m), although thicker than it is in the Mielnik IG-1 borehole – 3.4 m (URBANEK this volume, p. 168). Both of these values cannot, however, be compared with their equivalent in the Prague Basin because of the different palaeogeographic features of the two regions. The column or sections presented by JAEGER (in KRIŽ *et al.* 1986) show that, locally, the zone in question attains a thickness of as many as 4 m (Kosov Quarry) in the Prague Basin, although in most cases it does not exceed 1 m. According to PŘIBYL (1983), the thickness of this zone varies from 1.5 to 6.1 m. However, the latter author does not distinguish the *parultimus* Zone, as he does not recognize the validity of this species (personal information).

JAEGER's (in KRIŽ *et al* 1986) subdivision of the *lochkovensis* Zone into three subzones has not been corroborated by the data from the Chełm IG-1 section. What can be observed here is a fairly thick (70 m) interval of the *lochkovensis* Zone marked by the index species alone.

PŘIBYL (1940, 1983) recognizes the *lochkovensis* Zone in the Prague Basin, but unlike JAEGER he does not subdivide it into three subzones. PŘIBYL (1940, 1983) and JAEGER (in KRIŽ *et al.* 1986) agrees in establishing the *bouceki* Zone (with a thickness of 2.0–3.5 m) above the *lochkovensis* beds. Further up in the Prague Basin the former is replaced by the 2.0–3.0 m thick *perneri* Zone. This situation is similar to the Chełm IG-1 section not only from the point of view of the presence of both species but also of the thickness of the zones. JAEGER (in KRIŽ *et al.* 1986) introduces, between the two zones, the *M. beatus* Band. Such a sequence has not been observed in Chełm IG-1, but recorded at a depth of 1418.9–1419.5 m was a fragment which might be described as *M. hornyi*, a form originating from the Prague Basin.

No *M. pridoliensis* has been encountered either in the Chełm IG-1 section or in any other coeval sequence of the Polish part of the EEP. Hence no zone of this name can be distinguished there. Nevertheless PŘIBYL (1983) has established an independent *pridoliensis* Zone 1.5–6.3 m thick, recording in its top also the presence of *M. rectiformis*, a species unknown in Poland According to JAEGER (in KRIŽ *et al.* 1986), the Přidoli section of the Prague Basin is crowned by the *transgrediens* Interzone, which PŘIBYL (1940, 1983) defined as zone. This sequence has its analogues both in the Chełm IG-1 borehole and in other Polish sections. JAEGER's suggestion introducing an interzone seems to the present author unclear. In the Chełm IG-1 section, and not only there, the *transgrediens* morphotype features a distinct line of development: *I. t. rarus*, *I. t. chelmiensis*, and *I. t. samsonowiczi*, which makes it possible to distinguish at least three separate zones within the Přidoli. Both in the Chełm IG-1 section and in the Prague Basin, the *I. t. transgrediens* Zone terminates the Přidoli Series and with it, the Silurian.

The onset of the Devonian in both the Prague Basin and the Chełm IG-1 section is marked by the presence of two typical graptolites, *M. angustidens* and *M. uniformis*. According to JAEGER (1959), the first of them is a subspecies of the other, therefore not a zone but merely some basal beds should be recognized at the bottom of the sequence, and the only zone to be established there is the *uniformis* Zone. Within the Chełm IG-1 section these forms occur separately and function as index species of two independent zones The current analysis of the Chełm IG-1 graptolite sequence shows no considerable deviation from the results obtained by PŘIBYL (1983) and JAEGER (in KRIŽ *et al.* 1986) in their revisions of the Prague Basin. The small differences may have various causes and are of little significance for the biostratigraphic correlation of the two regions.

The predominance of carbonate sediments in the Prague Basin can be accounted for by its geographic position and chiefly shallow nerritic facies in the Přidoli time. The richness and abundance of the benthic fauna in the basin is not always matched by equal development of the graptoloid plankton whose diversity was controlled by a number of factors, e.g. tides, storms, water temperature, and wind direction. This explains why a continuous presence of graptolites was impossible in the Prague Basin. The possibility of breaks in sedimentation or periods with hard grounds cannot be eliminated either.

