

MALACOSTRATIGRAPHY OF VISTULIAN AND HOLOCENE IN POLAND

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Abstract

Structure and composition of molluscan assemblages depend on natural factors such as: climate, vegetation, character of background, environmental conditions and, intensity of geological processes as well as on the human impact. Vistulian and Holocene communities of snails and bivalves exactly reflect changes of habitats. Sequences of these fauna can be used for biostratigraphy and stratigraphical schedule. The oldest part of the presented scheme corresponds with Last Pleniglacial characterized by poor communities with a high content of open country species accepting the arctic and subarctic climate. Climatic fluctuations during the Late Glacial caused a substantial recomposition of assemblages. In colder phases communities abounding in open country species of high ecological tolerance occur commonly. Fauna connected with warmer stages usually contains woodland species. At the beginning of the Holocene, a rapid warming was followed by the expansion of forests. Shade-loving species increased in number, while cold tolerant snails gradually disappeared. The maximal expansion of woodland snails is connected with the Atlantic Phase. During the Upper Holocene molluscan communities indicate the progress of human impact. The proposal of malacostatigraphical subdivision presented below can be correlated with similar schemes defined in neighboring countries. It supplement palynological schemes or even can be used as main way to stratigraphical reconstructions.

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Key words: molluscs, malacostatigraphy, Vistulian, Holocene, Poland

INTRODUCTION

Well preserved shells of snails and bivalves occur in different types of Quaternary sediments particularly those containing a sufficient quantity of calcium carbonate. Numerous sites of deposits rich in subfossil molluscs are found in areas composed of carbonate rocks, mainly limestones and also marls, dolomites as well as sandstones with limy matrix. In geological regions rich in mollusc-bearing deposits palaeobotanical data are relatively rare, so they can be significantly supplemented by results of malacological investigations. In such deposits snails and bivalves are usually much more numerous than other subfossil organisms (vertebrates, ostracoda).

Mollusc shells occur commonly both in terrestrial and in freshwater sediments, often throughout the whole depositional sequence. Their assemblages correspond with local habitats and reflect almost original composition of malacocenoses living during deposition of sediments. Most of species living recently in Central Europe are known in this area since the Eemian Interglacial. Due to that, malacofauna appeared very useful in palaeogeographical and stratigraphical analyses of Late Quaternary formations (see e.g. Ložek 1964, 1973; S.W. Alexandrowicz 1987a; W.P. Alexandrowicz 2004). In this respect the knowledge of the ecology and geographical distribution of modern molluscs could be used for interpretation of subfossil assemblages.

During the last Pleniglacial, Late Glacial and Holocene climatic oscillations forced substantial changes of habitats and biocenoses including more or less fundamental rearrangement of mollusc assemblages, expressed by the appearance and extinction of particular species and their groups. Cyclic alternations of warmer and cooler and/or dryer and more humid phases were the first factor responsible for the intensity of geomorphological processes as well as the evolution of habitats, fitocenoses and finally malacocenoses. The human impact manifested mostly in the Middle and Late Holocene was the second factor of these changes (S.W. Alexandrowicz 1987a; W.P. Alexandrowicz 2004).

The classical subdivisions of Vistulian and Holocene reflect changes of climate. The dependence of snails and bivalves on prevalent climatic conditions makes molluscs as important material in stratigraphical investigations particularly in climatostratigraphy.

Sequences of mollusc assemblages described from numerous localities in Central Europe provided principles for paleogeographical reconstructions and enabled construction of more or less generalized malacostatigraphic schemes (Ložek 1964, 1982; Kerney 1977; S.W. Alexandrowicz 1987a; W.P. Alexandrowicz 2004) of regional importance.

Application of biostratigraphical units (different types of biostratigraphical zones) in the construction of stratigraphical subdivisions in older geological formations (Cam-

