Acta Geologica Polonica, Vol. 52 (2002), No. 2, pp. 217-238

Stratigraphic and biogeographic significance of Late Cambrian trilobites from Łysogóry (Holy Cross Mountains, central Poland)

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ABSTRACT:

ŻYLIŃSKA, A. 2002. Stratigraphic and biogeographic significance of Late Cambrian trilobites from Łysogóry (Holy Cross Mountains, central Poland). *Acta Geologica Polonica*, **52** (2), 217-238. Warszawa.

Revision of the Late Cambrian trilobites from Łysogóry in the Holy Cross Mountains, central Poland, enabled the application of a modified version of the Upper Cambrian biostratigraphic zonation established for the Baltica palaeocontinent. The following zones and subzones were recognised: *Olenus scanicus* and *Parabolina brevispina* subzones, *Leptoplastus – Protopeltura praecursor* Zone, *Peltura minor* Zone (*Ctenopyge tumida* and *Ctenopyge affinis* subzones), *Peltura scarabaeoides* Zone (*Ctenopyge linnarssoni* and *?Parabolina lobata* subzones) and the *Acerocare* Zone *sensu lato*. Biogeographically the trilobites of Łysogóry show a distinct change, from a low diversity fauna with a predominance of Avalonian forms in the early Late Cambrian, to more diversified assemblages, characterised by the constant increase to dominance of Baltic elements by the end of the Cambrian.

Key words: Late Cambrian, Holy Cross Mountains, Trilobites, Biogeography, Biostratigraphy, Łysogóry Block.

INTRODUCTION

The present study documents the stratigraphic and biogeographic significance of Late Cambrian trilobites from the Holy Cross Mountains, central Poland. The importance of this area stems from the fact that it is the only Palaeozoic structure exposed in the direct vicinity of the East European Craton. The Holy Cross Mountains are a part of the Trans-European Suture Zone (TESZ), one of the main geotectonic domains in Europe (BERTHELSEN 1992), the formation of which still remains highly controversial. The restudy of the biostratigraphy and biogeographic affinities of the Early Palaeozoic of the Holy Cross Mountains might thus be of crucial importance in deciphering the assembly of Laurussia during this interval.

The stratigraphy of the Upper Cambrian of the Łysogóry region of the Holy Cross Mountains presented in this paper is based on rich and well documented trilobite material (over 1300 specimens). Their revised systematic analysis was published recently (ŻYLIŃSKA 2001). Previous papers on the taxonomy and stratigraphy of the Late Cambrian trilobites (ORŁOWSKI 1968b; TOMCZYKOWA 1968) indicated the presence of mainly endemic species in Łysogóry, and consequently local zonations were applied hitherto.

GEOLOGICAL SETTING AND LOCALITIES

The Palaeozoic of the Holy Cross Mountains (Text-fig. 1a) consists of the Lower Cambrian up to and includ-

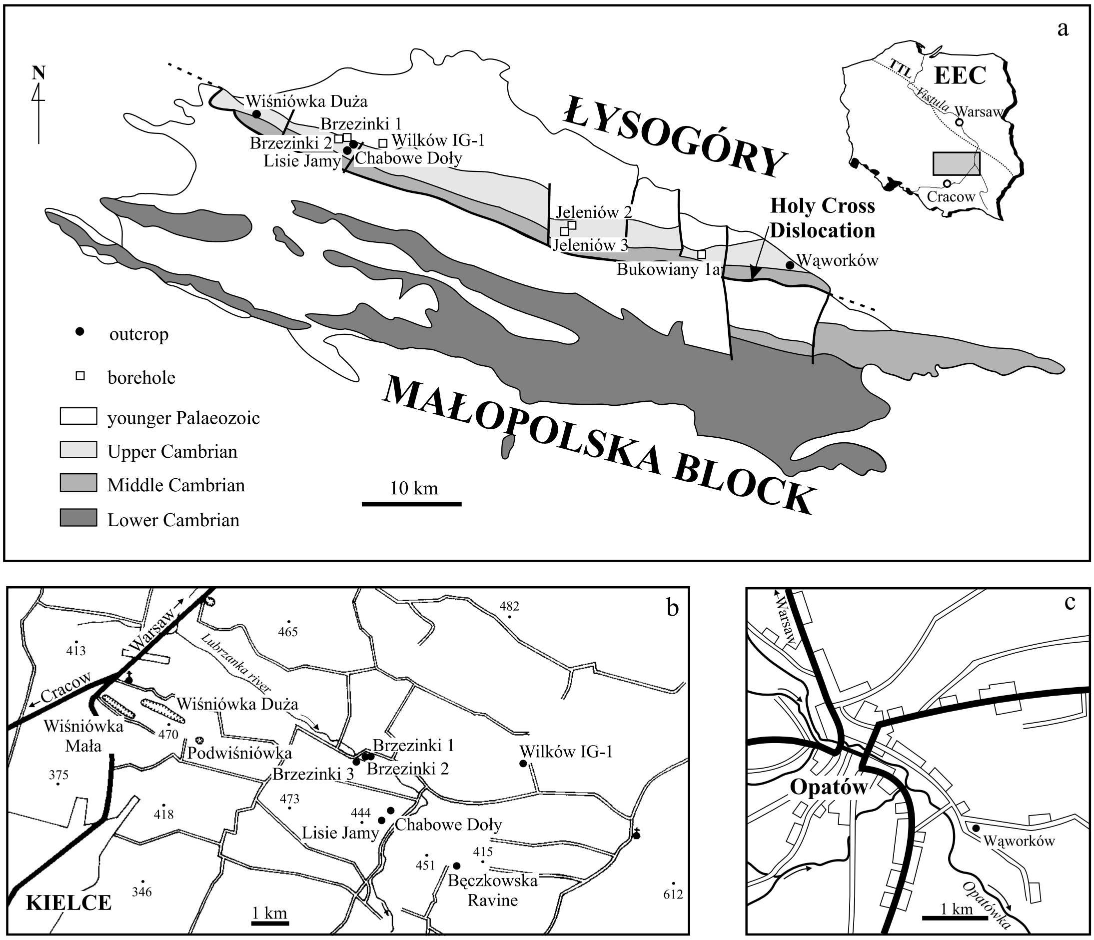

Fig. 1a. Geological sketch-map of the Holy Cross Mountains (distribution of Cambrian deposits after ORŁOWSKI 1992b), with location of studied outcrops and boreholes. 1b. Topographic sketch-map with location of outcrops and boreholes in the western part of Łysogóry. 1c. Location of the Wąworków quarry

ing the Lower Carboniferous. On the basis of different facies development, stratigraphy and tectonic evolution, they are divided into two regions (recognised first by CZARNOCKI 1919): the southern Kielce region and the northern Łysogóry region, separated by the WNW-ESE trending Holy Cross Dislocation. The Łysogóry region is generally the equivalent of the Łysogóry Block, whereas the Kielce region is considered to be the northern part of the Małopolska Massif (see POŻARYSKI 1990). The Upper Cambrian is known exclusively from the Łysogóry region; in its southern part, along the Holy Cross Dislocation, the Upper Cambrian crops out in a ca. 70 km long, 3-5 km wide belt. Lithostratigraphically it belongs to the Wiśniówka Formation and the Klonówka Formation (*sensu* ORŁOWSKI 1975). The Klonówka Formation was also found in boreholes situated farther to the north (TOMCZYKOWA 1968). The Wiśniówka Formation ranges in thickness between 400 and 1400 m, whereas the Klonówka Formation is about 400 m thick (ORŁOWSKI 1975, KOWALCZEWSKI 1995).

The trilobite-bearing sections with trilobite ranges and zonation are briefly characterised below (from west to east) (Text-figs 2-10) and their correlation is shown in Text-fig. 13. The lithological columns are generally after ORŁOWSKI (1968a) and TOMCZYKOWA (1968).

Wiśniówka Duża Quarry

Wiśniówka Duża is one of the quarries in the western part of Łysogóry (Text-fig. 1b). The Upper Cambrian of the section (Text-fig. 2) is composed of thick-bedded, hard sandstones, light grey to bluish in colour, with numerous intercalations of siltstones and silty and clayey shales, representing the Wiśniówka Formation, as well as shales and siltstones with sandstone intercalations of the Klonówka Formation (ORŁOWSKI 1968a, 1975; equivalents of the świętokrzyskie, mąchocickie and łysogórskie beds of TOMCZYKOWA 1968). Trilobites are very rare in both formations. However, the original abundance of var-

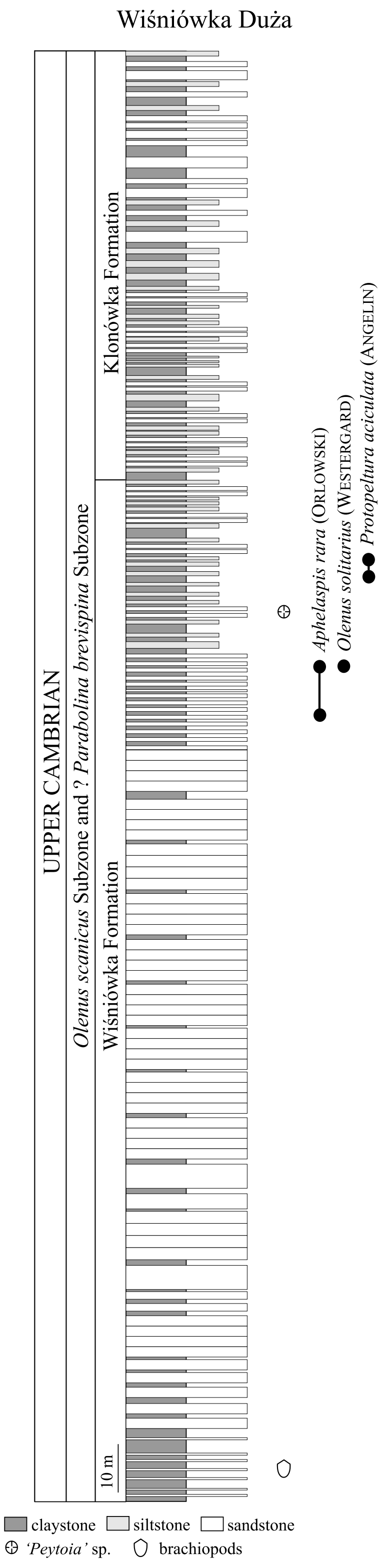

Fig. 2. Schematic lithological column of the Wiśniówka Duża Quarry section (after ŻYLIŃSKA 1992), with brachiopod record from JENDRYKA-FUGLEWICZ & MALEC (1997) and location of *'Peytoia'* sp. after MASIAK & ŻYLIŃSKA (1994).

ious organisms in the early Late Cambrian sea of the area is testified by the rich ichnocoenosis (e.g. RADWAŃSKI & RONIEWICZ 1963, 1972; ORŁOWSKI & *al.* 1970, 1971; ORŁOWSKI 1992a; ORŁOWSKI & ŻYLIŃSKA 1996).

Lisie Jamy

The exposure lies on the eastern slopes of Klonówka Hill, ca. 50 m to the west of the mouth of a narrow gorge, which lies perpendicular to the Lubrzanka river valley, opposite the red tourist route towards Radostowa Hill

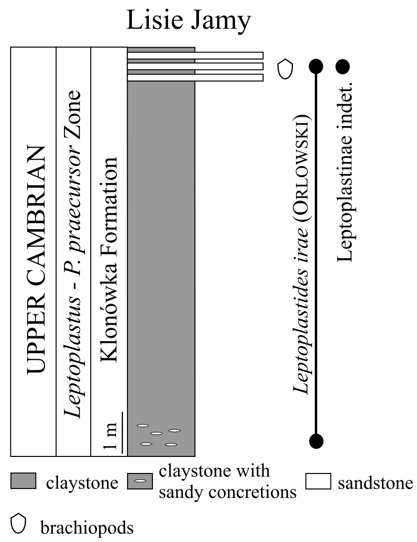

Fig. 3. Lithological column of the Lisie Jamy section, based on ORŁOWSKI (1968a); brachiopod data from JENDRYKA-FUGLEWICZ (1992)

(Text-fig. 1b). The ca. 10 m thick succession (Text-fig. 3) belongs to the Klonówka Formation, represented here by grey and greenish claystones with small sandstone-conglomerate concretions in the lower part and thin intercalations of fine-grained reddish and brownish sandstones in the upper part. Trilobites are rather rare and poorly preserved throughout the succession, although complete specimens were also encountered.

Chabowe Doły

The Chabowe Doły section is situated on the eastern slopes of Klonówka Hill along the road in the Lubrzanka river valley (Text-fig. 1b). The whole succession belongs to the Klonówka Formation and is ca. 80 m thick. Its lower part, referred to in the literature as Chabowe Doły Mill and Ravine, was first reported by GÜRICH (1896), who found specimens of *Olenus* sp. in it. Its upper part, devoid of trilobites, was uncovered by roadworks about ten years ago.

The Chabowe Doły Mill and Ravine section (Text-fig. 4) is ca. 33 m thick and is composed of grey, bluish, brown and yellow quartzitic sandstones and grey and brown claystones and siltstones of the Klonówka Formation. Its lower part (about 13 m thick), known as Chabowe Doły Mill, composed predominantly of sandstones with thin claystone and siltstone intercalations, contains an approximately 60 cm thick lens of yellow, friable sandstone with abundant trilobites [referred to by ORŁOWSKI (1975) as the Chabowe Doły Bed]. Its upper part, known as Chabowe Doły Ravine, is composed of claystones and siltstones, with thin intercalations of hard bluish quartzitic sandstones passing into brown, more friable sandstones in its upper part. Trilobites are not as numerous as in the Chabowe Doły Bed.

The upper part of the Chabowe Doły succession comprises ca. 46 m of claystones and siltstones with rare intercalations of hard bluish sandstones. So far, no trilobites were encountered in this part of the succession.

