Geological Quarterly, 2001, **45** (4): 417–433

The Ordovician stratigraphy and palaeogeography of the Nida-Holy Cross Mts. area, Poland — a review

Zdzisław MODLIŃSKI and Bronisław SZYMAŃSKI

Modliński Z. and Szymański B. (2001) — The Ordovician stratigraphy and palaeogeography of the Nida-Holy Cross Mts. area, Poland — a review. Geol. Quart., **45** (4): 417–433. Warszawa.

The Ordovician stratigraphy in the Holy Cross Mts. and the Nida region is reviewed. In the Holy Cross Mts. Ordovician rocks have been identified in the Łysogóry and the Kielce segments in tens of outcrops and borehole sections, in the Nida area in three boreholes. The deposits comprise a thin clastic-carbonate succession including palaeontologically dated Tremadoc, Arenig, Llanvirn, Llandeilo, Caradoc and Ashgill sediments. Their lithology, litho- and biostratigraphy and facies distribution are discussed. The most distinct lithofacies boundary and thickness contrast is observed between the Kielce and Łysogóry regions. The former is characterised by carbonates and clastics of shallower shelf with much greater thicknesses.

Zdzisław Modliński and Bronisław Szymański, Polish Geological Institute, Rakowiecka 4, PL-00-975 Warszawa, Poland (received: August 26, 1999; accepted: October 12, 1999).

Key words: Holy Cross Mts., Nida region, Ordovician, biostratigraphy, lithostratigraphy, lithofacies.

INTRODUCTION

This paper is aimed at the compilation of all the data on the Ordovician stratigraphy and palaeogeography dispersed in many papers, published during the last forty years, mainly in Polish. We think such a review to be useful in the nearest future when the geophysical results of the CELEBRATION 2000 experiment will be interpreted from the geological point of view. The Ordovician deposits of the Vistula-Pilica interfluve are known from two areas: the Holy Cross Mts. in the north and in the Nida (Miechów) Trough basement in the south (Fig. 1).

The Ordovician deposits of this region vary considerably as regards their position on the shelf and their geotectonic location. The northern part of the area, i.e. the Łysogóry region, was situated on the central distal portion of the shelf and simultaneously along the northern margin of the Małopolska Block (Pożaryski, 1986; Pożaryski and Karnkowski, 1992). The southern part of the area, including the Kielce and the Nida regions, was located within the Cadomian or Early Caledonian-Grampian Małopolska Block, limited to the north by the Holy Cross Fault and to the south by the Kraków-Zawiercie Tectonic Zone, which resemble terrane boundaries (Dadlez *et al*., 1994).

From the geotectonic point of view, the Łysogóry area made up a fragment of the outermost passive margin of the East European Craton (Baltica), whereas the Kielce-Nida area can be interpreted either as a separate proximal terrane (Dadlez *et al*., 1994) or as a fragment of the Avalonian Plate (Unrug *et al*., 1999). According to Dadlez *et al.* (1994), the cratonic fragment was originally located farther to SE, having separated from the craton, then shifted along a strike-slip fault and docked again in the Late Silurian.

Palaeomagnetic (Lewandowski, 1992) and palaeoclimatic (Dzik and Pisera, 1994) evidence indicate that during the Ordovician and the Silurian the East European Craton (Baltica) shifted from high (60°) to lower (30°) latitudes of the southern hemisphere. At the same time, Avalonia was also moving northward, i.e. toward the equator, undergoing variable rotation to collide finally, in a left-lateral transpressional regime, with Baltica in the Late Silurian.

NIDA REGION

In the Nida region, uniformly developed sandy-carbonate sediments of Ordovician age have hitherto been found in three borehole sections: Jaronowice IG 1 (depth 2274.9–2288.8 m), Książ Wielki IG 1 (depth 1260.5–1290.0 m) and Strożyska 5 (depth 3031.3–3100.5 m).

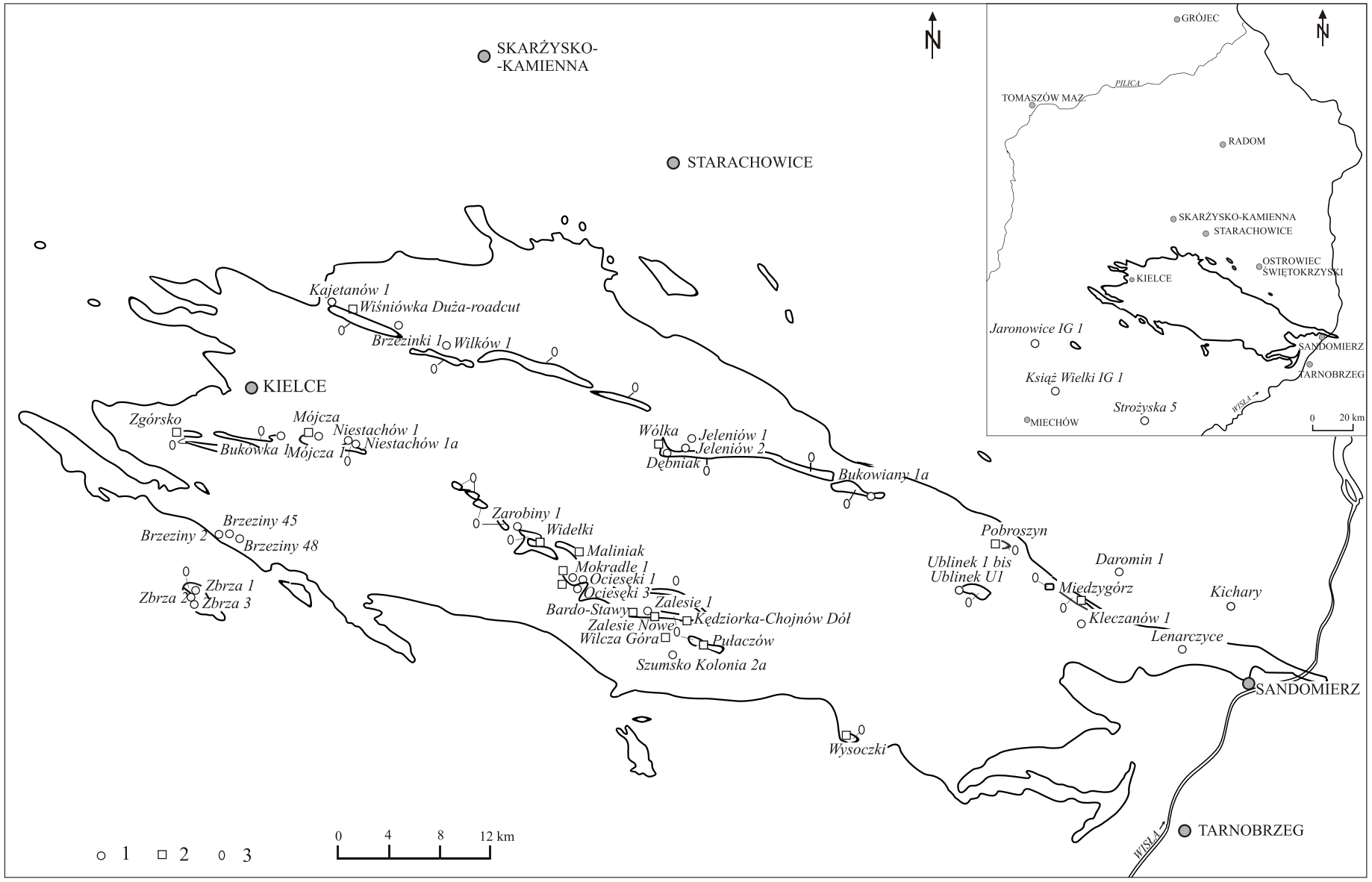


Fig. 1. Location map of boreholes and outcrops

1 — boreholes reaching Ordovician deposits, 2 — exposures of Ordovician deposits, 3 — outcrop areas

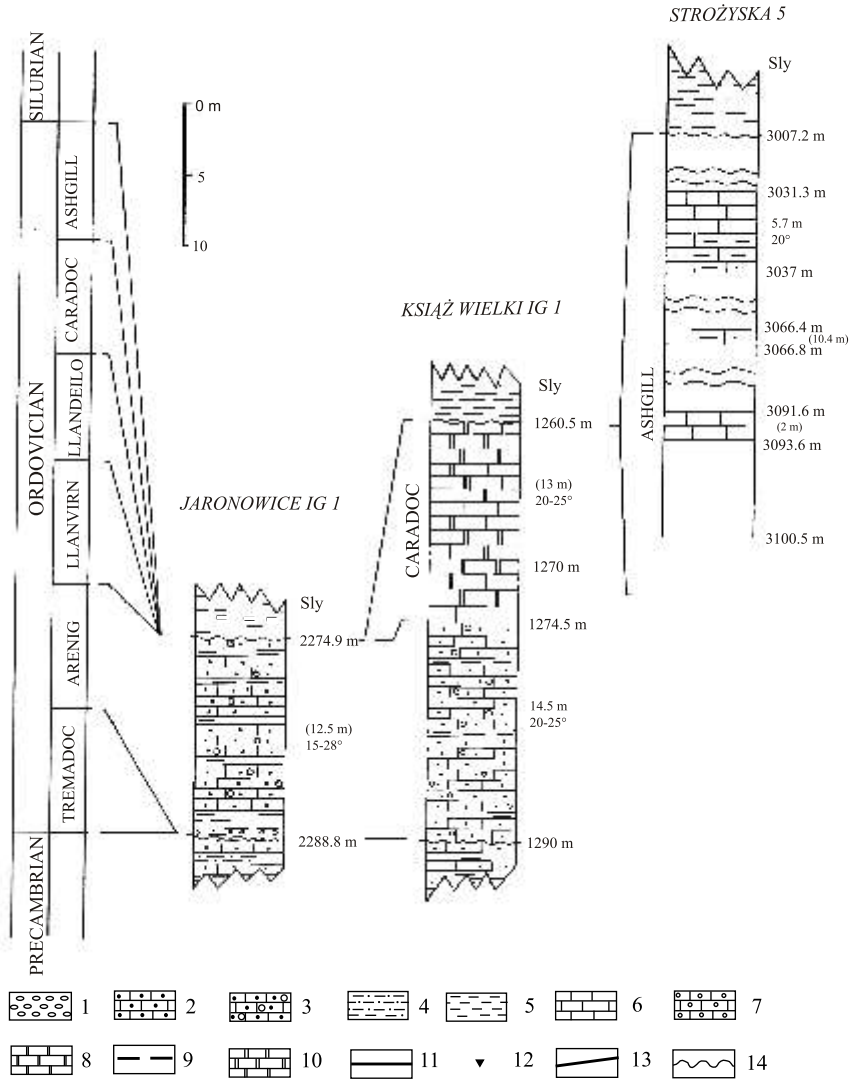


Fig. 2. Correlation chart of Ordovician sections in the Nida region

1 — conglomerates, 2 — sandstones, 3 — sandstones with glauconite, 4 — siltstones, 5 — claystones, 6 — limestones, marly limestones, 7 — limestones with glauconite, 8 — dolomites, dolomitic limestones, 9 — lydites, 10 — marls, 11 — bentonites, 12 — sulfides, 13 — faults, 14 — unconformities; stratigraphic indexes: Q — Quaternary, Sly — Silurian/Llandovery, Sw — Silurian/Wenlock, Cm_1 — Lower Cambrian, Cm_2 — Middle Cambrian, Cm_3 — Upper Cambrian

LITHOLOGY

There is no formal lithostratigraphic subdivision of the Ordovician deposits of the Nida region (Fig. 2).

Tremadoc. No sediments of this age have been encountered in any section. The sandy sediments from the Jaronowice IG 1 borehole (depth 2274.9–2288.8 m), previously regarded as Tremadoc in age (Jaworowski *et al.*, 1967), seem correspond to Arenig.

