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QUATERNARY MOLLUSCAN ASSEMBLAGES OF THE POLISH CARPATHIANS

INTRODUCTION

Rich and differentiated molluscan assemblages occur in particular types of Quaternary sediments in the Polish Carpathians. Less then ten localities of this fauna had been described till the late seventies while more than a hundred were found during the last fifteen years by the present authors. The most of the mentioned molluscs-bearing sediments are of the Holocene age, more than twenty represent the Vistulian and only a few of them are older then the last glaciation. Subfossil shells of gastropods and bivalves occur in loess and loess-like loams, in lacustrine chalk and calcareous gyttja, in fluviatile deposits such as mud, sand and gravel accumulated on the alluvial plain (overbank facies), filling ox-bows or dam-lakes, in calcareous tufa and travertines as well as in slope deposits and in soil profiles (Fig. 1). In many localities the age of these molluscs-bearing sediments is defined by the radiocarbon or TL dating. Quaternary molluscan fauna of the Slovak Carpathians was described in details by Ložek (1976, 1982, 1990). It was being developed in similar way in both sides of the main range of these mountains still remaining under the influence and control of the climate and environmental changes.

MALACOFAUNA OF PLEISTOCENE DEPOSITS

Shells of molluscs occur frequently in loess and related deposits connected with particular cold periods of the Pleistocene. The oldest fauna was found by Łanczont in Prałkowce near Przemyśl, in loess of the Odranian age. There is a poor assemblage with *Succinea oblonga elongata*, *Pupilla loessica*, *P. muscorum* and *Vallonia tenuilabris* (Maruszczak 1991). The fauna of the Warthanian age has been reported from two outcrops situated close to the previously mentioned one. In the first one (Orzechowce) there is a relatively rich assemblage with *Trichia hispida*, *Arianta arbustorum*, *Clausilia dubia*, *Vertigo parcedentata* and a few other

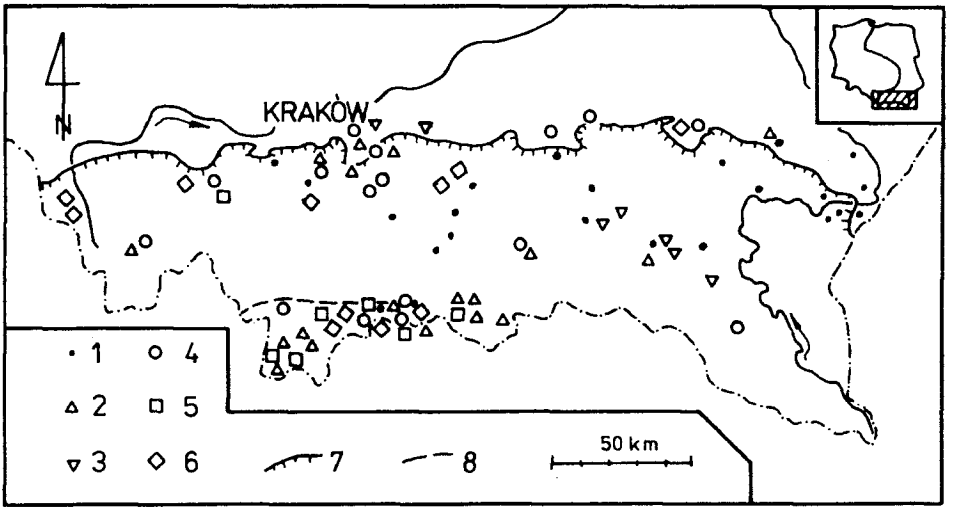

Fig. 1. Main localities of Quaternary molluscs-bearing sediments in the Polish Carpathians. 1 — loess and loess-like deposits, 2 — calcareous tufa and travertines, 3 — lacustrine chalk and calcareous gyttja, 4 — fluviatile sediments, 5 — slope deposits, 6 — soil profiles, 7 — northern border of Carpathians, 8 — northern border of Central Carpathians

Ryc. 1. Główne stanowiska czwartorzędowych osadów z malakofauną w polskich Karpatach. 1 — lessy i utwory lessopodobne, 2 — martwice i trawertyny, 3 — kredy jeziorne i gytje wapienne, 4 — osady rzeczne, 5 — utwory stokowe, 6 — profile glebowe, 7 — północny brzeg Karpat, 8 — północna granica Karpat Centralnych

species (S. W. Alexandrowicz *et al.* 1989), while in the other (Tarnawce) — a poor assemblage with numerous shells of *Arianta arbustorum* (Maruszczak 1991). This last mentioned species seems to be the most typical of the Upper Older Loess (Warthanian) in the Przemyśl Foothill.