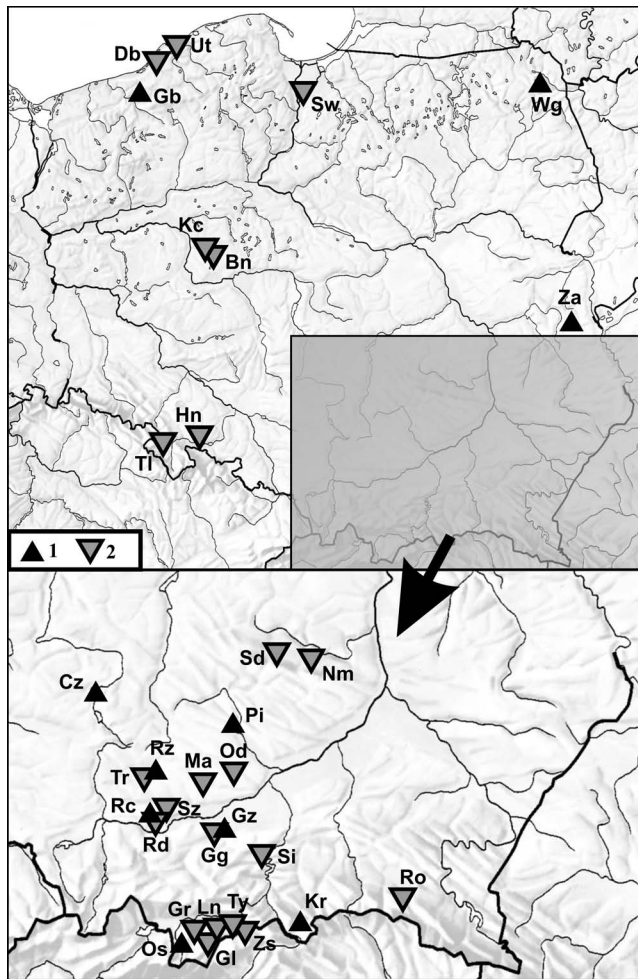


Fig. 1. Distribution of stratotype profiles of mollusc bearing deposits in Poland. 1. Stratotype profiles: Cz – Częstochowa, Gb – Grabowo, Gz – Gdów-Zabłocie, Kr – Krynica, Os – Ostrysz, Pi – Pińczów, Rc – Raclawka Stream Valley, Rz – Rzeżuśnia, Wg – Wigry Lake, Za – Zawadówka; 2. Hypostratotype profiles: Bn – Bnin Lake, Db – Dąbki, Gg – Gdów-Zagórze, Gl – Gliczarów, Gr – Groń, Hn – Henryków, Kc – Kórnickie Lake, Ln – Łapsze Niżne, Ma – Maszków, Nm – Nietulisko Małe, Od – Odonów, Rd – Rudawa, Ro – Roztoki, Sd – Sieradowice, Si – Sienna, Sw – Skowarcz, Sz – Szklarka Stream Valley, Tl – Tłumaczów, Tr – Trzebienie, Ty – Tylka, Ut – Ustka, Zs – Zaskale.

brian, Ordovician etc.) (Kutek 1972, Racki Narkiewicz (eds) 2006) is restricted or even useless in the respect to the Late Quaternary due to the short duration of this period. These units can be replaced by “nominal zones” – unformal units proposed by S.W. Alexandrowicz (1987a) regarded as ecostratigraphical ones.

This paper presents a new proposal of malacostratigraphical subdivision of Late Glacial and Holocene. This subdivision can be used as a basis for correlations, both in the local and regional scale, between malacological sequences representing profiles of sediments of different genesis. Majority of older proposals of such subdivisions are of local significance (e.g. Gedda 2001, Meyrick 2002) or can be used only to particular types of deposits (for example: S.W. Alexandrowicz 1995a; W.P. Alexandrowicz 2004). The presented scheme, in contrast to the older ones (e.g. S.W. Alexandrowicz

1987a; Skompski 1996), contains malacostratigraphical units defined basing on detailed description of the molluscan communities. It contains also, for the first time, appointed stratotype and hypostratotype profiles. Malacostratigraphical subdivision of fresh-water environments is the first such proposal not only in Poland, but also in the whole Europe.

DESCRIPTIONS OF ZONES

The proposed scheme is based on detailed analyses of numerous profiles of Late Glacial and Holocene molluscs-bearing deposits from Poland. The age of particular zones has been established according to radiocarbon data (cited by: S.W. Alexandrowicz 1983, 1995a; S.W. Alexandrowicz, W.P. Alexandrowicz 1995a, 1995b; Skompski 1996; W.P. Alexandrowicz 1999a, 2004, 2007; and references therein). The scheme consists of two elements: the first one including zones distinguished in faunal successions in terrestrial habitats, and the second related to successions in water biotopes. For each malacostratigraphical unit described below, the typical profile (stratotype) is pointed. In the stratotype profile the molluscan community used to define the zone is described in detail, and its stratigraphical position is well determined by radiocarbon dating. Other, well elaborated profiles are regarded as supplementary (hypostratotype) ones (Fig. 1, Tabs 1, 2).

Malacostratigraphic subdivision of terrestrial environments (Fig. 2-L)

Trichia hispida zone – 32,000–25,000 ¹⁴C years BP (Early Plenivistulian) (Fig. 2-L)

The tolerant open country and catholic species adapted to the cold, continental climate are the main component of the assemblage. It corresponds with the phase of open-country environments of the tundra or steppe-tundra type. The admixture of mesophilous snails indicate the occurrence of shrubs or even light forests and relatively humid habitats. The low intensity of loess accumulation is observed during the phase in question. The most characteristic assemblage is composed of the nominal taxon and typical loess species: *Pupilla muscorum* (L.), *Succinea oblonga* Drap., *Arianta arbustorum* (L.) and some others.