In the EEP, well-established graptolitiferous sections of Přidoli age are chiefly confined to the EEP slope region. The Palaeozoic sedimentary cover, overlying the Precambrian basement, was neither folded

nor metamorphosed. The marine basin of a bathyal type had unrestricted open connections with the SW branch of the Caledonian geosyncline. Graptolitic plankton, thus, could easily drift, which resulted in a greater diversity of the graptoloid fauna making possible its more detailed analysis. The thickness of the sediments is also of importance.

One more proof of close Upper Silurian connections between the Prague Basin and the SE part of Poland is the presence of an extremely rich and diverse Přidoli benthic fauna in the Chełm IG-1 section (KOREJWO and TELLER 1964). Its composition is similar to that of the Prague Basin, revealing equally strong ties with the Mediterranean Palaeotethys.

Wolhynia and Podolia. — In the territory of Volhynia and Podolia sediments of Přidoli age have been recognized in many boreholes, but only some of them contain graptolite fauna, and that of the lower members of the series alone. One of the earliest descriptions of the graptolite fauna from this area [boreholes: Gushcha-4015, Tomashovka-4116, and Pishcha-1, KRANDIEVSKY *et al.* (1968)] lists a number of species typical of the Přidoli and used as a basis for the regional zonal subdivision. Two zones were established for the Přidoli, known then as the Tiver.

The fourth (IV) Volhynian zone with *M. ultimus* as the index species was recognised in the Gushcha-4015 borehole, at a depth of 677.2–626.8 m. It is supposed to be characterized by *Monoclimacis ultimus* (PERNER), *Monograptus similis* PŘIBYL (= *Monograptus pridoliensis* PŘIBYL), *Monograptus similis* PŘIBYL (= *Monograptus pridoliensis* PŘIBYL) var. *triangulatus* subsp. n. KRAND, and *Linograptus posthumus* (Reinhard RICHTER).

The fifth (V) Volhynian zone with *Pristiograptus spectatus* PŘIBYL as the index species was also established in the Gushcha-4015 section, at a depth of 826.8–563.5 m. The index species is presumably accompanied by *Monograptus similis* PŘIBYL (= *Monograptus pridoliensis* PŘIBYL) and *M. similis* (= *Monograptus pridoliensis* PŘIBYL) var. *triangulatus* subsp. n. KRAND.

In the standard international biostratigraphic subdivision, these two regional Volhynian zones are believed to correspond to the *ultimus* and *lochkovensis* Zones of the Prague Basin (PŘIBYL 1940) and also to the *bugensius* and *samsonowiczi* Zones from the nearby Chełm IG-1 borehole (TELLER 1964).

In his description of the Gushcha-4015 section Krandievsky also records other graptolite species, including a mass occurrence of *M. formosus* at a depth of 821.7–677.2 m and *Monograptus lochkovensis* at a depth of 821.7–677.2 m (in the same interval), whilst the presence of *M. similis* PŘIBYL (= *M. pridolensis* PŘIBYL), was reported from a depth of 778.5–563.6 m.

If all the above identifications were correct, it would be possible to accept that the Gushcha-4015 section contains the early Přidoli Zones of *parultimus*, *ultimus*, and *lochkovensis*. This would be in accord with the sequence recognized in not too remote sections in Mielnik IG-1 (URBANEK, this volume, p. 97) and Chełm IG-1 (TELLER, this volume, p. 62), lying west of the frontier River Bug.

KRANDIEVSKY's *et al.* (1968) identifications, however, are not quite reliable (cf. descriptions and the Tables), and his stratigraphic conclusions are also doubtful, and hard to accept.

The next approach to the graptolite fauna from the borings in the above-mentioned area was made by TSEGELNJUK (1976a, b). He etched the material from several boreholes, obtaining a rich graptolite fauna isolated from the rock matrix. The vast majority of the graptolites, coming chiefly from the Brest-1 and Gushcha-4015 borings, however, provide evidence of the presence of only the Ludfordian stage. Typical Přidoli species have been recorded in no more than four wells. The Yegorany-409 borecore has yielded at a depth of 277.1 m *I. t. rarus* TELLER, which in the Chełm IG-1 section was identified from the interval between 1611.7–1607.4 m. The Davideny-1 section contains *M. perneri* BOUČEK (2227.0–2232.0 m), and the Gushcha-4015 borehole features *M. ultimus* at a depth of 662.4–676.0 m, whereas in the Tomashovka-4116 well *I. transgrediens* has been encountered at a depth of 640 m.

