Acta Geologica Polonica, Vol. 58 (2008), No. 1, pp. 43-74

Lithostratigraphy and regional significance of the Nowa Słupia Group (Upper Silurian) of the Łysogóry Region (Holy Cross Mountains, Central Poland)

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ABSTRACT:

KOZŁOWSKI, W. 2008. Lithostratigraphy and regional significance of the Nowa Słupia Group (Upper Silurian) of the Łysogóry Region (Holy Cross Mountains, Central Poland). *Acta Geologica Polonica,* **58** (1), 43-74. Warszawa.

The Ludlovian-Lochkovian succession of the Łysogóry Region of the Holy Cross Mountains (Central Poland) represents an infill of a Caledonian foreland basin situated at the SW margin of the East European Craton (EEC). The facies pattern and transport directions indicate that the source area was located westward from the basin and was separated from the Baltica mainland by the epicratonic sea. The 2.5 km thick succession, defined here as the Nowa Słupia Group, has been subdivided into 9 formations (from bottom to top: Trzcianka, Trochowiny, Winnica /Rachtanka, Sarnia Zwola /Bronkowice, Podchełmie, Rudki and Bostów formations). A revised lithostratigraphic scheme has been constructed. The lower part of the Nowa Słupia Group (Trzcianka and Trochowiny formations) represents the underfilled stage of the basin development and is composed of flysch-like sediments. The upper part of the group represents the filled to overfilled stage of the basin. In the latter stage the lateral migration of two main facies: red continental deposits (represented by the Rachtanka and Podchełmie formations) and open shelf hemipelagic sediments (represented by the Sarnia Zwola and Rudki formations and referred here to the Podlasie facies), is observed. The lateral facies migrations probably resulted from eustatic fluctuations. The two main facies zones are separated by a narrow belt of neritic sediments (represented by the Winnica, Bronkowice and Bostów formations), which are known for their rich benthic fauna. The facies trends observed show that during the latest Ludlovian through early Pridolian, the boundary between the continental and marine facies in the Łysogóry Region was oriented parallel to the Baltica margin (NNW-SSE).

Key words: Lithostratigraphy, Silurian, Foreland basin, Łysogóry Region, Holy Cross Mountains.

INTRODUCTION

The Holy Cross Mountains (HCM), Central Poland, represent a 100 km long and 40 km wide outcrop of Palaeozoic rocks within the Trans-European Suture Zone (TESZ). Although the age of the crystalline basement in this area has not yet been resolved, according to the palaeomagnetic and biogeographic data the region probably corresponds to the marginal part of the Baltica palaeocontinent (see NAWROCKI & *al.* 2007). Since the beginning of geological research in the HCM, the significant tectonic and facies differences between the Łysogóry Region located to the north of the Holy Cross Fault (HCF), and the Kielce Region south of that fault

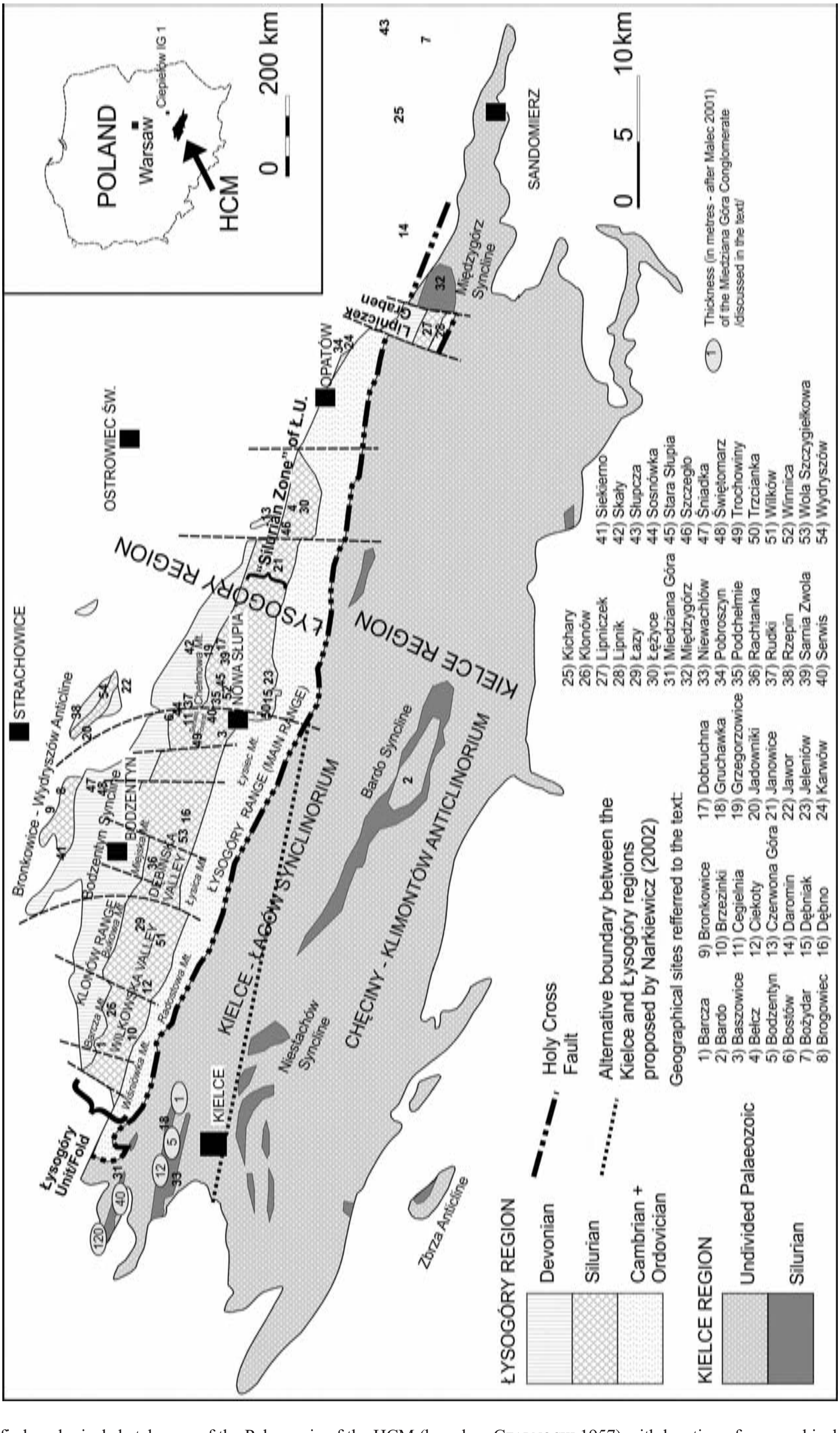


Fig. 1. Simplified geological sketch-map of the Palaeozoic of the HCM (based on CZARNOCKI 1957) with location of geographical sites, tectonic units, and regional geological data/interpretation discussed in the text

(Text-fig. 1), were recognised. These differences are particularly well manifested in the development of pre-Devonian strata (e.g. CZARNOCKI 1936, 1950; TOMCZYKOWA & TOMCZYK 2000; BEŁKA & *al.* 2002). As a result, different authors (e.g. BROCHWICZ-LEWIŃSKI & *al.* 1984; LEWANDOWSKI 1993; BEŁKA & *al.* 2002; NARKIEWICZ 2002) regarded the HCM as representing two separate terranes with independent development during the Early Palaeozoic. The most recent palaeomagnetic data (NAWROCKI 2000; SCHÄTZ & *al.* 2006; NAWROCKI & *al.* 2007) do not support the conclusions about large-scale strike-slip movements between these domains, however they do not exclude lithosphere remodelling at a scale smaller that the resolution of palaeomagnetic data.

The sedimentary history of the HCM area has been noticeably influenced by orogenic phenomena (?Cadomian, Sandomirian, Caledonian and Variscan) taking place on the nearby plate margin (see NAWROCKI & POPRAWA 2006; NAWROCKI & *al.* 2007). Silurian strata of the HCM perfectly illustrate this model. The 2.5 km thick, Upper Silurian – lowermost Devonian rocks in the Łysogóry Region represent the infill of a foreland basin (NARKIEWICZ 2002). The very similar, but less complete (only Ludlovian) succession of sediments preserved in the Kielce Region was probably deposited in a very similar setting (see discussion below). The sediments of the Silurian foreland basin, preserved in the HCM, were probably deposited on the continental shelf of Baltica, and derived from the southwest (MALEC 2001; KOZŁOWSKI 2003; KOZŁOWSKI & *al.* 2004), from the arc-continent orogen (KOZŁOWSKI & *al.* 2004), representing originally the continuation of the Avalonia-Baltica suture (NARKIEWICZ 2002).

The complete record of sedimentation in the foreland basin may be observed on the surface only in the Łysogóry area. Hence, future interpretation of the development of the basin should be based on detailed description of lithofacies evolution in this area. Stratigraphic terms so far applied to Silurian strata in the Łysogóry Region (eg. TOMCZYK 1962, 1970; TOMCZYKOWA & TOMCZYK 1981; see Text-fig. 3) are imprecise, often constructed on mixed litho-biostratigraphic or litho-chronostratigraphic criteria. The stratigraphic scheme thus constructed resulted subsequently in many misunderstandings (e.g. relationship of the Klonów and Bostów beds – PAWŁOWSKA 1961 *versus* TOMCZYKOWA 1962, see below and Text-fig. 3; or the age of the "Rzepin Stage" in BEDNARCZYK & *al.* 1983). The very poor recognition of the mutual relationships between particular lithosomes resulted from several factors: great lithological variability of the Silurian strata (CZARNOCKI 1950), poor exposures, and poorly recognized tectonic structure of the Silurian rocks. Establishing a formal lithostratigraphic scheme is thus crucial for further stratigraphic investigations and for a clear background to the new sedimentological, palaeogeographical and palaeontological data (KOZŁOWSKI 2006). The scheme presented provides a basis for the discussion of the history of the Łysogóry Region during Caledonian orogenic events within the TESZ and the palaeogeographical relationship between the Łysogóry and Kielce domains during the Silurian.

REGIONAL GEOLOGY

The Silurian rocks of the HCM belong to epicratonic, unmetamorphosed, moderately folded, Palaeozoic successions. In the Kielce Region, Ordovician and Silurian rocks unconformably overlie the Cambrian (CZARNOCKI 1928), whereas in the Łysogóry region this angular unconformity is absent (CZARNOCKI 1950; MIZERSKI 1979). According to the present recognition (e.g. TOMCZYKOWA & TOMCZYK 1981; MALEC 2006), the Llandoverian – lower Ludlovian, represented by 150-300 m thick succession of graptolite shales (Text-fig. 2), is uniform for the whole HCM. The shales pass up into a 300-500 m thick succession of greywackes (flysch-like sediments), of recycled arc-continent orogen provenance (KOZŁOWSKI & *al.* 2004). The graywackes, dated as early Ludfordian, are referred to the Niewachlów Beds in the Kielce Region, and to the Wydryszów Beds in the Łysogóry Region (see e.g. MALEC 2006; Text-fig. 2).

In the Kielce Region, the Niewachlów Beds are usually the youngest Silurian sediments and, in most cases, they are covered unconformably by Lower Devonian clastics. However, in a few places located close to the HCF, some still younger Silurian sediments occur. Such deposits were recognised e.g. in the northern part of the town of Kielce (Gruchawka area) (Text-figs 1, 2), where the lower Ludfordian greywackes are covered by a shale-sandstone complex (> 140 m thick), followed by an up to 120 m thick unit of conglomerates. The shale-sandstone complex was referred to as the Kielce Beds (MALEC 1993) and dated as late Ludfordian (TOMCZYKOWA 1993; MALEC 2001; Text-fig. 2), whereas the conglomerates are referred to the Miedziana Góra Conglomerates (MGC; MALEC 1993, 2001; Text-fig. 2). Whether the Kielce Beds and the MGC should be treated as the youngest Silurian rocks represented in the Kielce Region (MALEC 1993; KOZŁOWSKI 2003) or, as suggested by MALEC (2001) and NARKIEWICZ (2002), this part of the Kielce Region should actually be regarded as a part of the Łysogóry Region is still under debate (see discussion below).

One of the fundamental differences between the Kielce and Łysogóry regions is the absence in the Łysogóry Region of the Silurian/Devonian boundary (Caledonian) unconformity (e.g. CZARNOCKI 1950; MIZERSKI 1979). In the Łysogóry Region, the greywackes (lower part of the Wydryszów Beds) are followed by a thick succession of mainly clastic sediments (Text-fig. 2) referred to the: Wydryszów (upper part), Rzepin, Klonów and Bostów Beds (see e.g. CZARNOCKI 1936, 1950; TOMCZYKOWA & TOMCZYK 1981). All these units represent a continuous Late Ludlovian through Lochkovian succession of the foreland basin (NARKIEWICZ 2002). The definition of particular lithosomes and description of their mutual relationships are

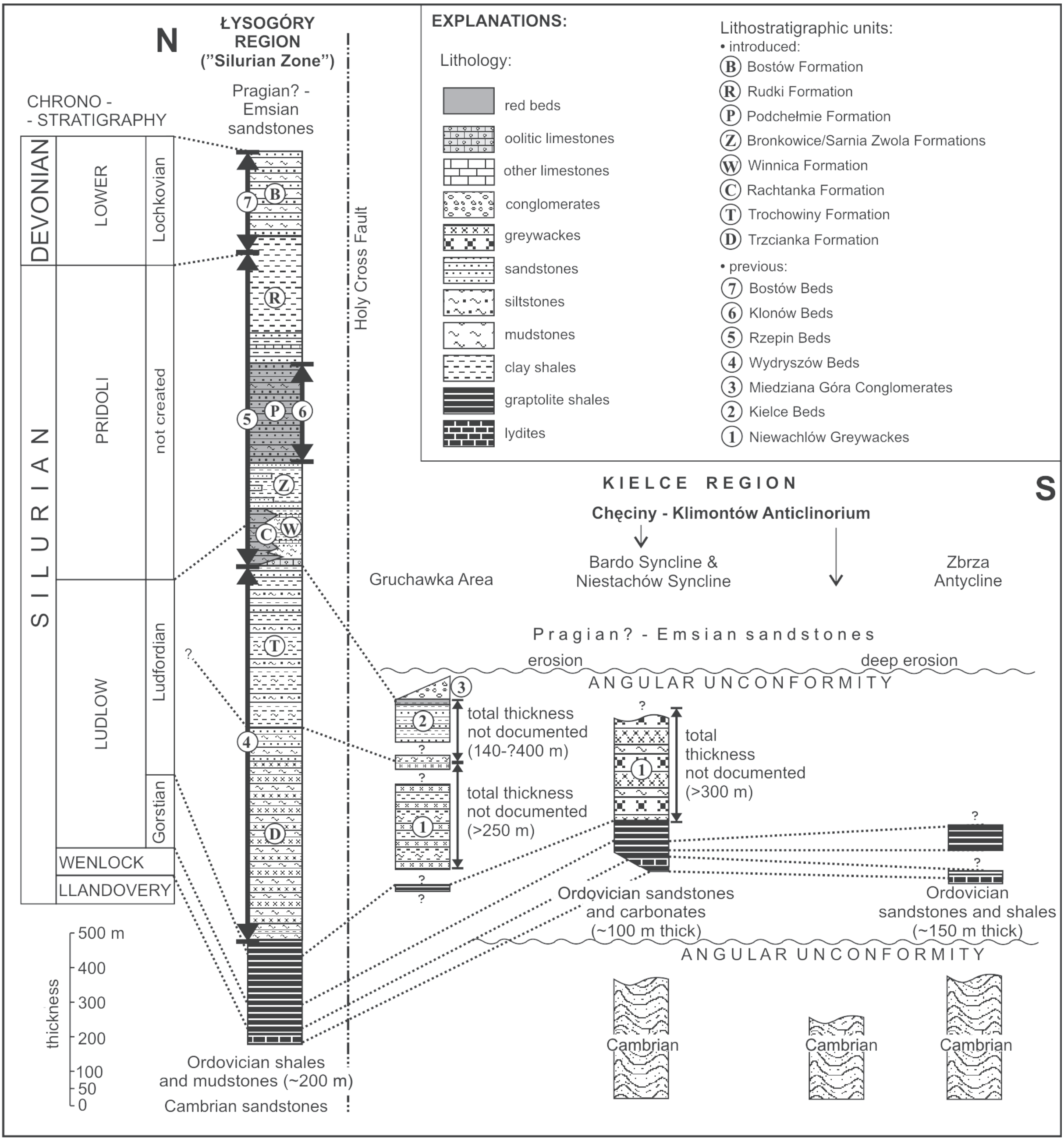


Fig. 2. Composite sections of the Silurian in the Łysogóry and Kielce regions with the position of the introduced and previously applied lithostratigraphical units used in the text (based on: Łysogóry "Silurian Zone" column – data presented herein; Gruchawka column – FILONOWICZ 1971; MALEC 1993, 2001; Bardo Syncline and Niestachów Syncline – FILONOWICZ 1971; KOZŁOWSKI & TOMCZYKOWA 1999; Zbrza Anticline – DECZKOWSKI & TOMCZYK 1969b)

the main aim of the present paper. The Ludlovian – Lochkovian succession of the Łysogóry Region is covered conformably by a younger Devonian clastic-carbonate complex (SZULCZEWSKI 1995; Text-fig. 2). The whole Cambrian to Devonian succession of the Łysogóry Region was not deformed until after the Famenian and was unconformably covered by the Late Permian – Early Triassic continental clastic rocks.

PREVIOUS REGIONAL STRATIGRAPHIC SUBDIVISIONS OF THE SILURIAN IN THE ŁYSOGÓRY REGION

In general, the Silurian succession in the HCM is twofold, which is reflected in its very early subdivision into a lower 'graptolitic shales' (ZEJSZNER 1868) and an upper, "greywacke series" (ROEMER 1866). In the Łysogóry Region above the "greywacke series" (=Niewachlów Beds*) CZARNOCKI (1919) additionally distinguished beds "transitional to the Devonian", corresponding to the British Downtonian. The first attempt at a complete subdivision of the upper Silurian in the HCM was undertaken by CZARNOCKI (1936). Within the upper Silurian – Lower Devonian interval of the Łysogóry Region he distinguished (Text-fig. 3): the graptolitic shales (Llandoverian to lower Ludlovian), Niewachlów Greywackes (middle and upper Ludlovian), Rzepin Beds, Miedziana Góra Conglomerates (lower Gedinnian in the Downtonian facies), and the Klonów Beds (red beds) (upper Gedinnian).