Pupilla muscorum loessica zone – 25,000–21,000 ¹⁴C years BP (Middle Plenivistulian) (Fig. 2-L)

The poor community with predominance of cold tolerant snails is typical for this zone. It corresponds with cold, severe and dry continental climate and indicates the environment of subarctic steppes with limited humidity. The most typical community contains only loess species such as: *Pupilla muscorum loessica* Ložek, *Pupilla muscorum densegyrata* Ložek, *Pupilla muscorum* (L.), *Vallonia tenuilabris* (Brown) and *Succinea oblonga* Drap. Progressive cooling of climate during the Pleniglacial and occurrence of stages of intensive loess accumulation are marked by the decrease of species diversity. In special cases the nominal taxon occurs as the only one in the assemblage. *Pupilla muscorum loessica* Ložek was defined by Ložek (1965) as a distinct species but according to the results of biometrical studies the mentioned taxon

Table 1

Stratotype and hypostratotype profiles of malacofauna of terrestrial environments

Zone	Main localities (stratotypes)	Supplementary localities (hypostratotypes)
<i>Trichia hispida</i>		Tumaczów (loess)
<i>Pupilla muscorum loessica</i>	Pińczów (loess)	Maszków (loess) Odonów (loess)
<i>Succinea oblonga</i>		Sienna (slope deposits)
<i>Vertigo parcedentata</i>	Częstochowa (aeolian sand and silt)	Nietulisko Małe (loess) Ustka (peat)
<i>Semilimax kotulae</i>	Krynica (slope deposits)	Groń (slope deposits) Gliczarów (slope deposits)
<i>Vertigo genesii</i>	Gdów-Zabłocie (calcareous tufa)	Szklarka Stream Valley (calcareous tufa) Gliczarów (calcareous tufa) Sieradowice (calcareous tufa)
<i>Discus ruderratus</i>	Raclawka Stream Valley (calcareous tufa)	Łapsze Niżne (fluvial deposits) Gliczarów (calcareous tufa) Sieradowice (calcareous tufa) Trzebienice (calcareous tufa)
<i>Discus perspectivus</i>	Raclawka Stream Valley (calcareous tufa)	Łapsze Niżne (fluvial deposits) Gliczarów (calcareous tufa) Trzebienice (calcareous tufa)
<i>Vallonia pulchella</i>	Raclawka Stream Valley (calcareous tufa)	Sieradowice (calcareous tufa) Trzebienice (calcareous tufa)
<i>Perforatella vicina</i>	Ostrysz (calcareous tufa)	Gliczarów (calcareous tufa) Zaskale (calcareous tufa)
<i>Cecilioides acicula</i>	Raclawka Stream Valley (calcareous tufa)	Gdów-Zagórze (fluvial deposits) Henryków (fluvial deposits) Rudawa (fluvial deposits)

Table 2

Stratotype and hypostratotype profiles of malacofauna of fresh-water environments

Zone	Main localities (stratotypes)	Supplementary localities (hypostratotypes)
<i>Psidium obtusale laponicum</i>	Zawadówka (peat and calcareous tufa)	Ustka (lacustrine chalk) Roztoki (lacustrine chalk) Skowarcz (lacustrine chalk)
<i>Gyraulus laevis</i>	Rzeżuśnia (calcareous tufa)	Roztoki (lacustrine chalk) Skowarcz (lacustrine chalk) Szklarka Stream Valley (calcareous tufa)
<i>Bithynia tentaculata</i>	Grabowo (calcareous tufa)	Roztoki (lacustrine chalk) Dąbki (lacustrine chalk) Skowarcz (lacustrine chalk)
<i>Bythyniella austriaca</i>	Ostrysz (calcareous tufa)	Gliczarów (calcareous tufa) Zaskale (calcareous tufa) Tylka (calcareous tufa)
<i>Dreissena polymorpha</i>	Wigry Lake (lacustrine chalk)	Kórnickie Lake (calcareous gyttia) Bnin Lake (calcareous gyttia)

can be regarded as subspecies or even only as ecoform of *Pupilla muscorum* (L.) adapted to a very cold climate and high intensity of aeolian accumulation (Łopuszyńska 2002). The described community is similar to the “Pupilla-fauna” described by Ložek (1965).

***Succinea oblonga* zone – 21,000 – 15,000 ¹⁴C years BP (Late Plenivistulian) (Fig. 2-L)**

This zone represents gradual warming of climate and decrease of intensity of loess deposition. The phase in questions corresponds with the expansion of wet or semi-wet, open

habitats. The nominal species usually predominates. Other cold tolerant snails: *Pupilla muscorum* (L.), *Semilimax kotulae* (West.), *Vertigo genesii* (Gredl.) and others occur as accessory components. *Succinea oblonga* Drap. found in loess deposits was earlier identified as *Succinea oblonga elongata* Standb. (Ložek 1965). However, according to recent biometrical analysis distinguishing the last mentioned taxon is not justified (Łopuszyńska 2002). The described community is similar to the “Succinea-fauna” (Ložek 1965).

The zones described above (*Trichia hispida*, *Pupilla muscorum loessica* and *Succinea oblonga*) could be distinguished in numerous profiles of loess and loess-like deposits