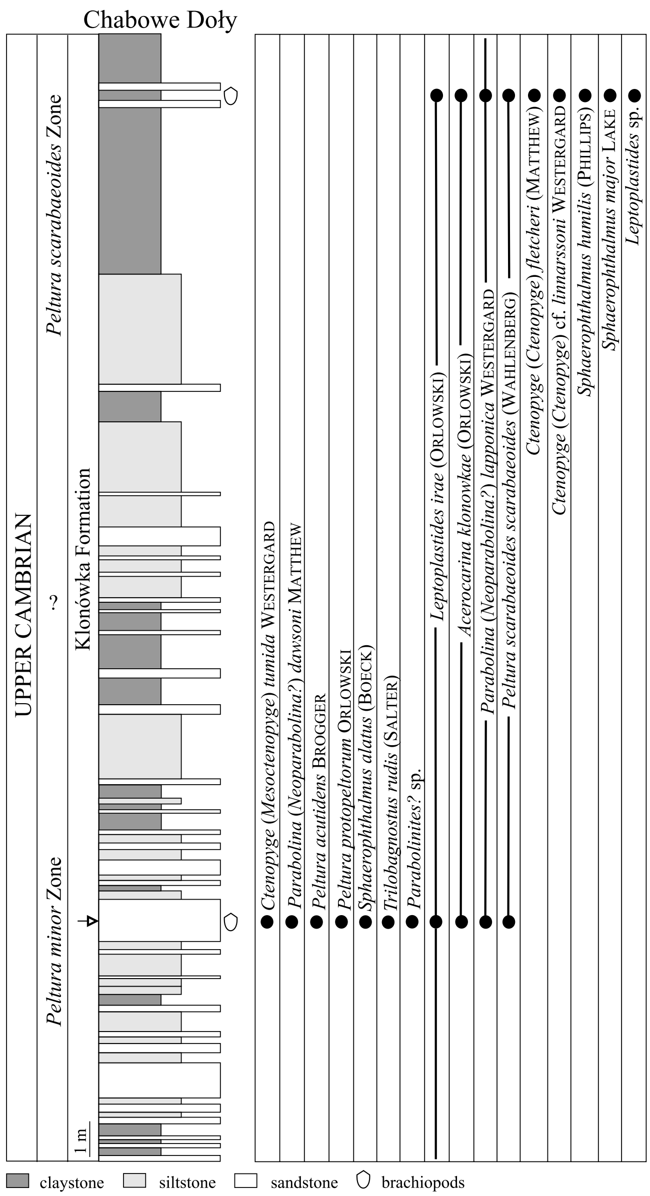

Fig. 4. Lithological column of the Chabowe Doły Mill and Ravine section, modified from ORŁOWSKI (1968a); the Chabowe Doły Bed is arrowed

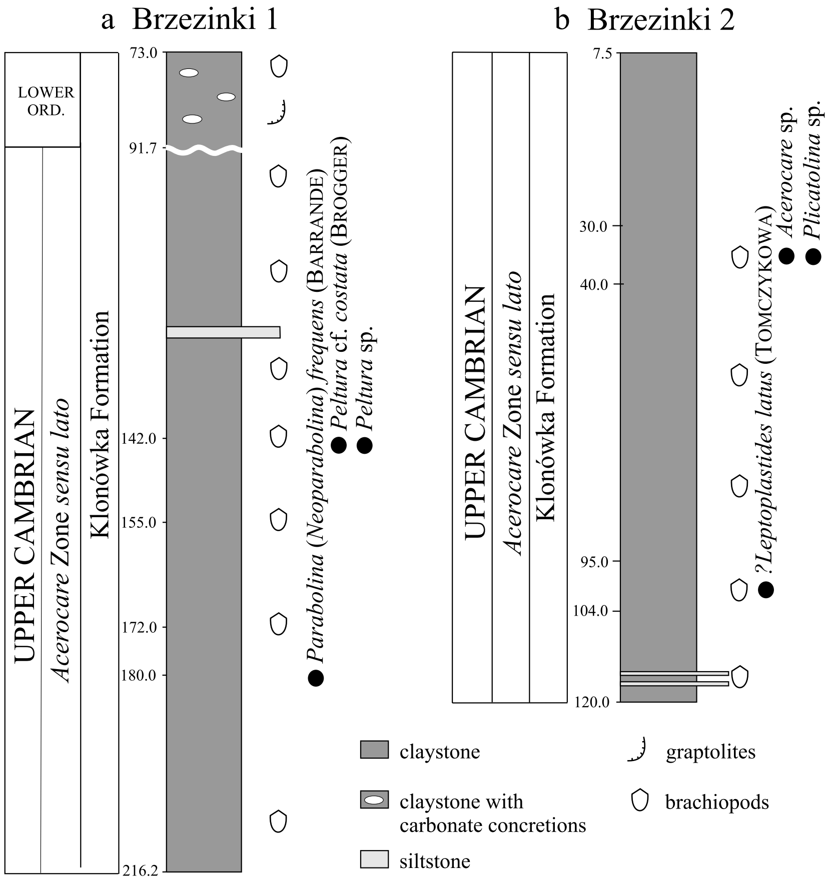

Fig. 5. Lithological columns of the a. Brzezinki 1 and b. Brzezinki 2 borehole sections; modified from TOMCZYKOWA (1968)

Brzezinki boreholes

The three boreholes were drilled near the village of Brzezinki (CZARNOCKI 1957; TOMCZYKOWA 1968) on the northern slopes of Klonówka Hill, ca. 1 km northwards from Chabowe Doły (Text-fig. 1b). Relying on archival data and cores, TOMCZYKOWA (1968) redrew the lithological columns of the individual sections. The specimen of *Peltura* sp. mentioned by TOMCZYKOWA (1968) from the Brzezinki 3 Borehole was not found in her collection and therefore the borehole is excluded here from detailed biostratigraphic and biogeographic analysis.

Brzezinki 1 Borehole [50°55’10”N, 20°47’30”E]

The Upper Cambrian occurs between 91.7 and 216.2 m (Text-fig. 5a). The series is composed mainly of grey to almost black claystones with thin mica-rich siltstone intercalations of the Klonówka Formation. The trilobites are rare and poorly preserved. The Upper Cambrian is overlain unconformably by claystones with carbonate concretions with *Rhabdinopora* sp., indicative of the Lower Tremadocian (TOMCZYKOWA 1968).

Brzezinki 2 Borehole [50º55’05”N, 20º47’20”E]

The Upper Cambrian occurs between 7.5 and 120 m (Text-fig. 5b). The series is composed of grey to almost black claystones, enriched with mica, with rare siltstone intercalations in the lower part of the succession and belongs to the Klonówka Formation. Trilobites are rare and poorly preserved.

Bęczkowska Ravine

The ravine separates the southern slopes of the Radostowa and Bęczkowska hills (Text-fig. 1b). The exposed up to 10 m thick series belongs to the Klonówka Formation and is composed of clayey and silty shales

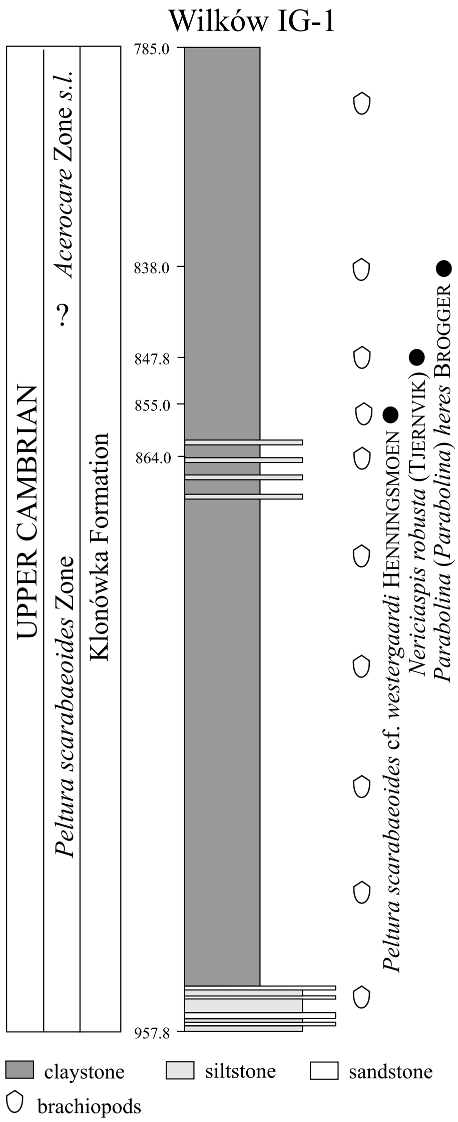

Fig. 6. Lithological columns of the Wilków IG-1 borehole section; modified from TOMCZYKOWA (1968)

with intercalations of yellow and brown sandstones (see ORŁOWSKI 1968a, fig. 6 for a detailed lithological column). Although SAMSONOWICZ (1916), CZARNOCKI (1919) and ORŁOWSKI (1968a) noted the occurrence of rare trilobites, only one specimen from this locality was traced in ORŁOWSKI's collection.

Wilków IG-1 Borehole [50°54'30"N, 20°50'45"E]

The borehole was drilled in 1961 in the Wilków valley at the western end of the village of Wilków (TOMCZYKOWA 1968) (Text-fig. 1b). The Upper Cambrian belonging to the Klonówka Formation occurs between 785 and 957.8 m (Text-fig. 6). The strata comprise ca. 7 m of grey quartzitic sandstones intercalated with grey to dark grey siltstones with mica in the lowermost part, followed by 166 m of grey to dark grey claystones with numerous mica and sporadic siltstone intercalations in the middle part. Trilobites are rare in the ca. 173 m succession.

Jeleniów boreholes

The boreholes were located in the eastern part of the Jeleniów village at the base of the northern slopes of the Jeleniów Hill (Text-fig. 1a). A rich trilobite assemblage was found in the Jeleniów 3 Borehole.

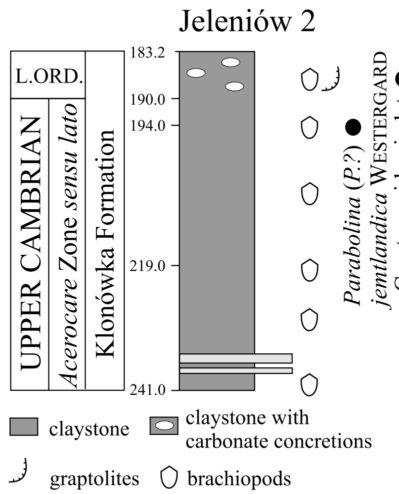

Fig. 7. Lithological column of the Jeleniów 2 borehole section; modified from TOMCZYKOWA (1968)

Jeleniów 2 Borehole [50°50'15"N, 21°07'20"E]

The Upper Cambrian occurs between 183.2 and 241 m (Text-fig. 7). The succession belonging to the Klonówka Formation is composed of ca. 58 m of grey to dark grey claystones, enriched with mica, with siltstone intercalations in the lowermost part. Trilobites are very rare. Three specimens of undetermined Ceratopygidae and two fragments of *Rhabdinopora* sp. (TOMCZYKOWA 1968) indicate the Lower Tremadocian age of the overlying claystones with carbonate concretions (between 183.5 and 190 m).

Jeleniów 3 Borehole [50°50'10"N, 21°07'10"E]

The Upper Cambrian occurs between 11 and 185 m (Text-fig. 8). This trilobite-rich succession belonging to

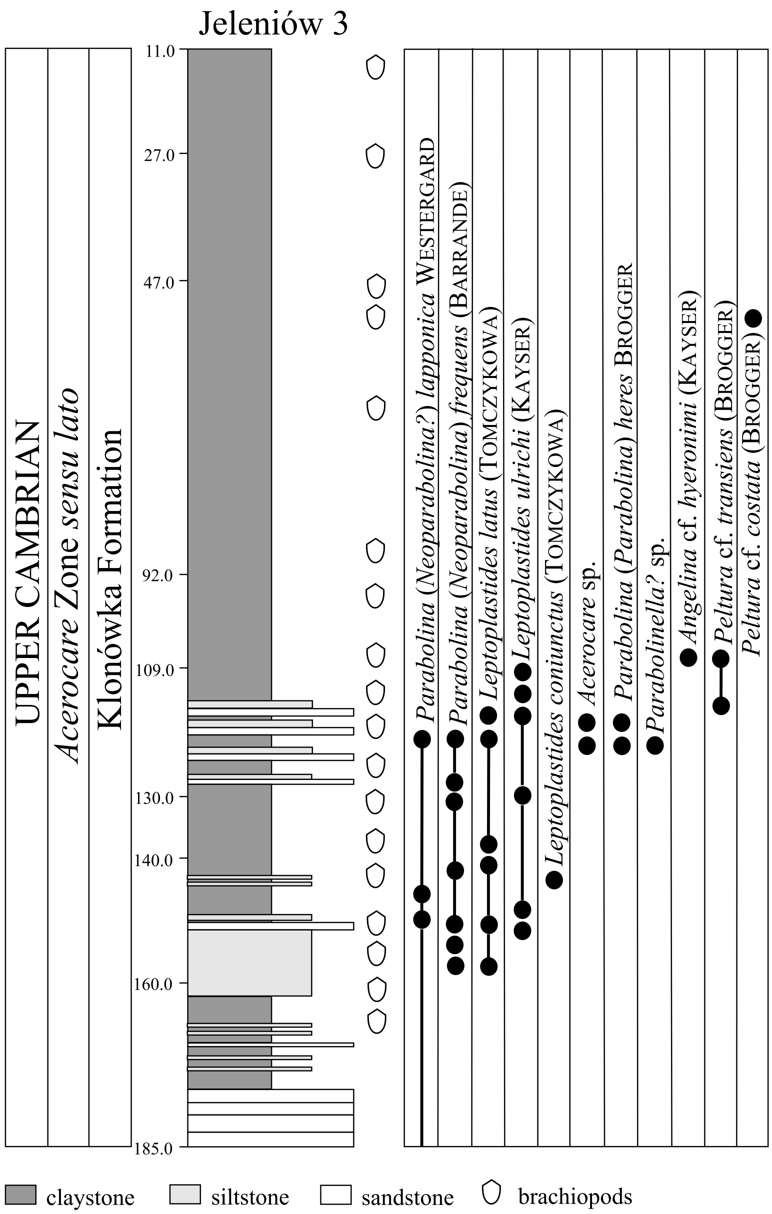

Fig. 8. Lithological column of the Jeleniów 3 borehole section; modified from TOMCZYKOWA (1968)

the Klonówka Formation is composed of siltstones and claystones, with frequent intercalations of grey quartzitic sandstones in the lowest part, followed by grey to dark grey claystones with siltstone intercalations, more common in the lowest part. Trilobites are common in the interval between 106 and 160 m.