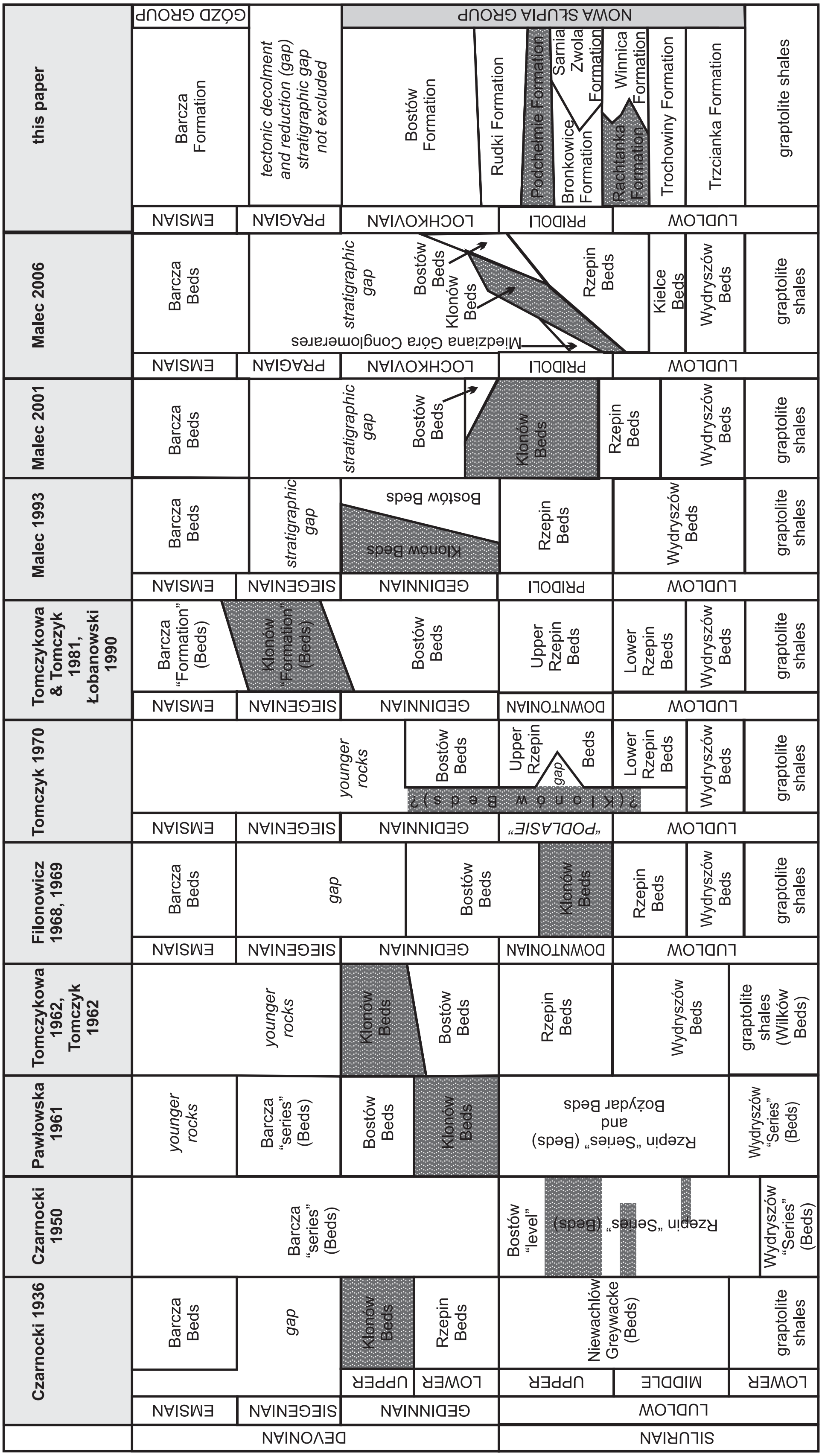
During his subsequent studies in the Łysogóry Region, CZARNOCKI (1950) distinguished the Wydryszów and Rzepin regional stages in a chronostratigraphic sense, albeit based on their lithological characteristics (Text-fig. 3). He correlated the "Rzepin stage" with the middle and upper Ludlovian of Great Britain (the Klonów Beds, as a subordinate part of the "Rzepin stage", were not distinguished in this scheme). In the uppermost part of the "Rzepin stage" CZARNOCKI (1950) introduced the "Bostów level" (a characteristic marine horizon with abundant benthic fauna) (Text-fig. 3). This effectively biostratigraphic unit (see below) was correlated with the top of the Silurian. The "Bostów level" is overlain by the Lower Devonian Barcza Beds. The mixed bio-/chrono-/litho- stratigraphical character of particular units introduced by CZARNOCKI (1936, 1950) caused their variable understanding by subsequent authors, either as lithostratigraphic or as local chronostratigraphic units. This is well exemplified by the discussion of the Klonów Beds (see description of the Podchełmie Formation below). The lack of a definitive lithostratigraphic scheme can also be seen in the inconsistent assignment of some Silurian lithosomes to particular units on the Nowa Słupia and Bodzentyn sheets of the Detailed Geological Map of Poland (FILONOWICZ 1968, 1969). The scheme proposed by CZARNOCKI (1936, 1950) has been applied until now, with only minor changes (e.g. MODLIŃSKI & SZYMAŃSKI 2001). In at least some of the recent publications the "beds" were often automatically referred to as "formations", without any serious analysis (e.g. TOMCZYKOWA 1988, TOMCZYKOWA & TOMCZYK 2000). On the other hand, TOMCZYKOWA and TOMCZYK used these terms also in a chronostratigraphic sense (as isochronous local stages), in the same way as their "local stages": Mielnik, Siedlce, and Podlasie, for various regions of Poland. This approach resulted in the complexity and lack of clarity of the stratigraphical terminology applied to the Silurian in Poland. The revised lithostratigraphical schemes for the Silurian of the HCM were recently published by MALEC (1993, 2001, 2006; see Text-fig. 3). Unfortunately, his scheme for the Łysogóry Region (MALEC 2006) is not accompanied by the documentation that would provide an essential basis for serious discussion.

KOZŁOWSKI (2003) introduced the Jadowniki Formation (here: Jadowniki Member), as well as the Trochowiny complex (here: Trochowiny Formation), Winnica complex (here: Winnica Formation) and other informal complexes (3, 4, 5). Most of these units are formally defined as formations in the present paper.

AN OUTLINE OF THE STRUCTURAL SETTING OF THE SILURIAN IN THE ŁYSOGÓRY REGION

The central structural unit of the Łysogóry Region is the Bodzentyn Syncline (Text-fig. 1). The syncline in its original definition (CZARNOCKI 1950) is built of Upper Devonian rocks in its axial part, and of Middle Devonian rocks in the limbs. The southern limb continues to the south into a homocline, composed of Lower Devonian, Silurian, Ordovician and Cambrian rocks (Text-fig. 1). The homoclinal part was referred to as the Łysogóry Fold/Anticline by CZARNOCKI (1950) and as the Łysogóry Unit by MIZERSKI (1979). The rocks of this zone together with the rest of the Devonian (Bodzentyn Syncline) form a tectonically conform-

* CZARNOCKI (1919, 1936) applied the term Niewachlów Beds to the greywacke complexes in both regions of the HCM. CZARNOCKI (1950) restricted the term to the greywackes in the Kielce Region, and this definition of the term has been applied until now.



Czarnocki 1936
Czarnocki 1950
Pawłowska 1961
Tomczykowa 1962, Tomczyk 1962
Filonowicz 1968, 1969
Tomczyk 1970
Tomczykowa & Tomczyk 1981, Łobanowski 1990
Malec 1993
Malec 2001
Malec 2006
this paper
DEVONIAN
SILURIAN
EMSIAN
SIEGENIAN
GEDINNIAN
LUDLOW
UPPER
LOWER
MIDDLE
DOWNTONIAN
"PODLASIE"
PRIDOLI
PRAGIAN
LOCHKOVIAN
Barcza Beds
gap
Klonów Beds
Rzepin Beds
Niewachlów Greywacke (Beds)
graptolite shales
Barcza "series" (Beds)
Bostów "level"
Rzepin "Series" (Beds)
Wydryszów "Series" (Beds)
younger rocks
Barcza "series" (Beds)
Bostów Beds
Rzepin "Series" (Beds) and Bożydar Beds
graptolite shales (Wilków Beds)
Wydryszów Beds
Lower Rzepin Beds
Upper Rzepin Beds
?(Klonów Beds)?
Barcza "Formation" (Beds)
Klonów "Formation" (Beds)
stratigraphic gap
Bostów Beds
Kielce Beds
Miedziana Góra Conglomerates
tectonic decolment and reduction (gap) stratigraphic gap not excluded
GÓZD GROUP
NOWA SŁUPIA GROUP
Barcza Formation
Bostów Formation
Rudki Formation
Podchełmie Formation
Bronkowice Formation
Sarnia Zwola Formation
Winnica Formation
Rachtanka Formation
Trochowiny Formation
Trzcianka Formation

able succession. To the north of the Bodzentyn Syncline occurs the Bronkowice – Wydryszów Anticline (Text-fig. 1, 4), composed of upper Silurian strata. The most extensive exposures of the upper Silurian are located in the Łysogóry Unit ("Silurian Zone" of the Łysogóry Unit of CZARNOCKI 1950; Text-figs 1, 4).

The entire Łysogóry Region (Łysogóry Unit, Bodzentyn Syncline, Bronkowice – Wydryszów Anticline) displays a southern vergence. To the south, the Cambrian of the Łysogóry Region is in tectonic contact with the Devonian of the Kielce Region along the Holy Cross Fault (e.g. CZARNOCKI 1950), which has a distinct shortening component across the fault zone with southern vergence. Inside the "Silurian Zone" (*sensu* CZARNOCKI 1950) some minor, southward-inclined folds have been noted (e.g. MIZERSKI 1979, fig. 15). Subordinate folds and contractional faults with a southern vergence are also present in the Devonian of the Bodzentyn Syncline (e.g. CZARNOCKI 1950, figs 13, 19; KŁOSSOWSKI 1985). The Palaeozoic rocks of the Łysogóry Region are cut by numerous transverse faults (cutting the Devonian rocks and covered by Permian – Triassic deposits – CZARNOCKI 1950). In the Łysogóry Region, the overall structural phenomena are most often linked with the Variscan (and possibly also younger) orogeny/-ies. The presence of an only Variscan (or younger) tectonic imprint on the Silurian rocks of the Łysogóry Region is evidenced by the very similar tectonic style as in the overlying Devonian strata, and by the conformable contact between the two systems (MIZERSKI 1979).

The considerable width of the outcrop area of the Silurian (up to 6 km) in the "Silurian Zone" (Text-fig. 4) was interpreted by CZARNOCKI (1950) as the result of significant folding of a great thickness of upper Silurian strata. However, the tectonic interpretation of CZARNOCKI (folded Silurian – 1950, fig. 19) is only very weakly supported by observations (extremely rare southern dips of strata, absence of reversed successions of strata in limbs of supposed folds). According to MIZERSKI (1979), the Łysogóry Unit shows a simple homoclinal structure with only some minor folds in the Silurian rocks.

MATERIALS, METHODS AND RESULTS

The Silurian rocks of the Łysogóry Region are rather weakly resistant to erosion. Consequently, they occur mostly in the floors of valleys and depression, and are usually covered by diluvia or loess. Larger exposures are rare and often need to be cleaned before study. About 50 outcrops were studied (see Text-figs 1, 4); observations on debris flows and numerous shallow hand-made boreholes were also used. Additional materials were provided by maps (FILONOWICZ 1968, 1969; DOWGIAŁŁO 1974; ROMANEK 1994), archival data (DULSKI 1961; ZAGÓRSKI 1961; CIEŚLA & *al.* 1962; TOMCZYKOWA 1969), and unpublished field notes of E. TOMCZYKOWA.

The lithostratigraphic units are defined following the recommendations of the revised Polish Stratigraphic Guide (RACKI & NARKIEWICZ 2006).

The fieldwork observations are compiled on the uncovered geological map (Text-fig. 4). Because of difficult field conditions, the presented map is only an interpretation based on lithological and graphical correlations between the outcrops.

INTERPRETATION OF THE TECTONIC STRUCTURE OF THE "SILURIAN ZONE"

The interpretations of the mutual relationships between the lithosomes, presented in this paper, were mainly based on observations of the Silurian strata in the "Silurian Zone". The rocks in this area dip to the north (25-70°) and maintain a constant regional strike (about 100°) (FILONOWICZ 1968,1969). Outcrop-scale tectonic deformations are very rare. These features, together with repeated superposition of the particular lithosomes confirm the general homoclinal structure of the strata studied. However, the width of the "Silurian Zone" is variable; from about 200 m in Pobroszyn, to about 6 km in the Wilków Valley and the Baszowice – Bostów area (see Text-fig. 4). Such variability is difficult to explain only by changes in the dip of strata. The width of the "Silurian Zone" changes most significantly across the transverse faults, which cut the area into a series of separate blocks (see CZARNOCKI 1950 – figs 18, 31, and Text-figs 1, 4). Such a relationship suggests an influence of the tectonic structure of particular blocks on the exposure width.

The general conclusion from the analysis of all blocks suggests a negative relationship between stratal dip and the calculated true thickness of the Silurian succession; in blocks with high dips (>50º) the thickness of the succession, obtained by simple geometrical calculation is evidently smaller than its true thickness (e.g. Dębińska valley between the Łysica and Miejska Hills

Fig. 3. Evolution of nomenclature and stratigraphic interpretation of the Upper Silurian – Lower Devonian deposits of the Łysogóry Region in the Holy Cross Mountains and lithostratigraphic units introduced in this paper; red beds facies complexes – dotted areas

– see Text-fig. 4); in contrast, in blocks with small dips (<30º) the calculated true thickness is evidently greater (e.g. the area north of the village of Łazy in the Wilków Valley see Text-fig. 4). The thickness reduction and/or expansion is explained herein by the presence of subordinate thrusts within the Silurian strata, with thrust plane dips close to the regional dip, towards the north (see interpretation in Text-fig. 5 A-B). The best example of such a thrust-fault is the Podchełmie Formation overthrust onto the Sarnia Zwola Formation, as observed in the Szczegło River-escarpment (Pl. 4, Fig. 1). Such faults are also well known from Devonian strata in the Świętomarz-Śniadka section (dominant dips 40°-70°) (CZARNOCKI 1950, fig. 13, 19; KŁOSSOWSKI 1985), with obvious subordinate folds and north-dipping contractional faults with southern vergence. As may be expected, the calculated thickness approaches the true thickness only in those cases where the dip is close to the dip of the supposed thrust surfaces. This interpretation is confirmed by blocks with moderate dips (35°-45°), with simple homoclinal structure (e.g. Serwis – Rudki Block). The same is documented by the homoclinal structure of the Devonian succession of the Grzegorzowice-Skały profile (dominant dips 35°-45°) (CZARNOCKI 1950; PAJCHLOWA 1957), without any tectonic reductions or repetitions.

Another conclusion drawn from cartographic analysis is the common lack of deposits representing the Silurian – Devonian transition (Text-fig. 4), although data from the exposures and boreholes in the vicinity of Rudki, Bostów and Czerwona Góra (see Text-figs 1, 4, 6, 7) clearly evidence their original presence here, at least locally. The preserved Silurian-Devonian boundary sequences comprise great thicknesses of distal shelf deposits (Text-figs 4, 7). It is thus highly probable that these deposits extended originally over the entire area. The boundary gap differs between particular blocks of the "Silurian Zone". Whereas in the Baszowice – Bostów section (Text-fig. 4) the ?Emsian sandstones overlie the upper Lochkovian deposits of the Bostów Formation conformably (TOMCZYKOWA 1969), in the vicinity of Karwów and Pobroszyn (Text-figs 1, 4) ?Emsian sandstones, or even Eifelian dolomites, are locally in direct contact with Ludlovian greywackes of the Trzcianka Formation (see TRELA & *al.* 2001; Text-fig. 5C) or even Ordovician or Cambrian rocks (ROMANEK 1994).

The contact of massive thick-bedded Emsian strata with Silurian – Lochkovian well-bedded deposits representing different lithologies is a zone predisposed for detachment (see also CZARNOCKI 1950, p. 72), along which a gap would be the end result due to tectonic reduction. The tectonic (post-depositional) nature of the gap has only been documented in the Klonów IG-1 borehole (KOWALCZEWSKI & *al.* 1998); however, in other places in the vicinity of the gap some additional tectonic reductions of different parts of the Palaeozoic succession have also been observed [e.g. in the outcrop at Pobroszyn (TRELA & *al.* 2001), in the Pobroszyn IG-1 (TOMCZYKOWA 1968) and Daromin IG-1 boreholes (TOMCZYKOWA & TOMCZYK 2000)]. Moreover, locally [southern slope of the Chełmowa Mt. near Nowa Słupia (Text-fig. 4)] along the gap, the N-dipping ?Emsian rocks are in contact with S-dipping Silurian strata, most probably as a result of a fault-related flexure connected with this thrust zone.

REFINED LITHOSTRATIGRAPHY

The lithostratigraphic nomenclature proposed herein generally abandons older terms. The redefinition of the Wydryszów and Rzepin Beds as formations is not possible due to their complex lithology and the need of their further subdivision. The Klonów Beds (*sensu* CZARNOCKI 1936) are redefined as the Podchełmie Formation. The term "Klonów Formation" (designation abandoned) has a very ambiguous meaning, e.g. as part of the Devonian Gózd Group (Siegenian – Emsian) of ŁOBANOWSKI (1990), underlain by Gedinnian (Lochkovian) Bostów Beds (different position in the succession – TOMCZYKOWA & TOMCZYK 1981, tab. 6; see also Text-fig. 3). Moreover, the Klonów Formation *sensu* ŁOBANOWSKI (1990) lacks boundaries, stratotype or any representative section. The Bostów Beds are referred to here as the Bostów Formation, albeit with a different definition of the lower boundary: at the level of lithological change (see Text-fig. 7), which is slightly higher than the lower boundary of the Bostów Beds, defined at the first occurrence of trilobites of *Acastella* group (see e.g. TOMCZYKOWA & TOMCZYK 1981). All of the introduced formations are subdivisions within the Nowa Słupia Group. The group has been named after the town of Nowa Słupia, located on the eastern and northern slopes of the Main Range of the HCM. The Nowa Słupia Group has been subdivided into nine formations summarized here (detailed definitions below; see also Text-figs 4, 7 and 8):

Trzcianka Formation (~500 m). Fine-grained greywackes (mainly sublithic arenites), commonly with graded bedding (Pl. 1, Fig. 3), interbedded with clayey-mud and silty shales (Pl. 1, Figs 1-2) with rich mica admixture, typically yellow-brownish to green-greyish. The unit is widely distributed in the entire Łysogóry Region (Text-fig. 4). Rare records of the graptolite *Bohemograptus bohemicus* suggest a middle Ludfordian age. An equivalent facies of thick siltstone and shale occurs at approximately the same time along the whole marginal part of the East European Craton in Poland (JAWOROWSKI 1971).

Trochowiny Formation (~550 m). Olive-green clayey-muddy shales with a few thin siltstone interbeds (Pl. 1, Figs 4-5), generally devoid of fossils. The upper part contains numerous interbeds of fine-grained sandstones with moulds of fauna (Brogowiec Member – Pl. 1, Fig. 6). The unit is widely distributed in the entire Łysogóry Region. The formation is probably of late Ludfordian age (?*kozlowskii* Zone).

