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MOLLUSCS OF THE EEMIAN INTERGLACIAL IN POLAND

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Abstract: Shells of subfossil snails and bivalves commonly noted in deposits of the Eemian Interglacial were used by several authors as more or less important stratigraphic indicators. In Poland, they have been noted in 35 sections, 20 of which are described as basic ones. Molluscan assemblages found at these sites include 60 species of freshwater molluscs and 58 species of land snails, the former being dominant. Climatic tolerance of particular species is the main attribute deciding on their stratigraphic values. Cold-tolerant snails are typical of the preceding Late Glacial and some of them occur also in early phases of the interglacial, while species connected with moderate climate and warm-demanding ones characterise the middle part of the Eemian Interglacial. The freshwater snail *Belgrandia marginata* is typical of the climatic optimum of this interglacial. Particular species of molluscs were related to regional pollen assemblage zones of the Eemian Interglacial in Poland.

Key words: Eemian Interglacial, basic and supplementary sections, molluscan assemblages, malacostratigraphy, Poland.

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INTRODUCTON

More or less rich assemblages of molluscs occur in different deposits of the last interglacial in Poland, mainly in lacustrine chalk, calcareous gyttja and marls. They were noted as early as in the second half of the 19th century in few outcrops from Pomerania and Lower Silesia, at first in publications by German geologists (W. Bau, G. Berendt, E. Beyrich, Gisevius, R. Goppert, G. Gürich, A. Jentzsch, K. Keilhack, G. Maas), listed by Głodek and Wardęska (1952). During the inter-war period and particularly after the Second World War, these deposits containing subfossil fauna were found at several localities in northern and central Poland as well as in western Belorus and southern Lithuania. Mollusc communities have been identified, reported or even described by Urbański (1951, 1954), Makowska (1970, 1971, 1979), Skompski (1980, 1983, 1996), S.W. Alexandrowicz (1987, 1994, 1997), Ciszewska (1989, 1996) and other authors. Freshwater snails and bivalves occur frequently as most numerous components of assemblages in question whereas shells of land snails are found only locally and rarely. Marine molluscs reported from Eemian deposits close to the coast of the Baltic Sea, particularly along the lower course of the Vistula River, studied in detail by Brodniewicz (1960, 1969) and Makowska (1979, 1986), were not regarded here.

All sections of the Eemian mollusc-bearing deposits known and reported until now in Poland (33 localities) were taken into consideration (Fig. 1). These are both sections described by present authors and characterised or mentioned by other ones. The range of information enclosed in particular publications is very uneven. Only in a limited part of papers there are tabulated lists of taxa identified from sequences of sediments, which occur in succeeding layers or in samples collected in stratigraphic order. Many others contain solely more or less complete data about species found at particular sites of interglacial deposits treated as a whole. The number of specimens forming each community or even symbols indicating their approximate quantity is most often completely omitted. Additionally, different authors in numerous other places noted exclusively the occurrence of single species of not identified mollusc shells and even only of shell detritus. Diagrams illustrating the composition of mollusc assemblages and their successions were presented a few times only: the diagram – in one section (W.P. Alexandrowicz, 2008), and spectra of species and specimens – in four sections (S.W. Alexandrowicz, 1994, 1997).

Our main purpose was to complete all details concerning the assemblages of molluscs of the last interglacial in

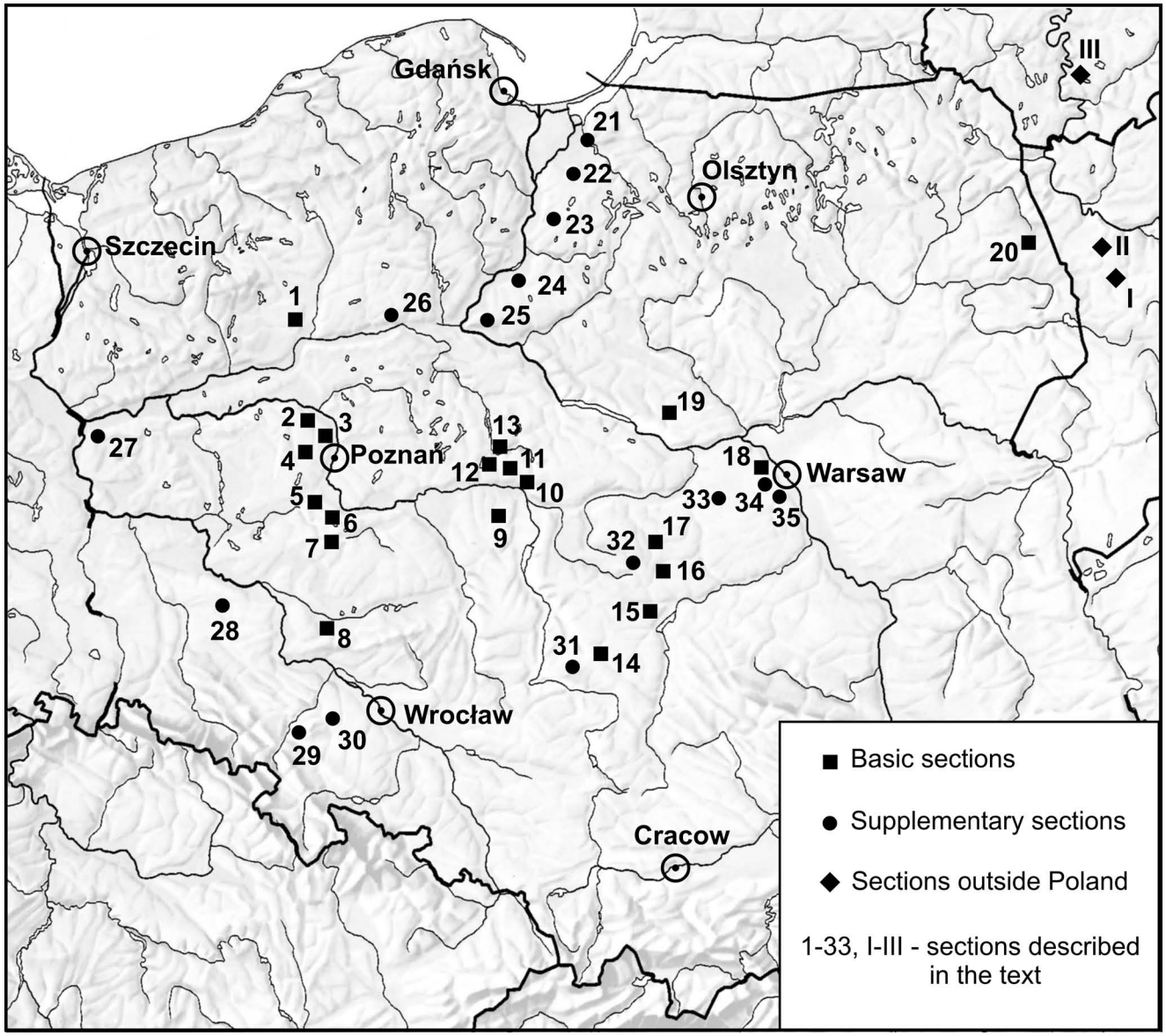

Fig. 1. Distribution of Eemian mollusc-bearing deposits in Poland

Poland and to illustrate their differentiation, connected with particular phases of ancient climate. Graphical presentations used here significantly facilitate the versatile interpretation of data, as it happened a few dozen years ago in pollen analyses. Pollen diagrams, showing clearly changes of plant communities corresponding with successive climatic phases, applied since that time and generally replacing tabulated data used and published formerly, contributed to considerable progress in the knowledge and interpretation of Quaternary stratigraphy.

Preliminary results of our study were reported in 2004 during the scientific session organised by the Commission for Quaternary Palaeogeography of the Polish Academy of Arts and Sciences in Kraków (S.W. Alexandrowicz & W.P. Alexandrowicz, 2005). Basing on our own investigations, newly revised, and on data published previously by other authors, nine malacological diagrams were drawn using the computer programme COREL-DRAW X3. They can be presented as basic sections together with other ones, characterised by spectra of species (MSS) and specimens (MSI), prepared according to a method proposed by Ložek (1964) and later by S.W. Alexandrowicz (1987, 1999a). In addition, all localities of the Eemian mollusc-bearing sediments described or mentioned by different authors, in which the occurrence of particular species was noted, are enclosed as supplementary sections.

SPECIES OF MOLLUSCS

The hitherto-identified molluscan fauna of the Eemian Interglacial in Poland consists of 118 taxa: 58 species of land snails, 41 species of freshwater snails, and 19 species of bivalves (molluscs found in sediments of the late glacial preceding the interglacial and of the following early glacial are included). Names of taxa determined by different

authors are revised according to the CLECOM-PROJECT (Falkner *et al.*, 2001). Freshwater molluscs listed in Table 1 clearly dominate and represent subfossil thanatocoenoses characterising different types of lakes or small water bodies. One species (*Valvata piscinalis*) occurs in nearly all localities and three others (*Valvata cristata*, *Bithynia tentaculata*, *Armiger crista*) in most of the localities studied. Shells of land snails accumulated in lacustrine sediments by streams and rivers have been found in some localities as an admixture forming allocoenoses composed of numerous species (Table 2). These are mainly species typical of humid habitats, meadows, mesophile species, as well as taxa of woodland snails.

The indices of constancy (C) and domination (D) as well as the synthetic index Q (geometric mean of C and D, known as "ecological meaning") of each species were calculated to distinguish most important, characteristic and accessory components of the described faunal communities. Both standard method (S.W. Alexandrowicz, 1987, 1999a) and the technique indicated by Strzelec (1993), taking into consideration only most numerous and important species, were used. According to the first mentioned method, values of constancy and domination are classified in five sections (C-1 – C-5, D-1 – D-5). Several water molluscs as dominating elements fall in higher classes (C-3 – C-5, D-2 – D-4), while the majority of land snails belong to lowest ones (C-1 – D-1) as accessory components (Table 3). The normalised indices of constancy and domination attain relatively low values ($C_i = 9.0 – D_i = 4.5$) indicating a considerable differentiation of the fauna. These indices, calculated separately

Table 1

Water molluscs of the Eemian Interglacial (including Late Wartanian and Early Vistulian) in Poland

Species	Species
Theodoxus fluviatilis (Linnaeus)	*Anisus contortus* (Linnaeus)
Viviparus contectus (Millet)	*Gyraulus albus* (Müller)
Bithynia tentaculata (Linnaeus)	*Gyraulus laevis* (Alder)
Bithynia leachii (Sheppard)	*Gyraulus acronicus* (Férussac)
Belgrandia marginata (Michaud)	*Gyraulus rossmaessleri* (Auerswald)
Marstoniopsis scholtzi (Schmidt)	*Gyraulus riparius* (Westerlund)
V*alvata cristata* Müller	*Armiger crista* (Linnaeus)
Valvata macrostoma Mörch	*Hippeutis complanatus* (Linnaeus)
Valvata piscinalis (Müller)	*Segmentina nitida* (Müller)
Valvata piscinalis antiqua Sowerby	*Acroloxuxs lacustris* (Linnaeus)
Valvata piscinalis alpestris Küster	*Unio pictorum* (Linnaeus)
Borysthenia naticina Menke	*Unio tumidus* Philipsson
Galba truncatula (Müller)	*Unio crassus* Philipsson
Stagnicola palustris (Müller)	*Anodonta cygnea* (Linnaeus)
Stagnicola occulta (Jackiewicz)	*Sphaerium corneum* (Linnaeus)
Stagnicola corvus (Gmelin)	*Sphaerium rivicola* (Lamarck)
Radix auricularia (Linnaeus)	*Musculium lacustre* (Müller)
Radix balthica (Linnaeus)	*Pisidium amnicum* (Müller)
Myxas glutinosa (Müller)	*Pisidium henslowanum* (Sheppard)
Lymnaea stagnalis (Linnaeus)	*Pisidium supinum* Schmidt
Aplexa hypnorum (Linnaeus)	*Pisidium milium* Held
Physa fontinalis (Linnaeus)	*Pisidium subtruncatum* Malm
Planorbarius corneus (Linnaeus)	*Pisidium nitidum* Jenyns
Planorbis planorbis (Linnaeus)	*Pisidium obtusale* (Lamarck)
Planorbis carinatus Müller	*Pisidium casertanum* (Poli)
Anisus spirorbis (Linnaeus)	*Pisidium ponderosum* (Stelfox)
Anisus leucostomus (Millet)	*Pisidium convectus* (Clessin)
Anisus vortex (Linnaeus)	*Pisidium moitessierianu*m (Paladilhe)
Anisus vorticulus (Troschel)	*Dreissena polymorpha* (Pallas)