Unfortunately, the stratigraphic methods applied by TSEGELNJUK to the study of the material in question were woefully inadequate, resulting in a high degree of confusion. This is especially true of the Ludfordian fauna, as is shown in detail by URBANEK (this volume, p. 43), and the present author fully shares his objections.

As far as species permitting the establishment of the Přidoli Series are concerned, the species listed by TSEGELNJUK are also present in the Chełm IG-1 section (TELLER 1964). The correlation of *I. t. rarus* TELLER and *M. perneri* creates no problems, provided the identifications are correct. However, the supposed 14-meter thick bed bearing *ultimus* in the Gushcha-4015 section seems to be an exagerration in comparison with that in the nearby Chełm IG-1 and Mielnik IG-1 borings. It seems likely that the 662.4–676.0 m interval embraces both the *parultimus* and *ultimus* Zones. *I. transgrediens*, recorded in the

Tomashovka-4116 boring is, however, an entirely different matter. According to JAEGER (in KRIŽ *et al.* 1986), the *transgrediens* morphotype can be encountered in different zones of the Přidoli Series, and, what is more, he introduces a subzone based on this species. In the Chełm IG-1 section, the *I. transgrediens* morphotype reappears at least four times, beginning with *I. rarus* in the bottom and ending in *I. t. transgrediens* at the top. From TSEGELNJUK's (1976b) considerations it is not at all clear which morph he is discussing, for it can be anything – a Lower, Middle or Upper Přidoli form. It also seems strange that TSEGELNJUK (1976b) skips over KRANDIEVSKY's *et al.* (1968) identifications and conclusions, although the material for analysis comes in both cases from the same source.

A close correlation between the Přidoli Series of the Bug Depression and that of the adjacent area lying E of the frontier river Bug is practically impossible. This is a great disappointment, for the graptolite fauna, obtained chiefly by TSEGELNJUK (1976b), is represented by a qualitatively and quantitatively rich association, which raises it, alongside the Polish assemblage (URBANEK 1970 and this volume; TELLER 1964 and this volume), to a very high rank of second in the world.

Central Asia. — In Kazakhstan the Přidoli Series was established as early as the 1960s but was then included in the Tokrau horizon (local stage?) recognized by BANDALETOV and MIKHAJLOVA (1971). The first graptolites suggestive of the Přidoli Series were identified by MIKHAJLOVA (1971, 1976) and revised by KOREN' (1983) who also described a number of new taxa. From the viewpoint of the present author, this more detailed study may raise some doubts, as the sequence features several new forms typical of the Ludlow (Ludfordian) rather than the Přidoli.

The same graptolite assemblage from the Tokrau horizon was described by KOREN' (1986) again, almost without changing its stratigraphic position. A further analysis of the fauna was presented in 1989 (KOREN' 1989). It was stressed in the conclusions (KOREN' 1989: p. 155) that the graptolite fauna in the Tokrau horizon did not provide full information about late Silurian graptolites (Ludfordian and Přidoli).

No matter how interesting, the Přidoli section of the Tokrau Regional Stage cannot at present be correlated with other coeval sections, including the Chełm IG-1 parastratotype in Poland. This may be a consequence of intense tectonic deformation of the beds, making impossible an accurate reconstruction of the graptolite sequence. Naturally, one cannot exclude the presence here of some fragments of the Přidoli Series, but the bulk of the graptolite fauna described up to now bears a Ludlow, especially Ludfordian, aspect. Any degree of provincialism of this fauna can hardly be taken into account because in the not too remote sections of South Tien Shan the Přidoli fauna appears in its typically cosmopolitan composition.

Tien Shan. — In Central Asia, the most complete Přidoli sections have been recognized in South Tien Shan. RINENBERG (in OBUT *et al.* 1968) describes a number of taxa indicative of the *bouceki*, *perneri*, *bugensius*, and *chelmiensis* Zones. ABDUAZIMOVA (1970) also reports the presence, in the section on the Isfara River, of a *bugensius* form, which in view of the revision presented herein is now assigned to *lochkovensis*.

Further data concerning the presence of the Přidoli Series in this region have been provided by SOLONCHENKO and RINENBERG (1984) who have recorded not only *Monograptus bouceki*, but also a number of other taxa characteristic of the Lower Devonian. RINENBERG (1985) also mentions some representatives of the Přidoli in the Isfara horizon Regional Stage of the Fergana Valley margin, suggesting that there, the morphotypes of the *transgrediens* stock co-occur with *M. formosus*, *M. bouceki*, and *M. perneri* – the taxa characteristic of the Přidoli Series.