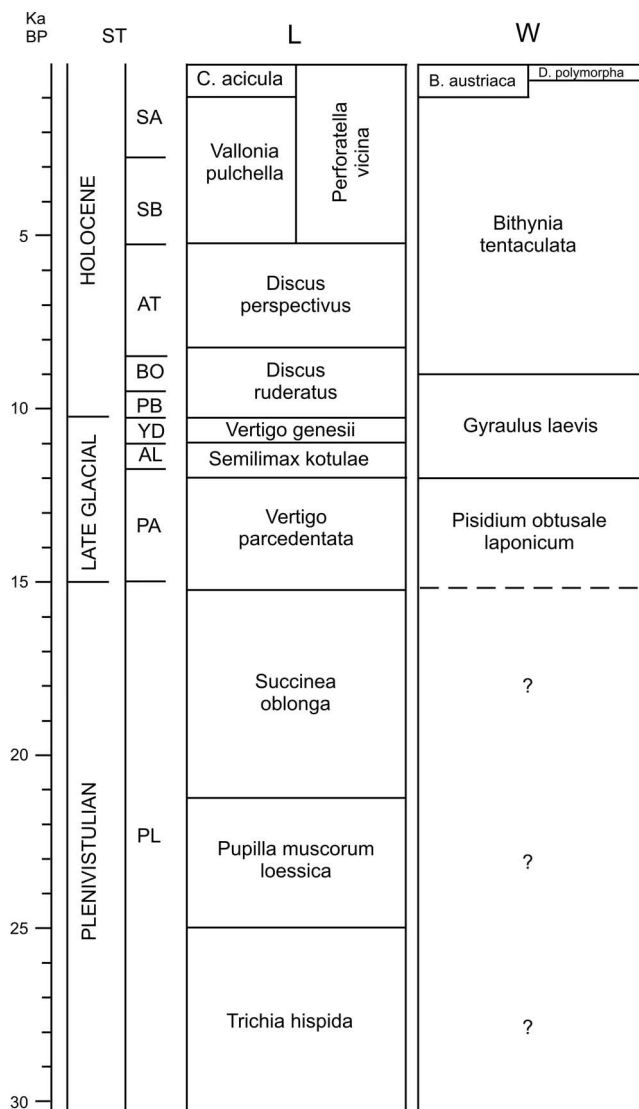


Fig. 2 Malacostratigraphic scheme of the Last Pleistiglacial, Late Glacial and Holocene in Poland. Ka – ¹⁴C age BP in thousands years; ST – stratigraphy: PL – Last Pleistiglacial, PA – Pre-Alleröd Period (*sensu* W.P. Alexandrowicz 1997, 2004), AL – Alleröd, YD – Younger Dryas, PB – Preboreal Phase, BO – Boreal Phase, AT – Atlantic Phase, SB – Subboreal Phase, SA – Subatlantic Phase; L – terrestrial snails, W – fresh-water molluscs.

described in Southern Poland. The most complete sequences were found in Pińczów (Nida Basin) (W.P. Alexandrowicz, Urban 2002) – stratotype profile. Profiles in Tłumaczów (Sudety Mts.) (W.P. Alexandrowicz 1999b), Maszków and Odonów (Małopolska Upland) (S.W. Alexandrowicz 1986, 1991a, 1995a) and in Sienna (Flysch Carpathians) (S.W. Alexandrowicz 1988, S.W. Alexandrowicz *et al.* 1991) can be regarded as supplementary (hypostratotype) ones (Fig. 1, Tab. 1).

Vertigo parcedentata zone – 15,000–11,800 ¹⁴C years BP (Pre-Alleröd) (Fig. 2-L)

This is the phase of cool climate with intensive development of humid, wet and swampy habitats. The typical community contains cold tolerant species, preferring wet habitats

such as: *Vertigo genesii* (Gredl.), *Vertigo geyeri* Lindh., *Columella columella* (G. Mart.). Loess taxa which were the main components of Pleniglacial malacocenoses gradually decreased. In a single localities more diverse communities enriched in catholic snails are noted. These profiles could be probably correlated with Bølling Interphase, however, according to malacological data this warmer episode practically cannot be distinguished. Stratotype succession – Częstochowa (Cracow-Częstochowa Upland) (W.P. Alexandrowicz, Kobjek 1997). Profiles in Nietulisko Małe (Holy Cross Mts) (S.W. Alexandrowicz 1987b) and Ustka (Baltic coast) (S.W. Alexandrowicz *et al.* 1989) are hypostratotypes (Fig. 1, Tab. 1).

Semilimax kotulae zone – 11,800–11,000 ¹⁴C years BP (Alleröd Interphase) (Fig. 2-L)

This zone represents warming of climate and consequent expansion of shady habitats, most probably bushes or light coniferous forests. The typical assemblages contain shade-loving, cold-tolerant species such as: *Semilimax kotulae* (West.), *Arianta arbustorum* (L.) accompanied by mesophilous snails: *Nesovitrea hammonis* (Ström), *Euconulus fulvus* (Müll.) and others. Species characteristic for cold, arctic climate like *Vertigo genesii* (Gredl.), *Vertigo geyeri* Lindh., *Columella columella* (G. Mart.) as well as forest snails appear occasionally. Stratotype succession – Krynica (Flysch Carpathians) (S.W. Alexandrowicz, Z. Alexandrowicz 1998, 1999; W.P. Alexandrowicz 2004), hypostratotype profiles are located in Podhale Basin – Groń (W.P. Alexandrowicz 1997) and Gliczarów (W.P. Alexandrowicz 1997, 2003) (Fig. 1, Tab. 1).