Bukowiany 1a Borehole [50º48'30"N, 21º19'15"E]

The borehole was located near the village of Bukowiany, ca. 4 km from the Truskolaska Hill (TOMCZYKOWA 1968). The Upper Cambrian was stated to occur between 198.8 and 292.5 m (Text-fig. 9) and is composed of fine-grained grey sandstones with mica, followed by claystones with rare sandstone and siltstone intercalations. Trilobites are particularly common between 238 and 243 m.

Wąworków Quarry

This abandoned quarry is located along the valley of the river Opatówka, ca. 2 km south-east of Opatów

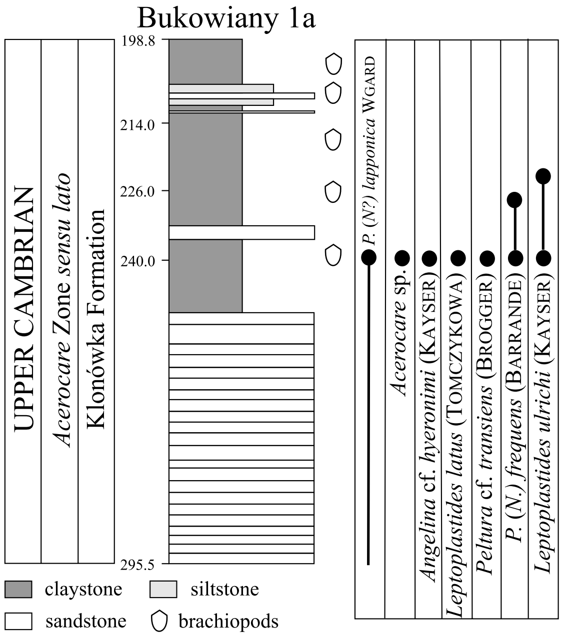

Fig. 9. Lithological column of the Bukowiany 1a borehole section; modified from TOMCZYKOWA (1968); *P.* (*N.*) stands for *Parabolina* (*Neoparabolina*)

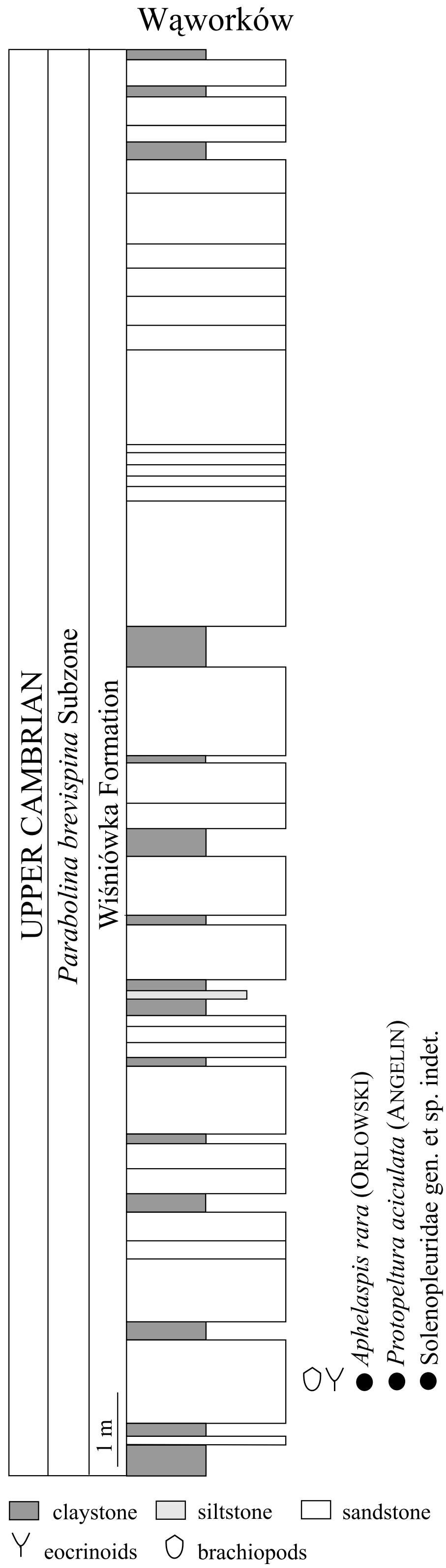

Fig. 10. Lithological column of the Wąworków quarry section; modified from ORŁOWSKI (1968a).

(Text-fig. 1c). The exposed succession (Text-fig. 10), belonging to the Wiśniówka Formation, is ca. 30 m thick and includes thick- and medium-bedded quartz sandstones, white, grey, bluish and reddish in colour, with intercalations of claystones and siltstones. The numerically rich fauna is limited to a 1 m thick sandstone bed in the lower part of the succession (SAMSONOWICZ 1934; ORŁOWSKI 1968b; DZIK & ORŁOWSKI 1993, figs 1b-c).

BIOSTRATIGRAPHY

Because the Late Cambrian trilobite fauna of Łysogóry is represented mostly by forms known from Scandinavia (see discussion on biogeography), the biostratigraphic zonation applied here (Text-fig. 11) is a slightly modified version of the zonation used in the Baltic region (e.g. GEYER & SHERGOLD 2000). The biozones are assemblage zones, whereas the subzones are defined as range subzones (WESTERGÅRD 1922, 1947; HENNINGSMOEN 1957; MARTINSSON 1974; GEYER & SHERGOLD 2000). The trilobite zonation applied to the Upper Cambrian of Łysogóry is discussed below in ascending stratigraphical order. The ranges of the trilobite taxa are shown in Text-fig. 12. The biostratigraphic value of non-trilobite fossils (brachiopods, acritarchs, trace fossils) is also discussed.

Olenus scanicus Subzone and *Parabolina brevispina* Subzone

Trilobites characteristic of the subzones of *Olenus scanicus* and *Parabolina brevispina* are: *Aphelaspis rara* (ORŁOWSKI, 1968), *Olenus solitarius* (WESTERGÅRD, 1922), *Protopeltura aciculata* (ANGELIN, 1854) and Solenopleuridae gen. et sp. indet. The first three taxa are known from rare specimens from the Wiśniówka Duża Quarry (Text-fig. 2). *Aphelaspis rara*, *Protopeltura aciculata* and Solenopleuridae gen. et sp. indet. are common in Wąworków, in a bed in the lower part of the section (Text-fig. 10), where they are accompanied by various brachiopods, including *Orusia* cf. *lenticularis* (ORŁOWSKI 1968b, JENDRYKA-FUGLEWICZ 1992). In Scandinavia, and in England and Wales *Orusia lenticularis* marks the base of the *Parabolina brevispina* Subzone (RUSHTON 1983). *Aphelaspis rara* was reported from the *Olenus cataractes* Subzone of the Maentwrog Formation of North Wales (ALLEN & *al.* 1981, ALLEN & JACKSON 1985). The *Olenus cataractes* Subzone represents the upper part of the *Olenus* and *Homagnostus obesus* Zones of Eastern Avalonia and is an equivalent of the *Olenus scanicus* Subzone of the upper part of the *Olenus* Zone in Baltica (e.g. GEYER & SHERGOLD 2000). *Olenus solitarius* occurs in the *Parabolina brevispina* Subzone of Sweden (WESTERGÅRD 1922). *Olenus* cf. *solitarius* is known from the upper part of the *Olenus cataractes* Subzone in North Wales (RUSHTON 1983). The vertical range of *Protopeltura aciculata* encompasses the *Parabolina brevispina* and *Parabolina spinulosa* subzones of Norway, Sweden and England; in Sweden and England *Protopeltura aciculata aciculata* (ANGELIN) occurs in the *Parabolina brevispina* Subzone, and in Norway and Sweden *Protopeltura aciculata pusilla* WESTERGÅRD is common in the *Parabolina spinulosa* Subzone (HENNINGSMOEN 1957; MORRIS 1988). The co-occurrence of *Aphelaspis rara* and *Protopeltura aciculata* in Wąworków indicates the presence of the *Parabolina brevispina* Subzone. Solenopleuridae range from the Middle Cambrian to the Lower Ordovician, whereas *Andrarina? pusilla* (WESTERGÅRD), to which the specimens from Wąworków are provisionally referred, comes from the *Parabolina brevispina* Subzone (WESTERGÅRD 1922). In the case of the Wiśniówka Duża Quarry the abundances of trilobites are very low. The *Parabolina brevispina* Subzone is indicated only by three specimens of *Protopeltura aciculata*. Moreover, the assemblage lacks representatives of *Orusia* cf. *lenticularis* or Solenopleuridae gen. et sp. indet. Thus it is not clear whether the succession from Wiśniówka Duża belongs to the *Parabolina brevispina* Subzone or to a wider interval encompassing the *Olenus scanicus* Subzone and the *Parabolina brevispina* Subzone.

The acritarchs documented from the Wiśniówka Duża Quarry (KOWALCZEWSKI & *al.* 1986, KOWALCZEWSKI 1995) are represented exclusively by long-ranging forms (Middle Cambrian – Early Tremadocian) and do not permit a precise dating. Early Tremadocian acritarchs were noted in the northern (stratigraphically youngest) part of the Wiśniówka Duża Quarry (KOWALCZEWSKI & *al.* 1986). This part of the sequence also yielded a mouth-piece of an anomalocaridid (MASIAK & ŻYLIŃSKA 1994). Anomalocaridids and related forms occur in Lower, Middle and very rarely Upper Cambrian strata in different parts of the world (CONWAY MORRIS 1989, DZIK 1993, MCHENRY & YATES 1993) and their occurrence in the Lower Tremadocian is highly improbable. Recent data on acritarchs from samples collected from the trilobite-bearing beds from the central part of the Wiśniówka Duża Quarry indicate concordance between the trilobite and acritarch ages. The acritarch assemblages indicate an interval not older than the *Olenus* Zone and not younger than the lower part of the *Parabolina spinulosa* Zone (Z. SZCZEPANIK, personal communication). So far, the presence of Early Tremadocian forms has not been confirmed at this locality.

Based on the occurrence of the trace fossil *Cruziana barbata* SEILACHER in the southern (stratigraphically oldest) part of the Wiśniówka Duża Quarry, ORŁOWSKI (1992a, b) suggested a Middle Cambrian age for the oldest deposits in the quarry. The use of *Cruziana barbata* as an index fossil of the uppermost Middle Cambrian has already been questioned by KOWALCZEWSKI (1995). Recently, *Cruziana barbata* was found in higher parts of the Wiśniówka Duża succession (ŻYLIŃSKA 1992). It thus definitely possesses a much wider stratigraphic range and should not be regarded as an indicative taxon of the late Middle Cambrian.

The interpretation of the stratigraphic range of the Wiśniówka Duża section became even more confusing after the publication of JENDRYKA-FUGLEWICZ & MALEC (1998), who, based on brachiopods, suggested a Tremadocian (!) age for the oldest strata in the quarry. The brachiopods were provisionally referred to Obolidae; however, their poor preservation does not allow accurate assignment, and the supposed Tremadocian age cannot be confirmed.

The trilobites from the Wiśniówka Duża Quarry indicate that at least part of the sequence represents the lower Upper Cambrian (*Olenus scanicus* and *Parabolina brevispina* subzones or only the *Parabolina brevispina* Subzone). Analysis of trilobites from the Wąworków Quarry, assigned by SAMSONOWICZ (1934) to the genera