These data are, however, too fragmentary to provide a complete picture of the Series and the graptolites it contains. Nevertheless, RINENBERG (1985) correlates the sections studied by her with the Prague Basin and the Chełm IG-1 section.

In their discussion of a biozonal scheme for the Upper Silurian of the Turkestan-Alai, KOREN', and LYTOCHKIN (1992) recognize, within the Přidoli Series, the following Zones: *parultimus*, *ultimus*, *branikensis*, *M.* aff. *lochkovensis*, *M. bouceki*, *M.* ex.gr. *transgrediens*, and *M. transgrediens*. They provide a correlation with the Prague Basin and with the zonal scheme established for it by JAEGER (in KRIŽ *et al.* 1986). This correlation seems to be perfectly correct in relation to the *parultimus*, *bouceki*, and *transgrediens* s.s. Zones, but it becomes dubious as regards *M. branikensis*, *M.* aff. *lochkovensis*, and *M.* ex. gr. *transgrediens*.

M. branikensis was distinguished by JAEGER (in KRIŽ *et al.* 1986) only once in the Branik section, in a one-meter band underlying the *pridoliensis* Zone. He also presumes its presence (JAEGER in KRIŽ *et al* 1986) in the Hviždalka section, but much higher up, at the boundary between the *pridolensis* Zone and

the upper *lochkovensis* Subzone. In the present author's opinion the diagnosis of *M. branikensis* is generalised and unconvincing. JAEGER himself points to its similarity with *lochkovensis* and the difficulty in distinguishing one from the other, especially in the juvenile stages.

Having studied the holotype and the paratypes of the species in question in Prague, 1992, the present author is inclined to assign the taxon identified by JAEGER to *Neocolonograptus lochkovensis*, a form showing great intraspecific variation. The stratigraphic position of the taxon – above the *ultimus* and below the *pridolensis* Zone – is in conformity with that of the lower part of the *lochkovensis* Zone.

In Tien Shan, the stratigraphic position of *M. branikensis* seems to be similar to the interval occupied by the lower *lochkovensis* Zone (JAEGER in KRIŽ *et al.* 1986).

As to the form itself, the present author believes, after having examined the type material in St. Petersburg, that it should be identified as *lochkovensis*. KOREN' and SUYARKOVA (personal comunication) have also identified a new species *N. tumultuosus* KOREN' *et* SUYARKOVA. The taxon is very similar and most probably conspecific with *N. lochkovensis*. In the Tien Shan section, it occurs above *branikensis* and below *bouceki*, which confirms the author's conviction that it also represents the *lochkovensis* Zone. It is hard to find a reliable justification for the fundamental difference between the Přidoli graptolite faunas of Tien Shan, on the one hand, and those from the Prague Basin or the parastratotype Chełm IG-1 section, on the other. Why should only these two species, that are hardly distinquishable from *N. lochkovensis*, be an indication of provincialism, when all those recognized above and below are cosmopolitan?

Such species as *Monograptus bouceki*, *M. perneri*, and *Istrograptus transgrediens* provide another indicator of a close similarity between the sections, the Přidoli Series of Tien Shan being a sort of a replica of the zonal sequences in the Prague Basin and in Poland. In the EEP part of Poland with its unfolded sequence, the last of the three above species yields several distinct populations, constituting an evolutionary lineage. In Tien Shan, the *transgrediens* morphotype has been recorded in different intervals, being identified as s.l. and s.s. It is likely that each of the intervals contains a separate morph which would allow a correlation of the whole with the Polish sequence, resulting in a very similar picture.

The Tien Shan sections are tectonically highly deformed and isolated from one another, making studies of them susceptible to error. Nevertheless, it is highly probable that the Přidoli sequences of Tien Shan are very comparable to the sections known from the EEP (TELLER 1964) and the Prague Basin (PŘIBYL 1940; JAEGER in KRIŽ *et al.* 1986). It is its tectonic involvment and incomplete knowledge of the graptolite fauna that make an accurate correlation impossible.

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REFERENCES

ABDUAZIMOWA, Z.M. 1970. Graptolites of the Upper Wenlockian, Ludlovian and overludlovian in some regions of Southern Tien -Shan [in Russian]. *In:* T.S. Shajakubov (ed.), *Biostratigraphy of the sedimentary structures of the Uzbekistan 9*, 34–69. Nedra.