Rachtanka and Winnica Formations (100-200 m). The Rachtanka Formation is composed of reddish-coloured mudstones and sandstones (Pl. 2, Figs 4-5). These are probably continental sediments, deposited during the late Ludfordian regression in the western part of the Łysogóry Region (KOZŁOWSKI 2003). In the central part of the Łysogóry Region, the Rachtanka Formation interfingers (Pl. 2, Fig. 4; Pl. 3, Fig. 3) with the shallow marine (marginal marine in parts) sediments of the Winnica Formation. The Winnica Formation occurs in the central and eastern part of the Łysogóry Region and is composed of fine-grained siliciclastics and neritic carbonates (Pl. 2, Figs 1-3; Pl. 3, Figs 1-4). The Winnica Formation contains rich trilobite and ostracod faunas indicating the latest Ludlovian (Jadowniki Member) – earliest Pridolian (Słupianka Member) age of both formations.

Sarnia Zwola and Bronkowice Formations (~150 m). The Sarnia Zwola Formation, present only in the eastern and central parts of the Łysogóry Region, is composed of green clayey shales (Pl. 3, Figs 5-6) and in parts contains abundant fossils of nektonic (nautiloids) and planktonic organisms (graptolites). The Bronkowice Formation, present in the western and central parts of the area, is composed of similar green shales, but with rich sandstone intercalations (sandstones form more than 25% of the unit). This formation is regarded a time-equivalent of the Sarnia Zwola Formation. Both formations yield the trilobite *Acaste dayiana*, which suggests their Pridolian age. The two formations most probably represent a transition between the open basin and the neritic zone. In the central part of the Łysogóry Region the rocks of the Bronkowice Formation (mainly sandstones) occur below and above the Sarnia Zwola Formation and form the transition between the Winnica and Sarnia Zwola formations, and between the Sarnia Zwola and Podchełmie formations.

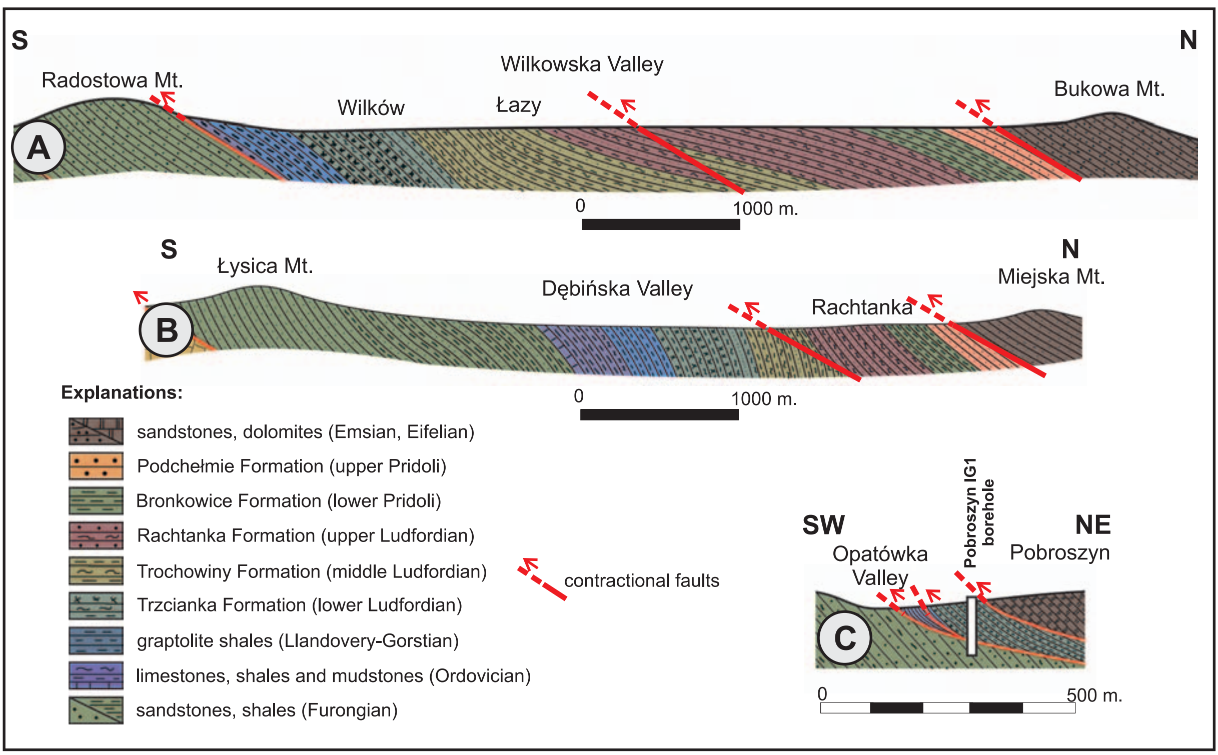


Fig. 5. Schematic geological cross-section across the "Silurian Zone" of the Łysogóry Unit; A – between the Radostowa and Bukowa Mts, B – between the Łysica and Miejska Mts; C – geological cross-section across the Pobroszyn area near Opatów (Pobroszyn borehole section after TOMCZYKOWA 1968)

Podchełmie Formation (~300m). Cherry-red sandstones with subordinate red clayey shales and mudstones (Pl. 4, Figs 2-3). The sediments are devoid of fossils and most probably represent continental fluvial environments (KOWALCZEWSKI & *al.* 1998). The formation is widely distributed in the entire Łysogóry Region. In the central part of the region it is covered (Pl. 4, Fig. 4) by the upper Pridolian – lowermost Lochkovian Rudki Formation. Consequently, a middle or even late Pridolian age is proposed for the unit (see also KOWALCZEWSKI & *al.* 1998).

Rudki Formation (~350 m). Dark-grey clayey shales with rare intercalations of crinoid limestones and fine-grained sandstones (Pl. 4, Figs 4-6). The shales are rich in bivalves, small orthocone nautiloids, crinoid columnals, rare brachiopods and sporadic graptolites. In the upper part of the formation the occurrence of graptolites of the *Monograptus uniformis* group evi-

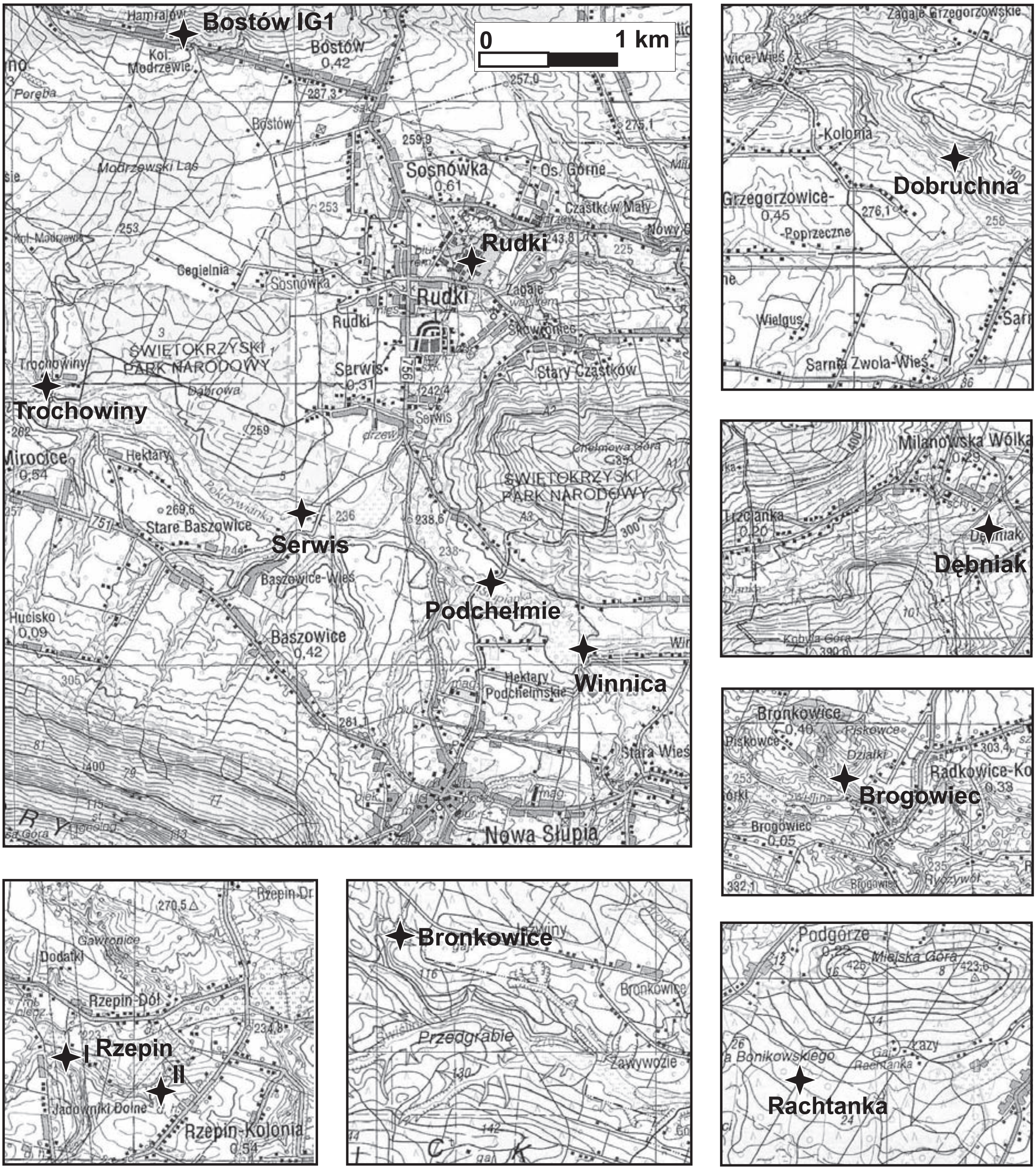


Fig. 6. Detailed location of the main outcrops (stratotype and hypostratotypes) of the introduced formations

dences the Silurian – Devonian boundary (PORĘBSKA 2003). The sediments were probably deposited in an open shelf environment.

Bostów Formation (250 m). Green-grey mudstones interbedded with fine-grained clayey-siliceous quartz sandstones, and subordinate marl and claystone beds. The formation yields an abundant benthic fauna of brachiopods, trilobites, bivalves, tentaculoids, etc. Abundant trilobites of the genus *Acastella* indicate an early to late Lochkovian age of the formation. The sediments were probably deposited in a neritic, shelf environment. The Bostów Formation is overlain by the siliceous quartz sandstones of the Barcza Formation (Gózd Group) of probable Emsian age.

FORMAL DEFINITIONS OF LITHOSTRATIGRAPHIC UNITS

Nowa Słupia Group (Polish name: grupa z Nowej Słupi)

Derivation of name: After the town of Nowa Słupia, located on the eastern and northern slopes of the Main Range of the HCM (Text-fig. 1).

Purpose of establishing the group and outline of its subdivision: The group comprises Upper Silurian and Lower Devonian deposits (middle Ludfordian – Lochkovian) of the Łysogóry sub-basin (part of the southwest Baltica Caledonian foreland) in the HCM. As a rule it shows: high lithological variability, great thicknesses of the subunits and predominance of fine-grained clastic rocks, green or red colour of the sediments and dynamic environmental changes (flysch-like deposits, hemipelagic sediments, shallow-marine carbonates, fluvial deposits) within one cycle of a foreland basin infilling.

Trzcianka Formation
(Polish names: formacja szarogłazów z Trzcianki, formacja z Trzcianki)

Derivation of name: After the village of Trzcianka located 2.5 km S of Nowa Słupia.

Earlier names (see Text-fig. 3): Greywacke deposits from the Łysogóry Region were referred to the Niewachlów greywackes (CZARNOCKI 1919, 1936), Wydryszów Stage or Series (CZARNOCKI 1950), defined subsequently as the Wydryszów Beds (TOMCZYK 1962, 1970; TOMCZYKOWA & TOMCZYK 1981; MALEC 2006). TOMCZYKOWA & TOMCZYK (2000) subdivided this complex into two parts, "Lower Wydryszów Formation" and "Upper Wydryszów Formation", however without formal descriptions. The proposed Trzcianka Formation corresponds approximately to the "Lower Wydryszów Formation" of TOMCZYKOWA & TOMCZYK (2000). This lithological unit on the Nowa Słupia and Bodzentyn charts of the Detailed Geological Map of Poland (scale 1:50000) corresponds to the lower part of the Wydryszów Beds (FILONOWICZ 1968, 1969).

Definition: Fine-grained (mean grain diameter 0.2-0.4 mm; maximum 0.5-1 mm) greywackes (sublithic arenites, subordinate lithic arenites, quartz and lithic wackes), commonly with graded-bedding (Pl. 1, Fig. 3), interbedded with clay, mud and silty shales (Pl. 1, Figs 1-2) with rich mica admixture, typically yellow-brownish, subordinately green-greyish. The unit contains characteristic horizons of siderite concretions.

Stratotype and hypostratotypes: The type section of the formation is part of the Wilków IG-1 borehole section between 8 and 308 m depth (Text-Fig. 7); the hypostratotypes are defined in several exposures, which represent the following parts of the formation (for localization see Text-fig. 6): the bottom part – outcrops in the right bank of the Słupianka to the north of the village of Dębniak (50°50'35''N 21°05'13''E; Pl. 1, fig. 1); the middle part – outcrop in Serwis (50°52'57''N 21°04'43''E; Pl. 1, fig. 2); the uppermost part – Dębno outcrop (50°53'55''N 20°59'28''E).

Boundaries: The lower boundary is placed at the lithological change in deposits representing the background sedimentation of periodic greywacke beds. This change is reflected as the gradual transition between black graptolitic shales to light grey and greenish clayey-muddy shales, often laminated with silt. In the Wilków IG-1 borehole this change occurs at 308 m depth (CIEŚLA & *al.* 1962; Text-fig. 7); thick greywacke beds appear higher, at 270 m depth (CIEŚLA & al 1962). The upper boundary corresponds to the base of the overlying Trochowiny Formation (see below).

Thickness: Between about 500 m, based on cartographic calculation in the vicinity of Wilków and Wola Szczygiełkowa.

Description: The lower 150 m of the formation contain numerous, over 1 m thick complexes dominated by medium-bedded greywackes (CIEŚLA & *al.* 1962, Pl. 1, Fig. 1). The middle part of the unit contains much thinner and rarer greywackes (reaching 10-20 cm in thickness; Pl. 1, Fig. 2). The uppermost part is dominated by yellow mudstones with rare thin greywacke and sandstone beds (Text-fig. 7). The greywacke beds often show graded bedding (Pl. 1, Fig. 3). Their lower surfaces commonly bear current marks. Shale and mudstone intercalations contain rare graptolites, while small fragments of benthic fauna (mainly crinoid fragments up to 2 mm in diameter) were noted in the greywackes. Larger fragments of redeposited benthic fauna, in contrast to contemporaneous deposits from the Kielce Region (see KOZŁOWSKI & TOMCZYKOWA 1999), have not been observed. The greywackes comprise mainly quartz grains, fragments of siliceous rocks (cherts), and numerous fragments of volcanic rocks from the andesite group. Transport directions (KOZŁOWSKI & *al.* 2004) suggest that the source area of the clastic material was located to the west (in present-day coordinates).

Regional distribution: Common in the Łysogóry Region. The exposures occur between Opatów in the east to Kajetanów in the west (Text-figs 1, 4, 8). Deposits of this formation have been noted in: Pobroszyn (50°47'25''N 21°26'57''E), Łężyce (50°48'48''N 21° 19'23''E), Jeleniów (50°50'36''N 21°07'32''E), Dębniak (50°50'35''N 21°05'13''E), Serwis (50°52'57''N 21°04'43''E), Dębno (50°53'55''N 20°59'28''E), Wola Szczygiełkowa (50°54'30''N 20°56'49''E), Wilków (50°54'30''N 20°51'05''E), Ciekoty (50°54'31''N 20° 49'28''E), Brzezinki (50°55'60''N 20°46'30''E) and Kajetanów (50°56'38''N 20°42'01''E). Significant lateral variability of the unit has not been observed.

Regional equivalents: Along the entire south-western margin of the EEC, intense sedimentation of slightly distal facies represented by greywacke siltstones took place in a corresponding stratigraphic interval (JAWOROWSKI 1971, 2000). More proximal (coarser grained and less mature greywackes – see KOZŁOWSKI & *al.* 2004) time-equivalent deposits are known from the Kielce Region, where they are referred to the Niewachlów greywackes (CZARNOCKI 1936; TOMCZYK 1962; Text-fig. 2). Highly proximal greywacke facies from the same stratigraphic interval have also been noted in boreholes from the south-western marginal part of the Malopolska Block, and referred to as the Łapczyca Formation (BUŁA 2000).

Chronostratigraphy: Deposits of this unit overlie graptolitic shales of the *Saetograptus leintwardinensis* Zone and contain rare graptolites, *Bohemograptus bohemicus* and *Pristiograptus* sp. (TOMCZYK 1970), thus probably corresponding to the middle part of the Ludfordian (Text-fig. 2, 8).

Genetic interpretation: The most typical feature of the deposits of the Trzcianka Formation is their flysch-like development, with preserved fragments of the Bouma sequence, current ripple marks and loading cast structures. The predominance of graptolites and the lack of benthic fauna point to an open-marine sedimentary environment. These deposits are interpreted as representing a deep intrashelf basin with high sediment influx. In the development of a Caledonian foreland basin such an environment corresponds well to the underfilled stage with a high sedimentation rate and a lower subsidence rate (cf. KOZŁOWSKI 2003). The inferred source area was a suture zone of an arc-continent orogen (KOZŁOWSKI & *al.* 2004) located at the south-western margin of Baltica (NAWROCKI & *al.* 2007).

Trochowiny Formation
(Polish names: formacja łupków ilasto-mułowcowych z Trochowin, formacja trochowińska)

Derivation of name: After the village of Trochowiny, 5 km NW of the town of Nowa Słupia (Text-fig. 1). Numerous exposures of this unit occur in the neighbourhood.

Earlier names (Text-fig. 3): The deposits distinguished here as the Trochowiny Formation were included by CZARNOCKI (1950) in the Wydryszów Stage and, in the scheme of TOMCZYKOWA & TOMCZYK (2000), correspond approximately to the "Upper Wydryszów Formation". In general lithology and age the Trochowiny Formation also corresponds to the Kielce Beds of MALEC (1993, 2001), the term used both in the north-western part of the Kielce Region (as interpreted herein), as well as in the area north of the Holy Cross Fault (MALEC 2006). On the Nowa Słupia and Bodzentyn sheets of the 1:50000 Detailed Geological Map of Poland the Trochowiny Formation corresponds to the upper part of the Wydryszów Beds (FILONOWICZ 1968, 1969); but sometimes its upper part has also been included in the Rzepin Beds (FILONOWICZ 1968).

Definition: Monotonous, internally homogeneous, thick complex of clayey-muddy shales with rare intercalations of thin-bedded (a few millimetres to decimetre-thick) siltstones and fine-grained sandstones (uppermost part of the unit) (Pl. 1, Figs 4-5). The shales are often laminated by silt. The siltstone beds are structureless or exhibit fine horizontal to low-angle cross-lamination. The deposits show an original olive-green colour.

