THE SUBSURFACE SILURIAN IN THE EAST EUROPEAN PLATFORM

LECH TELLER

Teller, L. 1997. The subsurface Silurian in the East European Platform. *In:* A. Urbanek and L. Teller (eds), Silurian Graptolite Faunas in the East European Platform: Stratigraphy and Evolution. — *Palaeontologia Polonica* **56**, 7–21.

A state of art overview of the Silurian System within the deep substratum of the East European Platform (EEP) is presented. Structural Regions are characterized in terms of biostratigraphy, tectonics and palaeogeography. The most instructive sections based on keywells have been briefly described with an emphasis on the western margin of the platform. The Silurian basin displays a typical platform development and may be traced from the neritic to the deep basinal facies. While the neritic belt is recognized from Gotland through Estonia, Volhynia to Podolia, the deep basinal facies has been documented NE of the Törnquist-Teisseyre lineament. The results presented are based on some 700 deep borings. They offer a summary of Silurian history of NE Poland and the adjacent areas, as well as a setting for graptolite biostratigraphy.

Key words: Silurian, East European Platform, Biostratigraphy, Tectonics, Palaeogeography.

Lech Teller, Instytut Paleobiologii PAN, ul. Twarda 51/55, 00-818 Warszawa, Poland.

Received 13 March 1995, accepted 30 June 1995

CONTENTS

HISTORY OF RESEARCH

An especially great contribution to the knowledge of the Palaeozoic sedimentary cover above the crystalline basement in the EEP was made between 1957–1970. It was the time when a wide-scale study of subsurface geological structures in the Polish Lowland was conducted in association with mineral resources prospecting. This project involved drilling of hundreds of deep boreholes, 100 per cent of which, in the early period, were completely cored. As a result, new research material became available, so plentiful that its detailed analytical study was beyond the capacity of the Polish Geological Institute. Silurian deposits were revealed or pierced in more than 320 boreholes. Their preliminary faunal documentation, especially that concerning graptolites, considerably enriched the general knowledge of the Silurian System not only in Poland (Fig. 1).

Until the mid-1950s, sediments of this age had only been known from the outcrops in the Holy Cross Mountains and in the Sudeten. Their stratigraphy was chiefly described by CZARNOCKI (1919, 1942), SAMSONOWICZ (1916, 1934) as well as by DAHLGRÜN and FINCKH (1934) and FINCKH (1932), FINCKH *et al.* (1942).

The materials analyzed mainly by the Polish Geological Institute and by the oil prospecters provided a deep insight in the stratigraphy and tectonic structure of the Paleozoic cover of the Platform area. A rich and varied fauna contained in the drilled sedimentary series was the source of fascinating and frequently unique palaeontological material.

The most interesting among Silurian deposits were the unfolded series encountered in the Polish part of the south-western EEP over a large area of 100 thousand km^2. The Törnquist-Teisseyre (T.T.) lineament forms the SW boundary of the Silurian sediments not folded in Caledonian time (Fig. 1).

The Silurian sediments deposited in this part of the Platform are fairly thick. Their thickness increases as the Platform slope plunges south-westwardly, reaching a maximum of 3340 m (TOMCZYK 1976) in the borehole near Słupsk.

Unfolded platform Silurian deposits were recorded for the first time in 1936 in the Łeba borehole below Zechstein. The borehole was drilled on the elevation of the same name by the former German Reichsamt für Bodenforschung in 1935/1936. The section obtained was 609 m thick (664.5–1273.4 m) and represented only the Upper Silurian. Its preliminary description was made by DAHLGRÜN and SEITZ (1944) and TELLER (1962). Over one hundred further boreholes drilled close to one another in 1960–1975 confirmed the conclusions of both of these earlier studies (TOMCZYK 1968, 1976) (Fig. 1).

Chełm IG-1 (Fig. 1), a borehole drilled by the Polish Geological Institute in 1954/1955, was another well within the SE-most edge of the Polish part of the marginal EEP, where Silurian fossil-bearing strata were demonstrated palaeontologically. Here, at a depth of 1207.4–1607.4 m, an almost 400 m thick Přidoli Series was penetrated in sedimentary continuity below the lower Lochkovian (TOMCZYK and TELLER 1956; TELLER 1960). It contained a rich graptolite (TELLER 1964) and benthic (KOREJWO and TELLER 1964) fauna similar to the one known from the present Přidoli Series of the Prague Basin (HAVLIČEK and ŠTORCH 1990;

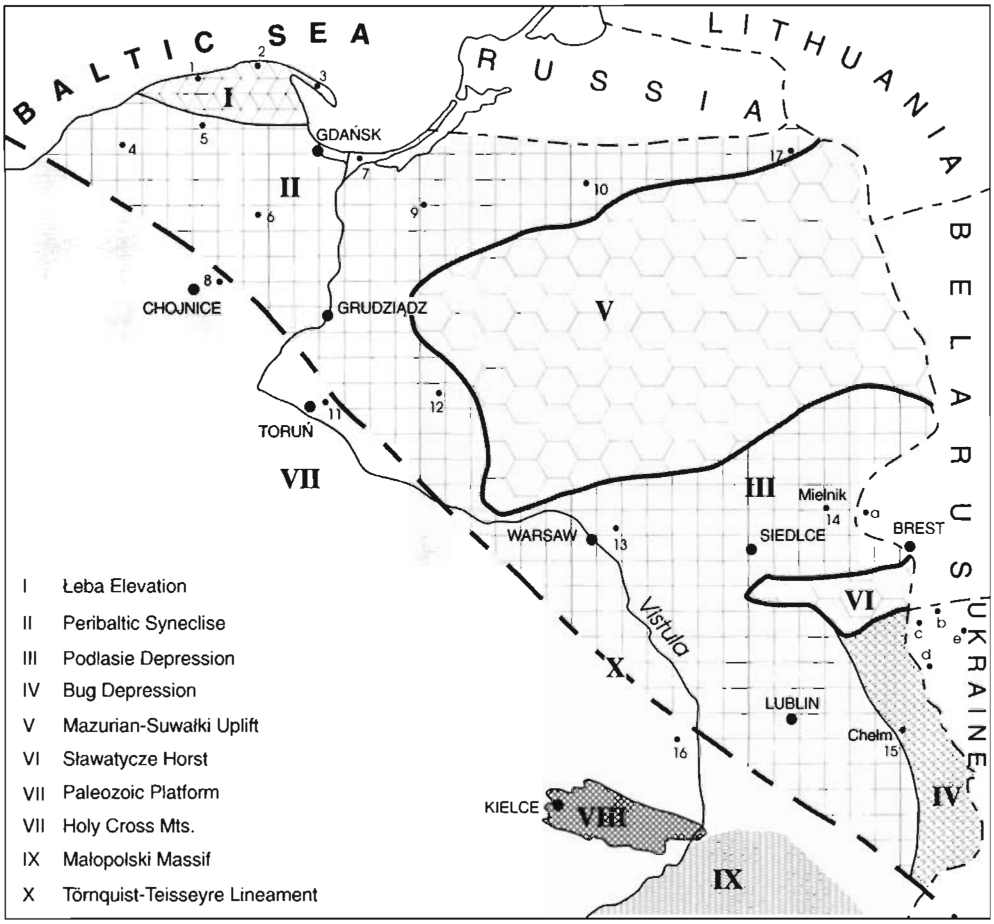

Fig. 1
A structural map of the marginal part of the EEP (Poland).
Selected Polish boreholes: 1 – Łeba, 2 – Żarnowiec, 3 – Hel, 4 – Słupsk, 5 – Lębork, 6 – Kościerzyna, 7 – Gdańsk, 8 – Lutom, 9 – Pasłęk, 10 – Bartoszyce, 11 – Toruń, 12 – Szczawno, 13 – Okuniew, 14 – Mielnik, 15 – Chełm, 16 – Ciepielów, 17 – Okrągłe Lake. Selected boreholes outside Poland: a – Brest-1, b – Pishcha-16, c – Tomashovka-406, d – Gushcha-4015, e – Yegorany-409.

PŘIBYL 1940, 1981, 1983; HORNY 1955; KŘIŽ *et al.* 1986). At that time this was the second locality in the world with this kind of fauna. Its stratigraphic position and correlation, especially in relation to the British sequence which at that time was generally accepted and regarded as classical, posed an uneasy task for geologists and palaeontologists.

A number of boreholes drilled in SE Poland and the Bug Depression (TOMCZYK 1974a–d, 1975a–d, 1977) in later years have confirmed the results obtained for Chełm IG-1 section.