Arenig. This series consists of fine-grained quartz sandstones with a median grain size of 0.1–0.15 mm, light gray and greenish-gray with glauconite, with irregular streaks and individual dark gray and greenish-gray thin beds of calcareous and siliceous claystones (Jaworowski *et al.*, 1967). Their thickness varies from 12.5 m in the Jaronowice IG 1 borehole (depth 2274.9–2288.8 m) to about 14.5 m in the Książ Wielki IG 1 borehole (depth 1274.5–1290.0 m). In the first section, this succession is unconformably overlain by Silurian (lower Llandovery) claystones.

Llanvirn-Llandeilo. This interval has not been palaeontologically documented. According to Jurkiewicz (1975), the upper portion of the sandstones from borehole Książ Wielki IG 1 seems to be of this age. Alternatively, the Llanvirn and the Llandeilo may be represented by carbonates encompassing the lowermost portion of the overlying organodetritic and dolomitic limestone succession. Nonetheless, extrapolation from adjacent areas indicates that the thickness of Llanvirn and Llandeilo deposits does not exceed several metres.

Caradoc. This series encompasses gray organodetritic limestones composed primarily of echinoderm bioclasts cemented by medium- and finely-crystalline sparite with pink and red coarse- and medium-crystalline dolomitic limestone

interbeds. In the Książ Wielki IG 1 borehole, the Caradoc carbonates are sharply and discordantly overlain by Silurian/lower Ludlow claystones. Their thickness is about 13 m (depth 1260.5–1274.5 m).

Ashgill. This series is represented by carbonates which include, in the lower part, dark gray dolomitic and marly micritic limestones with a variable amount of recrystallised bioclastic material, and in the upper part light gray finely-crystalline limestones. These rocks were penetrated only by the Strożyska 5 borehole (depth 3007.2–3100.5 m), where they are overlain by lower Ludlow claystones, the boundary being in a non-cored interval. The thickness of the Ashgill carbonates is about 100 m (Bednarczyk *et al.*, 1968).

BIOSTRATIGRAPHY

The biostratigraphy of the Ordovician deposits in the Nida region is incomplete, with scarce macro- and microfauna, not allowing precise age determinations.

Tremadoc-Arenig. Fossils were only recorded from the Jaronowice IG 1 borehole in which scarce inarticulate brachiopods ascribed to the species *Lingulella lepis* (Salter) were found (W. Bednarczyk in: Jaworowski *et al.*, 1967). This is a long-ranging species, from the Upper Cambrian to the lower Arenig.

Llanvirn-Llandeilo. No fossils of this age were recorded.

Caradoc. Carbonates in the Książ Wielki IG 1 borehole yielded to W. Bednarczyk (in: Jurkiewicz, 1975) the conodont assemblage *Acodus similaris* Rhodes, *Drepanodus alticeps* Henningsmoen and *Scandidud inlexus* Hamar. This assemblage unequivocally indicates the Caradoc, without allowing further precision.

Ashgill. This series was unequivocally documented palaeontologically in the Strożyska 5 borehole (Bednarczyk *et al.*, 1968). The following brachiopod assemblage was documented: *Orbiculoidea radiata* (Troedson), *Eostropheodonta hirnatensis* (McCoy), *Nicolella* sp., *Lingulella* sp. and *Leptaena* sp. *Eostropheodonta hirnatensis* (McCoy) is included in the "Hirnantia fauna", widespread across Europe in upper Ashgill to Ashgill/Llandovery boundary deposits (Jaeger *et al.*, 1975). The accompanying conodonts *Acodus* cf. *similaris* Rhodes, *Panderodus unicostatus* (Branson et Mehl) and *Tetraprioniodus* cf. *superbus* (Rhodes) indicate only an Ashgill age.

HOLY CROSS MTS. — KIELCE REGION

The uplifted Palaeozoic block of the Holy Cross Mts. may be divided into two regions of contrasting palaeogeographic position and facies character: the Kielce region in the south and the Łysogóry region in the north. These two regions are separated by the Holy Cross Fault (Czarnocki, 1919, 1957*a, b*).

In the Kielce region Ordovician sediments occur in outcrops and borehole sections including, from west to east: Zbrza 1 (depth 9.5–138.0 m), Zbrza 2 (depth 6.0–25.5 m), Zbrza 3 (depth 6.0–33.5 m), Brzeziny 2 (depth 19.5–83.0 m), Brzeziny 45 (depth 41.5–236.8 m), Brzeziny 48 (depth 40.0–258.0 m), Zgórsko (about 50 m), Bukówka 1 (depth 26.6–98.5 m), Mójcza (about 9 m), Mójcza 1 (depth 63.8–77.0 m), Niestachów 1a (depth 36.2–41.0 m), Niestachów 1 (depth 46.2–49.3 m), Widełki (?), Zarobiny 1 (132.0–139.0 m), Maliniak (about 9 m), Powalisko (about 21 m), Koziel (about 70 m), Mokradle 1 (depth 179.4–204.9 m), Ociesęki 1 (depth ?–25.1 m), Ociesęki 3 (depth 13–30 m), Bardo-Stawy (about 28 m), Zalesie Nowe (about 30 m), Zalesie 1 (depth 219–?), Wilcza Góra near Szumsko (about 6 m), Kędziorka–Chojnów Dół (about 33 m), Szumsko Kolonia 2a (depth 22.9–67.8 m), Pułaczów (about 19 m), Wysoczki (about 16 m), Ublinek U 1 (depth 18.5–21.0 m), Ublinek 1 bis (depth 11.0–18.1 m), Międzygórz (about 55 m), Kleczanów 1 (depth 269.0–277.2 m) and Lenarczyce (depth 44.9–68.2 m) (Fig. 1).

LITHOSTRATIGRAPHY

The Ordovician deposits of the Kielce region (Fig. 3) are characterised by lithofacies diversity. In the northern and central part carbonate and sandy lithofacies are prevalent, whereas in the southern part, clayey sediments prevail. Thus, a single lithostratigraphy cannot be established for the entire region. Classifications proposed to date do not represent true lithostratigraphies according to the Principles of the Polish Stratigraphic Classification, Terminology and Nomenclature (1975), corresponding only partly to the recommended formal criteria (Tomczyk, 1962, 1964; Tomczykowa and Tomczyk, 1968; Bednarczyk, 1981; Dzik and Pisera, 1994); they are more akin to regional chronostratigraphic divisions (for example, Czarnocki, 1950; Samsonowicz, 1952; Bednarczyk, 1964; Tomczyk and Turnau-Morawska, 1964; Deczkowski and Tomczyk, 1969).

A comparison of selected lithostratigraphic schemes, the relationships of particular units, and their stratigraphic extent and thickness are given in Table 1.

According to Tomczyk (1962), the Ordovician rocks of the region comprise four units (or "beds"). The type area for the lower three units is the Kielce-Łagów Syncline and that for the fourth (the uppermost) is the Bardo Syncline. In this scheme, the section starts with the Tremadoc Międzygórz Beds developed as glauconitic sandstones with basal chalcedonitic and quartzitic shale interbeds. These are succeeded by the Bukówka Sandstones (Arenig) represented by sandstones with limestone and claystone interbeds at their base. The Mójcza Limestones, overlying these, are typically developed in the Kielce-Łagów Syncline, while in the Bardo Syncline they comprise clayey-marly-dolomitic sediments. The Mójcza Limestone unit are of Llandeilo-lower Caradoc age, terminating the Ordovician section in the Kielce-Łagów Syncline. In the Bardo Syncline the Mójcza Limestones are unconformably overlain by the claystone and marl deposits of the upper Ashgill Zalesie Beds.

A subdivision of the Lower Ordovician was given by Bednarczyk (1964) who distinguished: in the Tremadoc — the Międzygórz, the Zbilutka and the Kozielsk Beds, and in the Arenig — the Bukówka and the Dyminy Beds. In 1981, Bednarczyk modified and broadened this scheme giving it more lithostratigraphic character, defining three formations and five members, though without satisfying all formal requirements.

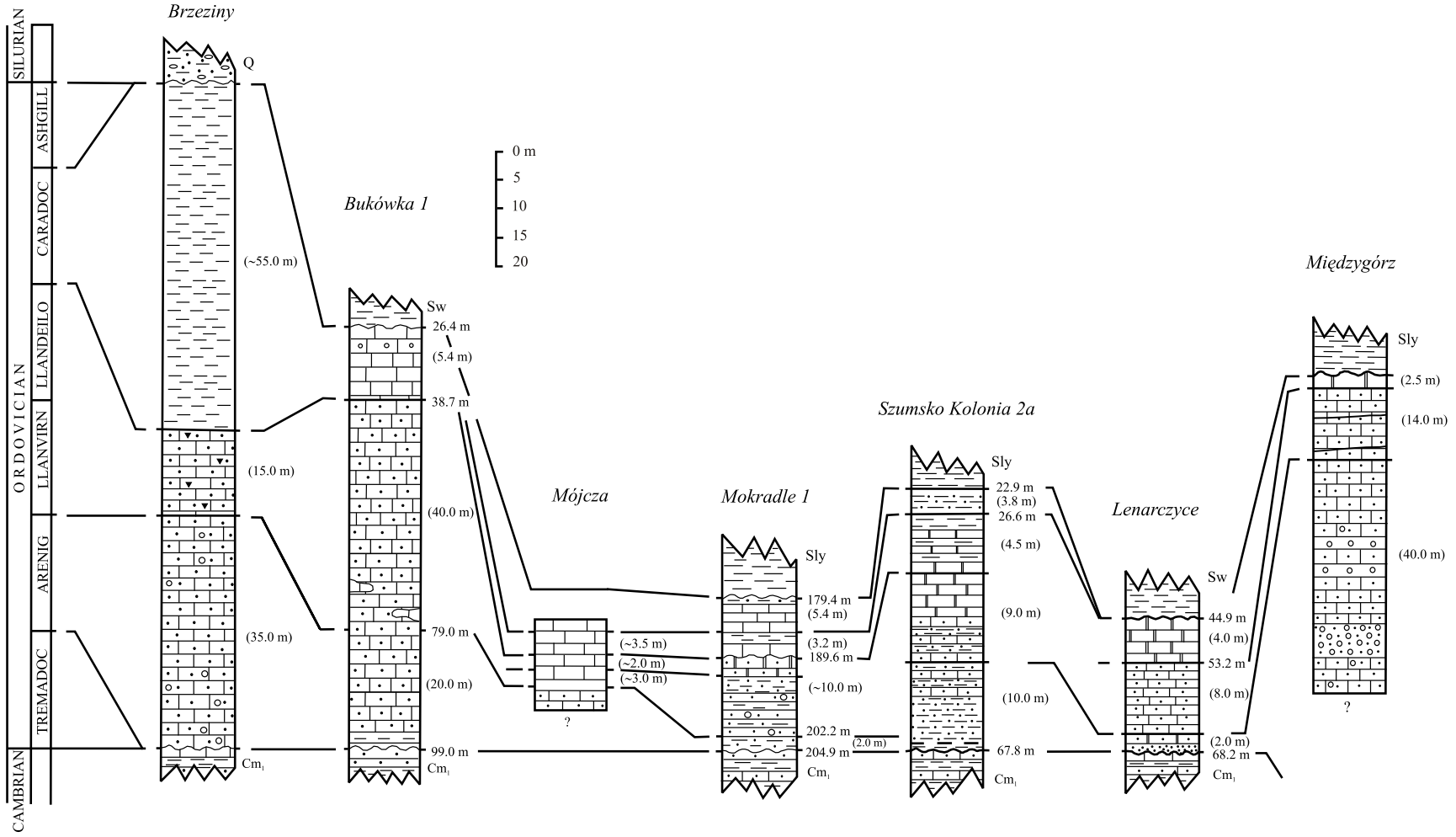


Fig. 3. Correlation chart of Ordovician sections in the Kielce region

For explanations see Figure 2

In the lower part of the section, Bednarczyk distinguished the Międzygórz Sandstone Formation that starts with the Chełm Conglomerate Member or locally with the Zbilutka Siltstone and Chalcedonite Member, passing higher into the Kleczanów Sandstone Member and the Dyminy Sandstone Member. The extent of this formation spans the Tremadoc-Arenig-lower Llanvirn, its upper boundary being diachronous. Higher in this section is the Mójcza Limestone Formation locally including the Mokradło Dolomite Member. The Mójcza Limestone unit spans the Llanvirn to the lower Caradoc; its lower and upper boundaries are diachronous. The uppermost portion of the section (upper Caradoc-Ashgill) is represented by the Zalesie Claystone and Bentonite Formation.