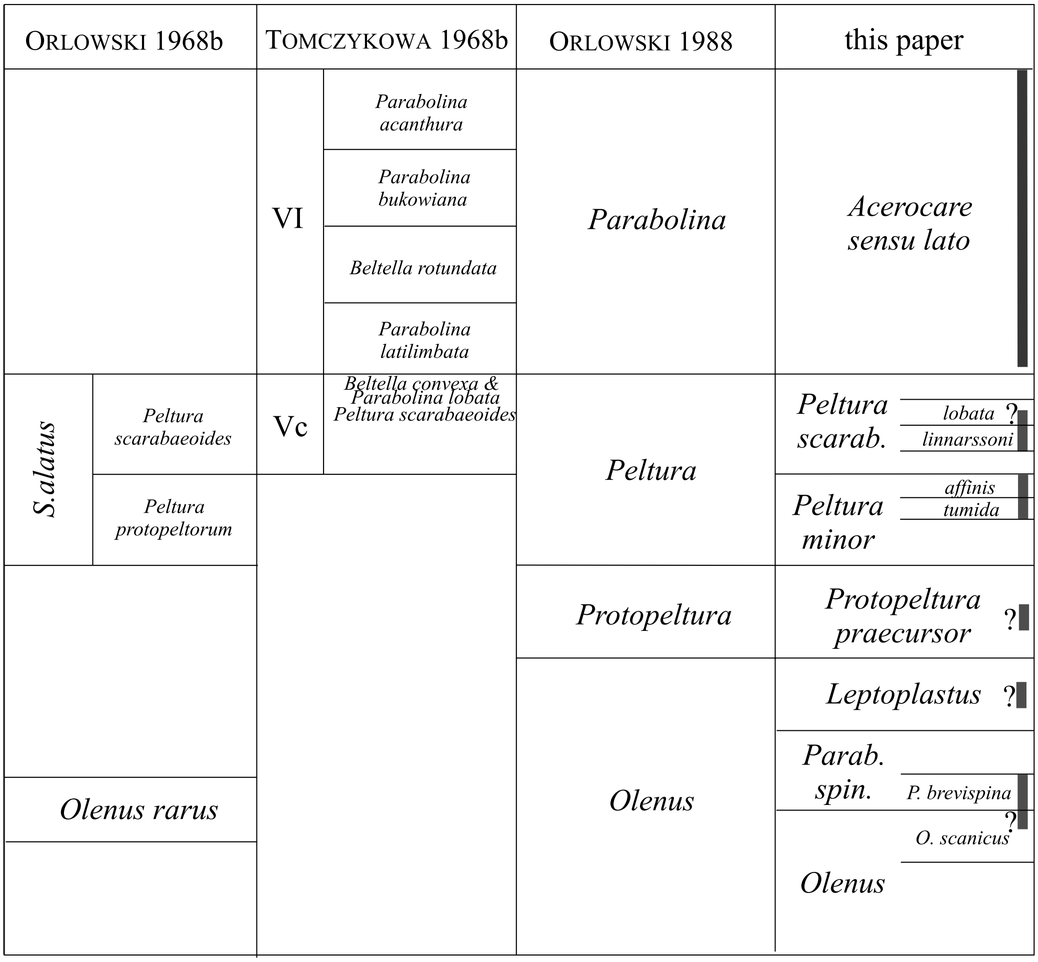

Fig. 11. Correlation of the zonal scheme applied in this paper with schemes presented by ORŁOWSKI (1968b, 1988) and TOMCZYKOWA (1968) for the Upper Cambrian of the Holy Cross Mountains. The vertical bars show intervals directly documented by trilobite fauna. *Parab. spin.* stands for *Parabolina spinulosa*, *P. brevispina* stands for *Parabolina brevispina, S. alatus* stands for *Sphaerophthalmus alatus*

Peltura, *Cyclognathus* and (in part) *Parabolina*, clearly demonstrates that most of those forms belong to *Aphelaspis rara* (ŻYLIŃSKA 2001). The remaining specimens should be assigned to *Protopeltura aciculata*. Thus, the trilobites in Wąworków are indicative of the *Parabolina brevispina* Subzone.

Leptoplastus – Protopeltura praecursor Zone

Trilobites indicative of this interval are represented by Leptoplastinae gen. et sp. indet. – *Leptoplastus* or *Eurycare* – from Lisie Jamy (Text-fig. 3); their poor preservation does not allow definite taxonomic determination. Additionally, this section yields *Leptoplastides irae* (ORŁOWSKI, 1968), which is also present in the *Peltura minor* and *Peltura scarabaeoides* zones of the Chabowe Doły Mill and Ravine section (Text-fig. 4) (see below for discussion). Brachiopods (*Eoorthis* sp.) from Lisie Jamy (JENDRYKA-FUGLEWICZ 1992) have no stratigraphic value. Based on the fact that the representatives of the genera *Leptoplastus* and *Eurycare* are encountered in Scandinavia, England and Wales in the *Leptoplastus* Zone and range upward to the *Protopeltura praecursor* Zone (WESTERGÅRD 1922, 1947; HENNINGSMOEN 1957; TAYLOR & RUSHTON 1972), it is assumed that the Lisie Jamy section represents an interval spanning the *Leptoplastus – Protopeltura praecursor* Zone.

Peltura minor Zone

The *Peltura minor* Zone in Łysogóry is characterised by *Trilobagnostus rudis* (SALTER, 1864), *Peltura acutidens*

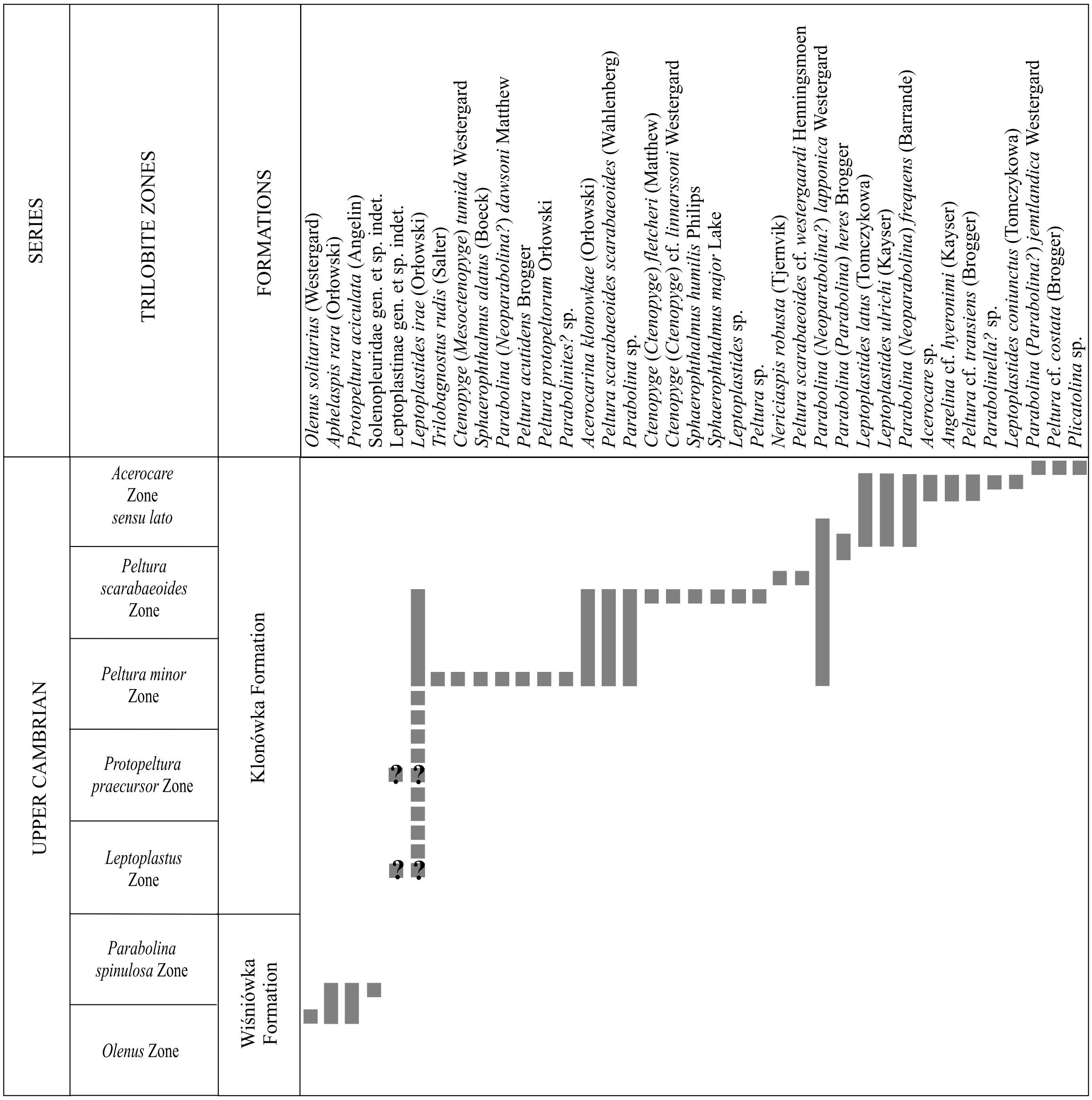

Fig. 12. Range chart of the Late Cambrian trilobites from Łysogóry

BRØGGER, 1882, *Peltura protopeltorum* ORŁOWSKI, 1968, *Sphaerophthalmus alatus* (BOECK, 1838), *Ctenopyge* (*Mesoctenopyge*) *tumida* WESTERGÅRD, 1922, and *Peltura scarabaeoides scarabaeoides* (WAHLENBERG, 1818), found in the Chabowe Doły Bed from the Chabowe Doły Mill section (Text-fig. 4). *Trilobagnostus rudis* occurs in Sweden and North Wales in the *Peltura minor* Zone (MORRIS 1988, AHLBERG & AHLGREN 1996). In Sweden it is associated with *Peltura minor* (BRØGGER), *Ctenopyge* (*Mesoctenopyge*) *tumida*, *Parabolinella laticauda* WESTERGÅRD and *Sphaerophthalmus alatus* (WESTERGÅRD 1922, HENNINGSMOEN 1957), and thus is characteristic of the *Ctenopyge tumida* Subzone, from which the species *Peltura acutidens* is also known. The species *Sphaerophthalmus alatus* found in Scandinavia (Norway, Sweden and Denmark), and in England (HENNINGSMOEN 1957, RUSHTON 1968) both in the *Ctenopyge tumida* and the *Ctenopyge affinis* subzones, ranges higher, to the lower part of the succeeding *Peltura scarabaeoides* Zone in Sweden and in stinkstone boulders in northern Germany (WESTERGÅRD 1947, SCHRANK 1973).

The subspecies *Peltura scarabaeoides scarabaeoides*, although regarded commonly as a *Peltura scarabaeoides* Zone taxon, first appears already in the *Ctenopyge affinis* Subzone. It is well known from Sweden (Öland, Västergötland – WESTERGÅRD 1922), where it co-occurs in its lower range with *Peltura minor* and *Ctenopyge*

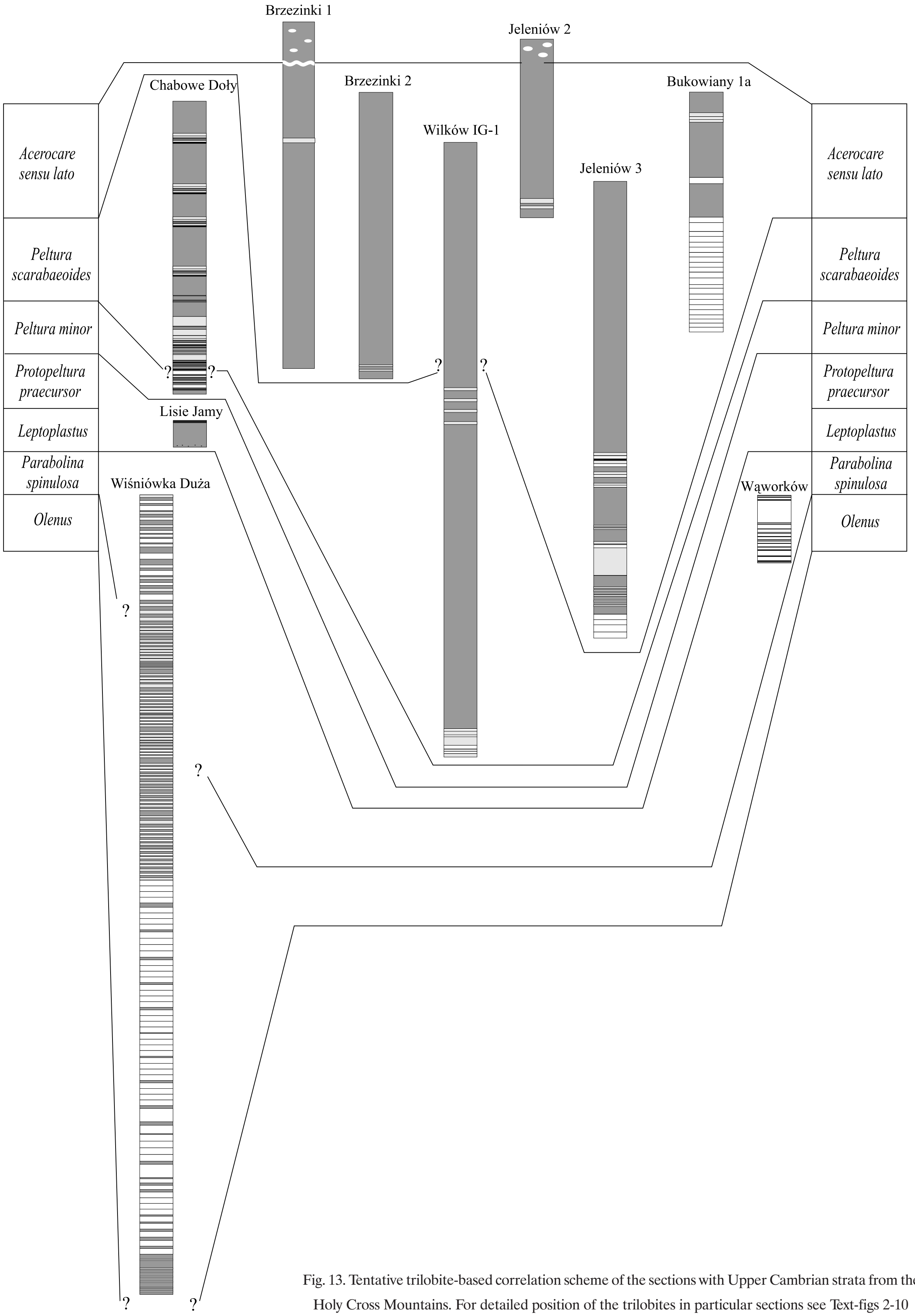

Fig. 13. Tentative trilobite-based correlation scheme of the sections with Upper Cambrian strata from the Holy Cross Mountains. For detailed position of the trilobites in particular sections see Text-figs 2-10

(*Ctenopyge*) *affinis* WESTERGÅRD*. Thus most of the mentioned taxa are characteristic of the *Ctenopyge tumida* and *Ctenopyge affinis* subzones.