The next well of importance drilled during the second half of the 1950s was the prospecting well Mielnik IG-1 (Fig. 1) located in the eastern part of the Podlasie Depression. It yielded an interesting and rich Lower Ludlow (Gorstian) graptolite fauna and also, above the *leintwardinensis* Zone, a new Early Ludfordian fauna subsequently studied by URBANEK (1963, 1966, 1971). His studies shed light on the evolution of this graptolite fauna, revealing a new, heretofore unknown stage in the development of monograptids whose mass occurrence was recorded for the first time in the Polish subsurface Silurian. The study of the Late Ludfordian graptolite fauna, based on the Mielnik IG-1 material (URBANEK this volume p. 89) supplements the preliminary results presented by TSEGELNJUK (1976a, b) for Volhynia and Podolia.

The information concerning this fauna which began appearing as early as the beginning of the 1960s (TELLER 1966, 1971; URBANEK 1963, 1966, 1971) did not bring a ready response from specialists in the field. It was not until some time later that similar fossil assemblages although less numerous (with the exception of, probably, Volhynia and Asia, were encountered in various sequences around the world: Canada – JACKSON and LENZ (1963, 1972), JACKSON *et al.* (1978), LENZ and JACKSON (1971); Volhynia

– TSEGELNJUK (1976a, b); Central Asia – MIKHAILOVA (1971, 1976), KOREN' (1983, 1986, 1989); Australia – JENKINS (1982); Morocco – WILLEFERT (1962); Prague Basin – PŘIBYL (1981 1983); ŠTORCH (1995).

Silurian deposits associated with the late Caledonian movements in the SE branch of the Caledonian geosyncline running through Poland have also been recorded in several points along the T.T. lineament marginal zone. They have been penetrated by deep borings within the narrow Koszalin–Chojnice belt (TELLER and KOREJWO 1968a, b, c; TELLER 1969; DADLEZ 1967) and also in SE Poland (TOMCZYK 1962; DADLEZ 1974a, b, c). It is not impossible that these deposits (mainly Ordovician and Silurian) have been partially overthrust onto the EEP (DADLEZ 1967, 1974c) (Fig. 1).

New material supplied by the boreholes since 1956 was studied from the point of view of stratigraphy by TELLER (1960–1990), TELLER and KOREJWO (1968a, b, c) and TOMCZYK together with TOMCZYKOWA (1958–1990). Palaeontological research of the graptolite fauna has been conducted since 1954 by TELLER (1962, 1964, 1966, 1975, 1976, 1988) and URBANEK (1954, 1958, 1960, 1963, 1966, 1970, 1976).

Other faunas have been described by KOREJWO and TELLER (1964), TOMCZYKOWA (1971, 1975), TOMCZYKOWA and WITWICKA (1972, 1974), NEHRING (1973), NEHRING-LEFELD (1985, 1987), WOLSKA (1969), WRONA (1980), and ŻBIKOWSKA (1973a, b, 1974). LANGIER-KUŹNIAROWA (1967, 1971, 1976) carried out penetrating petrographic studies. JAWOROWSKI (1965, 1966, 1971) and JAWOROWSKI and MODLIŃSKI (1968) conducted sedimentological and some stratigraphic research.

The results thus obtained provided a complete picture of the development of the Silurian deposits and faunas in the Polish part of the EEP. This places the Polish Silurian among the best recognized in Central Europe, a fact, which for reasons unknown, has been overlooked by many researchers (COCKS *et al.* 1992).

The problem that requires further work is the lithostratigraphic subdivision of the sediments. The subdivision suggested by TOMCZYK (1962: pp. 10–23, 110) was highly useful at the early stages of investigations, but is now inadequate for the present state of knowledge on the subject.

Having distinguished the Pasłęk, Mielnik, Siedlce and Podlasie Beds, TOMCZYK (1962: p. 119, tables 2 and 10) did not specify either the litho- or the chronostratigraphic criteria necessary for their discrimination, nor did he define the nature of the units recognized. In later years he never reconsidered his original scheme, but instead, only offered numerous interpretations and correlations of it.

In some of his papers the above author maintains that the units recognized by him correspond to beds (TOMCZYK 1970), in others, to regional stages (TOMCZYKOWA 1983) or even to formations (TOMCZYK and TOMCZYKOWA 1983). The same discrepancies are evident when analyzing the various correlation tables compiled by these authors (TOMCZYKOWA 1988: table 1; TOMCZYK 1990: table 16).

The entire Silurian in Poland fits well in the existing international chronostratigraphic subdivision, the regional names introduced by TOMCZYK (1962) having a purely local significance. They are the equivalents of the names of formations, groups, members, and beds in an informal lithostratigraphic subdivision; it is not until they have been redefined in conformity with the Polish stratigraphical code that some of them may acquire a formal status.

The unfolded platform Silurian deposits of Poland and the fauna they contain are fully comparable from the point of view of both their chrono- and biostratigraphy with coeval sediments of other regions in and outside Europe. Furthermore, the youngest Series of the System (Ludlow and Přidoli) are much more complete in Poland than are their counterparts in the regions of classical development (e.g., Britain, Bohemia).

THE WESTERN MARGINAL ZONE OF THE EAST EUROPEAN PLATFORM

What is understood by the western marginal zone (Fig. 1) is the region NE of the T.T. lineament that cuts Poland diagonally and extends from Koszalin in the NW to Dobruja and the mouth of the Dnester River to the Black Sea in the SE. Bathymetrically differentiated, this area was, during the Silurian, covered by an epicontinental sea (POŻARYSKI 1974a, b; TYSKI 1974). As such, it displayed a varied carbonate-dolomitic-marly sedimentation and is richly fossiliferous. The epicontinental sedimentation embraced the present-day eastern part of the Baltic Sea with Silurian deposits cropping out on several islands, e.g. Gotland (BASSETT *et al.* 1989), Saaremaa or Hiiumaa, and also Western Estonia (EINASTO *et al.* 1980; KALJO *et al.* 1970, 1977, 1991; KALJO 1971; NESTOR and EINASTO 1977, 1982), Lithuania (PAŠKEVIČIUS 1979, 1986), Latvia (ULST 1968), NE Poland, Belarus, and Volhynia and Podolia (KRANDIEWSKI *et al.*

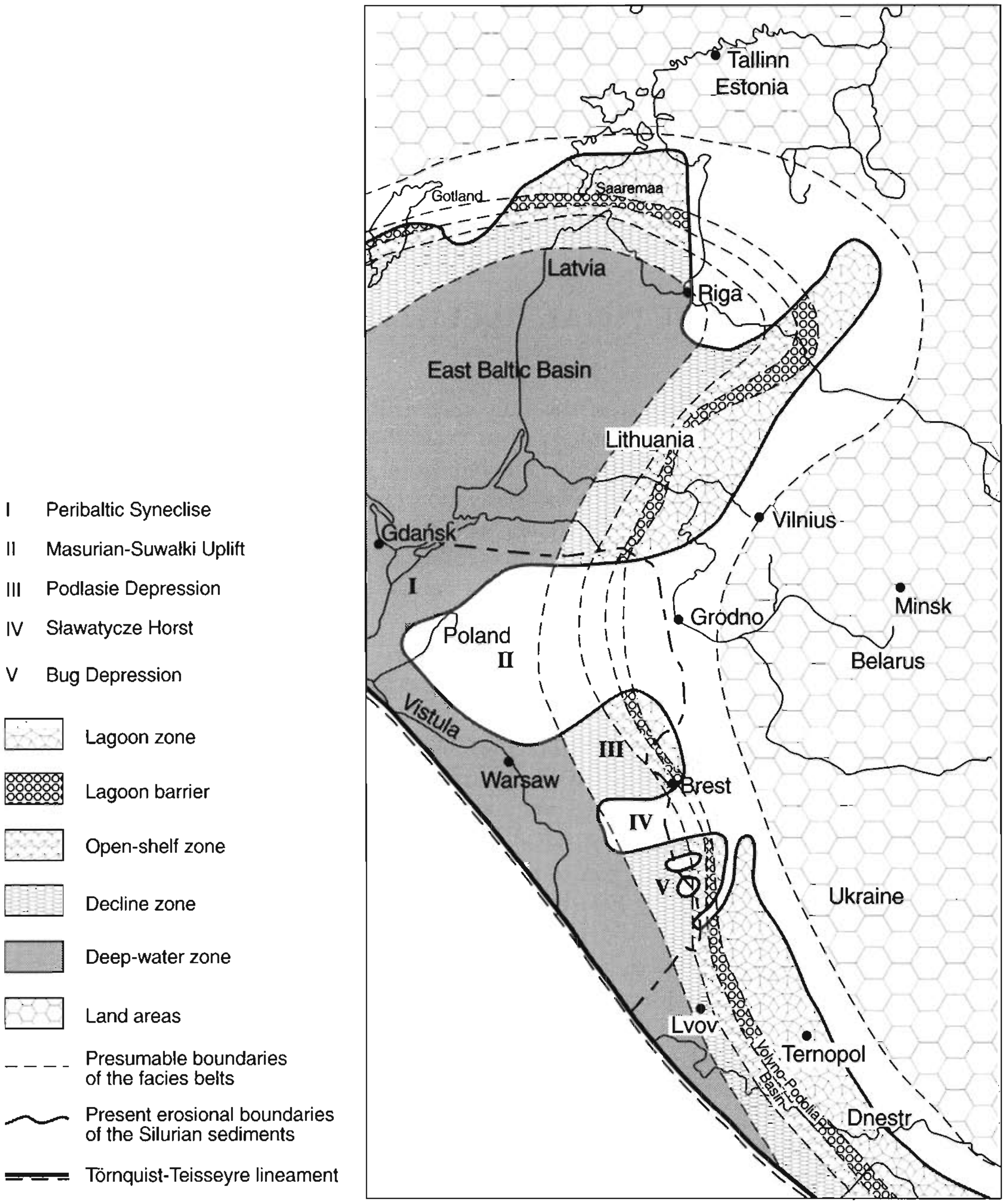

Fig. 2
The facies belts of the western margin of the EEP (Upper Wenlock time).
After EINASTO *et al.* (1986), modified.

