Some biostratigraphic problems of the Cambrian in the Holy Cross and Nida areas of Poland

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INTRODUCTION

The biostratigraphy of the Cambrian of the Holy Cross Mountains is based upon trilobites represented by Scandinavian-type and endemic species. Apart from trilobites and abundant trace fossils there are also foraminifers, coelenterates, worms, brachiopods, gastropods, echinoderms and acritarchs.


Cambrian trilobites from the Holy Cross Mts. indicate connections with the Atlantic-Baltic Subprovince and, sometimes, with the Atlantic-Mediterranean Subprovince, while the Cambrian biota as a whole possessed distinctive regional characteristics (Orłowski, 1964a, b, 1967, 1968b, c, 1974, 1975, 1985a, b, 1988a, b; Bednarzyk et al., 1965). The Cambrian from Scandinavia is the reference section for the Atlantic-Baltic Subprovince.

Polish Cambrian deposits are best explored in the Holy Cross Mts. Trilobite zones and subzones have been defined (Tomczykowa, 1968; Orłowski, 1974, 1975, 1985b, 1988a, b, 1992a–c; Orłowski and Mizerski, 1995a, b), though correlation is locally problematic. Some of the zones are well documented, while others are defined by endemic species and rare taxa or even single species; the latter may have poorly delineated boundaries.

HISTORICAL SUMMARY

The first studies on the Cambrian deposits of the Holy Cross Mts. were by Gürich (1892), who recognised the Scandinavian-type trilobites Agnostus gibbus Linnarsson, A. fallax Linnarsson, Liostracus linnarssoni Brögger and Paradoxides cf. tessini Brongniart (according to contemporary synonymy) in the Pieprzow Mts. and assigned these deposits to the Middle Cambrian, correlating them with the Paradoxides tessini (= P. paradoxissimus) Beds of Scandinavia. His conclusions still stand. Solenopleura munsteri (Strand) and S. cf. canaliculata (Angelin) were subsequently recognised by Orłowski (1964a, b, 1985b) (Fig. 1). Gürich (1896) also first noted the occurrence of Upper Cambrian deposits in the vicinity of Małochoce.

Later investigations in the Holy Cross Mts. were conducted by Czarnocki (1919–1950) and Samsonowicz (1916–1959) and these outlined the stratigraphy of the Cambrian deposits of the Holy Cross Mts. Since 1957 the Cambrian deposits have
Fig. 1. Geographic distribution of lithostratigraphic formations of the Cambrian and uppermost Precambrian in the Holy Cross Mts. (after Orłowski, 1975)

1 — limits of Palaeozoic core of the Holy Cross massif; 2 — limits of Cambrian exposures; 3 — boundaries of formations, stated; 4 — boundaries of formations, supposed; 5 — the Holy Cross thrust; 6 — important faults; S — the Slowiós Sandstone Formation
been studied by Orłowski who described new trilobite, brachiopod and eocrinoid species and further elaborated the litho- and biostratigraphic subdivision of the Cambrian.

The stratigraphy of the uppermost Cambrian and the problem of the Cambrian/Ordovician boundary in Lysogóry were analysed by Tomczykowa (1968) who described new Upper Cambrian trilobites and distinguished two subzones in the top part of the Peltura Zone, and four subzones in the Parabolina Zone (a zone introduced later by Orłowski, 1975). These subzones correspond to the four subzones of the uppermost Cambrian Acerocare Zone in Scandinavia.

Analysis of acritarchs by Vidal (in: Po arsky et al., 1981) allowed revision of the age of deposits previously assumed to be Precambrian. Thus, rocks from Kotuszów and the Nida Trough (Jędrzejów IG 1 and Wegleszyn IG 1 boreholes) are not Precambrian in age but may rather be correlated with the Holmia Zone.