Additionally, the Chabowe Doły Mill section is characterised by *Parabolina* (*Neoparabolina?*) *lapponica* WESTERGÅRD, 1947, which was described originally from the *Peltura scarabaeoides* Zone, but judging by the material from Łysogóry, has a much longer range (from the *Peltura minor* Zone to the *Acerocare* Zone *sensu lato*), as well as by *Acerocarina klonowkae* (ORŁOWSKI, 1968), a dominant form of the *Peltura scarabaeoides* Zone at Chabowe Doły Ravine (Text-fig. 4). The assemblage also contains *Parabolina* (*Neoparabolina?*) *dawsoni* MATTHEW, 1901, a species described from the *Peltura* Zones (*s.l.*) of Newfoundland, where it is associated with *Ctenopyge* (*Ctenopyge*) *fletcheri* (MATTHEW, 1901) and *Peltura scarabaeoides scarabaeoides* (HUTCHINSON 1952), indicating the *Peltura scarabaeoides* Zone. Its presence in the *Peltura minor* Zone of Chabowe Doły Mill section indicates its much longer vertical range. *Peltura protopeltorum* ORŁOWSKI, 1968 is known exclusively from Chabowe Doły Mill. It is inferred therefore that this species is restricted to the upper part of the *Peltura minor* Zone. *Leptoplastides irae* ranges from the *Leptoplastides* or *Protopeltura praecursor* zones to the *Peltura scarabaeoides* Zone and is thus of low stratigraphic value.

Summing up, the assemblage from the Chabowe Doły Mill section is considered to represent the *Ctenopyge tumida* and *Ctenopyge affinis* subzones of the *Peltura minor* Zone. It is worth noting, however, that the fauna indicative of both subzones is limited to the 60 cm thick lens comprising the Chabowe Doły Bed. Although this is a thickness comparable to the thickness of the zone in Scandinavia, where the Upper Cambrian strata are represented by condensed alum shale facies (BERGSTRÖM & GEE 1985, THICKPENNY 1987), such an occurrence is extremely unusual in Łysogóry, where the Upper Cambrian succession is greatly expanded, presumably up to 1800 m thick (see ORŁOWSKI 1975, 1988, 1992b; KOWALCZEWSKI 1995). The Chabowe Doły Bed, with a randomly distributed fauna characteristic of both the *Ctenopyge tumida* and *Ctenopyge affinis* subzones, thus suggests strong condensation.

Peltura scarabaeoides Zone

In Łysogóry, the lower part of this zone is indicated by the occurrence of *Peltura scarabaeoides scarabaeoides*, *Ctenopyge* (*Ctenopyge*) *fletcheri*, *Ctenopyge* (*Ctenopyge*) cf. *linnarssoni* WESTERGÅRD, 1922, *Sphaerophthalmus humilis* (PHILLIPS, 1848) and *Sphaerophthalmus major* LAKE, 1913 in the Chabowe Doły Ravine section (Text-fig. 4). *Peltura scarabaeoides scarabaeoides* ranges from the *Ctenopyge affinis* Subzone of the *Peltura minor* Zone to the upper part of the *Ctenopyge linnarssoni* Subzone (defined by the total range of its index taxon) of the *Peltura scarabaeoides* Zone (WESTERGÅRD 1922, HENNINGSMOEN 1957). *Ctenopyge* (*Ctenopyge*) *fletcheri* also has the same vertical range. *Sphaerophthalmus humilis* occurs in the *Ctenopyge bisulcata* and *Ctenopyge linnarssoni* subzones in Scandinavia and Wales (HENNINGSMOEN 1957, RUSHTON 1968). *Sphaerophthalmus major* is found in the *Ctenopyge linnarssoni* Subzone in Scandinavia and England. Consequently, the association from the Chabowe Doły Ravine indicates the *Ctenopyge linnarssoni* Subzone.

Slightly younger strata are indicated by the presence of *Peltura scarabaeoides* cf. *westergaardi* HENNINGSMOEN, 1957, accompanied by *Nericiaspis robusta* (TJERNVIK, 1953), in the Wilków IG-1 Borehole (Text-fig. 6). *Peltura scarabaeoides westergaardi* characterises mainly the *Parabolina lobata* Subzone, but appears already in the uppermost part of the *Ctenopyge linnarssoni* Subzone (HENNINGSMOEN 1957). In Scandinavia *Nericiaspis robusta* is known exclusively from a few cranidia from the *Ctenopyge bisulcata* and *Ctenopyge linnarssoni* subzones (TJERNVIK 1953, 1955), and *Nericiaspis* cf. *robusta* is noted from stinkstone boulders in northern Germany, where it is accompanied by taxa characteristic of the *Ctenopyge linnarssoni* Subzone (SCHRANK 1973). Therefore, the strata between 856 and 847.8 m in the Wilków IG-1 Borehole represent the uppermost part of the *Ctenopyge linnarssoni* Subzone. If, however, the vertical range of *Nericiaspis robusta* is extended, the strata in question would represent the *Parabolina lobata* Subzone.

Acerocare Zone *sensu lato*

In Łysogóry, this zone is characterised by both long-ranging inter-regionally distributed taxa (in Scandinavia, England and Wales, Argentina and Bolivia) and short-ranging taxa, characteristic of this interval. For this reason, this part of the Upper Cambrian, corresponding to

* According to HENNINGSMOEN (1957, p. 232), the vertical range of *Peltura minor* overlaps that of *Peltura scarabaeoides scarabaeoides* in the lower part of the *Peltura scarabaeoides* Zone; this, however, does not find confirmation in the sections from Öland and Västergötland in Sweden (WESTERGÅRD 1922, pp.31, 34, 51, 71), where *Peltura scarabaeoides scarabaeoides* co-occurs also with *Ctenopyge* (*Ctenopyge*) *affinis*. If HENNINGSMOEN's view is to be accepted, the range of the index fossil for the *Ctenopyge affinis* Subzone would be wider than the range of this subzone. This is assumed to be incorrect.

the zones of *Peltura transiens, Peltura costata*, *Westergaardia* and *Acerocare ecorne* (GEYER & SHERGOLD 2000) is referred to here as the *Acerocare* Zone *sensu lato* (*Acerocare* Zone of HENNINGSMOEN 1957 and AHLBERG & AHLGREN 1996).

The zone is present in the Brzezinki 1 and 2, Wilków IG-1, Jeleniów 2, Jeleniów 3 and Bukowiany 1a boreholes (Text-figs 5-9). *Parabolina* (*Neoparabolina*) *frequens* (BARRANDE, 1868), *Leptoplastides latus* (TOMCZYKOWA, 1968) and *Leptoplastides ulrichi* (KAYSER, 1897) dominate among the long-ranging taxa. They are accompanied by rare *Parabolina* (*Parabolina*) *heres* BRØGGER, 1882, *Acerocare* sp., *Peltura* cf. *costata* (BRØGGER, 1882), *Peltura* cf. *transiens* (BRØGGER, 1882), *Angelina* cf. *hyeronimi* (KAYSER, 1876), *Plicatolina* sp., *Parabolina* (*Parabolina?*) *jemtlandica* WESTERGÅRD, 1922, *Parabolinella* sp. and *Leptoplastides coniunctus* (TOMCZYKOWA, 1968). Also present is *Parabolina* (*Neoparabolina?*) *lapponica*, known from the underlying *Peltura minor* and *Peltura scarabaeoides* zones.

Parabolina (*N.*) *frequens*, long considered an Early Tremadocian species (SDZUY 1955; HENNINGSMOEN 1957; HARRINGTON & LEANZA 1957; PŘIBYL & VANĚK 1980), is now recognised to range down into the Late Cambrian (RUSHTON 1982; ACEÑOLAZA 1983; SHERGOLD 1988; LANDING & *al.* 2000; FRANCO TORTELLO, personal communication). Its occurrences are inferred from its appearance well below the entrance level of *Rhabdinopora flabelliformis* (e.g. in Argentina – HARRINGTON & LEANZA 1957; SHERGOLD 1988, and Wales – RUSHTON 1982; SHERGOLD 1988; LANDING & *al.* 2000); and its association with the conodont *Cordylodus proavus* MÜLLER, the first appearance of which coincides with the base of the Symphysurinid biomere in Laurentia, and the last appearance of which is below the Cambrian – Ordovician boundary (BRUTON & *al.* 1988; COOPER & NOWLAN 1999; PUURA & VIIRA 1999; GEYER & SHERGOLD 2000; LANDING & *al.* 2000; COOPER & *al.* 2001).

In Łysogóry *Parabolina* (*N.*) *frequens* first appears well below the occurrence of *Rhabdinopora* sp. in the Brzezinki 1 Borehole (Text-fig. 5a), and in the Jeleniów 3 and Bukowiany 1a boreholes (Text-figs 8-9), where it is associated with *Parabolina* (*N.?*) *lapponica*, *Leptoplastides*, *Acerocare* sp., as well as with *Peltura* cf. *transiens*. In Scandinavia, *Acerocare* and *Peltura transiens* are restricted to the *Acerocare* Zone *sensu lato*, with the latter taxon limited to the lowermost part of this zone (HENNINGSMOEN 1957). *Parabolina* (*N.?*) *lapponica*, known from the *Peltura minor* Zone in Łysogóry (Chabowe Doły Mill) and from the *Peltura scarabaeoides* Zone of Scandinavia and Łysogóry (Chabowe Doły Ravine), co-occurs in the topmost part of its Łysogóry range with *Acerocare* sp. and *Peltura* cf. *transiens,* thus proving its occurrence also in at least the lower part of the *Acerocare* Zone *sensu lato. Leptoplastides* was long considered as a Tremadocian genus, but NIKOLAISEN & HENNINGSMOEN's (1985) revision of the genus shows that it appears already in the Late Cambrian, which is also confirmed here. *Leptoplastides ulrichi* is a characteristic species of the *Parabolina argentina* Zone in Argentina and Bolivia (HARRINGTON & LEANZA 1957, PŘIBYL & VANĚK 1980), but because of its association there with *Parabolina* (*N.*) *frequens* (synonym of *Parabolina argentina*) and various agnostid species (e.g. *Gymnagnostus thoas* PŘIBYL & VANĚK or *Gymnagnostus bolivianus* HOEK), the ranges of which are partly within the Late Cambrian (NIELSEN 1999), it can also be considered as Late Cambrian in age. *Leptoplastides* cf. *latus* and *Leptoplastides* cf. *ulrichi* have been recognised in the *Protopeltura praecursor* Zone, and most probably also higher in the Kistedal Formation of the Digermul Peninsula, Norway (NIKOLAISEN & HENNINGSMOEN 1985). The *Acerocare* Zone *sensu lato* is also indicated by *Parabolina* (*P.*) *heres*. The range of *Angelina hyeronimi* is, similarly to that of *Parabolina* (*N.*) *frequens*, considered to span the Cambrian – Ordovician boundary, and its Late Cambrian occurrences were recognised e.g. in the *Cordylodus proavus* Zone in Mexico (ROBISON & PANTOJA-ALOR 1968) and in the Cardonal Formation of Jujuy in Argentina (TORTELLO & *al.* 1999). Rare specimens of *Plicatolina* SHAW and *Parabolinella* BRØGGER from Łysogóry are not specifically determined, but representatives of both genera occur also in the *Acerocare* Zone of Wales (RUSHTON 1982). *Peltura* cf. *costata* from the Brzezinki 1 (Text-fig. 5a) and Jeleniów 3 (Text-fig. 8) boreholes, as well as *Parabolina* (*P.?*) *jemtlandica* from the Jeleniów 2 Borehole (Text-fig. 7), represent probably slightly younger horizons of the *Acerocare* Zone *sensu lato. Parabolina* (*P.?*) *jemtlandica* is known from Sweden and probably from Wales (WESTERGÅRD 1922, ALLEN & *al.* 1981), and in both areas it is regarded as an *Acerocare* Zone species.

At present no detailed subdivision is possible for the *Acerocare* Zone *sensu lato*, as proposed herein for Łysogóry (Text-figs 11-13). This is caused by the rather poor representation of biostratigraphically important taxa, above all of *Peltura*, which gives a series of good index species in other areas.

BIOGEOGRAPHY

Palaeogeographic reconstructions for the Late Cambrian are still very controversial, mainly because of the lack of good quality palaeomagnetic data. For Baltica, for instance, the scarcity of reliable palaeomagnetic data is caused by inappropriate lithologies (deposits with low or unstable natural remanent magnetisation) or by the frequent remagnetisation of the deposits during Caledonian deformations and/or Variscan igneous activity (TORSVIK & REHNSTRÖM 2001). In many cases the thermal overprint and the complex subsequent tectonic history is a reason of unequivocal palaeomagnetic data (LEWANDOWSKI 1993). The existing biogeographic interpretations of the Łysogóry Upper Cambrian suggested the presence of totally endemic faunas (ORŁOWSKI 1968b; TOMCZYKOWA 1968) or their close relationship to Avalonia (see in BELKA 2000; BELKA & *al.* 2000). Recent revision of the trilobite fauna (ŻYLIŃSKA 2001) showed that the biogeographic relationships of the studied area are more complex.

Affinities of the Late Cambrian trilobites from Łysogóry

Thirty-seven trilobite taxa are recognised in the Upper Cambrian of Łysogóry (ŻYLIŃSKA 2001); twenty-eight at species level, seven at generic level, and two at family level. At generic level (Text-fig. 14), the fauna has a *mixed Avalonian-Baltic* character, i.e. it is dominated by genera occurring in both Avalonia and Baltica. It also contains some exclusively Baltic genera (*Acerocare* ANGELIN, *Acerocarina* POULSEN and *Nericiaspis* TJERNVIK), as well as some genera unknown from Baltica, but occuring widely in other areas: *Aphelaspis* RESSER, known from Laurentia and Avalonia; *Plicatolina* SHAW, reported from Laurentia, Avalonia and Gondwana; and *Angelina* SALTER, noted from the Upper Cambrian of Gondwana, and also from the Tremadocian of Avalonia.

The species-level biogeographic analysis of the Łysogóry Late Cambrian focuses on Baltica, Avalonia and part of Gondwana proper (South America), that is areas dominated by the presence of olenid trilobites (Baltic province *sensu* SHERGOLD 1988).