1968; TSEGELNJUK 1983a, b) where the presence of Silurian rocks has been recorded in numerous boreholes (Fig. 2).

One of the world's most beautifully exposed Silurian rocks of the same epicontinental basin can be found along the north bank of the Dnester River and its tributaries in Podolia (NIKIFOROVA *et al.* 1972) (Fig. 3).

Towards the SW, the East European Platform marginal zone features an abrupt overdeepening, forming a slope. The epicontinental basin becomes a deep-water one connected to the NW with the SE branch of the Caledonian geosyncline. The entire basin displays a predominantly continuous argillaceous-marly sedimentation. The planktonic graptolite faunas amassed in these sediments are abundant and continuous as to allow a study of their phylogeny and astogeny (TELLER 1969).

The deep-water zone forms a fairly narrow belt parallel to the T.T. lineament. Throughout the epicontinental area and the deep-water basin situated on the Platform slope, Silurian deposits did not undergo folding at the Caledonian time, the only folded structures having been encountered in the elevated foreland of the EEP in the Koszalin–Chojnice belt (TELLER and KOREJWO 1968b; MODLIŃSKI 1968, 1982; DADLEZ 1974a, c) and also encountered in several boreholes in the SE (TELLER 1964; TOMCZYK 1968) (Fig. 1).

STRUCTURAL FACIAL REGIONS

In the Palaeozoic, the marginal zone of the Epigothic EEP was fairly labile, which accounted for a considerable differentiation of the morphology of its crystalline basement and also of the sedimentary cover (POŻARYSKI 1974b). The Silurian Sea was a continuation of the Cambrian basin, limited on the N and NE by the crystalline Baltic Shield and on the SE by the Ukrainian Shield. The bathymetric conditions prevailing in the extensive and calm basin together with a moderately warm climate contributed to the development of a rich and varied organic world. This facilitated a detailed stratification of the sediments, permitting a reconstruction of the basin's history and compilation of litho- and biostratigraphic schemes instrumental in interregional correlation.

NE of the T.T. lineament, one can distinguish several negative and positive structures that had a strong impact on the development of the sediments and fauna in that region (TYSKI 1974; POŻARYSKI 1974b) (Fig. 1).

The largest is the well-recognized Peribaltic Syneclise. It includes Latvia, Lithuania, part of SW Estonia, a small section of N and NW Poland which stretches from Koszalin to the Okrągłe Lake in the east, via the Łeba Elevation, the Gdańsk Bay, and a narrow belt running from Elbląg. That narrow strip forms the southern limb of the Peribaltic Syneclise in that area.

The Silurian sediments of the eastern part of the Syneclise (Estonia, Latvia, Lithuania) are described, especially by Estonian geologists, as the East-Baltic Silurian forming part of the East-Baltic Sedimentary Basin recognized there (EINASTO *et al.* 1986; KALJO 1971; KALJO *et al.* 1970; KALJO and JURGENSON 1977).

Within the Polish part of the EEP slope, as well as in the more shallow parts of the Peribaltic Syneclise, it is possible to distinguish larger and smaller structures of the second order. Some authors (ZNOSKO 1962, 1963, 1964, 1965, 1970; ZNOSKO and PAJCHLOWA 1968; TYSKI 1974; POŻARYSKI 1974a, b) associate the structures with the Caledonian movements, whilst others (VASILIAUSKAS 1965; SUVEJZDIS 1968) ascribe them to the Variscan movements. Among the most important structures are the Łeba elevation, the Masurian–Belarussian Anteclise, the Podlasie Depression, and also a number of smaller uplifts and depressions in the SE Lublin Region and in Southern Podlasie (Fig. 1).

The epicontinental Silurian of the marginal zone of the EEP also features two main sedimentary basins, each having a different configuration. These are the East Baltic and Podolian Basins (EINASTO *et al.* 1980) (Fig. 2).

The East Baltic Basin cut deeply into the Fennosarmatian continent forming an open bay whose N and NW shores marked the S slope of the Baltic Shield and the NW slope of the Ukrainian Shield, respectively. This basin was an extension of the Central European Caledonian geosyncline tapering out towards the East.

On the contrary, the fairly narrow Podolian Basin extended almost meridionally, running parallel to the SW margin of the crystalline Ukrainian Shield. It descended rapidly south-westerly to become an open sea (EINASTO *et al.* 1980).

Connected with the same marginal epicontinental sea, both the basins basically developed along the same lines. There was a considerable difference, however, in that the Early Silurian transgression began in the East Baltic Basin as early as the Middle Llandovery, whilst in the Podolian Basin it did not start until the onset of the Wenlock. Similarly, the Late Silurian regression, which in the East Baltic Basin was recorded as early as the Late Silurian (Přidoli), does not appear in Podolia until the Early Devonian (the Dniester Formation) (EINASTO *et al.* 1980). A transition zone between the two basins has also been confirmed by boreholes in eastern Poland (TOMCZYKOWA and TOMCZYK 1979).

The East Baltic Basin (Latvia, Lithuania and the SW part of Estonia) (Fig. 2). — Thanks to natural exposures in W Estonia and on Saaremaa and Hiiumaa islands, as well as to numerous boreholes drilled in Estonia, Lithuania and Latvia, the basin has been well described (EINASTO 1986; EINASTO *et al.* 1980; KALJO *et al.* 1970; NESTOR 1994; PAŠKEVIČIUS 1979, 1986; PAŠKEVIČIUS *et al.* 1994; ULST 1968; GAJILIITE *et al.* 1967). Throughout the entire Silurian, highly favourable living conditions existed for the continuous development of fauna. This made possible the execute a graptolite-based orthostratigraphic subdivision that could be further correlated with the areas featuring the predominance of argillaceous facies (PAŠKEVIČIUS 1986). Orthostratigraphic subdivisions based on conodonts, ostracods and ichthyofauna allowed, in turn, the more shallow facies of the basin to be connected and correlated with the regions farther West and South (the Podolian Basin).

Bathymetric analysis permitted three regions to be distinguished in the basin (KALJO *et al.* 1983). They are:

1) The shelf showing a predominance of various carbonates and distinctly subdivided into three macrofacial zones with a specific rock and faunal composition.

2) The gentle slope of the crystalline basement with prevailing muddy-carbonate-terrigenous rocks; the top part is dominated by calcareous marls containing numerous concretions and intercalations of detrital-muddy limestone, whilst in the lower portions, marls are fairly uniform.

3) A depression area featuring basically muddy-terrigenous facies and occupying the deepest central part of the basin. The rock is predominantly dark grey bituminous laminated horizontal claystones interbedded with marls (NESTOR and EINASTO 1977; KALJO *et al.* 1970; EINASTO, *et al.* 1980; KALJO and JURGENSON 1977).

According to KALJO *et al.* (1983), there were three basic stages of sedimentation each strongly influenced by transgressions and regressions, changes in climatic and alimentation conditions, extent of terrigenous material transport, tectonic development, and finally through the rate of sedimentation. The first stage was of a limited duration, namely from the Early to the Middle Llandovery. It was characterized by a limited supply of terrigenous material and a rapid deepening of the basin. The second stage, which began in the Late Llandovery and lasted until about the end of the Ludlow, displayed a fairly intensive muddy-carbonate sedimentation in the open shelf area, a marly-muddy type on the slope, and a muddy one in the deeper parts of the basin. The third stage is associated with the latest Silurian — the Přidoli, and extends into the Early Devonian. During that time the sedimentation of terrigenous material was quite intensive due to the Caledonian orogenic movements to the North.

The Podolian Basin (Fig. 2). — The Basin belonged to the same epicontinental area which, in the Silurian, stretched along the marginal zone of the EEP. Connected with the East Baltic Basin via E Poland, Belarus, Lithuania, and Latvia, the Podolian Basin can be easily distinguished as a separate one (EINASTO *et al.* 1986) by its position on the platform, its facial zonation and also by the timing of the Early Silurian transgression and the Late Silurian regression.