Vertigo genesii zone – 11,000–10,250 ¹⁴C years BP (Younger Dryas) (Fig. 2-L)

This zone represents woodless, open tundra-type habitats with marshes and swamps generally reflecting cooling of climate. Bushes and light forests decrease. The mollusc fauna comprises mainly cold tolerant, hygrophilous snails: *Vertigo genesii* (Gredl.), *Vertigo geyeri* Lindh. and *Columella columella* (G. Mart.). Catholic species: *Nesovitrea hammonis* (Ström), *Euconulus fulvus* (Müll.) supplement this community. Forest and shade-loving snails occur sporadically. Stratotype succession – Gdów-Zabłocie (Flysch Carpathians) (S.W. Alexandrowicz, Chmielowiec 1992). Profiles in Gliczarów (Podhale Basin) (W.P. Alexandrowicz 1997, 2003), Sieradowice (Holy Cross Mts) (S.W. Alexandrowicz *et al.* 1987, W.P. Alexandrowicz 2004) and in Szklarka Stream Valley (Cracow-Częstochowa Upland) (S.W. Alexandrowicz 1983, 1989; W.P. Alexandrowicz 2004) can be regarded as hypostratotypes (Fig. 1, Tab. 1).

Discus ruderatus zone – 10,250–8,400 ¹⁴C years BP (Early Holocene) (Fig. 2-L)

This zone corresponds to amelioration of climate and significant rearrangement of plant formations. Open and wet tundra-type biotopes are replaced by shady ones. Dominance of forest habitats with significant proportion of conifer trees growing in climate of strong continental influence is com-

monly observed. These changes lead to extension of taxonomical diversity of molluscan assemblages. Woodland species become dominant components of the communities, and are supplemented with snails living in shady or partly shady, wet biotopes: *Perforatella bidentata* (Gmel.) and *Vertigo substriata* (Jeffr.) as well as with mesophilous taxa. Occurrences of single shells of glacial relicts: *Vertigo genesii* (Gredl.), *Vertigo geyeri* Lindh. and *Columella columella* (G. Mart.) are noted. The described community is similar to the "Ruderatus-fauna" (Dehm 1967). Stratotype profile: Racławka Stream Valley (Cracow-Częstochowa Upland) (S.W. Alexandrowicz 1983; S.W. Alexandrowicz, Stworzewicz 1983; W.P. Alexandrowicz 2004). Hypostratotypes are located in: Łapsze Niżne and Gliczarów (Podhale Basin) (W.P. Alexandrowicz 1997, 2003), Sieradowice (Holy Cross Mts) (S.W. Alexandrowicz *et al.* 1987; W.P. Alexandrowicz 2004) and Trzebienice (Cracow-Częstochowa Upland) (W.P. Alexandrowicz 2004) (Fig. 1, Tab. 1).

***Discus perspectivus* zone – 8,400–5,100 ¹⁴C years BP (Middle Holocene) (Fig. 2-L)**

This zone corresponds with the postglacial climatic optimum and increasing influence of oceanic climate. In consequence expansion of dense deciduous forests appears. Communities of molluscs are supplied by many species of high ecological preferences. Rich and differentiated malacoceoses are composed of woodland snails such as: *Discus perspectivus* (Müllhf.), *Ruthenica filograna* (Rossm.), *Aegopinella minor* (Stab.) and many others. Mesophilous and hygrophilous species are accessory components of this fauna, while the meadow taxa are practically absent. The described community is similar to the "Perspectivus-fauna" described by Dehm (1987). Stratotype profile: Racławka Stream Valley (Cracow-Częstochowa Upland) (S.W. Alexandrowicz 1983; S.W. Alexandrowicz, Stworzewicz 1983; W.P. Alexandrowicz 2004). Hypostratotype profiles have been described from: Łapsze Niżne and Gliczarów (Podhale Basin) (W.P. Alexandrowicz 1997, 2003) and Trzebienice (Cracow-Częstochowa Upland) (W.P. Alexandrowicz 2004) (Fig. 1, Tab. 1).

***Vallonia pulchella* zone – 5,100–1,000 ¹⁴C years BP (Late Holocene) (Fig. 2-L)**

This zone is connected with the development of human activity and settlements, in particular with deforestation and related transformation of forest biotopes into open grasslands. Taxonomical diversity of molluscan assemblages markedly decrease. Rich communities of woodland snails are replaced by relatively poor assemblages dominated by open-country taxa (*Vallonia pulchella* (Müll.), *Vallonia costata* (Müll.) and others). Shade-loving forms typical for bushes as well as mesophilous species are only subordinate components of the fauna. The described zone can be distinguished mainly in Mid-Polish Uplands. Stratotype profile: Racławka Stream Valley (Cracow-Częstochowa Upland) (S.W. Alexandrowicz 1983; S.W. Alexandrowicz, Stworzewicz 1983; W.P. Alexandrowicz 2004), hypostratotypes: Sieradowice (Holy Cross Mts) (S.W. Alexandrowicz *et al.* 1987; W.P. Alexandrowicz 2004) and Trzebienice (Cra-

cow-Częstochowa Upland) (W.P. Alexandrowicz 2004) (Fig. 1, Tab. 1).

