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Stratigraphy of the Cambrian System in the Holy Cross Mts

Four areas with Cambrian deposits are recognized in Poland. The most important from the point of view of the paleontology, sedimentology and stratigraphy (both lithostratigraphy and biostratigraphy) of the Cambrian System is the area of the Holy Cross Mts situated almost in the center of the country. The progress in description of trilobites, hyolithids, some other groups of fossils and trace fossils together with more exact data of the formation thicknesses have given the opportunity to demonstrate in this publication the synthesis of the stratigraphy of the Cambrian System. Additionally the complete list of trilobites and list of some other fossils is presented on the background of the detailed stratigraphy. The Cambrian sequences of the other regions of Poland may be compared with classical section in the Holy Cross Mts. The other areas are: Kaczawa Mts in the Sudety Mts (SW Poland) with exposed Cambrian rocks, Upper Silesian Coal Basin (SW Poland) with Cambrian rocks known only from boreholes, and Cambrian platform deposits (North and East Poland) covering Precambrian basement of the Precambrian East-European Platform, known also from boreholes only.

INTRODUCTION

Cambrian rocks were recognized in some regions of Poland (Fig. 1) but they outcrop only in the Holy Cross Mts and in Sudety Mts. A complete sequence of Cambrian rocks with common and differenciated fossils is known from the Holy Cross Mts only (S. Orłowski, 1964, 1968*a*, *b*, 1985*a*, *b*, 1987; S. Orłowski, B. Waksmundzki, 1986). Fossils in the Cambrian sequence in Sudety Mts are very scarce (T. Gunia, 1967), therefore the precision of the stratigraphic subdivisions is very low. The Cambrian rocks of both areas were deposited in the open marine basin, which was a part of the Mid-European Caledonian Geosyncline.

In the other areas of Poland the Cambrian rocks were penetrated by boreholes, mainly in Northern and Eastern Poland. There they cover the cristalline basement of the Precambrian European Platform at the different depths, up to 5 km. The Cambrian System in the latter area is rather similar – from the point of view of fossils and biostratigraphy – to the Cambrian in Scandinavia with some addi-

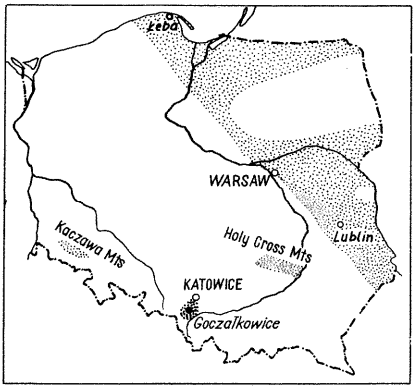

Fig. 1. Cambrian deposits in Poland
Występowanie osadów kambru w Polsce

tional features comparable with Estonia, Lithuania, Latvia, and Western Ukraine but the thickness of Cambrian series is as a rule much bigger.

The Cambrian rocks were penetrated by borings on the area of the Upper Silesian Coal Basin (SW Poland) under the thick cover of Carboniferous and Devonian rocks. Trilobites, very important for Lower Cambrian stratigraphy, were found in Goczałkowice borehole (S. Orłowski, 1975*b*).

Trilobites from the Cambrian System in Poland belong to Atlantic zoogeographic province or – more precisely – to Baltic or Scandinavian subprovince. Some scarce trilobites from other zoogeographic provinces are also present. They show that Cambrian seas of Poland were influenced by trilobites from Marokko, Great Britain, Bohemia, North America and Siberia.

STRATIGRAPHY

Folded Cambrian rocks of the Holy Cross Mts are recognized as a part of the Małopolska Massif situated in SE Poland. Riphean, Vendian and Paleozoic rocks of this massif are known from the boreholes only, because they are covered by marine Miocene deposits. Stratigraphy of the Precambrian rocks of this area is still disputable. New stratigraphic subdivision of the Upper Riphean and Vendian of the Southern Poland was given by W.R. Kowalski (1983) and K. Łydka, L.J. Fiłatowa (1987).

Cambrian sequence of the Holy Cross Mts is recognized as Holy Cross Group (Fig. 2) reaching from the lowermost Lower Cambrian and including the Lower Tremadocian (Ordovician) at the top. The Group is limited at the top by the foldings of the local tectonic Sandomirian Phase, which may be compared with the Grampian Phase in Scotland and/or Finnmark Phase in Scandinavia.