Table 2

Land snails of the Eemian Interglacial (including Late Wartanian and Early Vistulian) in Poland

Species	Species
Acicula polita (Hartmann)	*Punctum pygmaeum* (Draparnaud)
Carychium minimum Müller	*Discus rotundatus* (Müller)
Carychium tridentatum (Risso)	*Vitrea contracta* (Westerlund)
Succinea oblonga Draparnaud	*Aegopis verticillus* (Lamarck)
Succinea putris (Linnaeus)	*Aegopinella pura* (Alder)
Succinea elegans Risso	*Aegopinella nitidula* (Draparnaud)
Cochlicopa lubrica (Müller)	*Aegopinella nitens* (Michaud)
C*olumella columella* (Martens)	*Nesovitrea hammonis* (Ström)
Truncatellina cylindrica (Ferussac)	*Zonitoides nitidus* (Müller)
Vertigo antivertigo (Draparnaud)	Limacidae
Vertigo pusilla Müller	*Euconulus fulvus* (Müller)
Vertigo substriata (Jeffreys)	*Cochlodina laminata* (Montagu)
Vertigo pygmaea (Draparnaud)	*Ruthenica filograna* (Rossmaessler)
Vertigo moulinsiana (Dupuy)	*Macrogastra ventricos*a (Draparnaud)
V*ertigo lilljeborgi* (Westerlund)	*Clausilia parvula* Férussac
Vertigo genesii (Gredler)	*Clausilia bidentata* (Ström)
Vertigo geyeri Lindholm	*Clausilia dubia* Draparnaud
Vertigo parcedentata (Braun)	*Clausilia pumila* Pfeiffer
Vertigo alpestris Alder	*Bulgarica cana* (Held)
Vertigo angustior Jeffreys	*Bradybaena fruticum* (Müller)
Orcula doliolum (Bruguiere)	*Perforatella incarnata* (Müller)
Pagodulina pagodula (Moulins) (??)	*Tricha hispida* (Linnaeus)
Pupilla muscorum (Linnaeus)	*Helicodonta obvoluta* (Müller)
Pupilla muscorum loessica Ložek	*Arianta arbustorum* (Linnaeus)
Vallonia pulchella (Müller)	*Chilostoma banaticum* (Rossmaessler)
Vallonia costata (Müller)	*Cepaea hortensis* (Müller)
Vallonia tenuilabris (Sandberger)	*Cepaea vindobonensis* (Férussac)
Vallonia enniensis (Gredler)	*Helix pomatia* Linnaeus
Acanthinula aculeata (Müller)	

Table 3

Structure of molluscan assemblages of the Eemian Interglacial in Poland

	D-1	D-2	D-3	D-4	D-5
C-5				2/-	1/-
C-4		1/-	2/-	1/-	
C-3	2/-	2/-			
C-2	12/6	2/-			
C-1	35/52				

C-1 – C-5 classes of constancy, D-1 – D-5 classes of domination; 12/6 – species of water molluscs / species of land snails

for water molluscs and land snails, distinctly differ from one another. Values characterizing the former fauna (C_{iW} = 19.5 – D_{iW} = 9.25) are significantly higher than other ones (C_{iL} = 2.5 – D_{iL} = 0). This reflects differences between the participation of both groups of species in assemblages found in sediments of the Eemian Interglacial.

The second method enabled us to divide all mollusc species into three classes, according to the following features of constancy and domination: class **C-D** with C> 50%, D>5%, class **C-d** – C>50%, D<5%, and class **c-d** – C<50%, D< 5%. No one species belongs to the fourth class **c-D** (C<5%, D>50%). The synthetic index – geometric mean of C and D known as "ecological meaning", calculated as $Q = \sqrt{C\ D}$, was used to attain the order of species according to their constancy and domination. Most important elements of assemblages, characterised by values Q>20, including the dominating freshwater snail – *Valvata piscinalis*, fall into the class **C-D**. Together with species of the **C-d** class (Q>10) they are exclusively water molluscs. All others, as accessory components, belong to the class **c-d** (Table 4). Additionally, the quantitative relations between the number of shells and opercula of *Bithynia tentaculata* were calculated as the Bithynia-index, illustrating the overgrowing of lakes and other water bodies (S.W. Alexandrowicz, 1999b).

BASIC SECTIONS

Sections documented by malacological diagrams are most important for stratigraphic interpretations. These are six sites noted by present authors and seven other sites known from publications. Other sections (seven sites) illustrated by malacological spectra can be pointed out as instructive indicators of the ancient environment (Fig. 1 – 1-20). All these sections will be taken into account. Besides most important species distinguished on diagrams, three groups of freshwater molluscs are presented: TW – species of temporary water reservoirs, SW – species of stagnant water bodies, and RS – reophile species.

The Eemian Interglacial sediments have been found and characterised by Dobosz *et al.* (2008) from the borehole localised in the western part of the town **Piła** (Fig. 1 – 1).

Table 4

Dominant and most important species of molluscs of the Eemian Interglacial in Poland

	D		d
C	*Valvata piscinalis* [**48,5**]		*Planorbis planorbis* [**14,3**]
	Armiger crista [**32,2**]		*Pisidium nitidum* [**10,4**]
	Valvata cristata [**32,0**]		*Radix balthica* [**10,1**]
	Bithynia tentaculata [**31,4**]		
	Gyraulus laevis [**27,4**]		
	Gyraulus albus [**21,4**] **C-D**		**C-d**
c	**c-D**	*Segmentina nitida* [**7,3**]	*Carychium minimum* [**7,1**]
		Hippeutis complanatus [**6,2**]	*Vallonia pulchella* [**3,7**]
		Acroloxus lacustris [**5,2**]	*Succinea putris* [**3,2**]
		Pisidium moitessierianum [**3,7**]	*Carychium tridentatum* [**3,2**]
		Sphaerium corneum [**3,5**]	*Discus rotundatus* [**3,2**]
		Pisidium milium [**3,2**]	*Vertigo antivertigo* [**2,1**]
		Pisidium subtruncatum [**3,1**]	*Acanthinula aculeata* [**1,7**]
		Anisus leucostomus [**3,1**]	*Zonitoides nitidus* [**1,7**]
		Galba truncatula [**3,0**]	*Nesovitrea hammonis* [**1,6**]
		Belgrandia marginata [**2,8**]	*Vertigo angustior* [**1,5**]
		Pisidium casertanum [**2,8**]	*Cochlicopa lubrica* [**1,3**]
			Punctum pygmaeum [**1,1**]
		+	+
		39 species of freshwater molluscs	46 species of land snails
		c-d	

C-D – c-d: classes of constancy and domination explained in the text. **C** – index of constancy >50, **c** – index of constancy <50; **D** – index of domination >5, **d** – index of domination <5; values of the synthetic index $Q = \sqrt{C\ D}$ – in square brackets

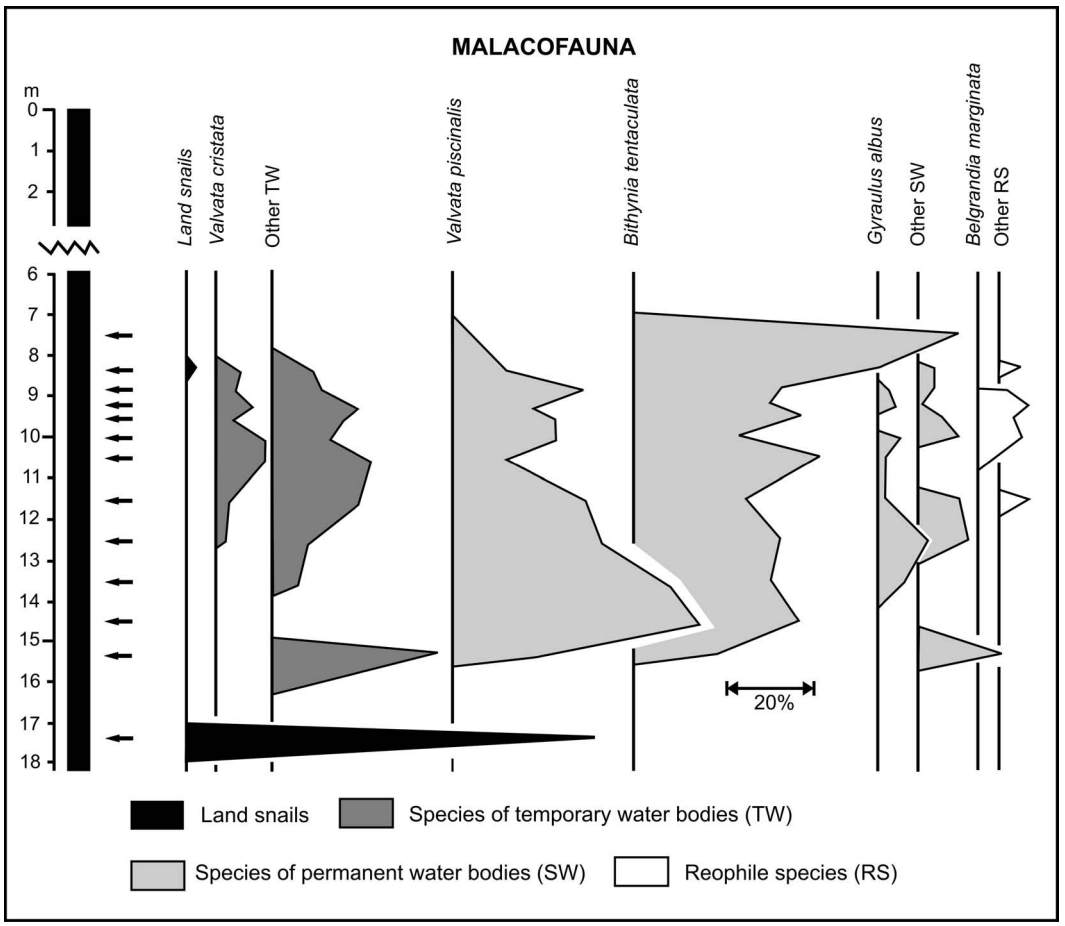

Fig. 2. Malacological diagram of the section at Piła (Fig. 1 – 1)

These are silts, sandy silts and clayey silts reaching about 10 m of thickness, containing rich and differentiated assemblages of molluscs composed of 21 species (land snails – 4, freshwater snails – 13, bivalves – 4). Snails living in different types of water bodies are main components of each community (W.P. Alexandrowicz, 2008). Only in the lowermost part of this section, cold-tolerant land snails typical of open habitats do occur (*Pupilla muscorum loessica*, *Vallonia tenuilabris*). This assemblage begins the succession and corresponds with the late glacial (Late Wartanian) preceding the following interglacial. Two species of water snails: *Valvata piscinalis* and *Bithynia tentaculata* are dominating components of the interglacial fauna. The lower part of the sequence is characterised by the first mentioned species, while the upper part – by the other one. Between them, the zone with *Belgrandia marginata* accompanied by *Gyraulus albus* has been distinguished (W.P. Alexandrowicz, 2008). It indicates the climatic optimum of the interglacial (Fig. 2). A result of pollen analysis presented by Kuszell (2008) confirms this conclusion.