***Cecilioides acicula* zone – 1,000–0 ¹⁴C years BP (historical epoch) (Fig. 2-L)**

This zone represents extension of plough-fields and farmlands *i.e.* areas remaining under the intensive landuse and anthropopressure. Mollusc assemblages are very poor and contain species inhabiting agriculture areas (*Oxychilus inopinatus* (Uli.), *Cecilioides acicula* (Müll.)) as well as grasslands (*Vallonia pulchella* (Müll.), *Vallonia costata* (Müll.)). The mentioned zone can be distinguished in areas transformed by human activity, mainly agriculture (Mid-Polish Uplands, Carpathian Foothills). Stratotype profile: Racławka Stream Valley (Cracow-Częstochowa Upland) (S.W. Alexandrowicz 1983; S.W. Alexandrowicz, Stworzewicz 1983; W.P. Alexandrowicz 2004), hypostratotype ones are located in: Rudawa (Cracow-Częstochowa Upland) (Rutkowski 1991; W.P. Alexandrowicz 2004), Gdów-Zagórze (Flysch Carpathians) (S.W. Alexandrowicz, Chmielowiec 1992) and Henryków (Sudety Foothill) (S.W. Alexandrowicz, Teisseyre 1997) (Fig. 1, Tab. 1).

***Perforatella vicina* zone – 5,100–0 ¹⁴C years BP (Late Holocene) (Fig. 2-L)**

This zone corresponds with areas of low human impact covered in significant part with natural forests. Communities of molluscs are relatively rich and differentiated. They comprise shadow-loving species: *Perforatella vicina* (Rossm.), *Ena montana* (Drap.), *Eucobresia nivalis* (Dum et Mort.) and others, accompanied by catholic snails such as: *Nesovitrea hammonis* (Ström) and *Euconulus fulvus* (Müll.). The mentioned zone can be distinguished mainly in Carpathians. The profile in Ostrysz (Podhale Basin) (W.P. Alexandrowicz 1997, 2001) is the stratotype one. Profiles in Gliczarów (Podhale Basin) (W.P. Alexandrowicz 1997, 2003) and in Zaskale (Pieniny Mts) (W.P. Alexandrowicz 2004) can be regarded as hypostratotype sequences (Fig. 1, Tab. 1).

Malacostратigraphic subdivision of fresh-water environments (Fig. 2-W)

***Pisidium obtusale laponicum* zone – older than 12,000 ¹⁴C years BP (Plenivistulian, Prealleröd) (Fig. 2-W)**

This zone corresponds with severe, subarctic or even arctic climate. Communities of molluscs comprise mainly cold tolerant bivalves such as: the nominal taxon, *Pisidium stevarti* Peterson, *Pisidium lillieborgi* Cless., accompanied by water snail: *Gyraulus laevis* (Ald.). Land species are represented by hygrophilous taxa inhabiting swamps and marshes (*Vertigo genesii* (Gredl.), *Vertigo geyeri* Lindh.). The described fauna developed in small and shallow fresh-water bodies with initial carbonate accumulations. Stratotype succession – Zawadówka (Lublin Upland) (W.P. Alexandrowicz 2004; Dobrowolski *et al.* 2005), hypostratotype profiles: Skowarcz (Żuławy Wiślane) (W.P. Alexandrowicz 1999a, 2002), Ustka (Baltic coast) (S.W. Alexandrowicz *et al.* 1989) and Roztoki near Jasło (Flysch Carpathians) (S.W. Alexandrowicz 1987c) (Fig. 1, Tab. 2).

***Gyraulus laevis* zone – 12,000 – 9,300 ¹⁴C years BP
(Alleröd, Younger Dryas, Preboreal Phase) (Fig. 2-W)**

This zone characterises cold climate with strong continental influence. Relatively poorly diversified assemblage includes cold tolerant and euryecological water species. *Gyraulus laevis* (Ald.), *Pisidium stevarti* Peterson, *Pisidium obtusale laponicum* Cless. belongs to the first mentioned group, while *Galba truncatula* (Müll), *Valvata piscinalis* (Müll.) and some others represent the second one. This community is usually supplemented by hygrophilous land taxa (*Vertigo genesii* (Gredl.), *Vertigo geyeri* Lindh.). The described fauna developed in small and shallow freshwater basins or flat zones of bigger lakes. Stratotype succession – Rzeżuśnia (Cracow-Częstochowa Upland) (W.P. Alexandrowicz 2004), hypostratotype profiles: Roztoki near Jasło (Flysch Carpathians) (S.W. Alexandrowicz 1987c), Szklarka Stream Valley (Cracow-Częstochowa Upland) (S.W. Alexandrowicz 1983, 1989; W.P. Alexandrowicz 2004) and Skowarcz (Żuławy Wiślane) (W.P. Alexandrowicz 1999a, 2002) (Fig. 1, Tab. 2).