The Holy Cross Group comprises a thick series of sandstones, siltstones and clayey and silty shales, at least 2500 to 3500 m thick. The Cambrian sequence is divided into following lithostratigraphic units according to *Zasady polskiej klasyfikacji, terminologii i nomenklatury stratygraficznej* (1975).

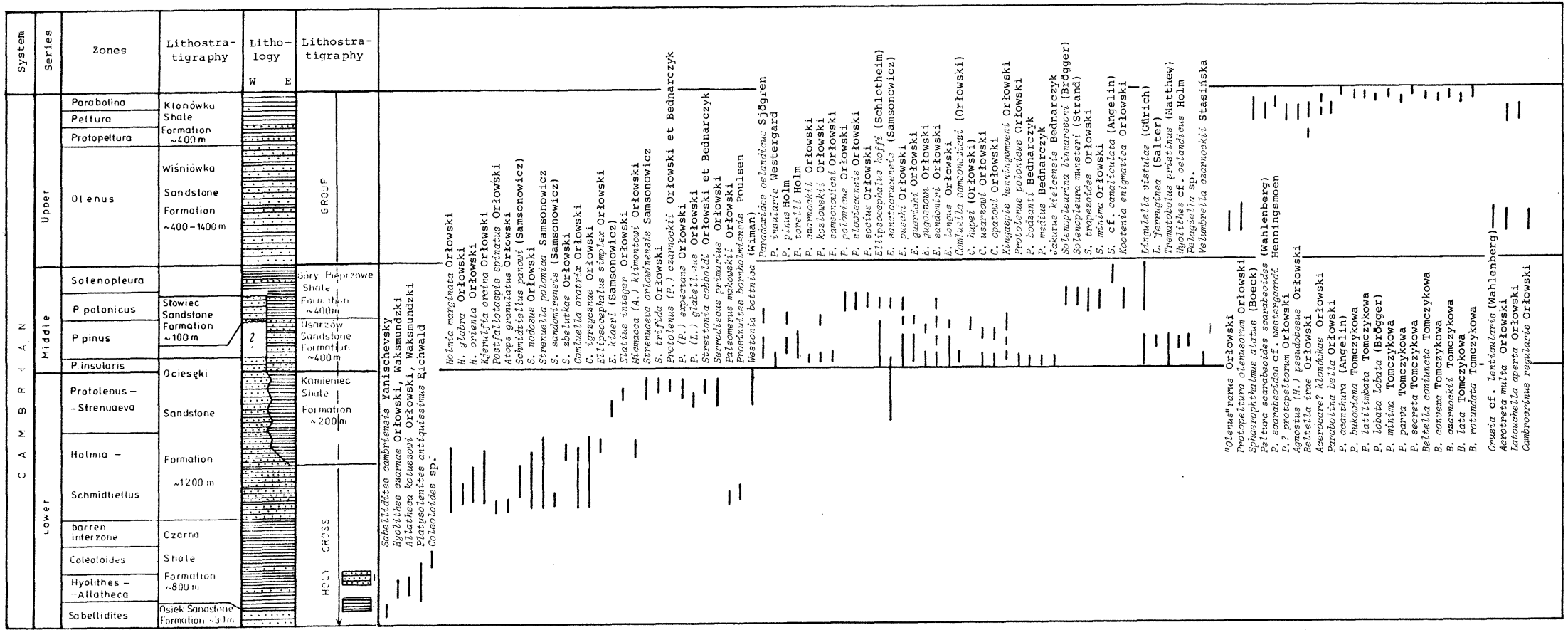

Fig. 2. Stratigraphic subdivisions of the Cambrian sequence with the list of trilobite species and selected species of other groups

Podział stratygraficzny kambru w Górach Świętokrzyskich wraz z wykazem trylobitów i wybranych skamieniałości innych grup

1 – sandstones; 2 – shales

1 – piaskowce; 2 – łupki

LOWER CAMBRIAN

Osiek Sandstone Formation was established by W.R. Kowalski (1983). The formation is thin (Fig. 2) and is known mainly from boreholes, the outcrops are few and small. It is represented by yellow and light-grey quartz sandstones passing upward into dark-grey sandstones. So far, no fossils were found in sandstones except for some trace fossils as: *Planolites montanus*, *Phycodes* sp. (W.R. Kowalski, 1983) in the upper part of the formation.