Stratotype: Trochowiny section in the left bank of the Pokrzywianka River, NW of the bridge (50°53’24”N 21°03’06”E; Text-fig. 6; Pl. 1, Figs 4-5).

Boundaries: The lower boundary of the formation is marked by a gradual decrease in the content of light-brown graded-bedded greywackes in the sandy fraction and their replacement by thin (up to 10 cm) beds of fine-grained, hard olive-green siltstones. Shales, at first representing the background sedimentation, become very homogeneous, with a relatively constant grain size and a predominantly olive-green colour. Lithological change is accompanied by a disappearance of sedimentary structures pointing to high-energy sedimentary environments (graded bedding, loadcast structures, current ripple marks, and cross-bedding). The lower boundary of the formation is located at the bottom of the monotonous green-coloured shale-siltstone complex (above the last yellow-coloured bed) within the fire-fighting ditch in the eastern part of the Serwis Forest, southwest of the village of Serwis (50°53’09”N 21°04’53”E). In the eastern part of the area the upper boundary of the formation corresponds to the base of the Winnica Formation, and in the western part it corresponds to the base of the Rachtanka Formation.

Thickness: About 550 m, based on cartographic calculation in the vicinity of the villages of Wilków, Trochowiny and Łężyce.

Description: The lower part of the formation shows a rather uniform lithology, whereas the upper part, besides clayey-muddy shales, occasionally contains numerous intercalations of fine-grained sandstones with moulds of fauna (see Brogowiec Member). The formation is poorly fossiliferous, with a single rare inarticulate brachiopod, *Lingula* cf. *lata*, and crushed fragments of articulated brachiopods, crinoids and bryozoans in the sandstone-siltstone beds in its topmost part. Sporadic hyolithids, cephalopods, bivalves of the *Cardiola* and *Nuculites* groups, ostracods, brachiopods, and trilobites were reported from the equivalent deposits from the Daromin IG-1 and Kichary IG-1 boreholes (Tomczykowa & Tomczyk 2000).

Regional distribution: The formation is widely distributed in the Łysogóry Region (Text-fig. 1, 4). From east to west it has been recognized: between Lipnik and Lipniczek (50°44’15”N 21°30’21”E); Łężyce and Bełcz (50°49’19”N 21°20’03”E); in the Słupianka valley, southwest of the village of Winnica (50°52’14”N 21°06’41”E); in Nowa Słupia at Bodzentyńska Street (50°51’49”N 21°05’09”E); in the vicinity of Trochowiny – to the southeast (50°53’06”N 21°04’06”E), south (50°53’23”N 21°03’14”E), west (50°53’25”N 21°03’06”E) and north (50°53’33”N 21°03’19”E) of the village; north of the village of Jeziorko (50°53’51”N 21°01’16”E); north of the eastern margin of the village of Brandys (50°53’55” N 21°00’12”E); in the Czarna Woda valley, north of Wola Szczygiełkowa (50°54’47”N 20°57’36”E; 50°54’32”N 20°53’32”E); in the left slope of the Lubrzanka valley, north of Wilków (50°55’01”N 20°50’37”E); in Rzepin Kolonia (50°58’03”N 21°04’30”E); Bronkowice (50°58’39”N 21°00’16”E); in a forest, west of Bronkowice (50°58’46”N 20°57’38”E); and in the vicinity of Siekierno-Przedgarbie (50°58’55”N 20°56’47”E). In the Kielce Region, the facies- and time-equivalent of the Trochowiny Formation are the Kielce Beds (*sensu* Malec 1993, 2001). The Trzcianka and Trochowiny formations most probably correspond in age and facies to the upper part of the complex of greywacke siltstones widely distributed along the entire south-western margin of the EEC (Jaworowski 1971).

Stratigraphic interval: No index fossils have been noted in the Trochowiny Formation. Based on the age of the underlying Trzcianka Formation (Text-fig. 7), yielding the graptolite *Bohemograptus bohemicus*, and of the overlying Jadowniki Member (Text-fig. 7, Pl. 2, Fig. 2) containing the late Ludfordian benthic fauna (see Kozłowski 2003), the Trochowiny Formation is dated as late Ludfordian (Text-figs 2-3), most probably *kozlowskii* Zone. A similar age is attributed to the Kielce Beds (*sensu* Malec 1993, 2001), which is confirmed by macrofauna (Tomczykowa 1993; Malec 2001; see also Malec 1993 and Kozłowski & Tomczykowa 1999).

Genetic interpretation: The Trochowiny Formation comprises hemipelagic, fine-grained sediments deposited in a low-energy environment. It is characterised by rhythmic intercalations of well-sorted, thin-bedded siltstones in claystones and mudstones. Biofacies indicators are rare, but the character of the assemblage indicates an open-shelf environment. The brachiopod *Lingula* cf. *lata* most probably points to the late Ludlovian open-shelf *Lingula lata – Saetograptus leintwardinensis* association, as recognised by Cherns (1999). The uniform wide geographical development of the Trochowiny Formation indicates the occurrence of a uniform sedimentary environment, probably corresponding to the outer shelf (see also Kozłowski 2003). These features, as well as the specific lithology and location of the formation above the turbiditic Trzcianka Formation, may indicate that its deposits can represent

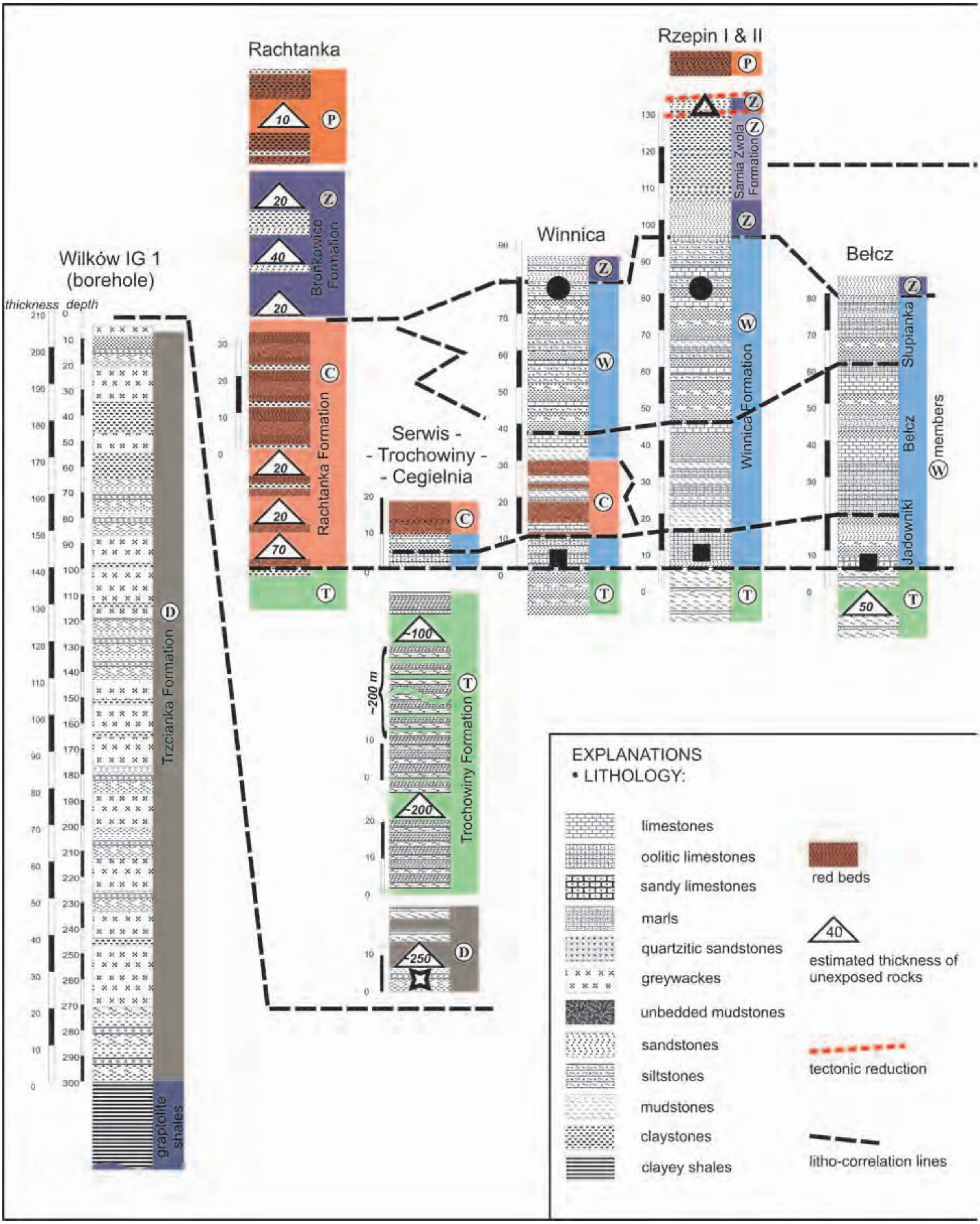
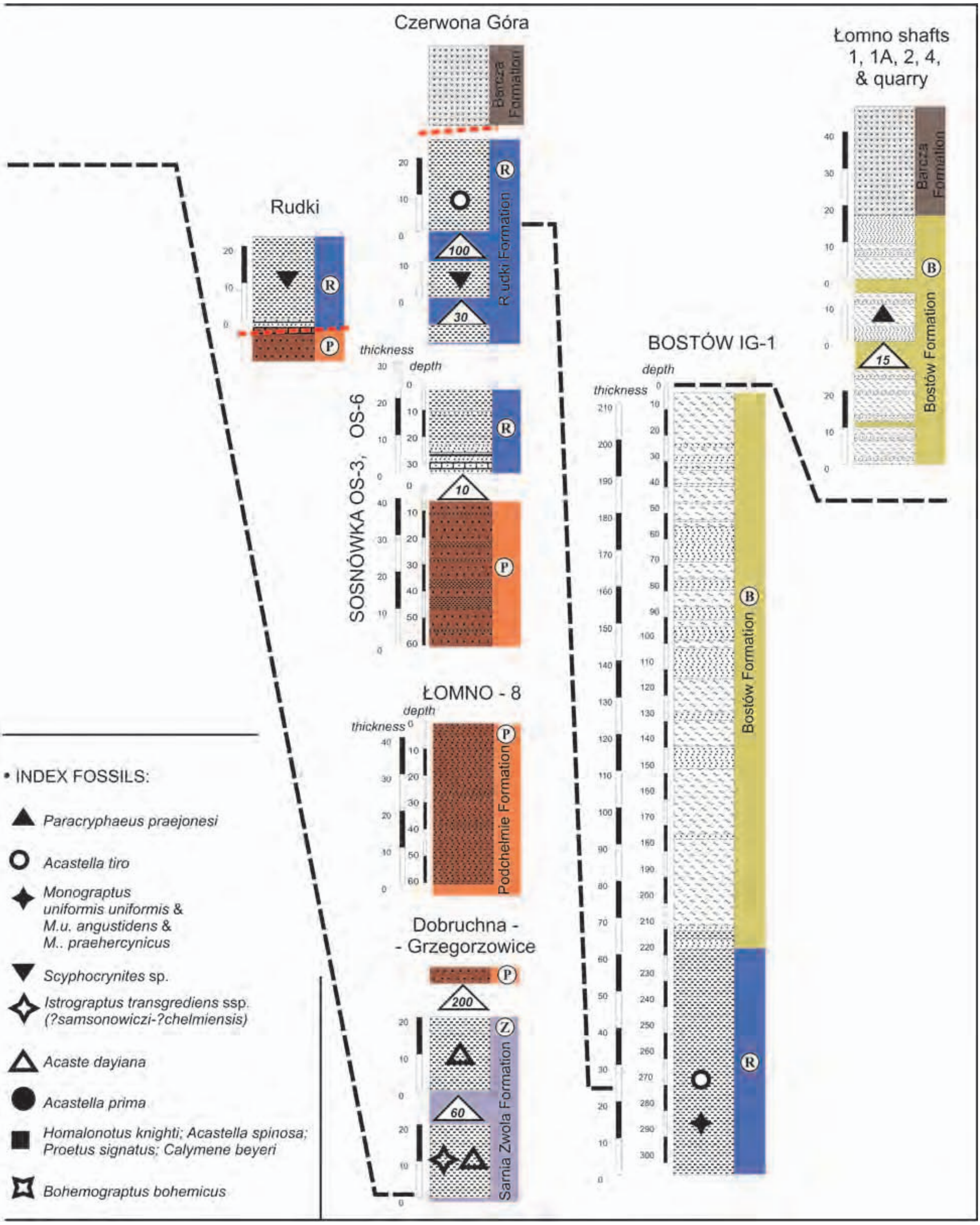


Fig. 7. Representative sections of the Nowa Słupia Group with their graphic - (triangles) and litho- (dashed lines) correlation and position of index fossils



(symbols); based on: CZARNOCKI (1950), CIEŚLA (1962), DULSKI (1961), ZAGÓRSKI (1961), TOMCZYKOWA (1969), PORĘBSKA (2003), KOZŁOWSKI (2006) a prodeltaic mudstone wedge of the foreland basin wedge-top (cf. MUTTI & *al.* 2003).

Brogowiec Member
(Polish names: ogniwo piaskowców i łupków z Brogowca; ogniwo brogowieckie)

Derivation of name: From the village of Brogowiec, 8 km south of the town of Starachowice. The type section of the member is located near the village.

Definition: Unit of clayey-muddy, olive-green shales interbedded with thick-bedded (0.2 to 1-2 m) fine-grained siliceous or calcareous olive-green sandstones, occasionally in the form of lenses (Pl. 1, Fig. 6).

Stratotype: A quarry close to the village of Brogowiec (50°58'38''N 21°00'48''E; Text-fig. 6).

Boundaries: The lower boundary of the member is placed at the base of the first bed of fine-grained sandstones with thickness exceeding 20 cm, within the Trochowiny Formation, in a ravine located at the forest margin, west of the village of Bronkowice (50°58'54''N 20°59'22''E).

Thickness: About 50 m, based on cartographic calculation in the vicinity of the village of Bronkowice.

Description: Some sandstone beds bear intense deformation structures (loadcasts, small synsedimentary folds). Locally the sandstone beds contain abundant brachiopods, crinoids and bryozoan fragments. Thicker sandstone bodies often represent fillings of erosional channels (Pl. 1, Fig. 6).

Regional distribution: It seems that the Brogowiec Member is distributed mainly in the central and western part of the Łysogóry Region. It is known from the following sections: north of Trochowiny (50°53'46'N 21°03'16''E); in the vicinity of Wydryszów (50°57'34''N 21°05'31''E); Bronkowice (50°58'54''N 20°59'22''E); Brogowiec (50°58'38''N 21°00'48''E); and Wilków-Łazy (50°55'08''N 20°50'37''E).

Rachtanka Formation
(Polish names: formacja czerwonych mułowców i piaskowców z Rachtanki, formacja z Rachtanki)

Derivation of name: After the forest-guard lodge Rachtanka, close to one of the larger outcrops of this formation.

Earlier names: (Text-fig. 3): According to CZARNOCKI (1936, 1950), the appearance of red colour and carbonates marks the beginning of the Rzepin Beds sedimentary cycle. It thus seems that CZARNOCKI (*op. cit.*) observed outcrops of this unit and assigned them to the Rzepin Beds. On the other hand, this "lower" red-bed complex (Rachtanka Fm.) has often been mistaken for the "upper" red-bed complex (Klonów Beds, referred herein to the Podchełmie Formation). On the Bodzentyn chart of the Detailed Geological Map of Poland at a scale of 1:50 000, the Rachtanka Formation corresponds to the lower part of the Rzepin Beds (FILONOWICZ 1969) and, on the Nowa Słupia chart, to the middle part of the Rzepin Beds (FILONOWICZ 1968).

Definition: Massive brittle mudstones with an original red-brown colour (Pl. 2, Fig. 5), often chaotic texture with numerous fine intraclasts and mica; as well as intercalations of the red and brown clayey-siliceous quartz sandstones. There are subordinate intercalations of green clayey quartz sandstone (Pl. 2, Fig. 5) with tabular bedding, and red clayey shales.

Stratotype: Natural exposures of the formation are rare due to its high susceptibility to erosion. It has been noted mainly during excavation work and in shallow, hand-made boreholes. Its best accessible outcrop, in a ravine located in the forest on the southern slope of the Miejska Hill near the forest-guard lodge Rachtanka (50°55'18''N 20°55'34''E; Text-fig. 6), is proposed herein as its type section. Although its best documented succession is the one near Winnica (50°52'20''N 21°06'21''E; Pl. 2, Figs 4-5; Text-fig. 6, 7), ca. 1.5 km northeast of Nowa Słupia (KOZŁOWSKI 2006), the deposits there represent the most distal parts of the formation, (interfingering with the Bełcz Member of the Winnica Formation - Pl. 2, Fig. 4, Pl. 3, Fig. 3; Text-fig. 4), which makes the section unrepresentative for the main part of the complex.

Boundaries: The Rachtanka Formation overlies the Brogowiec Member of the Trochowiny Formation (western part of the area). In the central part of the region, it interfingers with the Bełcz Member and both units together overlie the Jadowniki Member of the Winnica Formation (near Nowa Słupia – Rudki; Text-fig. 4; Pl. 2, Fig. 4, Pl. 3, Fig. 3). The lower boundary has been established in the Winnica section (50°52'20''N 21°06'21''E) at the base of the first bed of red mudstones. The formation is overlain by the Winnica (Winnica section) or the Bronkowice formations (boundary in the top of the last red mudstone bed; Pl. 3, Fig. 3).

Thickness: In the western part of the HCM the total thickness of the Rachtanka Formation is between 100 and 200 m (Rachtanka), and decreases in the central part of the area (Winnica section) to 30 m. In the eastern part of the HCM the unit does not occur, as it passes into the Winnica Formation.

Description: In the marginal part of the formation (Winnica), the lower and upper parts of the red mudstones that lie adjacent to the mudstones and marls of the Bełcz Member contain rare leperditicopid ostracods and bioturbation. Deposits from the main part of the formation contain red and brown, probably discontinuous sandstone intercalations.

Regional distribution: Only a few exposures of the Rachtanka Formation, mainly in the western part of the Łysogóry Region, are known: Winnica (50°52'20"N 21°06'19"E); Cegielnia-Rudki (50°53'45"N 21°04'36"E), Bronkowice (50°58'55"N 20°59'20"E), southern slopes of Góra Miejska hill near Bodzentyn (50°55'18"N 20°55'34"E), and north of Łazy-Wilków (50°55'13"N 20°50'32"E). The recognized lateral variability of the unit is marked by the predominance of mudstone deposits in its distal parts (vicinity of Nowa Słupia) and numerous red sandstone intercalations in the western part of the area (Dębińska and Wilkowska valleys, see DULSKI 1961, ZAGÓRSKI 1961).

Chronostratigraphy: Based on correlation with the time-equivalent Winnica Formation (see below), the Rachtanka Formation is regarded as latest Ludfordian – earliest Pridolian in age (Text-fig. 2, 8). According to eustatostratigraphic correlation (based on data of JOHNSON & *al.* 1998), the unit can be interpreted as a maximum regression of the late Ludfordian regressive event (RST – *latilobus/balticus*).