The stratigraphic scheme of the Cambrian system in the Holy Cross Mts., established by Orłowski (1975, 1992a–c), has been criticized by Kowalczewski (1995). He questioned the stratigraphical value of ichnozones introduced by Orłowski in the Middle and Upper Cambrian and argued that age of some litostratigraphical units, as determined by acritarchs, is different than indicated by trilobites. In his comment Orłowski (1997) rejected the criticism pointing out that stratigraphical significance of acritarchs might be overestimated. In this paper more arguments are presented that call for revision of the Cambrian stratigraphy in the Holy Cross Mts.

**LOWER CAMBRIAN**

The oldest sedimentary rocks in the southernmost Holy Cross area and the Nida Trough were until recently considered to be Upper Precambrian (Jaworsowski et al., 1967; Jurkiewicz and Kowalczewski, 1968; Deczkowski and Tomczyk, 1969; Jurkiewicz, 1975, 1980), partly on the basis of acritarchs studied by Michniak (1959) and Jagielska (1963, 1965; akowa and Jagielska, 1970). Those authors used the acritarch taxonomy and biostratigraphy of Timofeev (pers. comm.), which have however been questioned by Volkova, Jankauskas and Kirjanov (pers. comm.). The conclusions of Michniak and Jagielska were later revised by Vidal (in: Po arsky et al., 1981), Moczydłowska (1985 and in: Lendzion et al., 1983; Kowalczewski et al., 1987) and Szczepanik (1988, 1993a, b, 1996) who recognised the Holmia Zone in these deposits.

Kowalski (1983) came to stratigraphical conclusions based on material of doubtful organic affiliation; his descriptions do not provide reliable evidence for his recognition of the Sabellidites Zone. Kowalski (1983) also recognised stratigraphically useful acritarchs such as *Baltsphaeridium ornatum* Volkova [= *Skiagia ornata* (Volkova) Downie] and *Tasmanites bobrowskai*Wa yiiska; these are not known to occur together with *Sabellidites cambriensis* Yantishevska.

The acritarch assemblages indicate an age not older than the Holmia Zone (Lendzion et al., 1983; Moczydłowska, 1985; Kowalczewski et al., 1987). Kowalski’s (1983) conclusions were incorrect, but inspired, among others, Orłowski’s biostratigraphic studies of the lowermost Cambrian in the Holy Cross Mts.

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**Table 1**

<table>
<thead>
<tr>
<th>Series</th>
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<td>Upper Cambrian</td>
<td>Acerocare</td>
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<td>Peltura</td>
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<td>Leptoplatus and Eurycare</td>
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<td></td>
<td>Parabolina spinulosa</td>
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<td>Olenus and Agnostus (Homagnostus) obesus</td>
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<td>Agnostus pisiformis</td>
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<td>Middle Cambrian</td>
<td>Lejoyge luevigata</td>
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<td></td>
<td>Erratoincella (Solenopleura) brachymetopa</td>
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<td>Psychagnostus landgreni and Goniagnostus nathorsti</td>
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<td>Psychagnostus punctuosus</td>
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<td>Hypagnostus parvirostre</td>
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<td></td>
<td>Tomagnostus fissus</td>
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<td></td>
<td>Psychagnostus gibbus</td>
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<td>Eccaparadoxides pinus</td>
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<td></td>
<td>Eccaparadoxides insularis</td>
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<td>Lower Cambrian</td>
<td>Proampyx linnersssoni</td>
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<td>Holmia kjeralfi Group Zone</td>
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<td>barren interval</td>
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<td>Schmidtiella mickwitzi — Mobergella</td>
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<td>Platsolenites antiquissimus</td>
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<td>Sabellidites cambriensis</td>
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As has been already stated by Kowalszewski (1995) there is little substantial evidences, either, for placing the Osiek Sandstone Formation at the base of the Cambrian in the Holy Cross area (Fig. 1) (cf. Orłowski, 1981–1992; Mizerski et al., 1986; Orłowski and Mizerski, 1995b). This interpretation cannot be inferred from the stratal succession in the eponymous Osiek 141 borehole (Lendzion, 1995). These unfossiliferous sandstones overlie the claystones and mudstones of the Czarna Shale Formation in which Moczydłowska (1985) found *Baltsphaeridium compressum* Volkova [= *Skiagia compressa* (Volkova) Downie]. This species shows that these deposits are not older than the Holmia Zone, and thus the Osiek Sandstones, overlying an erosional surface, are certainly younger. Kowalszewski (1990, 1995) suggested they may even be Middle Cambrian.