The Eemian lacustrine deposits developed as gyttja and peat, described by Skompski (1994) as the Złotkowo Formation, occur at **Bogdanowo** about 15 km to the north of Poznań (Fig. 1 – 2). The fauna comprises 28 species: land snails – 3, freshwater snails – 17, and bivalves – 8. In the lower part of the section, the assemblage is relatively poor and significantly dominated by *Valvata piscinalis*. The next assemblage is enriched in *Armiger crista*, *Gyraulus laevis* and *Valvata cristata*, while in the upper part additional, numerous shells of *Gyraulus albus* and *Bithynia tentaculata* were found. The occurrence of *Belgrandia marginata* in the uppermost part of the section is also noteworthy (Fig. 3). The sequence points to the early stage of the interglacial up to the beginning of its optimal phase. This is confirmed by results of pollen analysis presented by Winter (1994).

The outcrop of Eemian deposits at **Poznań-Szeląg**, accessible eighty years ago, was described it in detail by members of the Physiographical Commission of the Polish Academy of Arts and Sciences (Pawłowski *et al.*, 1929). Now the outcrop is completely covered (Fig. 1 – 3). The rich assemblage of freshwater molluscs (14 taxa of snails and 3 taxa of bivalves) enriched in two species of land snails was found there by E. Lubicz-Niezabitowski (Pawłowski *et al.*, 1929) in calcareous sediments described as lacustrine marls. Shells of *Gyraulus albus*, *Valvata piscinalis*, *Acroloxus lacustris* and *Bithynia tentaculata*, as well as opercula of *Bithynia* are the main components of the fauna (Fig. 4). Beside them, numerous small specimens of *Belgrandia marginata*, distinguished and defined firstly by the quoted author as *B. marginata polonica*, were noted here. Both mollusc and plant remains indicate that the warm phase of the interglacial is represented at this site.

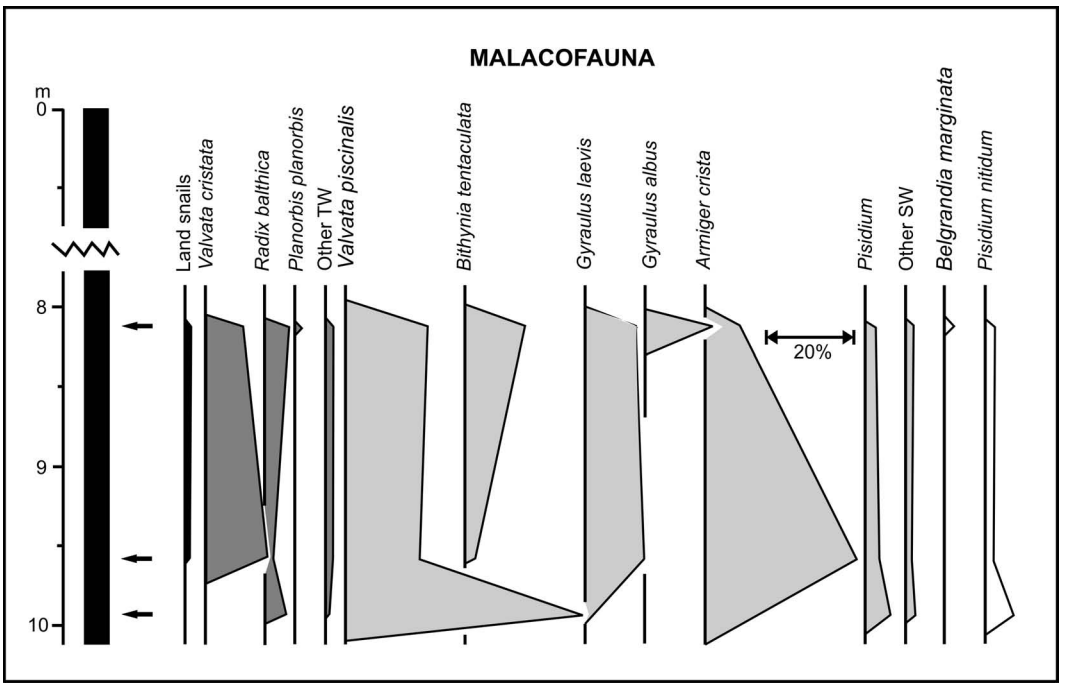

Fig. 3. Malacological diagram of the section at Bogdanowo (Fig. 1 – 2) (according to data published by Skompski, 1994). Explanations as in Fig. 2

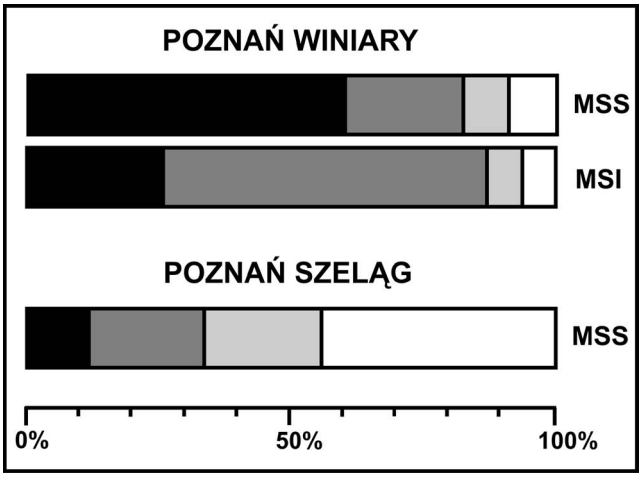

Fig. 4. Malacological spectra of deposits from sites Poznań-Szeląg (Fig. 1 – 3) and Poznań-Winiary (Fig. 1 – 4) (according to data published by Pawłowski *et al.*, 1929 and Gołąb & Urbański, 1938). MSS – spectra of species, MSI – spectra of specimens, other explanations as in Fig. 2

Quite different fauna of molluscs identified by J. Urbański (Gołąb & Urbański, 1938) was found at the outcrop **Poznań-Winiary** (Fig. 1 – 4), not accessible nowadays. Freshwater molluscs, such as: *Valvata cristata*, *Armiger crista*, *Hippeutis complanatus*, *Radix balthica* (original *Radix ovata*) and *Galba truncatula* dominate in the number of specimens, but beside them numerous species of land snails are also components of the assemblage. These are: *Cochlicopa lubrica*, *Vertigo angustior*, *V. pusilla*, *Acicula polita*, *Discus rotundatus*, *Cochlodina laminata*, *Punctum pygmaeum* and many others (Fig. 4). The fauna represents an allocoenose composed of species living in a small lake or pond and of shells derived from different surrounding habitats, accumulated during floods by the crossing stream or river (S.W. Alexandrowicz & W.P. Alexandrowicz, 2005). Several species suggest the moderate climate of the middle part of the interglacial, but no one indicates undoubtedly the climatic optimum.

Three sections of the Eemian mollusc-bearing sediments were found and described by Krzyszkowski and Winnicki (1994) and Chachraj and Krzyszkowski (1994) from the area located close to Leszno. At the site **Rogaczewo** three assemblages of molluscs have been distinguished in silts and peaty mud (Fig. 1 – 6). In all these assemblages *Valvata piscinalis* is the main component. In the first community, beside the mentioned species, shells of *Gyraulus laevis*, *Armiger crista*, *Bithynia tentaculata*, *Radix balthica* and *Pisidium nitidum* occur. The second community is relatively rich and differentiated, characterised particularly by *Gyraulus albus*, while in the upper part of the sequence *Bithynia-opercula* clearly dominate, indicating the overgrowing of the water body (Fig. 5). The section represents the pre-optimal zone of the interglacial and probably also the beginning of the climatic optimum (S.W. Alexandrowicz, 1994; Kuszell, 1994b).

The sequence from the site **Kopaszewko** (Fig. 1 – 6) begins with a very poor assemblage with *Radix balthica* and *Valvata piscinalis*, passing upward into the richest assemblage dominated by *Valvata piscinalis*, *V. cristata*, *Bithynia tentaculata* and *Gyraulus laevis*. At the top, the fauna is poor again, being mainly composed of *Radix balthica* and *Valvata cristata* (Fig. 6). A considerable number of *Bitynia-opercula* was noted, particularly in the middle part of the

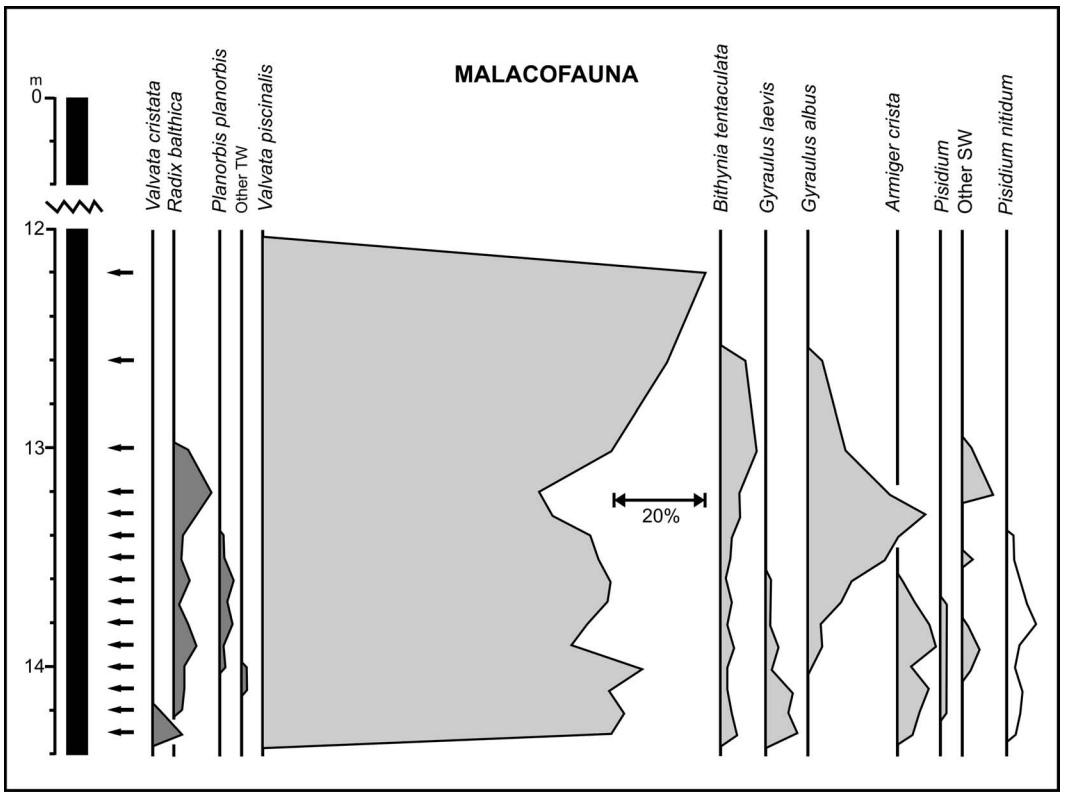

Fig. 5. Malacological diagram of the section at Rogaczewo (Fig. 1 – 5). Explanations as in Fig. 2