Formal lithostratigraphic division of the Ordovician sediments in the northern and central parts of the region has recently been proposed by Dzik and Pisera (1994). They briefly defined five formations (Table 1), some of which correspond to the units previously distinguished by Bednarczyk (1981).

According to Dzik and Pisera (1994), the lowest position in the section is occupied by the Wysoczki Chalcedonite Formation composed primarily of siltstones with chalcedonite interbeds. Conodonts described by Szaniawski (1980), dated this formation as late Tremadoc, though Znosko and Chlebowski (1976) using different criteria assigned these deposits to the lower (but not lowermost) Arenig.

This formation is followed by the Międzygórz Formation composed of thick-bedded conglomerates and dark glauconitic sandstones. Dzik and Pisera (1994) placed this in the lower Arenig; Bednarczyk (1964, 1971) considered it as of Tremadoc age; whereas Znosko and Chlebowski (1976) placed it in the lower Arenig, beneath deposits with chalcedonites.

The succeeding Bukówka Sandstone Formation is developed as coarse- and medium-bedded light gray sandstones assigned by Dzik (1994) to the upper Arenig (upper Wolchow). According to Tomczyk and Turnau-Morawska (1967), as well as Bednarczyk (1971), the Bukówka Sandstones formed in a longer time interval, from the early Arenig to the early Llanvirn. Their upper boundary is diachronous, from the upper Arenig to the lower Llanvirn.

Above this, the Mójcza Limestone Formation corresponds exactly to the unit previously defined by Bednarczyk (1981). It includes thick-bedded limestones with phosphatised grains and ferric ooids (Trela, 1998). This unit spans the upper Arenig to the Caradoc, its upper boundary being diachronous within the Caradoc.

The highest unit (Zalesie Formation), according to Dzik and Pisera's scheme (1994), is composed of thin-bedded marls, clayey shales and clayey limestones ascribed to the Caradoc and Ashgill. Its upper boundary, like its lower, is diachronous.

In the southern part of the Kielce region near Zbrza and Brzeziny, Tomczyk and Turnau-Morawska (1964), and Deczkowski and Tomczyk (1969) employed a regional division of the Ordovician into the Międzygórz Beds (Tremadoc), the lower Brzeziny Beds (Arenig), the upper Brzeziny Beds (Llanvirn), the lower Morawica Beds (Llandeilo) and the upper Morawica Beds (Caradoc). These units do not comply with current formal criteria for lithostratigraphic divisions.

BIOSTRATIGRAPHY

Biostratigraphic studies of Ordovician rocks have been carried out since the turn of the 19th century. Yet, the macro- and micropalaeontological record and biostratigraphic zonation remain incomplete.

Tremadoc. Deposits of this age were documented in boreholes Ublinek U 1 and Ublinek 1 bis (Fig. 1). The former includes a small strongly folded fragment (depth 18.5–21.0 m) wedged into Cambrian rocks. In these deposits Jankauskas (in: Michniak and Olkowicz-Paprocka, 1976) found a rich assemblage of about 25 species of acritarchs including *Priscogalea cortinula* Deunff and *P. furcata* Deunff, typical of the Tremadoc. In borehole Ublinek 1 bis, claystones with an acritarch assemblage indicating a transitional interval between the Cambrian and the lower Tremadoc was found (Szczepanik, 1996).

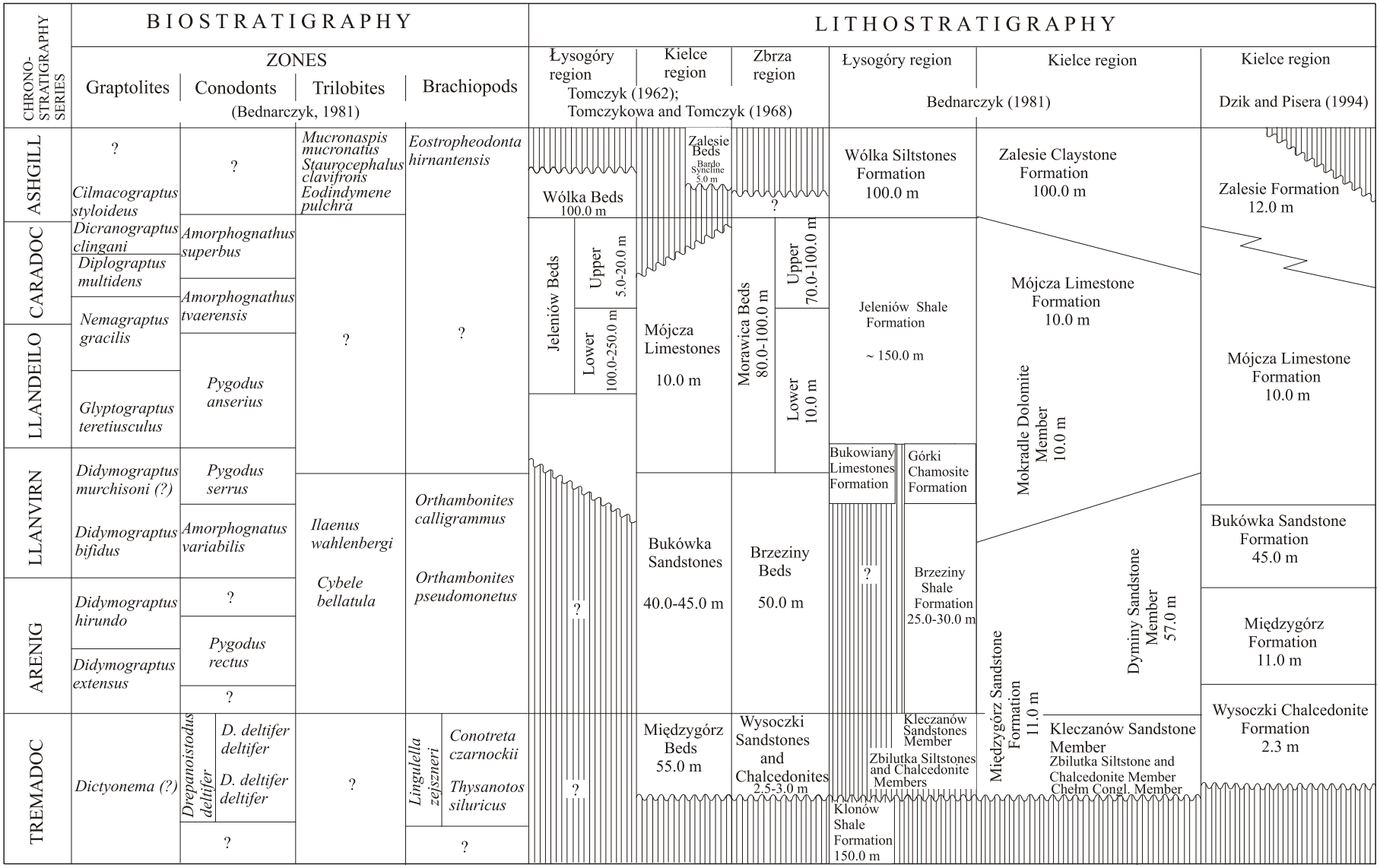
The occurrence of Tremadoc deposits in the remaining sections of the region is doubtful. There are claims of upper Tremadoc deposits in some sections (Bednarczyk, 1971; Szaniawski, 1980; Dzik and Pisera, 1994), though others consider the same rocks to be lower Arenig in age (Znosko and Chlebowski, 1976; Kowalczewski in: Modliński *et al.*, 1990).

Deposits with chalcedonites of uncertain age contain graptolites, inarticulate brachiopods and conodonts. A distinctive conodont assemblage of the *Drepanoistodus deltifer* Zone (Szaniawski, 1980) corresponds to the Ceratopyge stage (= late Tremadoc) of the Baltic area. In turn, an inarticulate brachiopod assemblage, including *Thysanotos siluricus* (Eichwald), *Acrothele ceratopygarum* Brogger, *Lingulella insons* Barrande, and species of the genera *Conotreta*, do not unequivocally indicate a Tremadoc age because these forms are also known from the early Arenig. The dendroid graptolite assemblage, dissolved out of chalcedonites by Kozłowski (1949), comprises only new species with no index fossils that could enable dating of these sediments. Znosko and Chlebowski (1976) noted that the dendroids occur only as detritus within chalcedonites, reworked from black Dictyonema Shales. These graptolites are thus evidence for the earlier presence of lower Tremadoc deposits in this region.

Arenig. Deposits of this age are best documented near Brzeziny (Tomczyk, 1962; Tomczyk and Turnau-Morawska, 1964). The base of the section includes an undetermined assemblage of inarticulate brachiopods. The overlying deposits contain graptolite assemblages characteristic of the Arenig, with over 30 taxa representing three graptolite zones, of *Loganograptus logani*, the *Didymograptus deflexus* and the *Didymograptus hirundo*. Only the lowermost Arenig (the *Tetragraptus approximatus* Zone of Great Britain (Williams *et al.*, 1972) or the *Tetragraptus phyllograptoides* Zone from Scandinavia and NE Poland) seems to be absent.

The lower Arenig elsewhere is documented primarily by inarticulate brachiopods. The species *Lingulella zejszneri*

Bio- and lithostratigraphy of the Ordovician in the Holy Cross Mts.