Genetic interpretation: The intercalation with marginal-marine deposits, red colour, lack of fossils and chaotic texture point to continental environments during seasonal emersions of the foreland wedge-top and progradation of the coastal mud plain (see eg. WOODROW 1985, ETTENSOHN 2004). It is also probable that the formation comprises fluvial deposits (the red-brown sandstone beds).

Winnica Formation
(Polish names: formacja mułowców i margli z Winnicy, formacja winnicka)

Derivation of name: After the hamlet Winnica of the village of Stara Słupia, ca. 1.5 km northeast of Nowa Słupia.

Earlier names (Text-fig. 3): Because of the abundant fauna the deposits of the Winnica Formation are the best-known part of the Silurian succession of the Łysogóry Region. They are considered by many geologists as representative of the entire Upper Silurian of the area (eg. TOMCZYKOWA 1988, p. 31). CZARNOCKI (1950) included these deposits into his Rzepin stage, and later they were distinguished by TOMCZYK (1970) as the Lower Rzepin Beds. TOMCZYKOWA & TOMCZYK (2000) have referred similar carbonate-clastic deposits, known from the boreholes in the eastern part of the Łysogóry Region, to the "Lower Rzepin Formation". On the Nowa Słupia sheet of the Detailed Geological Map of Poland (scale 1:50 000) this lithological unit corresponds to the upper part of the Rzepin Beds (FILONOWICZ 1968) and, on the Opatów sheet, to the Lower Rzepin Beds (DOWGIAŁŁO 1974).

Definition: A very variable, olive-green in colour, clastic-carbonate deposits representing a wide facies spectrum. The unit includes clayey and muddy shales, mudstones, siltstones, fine-grained sandstones, marls and various limestones (Text-fig. 7; Pl. 2, Fig. 3; Pl. 3, Figs 1-4), with beds that generally do not exceed 0.5 m in thickness, in single cases reaching 3 m. It is difficult to point out the dominant lithological component. Therefore, the basic lithological feature of these deposits is their complex lithology (e.g. Pl. 3, Fig. 4), thereby contrasting strongly with the other, rather monotonous, upper Silurian lithostratigraphic units. The next typical feature of this formation is the presence of limestone-marly intercalations within generally siliciclastic, mudstone-dominated deposits. Another characteristic feature of this unit is the occurrence of rich and very diverse benthic faunal assemblages, representing both open-marine and marginal-marine associations. In the Bełcz section (50°49'29"N 21°20'04"E), the unit is cherry-red, what might be linked with the infiltration of ferruginous compounds from the unconformably overlying diluvial deposits of the Rotliegend.

Stratotype: Rzepin I section (50°58'08"N 21°04'27"E; Text-figs 6, 7; Pl. 2, Fig. 1) located *ca.* 7 km to the south of Starachowice, 200 m east of the northern margin of the village of Jadowniki Dolne, on the right steep valley slope of an unnamed right-hand tributary of the Świślina, between the Romański quarry and the outlet of the valley to the Świślina valley (Text-fig. 6).

Boundaries: The base of the formation was observed in its type section (KOZŁOWSKI 2003). The base of the sandstone-oolitic Jadowniki Member (ratio of sandstones and/or limestones to shales > 50%) marks the lower boundary of the unit (Pl. 2, fig. 2). The top of the formation corresponds to the base of the Bronkowice Formation (see below).

The "western" lateral boundary of the formation was observed in the lower part of the Winnica section (50°52'20"N 21°06'21"E), where there are intercalations of complexes of red mudstones of the probably continental deposits of the Rachtanka Formation.

Thickness: About 80-100 m in the vicinity of Opatów, Nowa Słupia and Rzepin; the formation disappears completely in the western part of the area. Towards the east (near Lipniczek) the thickness also diminishes (~ 50 m), passing into the open shelf deposits of the Trochowiny and Sarnia Zwola formations (green clayey shales).

Regional distribution: The formation is laterally very variable. In the vicinity of Bełcz marly-clayey deposits predominate, whereas mudstones and siltstones predominate near Winnica (Text-fig. 7). This is probably linked with the pattern of facies belts perpendicular to a SW-NE direction. The formation (with all its members discussed below) was found in small outcrops only in the central and eastern part of the Łysogóry Region, passing into the Rachtanka Formation in the western part (Text-fig. 4). The Winnica Formation is known from near Lipniczek (50°44'16"N 21°30'50"E), Bełcz (50°49'29"N 21°20'04"E), Winnica (50°52'20"N 21°06'22"E), Rudki-Cegielnia (50°53'45"N 21°04' 36"E), Wydryszów (in the right bank of the Jawor stream valley – 50°57'38"N 21°05'34"E) and Rzepin (I – 50°58'08"N 21°04'27"E and II – 50°57'60"N 21°04'54"E). It is highly probable that the age-equivalents of the Winnica and Rachtanka formations in the Kielce Region are red deposits of the upper part of the Kielce Beds and Miedziana Góra Conglomerates of the Gruchawka section (MALEC 1993, 2001). These deposits terminate the late Silurian sedimentation in the Kielce Region (unconformity with Lower Devonian – see MALEC 1993).

Chronostratigraphy: The age of the lower part of the formation (Jadowniki Member) was discussed by KOZŁOWSKI (2003). Based on the trilobite fauna, sedimentation began in the late Ludlow. The upper part of the formation yields an early Pridolian fauna, including trilobites (*Acastella prima* – KOZŁOWSKI 2003) and ostracods (MALEC 2000). Consequently, the formation may be dated as late Ludlow through early Pridoli (Text-fig. 8). According to the eustatostratigraphic interpretation, it is assumed (KOZŁOWSKI 2003) that the lower part of the formation corresponds to the late Ludfordian regressive event (JOHNSON & *al.* 1998). Based on this fact, the lower part of the Winnica Formation (Jadowniki Member) corresponds in age (and facies) to the Burgsvik Formation in Gotland (KOZŁOWSKI 2003), indicating the *latilobus/balticus* Chronozone.

Jadowniki Member
(Polish names: ogniwo piaskowców i wapieni oolitowych z Jadownik, ogniwo jadownickie)

Earlier names: This unit corresponds to the Jadowniki Sandstone and Oolitic Limestone Formation, as defined and described by KOZŁOWSKI (2003). Due to the small thickness of the unit and the recently recognized genetic link with slightly younger deposits, a change of its rank to a member-level unit is proposed herein.

Definition [after KOZŁOWSKI (2003)]: The Jadowniki Member " is composed of sandstones, calcareous sandstones with ooids, sandy limestones and oolites; grey or yellowish-grey in colour. The deposits are generally thick-bedded and hard. Locally they contain an abundant fauna, represented by brachiopods, crinoids, gastropods, trilobites, ostracods, bryozoans and sporadic tabulate corals" (Pl. 2, fig. 3).

Regional distribution: The member is known from the Rzepin I section (50°58'08"N 21°04'27"E), Winnica (50°52'20"N 21°06'19"E), Bełcz (50°49'29"N 21°20'04"E), and the vicinity of Cegielnia-Rudki (50°53'45"N 21°04'36"E).

Genetic interpretation: The member is interpreted as representing the shoreface – barrier environment (KOZŁOWSKI 2003).

Bełcz Member
(Polish names: ogniwo mułowców i margli z Bełcza, ogniwo bełczańskie)

Derivation of name: After the hamlet Bełcz of the village of Łężyce, located 7 km to the northwest of Opatów.

Definition: The Bełcz Member is composed of mudstones, marls and limestones with abundant marginal-marine faunal assemblages (leperditicopid ostracods, lingulid brachiopods, fishes, eurypterids, etc.). Peliticmarly limestones containing numerous leperditicopid ostracods (leperditicopid limestones) are the dominant limestone facies (Pl. 3, Fig. 3). Open-shelf faunas (crinoids, brachiopods, trilobites, etc.) occur sporadically.

Stratotype: Part of the Rzepin I section between 10 and 29 m (50°58'08''N 21°04'27''E; Text-fig. 6, 7).

Boundaries: The base of the member is located at the top of the uppermost oolitic-sandstone bed of the Jadowniki Member in the Romański Quarry in Rzepin

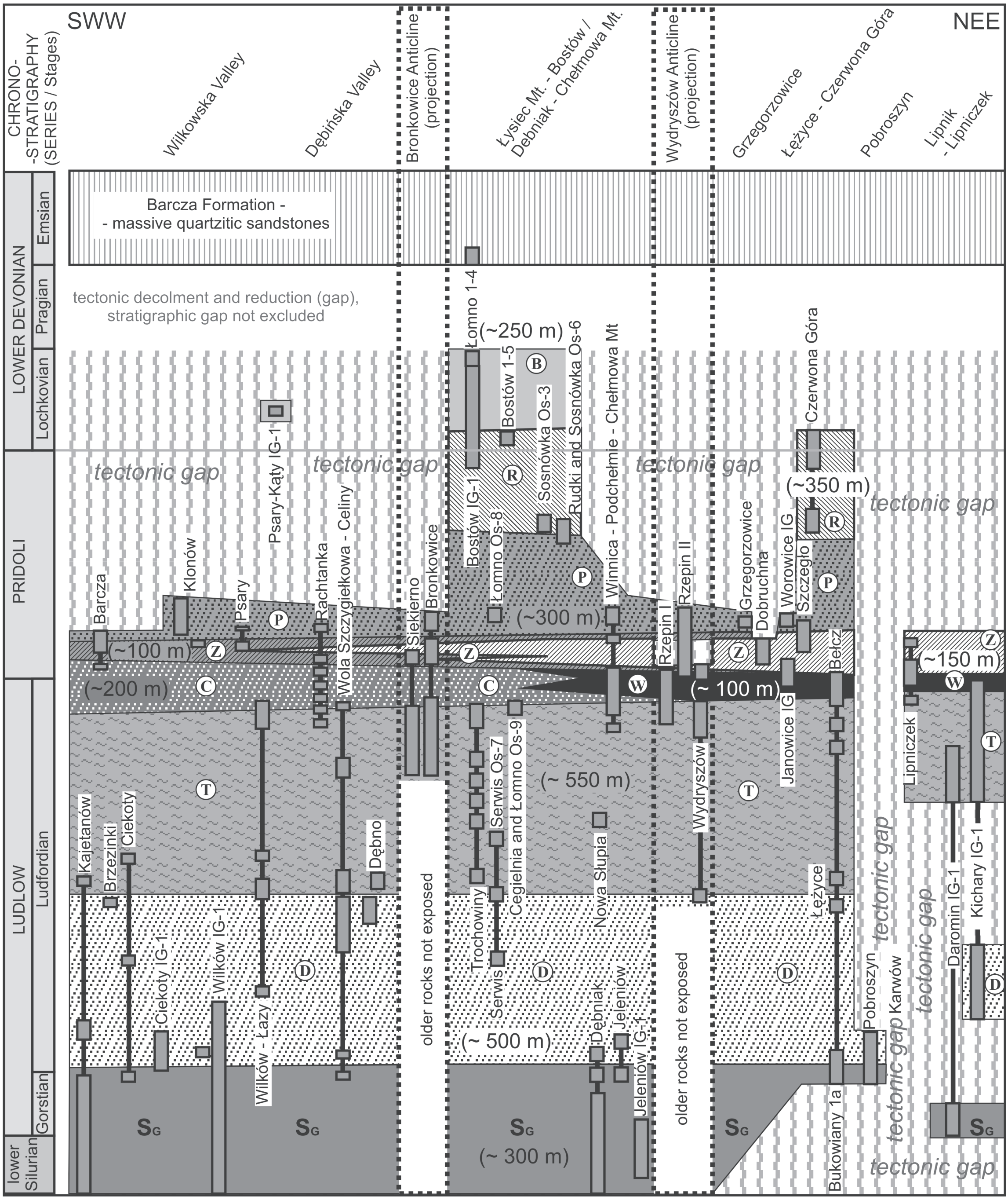


Fig. 8. Schematic, SWW to NEE lithostratigraphical chart of vertical and horizontal relations of the Ludlovian – Lochkovian deposits of the Łysogóry Region of the HCM (Nowa Słupia Group) with position of main outcrops and boreholes. The correlation is based on the assumption of an isochronous nature of the open shelf ingressions (Sarnia Zwola Formation, Rudki Formation), and regional (isochronous) nature of regressions during the time of sedimentation of the Rachtanka-Winnica, and Podchełmie formations

(see KOZŁOWSKI 2003, Text-fig. 7; Pl. 3, Fig. 1). The top of the member corresponds to the base of the Słupianka Member (see below). The westernmost extent (observed in the lower part of the Winnica section – 50°52’20”N 21°06’21”E), is marked by the intercalation of deposits of this member into the red mudstones of the Rachtanka Formation. Its easternmost extent, observed in the Bełcz section, is marked by the intercalation of thin beds of oolitic limestones, suggesting that the Bełcz and Jadowniki Members are here partially isochronous.

Thickness: About 20 m, as observed in the Rzepin I section.

Regional distribution: The deposits of the Bełcz Member are known from the Lipniczek area (outcrop in the village, part S – 50°44’16”N 21°30’50”E), from Bełcz (50°49’29”N 21°20’04”E), Winnica (50°52’20”N 21°06’22”E), and Rzepin (50°58’08”N 21°04’27”E). The clastic material content varies strongly within the member. In the Rzepin section (central part of the area), the member is mudstone-dominated, whereas in the Bełcz section (eastern part of the area), it is dominated by marls, claystones and limestones. This is an expression of the general regional trend in the formation, i.e. more abundant clastic material in the west.

Genetic interpretation: The fossil assemblages (with abundant leperditicopid ostracods), and limestone microfacies (mainly microbial peloidal limestones with ostracods) indicate that the deposits of the Bełcz Member represent marginal marine environments (KOZŁOWSKI 2006).

Słupianka Member
(Polish names: ogniwo iłowców, mułowców, pyłowców i wapieni Słupianki, ogniwo Słupianki)

Derivation of name: From the Słupianka river, in the valley of which its stratotype is located.

Definition: Variable clastic deposits, from claystones to siltstones, which often form numerous normal-graded cycles terminated with a bed of marls or marly limestones (Pl. 3, Fig. 4). The lowermost part of the cycles contains the “*Nuculites* shales” that are typical of this unit – clay shales with abundant specimens of the bivalve *Nuculites*, long crinoid stems and inarticulate brachiopods (*Craniops* sp.). In the more distal (eastern) part of the unit (Bełcz section), clay deposits with numerous beds of neritic carbonates with diverse faunas are equivalents of the cyclic sedimentation.

Stratotype: The outcrop near the village of Winnica near the town of Nowa Słupia (50°52’23”N 21°06’16”E; Text-fig. 6, 7). The boundaries of the member are not exposed in the stratotype.

Boundaries: The lower boundary of the member is defined in the Rzepin I section (50°58’08”N 21°04’27”E; Text-fig. 7) at the base of the lowest occurrence of the “*Nuculites* shales”. Its upper boundary is taken at the base of the overlying Bronkowice Formation.

Thickness: From 35 (Bełcz) to 70 m (Rzepin).

Regional distribution: The Słupianka Member is known in the vicinity of Rzepin (I – 50°58’08”N 21°04’27”E and II – 50°57’60”N 21°04’54”E; Text-fig. 6), Bełcz (50°49’29”N 21°20’04”E) and Winnica (50°52’23”N 21°06’16”E). The member dispays strong lateral facies variability; from the mudstone- to siltstone-dominated, in Winnica, to the clayey-shales, marls and limestones, in Bełcz (Text-fig. 7).

Genetic interpretation: The member represents a shallow shelf with an intermittent, limited communication with an open basin (KOZŁOWSKI 2006).

Bronkowice Formation
(Polish names: formacja piaskowców i łupków z Bronkowic, formacja bronkowicka)

Derivation of name: From the village of Bronkowice (Text-fig. 1), near which exposures of this unit occur.

Earlier names: The deposits of the Bronkowice Formation were formerly referred to the Rzepin Beds (FILONOWICZ 1969).

Definition: Green, red and brown clay-shales with numerous intercalations of green, grey, red to brown quartz sandstones with siliceous, rarely calcareous matrix (sandstones form more than 25% of the profile). Accumulations of benthic fauna (mainly brachiopods) on the bedding planes are a typical feature of this unit.

Stratotype: Bronkowice – exposures located in a forest ravine to the west of the village (50°59’19”N 20°58’06”E, Text-fig. 6).

Boundaries: In the western part of the Łysogóry Region, the Bronkowice Formation covers the Rachtanka Formation. The transition between the formations has only been observed in weathered material and shallow diggings in the vicinity of Bronkowice (50°59’19”N 20°58’06”E, 50°58’51”N 21°00’04”E), and in the Dębińska valley, on the southern slopes of the Miejska Mt., near the Rachtanka hamlet (50°55’18”N 20°55’34”E). In the central part of the region, the formation is represented by two sandstone complexes (up to 20 m thick) which form respectively the transition beds between the Winnica and Sarnia Zwola formations, and between the Sarnia Zwola and Podchełmie formations. In this area the boundaries of the Bronkowice Formation are much better exposed. Thus, the base of the formation is established in the Rzepin I section (50°58’08”N 21°04’27”E) at the first occurrence of a thick sandstone bed with moulds of brachiopods and crinoids in the upper part of the succession. The top corresponds to the base of the Podchełmie Formation (see below).

Thickness: In the Wilkowska Valley the thickness of the formation was estimated at about 100 m.

Regional distribution: The formation is known from the vicinity of the village of Bronkowice (50°59’14”N 20°58’07”E; 50°58’52”N 21°00’02”E) and from the northern part of the Dębińska valley (50°55’18”N 20°55’34”E). Poorly recognized exposures of this formation are also present in the floor of the northern part of the Wilkowska valley [southern slope of the Barcza Mt. (50°56’55”N 20°45’32”E), and southern slope of the Bukowa Mt., east of Klonów (50°56’31”N 20°50’44”E)]. The formation is also known near Wydryszów, Rzepin, Winnica, Szczegło and Bełcz, and on the southern slopes of the Chełmowa and Barcza Mountains, where it forms the transition beds between the Winnica and Sarnia Zwola formations, and between the Sarnia Zwola and the Podchełmie formations.

Chronostratigraphy: Based on the position between the Rachtanka Formation below and the Podchełmie Formation above, and on the occurrence of *Acaste dayiana*, the formation is regarded as an age-equivalent of the Sarnia Zwola Formation, and consequently dated as middle Pridolian (see below).

Genetic interpretation: The lithological characteristics and faunal assemblages suggest that the Bronkowice Foramtion represents a shallow, open shelf environment.

Sarnia Zwola Formation
(Polish names: formacja łupków ilastych i piaskowców ze Zwoli, formacja Zwoli)

Derivation of name: From the village of Sarnia Zwola, about 7 km east of Nowa Słupia (Text-fig. 1).

Earlier names (Text-fig. 3): PAJCHLOWA (1957) referred the Silurian deposits near Sarnia Zwola, occurring on the right bank of the Dobruchna River, to the Rzepin Beds. Subsequently, TOMCZYK (1970) and TOMCZYKOWA & TOMCZYK (1981) referred these deposits to the Upper Rzepin Beds. On the Nowa Słupia sheet of the Detailed Geological Map of Poland (scale 1:50 000) they are classified as the Bostów Beds (FILONOWICZ 1968).