Among the Late Cambrian trilobite species from Łysogóry the following biogeographic groups have been distinguished (Text-fig. 15):

– *Avalonian fauna* – known also from the upper part of the Maentwrog, Ffestiniog Flags and Dolgellau Formations of North Wales, and the Outwoods Shales, Monks Park Shales and White-Leaved-Oak Shales of England, as well as from maritime eastern North America (Nova Scotia, New Brunswick, eastern Newfoundland in Canada);

– *Baltic fauna* – known also from Scandinavia within the Alum Shale Formation and in the Kistedal Formation of the Digermul Peninsula, Finnmark (Norway), as well as in the clastic deposits from the Polish part of the East European Craton;

– *endemic fauna* – occurring only in Łysogóry;

– *Gondwanan fauna* – known also from the Angosto, Santa Rosita and Volcancito Formations of Argentina, Taraya Formation of Bolivia and lower Tiñu Formation of Mexico;

– *mixed Avalonian-Baltic fauna*;

– *mixed Baltic-Gondwanan fauna*;

– *mixed Avalonian-Baltic-Gondwanan fauna.*

The spectra of particular biogeographic groups represented in the studied material are analysed for the following intervals*:

– *Olenus scanicus* Subzone and *Parabolina brevispina* Subzone;

– *Peltura minor* Zone;

– *Peltura scarabaeoides* Zone;

– *Acerocare* Zone *sensu lato*.

The species-level analysis demonstrates that the biogeographic relationships of the Late Cambrian Łysogóry trilobites are much more complex than inferred from generic level analysis, and moreover, that they underwent a distinct change during that interval (Text-fig. 16). The *Baltic fauna*, including faunas occurring also in other areas, is present in all of the intervals. Its diversity and abundance increases towards the top of the Cambrian. The *Avalonian fauna* is common only in the lowermost part of the sequence. In the *Peltura minor* Zone it is represented by a single taxon, and above this zone it completely disappears. On the other hand, the *Gondwanan fauna* appears only in the uppermost part of the sequence. Towards the top there is also a constant decrease in species diversity and abundances of the *endemic fauna*. The *mixed Avalonian-Baltic fauna* is present in all of the intervals, although decreasing distinctly in the *Acerocare* Zone *sensu lato*, both in species diversity and in abundances. In this interval it is replaced by the *mixed Avalonian-Baltic-Gondwanan fauna* and by the *mixed Baltic-Gondwanan fauna*.

The biogeographic analysis shows that in different stratigraphic intervals of the Late Cambrian the Łysogóry Block shares up to 80% of trilobite species with Baltica, including *mixed Avalonian-Baltic* species, whereas up to 40% comprises solely *Baltic* species. *Avalonian* species in contrast never exceed 33%, and their number decreases rapidly in the *Peltura minor* Zone, to disappear completely above. The *endemic fauna* appears in the *Peltura minor* Zone and comprises

* Fauna recognised in the Lisie Jamy exposure is excluded from this analysis. It is represented by a very small number of specimens, including a long-range endemic species and a form assigned only at family level; furthermore, the stratigraphic horizon cannot be precisely defined.

	Acerocare	*Acerocarina*	*Angelina*	*Aphelaspis*	*Ctenopyge*	*Leptoplastides*	*Nericiaspis*	*Olenus*	*Parabolina*	*Parabolinella*	*Parabolinites*	*Peltura*	*Plicatolina*	*Protopeltura*	*Sphaerophthalmus*	*Trilobagnostus*
Baltica	+	+			+	+	+	+	+	+	+	+		+	+	+
Avalonia			*	+	+	+		+	+	+	+	+	+	+	+	+
Laurentia				+				+	?				+			+
Gondwana		?	+			+			+				+			+
Łysogóry	+	+	+	+	+	+	+	+	+	?	?	+	+	+	+	+

*the genus appears here in the Early Tremadocian

Fig. 14. Distribution of trilobite genera in the Upper Cambrian of Łysogóry and in other biogeographic areas (based on HENNINGSMOEN 1957a, HARRINGTON & LEANZA 1957, SHERGOLD 1988 and MORRIS 1988)

Avalonian species: *Aphelaspis rara* *Parabolina* (*Neoparabolina?*) *dawsoni*	**Avalonian-Baltic species:** *Ctenopyge (Ctenopyge) fletcheri* *Ctenopyge (Ctenopyge)* cf. *linnarssoni* *Ctenopyge (Mesoctenopyge) tumida* *Olenus solitarius* *Parabolina (Parabolina) heres* *Parabolina (Parabolina?) jemtlandica* *Peltura scarabaeoides scarabaeoides* *Peltura scarabaeoides* cf. *westergaardi* *Protopeltura aciculata* *Sphaerophthalmus alatus* *Sphaerophthalmus humilis* *Sphaerophthalmus major* *Trilobagnostus rudis*
Baltic species: *Leptoplastides latus* *Nericiaspis robusta* *Parabolina* (*Neoparabolina?*) *lapponica* *Peltura acutidens* *Peltura* cf. *costata* *Peltura* cf. *transiens*	
endemic species: *Acerocarina klonowkae* *Leptoplastides coniunctus* *Leptoplastides irae* *Peltura protopeltorum*	**Baltic-Gondwanan species:** *Leptoplastides ulrichi*
Gondwanan species: *Angelina* cf. *hyeronimi*	**Avalonian-Baltic-Gondwanan species:** *Parabolina* (*Neoparabolina*) *frequens*

Fig. 15. Distribution of the Łysogóry trilobite species in particular biogeographic groups

30% of the species with regard to the taxonomic content, and over 50% with regard to the abundances. Towards the top of the Cambrian the *endemic fauna* decreases in diversity and abundances.

The trilobite diversity in Łysogóry varied from a low diversity assemblage in the early Late Cambrian, with the predominance of the *Avalonian fauna*, to more diversified assemblages in the late Late Cambrian with a constant increase in the *Baltic fauna*, and a parallel decrease in the *endemic fauna* (Text-fig. 16). It is inferred therefore that the Łysogóry Block maintained constant and increasing proximity to Baltica in the Late Cambrian. The dominance of the *Avalonian fauna* in the lower part of the sequence might suggest that this area was much closer to Avalonia than to Baltica in the early Late Cambrian. Later on, the migration of trilobites between Avalonia and the Łysogóry Block was impeded. The appearance of endemic taxa in the *Peltura minor* Zone may be a result of geographic isolation. On the other hand, the appearance of the *Gondwanan fauna* as well as the *mixed Baltic-*

Gondwanan fauna at the end of the Late Cambrian suggests exchange of faunas between the Łysogóry Block and the South American part of Gondwana. Low abundances of *mixed Avalonian, Baltic and Gondwanan* species [*Parabolina* (*Neoparabolina*) *frequens* – RUSHTON 1982, LANDING & *al.* 2000] and the lack of *mixed Avalonian and Gondwanan* genera (e.g. *Angelina* SALTER) before the Tremadocian in Avalonia suggest its isolation during this interval.

It is also notable that whereas the *Baltic* and *mixed Avalonian-Baltic faunas* recorded from Łysogóry in the *Peltura minor* and *Peltura scarabaeoides* zones are identical with those from the Alum Shale Formation in Scandinavia (WESTERGÅRD 1922, 1947; HENNINGSMOEN 1957; MARTINSSON 1974; BERGSTRÖM & GEE 1985), Wales, England (e.g. TAYLOR & RUSHTON 1972, ALLEN & *al.* 1981; RUSHTON 1983), and the Polish part of the East European Craton (BEDNARCZYK 1972, 1984; LENDZION 1976, 1982, 1983, 1988), the faunas from the *Acerocare* Zone *sensu lato* are different. The Alum Shale fauna is poorly represented in this zone in Łysogóry. The commonest taxa here are *Leptoplastides* RAW and *Parabolina (Neoparabolina) frequens*, the forms known from shaly-arenaceous sediments (READING 1965) of the Kistedal and Berlogaissa Formations of the Digermul Peninsula, Finnmark (Norway) (NIKOLAISEN & HENNINGSMOEN 1985), deposited at the margin of Baltica (BERGSTRÖM & GEE 1985, COCKS 2000). These taxa also occur in Avalonia: in the Upper Cambrian of England, Wales and maritime eastern North America (RUSHTON 1982; SHERGOLD 1988; LANDING & *al.* 2000), as well as in Gondwana: in Argentina and Bolivia (PŘIBYL & VANĚK

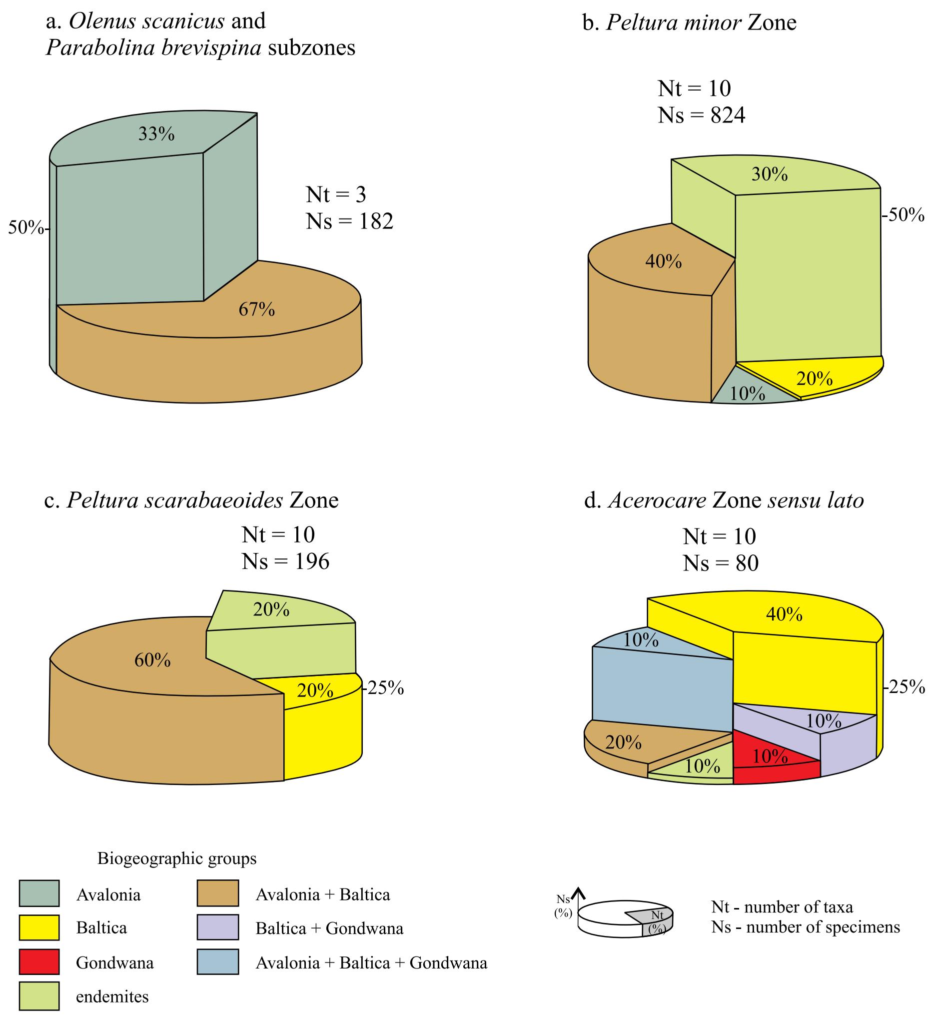

Fig. 16. Composition of the Late Cambrian trilobite fauna of Łysogóry with respect to its biogeographic affinities. Note the distinct change in the composition towards the dominance of *Baltic* forms in the latest Cambrian

1980; ACEÑOLAZA 1983; FRANCO TORTELLO, personal communication). It is quite possible that the trilobites from Finnmark and Łysogóry could represent forms poorly adapted to the extreme conditions of the 'Alum Shale' sea (NIKOLAISEN & HENNINGSMOEN 1985; CLARKSON & TAYLOR 1995), that is disaerobic environments which could have been dominated by chemoautotrophic symbionts from the olenid family (FORTEY 2000). The trilobites in question probably flourished on the margins of Baltica, from where they could be distributed onto the Avalonian and South American segment of Gondwana, for instance by changing current patterns (SHERGOLD 1988).

Palaeogeographic position of the Łysogóry Block during the Late Cambrian

The Łysogóry Block was regarded either as a part of Baltica (DADLEZ 1983, TOMCZYK 1988, DADLEZ & *al.* 1994, MIZERSKI 1995, COCKS 2000), or as an exotic terrane (POŻARYSKI 1990, POŻARYSKI & *al.* 1992, BELKA & *al.* 2000, TOMCZYKOWA & TOMCZYK 2000, VALVERDE-VAQUERO & *al.* 2000). In the latter case the time of its accretion to Baltica, similar to that of other exotic terranes of the TESZ (e.g. Małopolska Block), remains unknown. However, the event certainly took place before the Devonian (e.g. LEWANDOWSKI 1987, 1993; NAWROCKI 2000).

Recent geophysical soundings show that the Łysogóry Block is a narrow, ca. 30 km wide zone, separated from the East European Craton (Baltica in the early Palaeozoic) by an almost vertical, deep fault (SEMENOV & *al.* 1998). Its basement, of unknown provenance, is supposed to lie at depths of about 6-7 km (SEMENOV & *al.* 1998). GUTERCH & *al.* (1986) postulated that the Moho underneath this unit lies at much greater depths in comparison to that of the Palaeozoic platform, being otherwise similar to the Moho depth of the East European Craton. Palaeomagnetic data obtained from the Upper Cambrian sandstones of Łysogóry are most probably of secondary origin, and are thus inconclusive for determining the position of the Łysogóry Block in the Late Cambrian (LEWANDOWSKI 1993).