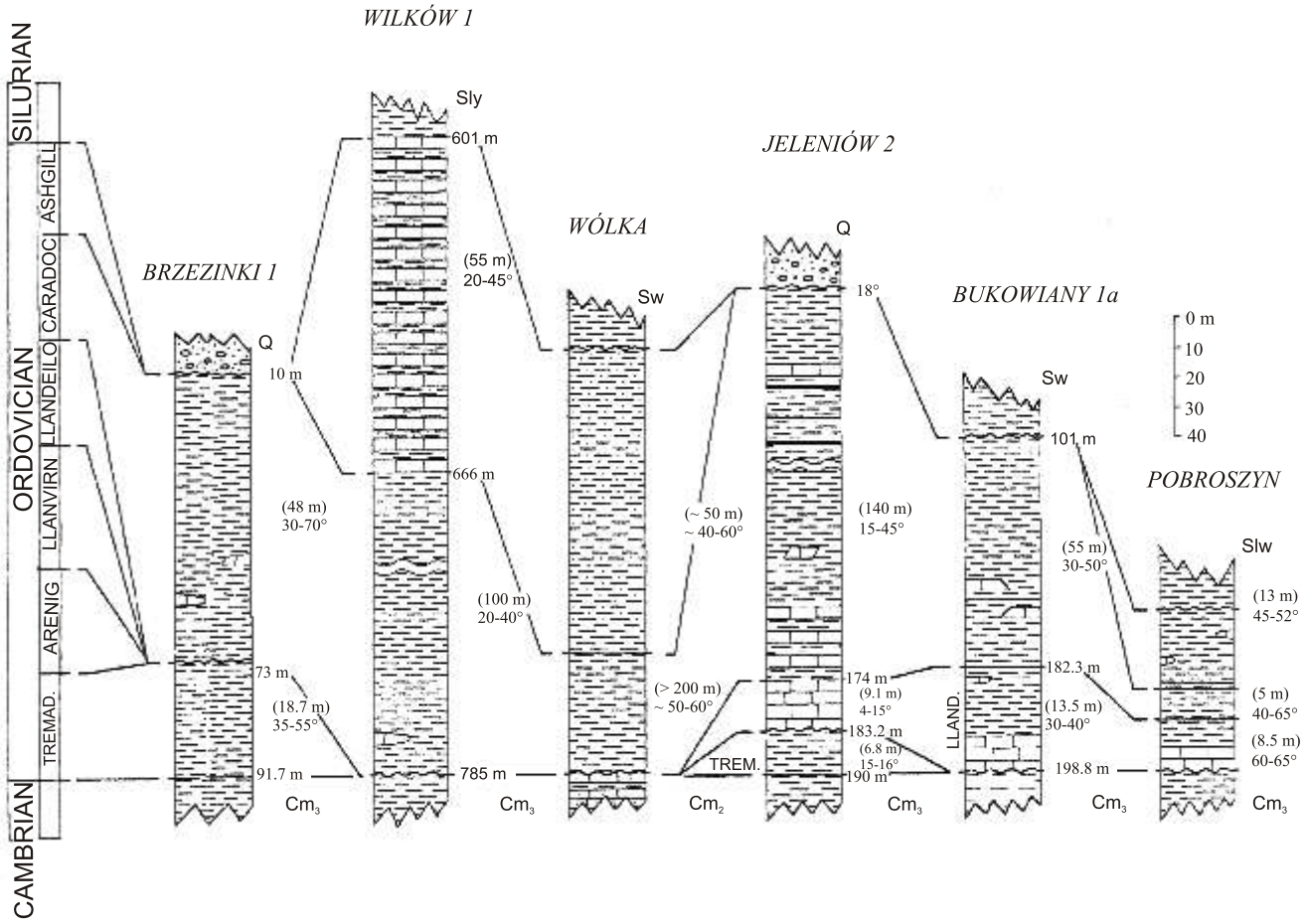


Fig. 4. Correlation chart of Ordovician sections in the Łysogóry region

For explanations see Figure 2

Bednarczyk or *Conotreta czarnockii* Bednarczyk, are index taxa for local biostratigraphic correlation, but do not allow wider correlation. Upper Arenig deposits include inarticulate brachiopods such as *Antigonambonites planus* (Pander) and *Orthambonites semicircularis* Pander, scarce trilobites *Cyrtometopus clavifrons* (Dalman) and *Cybele bellatula* (Dalman), and conodonts of the local *Acontiodus rectus sulcatus* Zone which enables correlation with the late Arenig of the Baltic-Scandinavian area (Bednarczyk 1964, 1971).

The uppermost Arenig to Llanvirn transition has been biostratigraphically documented in the Mójcza section (Dzik *et al*., 1994), where the lower portion of the *Amorphognathus variabilis* conodont Zone was recorded. Numerous ostracods including *Mojczella polonica* Olempska, and trilobites, gastropods, bryozoans and brachiopods were also found.

Llanvirn. The lower Llanvirn of the *Didymograptus bifidus* Zone was documented in the Brzeziny section (Tomczyk and Turnau-Morawska, 1964), with *Didymograptus robustus* Ekstrom, *D. artus* Elles et Wood, *D. indentus* Hall and a few specimens of *Phyllograptus* and *Azygograptus* being identified. Higher in the section, the unfossiliferous “chamosite” bed is conventionally referred to the upper Llanvirn (*Didymograptus murchisoni* Zone) (Kowalczewski and Wróblewski, 1974).

The Llanvirn Mójcza carbonate series has recently been zoned using conodonts (Dzik *et al*., 1994). The *Amorphognathus variabilis* Zone, corresponding to the lower Baltic Kunda stage, and the overlying *Pygodus serrus* Zone (= the Baltic Lasnamagi stage and the lower Uhaku stage), were identified. A stratigraphic gap, encompassing the upper Kunda stage, the Aseri stage, and probably the lower Lasnamagi stage, occurs here. The Mójcza ostracod assemblage includes short-ranging species such as *Pinnatulites procera* (Kmmeraw) and *Vogdesella aequae* Olempska, which can be used for distinguishing local biozones.

The scarce macrofauna includes trilobites such as *Illaenus wahlenbergi* (Eichwald) and *I. polonicus* Gürich, (Bednarczyk, 1971; Dzik and Pisera, 1994). Both species confirm the lower Llanvirn; the former is known from coeval deposits in the Baltic-Scandinavian region, while *I. polonicus* shows a close affinity with *I. ex gr. sarsi* Jaanusson also widespread in those deposits.

The Llanvirn sandy deposits (for example, Bukówka, Niestachów and Międzygórz) are documented primarily by

brachiopods of Baltic affinity (Bednarczyk, 1964, 1971). An assemblage of *Orthambonites calligrammus* (Dalman) and *Lycophoria nucella* (Dalman) and *Productorthis obtusa* (Pander) indicates the lower Llanvirn, corresponding to the Baltic Kunda stage.

Llandeilo. The most commonly used correlation schemes (for example, Williams *et al*., 1972; Jaanusson, 1982), suggest that the Llandeilo encompasses the *Glyptograptus teretiusculus* and the lower *Nemagraptus gracilis* graptolite Zones and the upper *Pygodus serrus* and the lower *Pygodus anserinus* conodont Zone (Table 1).

In the Zbrza and Brzeziny area, Llandeilo sediments contain graptolites (Tomczyk and Turnau-Morawska, 1964; Deczkowski and Tomczyk, 1969). Their lower boundary is determined by the appearance of an assemblage containing *Glyptograptus teretiusculus* (Hisinger), *Pseudoclimacograptus scharenbergi* (Lapworth), *Dicellograptus* sp. and *Dicranograptus* sp. Higher in the section, the short-ranged index species *Nemagraptus gracilis* Hall helps locate the Llandeilo/Caradoc boundary. The Llandeilo deposits also contain a rich and diverse assemblage of trilobites (including *Lonchodomas* sp., *Selenopeltis* sp., *Cyclopyge* sp. and *Flexicalymene* sp., preliminarily determined by E. Tomczykowa), brachiopods, cephalopods, ostracods and bryozoans.

Limestones of the Mójcza section, assigned to the Llandeilo by Dzik *et al.* (1994), encompass only the higher portion of the *Pygodus anserinus* conodont Zone and cannot be correlated with Llandeilo sediments in NE Poland (Modliński, 1982) or Scandinavia (Jaanusson, 1982), which contain the upper *Pygodus serrus* and the lower *Pygodus anserinus* Zones. In the Mójcza section, the last-mentioned interval corresponds approximately to the deposits in which ostracods of the species *Mojczella jaanussoni* Olempska and *Orechina krutai* Olempska co-occur.

In the remaining sections of the Kielce region, Llandeilo sediments are poorly documented (Zalesie Nowe, Kleczanów 1) and their diagnosis is based on scarce conodonts (Bednarczyk, 1971).

Caradoc. The most complete graptolitic Caradoc sections were found in the Zbrza and Brzeziny area (Tomczyk, 1962; Tomczyk and Turnau-Morawska, 1964; Deczkowski and Tomczyk, 1969). The succession starts with the *Nemagraptus gracilis* Zone which includes the index taxon. This is overlain by the relatively thick *Diplograptus multidens* Zone, correlated with the Scottish *Climacograptus peltifer* and *C. wilsoni* Zones. Numerous graptolites including the genera *Climacograptus*, *Amplexograptus*, *Diplograptus*, *Orthograptus* are yet to be examined. Higher in the section, the *Dicranograptus clingani* Zone is present. The overlying upper Caradoc sediments correspond to the *Climacograptus styloideus* Zone (= the British *Pleurograptus linearis* Zone). They contain few fossils; only *Pleurograptus* sp. and *Climacograptus* sp. were recorded here.

Caradoc limestones are zoned by conodonts, and the Mójcza section includes the *Amorphognathus taverensis* and *A. superbus* Zones (Dzik *et al*., 1994). Numerous ostracods and bryozoans, and scarce brachiopods, trilobites, molluscs and echinoderms were also identified.

In the remaining sections of the Kielce region, the Caradoc has not been subdivided, though recognised on the basis of conodonts or brachiopods (Bednarczyk, 1971).

Ashgill. In the southern part of the region deposits of this age were reported from the Zbrza 1 borehole (Deczkowski and Tomczyk, 1969), though neither macro- nor microfossils have been documented.

In the Mójcza area the uppermost strata can be ascribed to the Ashgill, on the basis of conodonts of the *Amorphognathus ordovicicus* Zone (Dzik, 1994).

Fossiliferous Ashgill deposits occur in the Zalesie, Bardo-Stawy and Szumsko 2a sections. The Zalesie section was originally described by Czarnocki (1928), then examined in detail by Kielan (1959) who established the trilobite succession. In the "Dalmanitina beds", species including *Mucronaspis mucronatus* (Brongniart), *M. olini* (Temple), *Brongniartella platynota* (Dalman) and *Leonaspis olini* Troedsson, were identified. This assemblage unequivocally dates these rocks as late Ashgill and enables precise correlation with the Ashgill elsewhere in Europe. Trilobites of this assemblage were also found in the Bardo-Stawy section and in the Szumsko 2a borehole (depth 26.6–28.1 m).

In the upper Ashgill beds outcropping in Zalesie and Bardo-Stawy, numerous brachiopods, including *Eostropheodonta hirnantensis* (McCoy), *Hirnantina sagittifera* (McCoy), *H. kielanae* Temple, *Dalmanella testudinaria* (Dalman), occur (Temple, 1965), and these make up the "Hirnantia fauna" characteristic of the latest Ashgill of many areas of Europe.

HOLY CROSS MTS. — ŁYSOGÓRY REGION

In the Łysogóry region, Ordovician sediments were identified in several boreholes and outcrops (Fig. 4). They are as follows: Kajetanów (depth 93.15–185.0 m), Kajetanów 1 (depth 255.2–275.0 m), Wiśniówka 1 (depth 8.0–160.0? m), Wiśniówka Duża — roadcut in the quarry (about 150? m), Brzezinki (about 77 m), Brzezinki 1 (depth about 10.0–91.7 m), Wilków 1 (depth 601.0–785.0 m), Wólka (about 40 m), Dębniak (depth ?–69.5 m), Jeleniów 1 (depth 111.0–261.65 m), Jeleniów 2 (depth 18.0–190.0 m), Bukowiany 1a (depth 106.0–198.8 m), Pobroszyn (about 27 m), Daromin (196.0–340.0 m), Kichary (undetermined).

LITHOSTRATIGRAPHY

The Ordovician sediments of the Łysogóry region are litologically diverse compared to the coeval deposits of the Kielce region. Proposed subdivisions were given by Tomczyk (1962), Tomczykowa (1968), Orłowski (1975) and Bednarczyk (1981). Units as the Jeleniów Beds, the Wólka Beds and Łysogóry Beds proposed by H. Tomczyk and E. Tomczykowa, are of mixed litho- and biostratigraphic character and cannot presently be recognised as formal units. The Klonówka Shale Formation of S. Orłowski, and the Bukowiany Limestone Formation, Jeleniów Claystone Formation and Wólka Siltstone Formation, proposed by W. Bednarczyk, are somewhat more correctly defined on modern criteria.