***Bithynia tentaculata* zone – 9,300–1,000 ¹⁴C years BP
(Boreal, Atlantic, Subboreal, Subatlantic Phases)
(Fig. 2-W)**

This zone represents different types of freshwater reservoirs developed in temperate or relatively warm climate. Rich and diverse assemblage comprises numerous water species of limited climatic tolerance: *Anisus contortus* (L.), *Anisus vortex* (L.), *Gyraulus albus* (Müll.) and many others. Single shells of cold tolerant taxa: *Gyraulus laevis* (Ald.), *Gyraulus acronicus* (Fér.) are sometimes found, too. Two types of the described communities can be distinguished. The first one contains snails and bivalves inhabiting large lakes (*Lymnaeidae*, *Unioidea*), while the second one is composed of taxa preferring shallow or even temporary water bodies (*Anisus vorticulus* (Trosch.), *Armiger crista* (L.) and others). Stratotype succession is located in Grabowo near Koszalin (Middle Pomerania) (S.W. Alexandrowicz 1995b). Profiles in Roztoki near Jasło (Flysch Carpathians), (S.W. Alexandrowicz 1987c), Dąbki near Darłowo (Baltic coast) (S.W. Alexandrowicz 1991b) and Skowarcz (Żuławy Wiślane) (W.P. Alexandrowicz 1999a, 2002) are hypostratotypes (Fig. 1, Tab. 2).

***Bythinella austriaca* zone – 1,000–0 ¹⁴C years BP
(historical period) (Fig. 2-W)**

This zone can be distinguished in recently deposited travertines and calcareous tufa. Typical feature of this assemblage is a very common occurrence of stenotopic snail *Bythinella austriaca* (Frfld.) which constitutes from 60 to 90% of taxa and may even exceed 95%. The malacocenoses includes also rare specimens of terrestrial species, *i.e.* hygrophilous, open-country forms (*Succinea putris* (L.)) or shade-loving ones (*Perforatella bidentata* (Gmel.)), and even less abundant taxa typical of more dry habitats. Important members of the assemblage are other freshwater molluscs the most common of which is usually *Pisidium personatum* Malm.. The described fauna is typical of cold waters of con-

stant temperature and was encountered mainly in spring zones rich in calcium carbonate. However, this assemblage may appear also in fast-flowing streams of pebbly channels. Stratotype succession – Ostrysz (Podhale Basin) (W.P. Alexandrowicz 1997, 2001). Hypostratotypes are located in Gliczarów (Podhale Basin) (W.P. Alexandrowicz 1997, 2003), Zaskale (Pieniny Mts) (W.P. Alexandrowicz 2004) and in Tylka (Pieniny Mts) (W.P. Alexandrowicz 2004, 2009) (Fig. 1, Tab. 2).

***Dreissena polymorpha* zone – 300–0 ¹⁴C years BP (historical period) (Fig. 2-W)**

This zone corresponds with period of strong anthropopressure. One result of human activity is the increased migration of molluscs. During the last 300 years the native water fauna became supplemented by numerous taxa of high ecological tolerance (*Dreissena polymorpha* (Pallas), *Potamo-pyrgus antipodarum* (Grey), *Physa acuta* Drap.). These species are noted from both artificial and natural habitats. They are usually well developed in polluted environments, and gradually pass into freshwater reservoirs and rivers. Stratotype succession – Wigry Lake (North-East Poland) (W.P. Alexandrowicz 2000), hypostratotype profiles: Kórnickie Lake and Bnin Lake (Wielkopolska Lowland) (Wojciechowski 1999) (Fig. 1, Tab. 1).

CONCLUSIONS

The malacostratigraphic subdivisions of the Last Pleniglacial, Late Glacial and the Holocene, in Poland is based upon analyses of molluscs assemblages and selected species, which occur in different types of sediments like loess, silt, slope wash, hillwash, calcareous tufa, lacustrine chalk, as well as deposits accumulated by rivers and streams or filling caves and niches. Schemes of more or less regional extent were just proposed in several European countries.

Malacostratigraphical subdivisions elaborated in Western Europe are usually based on single localities or on several profiles of deposits of similar genesis distributed in a single geographical region (Mania 1973, 1995; Kerney 1977; Kerney *et al.* 1980; Keen 1987; Limondin-Lozouet, Rousseau 1991; Rousseau *et al.* 1993, 1994; Gedda 2001; Meyrick 2001, 2002; Limondin-Lozouet, Preece 2004). For that reason they have only local importance, and regional stratigraphical correlation between particular schemes is difficult, or even impossible.

Subdivisions worked out in Hungary, Czech and Slovakia (Ložek 1967, 1983, 2000; Krolopp 1983; Füköh 1993, 2000; Füköh *et al.* 1995) have more regional importance and can be used to the regional correlation. However they show substantial differences with respect to the scheme presented above, most probably because of distinctly different climatic regimes. In consequence malacostratigraphical zones are defined by different nominal species, different stratigraphical position and time spans of zones (Fig. 3). These differences occur particularly in the Holocene, while in Plenivistulian and Late Glacial succession and composition of mollusc assemblages are quite similar in the whole Central Europe.