On the western slope of the Ukrainian Shield, the Podolian Basin displays a predominance of carbonate-marly deposits interbedded with dolomites. They contain rich, diverse and adequately studied benthic fauna. Where the slope of the EEP plunged and the sea became deeper, clayey-marly and clayey-muddy sedimentation prevailed, yielding abundant faunas (TSEGELNJUK *et al.* 1983b; KOREN' *et al.* 1989).

Silurian deposits are conspicuously exposed along high escarpments (100–200 m) of the north bank of the River Dnester flowing in a deeply cut valley and along its north tributaries. Stretching for about 100 km, between the villages Naddnestrovka in the East and Dnestrovoe in the West, the outcrops reveal Cretaceous and Tortonian deposits 30 to 50 m thick.

Due to the monoclinal aspect of the layers and their gentle 1–2° dip, towards WSW, the oldest deposits are exposed in the East, and the youngest, in the West (NIKIFOROVA *et al.* 1972; TSEGELNJUK *et al.* 1974).

The Silurian deposits disconformably overlying the Ordovician rocks, are in turn, overlain by a conformable and continuous sequence of marine Early Devonian terrigenous-carbonate sediments. According to some estimates (NIKIFOROVA *et al.* 1972), their thickness attains 370 m, whilst other authors (TSEGELNJUK *et al.* 1983b) suggest a thickness as high as 471 m.

The Podolian section (Fig. 3) features a complete sedimentation cycle starting with a marine transgression in the Early Silurian (Late Llandovery) and ending in a regression and replacement of the marine conditions by the continental ones in the Early Devonian (NIKIFOROVA *et al.* 1972; PREDTECHENSKY *et al.* 1983). Carbonate deposits prevail throughout the cycle, with dolomites, some barren or Red Beds also

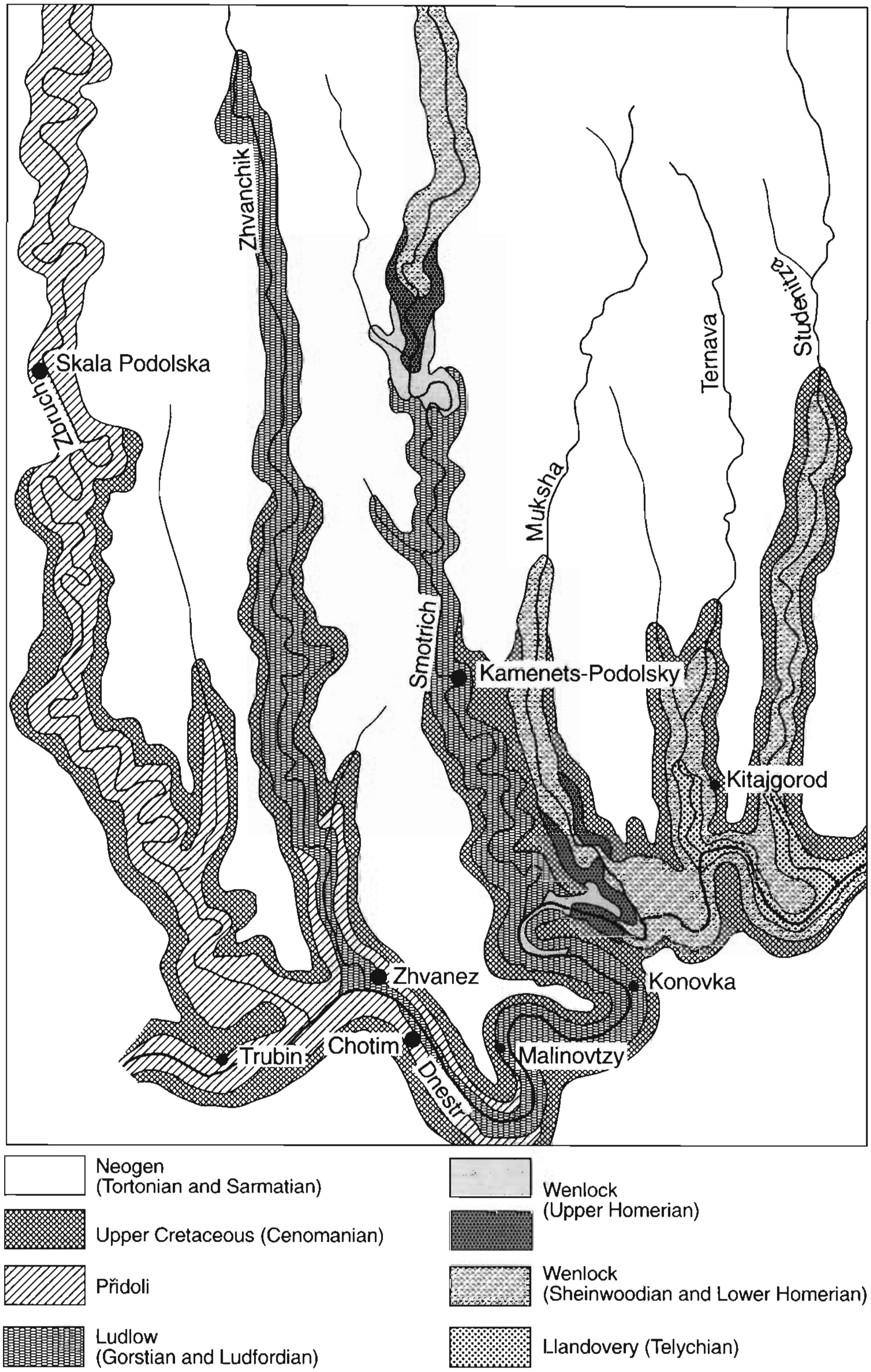

Fig. 3
Silurian key section of Podolia outcroping along the Dniester tributaries.
After O.I. NIKIFOROVA *et al.* (1972) and T.N. KOREN' *et al.* (1989), modified.

occurring at different stratigraphic levels. All this is suggestive of a considerable mobility of the sea bottom, including the possibility of breaks in deposition. However, on the basis of the continuity of the fauna (NIKIFOROVA *et al.* 1972), a break in sedimentation seems unlikely.

The western part of the Peribaltic Syneclise (Fig. 1). — Numerous structural boreholes and those for oil and gas prospecting drilled between 1960 and 1980 revealed, under the Permian cover, an erosional surface of Silurian deposits varying in age. They were either partly penetrated or bored through. The thickness of the Silurian rocks ranges from about 300 m in the East, in the southern limb of the Peribaltic Syneclise (the Gołdap IG-1 borehole), to about 3300 m in the western part (the Słupsk IG-1 borehole) (TELLER 1969; TOMCZYK 1968).

The extreme west of the Syneclise featuring a fairly sudden overdeepening of the Silurian Basin that developed in the marginal zone of the EEP, is dominated by clayey-muddy facies with subordinate carbonate interbeds. Silurian deposits rest on an uneven Late Ordovician surface of the epeirogenic Taconian phase. The chief faunal elements are graptolites which serve as the basis for biostratigraphic subdivision (TELLER 1964, 1969; URBANEK 1966, 1970), although Late Silurian (Ludlow, Early Přidoli) deposits in the region of the epicontinental facies development (the Łeba Elevation and further East) also yield an abundant benthic fauna instrumental in achieving a more accurate biostratigraphy (MARTINSSON 1964; TOMCZYKOWA and WITWICKA 1972, 1974; ŻBIKOWSKA 1973a, b).

The onset of the Llandovery Series is marked by the deposition of graptolite-bearing black claystone interbedded with a barren grey-green variety and having thin intercalations of dolomitic limestone with scarce brachiopods. In some parts of the basin, interbeds of unfossiliferous red-brown claystone are found. The thickness of the series varies, ranging from 25 m near the Pasłęk IG-1 and Prabuty IG-1 boreholes to almost 70 m in the Kościerzyna IG-1 deep boring. This is indicative of a fairly varied relief on the Ordovician surface. The abundant and well-preserved graptolite faunas provide a complete record of the Llandovery Series from the *acuminatus* Zone up to the *crenulata–spiralis* Zone (TELLER 1969).

The Wenlock Series is characterized by a uniform and fairly monotonous clayey sedimentation with a growing local proportion of carbonates. The deposits contain a rich and well-preserved graptolite fauna permitting the recognition of a complete section (TELLER 1976, 1986). The thickness of the series ranges between 80–100 m, although in places (the Lębork IG-1 borehole) it may reach 150 m. The Wenlock seems to be a time when the Late Silurian transgression in this area reached its peak, whereas the later Silurian tends to have a regressive character.