Malacofauna of the Vistulian age is connected mainly with loess and loess-like loam but in a few localities it occurs also in fluviatile sediments. A rich and interesting fauna was found by Łanczont in Krzeczkowa Stream Valley near Przemyśl, in sandy mud covered with solifluction debris and loess (S. W. Alexandrowicz and Łanczont 1994). There is an assemblage with *Discus ruderatus*, *Vitrea crystallina*, *Punctum pygmaeum*, *Cochlicopa lubrica*, *Pupilla muscorum*, *Succinea oblonga elongata*, *Vallonia tenuilabris* and a lot of other species, typical of both temperate and cold climate. It characterizes an environment of an Early Vistulian interstadial (Brörup), confirmed with the TL datation.

Another locality of fluviatile molluscs-bearing mud is situated near Jasło. In mud intercalated with peat and sand an assemblage dominated by water molluscs occurs. Its main component are: *Valvata cristata*, *Gyraulus laevis*, *Armiger crista* and *Pisidium milium*. According to the C-14 datation these sediment are connected with one of the Middle Vistulian interstadials (Poprawa 1985).

Several types of molluscan assemblages occur in loess series (S. W. Alexandrowicz 1987a). Six of them can be quoted as the most important.

— The assemblage with *Pupilla loessica* is characterized by a low number of taxa and the predominance of the nominal species. This fauna reflect severe climatic conditions and relatively dry habitats. It pass gradually into mixed assemblages with a growing content of a few other taxa.

— The assemblage with *Succinea oblonga elongata* is clearly dominated by the nominal taxon, indicating a cold climate and moderately humid habitats. Like the above-cited one it pass gradually into the fauna of mixed types.

— The assemblage with *Trichia hispida*, *Arianta arbustorum*, *Vallonia tenuilabris*, *Clausilia dubia* and a few other taxa, contain also species typical of the two previously described assemblages as well as species living recently in the temperate zone. It is clearly differentiated and characterizes less severe climatic conditions of interstadials or the interpleniglacial.

— The fauna with *Helicopsis striata*, *Pupilla sterri* and a few other open-country species is typical of dry habitats of the steppe-type.

— The assemblage with numerous shells of *Columela columella* and *Vertigo parcedentata* associated a.o. with *Succinea oblonga elongata* and *Semilimax kotulai*, corresponds mainly with the humid or even swampy habitats and open environments of the tundra-type.

— The fauna with *Gyraulus laevis*, *Lymnaea truncatula*, *Pisidium stewarti*, *P. obtusale lapponicum* and *P. milium* is typical of water bodies developed temporary during the cold period within alluvial plains and valley bottoms.

In a few profiles a succession of molluscan assemblages has been described. It characterizes changes of both the climate and local conditions subsequently to the deposition of loess and loess-like loam and reflects the evolution of environment during the interpleniglacial or the ascending and the descending phases of the last pleniglacial. The age of the molluscan fauna from localities in Mizerna, Sowliny and Humniska was defined with the C–14 method (S. W. Alexandrowicz 1988a, Gerlach *et al.* 1991).

FAUNA OF THE LATE VISTULIAN / HOLOCENE AGE

Malacofauna of the Late Glacial and Early Holocene sediments has been described from many outcrops. There are mainly sediments accumulated in permanent or temporary water bodies or in swamps and marches within quite open areas. Lacustrine chalk and related deposits are known mainly from the Jasło–Sanok Depression (Klimaszewski 1948, Wójcik 1987, Gerlach 1990). Rich and differentiated molluscan asseemblages occur in these sediments (S. W. Alexandrowicz 1981, 1987b). In its older part it is a fauna with *Gyraulus laevis*, *Pisidium obtusale lapponicum* and *P. stewarti* (laevis-fauna) passing upward into a fauna with *Lymnaea peregra* and *Pisidium nitidum* (peregra-fauna). The youngest assemblage contain a.o. *Bithynia tentaculata* and *Planorbis planorbis* (bithynia-fauna). According to the results of the C–14

dating and the palynological data (Harmata 1987) the two first mentioned assemblages represent the Late Vistulian while the thirds is typical of the Early Holocene. Beside water molluscs an admixture of land snails is noted in many samples. There are mainly species living in swamps and marches as well as mesophile ones, such as: *Vertigo genesii*, *V. geyeri*, *Succinea putris* and *Euconulus fulvus*. In the lower part of some profiles single shells of species connected with a cold climate (*Columella columella*, *Semilimax kotulai*) have been found. Isolated localities of the lacustrine chalk with similar molluscan fauna occur close to the northern border of Carpathians eastward of Cracow.

Sediments of the age 12.5–9.5 thousand years BP developed as mud, calcareous silt and tufa or even slope debris have been described from different parts of Carpathians. They contain molluscan assemblages comprising four main elements:

— species of the cold climate abounding in loess such as *Columella columella*, *Vertigo parcedentata*, *Semilimax kotulai* and *Vallonia tenuilabris;*

— species living both in cold and temperate climatic zones, reaching recently the north polar circle: *Nesovitrea hammonis*, *Trichia hispida*, *Punctum pygmaeum*, *Euconulus fulvus*, accompanied by snails typical of open environment (*Vallonia pulchella*, *V. costata);*

— species connected mainly with the mentioned time interval (*Vertigo genesii*, *V. geyeri*) noted as the most typical component of assemblages in question;

— species migrating subsequently to the warming of the climate and the growing afforestation: *Discus ruderatus*, *Vitrea crystallina*, *Aegopinella pura*, *Cochlodina laminata*.