Czarna Shale Formation was recognized by S. Orłowski (1975*a*). The Formation consists of clayey and silty shales with intercalations of fine-grained siltstones and sandstones; the sandstone intercalations are more frequent toward the top of the formation. The thickness of formation may be estimated at 800 m (S. Orłowski, 1987). Within the formation the skeletal fauna is represented by: *Hyolithes czarnae*, *Allatheca kotuszowi* (S. Orłowski, B. Waksmundzki, 1986), *Coleoloides* sp. (J. Samsonowicz, 1962), *Prosinuites bornholmiensis*, *Aluta* sp., *Bradoria* sp. (K. Lendzion et al., 1982), *Sabellidites cambriensis*, *Tyrasotenia podolica*, *Pilitella composita* (W.R. Kowalski, 1983) and *Platysolenites antiquissimus* (R. Michniak, A.Y. Rozanow, 1969). Trace fossils are not very common, there were recognized: *Planolites montanus*, *P. beverleyensis*, *Diplocraterion parallelum*.

Ciesęki Sandstone Formation was established by S. Orłowski (1975*a*). It consists of fine-grained, thin- to medium-bedded, hard sandstones, with siltstone and occasional shale intercalations. The greatest thickness of this formation occurs in the middle part of this area, where it includes also the lowermost Middle Cambrian; it is estimated at 1200 m; major part of this thickness reaching 1100 m falls on the Lower Cambrian (S. Orłowski, 1975*a*, 1985*a*, 1987; W. Mizerski et al., 1986). The body fossils are very common, especially the trilobites (Fig. 2). The Holmia-Schmidtiellus Assemblage Zone within this formation is characterized by trilobites: *Holmia marginata*, *Kjerulfia orcina*, *Schmidtiellus panowi*, *S. nodosus*, *Strenuella polonica*, *Postfallotaspis spinatus*, *Atops granulatus* (S. Orłowski, 1983, 1985*a*, *c*).

The Protolenus-Strenuaeva Assemblage Zone of this formation is documented by trilobites: *Ellipsocephalus sanctacrucensis*, *Strenuaeva orlovinensis* (for complete list of trilobites see S. Orłowski, 1985*a* and W. Bednarczyk et al., 1965).

The Insularis Zone of the Middle Cambrian within this formation is evidenced by: *Ellipsocephalus puschi*, *E. guerichi*, *Comluella opatowi*, *C. usarzowi* (S. Orłowski, 1985*b*).

Trace fossils are very common and rich in ichnogenera, the most common and interesting are: *Monocraterion tenticulum*, *Planolites montanus*, *P. beverleyensis*, *P. annularis*, *Diplocraterion parallelum*, *Phycodes palmatum*, *Rhizocorallium jenense*, *Syringomorpha nilssoni*, *Arcuatichnus wimani*, *Teichichnus rectus*, *Cruziana rusoformis*, *Dimorphichnus obliquus*, *Monomorphichnus lineatus*.

Kamieniec Shale Formation was established by S. Orłowski (1975*a*). The formation is limited to the eastern part of the area and is represented by clay and clay-siltstone shales with fine-grained sandstone intercalations. The thickness of formation is difficult to estimate but it is at least 200 m. The trilobites are less abundant. The Holmia-Schmidtiellus Assemblage Zone inside this formation is documented by: *Holmia marginata*, *Kjerulfia orcina*, *Micmacca klimontowi* (S. Orłowski, 1985*a*).

The Protolenus-Strenuaeva Assemblage Zone is here very well documened by: *Protolenus expectans*, *P. glabellosus*, *Strenuaeva trifida*, *Serrodiscus primarius* (S. Orłowski, 1985*a*). Trace fossils are rare, there were noticed: *Planolites beverleyensis*, *Phycodes pedum*, *Bergaueria perata*.

MIDDLE CAMBRIAN

This series is divided into four biostratigraphic zones: Insularis, Pinus, Polonicus, Solenopleura, characteristic by their index fossils (S. Orłowski, 1985*b*).