The Early Ludlow (Gorstian) Series is a continuation of the Wenlock clayey sedimentation, but there is a distinct interval between the two marked by a crisis in the graptolite fauna when almost all Wenlock representatives become extinct and new lines appear. This event has a global range and is recorded in every better known section the world over (JAEGER 1991; KOREN' and URBANEK 1994). The postcrisis dynamic development of the Gorstian fauna was studied by URBANEK (1966, 1970) using etched material from the Mielnik IG-1 borehole, the Podlasie Depression. URBANEK established several new graptolite zones which were subsequently confirmed not only in other Polish sections but also in a number of coeval sections throughout the world. The thickness of the Ludlow (Gorstian) Series varies between 270 m on the Łeba Elevation to 350 m in the Lębork IG-1 borehole (TOMCZYK 1968).

The Late Ludlow (Ludfordian) Series displays a considerable increase in the thickness of the deposits, 800 m at the most, starting from the *aversus* Zone and embracing vast areas of the western part of the Peribaltic Syneclise. The muddy fraction becomes more prominent. The graptolite faunas present in clayey interbeds allow zonal subdivisions from the *aversus* Zone to the *spineus* Zone (URBANEK and TELLER, this volume, p. 35).

The latest unit of the Silurian, the Přidoli Series is distinctly regressive, the basin showing signs of gradual shallowing and general disappearing as a result of the final stage of the Caledonian orogeny. The clayey-muddy facies gives way to a marly-carbonate one with abundant benthic faunas in frequent carbonate intercalations, whilst graptolite plankton becomes eliminated.

The western Peribaltic Syneclise, as demonostrated by trilobites and ostracodes (TOMCZYKOWA and WITWICKA 1972, 1974), contains only the Lower Přidoli, the absence of its upper part and of Devonian deposits being probably due to the pre-Permian erosion.

The southern slope of the western part of the Peribaltic Syneclise can be traced in Poland to the Lithuanian and Russian borders as a narrow belt extending from the Gołdap IG-1 borehole in the East as far as the Żarnowiec IG-1 borehole in the West. The Silurian deposits recorded here show a greater carbonate content and reduced thickness. That sedimentation occurred in much more shallow conditions is evidenced by the presence, in the Early Llandovery, of nodular limestone overlying Ordovician deposits with only a small break in sedimentation. The complex of younger Silurian sediments contains a much greater proportion of carbonates yielding a rich graptolite fauna. Here again various units of the latest

Silurian are sometimes missing; where they do occur, marls bear abundant benthic faunas, especially trilobites, which make careful biozonation possible (TOMCZYKOWA 1988).

In this region, the development of the Silurian sedimentation is closely associated with facial zones typical of the East Baltic Basin. As a result of the recent Masurian–Suwałki Elevation, whose Silurian deposits have been eroded, these zones (Fig. 1) were connected with the eastern part of the Podlasie Depression and the Bug Depression, extending further through Volhynia and what is known today as Podolia and as far as the Black Sea in the south east.

The Podlasie Depression (Fig. 1). — The western Epigothic EEP was strongly restructured during the Caledonian and Variscan times. The megastructures that appeared then had a great impact on the development of the Palaeozoic sedimentation cover (POŻARYSKI 1968). The Podlasie Depression was formed due to the elevation of the Masurian–Belarus Anteclise as late as the Variscan time (SUVEJZDIS 1968). The Baltic Syneclise was split into the Peribaltic Syneclise which developed in the North and the Podlasie Depression situated to the South of it. The Bug Depression and the Łuków–Wisznica horst (POŻARYSKI 1968) also appeared at the same time.

Silurian deposits recognized in the Podlasie Depression show a considerable facial diversity, as well as the lack of some stratigraphic units at the base and the top of the series. In the western part of the Depression (boreholes: Okuniew IG-1, Dobre IG-1, Terebin IG-1, Żebrak IG-1, Siedliska IG-1, and others, TOMCZYK 1975a, c, d, TOMCZYKOWA and TOMCZYK 1979), various parts of the Early Llandovery are represented by argillaceous-muddy deposits that overlie Late Ordovician deposits with a Taconian hiatus. Their age is well-established due to graptolites occurring in all sections.

The Ludlow and Přidoli Series continue the argillaceous-muddy sedimentation, although some parts have been removed by post-Silurian erosion. The erosion surface of the Silurian is overlain by Carboniferous, Permian, or Jurassic deposits. The thickness of the Silurian deposits, ranging within 300–1300 m, increases considerably towards SW, especially those of the Ludfordian.

The eastern part of the Depression (boreholes: Wrotnów IG-1, Biała Podlaska IG-1, Terespol IG-1, Mielnik IG-1, Stadniki IG-1, Bielsk Podlaski IG-1, and Widowo IG-1, TOMCZYKOWA 1988) displays a chiefly carbonate-marly facies, with the base of the section being made up of the most completely developed Wenlock and partly Llandovery Series overlying the Ordovician strata with a sedimentation hiatus (PUSHKIN *et al.* 1991). Abundant graptolites (URBANEK 1966, 1970) and trilobites (TOMCZYKOWA 1988) allow the age to be confidently defined.

The Ludlow is dominated by marly deposits yielding a rich graptolite fauna which served as the basis for not only a new zonal subdivision scheme of the series (TELLER 1971; URBANEK 1963, 1970, 1971), but also for establishing the presence of a new, heretofore unknown developmental stage of this fauna.

The Přidolian Series is complete only in the lower part, its upper member having been removed by erosion. The thickness of the Silurian succession varies between 9 and 225 m and is incomplete.

Towards SW, the belt containing Silurian deposits tapers out, and, on the Łuków–Wisznica horst, they are completely absent.

The Bug Depression (Fig. 1). — In the Bug Depression, Silurian deposits are shown to be present in deep boreholes: Kaplonosy IG-1, Krowie Bagno IG-1, Busówno IG-1, Chełm IG-1, Białopole IG-1, Narol IG-1, Terebin IG-1, and Strzelce IG-1) (TELLER 1964; TOMCZYKOWA 1988). Some of the sections repeatedly display the transition from the marine Silurian to the marine facies of the Early Gedinnian (Early Lochkovian). Argillaceous-muddy sediments prevail, their carbonate-content increasing towards the top. This is evidenced by fine intercalations of argillaceous limestone and carbonate nodules. Complete Silurian sections as well as the Early Devonian developed in the Rhine facies (Gedinnian) can be traced on the basis of abundant graptolites (TELLER 1964; TOMCZYKOWA and TOMCZYK 1979). Apart from graptolites, there are abundant and diverse benthic fauna (trilobites, bivalves, crinoids, brachiopods, and others) (KOREJWO and TELLER 1964; TOMCZYKOWA 1975), revealing strong ties with the Mediterranean (Palaeotethys). The unfolded Silurian of the Bug Depression extends south-westwardly as far as the T.T. lineament, whilst coeval strongly folded sequences have been discovered on the foreland of the area elevated by the EEP in the Ruda Lubycka and Rawa Russkaya boreholes and also in the boreholes near the city of Lvov. The thickness of the undeformed Silurian deposits of the Bug Depression can attain 1100 m.

The East European Foreland (Fig. 1). — Penetrated in only a few wells, Silurian deposits of the T.T. lineament zone are associated with the Caledonian structural complex. Their folding and, probably, partial overthrust onto the rigid platform occured during the fading phases of the Caledonian orogeny (DADLEZ 1967, 1974a, b; ZNOSKO 1962, 1963, 1964, 1965, 1970; MODLIŃSKI 1968, 1982; TELLER 1969, 1974; TELLER and KOREJWO 1968a, b, c; TOMCZYK 1980).

In NW Poland, various fairly thick members of Llandovery, Wenlock and Ludlow deposits have been documented as lying below the Devonian, Carboniferous or the Permian deposits of the Koszalin–Chojnice zone (MODLIŃSKI 1968; TELLER and KOREJWO 1968a, b, c; CZERMIŃSKI 1967; DADLEZ 1967; HAJŁASZ 1967).

In the boreholes of nearby Rugia, however, FRANKE (1967, 1978) and JAEGER (1967) have encountered a very thick complex of variably dipping Ordovician graptolitic shales.

In Central Poland (the Warsaw Synclinorium), the Caledonian structural complex is rather poorly known (DADLEZ 1974a, b). Silurian sediments penetrated in several borings attain a considerable thickness and must have been deposited in a geosynclinal basin. However, volcanism and intrusive magmatism are lacking, and there are no signs of Caledonian movements. The presence of Upper Silurian folded deposits has also been recorded in the extreme SE Polish part of the T.T. lineament, in the Ruda Lubycka borehole (TOMCZYK 1962; TELLER 1964), and also not far away, but already beyond the Polish border, in the Rava Russkaya well.

Acknowledgements. — Thanks are due to Dim KALJO (Tallinn), Piotr TSEGELNJUK (Kiev), Lech MIŁACZEWSKI (Warsaw), and Jan MALEC (Kielce) for valuable opinions and suggestions, as well as to Mrs Irina BAGAJEWA-URBANEK for translating the Polish manuscript into English. I am also grateful to the referee, Professor A.C. LENZ (London, Ontario, Canada), for helpful suggestions, corrections and improvements.