The succeeding zones of the lowermost Lower Cambrian — the *Hyolites-Allatheca* and *Coeoloides* Zones, distinguished by Orłowski (1987), were included to the Czarna Shale Formation. They were earlier combined as the *Platsolenites* Zone (Orłowski, 1981, 1985a). The *Hyolites-Allatheca* Zone is represented by the endemic species *Allatheca kotuszowi* Orłowski et Waksundzki and *Hyolites czarna* Orłowski et Waksundzki which do not constrain the age of deposits. The genera *Allatheca* and *Hyolites* have broad stratigraphical ranges (Lower Cambrian-Permian). Their occurrence in the southernmost Cambrian exposures is no proof that these are the oldest Cambrian rocks. These rocks were dated as sub-Holmia on the basis of *Platsolenites antiquissimus* Eichwald, found by Michniak and Rozanov (1969) at an exposure between Kotuszów and Jasiętna, and may correlate with the Lontov horizon of Eastern Europe and the *Platsolenites* Zone of Eastern Poland. However, it appears that *Platsolenites* specimens also occur in younger Lower Cambrian rocks in Eastern Europe.
Scandinavia, Great Britain and California (Firby-Durham, 1977; Rozanov, 1983; Bergström and Gee, 1985). In Eastern Europe this species occurs also in the Talsi and Vergale horizons, and in Scandinavia in the Mobergella-Schmidtiiella mickwitzii Zone. Deposits from the Kotuszów-Jasień exposures should probably be correlated with the last zone, as is also indicated by acritarchs identified by Vidal (in: Po aryski et al., 1981) and Moczydlowska (in: Lendzion et al., 1983; Kowalczewski et al., 1987). The presence of Lophosphaeridium tentatitum Volkova, Micrhystridium

![Fig. 2. Stratigraphic divisions of the Cambrian in the Holy Cross Mts. with ranges of selected fossils and trace fossils (after Orłowski, 1992c)](image-url)
The Middle Cambrian fauna of the Holy Cross Mts. shows affinities to that from Scandinavia. This should be reflected in the biostratigraphy, though Orłowski continues to include the \textit{Paradoxides insularis} and \textit{Paradoxides pinus} Zones (Fig. 2) into his biostratigraphic scheme of the lower Middle Cambrian, though these taxa are now referred to as \textit{Eccaparadoxides insularis} and \textit{E. pinus} (Bergström and Levi-Setti, 1978; Table 1).

Higher, in the Middle Cambrian section, Orłowski (1975) distinguished the \textit{Paradoxides polonicus} Zone, based on endemic species of \textit{Paradoxides}. Apart from abundant \textit{Paradoxides} specimens, there are also \textit{Psychagnostus gibbus} (Linnarsson), \textit{Solenopleura munsteri} (Strand), \textit{S. linnarssoni} (Brögger) and \textit{Peronopsis fallax} (Linnarsson) that indicate connections between the \textit{Paradoxides polonicus} Zone and some of the trilobite zones of the \textit{Paradoxides paradoxissimus} Superzone in Scandinavia.

The age of deposits overlying the \textit{Paradoxides polonicus} Zone is poorly constrained. The subdivision of this part of the Middle Cambrian section into the \textit{Solenopleura} and \textit{Cruziana} \textit{barbata} Zones (Fig. 2), proposed by Orłowski (1988a, b, 1992a–c; Orłowski and Mizerski, 1995a, b), is based on scant palaeontological data. The \textit{Solenopleura} Zone is documented merely by one specimen of \textit{Solenopleura cf. canaliculata} (Angelin) indicating that the zone may correspond to the \textit{Solenopleura brachynetopa} Zone of the \textit{Paradoxides forchhammeri} Superzone of Scandinavia (Westergard, 1946).