Definition: The Sarnia Zwola Formation is composed of olive-green clay-shales and claystones with light-coloured mudstone laminae (Pl. 3, Figs 5-6). Numerous thin-shelled bivalves (*Pterinopecten* sp., *Actinopteria* sp., and *Lunulacardium* sp.), small nautiloids, gastropods, sporadic graptolites (*Istrograptus* gr. *transgrediens*), trilobites (*Acaste dayiana*), brachiopods (*Dayia navicula*), crinoids, ostracods and fragments of eurypterids (*Pterygotus* sp.) were reported from the Dobruchna section. Intercalations of yellow, green and brown sandstones with a rich fauna (brachiopods, trilobites, bivalves, tentaculoids, fragments of cephalopods) are known from the Rzepin II section (50°58’01”N 21°04’59”E).

Stratotype: Composite section; the exposures are located on the eastern slope of the Dobruchna valley (50°52’39”N 21°10’22”E and 50°52’43”N 21°10’ 00”E; Text-fig. 7; Pl. 3, Fig. 5), northeast of the village of Dobruchna.

Boundaries: The lower boundary of the formation was observed in the trench in the Rzepin II section (50°57’60”N 21°04’54”E), at the top of a thick (~10 m) sandstones of the Bronkowice Formation (Text-fig. 7). Its actual upper boundary is not exposed; in the Rzepin II and Szczegło sections the contact of the formation with the overlying Podchełmie Formation is tectonic (Pl. 4, Fig. 1).

Thickness: In its type area the boundaries of the formation are not exposed and thus direct thickness measurement is impossible. Cartographic analysis of the Silurian in the vicinity of Dobruchna – Grzegorzowice gave a thickness of at least 100 m. However, about 5 km to the west, in the Słupianka Valley, between the villages of Winnica and Podchełmie, the maximum estimated thickness [based on a calculation along a line between the outcrops of the Winnica Formation and the outcrops of the Podchełmie Formation] maybe as much as 180 m. The ca. 30 m thick succession of the formation in the Rzepin section is a tectonically reduced succession. The total thickness of 150 m is accepted herein as the most probable value.

Regional distribution: The deposits of the Sarnia Zwola Formation are known only from the central and eastern parts of the region; in the vicinity of Dobruchna, Rzepin and Szczegło, and in the Janowice 1 borehole (clay and mud shales with cephalopods – ROMANEK 1994). To the west the formation probably passes into the Bronkowice Formation.

Chronostratigraphy: The graptolites of the *Istrograptus* gr. *transgrediens* Group (most similar to the *samsonowiczi* or *chelmiensis* forms), and the trilobite *Acaste dayiana*, indicate a Pridolian (?mid-Pridolian) age of the formation (Text-figs 2, 8).

Genetic interpretation: Based on the lithology and the character of the faunal assemblages the formation is interpreted to represent a moderately deep shelf basin, far distant from a shoreline.

Podchełmie Formation
(Polish names: Formacja piaskowców i mułowców z Podchełmia, formacja z Podchełmia)

Derivation of name: From the village of Podchełmie, ca. 2 km north of Nowa Słupia.

Earlier names (Text-fig. 3): The Podchełmie Formation corresponds to the original definition of the Klonów Beds of CZARNOCKI (1936), a unit which has been inconsistently applied both by other workers and by CZARNOCKI himself, and is consequently not followed herein. Already in 1950 CZARNOCKI referred his Klonów Beds to the "Rzepin Stage". In the map published by FILONOWICZ (1968, 1969) the red coloured clastics, lying below the Bostów Beds (= in the upper part of the Rzepin Beds of CZARNOCKI 1950), are again referred to the Klonów Beds, in the original sense of CZARNOCKI (1936). To complicate matters even further, ŁOBANOWSKI (1981) assigned the Klonów Beds to the Lower Devonian Gózd Group [the rocks which cover the Bostów Beds – see TOMCZYKOWA (1962) and TOMCZYKOWA & TOMCZYK 1981)], and defined the Klonów Beds as the "Klonów Formation" (ŁOBANOWSKI 1990), interpreted as rocks underlying, in sedimentary conformity, the Barcza Formation of Emsian age. Consequently ŁOBANOWSKI (1990) assigned the Klonów Formation a Siegenian age. ŁOBANOWSKI's definition of the "Klonów Formation" is very similar to the definition of the Podchełmie Formation, but it lacks the stratotype and the definition of the boundaries. The rocks here assigned to the Podchełmie Formation were again referred to the Klonów Beds by KOWALCZEWSKI & *al.* (1998), who gave a similar chronostratigraphic interpretation to the one presented below (uppermost Silurian).

Definition: The formation is composed of red, cherry-red and brown, subordinately olive-green clastic deposits of different grain sizes (claystones to sandstones; Pl. 4, figs 2-3). Fining-upward cycles, cross-, horizontal- and trough-bedding are noted in the succession. The deposits are generally devoid of fossils; only the basal part yields rare leperditicopid ostracods and bivalves. Bioturbation and floral remains are also present.

Stratotype: The Klonów IG-1 and IG-2 boreholes (see KOWALCZEWSKI & *al.* 1998). The outcrops near the village of Podchełmie (Pl. 4, Figs 2-3) are hypostratotypes. The extended successions of the unit are known from numerous boreholes (e.g. Łomno-8 and Sosnówka Os3 – see Text-fig. 7).

Boundaries: The boundaries of the formation are still insufficiently known. The transition to the underlying Bronkowice Formation was observed in a shallow digging in a ravine on the southern slope of the Barcza Mt., northwest of the village of Barcza (50°56'55"N 20°45'32"E), and in the Szczegło section (50°50'19"N 21°16'30"E). In both cases, however, the contact is of a tectonic nature. The base of the formation is defined at the level of the disappearance of open-shelf (stenohaline) fauna and a parallel change of colour to red-brown.

Thickness: Up to 300 m. The thickness estimations from the western part of the region by KOWALCZEWSKI & *al.* (1998), suggesting values up to 600 m (near Klonów), are not confirmed by author's cartographic analysis (Text-fig. 4).

Regional distribution: The unit is widely distributed throughout the Łysogóry Region. It has been encountered in the vicinity of Szczegło (50°50'19"N 21°16' 30"E), Grzegorzowice (50°52'58"N 21°09'14"E), Podchełmie near Nowa Słupia (50°52'40"N 21°05' 41"E), Rudki (50°53'52"N 21°05'41"E), Rzepin II (50°58'02"N 21°04'58"E), Bronkowice (50°58'59"N 20°59'54"E) and Klonów (50°57'02"N 20°48'08"E), and in the Klonów 1 and 2 boreholes. CZARNOCKI (1950) documented its presence near Rudki in the Sosnówka Ostrostar-3, Sosnówka Os-5, Łomno Os-8, and Rudki-24 boreholes. A ca. 20 m thick succession of grey-purple fine-grained siliciclastics, with muscovite and tool marks, in the Worowice-74 borehole section (ROMANEK 1994) is also referred to the Podchełmie Formation. In the Bożydar and Słupcza boreholes, near Sandomierz, similar deposits have been described by PAWŁOWSKA (1961), although their relationship to the Łysogóry sections is not clear.

Chronostratigraphy: The position of the formation between the overlying Rudki Formation and the underlying Sarnia Zwola Formation (Text-figs 2, 7, 8) suggests a middle or upper Pridolian age.

Genetic interpretation: The formation represents a continental – fluvial sedimentary environment (see KOWALCZEWSKI & *al.* 1998).

Rudki Formation
(Polish name: formacja łupków ilastych z Rudek, formacja Rudek)

Derivation of name: After the village of Rudki, ca. 3 km north of Nowa Słupia.

Earlier names (Text-fig. 3): The deposits of the formation were first noted by CZARNOCKI (1950), who referred to them as the "*Scyphocrinus* Beds" and assigned them to the "Bostów level" (Beds). According to TOMCZYKOWA & TOMCZYK (1981) these deposits represent the upper Rzepin Beds and also the lower part of the Bostów Beds. On the Nowa Słupia sheet of the Detailed Geological Map of Poland (scale 1:50 000) this lithological unit represents part of the Bostów Beds (FILONOWICZ 1968).

Definition: The formation is composed of grey clayey shales with rare intercalations of crinoid limestones and fine-grained sandstones (Pl. 4, Figs 4-6). The clay beds yield abundant bivalves (*Lunulicardium* sp., *Cardiola* sp., *Pterochaenia* sp. and *Dualina* sp.), small orthocone nautiloids, crinoid columnals, rare brachiopods and sporadic graptolites.

Stratotype: A surface exposure in the "Staszic" mine in the village of Rudki (50°53'52"N 21°05' 38"E) (Pl. 4, Figs 4-6)

Boundaries: The lower boundary of the unit is poorly known. Although in the stratotype a transition from the Podchełmie Formation to typical deposits of the Rudki Formation was observed, the succession there is apparently strongly reduced tectonically. A much better section with these boundary beds has been observed about 300 m northwest of the stratotype, in trenches for the water supply system in the village of Sosnówka, along the Nowa Słupia – Starachowice road (50°54' 04"N 21°05'20"E). The same beds were also documented by CZARNOCKI (1950) in the Sosnówka Os-3 and Sosnówka Os-6 shallow boreholes (Text-fig. 4), near the same village. These borehole successions suggest that the boundary beds can attain a total thickness of *ca*. 40 m. The lower boundary is put at the change in the dominant colour of the rocks from red-brown to grey or green. The upper boundary of the formation corresponds to the base of the Bostów Formation (see below).

Thickness: Cartographic analysis indicates that the thickness of the formation attains about 350 m, both near Rudki and Czerwona Góra (Text-fig. 4).

Regional distribution: The deposits assigned to the Rudki formation are known from the Bostów IG1 borehole, and from the sections of Rudki and Czerwona Góra (50°50'46"N 21°18'14"E). Due to their open-shelf character, the original geographical extent of these deposits was surely much wider than today.

Chronostratigraphy: The upper part of the formation in the Bostów IG-1 (Text-fig. 7) borehole contains the index graptolites *Monograptus uniformis angustidens, M. uniformis uniformis* and *M. praehercynicus* (PORĘBSKA 2003), documenting its earliest Lochkovian age. The older part, yielding the crinoid *Scyphocrinus* (Rudki, Czerwona Góra), is probably of late Pridolian age (see Text-figs 2 and 8).

Genetic interpretation: The predominance of planktonic and nektonic fossils, as well as the lithology, suggests an open shelf environment.

Bostów Formation
(Polish names: formacja mułowców z Bostowa, formacja bostowska).

Derivation of name: After the village of Bostów (Text-fig. 6).

Earlier names (Text-fig. 3): The upper part of the Bostów Beds. Deposits of the "Bostów level" in a biostratigraphic sense were noted for the first time by CZARNOCKI (1950) and regarded as the uppermost part of the Rzepin Stage. Subsequently, these deposits were referred to as the "Bostów Beds" (eg. by TOMCZYK

1962), and became an independent subdivision. The original biostratigraphical definition then changed to a chronostratigraphical one, and the Bostów Stage, regarded as an equivalent of the Gedinnian, was introduced (e.g. TOMCZYK 1970); its lower boundary was defined as the base of the Devonian. The Bostów Beds were regarded as the marine facies of the Gedinnian/Lochkovian in the region (TOMCZYKOWA & TOMCZYK 1981). The chronostratigraphical content of the Bostów Beds was, however, variably interpreted (e.g. FILONOWICZ 1968, 1969; and subsequently MALEC 2006; who regarded this unit as belonging to both the Silurian and Devonian systems).

Definition: The formation is composed of green-grey mudstones alternating with fine-grained clay-siliceous quartz sandstones. Subordinate marl and claystone beds are present. A common feature of the formation is the occurrence of an abundant benthic fauna represented by brachiopods, trilobites, bivalves, and tentaculoids.

Stratotype: Bostów IG-1 borehole between 0 and 218 m depth. The core is not preserved. A detailed log of the borehole was published by TOMCZYKOWA (1969).

Boundaries: The lower boundary is defined at the base of the first bed of fine-grained sandstone at 218 m depth in the stratotype borehole section (Text-fig. 7). The upper boundary is known only from the Bostów-Łomno 4 shaft-section (TOMCZYKOWA 1969); the boundary succession is represented by a rapid, but conformable transition of brittle quartz sandstones and mudstones of the Bostów Formation into siliceous, strongly cemented sandstones ("quartzites") of the Barcza Formation (Text-fig. 7), with the boundary placed at the base of the first bed of fine-grained, hard siliceous quartz sandstones. The rapid change in lithology can reflect a sedimentary (or tectonic) gap, between Upper Lochkovian and Emsian strata.

Thickness: About 250 m, based on archive borehole data and excavations near Bostów (TOMCZYKOWA 1969).

Regional distribution: The formation is known only from its type locality. In the eastern part of the area, in the vicinity of Czerwona Góra, clayey shales containing the lowermost Lochkovian trilobite, *Acastella tiro*, correspond lithologically to the definition of the Rudki Formation. In the Lublin area, its equivalent is the Scyna Formation, which is similar in facies and faunal assemblage (MIŁACZEWSKI 1981). In the Ciepielów IG-1 borehole, located 50 km northeastwards of Bostów, the Scyna Formation is *ca*. 400 m thick (based on MIŁACZEWSKI 1981; PORĘBSKA 2003).

Chronostratigraphy: The occurrence, in the Bostów IG-1 stratotype borehole succession, of the earliest Devonian graptolites of the *Monograptus uniformis* group in the topmost part of the Rudki Formation, just below the base of the Bostów Formation, proves unequivocally that the base of the Bostów Formation lies above the Silurian/Devonian boundary. According to TOMCZYKOWA (1991), the lower part of the Bostów Formation contains the trilobite *Acastella tiro* and its uppermost part contains the trilobites *Proacanthina praejonesi* and *Acastella roualti*, which document its Lower to Upper Lochkovian (*hercynicus* Zone, cf. GANDL 1972) age.

Genetic interpretation: The formation, as revealed by its faunal assemblage and lithology, represents a shallow-marine (near wave base) environment. The upward lithological change (increased sandstone content), associated with the appearance of extremely shallow-marine trilobites of the family Homalonotidae, suggest a shallowing trend within an open marine environment.

DISCUSSION

Southern boundary of the Łysogóry region – a Silurian perspective

In the traditional view, the boundary between the Kielce and Łysogóry regions is identified with the Holy Cross Fault (HCF) (e.g. CZARNOCKI 1950, see Text-fig. 1) which is probably related to a deep crustal fracture (e.g. DADLEZ 2001). However, the affiliation of some areas (the Gruchawka - described by MALEC 1993, 2001; and Lipniczek areas – see Text-fig. 1) located close to the HCF remains controversial. In his recent summary of the Silurian stratigraphy in the HCM MALEC (2006) included one of these areas (Gruchawka) in the Łysogóry Region (see also NARKIEWICZ 2002), but retained the other (Lipniczek) in the Kielce Region. Consequently, the lithostratigraphical units defined in the Gruchawka area (Kielce Beds, Miedziana Góra Conglomerate, see Text-fig. 3) were moved to the Łysogóry stratigraphical scheme, whereas the "Lipniczek mudstones" unit (assigned to the Winnica Formation in this paper), defined in the Lipniczek area, was placed in the Kielce Region column. These opinions are not followed here, for the reasons discussed below.

According to NARKIEWICZ (2002), the boundary between the Łysogóry and Kielce regions corresponds to the HCF only in the eastern part of the HCM. Instead, in the western part of the HCM this boundary is located south of the town of Kielce (Text-fig. 1). This assumption is based on (NARKIEWICZ 2002, p. 256): (1) the shift of the regional strike in the western part of the HCM; (2) Devonian facies organization in this area; (3) thermal maturity data; and (4) the presence of clasts of Cambrian sandstones with alleged Łysogóry provenance (Wiśniówka Formation) in the Miedziana Góra Conglomerate (e.g. KOWALCZEWSKI & *al.* 1998; MALEC 2001, MALEC 2006).

The first two arguments are connected with post-Silurian events and are thus irrelevant to the identification of the palaeodomain organization in the early Palaeozoic. The age of the thermal maturity imprint is very controversial. The NARKIEWICZ (2002, p. 260, fig. 6) argument in favour of a pre-Variscan age of the thermal record in the pre-Devonian strata is not convincing, in my opinion. The Łysogóry provenance of the MGC clasts is disputable (see detailed discussion of SZULCZEWSKI 2006, and references therein). The main argument of MALEC (2001) for the Łysogóry provenance of the MGC clasts is the increase in thickness of the MGC towards the north-west. The field data (see Text-fig. 1), however, are equivocal; the outcrops analyzed are situated along a single line, oriented close to the regional strike (– i.e. ~ 110°, see Text-fig.1), and thus perpendicular to the theoretical shortest transport direction from the Łysogóry area (i.e. ~ 200°). The geographical distribution and number of outcrops also weakens an interpretation based on the grain size and roundness of the clasts. MALEC (2001) additionally postulated that the MGC clasts correspond to quartzitic sandstones of the Wiśniówka Sandstone Formation (Furongian), which form the Main Range of the Holy Cross Mts. (Łysogóry Area). This conclusion is based on the similarity of the grain size of the sandstones (see MALEC 2001 p. 411) and on other unspecified resemblances, which are not convincing. It is worth noting that CZARNOCKI (1936), who first expressed an opinion about the 'Łysogóry source area' of the clasts in the MGC, did not base his conclusion solely on the lithological resemblance, but also on the presence of numerous specimens of the trilobite *Paradoxides tessini* (CZARNOCKI 1936, p. 131 – footnote), found in one of the sandstone clasts. However, this species evidences the middle Cambrian age of the source rocks which, according to present knowledge, contradicts the Łysogóry provenance of this material. The Łysogóry Region lacks Cambrian sandstones of this age, and moreover, the middle Cambrian sandstone facies is typical of the Cambrian of the Kielce Region (e.g. KOWALCZEWSKI & *al.* 2006). Additionally contradicting CZARNOCKI's (1936) interpretation is the presence in the MGC of clasts of Ordovician glauconitic sandstone (CZARNOCKI 1936), a facies known exclusively from the Kielce Region.

Another contradiction to the 'Łysogóry source area' of the MGC clasts comes from the palaeogeographic evolution of the Łysogóry Region. From as early as the mid Ordovician up to to the Lochkovian this region was a site of continuous (mostly marine) sedimentation (Text-fig. 2). It is also significant that no clasts of pre-upper Silurian rocks have been observed in the Silurian and Lower Devonian deposits of the Łysogóry Region, and that the conglomerate intercalations in the "Klonów Beds" (KOWALCZEWSKI & *al.* 1998, p. 355) comprise exclusively intrabasinal intraclasts. The arguments above, plus the sedimentary record in the Łysogóry Region, show that, by the end of the Silurian, upper Cambrian (Furongian) rocks of the Wiśniówka Formation building the elevations of the Main Range (parallel to the Variscan strike), were covered (SZULCZEWSKI 1995, 2006) by strata at least 2.5 km thick (Nowa Słupia Group and older rocks), and as such could not have formed a morphological elevation providing a source area for the "surrounding" basins (compare with KOWALCZEWSKI & *al.* 1998; MALEC 2001, 2006). As a consequence, the development of the MGC must have been associated with the late Silurian/Early Devonian (Caledonian) tectonic events, which were exclusive to the Kielce Region. Based on the scale of exhumation, evidenced by the total thickness of Ordovician and Silurian strata removed, the calculated amplitude of the late Silurian vertical movements in that region would have been least 500 m and most probably even as much as about 1000 m. There are no signs of such movements in the "Silurian Zone" or Bronkowice-Wydryszów Anticline of the Łysogóry Region.