The Usarzów Sandstone Formation was established by S. Orłowski (1975*a*); it is exposed in the eastern part of the area and it comprises sandstones with subordinate clayey and silty shale intercalations. The thickness of the formation is about 400 m. Trilobites are very common with: *Paradoxides oelandicus*, *P. insularis*, *P. pinus*, *Ellipsocephalus hoffi*, *Comluella samsonowiczi* (for complete list of trilobites see S. Orłowski, 1964, 1985*b*). Trace fossils are scarce and only *Planolites*, *Arcuatichnus* and *Cruziana* were found.

The Słowiec Sandstone Formation was established by S. Orłowski (1975*a*); it is exposed as medium-grained, bedded sandstones and poorlysorted, often coarse-grained sandstones, thick bedded, light-grey, light-yellow or reddish in colour. Trilobites are very common with: *Paradoxides polonicus*, *P. socius*, *Ellipsocephalus hoffi*, *Solenopleura trapezoides*, *S. minima*, *Kootenia enigmatica* (S. Orłowski, 1985*b*). Trace fossils are scarce, some *Cruziana* were found.

The Góry Pieprzowe Shale Formation was established by S. Orłowski (1975*a*); it is represented by clayey and silty shales and siltstones, black or dark-grey with thin sandstone intercalations. Its thickness is up to 400 m. The body fossils are not numerous, there are trilobites: *Solenopleurina linnarssoni*, *Solenopleura* cf. *canaliculata*, *S. munsteri* (S. Orłowski, 1964, 1985*b*). Badly preserved agnostids are associated with numerous brachiopod *Lingulella vistulae*. Trace fossils are not common, they are: *Bergaueria perata*, *Teichichnus* sp.

UPPER CAMBRIAN

Four biostratigraphic zones were recognized: Olenus, Protopeltura, Peltura and Parabolina, characteristed by the index genera (S. Orłowski, 1975*a*).

The Wiśniówka Sandstone Formation was established by S. Orłowski (1975*a*); it consists of thick-bedded, very hard sandstones and quartzites from light-grey to blue with intercalations of siltstones and silty and clayey shales. The sandstone beds display numerous well preserved sedimentary structures typical to the shallow-water environment, as well as especially rich trilobite ichnocoenose. The fossils found here include: *„Olenus" rarus*, *Protopeltura olenusorum*, *Orusia* cf. *lenticularis* (S. Orłowski, 1968*a*). Trace fossils are very common with typical: *Cruziana semiplicata*, *Rusophycus polonicus*, *Bergaueria perata*, *Diplocraterion parallelum*, *Planolites beverleyensis*, *Multina magna*, *Dimorphichnus obliquus*, *Monomorphichnus lineatus* (S. Orłowski et al., 1970, 1971). The thickness of the formation varies greatly from about 400 to about 1400 m (W. Mizerski, 1979).

The Klonówka Shale Formation was established by S. Orłowski (1975*a*); it comprises shales and siltstones with sandstone intercalations, and is about 400 m thick. Only the lower part of the formation is exposed, the upper part is known from boreholes. Fossils are fairly numerous but occur in nest-like associations. The most characteristic trilobites are: *Peltura scarabaeoides scarabaeoides*, *P. scarabaeoides* cf. *westergaardi*, *P. protopeltorum*, *Beltella irae*, *Acerocare? klonówkae*, *Beltella rotundata*, *Parabolina acanthura* (S. Orłowski, 1968*b*; E. Tomczykowa, 1968). In the uppermost part of the formation was found *Dictyonema* sp. Trace fossils are rather rare and they consist of *Cruziana semiplicata*, *Rusophycus polonicus*, *Bergaueria perata*, *Planolites beverleyensis*.

The Holy Cross Group was folded in this region in the local tectonic phase – Sandomirian Phase – which have taken place after the deposition of the Lower Tremadocian. This phase corresponds with the Grampian or Finnmark Phases of the Caledonides in the North-West Europe. The Ordovician strata start to accumulate after a short break in the Upper Tremadocian or Lower Arenigian.