The first mentioned element occurs mainly in the lowermost part of particular profiles while the last — in its upper part. Well developed sequences of the molluscan assemblages characterizing the Vistulian/Holocene boundary have been reported in a few outcrops from different parts of the Carpathians, a.o. in Gliczarów and Ostrysz (Podhale — Central Carpathians), in Krynica (Beskidy Mts) as well as in Gdów and Husów close to the northern border of the mountains (S. W. Alexandrowicz 1987a, S. W. Alexandrowicz and Chmielowiec 1992, S. W. Alexandrowicz and Wyżga 1992, W. P. Alexandrowicz *et al.* 1992).

FAUNA OF CALCAREOUS TUFA AND TRAVERTINES

The mentioned calcareous sediments occur mainly in Central Carpathians (Podhale, Pieniny Mts) and in the Carpathian Foothill eastward of Cracow. In some profiles the tufa are intercalated or/and covered with organic mud. Rich and differentiated molluscan assemblages occur in these sediments. They reflect changes of the climate and the environment including the most important

phases of afforestation and deforestation. A few types of the fauna are dated with the radiocarbon method.

The fauna with *Discus ruderatus, Aegopinella pura* and *Vitrea crystallina* characterizes the Early Holocene calcareous tufa. In some outcrops, mainly in the Podhale region it contain a few species typical of the preceding period (*Vertigo genesii, V. geyeri, Semilimax kotulai*). The content of woodland snails increase gradually from 5% to 60%, such as the number of taxa and the diversity index of the fauna. Assemblages typical of the climatic optimum are particularly rich, with a considerable number of shadow-loving snails, such as *Discus rotundatus, Ruthenica filograna, Clausilia plicatula and Isognomostoma isognomostoma.* During the Subboreal Phase calcareous sediments were partly replaces with organic mud with a rich fauna characterized by a growing content of catholic species and open-country snails such as: *Vallonia pulchella, Cochlicopa lubrica, Punctum pygmaeum, Carichium tridentatum* and many others. Relations between the main components of the molluscan fauna (woodland — mesophile — open country species) depend also of local conditions. In consequence in some profiles calcareous tufa of the Middle Holocene age are characterized by an assemblage nearly devoid of woodland snails while in tufa of the Late Holocene age this component can be an important one or even prevail (S. W. Alexandrowicz 1987a, 1993b, W. P. Alexandrowicz *et al.* 1992)

A specific type of calcareous tufa abounding in shells of snails occurs in Tatra Mts and in Pieniny Mts, forming small cones at the foot of rock walls (S. W. Alexandrowicz 1988b). These sediments are quite young (the last milenium) and contain a fauna with *Eucobresia nivalis*, *Vitrea subrimata*, *Pyramidula rupestris* and *Vertigo alpestris*. The fauna corresponds with habitats widespread in the mentioned mountains till now.

MALACOFAUNA OF FLUVIATILE DEPOSITS

Sequences of molluscan assemblages have been found in sediments filling ox-bows. The most interesting profile of these sediments is known from Podgrodzie near Dębica, close to the northern border of Carpathians. The sequence begins with a rich fauna of water molluscs dominated by: *Valvata cristata*, *V. piscinalis*, *Bithynia tentaculata* and a few species of *Pisidium*. An admixture of march and catholic species is noted in the second assemblage passing upward into a fauna with a considerable content of land snails of different ecological groups: *Discus ruderatus*, *Bradybaena fruticum*, *Perforatella bidentata*, *Vallonia pulchella*, *Vitrea contracta*, *Carychium minimum* and *Succinea putris* accompanied by *Valvata cristata*. The described sequence corresponds with particular phases of the development of the mentioned water body during the

Lower Holocene (S. W. Alexandrowicz 1980). The fauna of sediments filling other ox-bows is of Middle or Upper Holocene age.

Rich molluscan assemblages occur in deposits of dam-lakes in valleys of streams dammed up with colluvial masses of landslides. The most interesting examples have been described from the Pieniny Mts. The fauna from the Harcygrunt Stream Valley dated at 7750 ± 130 BP comprises 50 taxa of molluscs with numerous shells of *Carychium tridentatum*, *Vitrea crystallina*, *V. subrimata* and *Acicula polita* (S. W. Alexandrowicz 1984). The fauna from two profiles in the Ścigocki Stream Valley represents the last milenium (680 and 250 years BP) and contain snails living in different habitats, a.o: *Discus perspectivus*, *Vitrea transsylvanica*, *Cochlicopa lubrica* and *Bythinella austriaca* (S. W. Alexandrowicz 1994). Molluscan fauna found in the Holocene stream sediments connected with landslides reflects mainly local environments developed close to the colluvial dam.