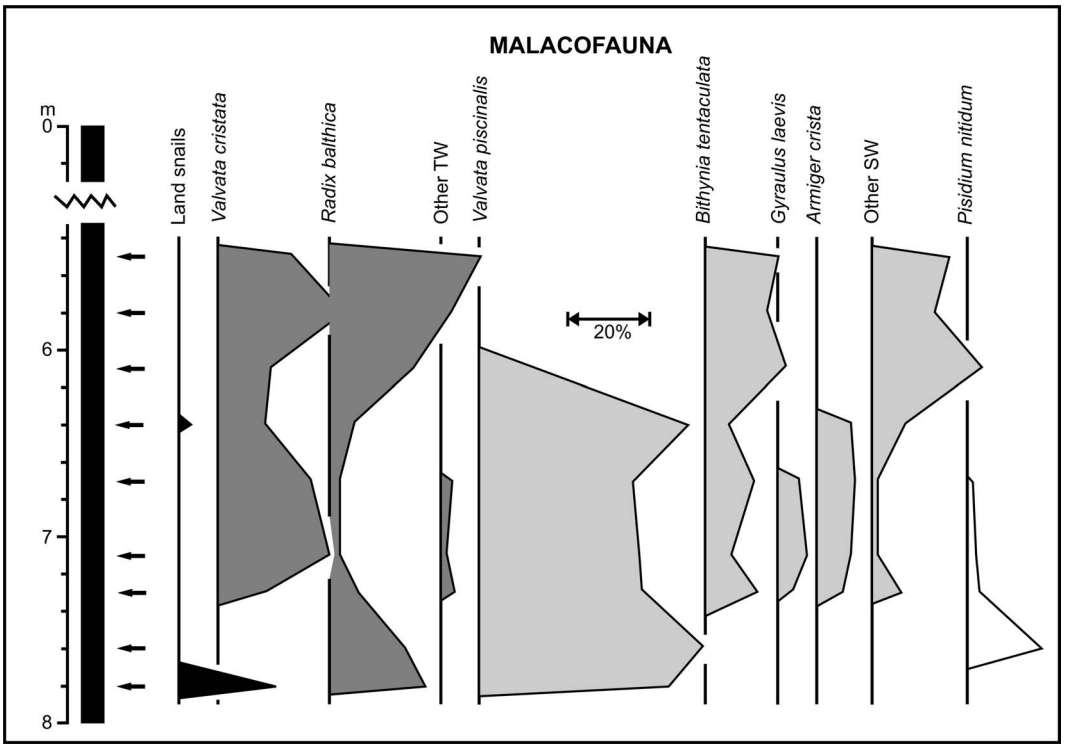

Fig. 6. Malacological diagram of the section at Kopaszewko (Fig. 1 – 6). Explanations as in Fig. 2

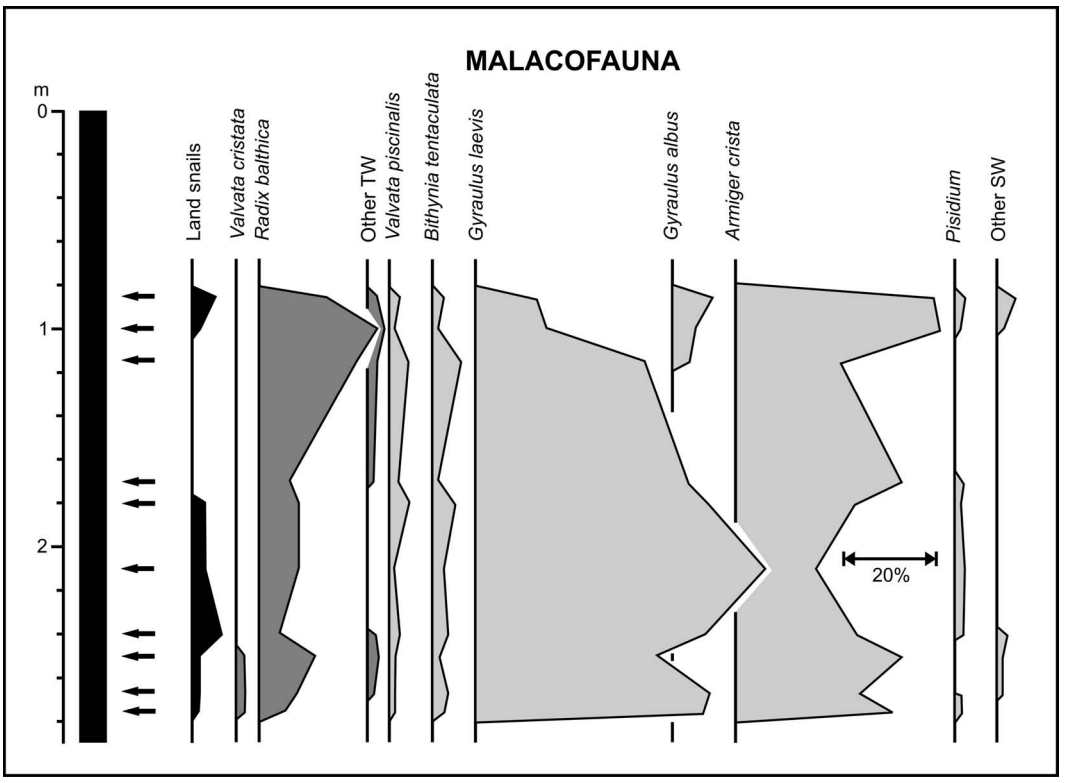

Fig. 7. Malacological diagram of the section at Zbytki (Fig. 1 – 7). Explanations as in Fig. 2

section. It suggests that the ancient water body at Kopaszewko should be interpreted as a small and shallow lake overgrown by reeds. It had been formed at the earliest phase of the interglacial or even just before and developed during successive phases of the Lower Eemian since the early part of the climatic optimum (S.W. Alexandrowicz, 1994; Kuszell, 1994b).

At the site **Zbytki**, the fauna occurs in silts and sandy silts recognised in two boreholes (Fig. 1 – 7). The assemblage dominated by *Gyraulus laevis* and *Armiger crista* with an admixture of *Valvata piscinalis* and *Bithynia tentaculata* occurs in the lower and middle parts of the sequence, while in its upper part the fauna contains also shells of *Gyraulus albus* and numerous specimens of *Radix balthica* (Fig. 7). These two assemblages characterise the lower part of the interglacial, namely stratigraphic zones preceding the climatic optimum (S.W. Alexandrowicz, 1994; Kuszell, 1994a).

The fauna of Eemian sediments at **Żmigród** (Lower Silesia, Fig. 1 – 8), determined by Schmierer, were noted by Schwarzbach (1942). The community found at that time was composed of land snails (4 species), freshwater snails (6 species) and bivalves (7 taxa). The sequence of mollusc assemblages was later described by Skompski (1983) from three boreholes. In its lower part, besides land snails (*Carychium*, *Vallonia*, *Succinea*) and numerous specimens of ordinary species (*Valvata piscinalis*, *Bithynia tentaculata*, *Pisidium* sp.), single shells of *Gyraulus albus* and *Belgrandia marginata* were found. In the upper part, *Valvata piscinalis* clearly prevails (Fig. 8). The position of two termophilous species indicates that the most part of this section corresponds with the post-optimal zone of the interglacial, while the optimal phase is represented within the lowermost segment the sequence.

Numerous sections of Eemian sediments were reported from the vicinity of Konin (Stankowski, 1991). In several of them, a relatively rich fauna of molluscs living in different types of water bodies occur. The sequence of assemblages from the large outcrop of the brown-coal mine in **Władysławów** (Fig. 1 – 9) was analysed first by S.W. Alexandrowicz and later by Ciszewska (1989). It begins with the fauna of water snails with *Valvata piscinalis*, *Gyraulus laevis* and two species of *Pisidium*, passing upward into the fauna with *Gyraulus albus* and land snails (*Acanthinula aculeata*, *Aegopinella nitidula*). Both mentioned species of *Gyraulus* accompanied by *Valvata piscinalis*, *V. cristata* and other freshwater molluscs constitute the community in the upper part of the section. The fauna can be related to the pre-optimal zones of the interglacial. Single shells of *Belgrandia marginata* found by one of us (S.W. Alexandrowicz) in the uppermost part of this sequence indicate the climatic optimum (Fig. 9).

A relatively rich assemblage of molluscs was found by Szałamacha and Skompski (1999) in boreholes situated at **Krzyżówki** near Koło (Fig. 1 – 10). It occurs in green-grey gyttja and is composed of 17 species of freshwater snails, 3 taxa of land snails and 7 taxa of bivalves. Shells of *Valvata piscinalis* clearly dominate reaching more than 60% of all specimens, while shells of *Armiger crista*, *Gyraulus laevis*, *Valvata cristata* and *Bithynia tentaculata* are also numerous (more than 70 pieces). The presence of *Belgrandia marginata* and *Gyraulus albus* indicate the phase of climatic opti-

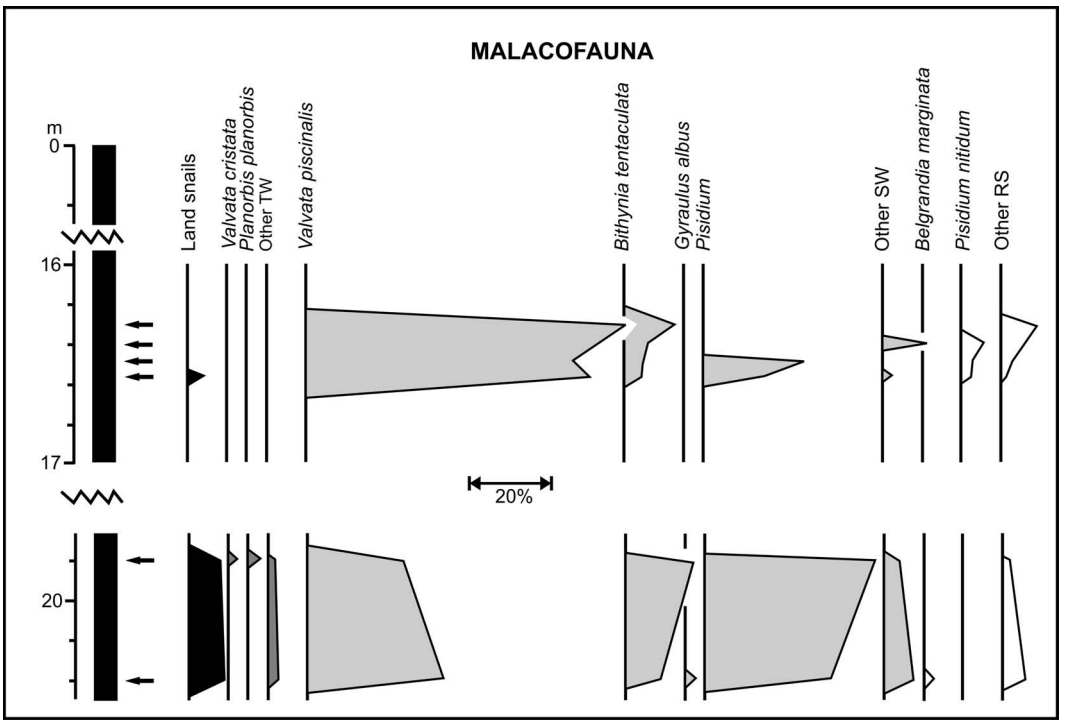

Fig. 8. Malacological diagram of the section at Żmigród (Fig. 1 – 8) (according to data published by Skompski, 1983). Explanations as in Fig. 2

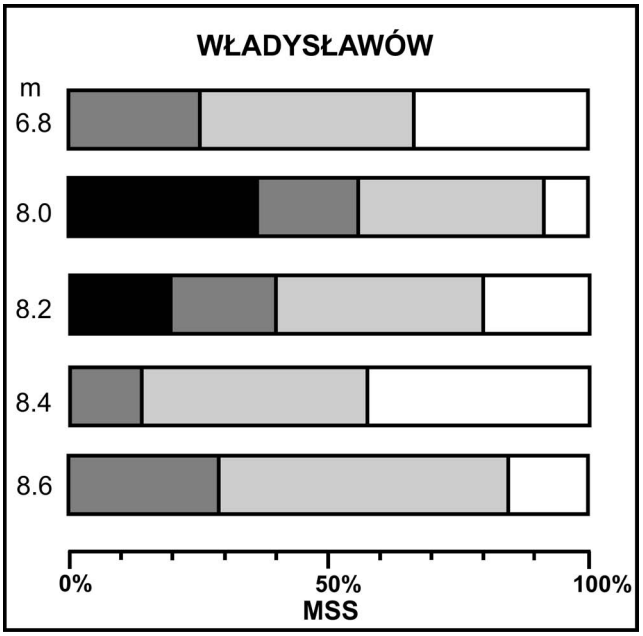

Fig. 9. Malacological spectra of deposits from the section at Władysławów (Fig. 1 – 9) (partly according to data published by Ciszewska, 1989). Explanations as in Figs 2 and 4

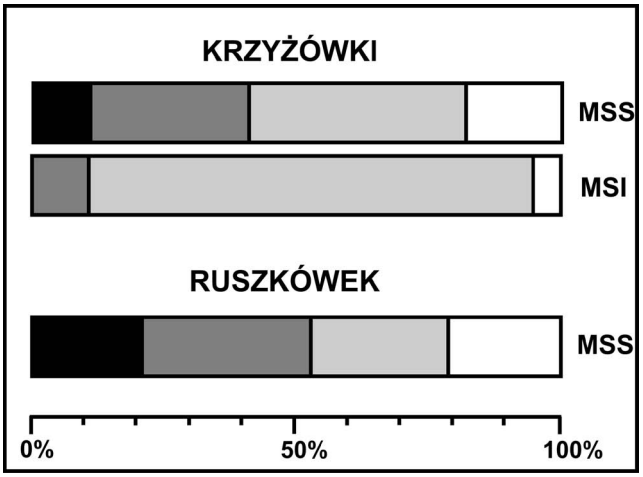

Fig. 10. Malacological spectra of deposits from sections in the Konin region (Fig. 1 – 10, 13) (according to data published by Szałamacha & Skompski, 1999 and Kozydra & Skompski. 1995). Explanations as in Figs 2 and 4

mum of the interglacial. Malacological spectra MSS and MSI suggest a gradually growing shallow lake (Fig. 10).