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STRATYGRAFIA KAMBRU W GÓRACH ŚWIĘTOKRZYSKICH

Streszczenie

W Polsce można wyróżnić cztery obszary występowania skał kambryjskich: Góry Świętokrzyskie, Sudety (Góry Kaczawskie), Polskę północną i wschodnią z kambrem typu platformowego oraz Górny Śląsk (fig. 1). Jedynie na dwóch pierwszych obszarach skały kambru odsłaniają się na powierzchni, natomiast na pozostałych zostały poznane za pomocą otworów wiertniczych. Najbogatszą dokumentację paleontologiczną ma kambr Gór Świętokrzyskich. Podziały zarówno litostratygraficzne, jak i biostratygraficzne obejmują cały profil i są dokonane zgodnie z *Zasadami polskiej klasyfikacji, terminologii i nomenklatury stratygraficznej* (1975).

Utwory kambru Gór Świętokrzyskich osadziły się w postaci naprzemianległych, grubych formacji piaskowców i łupków ujętych w grupę świętokrzyską; miąższość skał tej grupy wynosi 2500–3500 m (fig. 2). Utwory osadziły się w otwartym zbiorniku morskim, który znajdował się w obrębie środeuropejskiej geosynkliny kaledońskiej. Skały kambru omawianego obszaru zostały sfałdowane po dolnym tremadoku w lokalnej fazie sandomierskiej, którą można uważać za odpowiednik fazy grampiańskiej w kaledonidach Szkocji lub fazy Finnmark w kaledonidach Skandynawii.

Świad organiczny kambru świętokrzyskiego stanowią głównie trylobity i ślady organiczne, a podrzędnie ramienionogi, hyolity, ślimaki, archeocjaty, meduzy i eokrynoidy; dla celów stratygraficznych najważniejsze są trylobity. Trylobity z kambru świętokrzyskiego, podobnie jak trylobity z innych obszarów Polski, należą do atlantyckiej, trylobitowej prowincji zoogeograficznej, a w jej obrębie do podprowincji bałtyckiej lub skandynawskiej. Zdecydowana większość rodzajów, a nawet gatunków jest wspólna z obszarem Norwegii, Szwecji oraz Estonii. Kambryjski zbiornik świętokrzyski miał też otwarte połączenia z innymi zbiornikami, czego dowodem są trylobity wskazujące na pokrewieństwa z obszarami Maroka, Wielkiej Brytanii, Ameryki Północnej, Czech oraz Syberii.

Станислав ОРЛОВСКИ

СТРАТИГРАФИЯ КЕМБРИЯ В СВЕНТОКШИСКИХ ГОРАХ

Резюме

В Польше можно выделить четыре области залегания кембрийских пород: Свентокшиские горы, Судеты (Качавские горы), север Польши и ее южная часть, где залегают кембрийские породы платформенного типа, а также область Северной Слезии (фиг. 1). Только в двух первых областях кембрийские отложения выходят на поверхность, а в остальных они изучались по данным буровых скважин. Самый богатый палеонтологический материал получен по Свентокшиским горам. Литостратиграфически и биостратиграфически весь разрез расчленяется в соответствии с *Польской стратиграфической классификацией, терминологией и номенклатурой* (1975).

Осаждение кембрийских пород в Свентокшистих горах происходило в виде перемежающихся наслоений мощных свит песчаников и сланцев, сведенных в Свентокшискую группу; мощность пород этой группы составляет 2500—3500 м (фиг. 2). Эти породы накапливались в открытом море, занимавшем Центрально-Европейскую каледонскую геосинклиналь. На этой территории кембрийские отложения были смяты в нижнетремадокское время в локальной сандомерской фазе, которую можно считать аналогом грампианской фазы в каледонидах Шотландии или фазы Финнмарк в каледонидах Скандинавии.

Органическая жизнь в свентокшиском кембрии представлена преимущественно трилобитами и остатками организмов, а также подчиненно плеченогими, хиолитами, гастроподами, археоциатами, медузами и эокриноидами. Для стратиграфии важнейшее значение имеют трилобиты. Трилобиты свентокшиского кембрия так же как и других областей Польши, относятся к атлантической трилобитовой зоогеографической провинции, а внутри ее к балтийской или скандинавской подпровинции. Решительное большинство родов и даже видов этой фауны аналогичны тем, которые свойственны кембрию Норвегии, Швеции и Эстонии. Кембрийский Свентокшиский бассейн сообщался также с другими морями, доказательством чего являются трилобиты, родственные трилобитам Марокко, Великобритании, Северной Америки, Чехии и Сибири.