Silt, sand and mud forming terraces at the floor of river and stream valleys contain a quite differentiated molluscan fauna. The most common are assemblages with woodland and mesophile snails and assemblages dominated with catholic or open-country species accompanied with water molluscs. Both types of the fauna were noted in the Middle and Upper Holocene fluviatile deposits in valleys of a few tributaries of the Dunajec River in the Pieniny Mts. The first of them, described from Niedzica, Czorsztyn and Sromowce contains numerous shells of *Acicula polita*, *Vitrea transsylvanica*, *V. crystallina* and *Carychium tridentatum*, while the second one — *Vallonia costata*, *V. pulchella*, *Cochlicopa lubrica* and *Succinea putris*. This last mentioned fauna is connected with the deforestation of the area during the Medieval (S. W. Alexandrowicz 1990, 1993a). Similar assemblages dominated with open country snails occur in mud accumulated a few hundred years ago in the Przybędza Stream Valley in the Żywiec Basin (W. P. Alexandrowicz 1991).

FAUNA OF SLOPE DEBRIS AND SOIL PROFILES

An interesting sequence of molluscan assemblages occurs in loams with limestone lumps at the outlet of a small cave in the Sobczański Gorge, Pieniny Mts (S. W. Alexandrowicz *et al.* 1985). It begins with a fauna of the Lower Holocene with: *Discus ruderatus*, *Vallonia costata* and *Semilimax kotulai*, passing upward into a fauna enriched in snails living in partly shady habitats (*Vitrea crystallina*) and into a fauna with woodland species, such as *Ruthenica filograna*, *Orcula doliolum*, *Ena montana* and *Isognomostoma isognomostoma*. This last mentioned fauna is typical of the Middle Holocene while the fauna of the Upper Holocene contains numerous shells of kserophile and open-country snails such as *Pyramidula rupestris*, *Pupilla sterii* and *Truncatellina cylindrica*. Molluscan assemblages dominated by snails connected with dry and sunny habitats ac-

companied by *Helicigona faustina* and *H. cingulella* have been found in a few other profiles of the Late Holocene limestone scree both in Tatra Mts and in Pieniny Mts.

The Upper Holocene fauna occurs in a few localities of slope deposits in the Beskidy Mts and in the Carpathian Foothill. There are assemblages with snails of different ecological groups, corresponding with particular types of local habitats. Such taxa as: *Truncatellina cylindrica*, *Bradybaena fruticum*, *Alinda biplicata*, *Vitrina pellucida*, *Vallonia pulchella*, *Punctum pygmaeum* and *Carychium tridentatum* are the main components of these assemblages. The molluscs-bearing soil profiles are less know in the said area. In a few outcrops, mainly in the Carpathian Foothill a fauna of open-country snails has been found in soil developed on limestones and sandstones rich in calcium carbonate. It contains a.o.: *Pupilla muscorum*, *Vallonia pulchella*, *Vertigo pygmaea* and *Truncatellina cylindrica* accompanied by *Cochlicopa lubrica*, *Bradybaena fruticum* and *Vitrea contracta*. An admixture of woodland snails are noted locally. In the Pieniny Mts rich assemblages of subfossil molluscs occur in the rendsina-type soil. They comprise snails typical of both sunny and shady habitats: *Pyramidula rupestris*, *Chondrina clienta*, *Vallonia costata*, *Vertigo pusilla* and *Alinda biplicata*. The enrichment of shadow-loving species in the uppermost part of profiles reflect the afforestation following the protection of environment in the Pieniny National Park (S. W. Alexandrowicz 1993a).

SUCCESSIONS OF MOLLUSCAN ASSEMBLAGES

Two main sequences of the molluscan fauna analyzed in regard to land snails only, can be distinguished in quaternary deposits of the Polish Carpathians: one of them — in Central Carpathians and the other — in Carpathian Foothill. In the first mentioned region the sequence reflects changes of environment during the last thirty thousand years (Fig. 2). The period preceding the deglaciation is characterized by assemblages of climatically tolerant open-country snails and catholic species typical of cold climate (loess-fauna). During the Late Vistulian and the Lower Holocene the fauna became enriched in some palearctic species accompanied by both march snails (*Vertigo genesii*, *V. geyeri*) and relicts of the glacial period (*Columella columella*, *Semilimax kotulai*). Since the beginning of the Holocene the number of shade-loving snails increase markedly. It was at first *Discus ruderatus* and later species migrating from the West- and South Europe. In the Middle Holocene particular assemblages are quite differentiated and woodland snails clearly dominate. During the Subboreal Phase, subsequently with the early stage of the human impact this component of the fauna was locally reduced but stay still important up till the Medieval. The main phase of the deforestation arrived with the location of villages and the development of agriculture since the