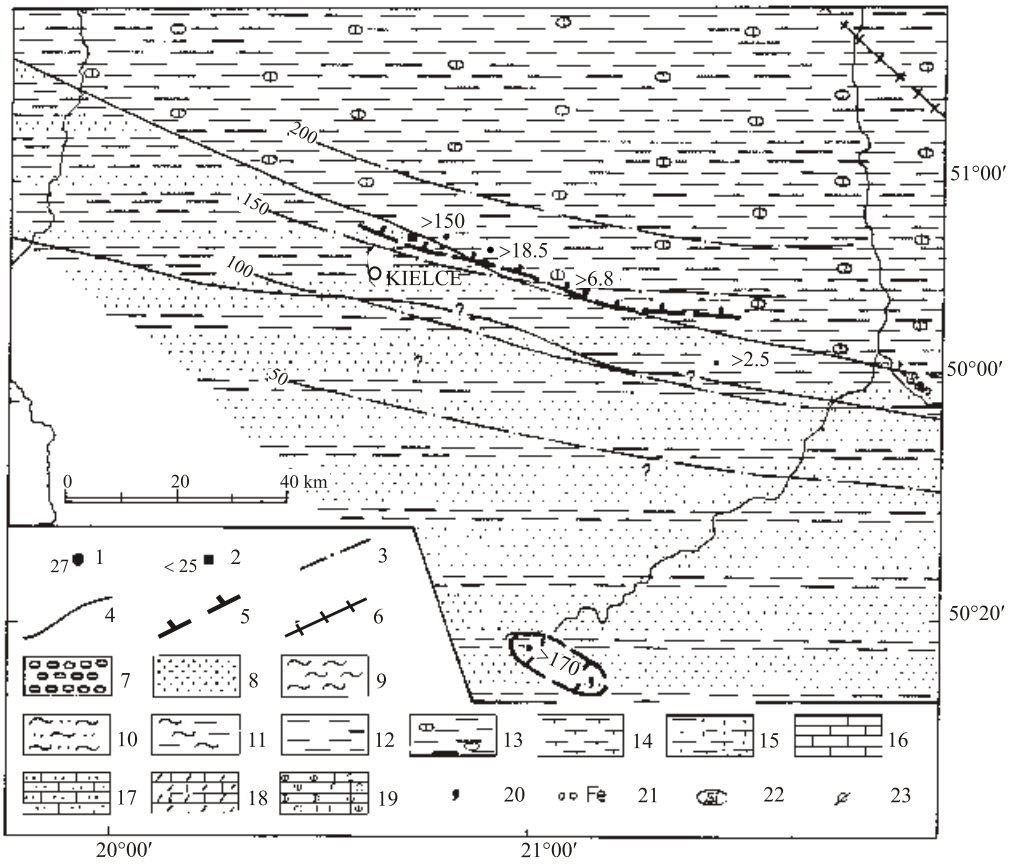


Fig. 5. Lithofacies-palaeothickness map of the Tremadoc in the Nida and Holy Cross Mts. areas

1 — boreholes reaching deposits of a patterned unit and confirmed thickness in metres, 2 — outcrops of deposits of a defined unit and confirmed thickness in metres, 3 — palaeoisopachs of deposits in a defined unit, 4 — lithofacies boundaries, 5 — present extent of deposits, 6 — hypothetical extent of fractures of the Teisseyre-Tornquist (T-T) Zone, 7 — conglomerates, 8 — sandstones, 9 — siltstones, 10 — sandy siltstones, 11 — siltstones and claystones, 12 — claystones, 13 — claystones with limestone lenses, 14 — marls, 15 — sandy marls, 16 — limestones, 17 — sandy limestones and dolomites, 18 — organodetritic limestones, 19 — oolitic limestones, 20 — glauconite, 21 — ferric ooids, 22 — siliceous concretions

Middle and Upper Cambrian and lower Tremadoc deposits make up the Klonów Shale Formation (Orłowski, 1975; Orłowski and Mizerski, 1995). These clayey and clayey-silty shales and siltstones with sandstone interbeds have a thickness of about 400 m. The upper part of this formation includes the uppermost Cambrian and lower Tremadoc, corresponding to the informal unit — the Łysogóry Beds, previously distinguished by Tomczykowa (1968). The Ordovician (lower Tremadoc) encompasses only the upper portion of this formation reaching about 150 m in thickness within a roadcut in the Wiśniówka Duża quarry (Kowalczewski, in: Modliński *et al*., 1990).

The uppermost portion of the succession ascribed to the Klonówka Shale Formation is somewhat different lithologically; only clayey shales with scattered limestone or calcareous claystone lenses and concretions occur here (Jeleniów 2 and Brzezinki 1 boreholes) (Tomczykowa, 1968). These lithological differences suggest that this portion of the Klonówka Shale Formation can be classed as a separate unit of lower rank, the Brzezinki Member.

Different lithologic members of the Klonówka Shale Formation assigned to the Upper Cambrian (Bukowiany 1a borehole) or lower Tremadoc (Jeleniów 2 borehole) are overlain by the lower Jeleniów Beds ascribed to the Llandeilo (Tomczyk, 1962) or upper Llanvirn (Kowalczewski, 1994). These rocks are lithologically diverse. In the lower portion, organodetritic and sideritic limestones with numerous ferric ooids, pass upwards into claystones and calcareous claystones with many organodetritic and sideritic limestone interbeds with scarce ooids. This succession was identified in the Jeleniów 2 (depth 180.5–183.2 m) and Bukowiany 1a (depth 188.0–198.8 m) boreholes (Tomczyk and Turnau-Morawska, 1967; Kowalczewski, in: Kowalczewski *et al*., 1976). Its equivalents can be found in the eastern part of the Łysogóry region, near Pobroszyn (Tomczykowa, 1968). Sediments of the lowermost Jeleniów Beds were regarded by Bednarczyk (1981) as the Bukowiany Limestone Formation and assigned to the upper Llanvirn.

The upper portion of the lower Jeleniów Beds and the overlying upper Jeleniów Beds were ascribed to the Caradoc (Tomczyk, 1962; Tomczyk and Turnau-Morawska, 1967; Tomczykowa, 1968). These clayey deposits were termed by Bednarczyk (1981) the Jeleniów Claystone Formation. They

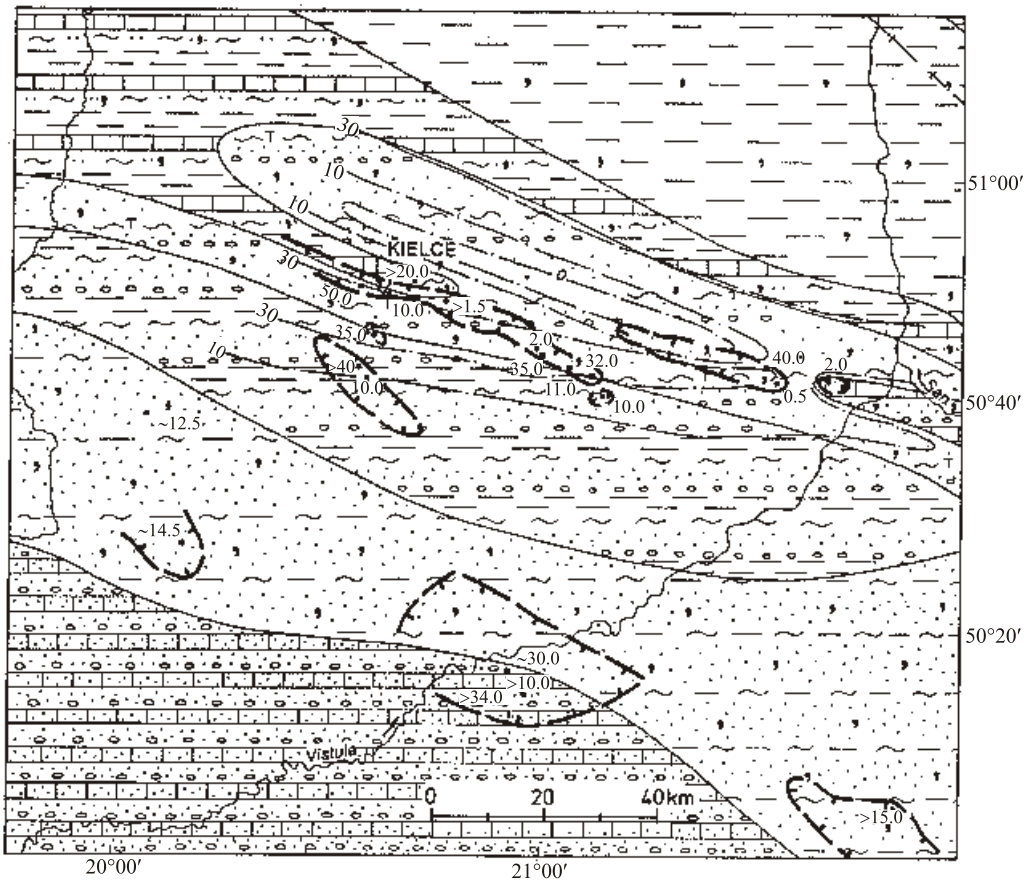


Fig. 6. Lithofacies-palaeothickness map of the Arenig in the Nida and Holy Cross Mts. areas

For explanations see Figure 5

are represented by gray, dark gray and greenish-gray claystones and calcareous claystones with scarce interbeds of gray limestone with lydite concretions and bentonites. The confirmed thickness of this formation exceeds 150 m in a stratotype section of the Jeleniów 2 borehole. The Jeleniów claystone unit concordantly adjoins the base and at the top of the Bukowiany Limestone Formation and the Wólka Siltstone Formation, respectively.

The Ordovician section of the Łysogóry region is topped by the Wólka Beds (Tomczyk, 1962; Tomczykowa, 1968), or the Wólka Siltstone Formation after Bednarczyk (1981), identified in outcrops at Brzezinki and Wólka, and in the Wilków 1, Kajetanów 1 and Jeleniów 1 boreholes. This is a succession up to about 100 m thick composed of gray and greenish-gray siltstones, sandy siltstones and calcareous claystones with interbeds of marly and sandy limestones and locally dolomites and sandstones.

BIOSTRATIGRAPHY

The first data on Ordovician deposits in the region are in Czarnocki (1928, 1929) and Samsonowicz (1934). Biostratigraphic subdivisions on the basis of graptolites and trilobites are given in Kielan (1957, 1959), Tomczyk (1957, 1962), Tomczyk and Turnau-Morawska (1967), Tomczykowa (1968), and Bednarczyk (1971).

Tremadoc. Tremadoc sediments were recorded in the Brzezinki 1 and Jeleniów 2 boreholes (Tomczyk and Turnau-Morawska, 1967; Tomczykowa, 1968) and in a roadcut in the Wiśniówka Duża quarry (Kowalczewski *et al*., 1986).

In the Brzezinki 1 and Jeleniów 2 boreholes, the uppermost Cambrian deposits assigned to the *Parabolina acanthura* Zone are conformably overlain by clayey deposits with poorly preserved fragments of *Dictyonema* (= *Rhabdinopora* after Erdtmann, 1988) and inarticulate brachiopods of the genera *Lingulella*, *Obolus* and *Acrotreta*. The presence of the graptolite *Rhabdinopora* sp. indicates the early Tremadoc age.

In the roadcut in the Wiśniówka Duża quarry sedimentary continuity between the Upper Cambrian and the Tremadoc deposits may also exist. The early Tremadoc age of the siltstones and claystones is indicated by an acritarch assemblage including *Timofeevia phosphoritica* Vang., *T. lancarae* (Cram et Diez) Vang., *Multiplicisphaeridium martae* Cram et Diez, *Vulcanisphaera frequens* Górka and *V. nebulosa* Den.