The \textit{Cruziana} \textit{barbata} (or \textit{Cruziana}) Zone spans the uppermost Middle Cambrian deposits, so it would correspond to the \textit{Lejopyge laevigata} Zone of Scandinavia (Westergard, 1946) on the evidence of acritarchs identified by Szczepanik (in: Studencik, 1994). The trace fossil zone of \textit{Cruziana barbata} should not strictly be included within the trilobite biostratigraphic scheme (Lendzion, 1995). Moreover, according to Seilacher (1970) the ichnospecies \textit{Cruziana barbata} is not limited to the upper part of the Middle Cambrian (see also Kowalczewski’s remarks, 1995). Current knowledge of the uppermost Middle Cambrian indicates that it is better to leave this part of the section unnamed.

### UPPER CAMBRIAN

The Upper Cambrian of the Holy Cross area was subdivided by Orłowski (1975) into four trilobite zones of, from bottom to top: “\textit{Olenus}”, \textit{Protopeltura}, \textit{Peltura}, \textit{Parabolina} (Fig. 2), which can be correlated with six Scandinavian zones. The reduction in the number of zones compared with the Scandinavian stratotype profile might have been due to a lack of exposures and incomplete drillcores through Upper Cambrian
strata. Orłowski indicated that the Upper Cambrian fauna record is fragmentary, with unfossiliferous intervals.

The “Olenus” Zone, which according to Orłowski (1975) spans the Scandinavian Agnostus pisiformis and Olenus + Homagnostus obesus Zones and the lower part of the Parabolina spinulosa Zone, is poorly documented. Endemic species, associated with this zone and found mostly at the Wąwórków exposure and described by Orłowski (1968b, c), are represented by “Olenus” rarus Orłowski, Protolentus olenusorum Orłowski, P. sp., Orygia cf. lenticularis (Wahlenberg), Acrotreta multa Orłowski, Obolus sp. and Cambrocricinus regularis Orłowski. All these species, excluding Acrotreta multa Orłowski, occur in the Holy Cross Mts., whereas the zonal name in the Upper Cambrian biostratigraphic scheme should not be put in quotation-marks (see also Lendzion, 1995). The “Olenus” Zone was established on the abundance of “Olenus” rarus Orłowski occurring in sandstones exposed at Wąwórków and assigned to the Wiśniówka Sandstone Formation (Orłowski, 1975).

The Protolentus Zone was distinguished and correlated by Orłowski (1975) with the top of the Parabolina spinulosa Zone and with the Leptoplatus Zone from Scandinavia. This zone in the Holy Cross Mts., however, contains no fauna at all and thus there seems little basis for placing such a zone in the Upper Cambrian stratigraphic scheme.

The uppermost zones of Peltura and Parabolina (Tomczykowa, 1968; Orłowski, 1968b, c) are the best-documented. The former corresponds only to the middle and upper parts of the Peltura Zone from the stratotype Scandinavian section, i.e. to the Peltura minor and Peltura scarabaeoides Subzones. No equivalent of the lower subzone in Scandinavia, of Protolentus praecursor, have been found. The position of the lower boundary of the Peltura Zone is also unknown.

The Parabolina Zone is evidently the equivalent of the Acerocare Zone of Scandinavia. Tomczykowa (1968) distinguished four subzones within this interval of (from bottom to top): Parabolina latilimbata, Beltella rotundata, P. bukowiana and P. acanthura; these correspond to the four subzones of the Acerocare Zone established by Westergard (1922) and Henningsmoen (1957) in Scandinavian profiles (Table 1).