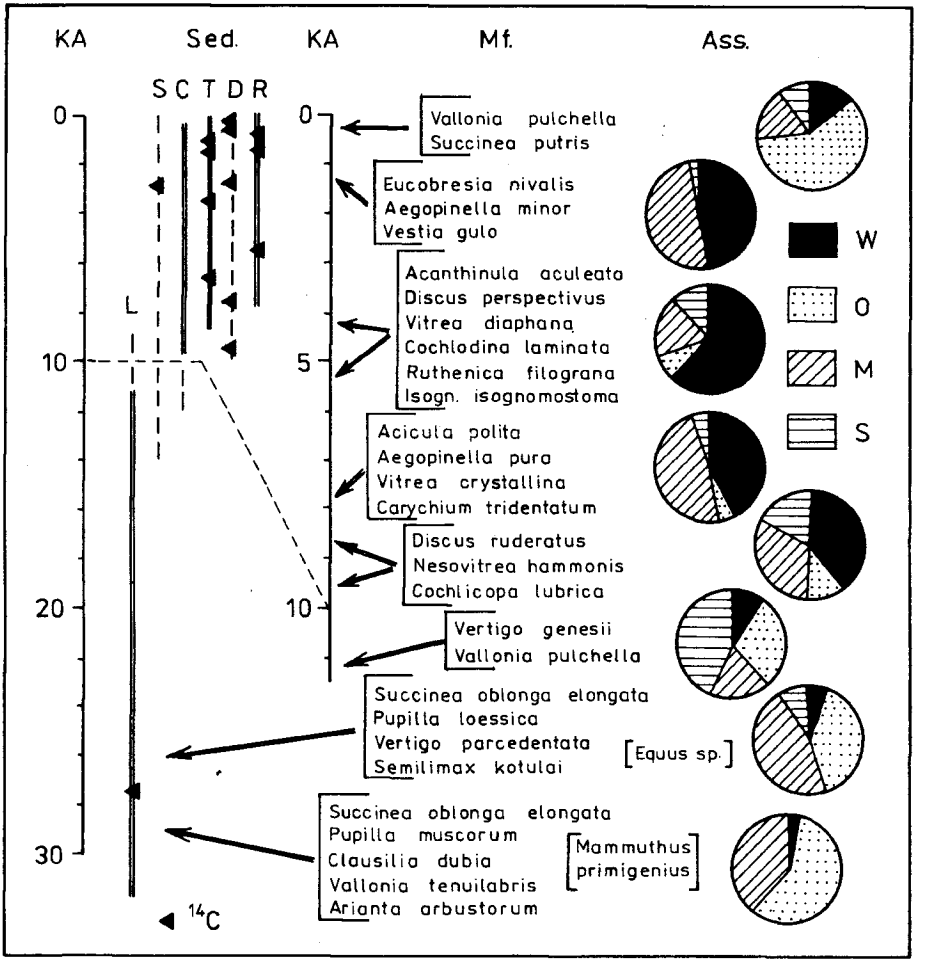

Fig. 2. Malacofauna of the Late Pleistocene and Holocene sediments of the Polish Central Carpathians. KA — age (BP) in thousand years. Sed — sediments: L — loess and loess-like loams, S — slope debris, C — cave deposits, T — calcareous tufa, D — sediments of dam-lakes, R — fluviatile sediments, W — lacustrine chalk, G — soil profiles, ^{14}C — radiocarbon dating, Mf — main components of molluscan assemblages (without water molluscs), W — woodland snails, O — open-country species, M — mesophile molluscs, S — march species

Ryc. 2. Malakofauna osadów późnego plejstocenu i holocenu polskich Karpat centralnych. KA — wiek (BP) w tysiącach lat, Sed — typy osadów: L — less i gliny lessopodobne, S — utwory stokowe, C — osady w jaskiniach, T — martwice wapienne, D — osady jeziorek zaporowych, R — osady rzeczne, W — kredy jeziorne, G — profile glebowe, ^{14}C — datowania radiowęglowe, Mf — główne składniki zespołów (bez mięczaków wodnych), W — ślimaki leśne, O — ślimaki środowisk otwartych, M — gatunki mezofilne, S — ślimaki siedlisk podmokłych

XII–XIII centuries. It is clearly expressed in changes of the molluscan fauna dominated by open-country species excluding areas protected as National Parks of the Tatra Mts and the Pieniny Mts (Fig. 2).

The sequence of molluscan assemblages in the Carpathian Foothill and the adjacent area begins in the Middle Pleistocene with the fauna of loess of the Odranian and the Warthanian age. It reflects also fluctuations of the climate during the last glaciation, particularly its early stage. The last pleniglacial is represented by a typical loess-fauna and the Late Vistulian — by an assemblage with march and open-country species. The fauna of the Lower Holocene and the Atlantic Phase is rich and contains a considerable number of woodland and mesophile snails while in the Subboreal Phase the content of open-country species and even snails typical of dry habitats increased markedly. Assemblages of the Upper Holocene corresponds with the growing of the human impact connected particularly with the Lusitian Culture and the Medieval. Since the few last centuries the accumulation of mud containing the fauna with *Vallonia pulchella*, *Cecilioides acicula* and *Succinea putris* began as a result of the intensification of agriculture and of the root plants cultivation (Fig. 3).