Arenig-Llanvirn. Most researchers have suggested that, no Arenig and Llanvirn sediments occur in this region (Tomczyk and Turnau-Morawska, 1967; Tomczykowa, 1968; Bednarczyk, 1971). Z. Kowalczewski, however, (in: Kowalczewski *et al.*, 1976) considered that detritic and oolitic lime-

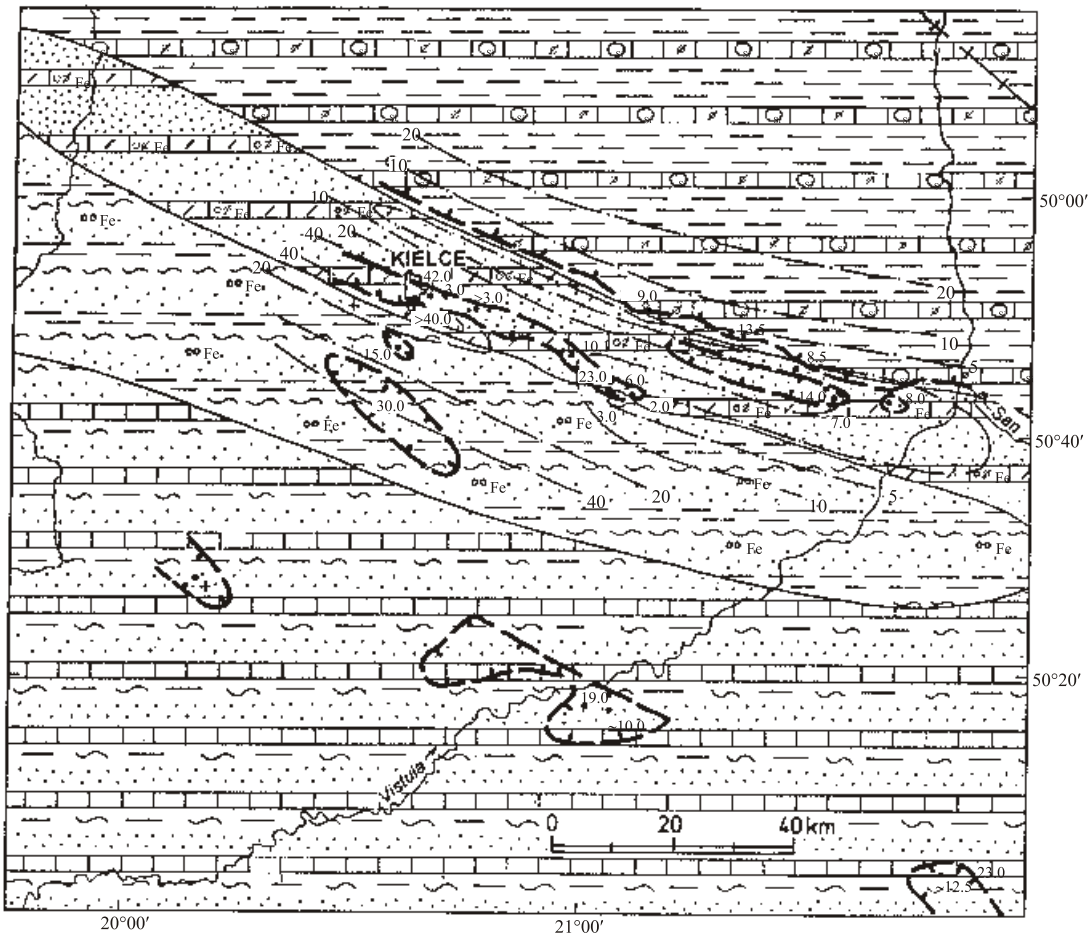


Fig. 7. Lithofacies-palaeothickness map of the Llanvirn-Llandeilo in the Nida and Holy Cross Mts. areas

For explanations see Figure 5

stones near Bukowiany and Jeleniów assigned, on the basis of scarce macro- and micropalaeontological data, to the lower Llandeilo, may represent the upper Llanvirn and lower Llandeilo. This is particularly the case of deposits that occur in the Jeleniów 2 (depth 180.4–183.2 m) and Bukowiany 1a (depth 188.0–198.8 m) boreholes and in an outcrop at Pobroszyn. Z. Kowalczewski's interpretation is supported by palaeontological studies by Bednarczyk (1981), who found numerous inarticulate brachiopods (*Scaphelasma septatum* Cooper, *Ephipelasma* sp.) and conodonts that indicated the *Pygodus serrus* Zone ascribed to the late Llanvirn. In the Bukowiany 1a borehole the graptolites *Didymograptus* (Tomczyk and Turnau-Morawska, 1967 — p. 11), generally indicating the Llanvirn or Arenig, occur.

Llandeilo. Deposits of this age were found in the Jeleniów 2 and Bukowiany 1a boreholes and in an exposure at Pobroszyn (Bednarczyk, 1971; Tomczyk and Turnau-Morawska, 1976; Tomczykowa, 1968). Their presence is documented by the scarce assemblage of graptolites including *Glyptograptus teretiusculus* (Hisinger), *Gymnograptus linnarssoni* (Tullberg), *Pseudoclimacograptus scharenbergi* (Lapworth), *Dicellograptus sextans* Hall and *Nemagraptus* sp. The most significant fossil is *Gymnograptus linnarssoni* (Tullberg) which is confined to the early Llandeilo. The remaining species, including the index taxon *Glyptograptus teretiusculus* (Table 1), have longer ranges, occurring also in the early Caradoc, and some in the Llanvirn. Of the other faunal groups, inarticulate brachiopods, including *Conotreta*, *Scaphelasma*, *Paterula*, of little stratigraphic significance, were identified (Bednarczyk, 1971).

Caradoc. Deposits of this age were recorded in most sections of the region. Biostratigraphically, these were examined in detail only in some of them, for example, in the Jeleniów 2 borehole (Tomczyk and Turnau-Morawska, 1967; Bednarczyk, 1971).

In the Jeleniów 2 section, the earliest Caradoc *Nemagraptus gracilis* Zone is distinct. Aside from the index taxon, these deposits contain the following faunal assemblage: *Glyptograptus euglyphus* (Lapworth), *Amplexograptus perexcavatus* (Lapworth), *Pseudoclimacograptus scharenbergi* (Lapworth), *Dicranograptus* sp., *Cyclopyge* cf. *redivivia* Barrande and many conodonts.

The succeeding *Diplograptus multidens* Zone is documented by the graptolite species: *Diplograptus multidens multidens* Elles et Wood, *D. m. compactus* Elles et Wood, *Pseudoclimacograptus scharenbergi* (Lapworth), *Climacograptus brevis* Elles et Wood. In addition, these sediments contain the trilobite *Cyclopyge redivivia* Barrande and brachiopods including *Paterula bohemica* Barrande, *P.* cf. *portlocki* (Geinitz) and *Hisigerella nitens* (Hisinger).

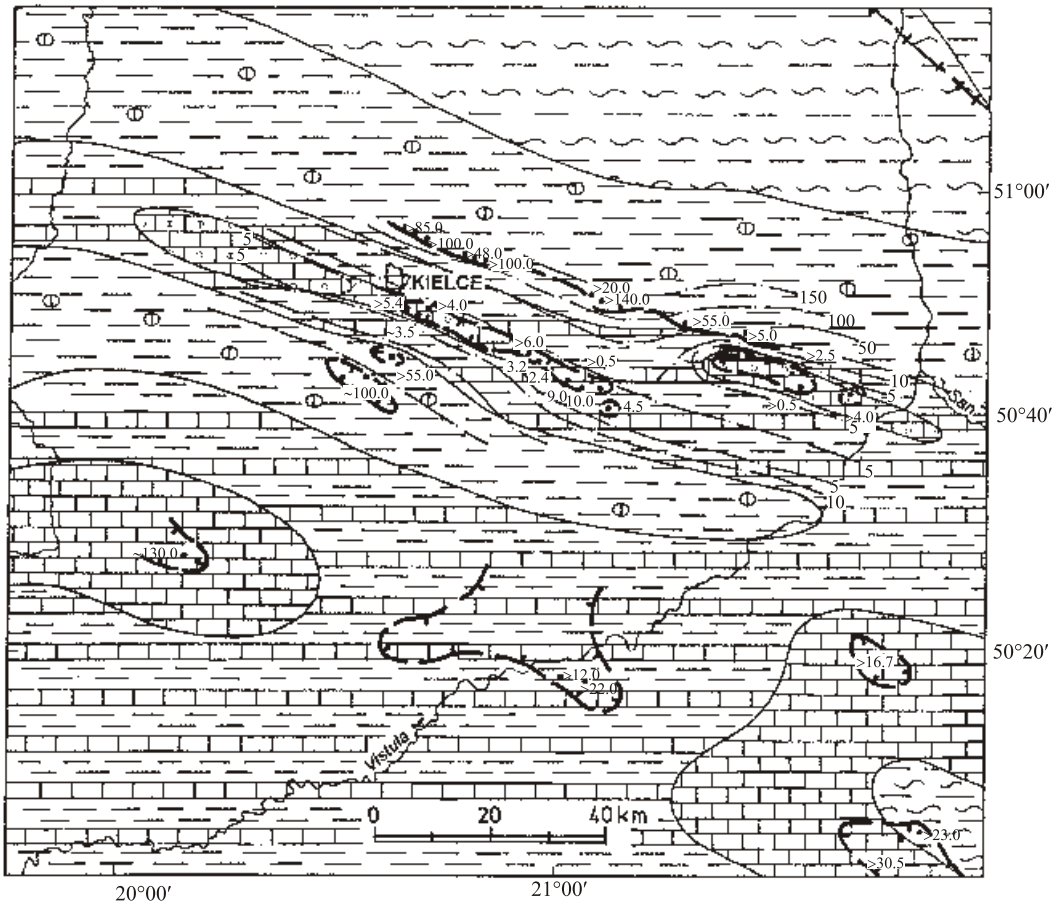


Fig. 8. Lithofacies-palaeothickness map of the Caradoc in the Nida and Holy Cross Mts. areas

For explanations see Figure 5

The upper Caradoc section is assigned to an undivided *Dicranograptus clingani-Climacograptus styloides* Zone interval. In the lower portion of this interval the following graptolites occur: *Dicranograptus clingani* Carruthers, *Climacograptus bicornis* (Carruthers), *C. tubuliferus* Lapworth, *Orthograptus truncatus truncatus* Lapworth, whereas the upper one contains: *Climacograptus styloideus* Lapworth, *C. tubuliferus* Lapworth, *C. minimus* Carruthers, *Pleurograptus sp.*, *Orthograptus calcaratus* Lapworth, *Dicellograptus* cf. *pumilus* Lapworth and *D.* cf. *caduceus* Lapworth.

Ashgill. Sediments of this age were found at Wólka and Brzezinki (Kielan, 1959) and in the Wilków 1 and Jeleniów 1 boreholes (Tomczykowa, 1968).

The trial pits at Wólka and Brzezinki yielded a rich fauna of early Ashgill age. Kielan (1959) examined trilobites that allowed the distinction of two biostratigraphic zones, of *Eodindymene pulchra* and the *Staurocephalus clavifrons*. The former one also contains *Nankinolithus granulata* (Wahlenberg), *Liocnemis recurvus* (Linnarsson), *Cyclopyge quadrangularis* Kielan, *Dindymene ornata* Linnarsson, *Ogmocnemis irregularis* Kielan and "*Illaenus*" cf. *angelini* Holm.

The late Ashgill, encompassing the *Mucronaspis mucronatus* Zone, is problematic. Based on analysis of the Brzezinki, Wólka and Dębniak sections, Kowalczewski (1965) supported Czarnocki is view (1939, 1950) of a complete and conformable Ashgill section passing up into Llandover rocks of the *Climacograptus scalaris normalis* Zone. This view was supported by Bednarczyk (1971) who thought the late Ashgill to be unfossiliferous. Kielan (1959), and H. Tomczyk (In: Tomczyk and Turnau-Morawska, 1967) thought, however, the late Ashgill to be absent.

LITHOFACIES

The Ordovician palaeogeography of the Nida-Holy Cross Mts. area is shown as simplified lithofacies-palaeothickness maps of varying reliability for: Tremadoc, Arenig, Llanvirn-Llandeilo, Caradoc and Ashgill (Figs. 5–9). These incorporate the authors' data and that from various authors, particularly Tomczyk (1962), Bednarczyk (1971), Modliński and Tomczykowa (1974) and Kowalczewski (1994).

In the Ordovician, deposition mostly occurred on a shallow area of open shelf located in the Nida region and the Kielce-Łagów segment of the Holy Cross area (in this account, the detailed subdivision of carbonate platform types proposed by Dzik and Pisera (1994) are not shown).