Brachiopods recognised in Łysogóry do not confirm the biogeographic conclusions based on trilobites. However, according to FORTEY & COCKS (1992), in the early Palaeozoic brachiopods reacted with delay to continental separations, and thus their affinities do not necessarily reflect true biogeographic relationships. Long-ranging *mixed Avalonian-Baltic* and *Avalonian* brachiopod taxa recognised in the area (BIERNAT & TOMCZYKOWA 1968, JENDRYKA-FUGLEWICZ 1992) were probably poorly adapted to the oxygen-depleted environments (THICKPENNY 1987) of the 'Alum Shale' sea (see JENDRYKA-FUGLEWICZ 1992).

The muscovites and zircons from the lower part of the Cambrian clastics of Łysogóry (Wiśniówka Duża and Wąworków quarries) suggest more than one source of clastic material. The possible source areas include a Cadomian (Gondwanan) provenance and detritus from the Svecofennian basement of Baltica (BELKA & *al.* 2000, VALVERDE-VAQUERO & *al.* 2000). These conclusions are thus in concordance with the trilobite-based biogeographic results inferred for this interval, suggesting Avalonian and mixed Avalonian-Baltic affinities.

Previous biogeographic interpretations based on trace fossils (SEILACHER 1983; see in BELKA 2000; VALVERDE-VAQUERO & *al.* 2000) pointed to the Gondwanan and Peri-Gondwanan provenance of the Łysogóry Block. The trace fossil in question, *Cruziana semiplicata* SALTER, was most probably made by *Aphelaspis rara* (ŻYLIŃSKA 1999), which is an Avalonian species characteristic of the early part of the Late Cambrian. Thus again, there is a strong evidence that the early Late Cambrian history of the Łysogóry Block was connected closely with Avalonia. On the other hand, the distribution of *Cruziana* trace fossils was probably not restricted to the Gondwanan realm, as suggested by SEILACHER (1983). Similar specimens were recognised on the margin of Baltica within the Upper Cambrian strata of the Digermul Peninsula (STRAND 1935).

As discussed above, the Late Cambrian trilobite assemblages in Łysogóry are dominated by the *Baltic fauna*, which indicates the location of the Łysogóry Block close to Baltica. However, the observed trends of biogeographic changes and the dominance of the *Avalonian fauna* at the beginning of the Late Cambrian point to a more complex scenario. It is possible that the Łysogóry Block was isolated from Baltica at the beginning of the Late Cambrian (dominance of the *Avalonian fauna*). Later on it moved away towards Baltica, but was in some way isolated (low and decreasing content of the *Avalonian fauna*, low but increasing content of the *Baltic fauna*, high but decreasing content of the *endemic fauna*), to attain very close connections (enabling mixing of faunas) with Baltica by the end of the Cambrian (high content of the *Baltic fauna*, low content of the *endemic fauna*, no *Avalonian fauna*). However, palaeogeographical reconstructions (MCKERROW & *al.* 1992, TORSVIK 1998, TORSVIK & REHNSTRÖM 2001) indicate that Avalonia (which during the Late Cambrian was still incorporated into the North African – South American part of Gondwana) was constantly in the vicinity of the shelf of southern Baltica (present-day co-ordinates). In this case, the significant decrease in the *Avalonian* faunal content in

Łysogóry towards the end of the Late Cambrian may not necessarily be a result of geographic isolation of the two areas linked with the width of the Tornquist Sea (COCKS & FORTEY 1982), but may have resulted from other factors, e.g. oceanic currents, environmental factors or the recently recognised rapid counter-clockwise rotation of Baltica during the Late Cambrian and the Early Ordovician (TORSVIK & REHNSTRÖM 2001). The latter event, combined with simultaneous counter-clockwise rotation of Gondwana, led to the juxtaposition of different shelves on both palaeocontinents in Early Ordovician time, the Avalonian shelf being shifted westwards.

CONCLUSIONS

1. The biostratigraphic zonation applied to the Upper Cambrian of Łysogóry is, with some modifications, the same as that used in the Baltic region (Text-fig. 11). The presence of the *Olenus scanicus* Subzone, *Parabolina brevispina* Subzone, *Leptoplastus* or *Protopeltura praecursor* Zone, *Peltura minor* Zone (*Ctenopyge tumida* and *Ctenopyge affinis* subzones), *Peltura scarabaeoides* Zone (*Ctenopyge linnarssoni* and *?Parabolina lobata* subzones) and the *Acerocare* Zone *sensu lato* are documented.

2. Biogeographic analysis of trilobites in Łysogóry shows a distinct change in composition of the assemblages during the Late Cambrian, from a low diversity fauna with a dominance of *Avalonian* forms, to more diversified assemblages characterised by the constant increase, to the domination, of *Baltic* elements. This trend was associated with a gradual decrease in the number of *endemic* species. The high content of *endemic* species in the *Peltura minor* Zone may be a result of palaeogeographic isolation. By the end of the Cambrian the Łysogóry Block was situated in close proximity to Baltica.

Acknowledgments

This paper is a part of my Ph.D. thesis prepared in the Department of Geology, University of Warsaw under the supervision of Prof. STANISŁAW ORŁOWSKI, to whom I am greatly indebted. Critical remarks and comments from WIESŁAW BEDNARCZYK and JERZY TRAMMER are kindly acknowledged. Constructive revisions by Zdzisław BEŁKA, Marek LEWANDOWSKI and John SHERGOLD greatly improved the paper. Gratitude is expressed to Per AHLBERG for his assistance during my stay in Lund, Sweden in 1998. Pete PALMER and Franco TORTELLO are warmly thanked for web-discussions. I appreciate the helpful remarks and comments from Jerzy NAWROCKI, Bogusław WAKSMUNDZKI and Ireneusz WALASZCZYK. Zbigniew SZCZEPANIK kindly supplied new data on the acritarchs and Michał POROS lent his specimens of *Protopeltura aciculata* from the Wiśniówka Duża Quarry. The research was supported by the Institute of Geology, Department of Geology, University of Warsaw (individual BW grants in 1996-2000), the European Commission (Tempus Phare Individual Mobility Grant in 1998), the Paleontological Society of America (PALSIRP grant in 1999) and the International Subcommission on Cambrian Stratigraphy. The financial support of the KOPIPOL Foundation is acknowledged with many thanks. This paper is a contribution to the project "Palaeozoic Accretion of Poland", Polish Committee for Scientific Research Grant no. PCZ 07-21.

REFERENCES

ACEÑOLAZA, F.G. 1983. The Tremadocian beds and the Cambrian – Ordovician boundary problems in Latin America. *In*: Papers for the Symposium on the Cambrian – Ordovician and Ordovician – Silurian Boundaries, 88-93. Nanjing Institute of Geology and Palaeontology, Academia Sinica. Nanjing.

AHLBERG, P. & AHLGREN, J. 1996. Agnostids from the Upper Cambrian of Västergötland, Sweden. *GFF,* **118**, 129-140. Stockholm.

ALLEN, P.M. & JACKSON, A.A. 1985. Geology of the country around Harlech. British Geological Survey, Natural Environment Research Council, Her Majesty's Stationary Office, 1-112. London.

ALLEN, P.M., JACKSON, A.A. & RUSHTON, A.W.A. 1981. The stratigraphy of the Mawddach Group in the Cambrian succession of North Wales. *Proceedings of the Yorkshire Geological Society*, **43** (3), 295-329.

BEDNARCZYK, W. 1972. The Precambrian and Cambrian of the Łeba Elevation (NW Poland). *Acta Geologica Polonica*, **22** (4), 685-710. [*In Polish*]

BEDNARCZYK, W. 1984. Biostratigraphy of the Cambrian deposits in the Łeba area. *Acta Geologica Polonica*, **34** (1-2), 95-110.

BELKA, Z. (*Ed*.) 2000. Excursion Guidebook, The Holy Cross Mountains. Joint Meeting of Europrobe (TESZ) and PACE Projects, Zakopane/Holy Cross Mountains, Poland. 5-38. Warszawa.

BELKA, Z., AHRENDT, H., FRANKE, W. & WEMMER, K. 2000. The Baltica-Gondwana suture in central Europe: evidence from K-Ar ages of detrital muscovites and biogeographical data. *In*: W. FRANKE, V. HAAK, O. ONCKEN & D. TANNER (*Eds*), Orogenic Processes: Quantification and Modelling in the Variscan Belt. *Special Publications of the Geological Society of London*, **179**, 87-102.

BERGSTRÖM, J. & GEE, D.G. 1985. The Cambrian in Scandinavia. *In*: D.E. GEE & B.A. STURT (*Eds*), The Caledonide Orogen - Scandinavia and Related Areas, 247-271. *John Wiley & Sons Ltd.*; London.

BERTHELSEN, A. 1992. From Precambrian to Variscan Europe.

In: D. BLUNDELL, R. FREEMAN & S. MULLER (*Eds*), A Continent Revealed: The European Geotraverse, 153-164. *Cambridge University Press;* Cambridge.

BIERNAT, G. & TOMCZYKOWA, E. 1968. On the Upper Cambrian *Lingulella* SALTER (Brachiopoda) from the Holy Cross Mountains, Poland. *Acta Palaeontologica Polonica*, **13** (2), 159-184.

BRUTON, D.L., KOCH, L., & REPETSKI, J.E. 1988. The Nærsnes section, Oslo region, Norway: trilobite, graptolite and conodont fossils reviewed. *Geological Magazine*, **125** (4), 451-455.

CLARKSON, E.N.K. & TAYLOR, C.M. 1995. The lost world of the olenid trilobites. *Geology Today*, July-August 1995, 147-154. London.

COCKS, L.R.M. 2000. The Early Palaeozoic geography of Europe. *Journal of the Geological Society, London*, **157**, 1-10.

COCKS, L.R.M. & FORTEY, R.A. 1982. Faunal evidence for oceanic separations in the Palaeozoic of Britain. *Journal of the Geological Society, London*, **139**, 465-478.

CONWAY MORRIS, S. 1989. The persistence of Burgess Shale-type faunas: implications fro the evolution of deeper-water faunas. *Transactions of the Royal Society of Edinburgh*, **80**, 271-283.

COOPER, R.A. & NOWLAN, G.S. 1999. Proposed global stratotype section and point for base of the Ordovician System. *Acta Universitatis Carolinae, Geologica*, **43** (1/2), 61-64.

COOPER, R.A., NOWLAN, G.S. & WILLIAMS, S.H. 2001. Global Stratotype Section and Point for base of the Ordovican System. *Episodes*, **24** (1), 19-28.

CZARNOCKI, J. 1919. Stratigraphy and tectonics of the Święty Krzyż Mountains. *Prace Towarzystwa Naukowego Warszawskiego*, **28**, 1-172. [*In Polish*]

CZARNOCKI, J. 1957. Tectonics of the Święty Krzyż Mountains. *Prace Państwowego Instytutu Geologicznego*, **18**, 11-97. [*In Polish*]

DADLEZ, R. 1983. On the concept of a major Early Paleozoic wrench movement along the edges of Laurentian and Baltic plates. *Przegląd Geologiczny*, **31** (6), 377-386. [*In Polish*]

DADLEZ, R., KOWALCZEWSKI, Z. & ZNOSKO, J. 1994. Some key problems of the pre-Permian tectonics of Poland. *Geological Quarterly*, **38** (2), 169-189.

DZIK, J. 1993. Early Metazoan Evolution and the Meaning of its Fossil Record. *Evolutionary Biology*, **27**, 339-386.

DZIK, J. & ORŁOWSKI, S. 1993. The Late Cambrian eocrinoid *Cambrocrinus. Acta Palaeontologica Polonica*, **38** (1/2), 21-34.

FORTEY, R. 2000. Olenid trilobites: The oldest known chemoautotrophic symbionts? *Proceedings of the National Academy of Sciences of the United States of America*, **97** (12), 6574-6578.

FORTEY, R.A. & COCKS, L.R.M. 1992. The early Palaeozoic of the North Atlantic region as a test case for the use of fossils in continental reconstruction. *Tectonophysics*, **206**, 147-158.

GEYER, G. & SHERGOLD, J. 2000. The quest for internationally recognised divisions of Cambrian time. *Episodes*, **23** (3), 188-195.

GÜRICH, G. 1896. Das Palaeozoicum im Polnischen Mittelgebirge. *Verhandlungen der Russisch-Kaiserlichen Mineralogischen Gesselschaft,* **32**, 1-539.

GUTERCH, A., GRAD, M., MATERZOK, R. & PERCHUĆ, E. 1986. Deep structure of the Earth's crust in the contact zone of the Palaeozoic and Precambrian platforms in Poland (Teisseyre-Tornquist zone). *Tectonophysics,* **128**, 251-279.

HARRINGTON, H.J. & LEANZA, A.F. 1957. Ordovician trilobites of Argentina. *University of Kansas Special Publication,* **1**, 1-259.

HENNINGSMOEN, G. 1957. The trilobite family Olenidae. *Skrifter utgitt av Det Norske Videnskaps-Akademi i Oslo, Matematisk-naturvidenskapelig klasse*, **1** (1957), 3-303.

HUTCHINSON, R.D. 1952. The stratigraphy and trilobite faunas of the Cambrian sedimentary rocks of Cape Breton Island, Nova Scotia. *Geological Survey of Canada, Memoir,* **263**, 1-124.

JENDRYKA-FUGLEWICZ, B. 1992. Comparison analysis of brachiopods from the Cambrian deposits of the Holy Cross Mountains. *Przegląd Geologiczny*, **40** (3), 150-155. [*In Polish*]

JENDRYKA-FUGLEWICZ, B. & MALEC, J. 1998. Znalezisko staropaleozoicznych brachiopodów w kamieniołomie Wiśniówka Duża, Góry Świętokrzyskie. *Posiedzenia Naukowe Państwowego Instytutu Geologicznego*, **54** (6), 1-4.

KOWALCZEWSKI, Z. 1995. Fundamental stratigraphic problem of the Cambrian in the Holy Cross Mts. *Geological Quarterly*, **39** (4), 449-470.