BANDALETOV, S.M. 1971. The Silurian of Kazakhstan [in Russian]. *In:* E.G. Shligin and S.M. Bandaletov (eds), *Stratigraphical Symposium on the prepaleozoic and paleozoic of Kazakhstan (abstracts of contributions)*, 8–10. Ministerstvo Geologii Kazakhskoi SSR, Alma-Ata.

BANDALETOV, S.M. and MIKHAJLOVA, N.F. 1971. The Upper Silurian and Silurian/Devonian boundary in Kazakhstan [in Russian]. *In:* D.W. Nalivkin (ed.), Silurian/Devonian boundary and Silurian biostratigraphy. — *Trudy III Meždunarodnogo Simpoziuma Tom I, Leningrad 1968*, 39–48.

BANDALETOV, S.M., PALETS, L.M., and OLENICHEVA, M.A. 1983. The Tokrau Horizon (Přidoli Stage) from Kazakhstan [in Russian]. *In:* M.K. Apollonov, S.M. Bandaletov, and N.K. Ivshin (eds), *Stratigrafiya i paleontologiya nizhnego paleozoya Kazakhstana*, 25–35. Nauka, Alma Ata.

BERRY, W.B.N. and MURPHY, M.A. 1975. Silurian and Devonian graptolites of Central Nevada. — *University of California Publication in Geological Sciences* **110**, 1–109.

DAHLGRÜN, F. and SEITZ, O. 1944. Die Bohrung Leba in Pommern. — *Jahrbuch Reichsamt für Bodenforschung* **63**, 82 –94.

JACKSON, D.E. and LENZ, C.E. 1969. Latest Silurian graptolites from Percupine Riwer, Yukon Territory. — *Contribution to Canadian Paleontology. Geological Survey of Canada. Bulletin* **182**, 12–29.

JACKSON, D.E., LENZ, A.C., and PEDDER, A.E. 1978. Late Silurian and Early Devonian graptolite, brachiopod and coral faunas from north-western and Arctic Canada. — *Geological Association of Canada Special Paper* **17**, 1–158.

JAEGER, H. 1959. Graptolithen und Stratigraphie des jüngsten Thüringer Silurs. — *Abhandlungen der deutschen Akademie der Wissenschaften. Klasse Chemie, Geologie, Biologie* **2**, 1–197.

JAEGER, H. 1967. Preliminary stratigraphical results from graptolite studies in the Upper Silurian and Lower Devonian of Southeastern Australia. — *Journal of the Geological Society of Australia* **14**, 281–286.

JAEGER, H. 1975. Die Graptolithenfürung im Silur? Devon des Cellon-Profiles (Karnische Alpen). — *Carinthia II* **65/85**, 111–126.

JAEGER, H., DORE, F., and PHILIPPOT, A. 1965. Présence du Budnanien en Normandie dans le Synclinal d'Urville (Calvados). — *Mémoires du Bureau de Recherches Géologiques et Minières* **33**, 41–42.

JENKINS, C.J. 1982. Late Přidolian graptolites from the Elmside Formation near Yass, New South Wales. — *Proccedings Linne Society New South Wales* **106**, 167–172.

KOREJWO, K. and TELLER, L. 1964. Upper Silurian non-graptolite fauna from Chełm borehole (Eastern Poland). — *Acta Geologica Polonica* **14**, 233–400.

KOREN', T.N. 1973. Late Silurian and Early Devonian graptolites of the Ural folded region [in Russian]. — *Trudy Instituta Geologii i Geokhimii* **99**, 132–168.

KOREN', T.N. 1983. New Late Silurian Monograptids from Kazakhstan. — *Palaeontology* **26**, 417–434.

KOREN', T.N. 1986. Graptolites [in Russian]. *In:* I.F. Nikitin and S.M. Bandaletov (eds), *The Tokrau horizon of the Upper Silurian Series: Balkhash segment*, 86–138. Nauka Kazakhskoi SSR, Alma Ata.

KOREN', T.N. 1989. The graptolitic Ludlow and Přidoli Series in Kazakhstan. *In:* C.H. Holland and M.G. Basset (eds), *A Global Standard for the Silurian System*, 149–157. National Museum of Wales, Geological Series 9, Cardiff.