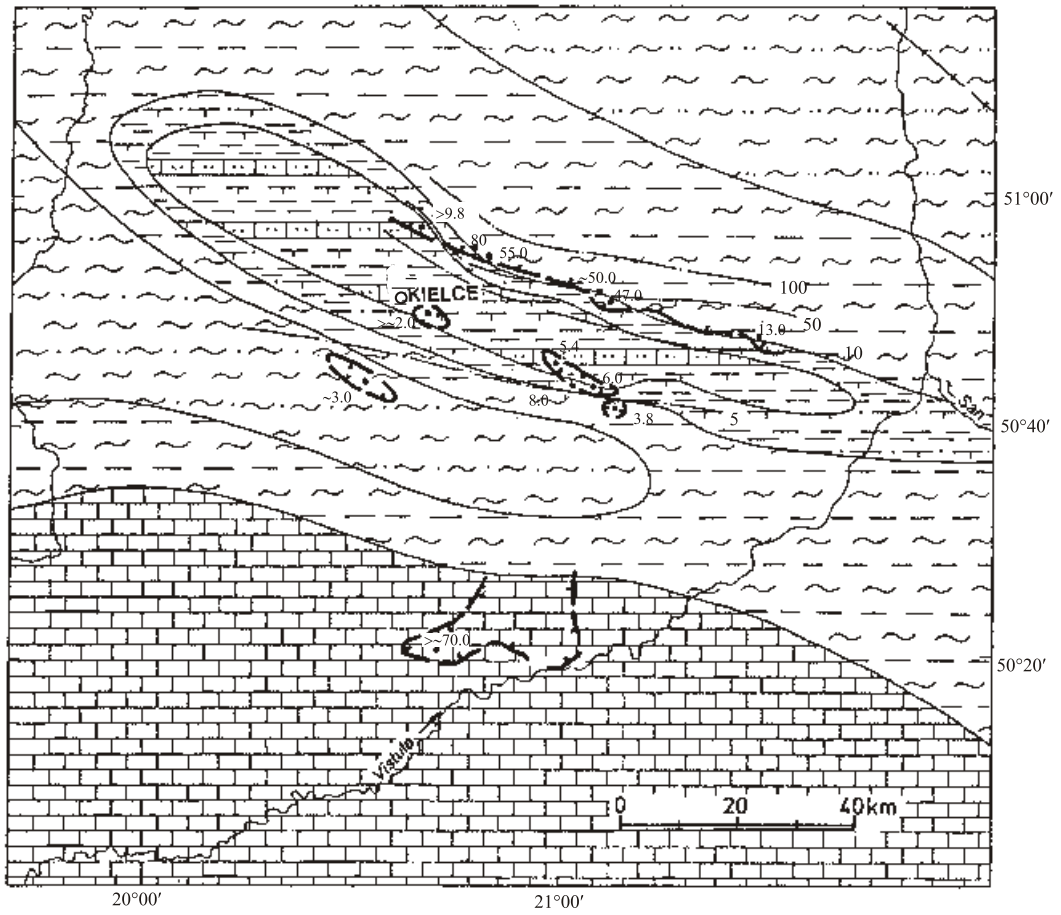


Fig. 9. Lithofacies-palaeothickness map of the Ashgill in the Nida and Holy Cross Mts. areas

For explanations see Figure 5

The vertical lithofacies succession can be referred to three consecutive transgressive-regressive phases of global eustatic nature (Erdtmann, 1988; Barnes *et al*., 1996). The lithologic expression of these sea level changes varies from clastic lithofacies with glauconite and pyroclastic material (Arenig) followed by terrigenous-carbonate sequences (Llanvirn-Llandeilo) to terrigenous rocks with subordinate carbonates (Caradoc-Ashgill).

Tremadoc. The lithofacies-palaeothickness map of the Tremadoc shows three fields: a clayey lithofacies field within the Łysogóry region and two lithofacies fields, clayey-sandy and sandy-clayey, in the south (Fig. 5). The trend of these fields broadly runs NNW–SSE. The Tremadoc lithofacies fields represent two groups of depositional environments, of open shelf (the clayey lithofacies) and the proximal part of this shelf (clayey sandy and sandy-clayey lithofacies).

The isopach pattern shows the maximum thickness of about 200 m in the Łysogóry region. The deposits thin to the SW, reaching 50 m at the southern margins of the Holy Cross Mts. and Nida region. This probably represents a general minimum thickness typical also of neighboring areas such as the Zawiercie-Lubliniec segment of the northeastern margin of the Upper Silesian Coal Basin. The general strike of Tremadoc isopachs is WNW–ESE.

Arenig. The Arenig lithofacies-palaeothickness map (Fig. 6) shows several lithofacies fields. These comprise the conglomerate-sandstone-siltstone lithofacies in the central part; the sandstone-siltstone-claystone and the conglomerate-sandstone-carbonate lithofacies in the south, and the claystone--siltstone-carbonate and the claystone lithofacies in the north.

The trends of these fields are indistinct, but generally resemble those of the Tremadoc (Fig. 5).

The Arenig deposits of this region were formed during a transgression. As in the Tremadoc, they reflect two depositional environments of contrasting bathymetry and water dynamics. The claystone, claystone-siltstone-carbonate and claystone-carbonate lithofacies fields probably represent open shelf environments in the north, whereas the clastics and carbonates of the remaining five fields may have been deposited in the relatively shallow environments of a proximal part of the shelf.

The isopach pattern shows a narrow zone outlined by the 0 m contour that marks an area of apparent non-deposition during the Arenig. This area corresponds more or less to the Main Range, i.e. to the northern part of the "Central Elevation" of Z. Kowalczewski (Kowalczewski *et al*., 1986).

The isopachs in both the north and south show a concentric pattern, where the thickness of Arenig sediments steadily increases to 30 m, though in the southern part of the Holy Cross

Mts. it decreases to 10 m, and in the southern margin of the Nida region the thickness varies from 5 to 10 m. The Arenig isopachs tend to run NNW–SSE.

Llanvirn-Llandeilo. The Llanvin-Llandeilo rocks show a clayey-carbonate lithofacies in the northern part, a sandy-carbonate and a sandy-silty-clayey lithofacies in the central area, and a sandy-silty-clayey-carbonate lithofacies in the south (Fig. 7).

The trends of the fields and facies boundaries differ from those of the Arenig and show a WNW–ESE direction. All four fields are diagonally elongated, narrow in the central (Holy Cross) part (sandstone-carbonate and sandstone-siltstone-claystone fields) and the broad in the Nida region (sandstone-siltstone-claystone-carbonate field).

The Llanvirn-Llandeilo deposits formed during stagnation of the Ordovician basin, and comprise lithofacies deposited on a shallow proximal shelf. The shallowest environments include the sandy-carbonate lithofacies of the central area whose sideritic sandstones and limestones with ferric ooids indicate proximity to wave base.

The Llanvirn-Llandeilo isopachs show two zones of minimum thickness in the Holy Cross Mts.: one in the northwestern part of the Kielce-Łagów segment and the other in the southeastern part within the Dyminy-Klimontów Anticlinorium.

Both northward and southward of these zones, the thickness steadily increases reaching maximum values near Kielce (Łagów-Kielce segment) and near Zbrza and Brzeziny.

The Llanvirn-Llandeilo isopachs show, as in the Arenig and Tremadoc, a WNW–ESE strike.

Caradoc. The Caradoc comprises northern and southern clayey lithofacies fields with carbonate nodules and lenses; clayey-carbonate and ooid-bearing carbonate fields in the central part (Holy Cross Mts.); and clayey-carbonate and carbonate lithofacies fields in the south (Nida region) (Fig. 8).

The trends remain the same. In the eastern and central parts of the area they are close to NNW–SSE, whereas in the western part they tend to assume a WNW–ESE direction.

The Caradoc deposits comprise relatively deep open shelf and shallower proximal shelf groupings. The former include the clayey lithofacies of the Łysogóry region and the southern margin of the Kielce-Sandomierz zone. The shallower environments of a proximal shelf may be linked with the carbonate, carbonate-clayey and ferric ooid-bearing carbonate lithofacies fields.

The isopach pattern includes three isolated zones outlined by the 5 m contour indicating areas of minimum thickness. All three zones are limited to the Kielce-Łagów segment.

Both northward and southward of these minimum thickness zones, the isopachs show a concentric pattern, the thickness of Caradoc deposits steadily increasing to maximum values of about 150 m in the north (in the Łysogóry region) and about 100 m in the south (near Zbrza).

The Caradoc isopachs, like those of the Llanvirn and Llandeilo, broadly show a WNW–ESE direction.

Ashgill. The Ashgill lithofacies include clayey-marly, clayey-marly-limestone and the silty-sandy fields in the Holy Cross Mts., and clayey-silty and carbonate fields in the Nida region (Fig. 9).

These in general replicate the Caradoc pattern (Fig. 8). The northern boundary of the southernmost carbonate field excepted, the facies boundaries trend in a WNW–ESE direction.

The Ashgill isopachs in the Holy Cross Mts. show a zone of minimum thickness outlined by the 5 m contour, extending WNW–ESE in the southern part of the Kielce region. Away from this isopach values steadily increase northwards reaching 50–100 m in the Łysogóry region.

CONCLUSIONS

1. Identification of Ordovician deposits in individual regions is partial. In the Holy Cross Mts. these deposits occur both in the Łysogóry and the Kielce regions where they were found in 30 outcrops and 50 boreholes. In the Nida region they were identified only in 3 boreholes.

2. The Ordovician succession shows various relations with underlying rocks (Figs. 2–4). In the Łysogóry region this contact may show continuous sedimentary passage from the Upper Cambrian (boreholes Brzezinki 1, Jeleniów) or there may be a stratigraphic hiatus of variable extent on the Upper Cambrian (boreholes Wilków 1, Bukowiany 1a) or Middle Cambrian (borehole Wólka); in the Kielce and the Nida areas the Ordovician succession overlies discordantly different members of the Lower Cambrian (boreholes Bukówka 1, Mokradle 1, Brzeziny, Jaronowice IG 1);

3. All the standard series of the Ordovician: Tremadoc, Arenig, Llanvirn, Llandeilo, Caradoc and Ashgill, have been identified in the Holy Cross Mts. Their occurrence and simplified lithologic composition in selected sections is given in Figures 3 and 4. In the Nida area Ordovician deposits are known from parts of three boreholes; they are of Arenig, Llanvirn, Llandeilo, Caradoc and Ashgill age (Fig. 2);

4. The Ordovician clastic-carbonate deposits are of diverse lithofacies and variable thickness, enabling the recognition of areal lithofacies zones for individual series; their extent and relationships are given in Figures 5–9.

5. The vertical succession of particular Ordovician lithofacies assemblages can be related to three transgressive-regressive phases. Their lithologic development varies from clastic lithofacies with glauconite and pyroclastic material (Arenig) and terrigenous-carbonate sequences (Llanvirn-Llandeilo) to terrigenous lithofacies with subordinate carbonates (Caradoc, Ashgill).

6. The maximum thickness of the Ordovician succession seems to have been located in the northern foreland of the Łysogóry segment of the Holy Cross Mts. This maximum thickness coincides with the deeper facies of the depositional basin.

Acknowledgements. Earlier versions of this paper were reviewed by R. Dadlez, Z. Kowalczewski and M. Narkiewicz, whom the present authors thank for critical remarks and discussion.

REFERENCES

BARNES C. R., FORTEY R. A. and WILLIAMS S. H. (1996) — The Pattern of Global Bio-Events during the Ordovician Period. In: Global Events and Event Stratigraphy (ed. O. Walliser): 139–172. Springer-Verlag.

BEDNARCZYK W., (1964) — The stratigraphy and fauna of the Tremadocian and Arenigian (Ölandian) in the Kielce region of the Holy Cross Mountains (Middle Poland) (in Polish with English summary). Biul. Geol. Wydz. Geol. Uniw. Warsz., **4**: 3–127.

BEDNARCZYK W. (1971) — Stratigraphy and palaeogeography of the Ordovician in the Holy Cross Mts. Acta Geol. Pol., **21** (4): 573–616.

BEDNARCZYK W. (1981) — Stratygrafia ordowiku Gór Świętokrzyskich. In: Przewodnik 53 Zjazdu Pol. Tow. Geol.: 35–41.

BEDNARCZYK W., KOREJWO K., ŁOBANOWSKI H. and TELLER L. (1968) — Stratigraphy of the paleozoic sediments from borehole Strożyska 5 (Miechów Trough, S Poland) (in Polish with English summary). Acta Geol. Pol., **18** (4): 677–689.

CZARNOCKI J. (1919) — Stratygrafia i tektonika Gór Świętokrzyskich. Stratygrafia i tektonika staropaleozoicznych utworów Gór Świetokrzyskich. (Kambr, sylur i dewon dolny). Pr. Tow. Nauk. Warsz., **28**.