KOWALCZEWSKI, Z., KULETA, M., LISIK, R. & MOCZYDŁOWSKA, M. 1986. New data on Cambrian and Lower Ordovician rocks in the vicinities of Wiśniówka in the Góry Świętokrzyskie Mts. *Geological Quarterly*, **30** (2), 201-228. [*In Polish*]

LANDING, E., BOWRING, S.A., DAVIDEK, K.L., RUSHTON, A.W.A., FORTEY, R.A., WIMBLEDON, W.A.P. 2000. Cambrian-Ordovician boundary age and duration of the lowest Ordovician Tremadoc Series based on U-Pb zircon dates from Avalonian Wales. *Geological Magazine*, **137** (5), 485-494.

LENDZION, K. 1976. Stratigraphy of the Cambrian in the Western Part of the Peri-Baltic Syneclise. *Biuletyn Instytutu Geologicznego*, **270**, 59-84. [*In Polish*]

— 1982. Stratigraphic correlation of the Cambrian in the Peribaltic Syneclise. *Przegląd Geologiczny*, **30** (5), 213-219. [*In Polish*]

— 1983. Biostratigraphy of the Cambrian deposits in the Polish part of the East-European Platform. *Geological Quarterly*, **27** (4), 669-694. Warszawa. [*In Polish*]

— 1988. Upper Cambrian of Roztocze. *Geological Quarterly*, **32** (3/4), 761-762. [*In Polish*]

LEWANDOWSKI, M. 1987. Results of the preliminary palaeomagnetic investigations of some Lower Palaeozoic rocks from the Holy Cross Mts. (Poland). *Geological Quarterly*, **31** (4), 543-556.

— 1993. Paleomagnetism of the Paleozoic rocks of the Holy

Cross Mts (central Poland) and the origin of the Variscan orogen. *Publications of the Institute of Geophysics, Polish Academy of Sciences*, **A-23** (**265**), 3-84.

MARTINSSON, A. 1974. The Cambrian of Norden. *In*: C.H. HOLLAND (*Ed*.), Lower Palaeozoic Rocks of the World. 2. Cambrian of the British Isles, Norden and Spitsbergen, 185-283. *John Wiley & Sons*, London.

MASIAK, M. & ŻYLIŃSKA, A. 1994. Burgess Shale-type fossils in Cambrian sandstones of the Holy Cross Mountains. *Acta Palaeontologica Polonica*, **39** (4), 329-340.

MCHENRY, B. & YATES, A. 1993. First report of the enigmatic metazoan *Anomalocaris* from the southern hemisphere and a trilobite with preserved appendages from the early Cambrian of Kangaroo Island, South Australia. *Records of the South Australia Museum*, **26**, 77-86.

MCKERROW, W.S., SCOTESE, C.R. & BRASIER, M.B. 1992. Early Cambrian continental reconstructions. *Journal of the Geological Society of London,* **149**, 599-606.

MIZERSKI, W. 1995. Geotectonic evolution of the Holy Cross Mts in central Europe. *Biuletyn Państwowego Instytutu Geologicznego*, **372**, 5-47.

MORRIS, S.F. 1988. A review of British trilobites, including a synoptic revision of SALTER'S monograph. *Palaeontographical Society Monographs*, **574**, 1-316.

NAWROCKI, J. 2000. Late Silurian paleomagnetic pole from the Holy Cross Mountains: constraints for the post-Caledonian tectonic activity of the Trans-European Suture Zone. *Earth and Planetary Science Letters*, **179**, 325-334.

NIELSEN, A.T. 1999. A Catalogue of Ordovician Agnostid Trilobites. *Danmarks og Grønlands Geologiske Undersøgelse Rapport* **1999/24**, 1-199. Copenhagen.

NIKOLAISEN, F. & HENNINGSMOEN, G. 1985. Upper Cambrian and lower Tremadoc olenid trilobites from the Digermul Peninsula, Finnmark, northern Norway. *Norges Geologiske Undersøkelse,* **400**, 1-49.

ORŁOWSKI, S. 1968a. Cambrian of Łysogóry Anticline in the Holy Cross Mountains. *Biuletyn Geologiczny Wydziału Geologii*, **10**, 153-222. [*In Polish*]

ORŁOWSKI, S. 1968b. Upper Cambrian fauna of the Holy Cross Mts. *Acta Geologica Polonica*, **18** (2), 257-291.

ORŁOWSKI, S. 1975. Cambrian and Upper Precambrian lithostratigraphic units in the Holy Cross Mts. *Acta Geologica Polonica*, **25** (3), 431-448.

— 1988. Stratigraphy of the Cambrian System in the Holy Cross Mts. *Geological Quarterly*, **32** (3/4), 525-532. .

— 1992a. Trilobite trace fossils and their stratigraphic significance in the Cambrian sequence of the Holy Cross Mountains, Poland. *Geological Journal*, **27**, 15-34.

— 1992b. Cambrian stratigraphy and stage subdivision in the Holy Cross Mountains, Poland. *Geological Magazine*, **129** (4), 471-474.

ORŁOWSKI, S., RADWAŃSKI, A. & RONIEWICZ, P. 1970. The trilobite ichnocoenosis in the Cambrian sequence of the Holy Cross Mountains. *In*: T.P. CRIMES & J.C. HARPER (*Eds*), Trace fossils. *Geological Journal Special Issue*, **3**, 345-360.

ORŁOWSKI, S., RADWAŃSKI, A. & RONIEWICZ, P. 1971. Ichnospecific variability of the Upper Cambrian *Rusophycus* from the Holy Cross Mts. *Acta Geologica Polonica*, **21** (3), 341-348.

ORŁOWSKI, S. & ŻYLIŃSKA, A. 1996. Non-arthropod burrows from the Middle and Late Cambrian of the Holy Cross Mountains, Poland. *Acta Palaeontologica Polonica*, **41** (4), 385-409.

POŻARYSKI, W. 1990. The Middle Europe Caledonides - wrenching orogen composed of terranes. *Przegląd Geologiczny*, **38** (1), 1-9. [*In Polish*]

POŻARYSKI, W., GROCHOLSKI, A., TOMCZYK, H., KARNKOWSKI, P. & MORYC, W. 1992. Tectonic map of Poland in the Variscan epoch. *Przegląd Geologiczny,* **40** (11), 643-651. [*In Polish*]

PŘIBYL, A. & VANĚK, J. 1980. Ordovician trilobites of Bolivia. *Rozpravy Ceskoslovenskej Akademie Ved,* **90** (2), 3-90. Praha.

PUURA, I. & VIIRA, V. 1999. Chronostratigraphy of the Cambrian-Ordovician boundary beds in Baltoscandia. *Acta Universitatis Carolinae, Geologica,* **43** (1/2), 5-8.

RADWAŃSKI, A. & RONIEWICZ, P. 1963. Upper Cambrian trilobite ichnocoenosis from Wielka Wiśniówka (Holy Cross Mountains, Poland). *Acta Palaeontologica Polonica*, **8** (2), 259-280. [*In Polish*]

— & — 1972. A long trilobite trackway, *Cruziana semiplicata* SALTER, from the Upper Cambrian of the Holy Cross Mts. *Acta Geologica Polonica*, **22** (3), 439-447.

READING, H.G. 1965. Eocambrian and Lower Palaeozoic geology of the Digermul Peninsuls, Tanafjord, Finnmark. *Norges Geologiske Undersøkelse*, **234**, 167-191.

ROBISON, R.A. & PANTOJA-ALOR, J. 1968. Tremadocian trilobites from the Nochixtlán Region, Oaxaca, Mexico. *Journal of Paleontology*, **42** (3), 767-800.

RUSHTON, A.W.A. 1968. Revision of two Upper Cambrian trilobites. *Palaeontology*, **11** (3), 410-420.

— 1982. The biostratigraphy and correlation of the Merioneth-Tremadoc Series boundary in North Wales. *In*: M.G. BASSETT & W.T. DEAN (*Eds*), The Cambrian - Ordovician boundary: sections, fossil distributions, and correlation. *National Museum of Wales, Geological Series*, **3**, 41-59.

— 1983. Trilobites from the Upper Cambrian *Olenus* Zone in central England. *Special Papers in Palaeontology,* **30**, 107-139.

SAMSONOWICZ, J. 1916. Kambr i kambro - sylur Gór Świętokrzyskich. *Sprawozdania Towarzystwa Naukowego Warszawskiego,* **9**, 321-330.

— 1934. Explication de la feuille Opatów. Carte géologique en 1:100000. P.I.G., f.1, [*In Polish*]

SCHRANK, E. 1973. Trilobiten aus Geschieben der oberkambrischen Stufen 3-5. *Paläontologische Abhandlungen* (A), **4** (4), 805-891.

SCOTESE, C.R. & MCKERROW, W.S., 1990. Revised World maps and introduction. *In:* W.S. MCKERROW & C.R. SCOTESE

(*Eds*), Palaeozoic Palaeogeography and Biogeography, *Geological Society Memoir*, **12**, 1-21.

SDZUY, K. 1955. Die Fauna der Leimitz-schiefer (Tremadoc). *Senckenbergischen Naturforschenden Gesellschaft, Abhandlungen,* **492**, 1-74.

SEILACHER, A. 1983. Upper Paleozoic trace fossils from the Gilf Kebir-Abu Ras area in southwestern Egypt. *Journal of African Earth Sciences*, **1**, 21-34.

SEMENOV, V.Y., JANKOWSKI, J., ERNST, T., JÓŹWIAK, W., PAWLISZYN, J. & LEWANDOWSKI, M. 1998. Electromagnetic soundings across the Holy Cross Mountains, Poland. *Acta Geophysica Polonica*, **46**, 171-185.

SHERGOLD, J.H. 1988. Review of trilobite biofacies distributions at the Cambrian-Ordovician Boundary. *Geological Magazine*, **125** (4), 363-380.

STRAND, T. 1935. A Cambrian fauna from Finnmark, northern Norway. *Norsk Geologisk Tidsskrift,* **15**, 19-24.

TAYLOR, K. & RUSHTON, A.W.A. 1972. The pre-Westphalian geology of the Warwickshire Coalfield. *Bulletin of the Geological Survey of Great Britain*, **35**, 1-69.

THICKPENNY, A. 1987. Palaeo-oceanography and depositional environment of the Scandinavian alum shales: sedimentological and geochemical evidence. *In*: J.K. LEGETT & G.G. ZUFFA (*Eds*), Marine Clastic Sedimentology, Concepts & Case Studies, 156-171. *Graham & Trotman*; London.

TJERNVIK, T. 1953. Notes on two new trilobites from the Upper Cambrian of Sweden. *GFF*, **75**, 72-76.

— 1955. *Nericiaspis*, a new genus of proparian olenids. *GFF*, **77**, 209-212.

TOMCZYK, H. 1988. Tectonic movements between the margin of the East European Platform and the Holy Cross Mountains region in the Paleozoic. *Przegląd Geologiczny*, **36** (1), 9-17. [*In Polish*]

TOMCZYKOWA, E. 1968. Stratigraphy of the Uppermost Cambrian deposits in the Świętokrzyskie Mountains. *Prace Instytutu Geologicznego*, **54**, 5-85. Warszawa. [*In Polish*]

TOMCZYKOWA, E. & TOMCZYK, H. 2000. The Lower Palaeozoic in the Daromin IG 1 borehole - confirmation of the concept of the terrane structure of the Łysogóry and Małopolska blocks (Góry Świętokrzyskie Mts.). *Biuletyn Państwowego Instytutu Geologicznego*, **393**, 167-203. [*In Polish*]

TORSVIK, T.H. 1998. Palaeozoic palaeogeography: A North Atlantic viewpoint. *GFF*, **120**, 109-118.

TORSVIK, T.H. & REHNSTRÖM, E.F. 2001. Cambrian palaeomagnetic data from Baltica: implications for true polar wander and Cambrian palaeogeography. *Journal of the Geological Society of London*, **158** (2), 321-329.

TORSVIK, T.H., SMETHURST, M.A., MEERT, J.G., VAN DER VOO, R., MCKERROW, W.S., BRASIER, M.D., STURT, B.A., WALDERHAUG, H.J. 1996. Continental break-up and collision in the Neoproterozoic and Palaeozoic - A tale of Baltica and Laurentia. *Earth Science Reviews*, **40**, 229-258.

TORTELLO, M.F., RÁBANO, I., RAO, R.I. & ACEÑOLAZA, F.G. 1999. Los trilobites de la transición Cámbrico-Ordovícico en la quebrada Amarilla (Sierra de Cajas, Jujuy, Argentina). *Boletín Geológico y Minero*, **110** (5), 555-572.

VALVERDE-VAQUERO, P., DÖRR, W., BELKA, Z., FRANKE, W., WISZNIEWSKA, J. & SCHASTOK, J. 2000. U-Pb single-grain dating of detrital zircon in the Cambrian of central Poland: implications for Gondwana versus Baltica provenance studies. *Earth and Planetary Science Letters*, **184**, 225-240.

WESTERGÅRD, A.H. 1922. Sveriges Olenidsskiffer. *Sveriges Geologiska Undersökning*, *C*, **18**, 1-205.

— 1947. Supplementary notes on the Upper Cambrian trilobites of Sweden. *Sveriges Geologiska Undersökning*, *C*, **489**, 3-35.

ŻYLIŃSKA, A. 1992. Geology of the western part of the Łysogóry Anticline (Wiśniówka Hill). *Unpublished M. Sc. Thesis,* Departmemt of Geology, University of Warsaw. 1-149. [*In Polish*]

— 1999. Trace maker of *Cruziana semiplicata* in the Upper Cambrian of the Holy Cross Mts. (Poland). *In:* A.R. PALMER (*ed.*) Abstracts, Laurentia 99, V Field Conference of the Cambrian Stage Subdivision Working Group, Utah, Nevada, California, U.S.A., 62-63. Boulder.

— 2001. Late Cambrian trilobites from the Holy Cross Mountains, central Poland. *Acta Geologica Polonica*, **51** (4), 333-383.

Manuscript submitted: 10th December 2001
Revised version accepted: 15th April 2002