KOREN', T.N. 1994. The Homerian monograptid fauna of Central Asia: zonation, morphology and phylogeny. *In:* Chen Xu, B-D. Erdtnann and Ni Yu-nan (eds), *Graptolite Research Today*, 140–148. Nanjing University Press.

KOREN', T.N. and LYTOCHKIN, V.N. 1992. A graptolite-based biozonal scheme of the upper Silurian in the Turkestan-Alai Range [in Russian]. — *Sovetskaya geologiya* **11**, 37–44.

KRANDIEVSKY, V.S., ISHCHENKO, T.A., and KIRYANOV, V.V. 1968. *Palaeontology and Stratigraphy of the Volyno-Podolian Lower Paleozoic* [in Russian], 1–124. Naukova Dumka. Kiev.

KRIŽ, J., JAEGER, H., PARIS, F., and SCHÖNLAUB, H.P. 1986. Přidoli – the Fourth Subdivision of the Silurian. — *Jahrbuch Geologischer Bundesanstalt* **129**, 291–360.

KRIŽ, J. 1989. The Přidoli Series in the Praque Basin (Barrandian area, Bohemia). *In:* C.H. Holland and M.G. Basset (eds), *A Global Standard for the Silurian System*, 90–100. National Museum of Wales, Geological Series 9, Cardiff.

LENZ, A.C. 1988. Upper Silurian and Lower Devonian graptolites and graptolite biostratigraphy, Northern Yukon, Canada. — *Canadian Journal Earth Sciences* **25**, 355–369.

LENZ, A.C. 1990. Ludlow and Přidoli (Upper Silurian) graptolite biostratigraphy of the Central Arctic Islands: a preliminary report. — *Canadian Journal Earth Sciences* **27**, 1074–1083.

LENZ, A.C. and JACKSON, D.E. 1971. Preliminary investigations on the Upper Silurian and Lover Devonian graptolite Biostratigraohy of the nortwestern Canadian Mainla nd. *In:* D.W. Nalivkin (ed.), Silurian/Devonian boundary and Silurian biostratigraphy. — *Trudy III Meždunarodnogo Simpoziuma Tom I, Leningrad 1968*, 127–134.

MIKHAJLOVA, N,F. 1971. Graptolite zonation of the Silurian deposits of Kazakhstan [in Russian]. *In:* E.G. Shligin and S.M. Bandaletov (eds), *Stratigraphical Symposium on the prepaleozoic and paleozoic of Kazakhstan (abstracts of contributions)*, 115–117. Ministerstvo Geologii Kazakhskoi SSR, Alma-Ata.

MIKHAJLOVA, N.F. 1976. Postludlovian graptolites of Kazakhstan [in Russian]. *In:* D. Kaljo and T. Koren' (eds), *Graptolites and Stratigraphy*, 99–104. Institute of Geology, Academy of Sciences of the Estonian SSR, Tallinn.

OBUT, A.M., ABDUAZIMOVA, Z.M., GOLIKOV, A.N., and RINNENBERG R.E. 1968. Graptolite-based zonation and correlation of Silurian deposits in Central Asia [in Russian]. *In:* B.S. Sokolov and A.B. Ivanovski (eds), *Biostratigraphy of Silurian/Devonian boundary deposits*, 75–85. Nauka, Moskva.

PŘIBYL, A. 1940. Die Graptolitenfauna des mittleren Ludlows von Böhmen (Oberes eß). — *Věstnik geologičeského ústavu* **16**, 63–73.

PŘIBYL, A. 1983. Graptolite biozones of the Kopanina and Přidoli Formations in the Upper Silurian of Central Bohemia. — *Časopis pro mineralogii a geologii* **18**, 149–167.

RICKARDS, R.B. and BANKS, M.R. 1992. Two Monograptus species from the Přidoli of Western Tasmania. — *Papers and Proceedings of the Royal Society of Tasmania* **26**, 9–11.

RINNENBERG, R.E. 1965. On the stratigraphy of Silurian terrigenous deposits from the northern slopes of the Alai Range. *In: Novye dannye po stratigrafii Tian'-Shanya*, 67–72.

RINNENBERG, R.E. 1973. New data on the graptolite-based Silurian biostratigraphy of the Fergana Range [in Russian]. *In: New data on palaeontology of Siberia and Middle Asia*, 45–48. Nauka. Novosibirsk.

RINNENBERG, R.E. 1985. The graptolite-based stratigraphy of the Silurian deposits from South Tian-Shan [in Russian]. — *Bulleten Moskovskogo Obshchestva ispytatelei prirody, Otdelenie geologii* **60**, 73–79.