The second area with controversial regional affiliation is the Lipniczek area, in the eastern part of the Holy Cross Mountains (Text-fig. 1). In the Lipniczek outcrop occur uppermost Ludlovian shallow-marine rocks referred to by TOMCZYKOWA (*fide* TOMCZYK 1962) as the "Lipniczek mudstones". Based on their geographical position (south of the interpolated strike of the HCF), these deposits were recently assigned to the Kielce Region (MALEC 2006). This view, however, is contradicted both by their development and by their tectonic position. According to TOMCZYKOWA & TOMCZYK (2000), they are situated in the Variscan Lipniczek Graben (see Text-figs 1, 4), a tectonic unit that is entirely distinct from the adjacent Międzygórz Syncline (*op. cit*. fig. 3). The succession, forming a simple homoclinal structure within the Lipniczek Graben, is composed of the Cambrian (Wiśniówka Formation), represented by the Łysogóry facies (DOWGIAŁŁO 1974), followed by Łysogóry-type Silurian facies [Trochowiny Formation, Winnica Formation (= "Lipniczek mudstones")], and succeeded by the Devonian, with apparently no Silurian/Devonian boundary unconformity. The entire Lipniczek structure lies in the direct neighbourhood of the interpolated HCF, and thus substantial tectonic remodelling is not required in the interpretation of TOMCZYKOWA & TOMCZYK (2000). According to these authors and myself, the HCF is located to the south of the Lipniczek area and may be identified as the southern limit of the exposure of the Wiśniówka Formation near the village of Lipnik (see Text-fig. 1). The controversial Lipniczek area consequently belongs to the Łysogóry Region.

Sedimentary development and regional significance of the Nowa Słupia Group

In the Łysogóry Region the deposition of the Nowa Słupia Group is preceded by a long (Llandoverian – early Ludlovian) period of slow pelagic sedimentation represented by graptolitic shales (Text-figs 2, 8). Acceleration of the sedimentation rate started in the late Silurian and a turning point came in the early Ludfordian with the onset of synorogenic sedimentation. The basal part of the Nowa Słupia Group is represented by the Trzcianka Formation, comprising the deposits of the turbidity currents, and representing the gradual infilling of the foreland basin during the underfilled stage (see COVEY 1986, ETTENSOHN 2004). The transition of turbidite-influenced deposits to traction- and suspension-influenced sediments of a prodeltaic mudstone wedge (Trochowiny Formation) probably separates deposits formed on the slope from deposits formed on the top of a clastic wedge infilling the basin (see MUTTI & *al.* 2003). At the scale of observation (~ 80 km in a line parallel to the transport directions) and at an assumed high rate of deposition, the boundary between the Trzcianka and Trochowiny formations is probably isochronous (Text-fig. 8). With the end of deposition of the Trochowiny Formation, a distinct regressive episode took place. The Jadowniki Member of the Winnica Formation probably marks the culmination of shallowing – resulting from basin filling by clastic sediments combined with eustatic regression (KOZŁOWSKI 2003). The younger formations represent the filled-overfilled stage of the basin development (see COVEY 1986, ETTENSOHN 2004), which is characterized by lateral migrations of two independent facies, most probably due to eustatic fluctuations. Continental red-beds facies probably formed west of the part of the basin studied, around the arc-continent orogen, since the beginning of the Ludlovian. Open-shelf facies (Podlasie facies*) occur mainly to the east of the Łysogóry Region in the Lublin area, which was a deep intra-shelf basin at that time. Data from the Ciepielów IG-1 borehole (TOMCZYK 1974) show that deposits of the Podlasie facies built the entire upper Silurian succession in an area at least up to 50 km to the northeast of the Łysogóry Region. A narrow zone dominated by shallow-marine sedimentation is located at the boundary between the two wide facies zones. Its lateral migrations are marked in the succession by thin horizons of neritic sediments yielding rich benthic faunas. During the time of sedimentation of the Winnica and Rachtanka formations, the western limit of the occurrence of the Jadowniki Member (oolitic beds), which corresponds to the maximum eastwards range of the contemporaneous continental deposits in the western part of the area (Rachtanka Formation), ran between Bronkowice and Rzepin and the vicinity of Cegielnia near Rudki and Winnica (Text-fig. 4E-z). Such orientation (NNW-SSE) of the facies zones is confirmed by the presence of upper Silurian shallow-marine deposits observed in deep boreholes NNW of the HCM area (Lisów-1, Szwejki-1, Karnkowo-1 see TOMCZYK 1987). The first regressive event was followed by a distinct marine ingression that covered the entire Łysogóry Region (Text-fig. 8). The graptolites, nautiloids and bivalves yielded by the clayey shales of the Sarnia Zwola Formation, corresponding to the Podlasie facies, point to an open-shelf environment. A more proximal environment is evidenced by the benthic fauna in the probably contemporaneous Bronkowice Formation, in the western part of the area. These deposits were followed by the continental red-beds (Podchełmie Formation, Text-fig. 8), which covered the whole Łysogóry Region but did not reach as far as the Ciepielów IG-1 borehole on its north-eastern margin. Marine conditions returned close to the Silurian/Devonian boundary. The fossiliferous clayey shales (Podlasie facies) of the Rudki Formation, known from the vicinity of Rudki-Bostów and Czerwona Góra, with graptolites, cephalopods, bivalves and *Scyphocrinites* crinoids (CZARNOCKI 1950; FILONOWICZ 1969), point to a probably wide-ranging transgression covering the entire Łysogóry Region. Gradual shallowing marks the succeeding Bostów Formation, of middle and late

*To the „Podlasie Facies" are assigned clayey pelagic sediments, generally green, grey or dark grey in colour with nautiloids, rare graptolites and a characteristic bivalve assemblage (*Pterochaenia, Lunulicardium, Pterinopecten, Cardiola, Dualina*).

Lochkovian age. However, even its uppermost part still yields typical outer shelf fauna and contains no signs of marginal marine deposits (TOMCZYKOWA 1969), and/or a gradual transition to distal Old Red facies (cf. the lithological succession of the Ciepielów IG-1 Borehole – TOMCZYKOWA 1974a, b). It can thus be assumed that an erosional episode took place in the Łysogóry Region between the Lochkovian and Emsian, resulting in a probable disconformity between the Nowa Słupia Group and the overlying Devonian sediments. On the other hand, the lack of marginal-marine deposits from this missing interval could have been a result of tectonic reduction, which could also have caused significant reductions in thickness of the upper part of the Nowa Słupia Group (see above).

The Nowa Słupia Group succession may be interpreted as a complete record of the development of a foreland basin (see COVEY 1986) – from pelagic, through flysch-like and prodelta-type sediments (underfilled stage), to shallow-marine and terrestrial deposits (filled and overfilled stages; Text-fig. 8). The described succession is also very similar to the development of several clastic wedges observed in the Appalachian Foreland Basin (e.g. the "Catskill Delta", see ETTENSOHN 2004). This type of evolution is common for early (arc-continent) subduction type orogenies on a continental margin (ETTENSOHN 2004). The general bathymetric change (shallowing) can be interpreted as a result of a sequence of flexural to infilling events, however with a possible significant influence of eustacy in the upper part of the foreland infill (ETTENSOHN 2004). The lower part of the Nowa Słupia Group (Trzcianka and Trochowiny formations) probably represents flexural-related filling of the basin. On the other hand, late Silurian (Pridolian) facies migrations, observed in the upper part of the group, show many similarities to sea-level oscillations in the interior part of the Laurussia shelf (LAZAUSKIENE & *al.* 2003), and correspond to the eustatic sea level curve of JOHNSON & *al.* (1998). The oscillatory nature of the changes in the sedimentary environment in the study area was most probably dependent on the high susceptibility of sedimentation to eustatic factors resulting from the earlier filling of the basin and the formation of a subtle equilibrium between deposition and subsidence rates (cf. POSAMENTIER & ALLEN 1993).

Relationship between the Łysogóry and Kielce Regions during the Silurian

The sedimentary development of the Łysogóry Region resembles in many aspects the record known from the adjacent Kielce Region to the south. The most important similarities which support the uniformity of both basins in the Silurian are:

1) The transition of Ordovician trilobite-bearing mudstone facies into dark graptolitic shales at the the base of the Silurian (e.g. TOMCZYK 1962, 1970);

2) Extremely low sedimentation rate in the Llandoverian with characteristic siliceous dark shales (e.g. TOMCZYK 1962);

3) A distinctly higher sedimentation rate in the upper part of the graptolitic shales* (Wenlockian and particularly lower Ludlovian);

4) The transition into flysch-like greywacke deposits succeeded by hemipelagic clayey-silty-dominated wedge-top sediments in the early Ludlovian; probably a little bit earlier in the Kielce Region (see footnote);

5) Similar source material of the synorogenic Ludlovian greywackes with similar transport directions (KOZŁOWSKI & *al.* 2004).

The similarities in sedimentary development in both regions during the Hirnantian through the Ludlovian, suggest that the Kielce and Łysogóry regions were parts of a single, large foreland basin at the south-western margin of Baltica (KOZŁOWSKI & *al.* 2004, see also JAWOROWSKI 1971). In contrast, NARKIEWICZ (2002) postulated two different basins in the Silurian of the HCM: a foreland basin in the Łysogóry Region and a stable cratonic basin in the Kielce Region. His interpretation is based on the comparison of tectonic subsidence curves from both areas. However, the usefulness (Zbrza Anticline curve), or correctness (Bardo Syncline curves) respectively of curves constructed for the Kielce Region in the model of NARKIEWICZ (2002) is questionable. The subsidence curve for the Zbrza Anticline should not be taken into account in the interpretation of the basin type, because this tectonic unit lacks upper Silurian deposits (Text-fig. 2). In turn, the subsidence curves for the Bardo Syncline have been based on doubtful litho- and chronostratigraphic data. The 100 m thickness of the Niewachlów greywackes in the Bardo Syncline assumed by NARKIEWICZ (2002) in variant A (after STUPNICKA & *al.* 1991) is evidently too low (see also discussion in KOZŁOWSKI 2003). Analysis of

* The difference in the thickness of the Lower Siluirian graptolitic shales (150 m in Kielce Region and 250 m in Łysogóry Region) is mainly a result of the distinct thickness variability of the graptolitic shales of the *leintwardinensis* Zone. In the Łysogóry Region, the graptolitic shales of this zone are about 150 m thick (based on DECZKOWSKI & TOMCZYK 1969a), whereas in the Kielce Region these sediments are only 5-30 m thick (based on TOMCZYK 1956, fig. 7 and TOMCZYK 1962, fig. 9). This difference is probably due to a slightly earlier beginning of greywacke facies development in the Kielce sub-basin.

maps of the Bardo region shows that the 250 m thickness (after ROMANEK & RUP 1989) in his variant B is more probable (Text-fig. 2). It is very important to remember that in the Bardo sections there are no unambiguous signs of bathymetric changes, particularly for shallowing of the basin in the late Ludlovian (see KOZŁOWSKI & TOMCZYKOWA 1999, MALEC 2006), hence the bathymetric correction is unjustified (compare NARKIEWICZ 2002 p. 259). The observed thickness of the Silurian greywackes in the axis of the Bardo Syncline is not complete, because the Silurian strata there underwent pre-Emsian erosion of unknown extent (Text-fig. 2). Moreover, the assumed duration of greywacke deposition of the Bardo Syncline (4 Ma – according to the scale in fig. 4. of NARKIEWICZ 2002) is unjustified, because these sediments probably correspond only to the upper *leintwardinensis* and *bohemicus* zones (see KOZŁOWSKI & TOMCZYKOWA 1999); the duration of greywacke sedimentation can therefore be estimated at up to 2 Ma. Taking into account all these constraints, the shape of the tectonic subsidence curve for the Bardo Syncline may become very close or even identical to the curve from the Łysogóry Region in the part preceding Caledonian movements in the Kielce Region (see also variant A in fig. 4 of NARKIEWICZ 2002).

Despite the significant similarities in the general evolution, timing of the sedimentary development and probably also the subsidence curve, at least between the Llandovery and Ludfordian, some differences in development of foreland infill between the Kielce and Łysogóry Regions can be observed. The most important of these are as follows (see also Text-fig. 2):

1) A somewhat earlier start of the turbidite sedimentation in the Kielce region (see above);

2) Petrofacies and lithofacies differences between the upper Silurian greywackes (i.e. lower maturity of the Niewachlów Beds than of the Trzcianka Formation) (KOZŁOWSKI & *al.* 2004);

3) The occurrence in the Kielce Region of the post-Ludlovian/pre-?Emsian (Caledonian) tectonic event (see discussion in SZULCZEWSKI 2006), registered as angular unconformities and/or uplift, exhumation and erosion of older Palaeozoic strata.

4) The occurrence of post-greywacke shallow-marine and fluvial sedimentation in the Łysogóry Region (Rzepin beds *sensu* CZARNOCKI 1936), not present in the Kielce Region.

Although the listed differences may lead to the conclusion that both regions were palaeogeographically independent (two sub-basins) in the Silurian, they can easily be explained by a more proximal position of the Kielce Region and relatively distal position of the Łysogóry Region in relation to the same orogen, within a single foreland basin (KOZŁOWSKI & *al.* 2004). Thus, the present-day spatial relationship of the Kielce and Łysogóry regions probably resulted from post-Silurian (most probably Variscan) small-scale tectonic remodelling (undetectable by palaeomagnetic methods), realised by left-lateral strike-slip along a deep fracture related to the Holy Cross Fault, which is in opposition to the interpretation of NARKIEWICZ (2002, p. 263 and his fig. 7) and also to the recent tectonic analysis by KONON (2007). As a result, what we observe today are two separate parts of a single foreland basin [(distal (Łysogóry Region) vs. proximal (Kielce Region)], lying adjacent to one another along a boundary parallel to the general directions of material transport within the basin and perpendicular to the general strike of the facies belts. The commonly noted sizes of foreland basins, particularly those linked with arc-continent orogens (e.g. COVEY 1986), considerably restrict the extent of the assumed slip, which can be estimated at most at 100-200 km.

CONCLUSIONS

1. Formations distinguished within the Nowa Słupia Group (Ludlovian to Lochkovian): Trzcianka, Trochowiny, Rachtanka, Winnica, Bronkowice, Sarnia Zwola, Podchełmie, Rudki, and Bostów formations attain a total thickness of about 2.5 km.

2. The Silurian succession of the Łysogóry Region in the HCM displays continuous sedimentation and represents a complete, model development of a foreland basin (see e.g. COVEY 1986; ETTENSOHN 2004) with distinct subsequent underfilled and filled-overfilled phases and a typical subsidence evolution (NARKIEWICZ 2002), which is confirmed by the thicknesses of the particular lithosomes.

3. The pattern of facies zones in the upper Silurian from the Łysogóry Region is generally NNW-SSE-oriented, which confirms earlier observations by CZARNOCKI (1936, 1950). This pattern is also parallel to the SW margin of Baltica and facies zones within the Baltica shelf. However, in the Łysogóry Region, the proximal to land facies occur to the west, whereas more distal sediments occupy the eastern part of the area – contrary to what is observed in the Baltica mainland neritic zone.

4. The Nowa Słupia Group records a continuous, dynamic sedimentation in Ludlovian to Lochkovian times in the Łysogóry sub-basin. Deep post-Ludlovian exhumation of older paleosoic rocks, typical of the Kielce Region, is not marked in the history of this sub-basin. In my opinion the differences between the sub-

basins discussed in the text support left-lateral rather than right-lateral (e.g. NARKIEWICZ 2002) post-Silurian strike-slip shift between the Kielce and Łysogóry regions.

5. The sedimentary history of the Łysogóry subbasin during the filled-overfilled stage shows very high correlation with the Silurian eustatic curve of JOHNSON & *al.* (1998). Therefore, until a more detailed biostratigraphic analysis is presented, the stratigraphic correlation based on eustatic events proposed herein seems to be the most useful.

6. As a rule, the upper part of the Nowa Słupia Group underwent variable tectonic reduction, probably as a result of the overthrust by the Emsian Barcza Formation. Cartographic analysis indicates the common presence of subordinate overthrusts also within the Silurian succession.

Acknowledgements

I would like to express my warmest gratitude to Prof. Stanisław SKOMPSKI and Prof. Ireneusz WALASZCZYK for numerous suggestions and support. Cordial thanks are due to the journal referees, Prof. Marek NARKIEWICZ (Polish Geological Institute), and Prof. Michał SZULCZEWSKI (Warsaw University). Thanks are also due to Anna ŻYLIŃSKA for the translation of the manuscript and to Bogusław 'Bodi' WAKSMUNDZKI for numerous discussions. The research was supported by the Institute of Geology, University of Warsaw (individual BW Grant 2007). Financial support for the author was supplied by the Foundation for Polish Science (Domestic Grant for Young Scientist 2007).

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Manuscript submitted: 30th June 2007
Revision version accepted: 10th December 2007

PLATES 1-4

PLATE 1

1 – Greywackes interbedded with mudstones and shales of the lower part of the Trzcianka Formation. Right bank of the Słupianka river valley near the village of Dębniak, south of Nowa Słupia.

2 – Mudstone-shale complex with few greywacke intercalations (arrowed) – upper part of the Trzcianka Formation in the Serwis outcrop north of Nowa Słupia.

3 – Graded bedding in a greywacke bed of the Trzcianka Formation. Right bank of the Słupianka river valley near the village of Dębniak, south of Nowa Słupia.

4-5 – Clay to mud shales with siltstone intercalations (arrowed) – Trochowiny Formation. Left bank of the Pokrzywianka river near the village of Trochowiny (Stratotype of the formation).

6 – Thick sandstone bed in the shale complex of the Brogowiec Member – upper part of the Trochowiny Formation. Note the erosive type of the sandstone bed bottom (arrowed). Quarry on the north slope of the Świślina river valley north of Brogowiec hamlet near Bronkowice.