CZARNOCKI J. (1928) — Le profil de L'Ordovicien inférieur et supérieur à Zalesie près Łagów comparé à celui des autres réginos de la partie centrale du massif de S-te Croix (in Polish with French summary). Spraw. Państw. Inst. Geol., **4** (3/4): 555–568.

CZARNOCKI J. (1929) — Compte-rendu des recherches géologiques effectuées en 1928 dans les environs de Kajetanów (in Polish with French summary). Posiedz. Nauk. Państw. Inst. Geol., **24**: 38–42.

CZARNOCKI J. (1939) — Field work in the Święty Krzyż Mountains in 1938 (in Polish with English summary). Biul. Państw. Inst. Geol., **15**: 1–27.

CZARNOCKI J. (1950) — The discovery of the graptolite facies within the Lower Ordovician in the Święty Krzyż Mts. (in Polish with English summary). Acta Geol. Pol., **1** (1): 3–12.

CZARNOCKI J. (1957*a*) — Prace geologiczne. **2**. Tectonics of the Świety Krzyż Mountains (in Polish with English summary). Pr. Inst. Geol., **18** (1): 109–133.

CZARNOCKI J. (1957*b*) — Prace geologiczne. **2**. Geology of the Łysogóry region (in Polish with English summary). Pr. Inst. Geol., **18** (3): 11–97.

DADLEZ J., KOWALCZEWSKI Z. and ZNOSKO J. (1994) — Some key problems of the pre-Permian tectonics of Poland (in Polish with English summary). Geol. Quart., **38** (2): 169–190.

DECZKOWSKI Z. (1963) — Wyniki badań przeprowadzonych w latach 1961–1963 nad utworami starszego paleozoiku Gór Świętokrzyskich (maszynopis). Arch. Państw. Inst. Geol.

DECZKOWSKI Z. and TOMCZYK H. (1969) — Geological structure of the Zbrza Anticline in the south-western part of the Góry Świętokrzyskie. Biul. Państw. Inst. Geol., **236**: 143–175.

DZIK J. (1994) — Conodonts of the Mójcza Limestone. Palaeont. Pol., **53**.

DZIK J., OLEMPSKA E. and PISERA A. (1994) — Ordovician carbonate platform ecosystem of the Holy Cross Mountains. Palaeont. Pol., **53**.

DZIK J. and PISERA A. (1994) — Sedimentation and fossils of the Mójcza Limestone. Palaeont. Pol., **53**.

ERDTMANN B. D. (1986) — Early Ordovician eustatic cycles and their bearing on punctuations in early nematophorid (planctic) graptolite evolution In: Global Bio-Events. (ed. O. H. Walliser): 139–152. Springer-Verlag.

ERDTMANN B. D. (1988) — The earliest Ordovician nematophorid graptolites taxonomy and correlation. Geol. Magazine, **125** (4): 327–348.

JAEGER H., HAVLICEK V. and SCHONLAUB H. P. (1975) — Biostratigraphie der Ordovizium-Silur Grenze in den Südalpen. Ein Beitrag zur Diskussion um die Himantia-Fauna. Verh. Geol. Bundesanstalt, **4**: 271–289.

JAANUSSON V. (1982) — Introduction to the Ordovician of Sweden. Palaeont. Contrib. Univ. Oslo, **279**: 1–9.

JAWOROWSKI K., JURKIEWICZ H. and KOWALCZEWSKI Z. (1967) — Sinian i Palaeozoic in the bore hole Jaronowice IG-1 (in Polish with English summary). Kwart. Geol., **11** (1): 21–38.

JURKIEWICZ H. (1975) — The geological structure of the basement of the Mesozoic in the central part of the Miechów Trough (in Polish with English summary). Biul. Inst. Geol., **283**: 5–100.

KIELAN Z. (1956) — On the stratigraphy of the Upper Ordovician in the Holy Cross Mts. (in Polish with English summary). Acta Geol. Pol., **6** (3): 253–271.

KIELAN Z. (1957) — On the trilobite family Staurocephalidae (in English with Polish summary). Acta Palaeont. Pol., **2** (2–3): 155–180.

KIELAN Z. (1959) — Upper Ordovician trilobites from Poland and some related forms from Bohemia and Scandinavia (in English with Polish summary). Palaeont. Pol., **11**.

KOWALCZEWSKI Z. (1965) — W sprawie strukturalnej i stratygraficznej pozycji warstw dalmanitinowych i mułowców tretaspisowych z górnego Ordowiku Gór Świętokrzyskich. Kwart. Geol., **9** (2): 455–456.

KOWALCZEWSKI Z. (1994) — The Holy Cross Mountains in the Early Paleozoic. In: EUROPROBE. Trans-European Suture Zone Workshop. Kielce, Poland. September 24th–October 1st. Excursion Guidebook. The Holy Cross Mts.: 19–33.

KOWALCZEWSKI Z. and WRÓBLEWSKI T. (1974) — Problem of ore contents in sediments in the light of diastrophism and volcanism of the Świętokrzyskie Mts. (in Polish with English summary). Kwart. Geol., **18** (3): 537–561.

KOWALCZEWSKI Z., LISIK R. and CHLEBOWSKI R. (1976) — New data on the geological structure of the Opatów area (in Polish with English summary). Biul. Inst. Geol., **296**: 167–207.

KOWALCZEWSKI Z., KULETA M., LISIK R. and MOCZYDŁOWSKA M. (1986) — New data on Cambrian and Lower Ordovician rocks in the Góry Świętokrzyskie Mts. (in Polish with English summary). Kwart. Geol., **30** (2): 201–224.

KOWALCZEWSKI Z. and MIGASZEWSKI Z. (1993) — Key problems of the tectonics and stratigraphy of the Paleozoic rocks in the Holy Cross Mountains (Góry Świętokrzyskie), Poland (in Polish with English summary). In: EUROPROBE. Symposium. Jabłonna 1991. Publ. Inst. Geophys. Pol. Acad. Sc., **A-20** (255): 99–104 99–105.

KOZŁOWSKI R. (1949) — Les graptolithes et quelques nouveaux groupes d'animaux du Tremadoc de la Pologne (in French with Polish summary). Palaeont. Pol., **3**.

LEWANDOWSKI M. (1992) — Paleomagnetic evidences for dextral strike-slip displacement of the southern block of the Holy Cross Mts. along the East European Platform border during Variscan orogeny and its continental-scale geotectonic implications. Geol. Carpath., **43** (3): 151–152.

MICHNIAK R. and OLKOWICZ-PAPROCKA I. (1976) — Older Palaeozoic deposits in the eastern part of the Kilece–Łagów Synclinorium (in Polish with English summary). Kwart. Geol., **20** (2): 261–272.

MODLIŃSKI Z. (1982) — The development of Ordovician lithofacies and palaeotectonics in the area of the Precambrian platform in Poland (in Polish with English summary). Pr. Inst. Geol., **102**.

MODLIŃSKI Z. and TOMCZYKOWA E. (1974) — Ordowik. In: Atlas Litologiczno-paleogeograficzny Obszarów Platformowych Polski. Część I — Proterozoik i Paleozoik (eds. J. Czermiński and M. Pajchlowa). Wyd. Geol. Warszawa.

MODLIŃSKI Z., KOWALCZEWSKI Z. and TOMCZYK H. (1990) — Paleotektonika ordowiku. Budowa geologiczna, paleogeodynamika oraz prognozy surowcowe staropaleozoicznego kompleksu strukturalnego (maszynopis). Arch. Państw. Inst. Geol. Warszawa.

ORŁOWSKI S. (1975) — Cambrian and Upper Precambrian lithostratigraphic units in the Holy Cross Mts. (in Polish with English summary). Acta Geol. Pol., **25** (3): 431–448.

ORŁOWSKI S. and MIZERSKI W. (1995) — Once more about geology of the Góra Wiśniówka outcrops (Holy Cross Mts.) (in Polish with English summary). Prz. Geol., **43** (1): 11–14.

POŻARYSKI W. (1986) — The Variscan stage of platform tectonical development of the Middle Europe (in Polish with English summary). Prz. Geol., **34** (3): 117–127.

POŻARYSKI W. and KARNKOWSKI P. (eds.) (1992) — Mapa tektoniczna Polski w epoce waryscyjskiej, 1:1 000 000. Inst. Geol. Warszawa.

SAMSONOWICZ J. (1934) — Objaśnienie arkusza Opatów ogólnej mapy geologicznej Polski w skali 1: 100 000. Inst. Geol. Warszawa.

SAMSONOWICZ J. (1952) — Era paleozoiczna w Polsce. In: Zarys Geologii Polski (eds. K. Książkiewicz and J. Samsonowicz). Państw. Wyd. Nauk. Warszawa.

SZANIAWSKI H. (1980) — Conodonts from the Tremadocian chalcedony beds, Holy Cross Mountains (Poland) (in English with Polish summary). Acta Palaeont. Pol., **25** (1): 101–121.

SZCZEPANIK Z. (1996) — Badania wieku najstarszych skał kambryjskich w jednostce łysogórskiej i ich tektoniki oraz badania wieku najmłodszych warstw kambryjskich w jednostce kieleckiej (maszynopis). Arch. Państw. Inst. Geol. Kielce.

TEMPLE J. E. (1965) — Upper Ordovician brachiopods from Poland and Britain (in English with Polish summary). Acta Palaeont. Pol., **10** (3): 379–427.

TOMCZYK H. (1957) — The graptolitic facies of the Caradocian in the Święty Krzyż Mountains (in Polish with English summary). Kwart. Geol., **1** (3–4): 462–481.

TOMCZYK H. (1962) — Stratigraphic problems of the Ordovician and Silurian in Poland in the light of recent studies (in Polish with English summary). Pr. Inst. Geol., **35**.

TOMCZYK H. (1964) — New data on stratigraphy and tectogenesis of the Older Palaeozoik in Poland (in Polish). Prz. Geol., **12** (6): 262–267.

TOMCZYK H. and TURNAU-MORAWSKA M. (1964) — Stratigraphy and petrography of the Ordovician in Brzeziny near Morawica (Holy Cross Mts., Central Poland) (in Polish with English summary). Acta Geol. Pol., **14** (4): 501–543.

TOMCZYK H. and TURNAU-MORAWSKA M. (1967) — Problems of stratigraphy and sedimentation of the Ordovician in Łysogóry (Holy Cross Mts., Central Poland) in connection with some profiles of the southern region (in Polish with English summary). Acta Geol. Pol., **17** (1): 1–46.

TOMCZYKOWA E. (1968) — Stratigraphy of the uppermost Cambrian deposits in the Świetokrzyskie Mountains (in Polish with English summary). Pr. Inst. Geol., **54**.

TOMCZYKOWA E. and TOMCZYK H. (1968) — Ordowik. In: Budowa geologiczna Polski. **2**, Stratygrafia, cz. 1, Prekambr i Paleozoik: 181–236. Inst. Geol.

TRELA W. (1998) — Sedimentary environment of the condensed Ordovician limestones from Mójcza section (Holy Cross Mts.) (in English with Polish summary). Geol. Quart., **42** (3): 289–300.

UNRUG R., HARAŃCZYK C. and CHOCYK-JAMIŃSKA M. (1999) — Eastern most Avalonian and Armorican-Cadomian terranes of central Europe and Caledonian-Variscan evolution of the polydeformed Kraków mobile belt geological constraints. Tectonophysics, **302**: 133–157.

WILLIAMS A., STRACHAN J., BASSET D. A., DEAN W. T., INGHAM J. K., WRIGHT A. D. and WHITTINGTON H. B. (1972) — A correlation of Ordovician rocks in the British Isles. Geol. Soc. London. Spec. Rep., **3**: 1–74.

ZASADY POLSKIEJ KLASYFIKACJI, TERMINOLOGII I NOMENKLATURY STRATYGRAFICZNEJ (1975) — Instrukcje i metody badań geologicznych. **33**. Inst. Geol.

ZNOSKO J. and CHLEBOWSKI R. (1976) — Revision of the Lower Ordovician stratigraphy in the Holy Cross Mts. (Central Poland) (in Polish with English summary). Rocz. Pol. Tow. Geol., **46** (1–2): 135–157.