REFERENCES

BASSETT, M.G., KALJO, D., and TELLER, L. 1989. The Baltic Region. *In:* C.H. Holland and M.G. Basset (eds), *A Global Standard for the Silurian System*, 158–170. National Museum of Wales, Geological Series 9, Cardiff.

CZARNOCKI, J. 1919. Stratygrafia i tektonika staropaleozoicznych utworów Gór Świętokrzyskich (kambr, sylur, dewon dolny). — *Towarzystwo Naukowe Warszawskie* **1**, 1–172.

CZARNOCKI, J. 1942. *Silur im Święty Krzyż-Gebirge.* Archiwum Państwowego Instytutu Geologicznego, Warszawa.

CZERMIŃSKI, J. 1967. Metamorficzne podłoże Dewonu w Gościnnie k. Kołobrzegu. — *Kwartalnik Geologiczny* **11**, 693–696.

COCKS, L.R.M., HOLLAND, C.H., and RICKARDS, R.B. 1992. A revised correlation of Silurian rocks in the British Isles. — *Geological Society Special Report* **21**, 1–32.

DADLEZ, R. 1967. Najnowsze profile podłoża cechsztynu w północno-zachodniej Polsce. — *Kwartalnik Geologiczny* **11**, 572–584.

DADLEZ, R. 1974a. Tectonic position of Western Pomerania (Northwestern Poland) prior to the Upper Permian. — *Biuletyn Instytutu Geologicznego* **274**, 49–87.

DADLEZ, R. 1974b. Some geological problems of the Southern Baltic Basin. — *Acta Geologica Polonica* **24**, 261–276.

DADLEZ, R. 1974c. Przedpole obszaru wyniesionego platformy wschodnioeuropejskiej, część północno-zachodnia. *In:* W. Pożaryski (ed.), *Budowa Geologiczna Polski 4. Tektonika 1. Niż Polski*, 88–109. Wydawnictwa Geologiczne, Warszawa.

DAHLGRÜN, F. and FINCKH , L. 1934. Ein Silurprofil aus dem Warthaer Schiefergebirge in Schlesien. — *Jahrbuch Preussische Geologische Landesanstalt* **44**, 281–289.

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

EINASTO, R.Z. 1986. Main stages of development and facies models of the East Baltic Silurian pericontinental basin [in Russian]. *In:* D. Kaljo and E. Klaamann (eds), *Theory and Practice of Ecostratigraphy*, 37–54. Institute of Geology, Academy of Sciences of the Estonian SSR, Tallinn.

EINASTO, R.Z., KOTYK, W.A., and YUSHKEVICH, B.I. 1980. Formation-based zonal subdivision in the Silurian pericontinental basin of the western East European Platform [in Russian]. *In: Tipy osadochnykh formacii neftegazonosnykh basseinov*, 87–90. Nauka, Moskva.

EINASTO, R.Z., ABUSHIK, A.F., KALJO, D.P., KOREN', T.N., MODZALEVSKAYA, T.L., and NESTOR, H.Z. 1986. Silurian sedimentation and the fauna of the East Baltic and Podolian marginal basins: a comparison [in Russian]. *In:* D. Kaljo and E. Klaamann (eds), *Theory and Practice of Ecostratigraphy*, 65–72. Institute of Geology, Academy of Sciences of the Estonian SSR, Tallinn.

FINCKH, L. 1932. Erläuterungen zur Geologischen Karte von Preussen und benachbarten deutschen Ländern. — 273 *Blatt Frankenstein*, 1–78. Berlin.

FINCKH, L., MEISTER, E., FISCHER, G., and BEDERKE, E. 1942. Geologische Karte des Deutschen Reiches. — 343 *Erläuterungen zu den Blättern Glatz, Königshain, Reichstein, Landeck*, 1–90. Berlin.

FRANKE, D. 1967. Zu den Wariszíden und zum Problem der Kaledoniden im nordlichen Mitteleuropa. — *Berichte deutschen Geselschaft Geologischer Wissenschaften (Geologie–Paläontologie)* **12**, 1/2, 83–140.

FRANKE, D. 1978. Entwicklung und Bau der Paläozoiden in nordlichen Mitteleuropa, Teil 1. Paläogeographisch-paläotektonische Entwicklung des Pradevon. — *Zeitschrift geologischer Wissenschaften* **6**, 1, 5–32.

GAJILIITE, P.K., RYBNIKOVA, M.V., and ULST, R.Zh. 1967. *Stratigraphy, Fauna and Sedimentation Environment of Silurian Deposits in the middle Peribaltic Region* [in Russian], 1–299. Zinatne, Riga.

HAJŁASZ, B. 1967. O znalezieniu *Tentaculites* sp. w otworze wiertniczym Gościnno IG-1. — *Kwartalnik Geologiczny* **11**, 697–698.

HAVLIČEK, V. and ŠTORCH, P. 1990. Silurian brachiopods and benthic communities in the Prague Basin (Czechoslovakia). — *Rozpravy Ústředniho ústavu geologického* **48**, 1–275.

HORNY, R. 1955. Studie o várstvách budňanských v západní části Barrandienského siluru. — *Sbornik Ústředniho ústavu geologického* **21**, 315–347.

JACKSON, D.E. and LENZ, A.C. 1963. A new species of *Monograptus* from the Road River Formation, Yukon. — *Palaeontology* **6**, 751–753.

JACKSON, D.E. and LENZ, A.C. 1972. *Monograptus* from the Upper Silurian and Lower Devonian of Yukon Territory, Canada. — *Palaeontology* **15**, 579–597.

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. 1967. Ordoviz auf Rügen — Datierung und Vergleich mit anderen Gebieten (Vorläufige Mitteilung). — *Berichte deutscher Gesellschaft geologischer Wissenschaften Abteilung (Geologie–Paläontologie)* **12**, 165–176.

JAEGER, H. 1991. Neue Standard-Graptolithenzonenfolge nach der "Grossen Krize" an der Wenlock/Ludlow-Grenze (Silur). — *Neues Jahrbuch Geologie–Paläontologie, Abhandlungen* **182**, 303–354.

JAWOROWSKI, K. 1965. Top of the Pasłęk beds in the Lithuanian depression and the Wenlockian–Ludlovian boundary. — *Kwartalnik Geologiczny* **9**, 511–526.

JAWOROWSKI, K. 1966. Laminacja pozioma, przekątna i konwolutna w ludlowie wiercenia Lębork. — *Kwartalnik Geologiczny* **10**, 724–734.

JAWOROWSKI, K. 1971. Sedimentary structures of the Upper Silurian siltstones in the Polish Lowland. — *Acta Geologica Polonica* **21**, 519–571.

JAWOROWSKI, K. and MODLIŃSKI, Z. 1968. Lower Silurian nodular limestones in North-East Poland. — *Kwartalnik Geologiczny* **12**, 493–606.

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.

KALJO, D. 1971. The tectonic factor in the geological history of the East Baltic Basin during the Silurian. — *Mémoires du Bureau de Recherches Géologiques et Minières* **73**, 275–281.

KALJO, D. (ed.) 1970. *The Silurian of Estonia* [in Russian], 1–343. Institute of Geology, Academy of Sciences of the Estonian SSR, Tallinn.

KALJO, D. and JURGENSON, E. 1977. Sedimentary facies of the East Baltic Silurian. *In:* D. Kaljo (ed.), *Facies and fauna of the Baltic Silurian*, 122–148. Institute of Geology, Academy of Sciences of the Estonian SSR, Tallinn.

KALJO, D., VIIRA, V.J, KLAAMANN, Z.R., MJANNIL, R.P. MAARSS, T.L., NESTOR, V.V., NESTOR, H.Z., RUBEL, M.P., SARV, L.I., and EINASTO, R.Z. 1983. An ecological model of the East Baltic Silurian Basin [in Russian]. *In:* L.A. Nevesskaja (ed.), Ecological problems of the fauna and flora in the old basins. — *Trudy paleontologicheskogo instituta* **194**, 43–61.

KALJO, D. and MAARSS, T. 1991. Pattern of some Silurian bioevents. — *Historical Biology* **5**, 145–152.

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. 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. Bassett (eds), A Global Standard for the Silurian System. — *National Museum of Wales. Geological Series* **9**, 149–157.

KOREN', T.N., ABUSHIK, A.F., MODZALEVSKAYA, T.L., and PREDTECHENSKY, N.N. 1989. Podolia. *In:* C.H. Holland and M.G. Bassett (eds), A Global Standard for the Silurian System. — *National Museum of Wales. Geological Series* **9**, 141–148.

KOREN', T.N. and URBANEK, A. 1994. Adaptive radiation of monograptids after the late Wenlock crisis. — *Acta Palaeontologica Polonica* **39**, 137–167.