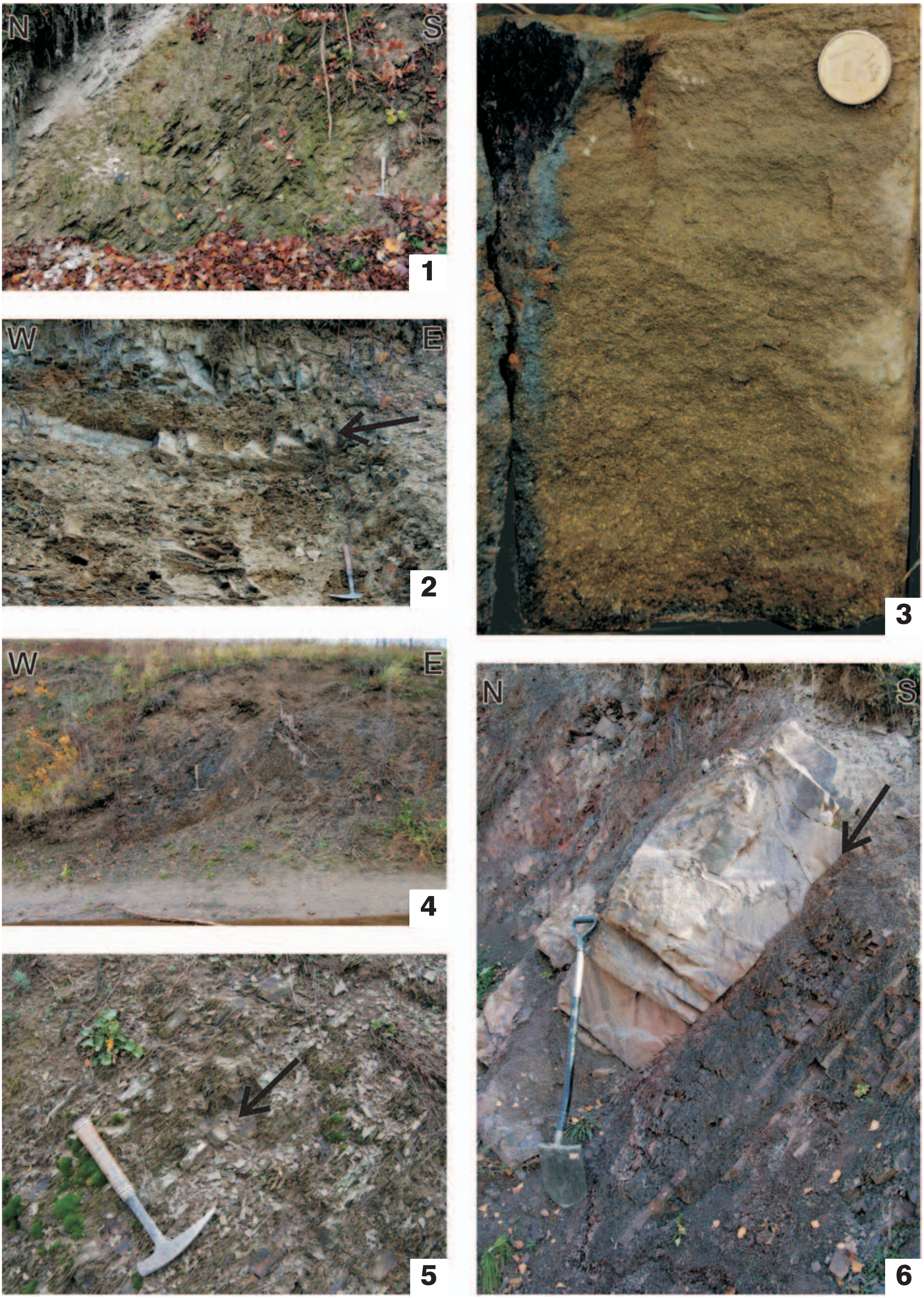
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PLATE 2

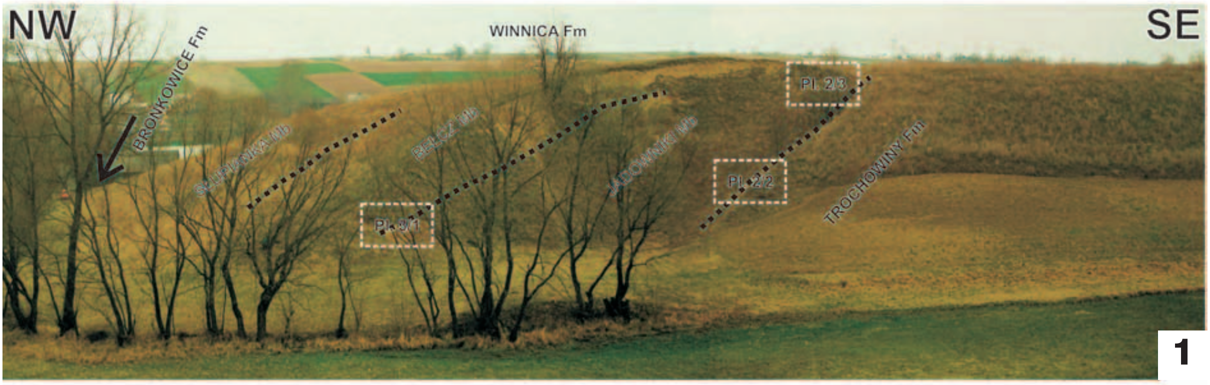
1 – Rzepin I section and Romański Quarry near the village of Jadowniki Dolne (reversed dips).

2 – Stratotype of the lower boundary of the Winnica Formation in the southern wall of the Romański Quarry. The boundary is the bottom of the sandstone-oolite complex (Jadowniki Member). For detailed localtion see Pl. 2, Fig. 1.

3 – Oolite limestones in the eastern wall of the Romański Quarry (Jadowniki Member, reversed dips). For detailed localtion see Pl. 2, Fig. 1.

4 – Lower boundary of the Rachtanka Formation in the Winnica section (shaft I). The red mudstones of the formation cover the leperditicopid limestones of the Bełcz Member – regressive phase of the Winnica Formation.

5 – Red mudstones with intercalations of green sandstones (arrowed) with tabular bedding (Rachtanka Formation). Winnca (shaft II) section near Nowa Słupia.


NW
SE
WINNICA Fm
BRONKOWICE Fm
BEŁCZ Mb
JADOWNIKI Mb
Pl. 3/1
Pl. 2/2
Pl. 2/3
TROCHOWINY Fm
1


N
S
WINNICA Fm.
TROCHOWINY Fm.
2


N
S
3


W
E
RACHTANKA Fm.
BEŁCZ Fm.
(WINNICA Fm.)
4


N
S
5

PLATE 3

1 – Stratotype of the boundary between the Jadowniki Member and Bełcz Member in the top of the last oolitic bed in the northwestern wall of the Romański Quarry near Jadowniki Dolne (reversed dips). For detailed localtion see Pl. 2, Fig. 1.

2 – Winnica outcrop in the right bank of the Słupianka river near Winnica hamlet of the village of Stara Słupia. Shales, mudstones, siltstones and limestones of the Słupianka Member (Winnica Formation) – for more details see Pl. 3, Fig. 4.

3 – Upper boundary of the Rachtanka Formation in the Winnica section (shaft III). The red mudstones of the Rachtanka Formation are covered by leperditicopid limestones of the Bełcz Member. The boundary is located in the top of the last red mudstone bed.

4 – Fragment of section showing a typical cyclothem of the Słupianka Member of the Winnica Formation. The limestone bed (bioclastic-algal packstone in this case – A) of the older cycle is covered by clayey shales ("Nuculites shales" – B) succeeded by mudstones with specific marginal-marine fauna (C). Winnica outcrop near Nowa Słupia.

5 – Green clayey shales of the Sarnia Zwola Formation ("Podlasie Facies") in an outcrop on the right slope of the Dobruchna river valley near the village of Dobruchna.

6 – Fragment of a detailed section of sediments of the Sarnia Zwola Formation. Note lamination of the thicker clayey beds (arrowed). Dobruchna outcrop.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BELCZ Mb.
(WINNICA Fm.)
JADOWNIKI Mb.
(WINNICA Fm.)
1


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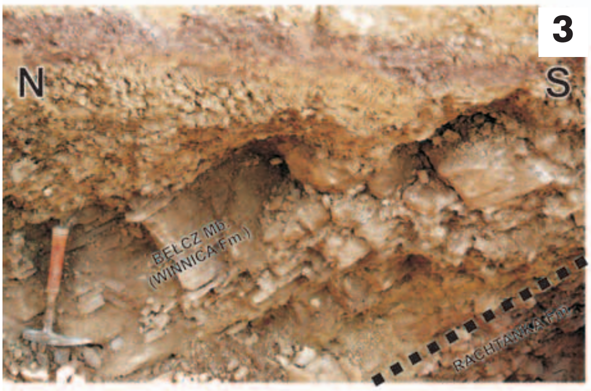
3
N
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(WINNICA Fm.)
RACHTANKA Fm.

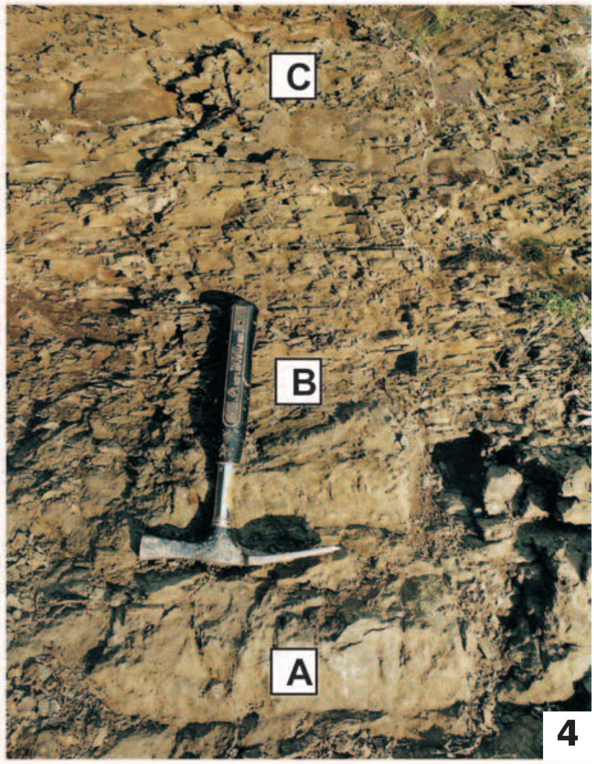
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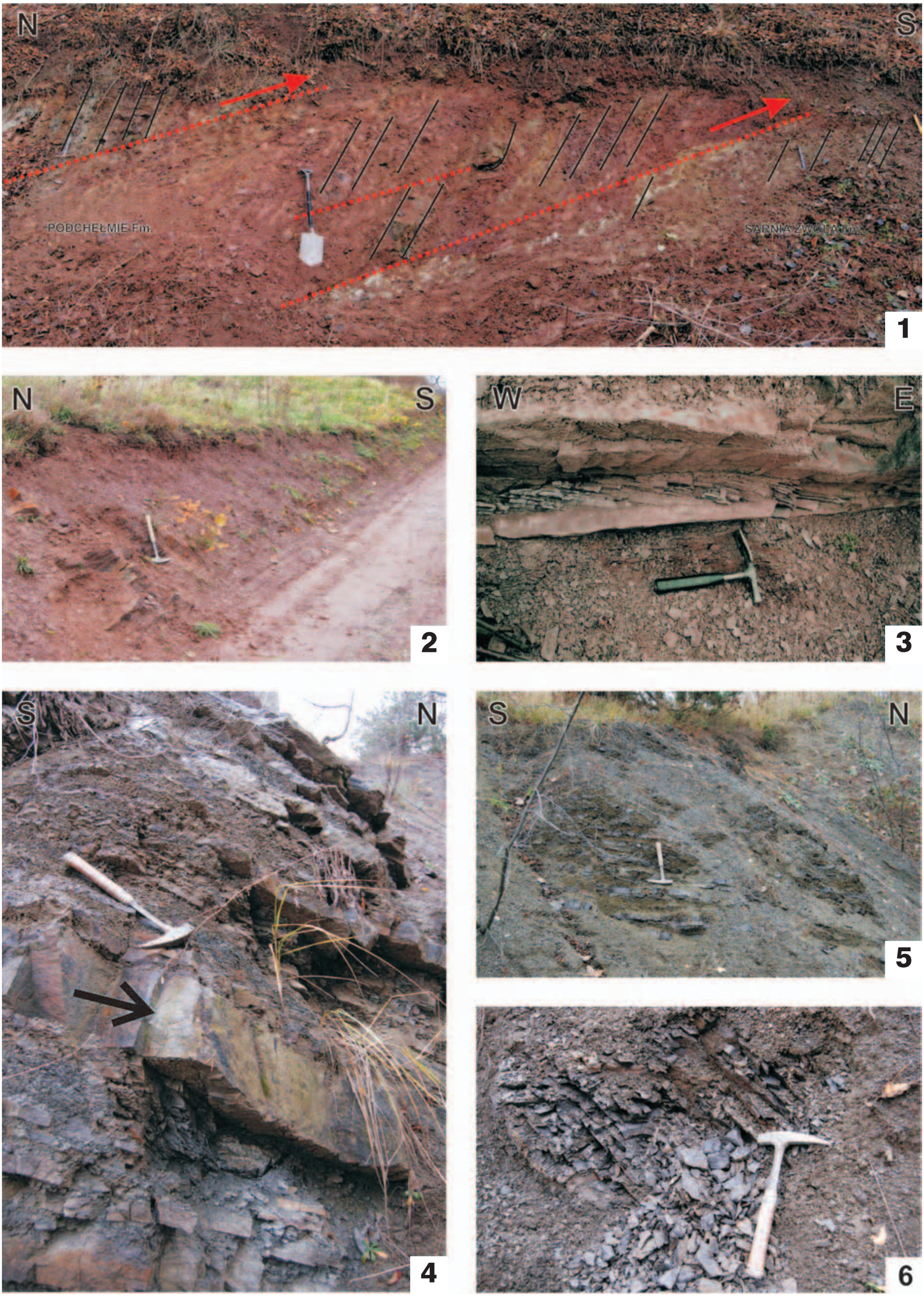
PLATE 4

1 – Tectonic contact between the Sarnia Zwola Formation and the Podchełmie Formation in the Szczegło outcrop. The fault between the formations is a case of a south vergent overthrusts which are probably the main reason for the width of the outcrop anomalies in the “Silurian Zone” of the Łysogóry Unit (compare Text-fig. 5).
2 – Podchełmie outcrop on the northern slope of the Nowa Słupia – Podchełmie road cutting. Red tabular-bedded sandstones and mudstones are present.
3 – Fragment of the detailed section of the Podchełmie Formation. The red clayey shales are covered with an erosive contact by the tabular-cross bedded red sandstones succeeded by red mudstones and clays. The outcrop documents the eastern direction of transport. Podchełmie outcrop.
4 – Fragment of the succession transitional between the Podchełmie Formation and Rudki Formation (Sosnówka complex) cropping out in the Rudki exposure. The green shales with red sandstone beds (arrowed) and small limestone lenses are covered by green to dark gray shales interbedded with green calcareous sandstones and siltstones.
5 – Lower part of the Rudki Formation – dark-grey shales interbedded with thin sandstone beds. Rudki outcrop.
6 – Higher part of the Rudki Formation – dark grey clayey shales with rich open shelf fossils (“Podlasie facies”). Rudki outcrop.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SARNIA ZWOLA Fm.
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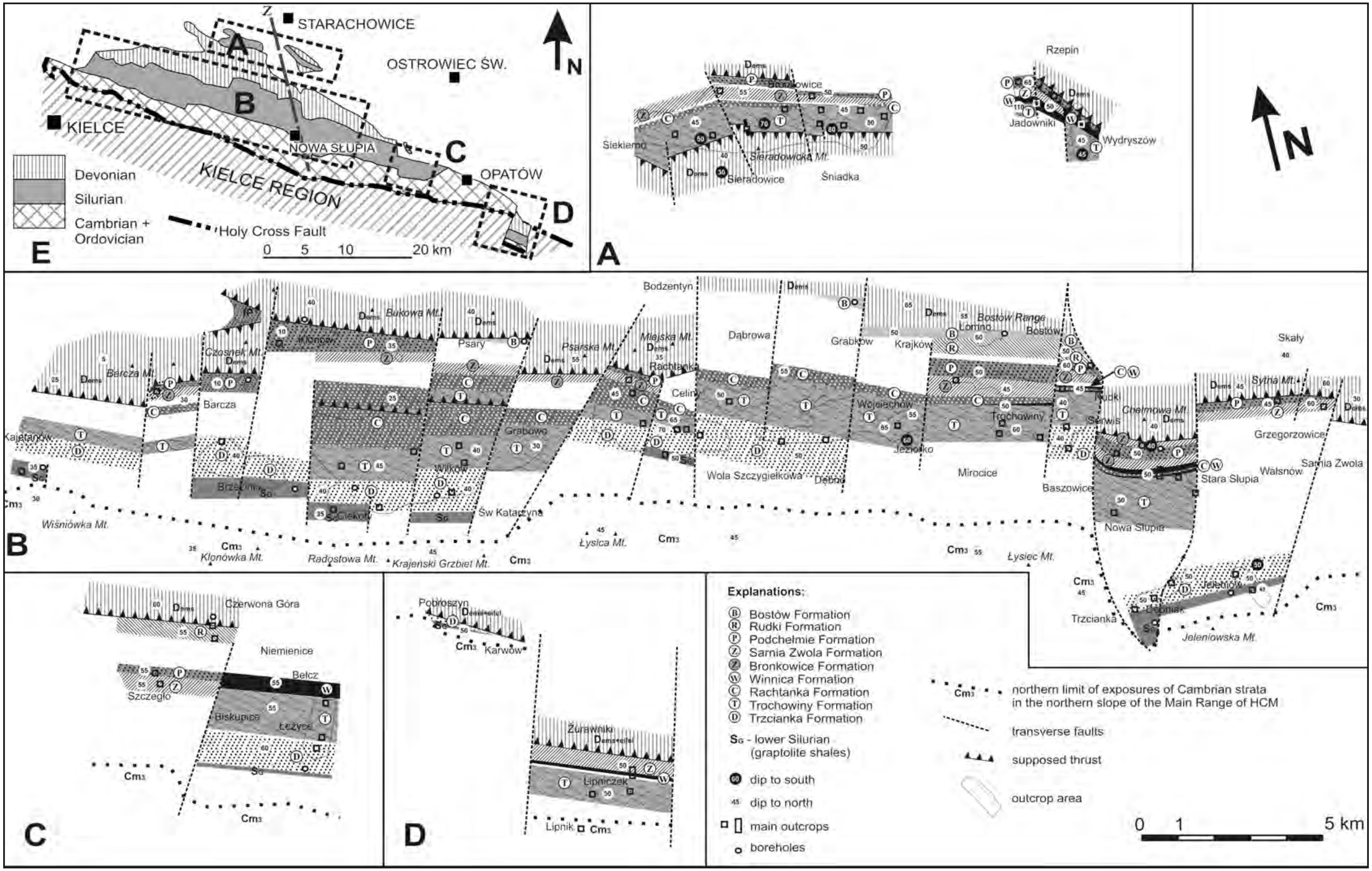

Fig. 4. Geological uncovered sketch maps of the Silurian formations in the Łysogóry Region (A-D) with location on the general geological map of the northern part of the HCM (E); cartographic data of DULSKI (1961), ZAGÓRSKI (1961), FILONOWICZ (1968, 1969) and unpublished data of TOMCZYKOWA.