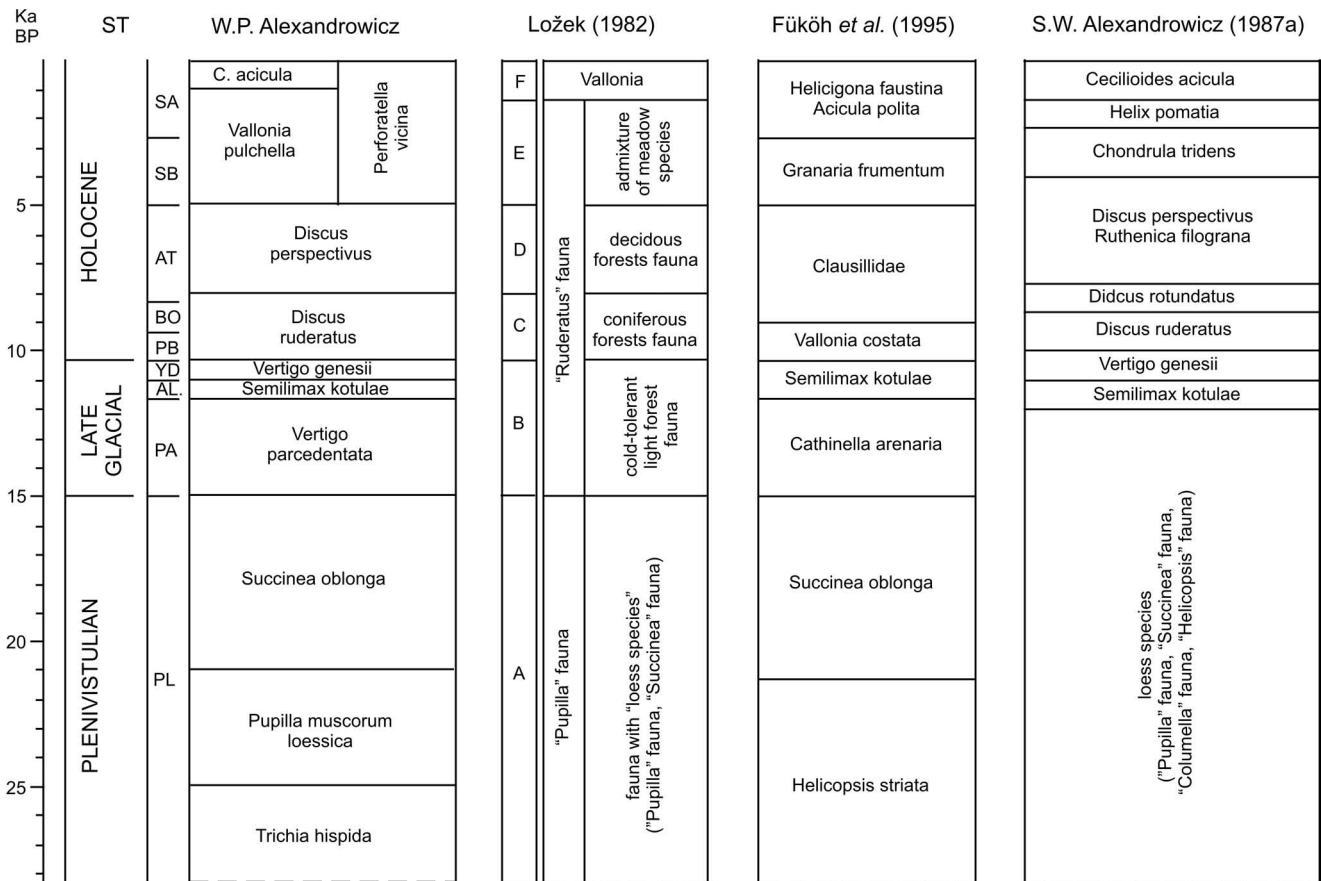


Fig. 3. Comparison of malacostratigraphic schemes in Central Europe. Ka – ¹⁴C age BP in thousands years; ST – stratigraphy; PL – Last Pleniglacial, PA – Pre-Alleröd Period (*sensu* W.P. Alexandrowicz 1997, 2004), AL – Alleröd, YD – Younger Dryas, PB – Preboreal Phase, BO – Boreal Phase, AT – Atlantic Phase, SB – Subboreal Phase, SA – Subatlantic Phase.

The scheme presented here is improved in relation to Polish subdivisions elaborated formerly (S.W. Alexandrowicz 1987a; Skompski 1996; W.P. Alexandrowicz 1997, 2004) since it is composed of well defined malacostratigraphical units, while in the previous subdivisions, the zones were distinguished basing on single species (usually one) only (Fig. 3).

Malacostratigraphical subdivision of fresh-water environments presented here (Fig. 2-W, Tab. 2) may be applicable over the large area of Central and Western Europe, because communities of fresh-water molluscs depend on environmental and climatic conditions in a limited range. Climatic fluctuations lead only to more or less important changes of the structure of assemblages, but usually do not induce (like as in terrestrial environments) essential recombination of taxonomical composition of the fauna. During the last 30 000 years, in particular climatic phases, similar communities of fresh-water molluscs occurred on the whole territory of Central and West Europe (Preece, Robinson 1982; S.W. Alexandrowicz 1987b; Walker *et al.* 1993; Griffiths *et al.* 1994; Willis *et al.* 1995; Schwalb *et al.* 1998; W.P. Alexandrowicz 1999a, 2007; Gaigalas *et al.* 2007). For this reason stratigraphical correlation among geographical regions seems to be relatively easy.

Acknowledgments

The research was financed through the Academy of Mining and Metallurgy grant No 11.11.140.560.

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