Eemian sediments were described from the brown-coal mine **Mikorzyn** situated 15 km northward of Konin (Fig. 1 – 11). The sequence of mollusc assemblages presented by Kozydra and Skompski (1996) is characterised by numerous land snails (22 taxa), such as: *Monachoides incarnata*, *Discus rotundatus*, *Vertigo angustior*, *V. pusilla*, and *Vallonia pulchella*. In its lower part, shells of *Valvata piscinalis* dominate while in the upper part additional, numerous specimens of *Valvata cristata* and *Armiger crista* occur. Moreover, specimens of a warm-demanding snail – *Gyraulus albus* were found (Fig. 11). Particular zones of the interglacial were distinguished according to the results of pollen di-

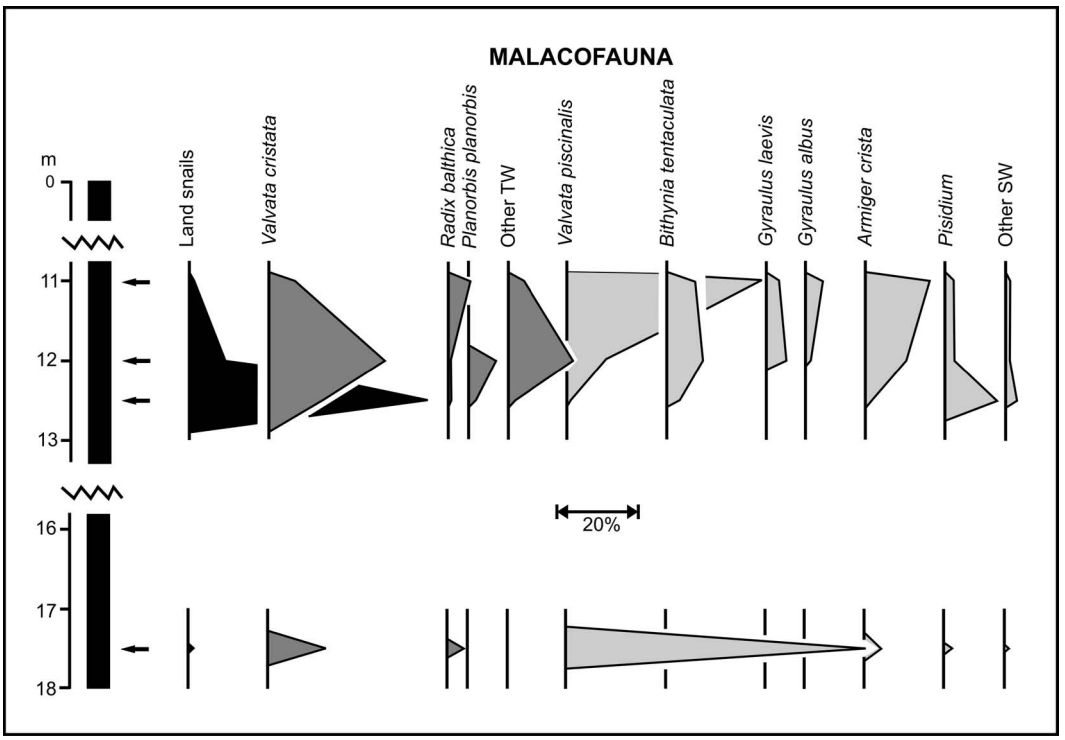

Fig. 11. Malacological diagram of the section at Mikorzyn (Fig. 1 – 11) (according to data published by Skompski, 1996). Explanations as in Fig. 2

agram by M. Nita (Stankowski *et al.*, 1999) in this outcrop, but unfortunately this palynological section has not been not correlated with the malacological diagram.

Sediments containing rich assemblages of molluscs occur in brown-coal mine at **Jóźwin**, situated close to the last mentioned one (Fig. 1 – 12). These contain 24 species of freshwater snails, 18 species of land snails and 6 species of bivalves, and also 7 taxa determined to the higher systematic level (Ciszewska, 1996). In the whole sequence specimens of *Valvata cristata*, *V. piscinalis*, *Armiger crista* and *Bithynia tentaculata* are numerous. The occurrence of *Gyraulus laevis* in its lower part and *Gyraulus albus* in the upper part is noteworthy in particular (Fig. 12). Land snails represent different ecological groups as species living in shady and partly shady habitats (*Cochlodina laminata*, *Discus rotundatus*), open country species (*Pupilla muscorum*, *Vallonia pulchella*), mesophile species (*Nesovitrea hammonis*, *Euconulus fulvus*), and hygrophile species (*Succinea putris*, *Zonitoides nitidus*). The fauna indicate the pre-optimal phase of the interglacial up to the climatic optimum, and a shallow basin passing upward into a temporary water body characterised by numerous shells of *Planorbis planorbis*.

Mollusc-bearing calcareous gyttja was distinguished by Kozydra and Skompski (1995) between tills of the Middle Polish (Warta) Glaciation and the Vistulian (Weichselian) Glaciation at **Ruszkówek** (Fig. 1 – 13). The fauna distinguished in the interglacial layer, presented without quantitative data, is composed of 12 species of freshwater snails, 4 species of land snails and 7 species of bivalves, all of them falling in the same sample. The termophilous snail – *Belgrandia marginata* occurs besides two species of *Planorbidae* tolerating the cold climate: *Gyraulus laevis* and *G. rossmaessleri*. Shells of *Valvata piscinalis*, *V. cristata*, *Armiger crista*, and *Bithynia tentaculata* are other components of this comprehensive community, including molluscs from several climatic phases of the Eemian. The content of species representing particular ecological groups of species is nearly the same (Fig. 10).

The sequence of molluscan assemblages from interglacial sediments of **Leśna Niwa** (Fig. 1 – 14) was described by Makowska (1971). The number of specimens pointed out with symbols of frequency enables one to present the diagram (Fig. 13). The main components of particular communities: *Valvata piscinalis*, *V. cristata* and *Armiger crista* reach the similar content throughout the section. The number of specimens of *Gyraulus laevis* and *Gyraulus albus* differs from the bottom upward. In the lower part of the section, the first mentioned species dominates while in the middle and upper parts the content of specimens representing both species is nearly the same. The sequence characterizes pre-optimal phases of the interglacial.

Eemian sediments abounding in shells of molluscs have been reported from two sections from the vicinity of Łódź. The first one is situated at **Świątniki**, about 30 km southeast of the town (Fig. 1 – 15). A rich fauna of molluscs occurs in silts and sandy silts recognised in three boreholes (S.W. Alexandrowicz, 1988). In the lowermost part of the section, the assemblage is relatively poor, containing mainly numerous specimens of *Valvata piscinalis*, the species dominating in the whole of the sequence. It passes upward into a more differentiated assemblage enriched in *Bithynia tentaculata*, *Gyraulus laevis*, *Valvata cristata* and few species of *Pisidium*, corresponding with the lower part

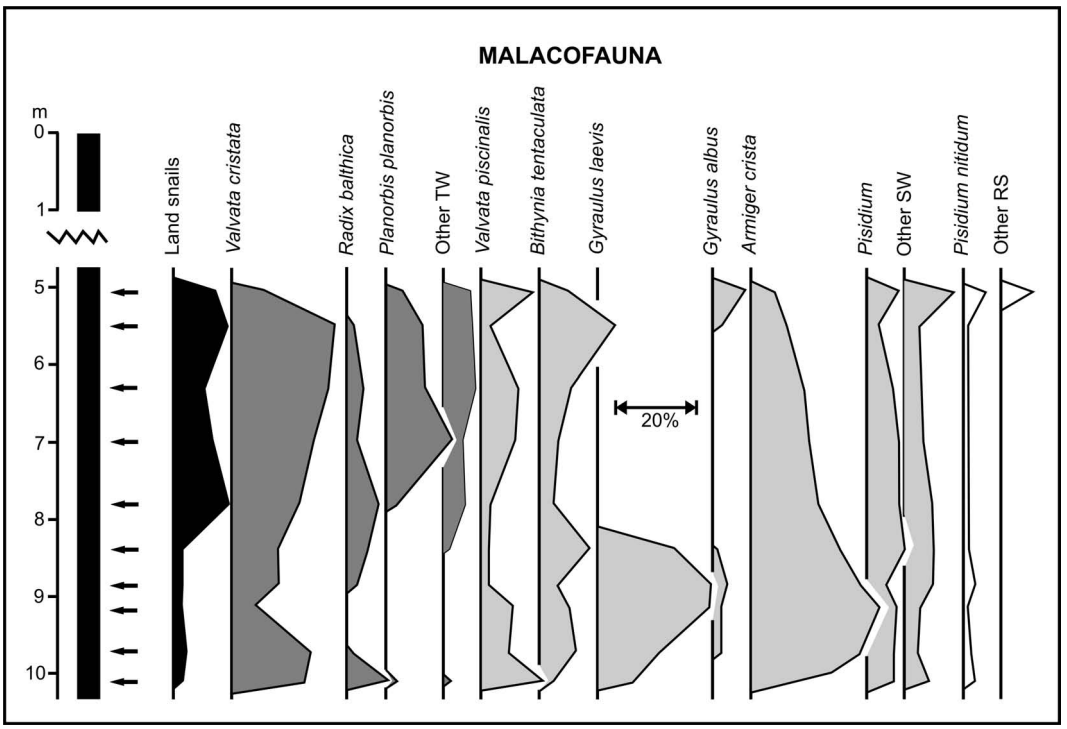

Fig. 12. Malacological diagram of the section at Jóźwin (Fig. 1 – 12) (according to data published by Ciszewska, 1996). Explanations as in Fig. 2