The two described sequences of the molluscan fauna differ from one another mainly by the content of woodland snails in sediments of the Subboreal Phase. In Central Carpathians, particularly in the Pieniny Mts assemblages of this age contain usually more then 40–60% of these snails while in the Carpathian Foothill the mentioned element reaches less then 30%. It reflects the progress of the human impact in particular parts of the mountains, noted by other authors (Starkel 1977). In the Carpathian Foreland and in the Carpathian Foothill it began in the Subboreal Phase subsequently to the development of the Eneolithic Cultures, while in the Central Carpathians it was elated, arriving in the Subatlantic Phase and growing since the Medieval.

MIGRATION OF SPECIES

Changes of the molluscan fauna controlled both by the climate and the human activity can be regarded as a result of the migration of species (S. W. Alexandrowicz 1987a). During the last thirty thousand years the main stages of these processes are connected with the deglaciation at the descending phase of the Vistulian, with the beginning of the Holocene, with the growing influence of the Atlantic climate and with the human impact. Subsequently to the warming of the climate the range of "loess-snails" decrease progressively, at the termination of the Pleistocene. Only some of them were still living in the area surrounding the Tatra Mts (*Columella columella*, *Semilimax kotulai*) while recently they occur as relicts above the timber line. In Bölling and Alloröd a few palearctic and boreo-alpine species connected with boreal forest (*Discus ruderatus*), swamps (*Vertigo genesii*, *V. geyeri*) and other habitats (*Nesovitrea hammonis*, *Punctum pygmaeum*) immigrated and occur in Carpathians till now. At the beginning of the Holocene the fauna was enriched in new elements (mainly woodland snails) while the most important stage of immigration falls