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

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

LANGIER-KUŹNIAROWA, A. 1967. Petrography of the Ordovician and Silurian deposits in the Lowland. — *Biuletyn Instytutu Geologicznego* **197**, 315–327.

LANGIER-KUŹNIAROWA, A. 1971. New data on petrography of the Ordovician and Silurian of the Polish Lowlands. — *Biuletyn Instytutu Geologicznego* **245**, 253–351.

LANGIER-KUŹNIAROWA, A. 1976. Ordowik i Sylur. – Rocks of the Precambrian Platform in Poland, 2. Sedimentary cover. — *Prace Instytutu Geologicznego* **74**, 48–72.

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

MARTINSSON, A. 1964. Palaeocope ostracodes from the Łeba-1 in Pomerania. — *Geologiska Foreningens i Stockholm Forhandlingar* **86**, 125–161.

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.

MODLIŃSKI, Z. 1968. Ordowik na Pomorzu Zachodnim. — *Kwartalnik Geologiczny* **12**, 488–492.

MODLIŃSKI, Z. 1982. Rozwój litofacjalny i paleotektoniczny na obszarze platformy prekambryjskiej w Polsce. — *Instytut Geologiczny. Prace* **102**, 1–66.

NEHRING, M. 1973. Mikrofauna dolnego dewonu z otworu wiertniczego Krowie Bagno IG-1. — *Kwartalnik Geologiczny* **17**, 57–72.

NEHRING-LEFELD, M. 1985. Konodonty z poziomu amorphognathoides (sylur) wschodniej części obniżenia podlaskiego. — *Kwartalnik Geologiczny* **29**, 625–639.

NEHRING-LEFELD, M. 1987. Małżoraczki wenloku z wybranych otworów wiertniczych zapadliska podlaskiego. — *Biuletyn Instytutu Geologicznego* **354**, 145–182.

NESTOR, H. 1994. Comments to the modernized Silurian chart of Estonia and Latvia. — *Geologija* **17**, 88–95.

NESTOR, H. and EINASTO, R. 1977. Facies sedimentary model of the Silurian Paleobaltic pericontinental basin. *In:* D. Kaljo (ed.), *Facies and fauna of the Baltic Silurian*, 89–121. Institute of Geology, Academy of Sciences of the Estonian SSR, Tallinn.

NESTOR, H. and EINASTO, R. 1982. Application of shelf and slope concepts to the Silurian Baltic. *In:* D. Kaljo and E. Klaamann (eds), *Ecostratigraphy of the East Baltic Silurian*, 17–23. Institute of Geology, Academy of Sciences of the Estonian SSR, Tallinn.

NIKIFOROVA, O.I., PREDTECHENSKY, N.N., ABUSHIK, A.F., IGNATOVICH, M.M., MODZALEVSKAYA, T.L., BERGER, A.I., NOVOSELOVA, L.S., and BURKOV, Y.K. 1972. *In:* B.S. Sokolov (ed.), *Silurian and Lower Devonian Key Sections of Podolia* [in Russian], 1–262. Nauka, Leningrad.

PAŠKEVIČIUS, J. 1979. *Biostratigraphy and Graptolites of the Lithuanian Silurian* [in Russian], 1–230. Maksklas, Vilnius.

PAŠKEVIČIUS, J. 1986. Assemblages of Silurian graptolites in various facies of the East Baltic region. — *Palaeoecology and Biostratigraphy of Graptolites. Geological Society Special Publication* **20**, 237–245.

PAŠKEVIČIUS, J., LAPINSKAS, P., BRAZAUSKAS, A., MUSTEIKIS, P., and JACYNA, J. 1994. Stratigraphic revision of the regional stages of the Upper Silurian part in the Baltic Basin. — *Geologija* **17**, 64–87.

POŻARYSKI, W. 1968. Rozwój tektoniczny starszego paleozoiku w środkowej i północnej Polsce. — *Kwartalnik Geologiczny* **12**, 1027.

POŻARYSKI, W. 1974a. Obszar wyniesiony platformy wschodnio-europejskiej – część środkowa. *In:* W. Pożaryski (ed.), *Budowa Geologiczna Polski* 4. *Tektonika* 1. *Niż Polski*, 71–77. Wydawnictwa Geologiczne, Warszawa.

POŻARYSKI, W. 1974b. Podział obszaru Polski na jednostki tektoniczne. *In:* W. Pożaryski (ed.), *Budowa Geologiczna Polski* 4. *Tektonika* 1. *Niż Polski*, 24–34. Wydawnictwa Geologiczne, Warszawa.

PREDTECHENSKY, N.N., KOREN', T.N., MODZALEVSKAYA, T.L., NIKIFOROVA, O.I., BERGER, A.I., and ABUSHIK, A.F. 1983. Sedimentation cycles and the change of faunal ecological assemblages in the Silurian of Podolia [in Russian]. *In:* L.A. Nevesskaja (ed.), Ecological problems of the fauna and flora in the old basins. — *Trudy paleontologicheskogo instituta* **194**, 61–74.

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

PŘIBYL, A. 1981. New graptolites of the family Monograptidae from the Upper Silurian of Bohemia. — *Věstnik Ústředniho ústavu geologičeského* **56**, 371–375.

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.

PUSHKIN, V.I., ROPOT, V.F., ABUSHIK, A.F., BRAZAUSKAS, A.Z., GRITSENKO, V.P., KRUCHEK, S.A., MODZALEVSKAJA, T.L., MOISEEVA, T.U., MJANNIL, R.M., PAŠKEVICIUS, J., and PISKUN, L.V. 1991. Ecostratigraphy: Results of investigations of Silurian deposits in the Byelarusian part of the Podljassk-Brest depression. *In:* A.S. Makhnach (ed.), 1–40. Nauka i Tekhnika, Minsk.

SAMSONOWICZ, J. 1916. Kambr i kambro-sylur Gór Świętokrzyskich. — *Sprawozdania z posiedzeń Towarzystwa Naukowego Warszawskiego* **9**, 321–358.

SAMSONOWICZ, J. 1934. Objaśnienia arkusza Opatów. — *Ogólna mapa geologiczna Polski* 1. Państwowy Instytut Geologiczny, Warszawa.

ŠTORCH, P. 1995. Upper Silurian (Upper Ludlow) graptolites of the *N. inexspectatus* and *N. kozlowskii* biozones from Kosov Quarry near Beroun (Barrandian area, Bohemia). — *Vestnik Českého geologickeho ustavu* **70**, 65–89.

SUVEJZDIS, P. 1968. Role of Caledonian and Hercynian movements in the tectonical development of the Peri-Baltic area. — *Kwartalnik Geologiczny* **12**, 797–811.

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

TELLER, L. 1962. Rewizja stratygrafii syluru z wiercenia Łeba-1. — *Przegląd Geologiczny* **11**, 595–597.

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**, *Sèrie des Sciences Biologiques*, 553–558.

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

TELLER, L. 1971. The Upper Silurian of Poland in the light of recent investigations. *In:* D.W. Nalivkin (ed.), Silurian/Devonian boundary and Silurian biostratigraphy. — *Trudy III Meždunarodnogo simpoziuma Tom I, Leningrad 1968*, 201–207.

TELLER, L. 1974. Sylur brzeżnej strefy platformy wschodnio-europejskiej w rejonie Miastko-Chojnice (NW Polska). — *Acta Geologica Polonica* **24**, 563–580.

TELLER, L. 1975. Silurian biostratigraphy of the Bachus 1 borehole (Eastern Poland). — *Acta Geologica Polonica* **25**, 567–573.

TELLER, L. 1976. Morphology of some Upper Wenlockian Cyrtograptinae from Zawada 1 profile (NE Poland). — *Acta Geologica Polonica* **26**, 469–484.

TELLER, L. 1986. Morphology of selected monograptidae from the Wenlock of NE Poland. — *Palaeontographica A* **192**, 51–73.

TELLER, L. 1988. A Wenlock ancestor of the *micropoma* phylogenetic lineage. — *Lethaia* **21**, 39–42.

TELLER, L. and KOREJWO, K. 1968a. Lower Silurian deposits from the borehole Lutom 1 (North-Eastern Poland). — *Acta Geologica Polonica* **18**, 293–301.

TELLER, L. and KOREJWO, K. 1968b. Early Paleozoic deposits in the deep substratum of north-western Poland. — *Acta Geologica Polonica* **18**, 613–619.

TELLER, L. and KOREJWO, K. 1968c. Stratigraphy of the Upper Silurian from the boreholes Chojnice-3 and Stobno-1 NW Poland. — *Acta Geologica Polonica* **18**, 750–759.

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. 1968. Silurian stratigraphy in the Peribaltic areas of Poland, based on drilling data. — *Kwartalnik Geologiczny* **12**, 35–36.

TOMCZYK, H. 1970. Silurian. *In:* S. Sokołowski, S. Cieśliński, and J. Czermiński (eds), *Geology of Poland* 1. 1. *Precambrian and Paleozoic*, 237–319. Wydawnictwa Geologiczne, Warszawa.