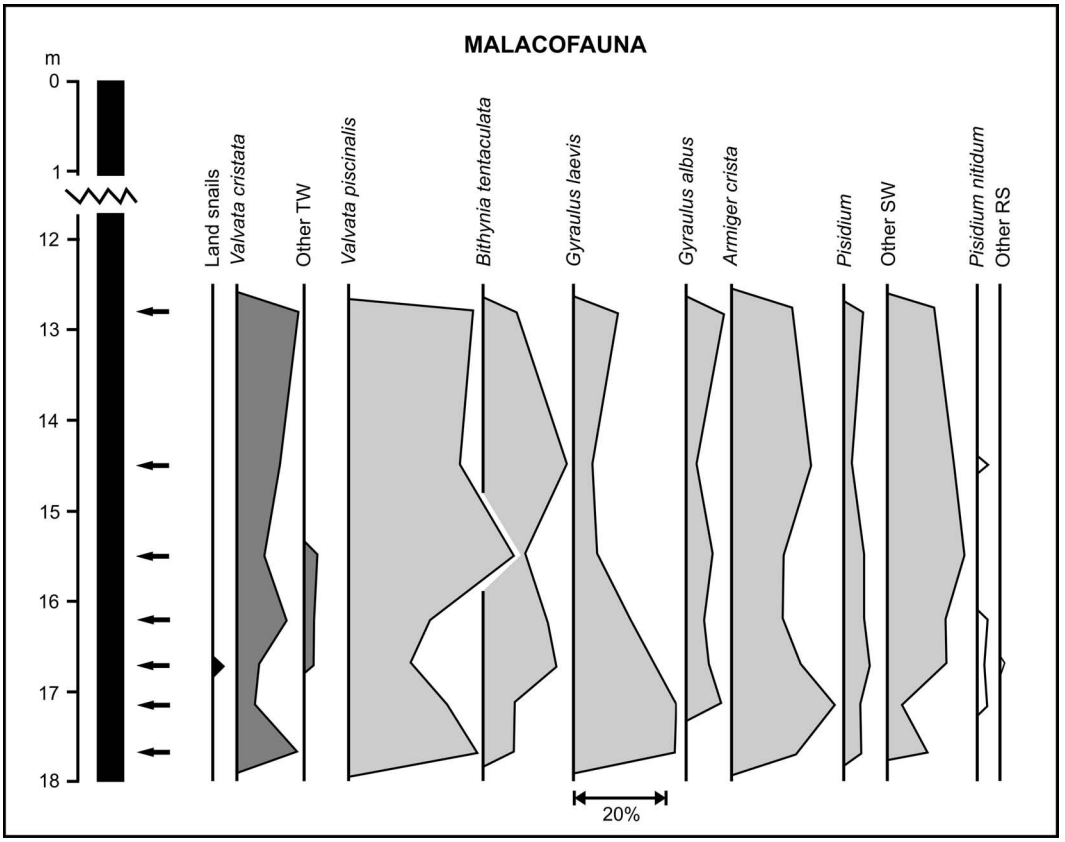

Fig. 13. Malacological diagram of the section at Leśna Niwa (Fig. 1 – 14) (according to data published by Makowska, 1971). Explanations as in Fig. 2

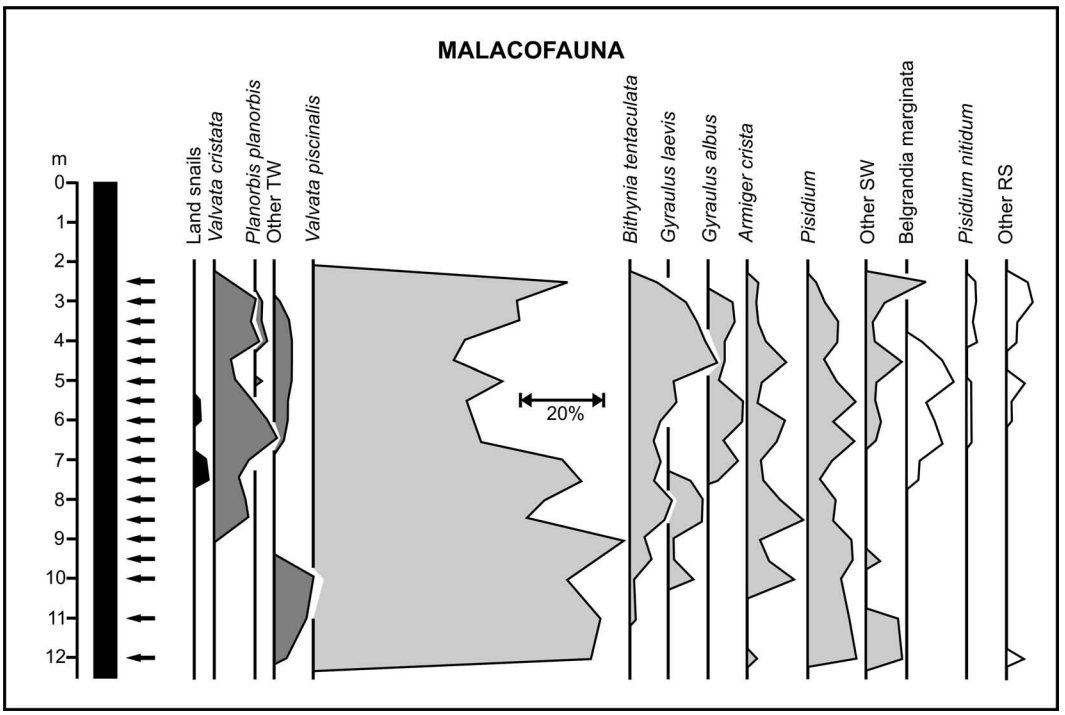

Fig. 14. Malacological diagram of the section at Świątniki (Fig. 1 – 15). Explanations as in Fig. 2

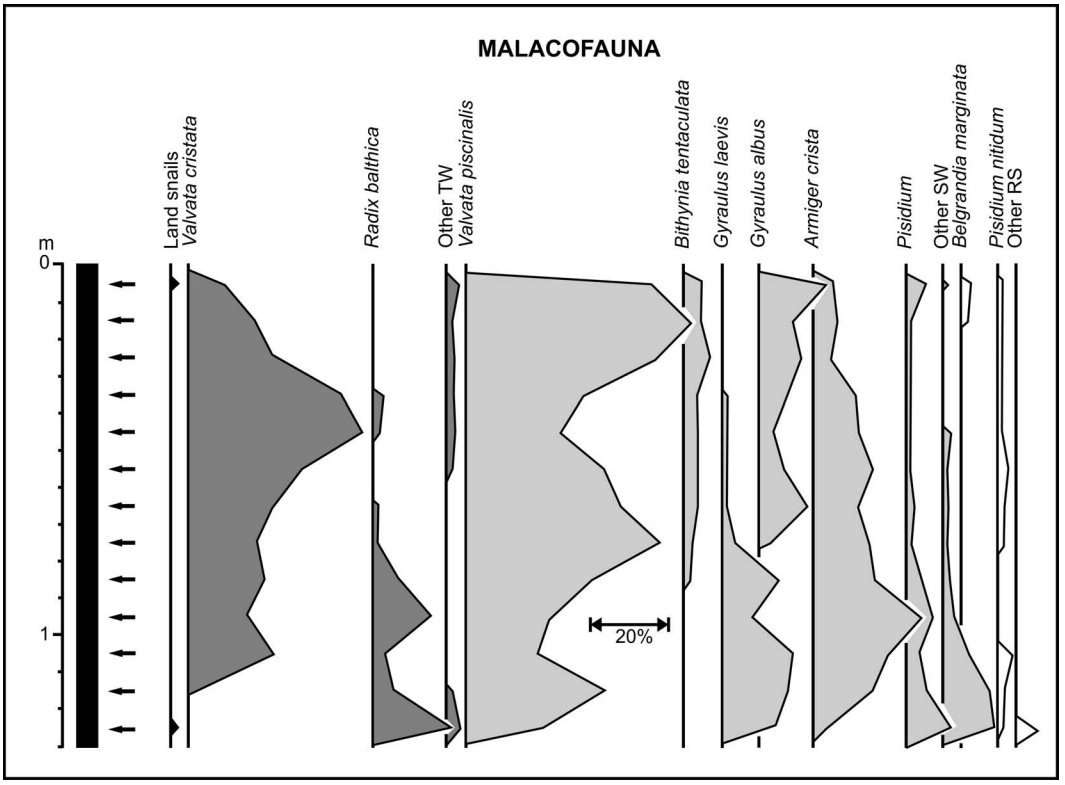

Fig. 15. Malacological diagram of the section at Kochanów (Fig. 1 – 16). Explanations as in Fig. 2

of the interglacial. In the next few samples *Gyraulus laevis* is gradually being replaced by *Gyraulus albus*. The following stratigraphic zone is characterised by *Belgrandia marginata*, indicating the optimal phase of the interglacial. The youngest assemblage is again devoid of this species and corresponds with the post-optimal phase. *Valvata piscinalis*, *V. cristata*, *Bithynia tentaculata* and *Planorbis planorbis* are the main components of this fauna (Fig. 14). A

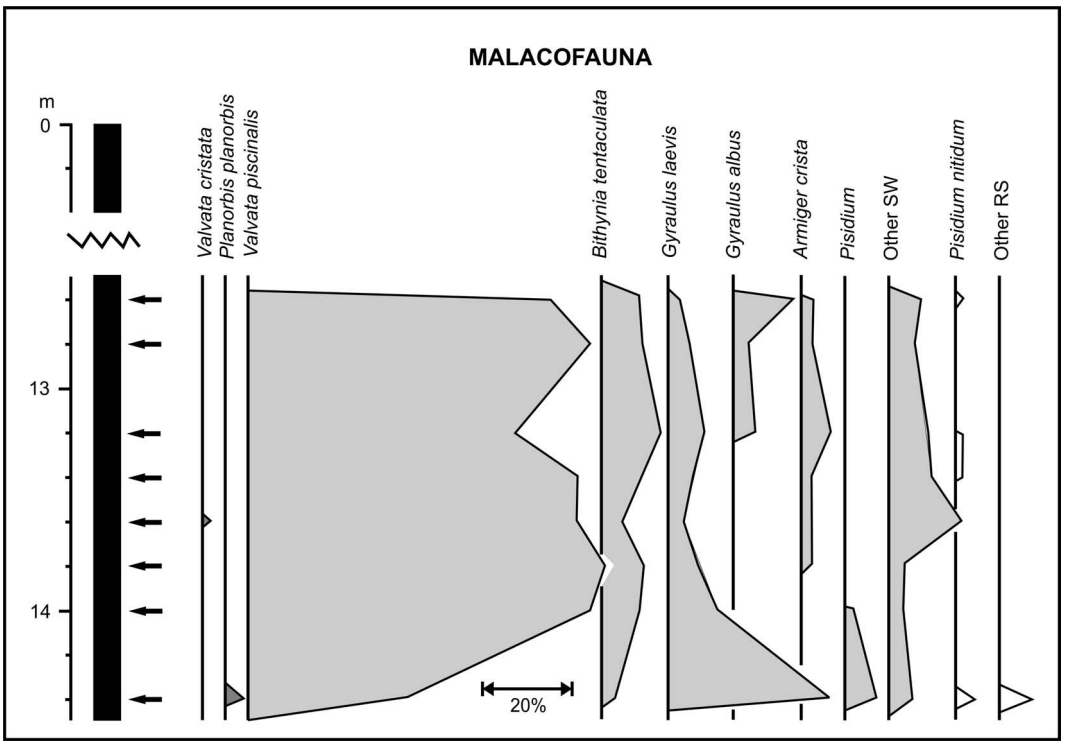

Fig. 16. Malacological diagram of the section in Lake Okręt (Fig. 1 – 17) (according to data published by Klajnert & Piechocki, 1972). Explanations as in Fig. 2

substantial number of *Bithynia-opercula* suggests the gradually overgrowing water body.

Another section is represented by lacustrine chalk exposed at **Kochanów**, about 35 km eastward of Łódź (Fig. 1 – 16). The sequence begins with the fauna of freshwater snails accompanied by few species of *Pisidium*, and in the lowermost part of the section also with the land snail – *Pupilla muscorum*. The assemblage is dominated by four species of water snails: *Gyraulus laevis*, *Valvata piscinalis*, *V. cristata*, and *Armiger crista*; the first one should be indicated as the conspicuous, most characteristic component of the assemblage. In the second assemblage numerous specimens of *Bithynia tentaculata* occur, while in the third one *Gyraulus albus* gradually replaces *Gyraulus laevis*. The number of freshwater snails increases upwards and the fauna characterises warming of the climate during the older part of the interglacial. The fourth assemblage distinguished in the uppermost part of the section contains a dozen species of water molluscs and two species of land snails (*Discus rotundatus*, *Zonitoides nitidus*). The occurrence of a warm demanding species – *Belgrandia marginata* accompanied by numerous specimens of *Gyraulus albus* is particularly noteworthy (Fig. 15). It indicates the phase of climatic optimum of the interglacial (S.W. Alexandrowicz, 1997).