SANDLER, Y.N. and GLUSHKO, V.V. 1955. The folded Silurian in the north-western Lvov Region [in Russian]. — *Doklady Akademii Nauk SSSR* **103**, 685–688.

SCHÖNLAUB, H.P. 1979. Das Paläozoikum in Österreich. — *Abhandlungen der Geologischen Bundesanstalt* **33**, 1–124.

SOLONTSCHENKO, I.I. and RINENBERG, R.E. 1984. Stratigraphy of the Silurian sediments of the Eastern Alai [in Russian]. — *Bulleten Moskovskogo Obsestva Ispytatelei Prirody, Otdelenie geologii* **56**, 70–82.

TELLER, L. 1960. Results obtained in borehole Chełm (Lublin Upland). — *Biuletyn Instytutu Geologicznego* **165**, 50–60.

TELLER, L. 1964. Graptolite fauna and stratigraphy of the Ludlovian deposits of the Chełm borehole — Eastern Poland. — *Studia Geologica Polonica* **13**, 1–88.

TELLER, L. 1966. Two species of Monograptidae from the Upper Ludlovian of Poland. — *Biulletin de l'Académie Polonaise des Sciences Cl. II* **14**, *Série des Sciences Biologiques*, 553–558.

TELLER, L. 1969. The Silurian biostratigraphy of Poland based on graptolites. — *Acta Geologica Polonica* **19**, 393–502.

TELLER, L. 1987. Přidolian graptolites and their use in correlation. — *Bulletin Geological Society of Denmark* **35**, 217– 222.

TOMCZYK, H. 1962. Stratigraphic problems of the Ordovician and Silurian in Poland in the light of recent studies. — *Instytut Geologiczny. Prace* **35**, 1–134.

TOMCZYK, H. and TELLER, L. 1956. The Ludlow deposits in Eastern Poland. — *Bulletin de l'Academie Polonaise des Sciences Cl. III* **4**, 549–553.

TOMCZYKOWA, E. 1988. Silurian and Lower Devonian Biostratigraphy and Palaeoecology in Poland. — *Biuletyn Instytutu Geologicznego* **359**, 21–41.

TSEGELNJUK, P.D. 1976a. The stratigraphy of the Silurian and Lower Devonian deposits of the Polesye Massif and Brest Depression [in Russian]. *In:* P.L. Shulga (ed.), *Palaeontology and stratigraphy of the Upper Precambrian and Lower Paleozoic of the SW part of the East European Platform*, 77–90. Naukova Dumka, Kiev.

TSEGELNJUK, P.D. 1976b. Late Silurian and early Devonian monograptids from the South-Western margin of the East European Platform [in Russian]. *In:* P.L. Shulga (ed.), *Palaeontology and stratigraphy of the Upper Precambrian and Lower Paleozoic of the SW part of the East European Platform*, 91–133. Naukova Dumka, Kiev.

TSEGELNJUK, P.D. 1980. The Rukshchinskaya and Tsyganskaya Series (Upper Silurian–Lower Devonian) of Podolia and Volynia [in Russian]. — *Institut geologicheskikh nauk Akademii Nauk Ukrainy. Preprint* **80–11**, 1–53.

TSEGELNJUK, P.D. 1981. Siluran Biochronology of Volyno-Podolia [in Russian]. — *Institut geologicheskikh nauk Akademii Nauk Ukrainy. Preprint* **81–26**, 1–55.

TSEGELNJUK, P.D. 1983. The Ulichian Stage of the Silurian System [in Russian]. — *Institut geologicheskikh nauk Ukrainy. Preprint* **83–1**, 1–53.

URBANEK, A. 1970. Neocucullograptinae n. subfam. (Graptolithina) their evolutionary and stratigraphic bearing. — *Acta Palaeontologica Polonica* **15**, 163–388.

URBANEK, A. 1993. Biotic crises in the history of Upper Silurian Graptoloids: A Palaeobiological Model. — *Historical Biology* **7**, 29–50.

WILLEFERT, S. 1962. Quelques graptolites du Silurien Superieur du Sahara Septentional. — *Bulletin de la Societé Géologique de France. Série 7*, **4**, 24–40.

WOLSKA, Z. 1969. Conodonts from a boring in (Poland). — *Acta Palaeontologica Polonica* **14**, 577–594.