TOMCZYK, H. 1974a. Sylur *In:* B. Areń (ed.), Tłuszcz IG-1. — *Profile głębokich otworów wiertniczych Instytutu Geologicznego* **13**, 61–68, 103–110.

TOMCZYK, H. 1974b. Sylur. *In:* Z. Modliński (ed.), Bartoszyce IG-1, Gołdap IG-1. — *Profile głębokich otworów wiertniczych Instytutu Geologicznego* **14**, 53–59, 93–100.

TOMCZYK, H. 1974c. Sylur. *In:* A. Krassowska (ed.), Kock IG-1. — *Profile głębokich otworów wiertniczych Instytutu Geologicznego* **15**, 45.

TOMCZYK, H. 1974d. Sylur. *In:* T. Niemczycka (ed.), Ciepielów IG-1. — *Profile głębokich otworów wiertniczych Instytutu Geologicznego* **20**, 75–78.

TOMCZYK, H. 1975a. Sylur. *In:* L. Miłaczewski (ed.), Krowie Bagno IG-1. — *Profile głębokich otworów wiertniczych Instytutu Geologicznego* **25**, 44–47, 100.

TOMCZYK, H. 1975b. Sylur. *In:* Z. Modliński (ed.), Prabuty IG-1. — *Profile głębokich otworów wiertniczych Instytutu Geologicznego* **27**, 69–76.

TOMCZYK, H. 1975c. Sylur. *In:* K. Lendzion (ed.), Żebrak IG-1. — *Profile głębokich otworów wiertniczych Instytutu Geologicznego* **28**, 47–68, 78–109.

TOMCZYK, H. 1975d. Sylur. *In:* B. Areń (ed.), Okuniew IG-1. — *Profile głębokich otworów wiertniczych Instytutu Geologicznego* **29**, 30–36, 55–62.

TOMCZYK, H. 1976. Development of the lithofacies of the Silurian in the western part of the Peribaltic Syneclize. — *Biuletyn Instytutu Geologicznego* **270**, 137–141.

TOMCZYK, H. 1977. Sylur, *In:* Z. Modliński (ed.), Olsztyn IG-2. — *Profile głębokich otworów wiertniczych Instytutu Geologicznego* **39**, 76–82, 107–118.

TOMCZYK, H. 1980. Sylur w brzeżnej części platformy prekambryjskiej na tle wyników wiercenia Toruń 1. — *Kwartalnik Geologiczny* **24**, 421.

TOMCZYK, H. 1990. Korelacja biostratygraficzna syluru Polski z innymi obszarami. *In:* M. Pajchlowa (ed.), *Budowa Geologiczna Polski* 3. *Atlas skamieniałości przewodnich i charakterystycznych* 1a. *Paleozoik starszy (z proterozoikiem górnym)*, 273–279. Wydawnictwa Geologiczne, Warszawa.

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

TOMCZYKOWA, E. 1971. Upper Silurian trilobites in Poland and their stratigraphical importance. — *Mémoires du Bureau de Recherches Géologiques et Minières* **73**, 431–436.

TOMCZYKOWA, E. 1975. The trilobite subfamily Homalonotinae from the Upper Silurian and Lower Devonian of Poland. — *Acta Palaeontologica Polonica* **20**, 3–46.

TOMCZYKOWA, E. 1983. The standard Upper Silurian Siedlce and Podlasie Series in Poland and their European correlation. — *Bulletin de l'Academie Polonaise des Sciences Sèrie des Sciences de la Terre* **30**, 45–57.

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

TOMCZYKOWA, E. and TOMCZYK, H. 1979. Middle Silurian in the Podlasie Depresion (Eastern Poland). — *Biuletyn Instytutu Geologicznego* **318**, 59–103.

TOMCZYKOWA, E. and WITWICKA, E. 1972. Z badań stratygraficznych górnego syluru na obszarze nadbałtyckim Polski. — *Kwartalnik Geologiczny* **16**, 1006–1008.

TOMCZYKOWA, E. and WITWICKA, E. 1974. Stratigraphic correlation of Podlasian deposits on the basis of ostracodes and trilobites in the Peri-Baltic Area of Poland (Upper Silurian). — *Biuletyn Instytutu Geologicznego* **276**, 55–80.

TSEGELNJUK, P.D. (ed.) 1974. The Silurian [in Russian]. — *Stratigrafiya Ukrainskoi SSR* **4**, 1–216.

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. 1983a. The Ulichian Stage of the Silurian System [in Russian]. — *Institut geologicheskikh nauk Akademii Nauk Ukrainskoi SSR. Preprint* **83–1**, 1–53.

TSEGELNJUK, P.D. (ed.) 1983b. *The Silurian of Podolia: A guide to the excursion*, 55–222. Naukova Dumka, Kiev.

TYSKI, S. 1974. Obszar wyniesiony platformy wschodnioeuropejskiej część północna. *In:* W. Pożaryski (ed.), *Budowa Geologiczna Polski* 4. *Tektonika* 1. *Niż Polski*, 60–71. Wydawnictwa Geologiczne, Warszawa.

ULST, R.Ž. 1968. Biostratigraphy and correlation of the Silurian of the middle Baltic Region [in Russian]. *In:* A.A. Grigelis (ed.), *Stratigraphy of the Baltic Lower Paleozoic and its correlation with other areas*, 241–249. Mintis, Vilnius.

URBANEK, A. 1954. Some observations on the morphology of Monograptidae. — *Acta Geologica Polonica* **4**, 291–306, Conspectus, 100–107.

URBANEK, A. 1958. Monograptidae from erratic boulders of Poland. — *Palaeontologia Polonica* **9**, 1–105.

URBANEK, A. 1960. An attempt at biological interpretation of evolutionary changes in graptolite colonies. — *Acta Palaeontologica Polonica* **5**, 127–234.

URBANEK, A. 1963. On generation and regeneration of cladia in some Upper Silurian monograptids. — *Acta Palaeontologica Polonica* **8**, 135–254.

URBANEK, A. 1966. On the morphology and evolution of the Cucullograptinae (Monograptidae, Graptolithina). — *Acta Palaeontologica Polonica* **11**, 291–544.

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

URBANEK, A. 1971. Zonal evolution of monograptids in the Siedlce Beds: a new chapter in graptolite history [in Russian]. *In:* D.W. Nalivkin (ed.), Silurian/Devonian boundary and Silurian biostratigraphy. — *Trudy III Meždunarodnogo simpoziuma Tom 1, Leningrad 1968*, 222–228.

URBANEK, A. 1976. Ultrastructure of microfusseli and the evolution of graptolite skeletal tissues. — *Acta Palaeontologica Polonica* **21**, 315–331.

VASILJAUSKAS, V.M. 1965. The Caledonian/Hercynian Boundary in the Deposits of the Polish-Lithuanian Syneclise [in Russian]. — *Gosydarstvennyi Geologicheskii Komitet SSSR. Institut Geologii. Trudy* **1**, 3–5. Vilnius.

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

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

WRONA, R. 1980. Upper Silurian–Lower Devonian Chitinozoa from the subsurface southern Poland. — *Palaeontologia Polonica* **41**, 103–165.

ZNOSKO, J. 1962. Present status of knowledge of geological structure of deep substratum of Poland beyond the Carpathians. — *Kwartalnik Geologiczny* **6**, 485–521.

ZNOSKO, J. 1963. Problems of the Outer Carpathian part of Poland. — *Prace Instytutu Geologicznego* **30**, 4, 71–99.

ZNOSKO, J. 1964. Opinions sur l'étude des Caledonides en Europe. — *Kwartalnik Geologiczny* **8**, 697–712.

ZNOSKO, J. 1965. The problem of Caledonides and the border of Precambrian Platform in Poland. — *Biuletyn Instytutu Geologicznego* **188**, 5–40.

ZNOSKO, J. 1970. Pozycja tektoniczna obszaru Polski na tle Europy. — *Biuletyn Instytutu Geologicznego* **251**, 45–70.

ZNOSKO, J. and PAJCHLOWA, M. 1968. *Geological Atlas of Poland 1:2 000000*. Geological Institute, Warsaw.

ŻBIKOWSKA, B. 1973a. Małżoraczki górnosylurskie z wyniesienia Łeby (N Polska). — *Acta Geologica Polonica* **23**, 607–638.

ŻBIKOWSKA, B. 1973b. New species of Upper Silurian ostracodes from Pomerania (N Poland). — *Bulletin de l'Académie Polonaise des Sciences. Sèrie des Sciences de la Terre* **21**, 139–146.

ŻBIKOWSKA, B. 1974. Upper Silurian ostracod zones in the Chojnice area (NW Poland). — *Bulletin de l'Academie Polonaise des Sciences. Sèrie des Sciences de la Terre* **22**, 1, 45–48.