The next section derives from cores of two boreholes drilled in the **Lake Okręt** situated within the Bobrówka River valley near Łowicz (Fig. 1 – 17). It was studied in detail by Klajnert and Piechocki (1972). The whole sequence of mollusc assemblages is dominated by *Valvata piscinalis* accompanied by *Bithynia tentaculata* and specimens of *Radix*. In its lower part, shells of *Gyraulus laevis* occur in a considerable number, markedly decreasing upwards. At the top, besides these, relatively numerous shells of *Gyraulus albus* were noted (Fig. 16). It suggests that the mentioned mollusc-bearing sediments represented by calcareous silt correspond with early phases of the interglacial, probably including the climatic optimum, distinguished according to the results of pollen analysis indicating zones E1 – E4 (Klajnert & Piechocki, 1972).

Mollusc fauna of the Eemian interglacial from **Żoliborz** (northern part of Warsaw, Fig. 1 – 18) was described from two different outcrops, first by Poliński (1927) and later by Skompski and Słowiański (1961). Results published and presented in a table by the last quoted authors are illustrated now in the diagram (Fig. 17). Land snails (*i.e.*: *Vallonia pulchella*, *Nesovitrea hammonis*, *Zonitoides nitidus*) occur in the lower part of the sequence together with numerous specimens of *Planorbis planorbis* and *Bithynia tentaculata*. In the upper part, the number of shells of *Valvata cristata*, *Bithynia tentaculata* and *Anisus vorticulus* increases. The sequence corresponds with the pre-optimal zone of the interglacial. Assemblages described by Poliński (1927), indicating changes and overgrowing of the water basin, may be correlated with optimal and post-optimal zones. The first of them is composed mainly of *Valvata piscinalis antiqua*, *Valvata piscinalis* and *Gyraulus albus* while numerous species of land snails occur in the next one. These are, *i.a.*: *Clausilia pumila*, *Macrogastra ventricosa*, *Vertigo moulinsiana*, and *Cepaea vindobonensis.*

Sediments of the Eemian Interglacial documented by pollen analysis and molluscs were described by Krupiński *et al.* (2006) from **Leszczyno**, a site situated about 15 km NE of Płock (Fig. 1 – 19). There occur sandy and peaty silts and clays with a layer of calcareous gyttja. The last ones

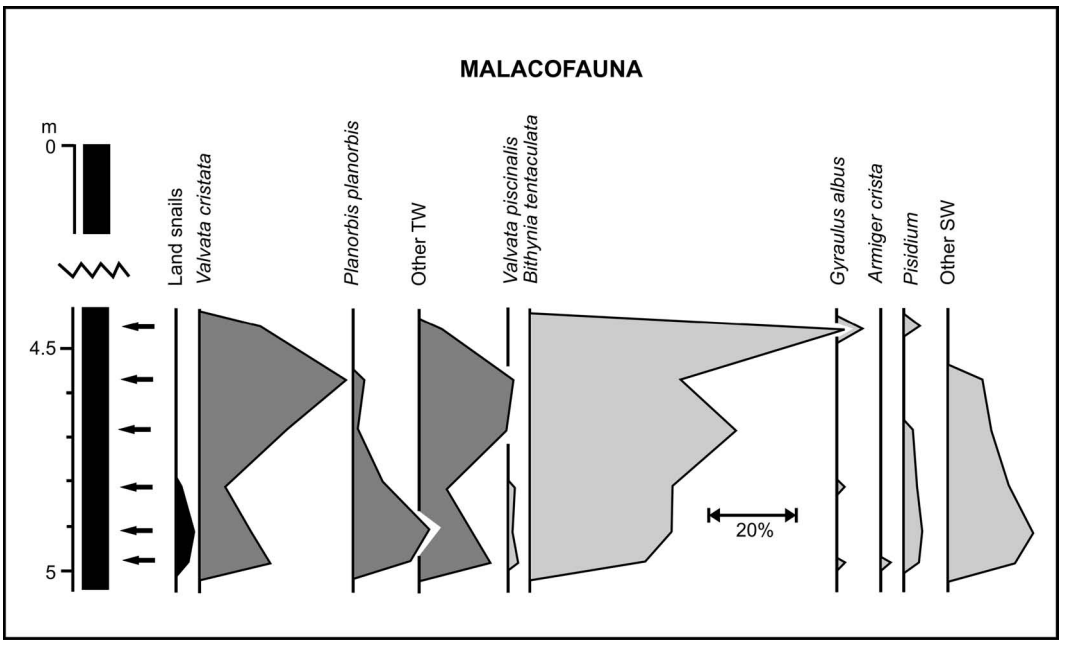

Fig. 17. Malacological diagram of the section at Warsaw-Żoliborz (Fig. 1 – 18) (according to data published by Skompski & Słowiański, 1961). Explanations as in Fig. 2

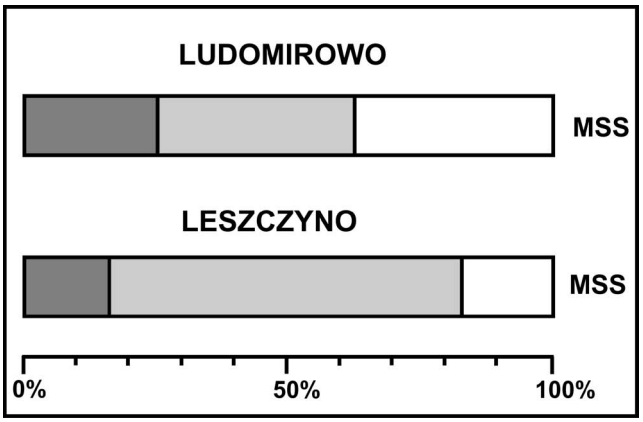

Fig. 18. Malacological spectra of deposits from sites Leszczyno (Fig. 1 – 19) and Ludomirowo (Fig. 1 – 20) (according to data published by Krupiński *et al.*, 2006 and Bitner, 1957). Explanations as in Figs 2 and 4

contains an assemblage of water species with *Valvata piscinalis*, *V. cristata*, *Bithynia tentaculata*, *Gyraulus albus* and *Pisidium nitidum* as well as with numerous *Ostracoda* (Fig. 18). This fauna is connected mainly with lakes and characterises the optimal phase of the interglacial corresponding with the pollen zone L PAZ-LE-5 – *Corylus*, distinguished by quoted authors (Krupiński *et al.*, 2006).

Sections of interglacial calcareous sediments: gyttja and lacustrine chalk, containing assemblages of molluscs are known from boreholes situated at **Ludomirowo** near Sidra, about 50 km northward of Białystok (Fig. 1 – 20). The fauna of water species with *Valvata piscinalis*, *Bithynia tentaculata*, *Armiger crista*, *Pisidium amnicum* and two species of *Gyraulus* was determined by Makowski (Bitner, 1957). In the lower part of the sections he found shells of *Gyraulus gredleri* (*rossmaessleri*) while in the middle and upper part – shells of *Gyraulus albus* (Fig. 18). It indicates the pre-optimal and optimal phases of the Eemian, what is confirmed by the results of pollen analysis (Bitner, 1957).

SUPPLEMENTARY SITES

Mollusc-bearing sediments of the last interglacial were noted in Poland in many sections, besides those presented here as basic ones. In most of them, only few species of freshwater snails or bivalves were mentioned without data pertaining to the composition of entire assemblages and the number of specimens. The list of such sections named by different authors includes 15 sites (Table 5).

In the area spreading along the lower course of the Vistula River, Eemian sediments containing both freshwater and marine molluscs have been found and described in numerous sections by Brodniewicz (1960, 1969) and Makowska (1970, 1979, 1986, 1999). These are concentrated in five places distributed along the right side of the river valley (Fig. 1 – 21-25). The two first of them are situated within the axial part of an ancient gulf formed during the Eemian transgression of the so-called Tychnowy Sea (Makowska, 1979, 1986). In the south-western part of the Elbląg Elevation, near the village **Pęklewo** (Fig. 1 – 21), the fauna with: *Valvata piscinalis*, *Gyraulus albus*, *Planorbarius corneus*, and *Pisidium moitessierianum* occurs in lacustrine and fluviatile sediments covered by clays and silts containing marine molluscs. About 30 km to the south, in the vicinity of **Dzierzgoń** (Fig. 1 – 22), just below marine sediments developed as sands with *Corbula*, *Nassa*, *Cardium* and *Tapes*, peaty clays with *Theodoxus fluviatilis*, *Valvata cristata* and *Bithynia tentaculata* were noted by Makowska (1979, 1986).

Table 5

Supplementary sites of the Eemian mollusc-bearing deposits in Poland

No	Locality	References	Selected species of molluscs
21	Pęklewo	Makowska (1999)	*Valvata piscinalis*, *Gyraulus albus*, *Planorbarius corneus*, *Bithynia*
22	Dzierzgoń - Nowiny	Makowska (1986, 1979)	*Theodoxus fluviatilis*, *Bithynia tentaculata*
23	Kwidzyń - Brachlewo	Makowska (1979, 2001), Brodniewicz (1960)	*Valvata piscinalis*, *V. cristata*, *Bithynia tentaculata*, *Belgrandia marginata*, *Gyraulus albus*, *Planorbis planorbis*
24	Grudziądz - Mniszek	Makowska (1979)	*Valvata piscinalis*, *Bithynia tentaculata*, *Physa* cf. *fontinalis*, *Pisidium* sp.
25	Solec Kujawski	Makowska (1979)	*Valvata piscinalis*, *V. cristata*, *Physa* sp., *Bithynia tentaculata*, *Succinea* sp.
26	Nakło	Noryśkiewicz (1978)	*Valvata piscinalis*, *V. cristata*, *Armiger crista*, *Bithynia tentaculata*, *B.* cf. *leachii*
27	Laski	Skompski (1980)	*Valvata piscinalis*, *Bithynia tentaculata*, *Gyraulus albus*
28	Szklary Dolne	Buksiński (1964)	V*alvata piscinalis antiqua*
29	Strzeganowice (Kąty Wroc.)	Gepperd (1854) Beyrich (1854)	*Chilostoma banaticum*, *Helicodonta obvoluta*, *Aegopis verticillus*
30	Imbramowice	Gürich (1908), Mamakowa (1989)	V*alvata* cf. *piscinalis*, *V.* cf. *cristata*, *Bithynia tentaculata*, *Succinea elegans* (orginal *S. pfeifferi*)
31	Zabrzezie	Makowska (1971)	*Valvata piscinalis*, *Bithynia tentaculata*
32	Rogów	Alexandrowicz (1997)	*Bithynia tentaculata*
33	Pruszków	Krupiński (1986)	*Valvata piscinalis antiqua*
34	Warszawa-Wola	Urbański (1954)	*Valvata piscinalis*, *Bithynia tentaculata*, *Pisidium casertanum ponderosum*
35	Warszawa - ul. Okopowa	Domosławska-Baraniecka (1965)	*Valvata piscinalis*, *V. piscinalis antiqua*, *V. piscinalis* cf. *alpestris*, *Bithynia*

In sections situated near **Kwidzyń**, close to the south-western border zone of the Tychnowy Sea (Fig. 1 – 23), shells of freshwater molluscs occur in deposits which underlay and cover fine-grained sands and silts with a rich marine fauna (*Abra*, *Nassa*, *Bittium*, *Ostrea*, *Cardium*, *Mytilus*). In the first mentioned ones, the fauna with *Valvata piscinalis*, *V. cristata*, *Bithynia tentaculata*, *Planorbis planorbis* and *Gyraulus albus* were found in borehole cores from Nicponie and Białki (Makowska, 1979) and, additionally, specimens of *Belgrandia marginata* – in Brachlewo (Brodniewicz, 1960, 1965). Silts representing the upper part of the interglacial, overlying marine deposits known from Nicponie and Obrzynowo, contain the fauna of freshwater molluscs with *Valvata piscinalis*, *Bithynia tentaculata*, *Anisus spirorbis*, and *Pisidium* sp. (Makowska, 2001).