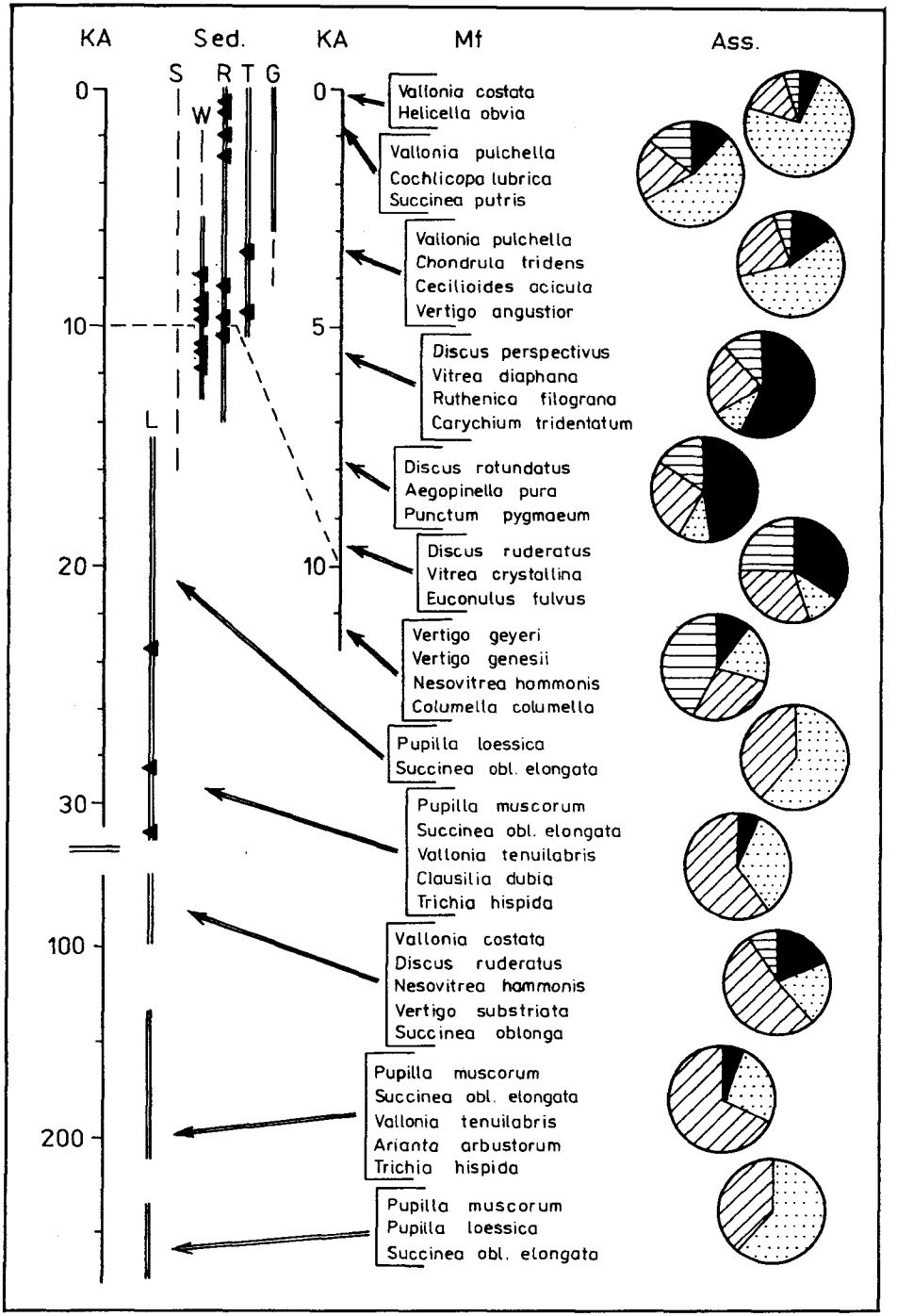

Fig. 3. Quaternary molluscan fauna of the Carpathian Foothill. Explanations as in Fig. 2

Ryc. 3. Malakofauna utworów czwartorzędowych Pogórza Karpat. Objaśnienia jak na Fig. 2

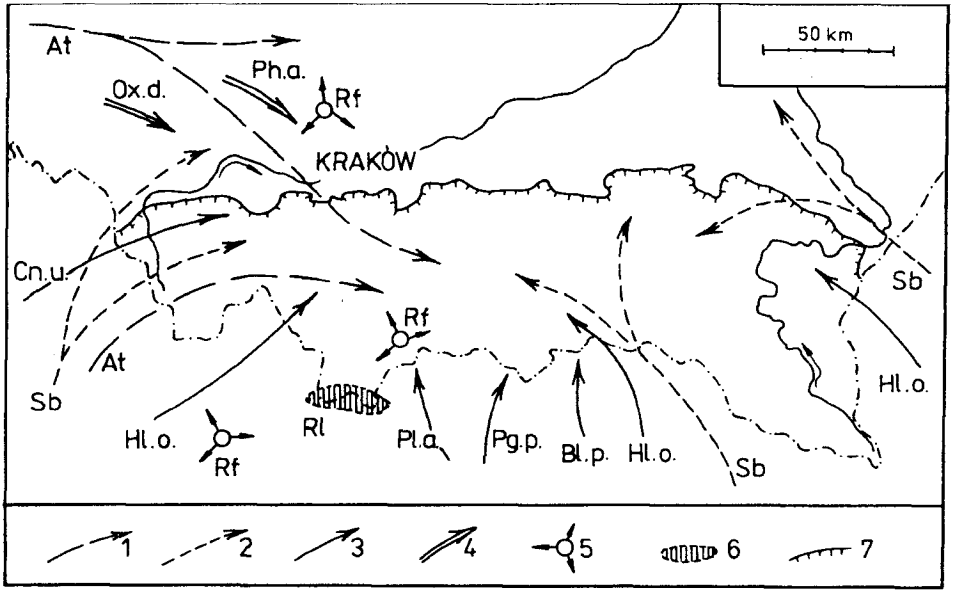

Fig. 4. Migrations of molluscs during the Holocene. 1 — species connected with the climatic optimum (At), 2 — species connected with the early phase of deforestation (Sb), 3 — snails migrating during the last milenium (Cn.u. — *Candidula unifasciata*, Hl.o — *Helicella obvia*, Pl.a. — *Pupilla alpicola*, Pg.p. — *Pagodulina pagodula*, Bl.p. — *Balea perversa*), 4 — species migrating in the current century (Ox.d. — Oxychilus draparnaudi, Ph.a. — Physa acuta), 5 — local refugies, 6 — area inhabitat by relicts of the cold climate, 7 — northern border of Carpathians

Ryc. 4. Migracje mięczaków w czasie trwania holocenu. 1 — gatunki związane z optimum klimatycznym (At), 2 — gatunki związane z wczesną fazą deforestacji (Sb), 3 — ślimaki migrujące w ostatnim tysiącleciu (Cn.u. — *Candidula unifasciata*, Hl.o. — *Helicella obvia*, Pl.a. — *Pupilla alpicola*, Pg.p. — *Pagodulina pagodula*, Bl.p. — *Balea perversa*), 4 — gatunki migrujące w bieżącym stuleciu (Ox.d.) — Oxychilus draparnaudi, Ph.a. — Physa acuta), 5 — lokalne refugia, 6 — strefa występowania reliktów glacjalnych, 7 — północna granica Karpat

into the climatic optimum. The last mentioned enclose such species as: *Discus rotundatus*, *D. persepcticus*, *Ruthenica filograna*, *Isognomostoma isognomostoma*, *Helicigona faustina* and many other coming from the South/Southwest or from small local refugees.