**GENERAL CONCLUSIONS FROM THE INTERREGIONAL COMPARISON OF CAMBRIAN MACROFAUNA**

Cambrian trilobites from the Holy Cross Mts., neighbouring platformal areas of Poland and the Upper Silesian Foredeep, are related to Scandinavian trilobites characteristic of the Atlantic-Baltic Subprovince (= Baltica). This subprovince communicated with other areas of the Atlantic Province and beyond. Species of the genera Schmidthiellus, Holmia, Kjerulfia, Strenuaeva and Ellipsopocephalus, occurring in the Holmia-Schmidthiellus Zone of the Holy Cross Mts. and Upper Silesia as well as in the Holmia Zone of the East European Craton, indicate strong relations with the Baltic-Scanian part of the platform and with the foreland of the Scandinavian Caledonides. The presence of the genus Postfallotaspis in the Holy Cross Mts., related to the Moroccan genus Fallotaspis, shows that trilobites from the Atlantic-Mediterranean Subprovince (= Gondwana) migrated into the area of Poland. The cosmopolitan genus Fallotaspis was very widespread. Its abundance enables distinction of the Fallotaspis Zone in the lower part of the Lower Cambrian of Morocco, California, Nevada, Canada and McKenzie Mts. as well as in the Atdaban Zone of the Siberian Platform (Fritz, 1976; Repina, 1976; Nelson, 1978). Single specimens of Fallotaspis have been found in Lower Cambrian deposits of the Polish part of the East European Craton (Lendzion, 1978), Sweden (Ahlberg, 1984) and in England (Cowie et al., 1972).

The interval spanning the uppermost Lower Cambrian (Protolenus-Strenuaeva Zone) to the top of the Upper Cambrian (Parabolina Zone) is only represented in Poland in the Holy Cross Mts. and — in the Protolenus Zone — in the East European Craton. Trilobites migrated into these areas from the present-day Spain and Morocco via Lausitz (Görliitz Syncline) and Frankenwald, and with England — via Normandy. Such a conclusion can be inferred mainly from the presence of Protolenus, Lasatiops (in the vicinity of Görliitz) and Serrodiscus (Hupé, 1960; Szudy, 1960, 1962, 1964; Rushton, 1966; Cowie et al., 1972; Orłowski, 1974, 1985a; Lendzion, 1983a, b; Geyer and Elicki, 1995). Communication with areas west of Poland also existed later, although contact between the Atlantic-Baltic and North Atlantic Subprovinces (= Baltica and Laurentia) were established since Middle Cambrian times. Common and closely related taxa of the Paradoxidae and Agnostidae occurred in the Holy Cross Mts., platform areas of Poland, Scandinavia, England and Newfoundland (Hutchinson, 1962; Rushton, 1966; Orłowski, 1964a, 1985b; Cowie et al., 1972; Bergström and Levi-Setti, 1978; Lendzion, 1983a, b; Martin and Dean, 1988). Many representatives of these families are cosmopolitan forms, and the index species from Scandinavia define the Middle Cambrian zones showing analogous or similar ranges even outside this province in Kazakhstan and Australia. In the Siberian Platform and Western Mongolia they are represented by only a few species (Dumicz et al., 1970; Daily and Jago, 1975; Öpik, 1979; Ergaliev, 1980; Lazarenko and Repina, 1983). The Middle Cambrian trilobite assemblage of the Holy Cross Mts., dominated by endemic species of the genera Paradoxidae and Ellipsopocephalidae, does not indicate a separate ecologic niche because the coeval forms of Kingaspis, Solenopleura and Solenopleurina show that the Holy Cross area was situated within a zone where the typical Atlantic-Baltic fauna mixed with an Atlantic-Mediterranean one.
The Upper Cambrian of Lysogóry and the platform area is represented by taxa of the families Oleniidae and Agnostidae also occurring in Upper Cambrian deposits of Scandinavia, England and Newfoundland. There is no evidence of connection with other areas.