The Eemian mollusc-bearing sediments from the area extending outside the range of marine transgression southward from the last described, occur in the vicinity of towns **Grudziądz** and **Solec Kujawski** (Fig. 1 – 24, 25). Relatively differentiated assemblages of molluscs with: *Valvata piscinalis*, *V. cristata*, *Bithynia tentaculata*, *Pisidium moitessierianum* and *Succinea* sp. were found there by Makowska (1979). Nearly the same species of fresh-water snails identified by Dmoch were noted in the section at **Nakło** (Fig. 1 – 26), described in detail by Noryśkiewicz (1978). Most of them are connected with post-optimal phases and occur in pollen assemblage zones E5 and E6.

In western Poland, fauna of the last interglacial occurs at **Laski**, about 15 km NE of Słubice-Frankfurt (Fig. 1 – 27). Shells of *Valvata piscinalis antiqua*, *Bithynia tentaculata* and *Gyraulus albus* were found by Skompski (1980) in calcareous gyttja characterised by the pollen assemblage with *Quercus* and *Corylus*. Specimens of *Valvata piscinalis antiqua* were also noted by Buksiński (1964) in Eemian sediments at **Szklary Dolne**, about 5 km westward of Lubin (Fig. 1 – 28).

The two next sites had already been known many years ago. One of them, situated between Wroclaw and Świdnica at **Imbramowice** (**Ingramsdorf**), was described first by Gürich (1908). This outcrop is not accessible nowadays. Water snails: *Gyraulus* (*Planorbis*) *albus*, *Bithynia tentaculata*, *Valvata piscinalis* and *Lymnaea* sp. as well as a land snail *Succinea elegans* (original *pfeifferi*) were mentioned by this author. Similar assemblage identified by Dmoch twenty years ago was found at the same locality (Fig. 1 – 29), in the borehole log analysed and described in detail by Mamakowa (1989) as a standard sequence of the Eemian Interglacial documented by pollen assemblage zones.

The other site – **Strzeganowice** near **Kąty Wrocławskie** was described by Gepperd (1854) and Beyrich (1854) from a village named at that time "Paschwitz neben Canth" (Fig. 1 – 30). The assemblage found in clays, silts and sand exploited in a brickyard, was composed of 23 species of land snails and 10 species of freshwater molluscs, *i.a.*: *Chilostoma banaticum* (*Helix canthensis*), *Aegopis* (*Helix*) *verticillus*, *Helicodonta* (*Helix*) *obvoluta*, *Discus rotundatus* (*Helix rotundata*), *Vallonia* (*Helix*) *pulchella*, as well as 5 species of *Planorbis* and 3 species of *Valvata*. The occurrence of the first mentioned species testifies to the climatic optimum of the interglacial.

Freshwater molluscs: *Bithynia tentaculata* and *Valvata piscinalis* as well as *Pisidium* were noted at three localities of Eemian sediments in the vicinity of Radomsko, and between Łódź and Warsaw. These are sections at **Zabrzezie** (Makowska, 1971; Fig. 1 – 31), **Rogów** (S.W. Alexandrowicz, 1997; Fig. 1 – 32) and near **Pruszków** (Krupiński,

Table 6

Species of molluscs of the Eemian Interglacial in Poland as stratigraphic indicators in relation to regional pollen assemblage zones

Regional pollen assemblage zones (Mamakowa 1989)		Water molluscs	Land snails
V(E)	Graminae-Artemisia-Betula nana	*Valvata piscinalis-Armiger crista*	*Vallonia tenuilabris-Pupilla muscorum loessica*
E7	Pinus	*Valvata piscinalis-Bithynia tentaculata*	(?)
E6	Picea-Abies-Alnus		
E5	Carpinus Corylus Alnus	*Gyraulus albus-Armiger crista- Bithynia tentaculata*	*Vallonia pulchella-Succinea oblonga*
E4	Corylus-Quercus-Tilia	*Belgrandia marginata-Gyraulus albus-Bithynia tentaculata*	*Chilostoma banaticum-Aegopis verticillus-Helicodonta obvoluta*
E3	Quercus-Fraxinus-Ulmus	*Gyraulus albus-Gyraulus laevis-Bithynia tantaculata*	*Discus rotundatus-Acicula polita-Monachoides incarnata*
E2	Pinus-Betula-Ulmus	*Gyraulus laevis- Bithynia tentaculata-Valvata piscinalis-*	*Cochlicopa lubrica-Vallonia pulchella-Vertigo geyeri*
E1	Pinus-Betula		
W(L)	Cyperaceae-Artemisia-Betula nana	*Valvata piscinalis-Gyraulus rossmaessleri-Armiger crista*	*Vertigo genesii-Pupilla muscorum-Vallonia tenuilabris-Columella columella*

1986; Fig. 1 – 33). Similar sections were also found within the city of Warsaw at two sites: **Warsaw-Wola** and **Okopowa Street**, described by Urbański (1954) and Domosławska-Baraniecka and Gadomska (1965) (Fig. 1 – 34, 35). In the last mentioned section, shells of molluscs accompany bones of big mammals (*Elephas antiquus*).

Three interesting sections of Eemian mollusc-bearing sediments situated quite close to the north-eastern frontier of Poland are known in western Belorus and southern Lithuania. The first of them was described by Halicki (1951) and Urbański (1951) from **Żukiewicze**, about 15 km SE of Grodno (Fig. 1 – I). The relatively rich and differentiated fauna occurs there in silts, lacustrine chalk and gyttja rich in plant remains. The assemblage of freshwater molluscs (*Valvata piscinalis*, *Galba truncatula*) containing cold-tolerant land snails (*Vertigo parcedentata*, *Vallonia tenuilabris* and *Pupilla muscorum*) occurs in the lowermost part of the sequence. It passes upwards into the fauna dominated by *Valvata piscinalis* with *Gyraulus rossmaessleri* and *Vertigo genesii*, accompanied later also by *Bithynia tentaculata*. In the upper part of the section, the warm-demanding snail – *Gyraulus albus* was noted. The sequence of assemblages characterises a shallow water basin and corresponds with few climatic phases dateding from the late glacial (Late Wartanian) up to the middle part of the interglacial.

The section at **Rumlówka** is situated close to the previous one (Fig. 1 – II). It is characterised in detail by pollen and diatoms diagrams related to the sequence of beds (Marciniak *et al.*, 2007). The mollusc fauna determined by San'ko was sampled inclusive from the whole layer of lacustrine sediments. It contains 10 species of land snails and 26 species of freshwater snails and bivalves. Assemblages characterizing particular zones of the interglacial were not distinguished there, but like in Żukiewicze, both cold-tolerant species (*Vallonia tenuilabris*, *Vertigo genesii*, *V. geyeri*) and warm-demanding ones (*Gyraulus albus*, *Clausillidae*) were found. The occurrence of *Belgrandia marginata* indicates that the zone of climatic optimum is represented in this section.

Mollusc-bearing sediments are known from the section **Nieciosy** (Netiesos), situated in southern Lithuania on the right bank of the Nemunas River, about 20 km from the famous health resort – Druskienniki (Fig. 1 – III). The site was described first by Bremówna and Sobolewska (1950), and the fauna identified by Urbański enclosed shells identified jointly from the entire interglacial. These were specimens of Limacidae and 8 species of freshwater molluscs, mainly *Valvata piscinalis*, *Gyraulus laevis* and *G. albus*. The sequence of assemblages identified and illustrated much later in the malacological diagram by San'ko and Gaigalas (2007) enables one to distinguish particular climatic phases documented by the following species (from the bottom upward): *Gyraulus laevis - Bithynia tentaculata - Pisidium casertanum* (pre-optimal phase); *Bithynia tentaculata - Belgrandia marginata* (climatic optimum), and finally *Bithynia tentaculata - Gyraulus albus* (post-optimal phase).

CONCLUSIONS

Selected species and assemblages of molluscs found in sediments of the Eemian Interglacial in Poland are useful for stratigraphic interpretations and reconstructions of sedimentary environments, considerably supplementing the results of studies of plant macrofossils and particularly of pollen analyses. In these interpretations, freshwater snails and bivalves are much more significant than land snails because they occur in all analysed sites, usually reaching a considerable number of specimens. On the other hand, land snails were found in few sections only and in general as a small number of shells.

Results of malacological analysis depend mainly on the method of sampling, on the number and size of samples and on sediment type. Calcareous sediments, like lacustrine chalk, gyttja or marls as well as sediments with an admixture of carbonates and some fine-grained terrigeneous sediments are most important mollusc-bearing deposits. In organogenic sediments abounding in plant remains and par-

ticularly suitable to pollen analysis (peat, peaty silt, peaty mud, some types of gyttja), shells of molluscs are found only exceptionally. These circumstances appear to be responsible for the differentiation and validity of data published by several authors and used to construct malacological diagrams presented here.

An attempt at correlating climatic phases identified by molluscs with the pattern of pollen stratigraphy presented by Mamakowa (1989) was the leading intention of present authors. In the standard section at Imbramowice, pollen assemblage zones of the Eemian Interglacial were defined and described in detail by Mamakowa (1989). There occur local zones: IP-1 – IP-14 (interglacial ones, including also the Late Wartanian and Early Vistulian symbolised as LW and EV) as well as the most important regional zones: E-1 – E-7 (only interglacial ones), supplemented by the preceding and succeeding zones. The last mentioned are from the bottom upward: **LW** – Cyperaceae-Artemisia-Betula nana, **E-1** – Pinus-Betula, **E-2** – Pinus-Betula-Ulmus, **E-3** – Quercus-Fraxinys-Ulmus, **E-4** – Corylus-Quercus-Tilia (climatic optimum), **E-5** – Carpinus-Corulus-Alnus, **E-6** – Pinus-Abies-Alnus, **E-7** – Pinus, **EV** – Gramineae-Artemisia-Betula nana.

Climatic tolerance of particular mollusc species is the main attribute deciding on their stratigraphic value. Taking into consideration the described basic and supplementary sections, with special attention paid to the most important and reliable ones (Piła and Kochanów – Figs 2, 15), species of water and land snails related to the mentioned regional pollen assemblage zones E-1 – E-5 can by listed (Table 6). Land snails typical of loess and other sediments of cold Pleistocene periods: *Vallonia tenuilabris*, *Pupilla muscorum loessica*, *Columella columella*, *Vertigo parcedentata* and few others, are typical of the late glacial preceding the Eemian Interglacial (LW) as well as of the next early glacial (EV). Few species of water snails belong to the same group (*Gyraulus rossmaessleri*) and occur together with species tolerating both cold and moderate climate. The latter ones are also to be found in the entire interglacial and particularly or in its lower part: E-1 and E-2 (*Gyraulus laevis*, *Valvata piscinalis*, *Armiger crista*, *Trichia hispida*, *Vallonia pulchella*), while two species of *Vertigo* (*V. genesii* and *V. geyeri*) are connected particularly with transitional phases of climatic changes. Numerous species are restricted only to phases of moderate climate characterizing the interglacial (*Bithynia tentaculata*, *Pisidium casertanum* and several land snails). Several of them have a limited climatic tolerance and indicate phases E-3 – E-5, marked by the development of deciduous forests. These are: *Gyraulus albus*, *Discus rotundatus*, *Monachoides incarnata*, *Acicula polita*) and few others. The most important of them is a termophilous water snail *Belgrandia marginata* that indicates the climatic optimum of the Eemian Interglacial (E-4). Land snails suggesting the optimal phase (*Chilostoma banaticum*, *Aegopis verticillus*, *Helicodonta obvoluta*) were found at one site only, and are therefore of limited importance.

Respective data concerning the zones of the upper Eemian (E-6, E-7) and the succeeding Early Vistulian (EV) are very poor and deficient. Malacofauna bearing freshwater snails: *Valvata piscinalis* and *Bithynia tentaculata* was noted at few sites (Żmigród, Nakło, Solec Kujawski) only. Cold-tolerant snails associated with freshwater molluscs, *i.e*. bearing the above-mentioned species, occur in younger sediments attributed to the Early Vistulian interstadials (Brodniewicz, 1966; Skompski, 1996).

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