Migrations connected with the human activity took place at first in the Carpathian Foothill as a result of the Neolithic land use and the spread of the Lusitian Culture. During the Subboreal Phase species typical of open habitats and even snails living in soil were coming from the south or spread from local refugees. There are: *Cepaea vindobonensis*, *Chondrula tridens*, *Cecilioides acicula* and *Oxychilus inopinatus*. During the Medieval and the last few centuries particular parts of Carpathians (Beskidy Mts, Central Carpathians) were progressively deforested and in consequence the immigration of species proceeded. Beside *Pupilla alpicola* and *Candidula unifasciata* forming recently isolated populations, another snail typical of dry, sunny habitats — *Helicella obvia* —

settled a whole area of South Poland. Two other species accept artificial and polluted habitats. The first one — *Oxychilus draparnaudi* can be found in towns (Nowy Sącz) while the other — *Physa acuta* lives in rivers close to factories and power stations (Ropa river in Gorlice). Molluscan assemblages typical of natural habitats corresponding with the actual stage of the Holocene are preserved now mainly in national parks and nature reserves.

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STRESZCZENIE

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CZWARTORZĘDOWE ZESPOŁY MIĘCZAKÓW KARPAT POLSKICH

Bogate i zróżnicowane zespoły mięczaków występują w różnych typach genetycznych osadów czwartorzędowych Karpat (Fig. 1). Najstarsze przykłady fauny zostały znalezione w lessach na Pogórzu Przemyskim. Są to: zespół z *Succinea oblonga elongata* i *Pupilla loessica* z lessów starszych dolnych (odranian) oraz zespół z *Trichia hispida* i *Arianta arbustorum* z lessów starszych górnych (wartanian). Interesujące stanowisko osadów rzecznych przypisanych do interstadiału Brörup, zawierających faunę z: *Discus ruderatus*, *Vitrea crystallina*, i *Vallonia tenuilabris* występuje w Krzeczkowej koło Przemyśla, a zespół fauny wodnej (*Valvata cristata*, *Gyraulus laevis*), odpowiadający jednemu z interstadiałów środkowego vistulianu jest znany z okolic Jasła. W lessach i glinach lessopodobnych można wyróżnić kilka typów fauny, z których najczęściej spotykane są zespoły: z *Pupilla loessica*, z *Succinea oblonga elongata*, z *Trichia hispida*, z *Helicopsis striata* oraz z *Columella columella*. Na przedpolu Karpat znajdowane były również lessy vistulianu z malakofauną wodną. Bardzo charakterystyczny zespół fauny, odznaczający się obecnością *Vertigo genessi* i *V. geyeri*, znamionuje osady późnego vistulianu. Kredy jeziorne i gytje wapienne, deponowane u schyłku glacjału i bezpośrednio później zawierają fauny z *Gyraulus laevis* i *Pisidium obtusale lapponicum* przechodzące ku górze w zespół z *Bithynia tentaculata*. Holoceńskie martwice wapienne obfitują w fauny typowe dla dolnego holocenu (zespół z *Discus ruderatus* i *Vitrea crystallina*), dla środkowego holocenu (zespół z *Discus rotundatus*, i *Ruthenica filograna*) oraz dla młodszego holocenu. Zmienny udział gatunków leśnych w obrębie tych ostatnich, odzwierciedla z jednej strony przejawy antropogenicznej deforestacji, a z drugiej — zróżnicowanie naturalnych siedlisk. Następstwa faun

znamionujące fazy wypełniania i zarastania starorzeczy lub zbiorników wodnych, utworzonych w wyniku zatarasowania doliny potoku przez osuwisko odznaczają się postępującą zmianą proporcji mięczaków wodnych w stosunku do lądowych, przy różnym udziale ślimaków leśnych i typowych dla środowiska otwartego. Fauny znajdowane w późnoholoceńskich terasach i stożkach napływowych dobrze odzwierciedlają zakres wylesień związanych z rozwojem rolnictwa w średniowieczu. Dwa typy sekwencji zespołów mięczaków zostały wyróżnione w Polskich Karpatach. Pierwszy z nich, występujący w Karpatach Centralnych, odznacza się ciągłością faun leśnych aż do czasów historycznych, podczas gdy drugi, związany z Pogórzem Karpat, wykazuje znaczny wzrost udziału faun wskazujących na wylesienia już od początku fazy subborealnej (Fig. 2, 3). Zmiany zespołów mięczaków, znajdowanych w poszczególnych typach osadów, odzwierciedlają migracje gatunków, następujące w wyniku postępującej ewolucji klimatu i nasilającej się działalności człowieka. Głównymi etapami tych zjawisk były: deglacjacja w późnym vistulianie, ocieplenie z początkiem holocenu, wpływ klimatu atlantyckiego wraz z nastaniem fazy optymalnej, wylesianie związane z rozwojem gospodarki neolitycznej oraz antropogeniczne zmiany środowiska, następujące w czasach historycznych (Fig. 4).