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# DEATH ASSEMBLAGES OF MOLLUSCS IN FLOOD DEPOSITS OF THE MUSZYNKA RIVER (POLISH CARPATHIANS)

## INTRODUCTION

Accumulations of organic remains in the present day fluviatile sediments described as thanatocenoses are composed mainly of shells of molluscs, plant detritus, fruits, seeds, fragments of wood and branches. They are deposited during floods along the river valley mainly on floodplains as lateral bars bordering the maximum extension of floodwater, in outer part of meanders or behind dams, weirs and obstacles. Such death assemblages have been sampled and described by many authors since more then hundred years as a rich material contributing to the knowledge about the occurrence and range of particular species (Heynemann 1870, Kotula 1882, Geyer 1908, Clessin 1908a, 1908b, 1911, Ankert 1922, Grahle 1954, Klemm 1973, Körnig 1987). On the other hand studies concerning the composition and the structure of molluscan thanatocenoses in relation to both sedimentary conditions and differentiation of habitats or even the whole environment of the catchment area are much less advanced till now. On the contrary a few accumulations of fruits and seeds in fluviatile deposits and their origin have been analysed in details by Pelc (1983), Cabaj and Pelc (1991), Cabaj (1993).

Detail investigations of different molluscan thanatocenoses within recent deposits are the subject of actuopaleontological studies initiated by Wasmund (1926, 1929) and Richter (1928). They include changes of molluscan assemblages inducted by selective elimination of shells, the influence of seasonal faunal fluctuations, the distribution and differentiation of habitats as well as the course and the mechanism of accumulation in various sedimentary environments. Such observations carried out "in statu nascendi" require the application of methods used in studies on recent malacofauna, a.o. quantitative sampling and statistical analysis proposed by Czogler and Rotarides (1938). The results may be used as a key to interpretation of subfossil assemblages in many aspects (Zeissler 1963, Alexandrowicz 1987, 1991). The model of faunal diversity pertaining to fluviatile environments has been described by Piechocki (1969).

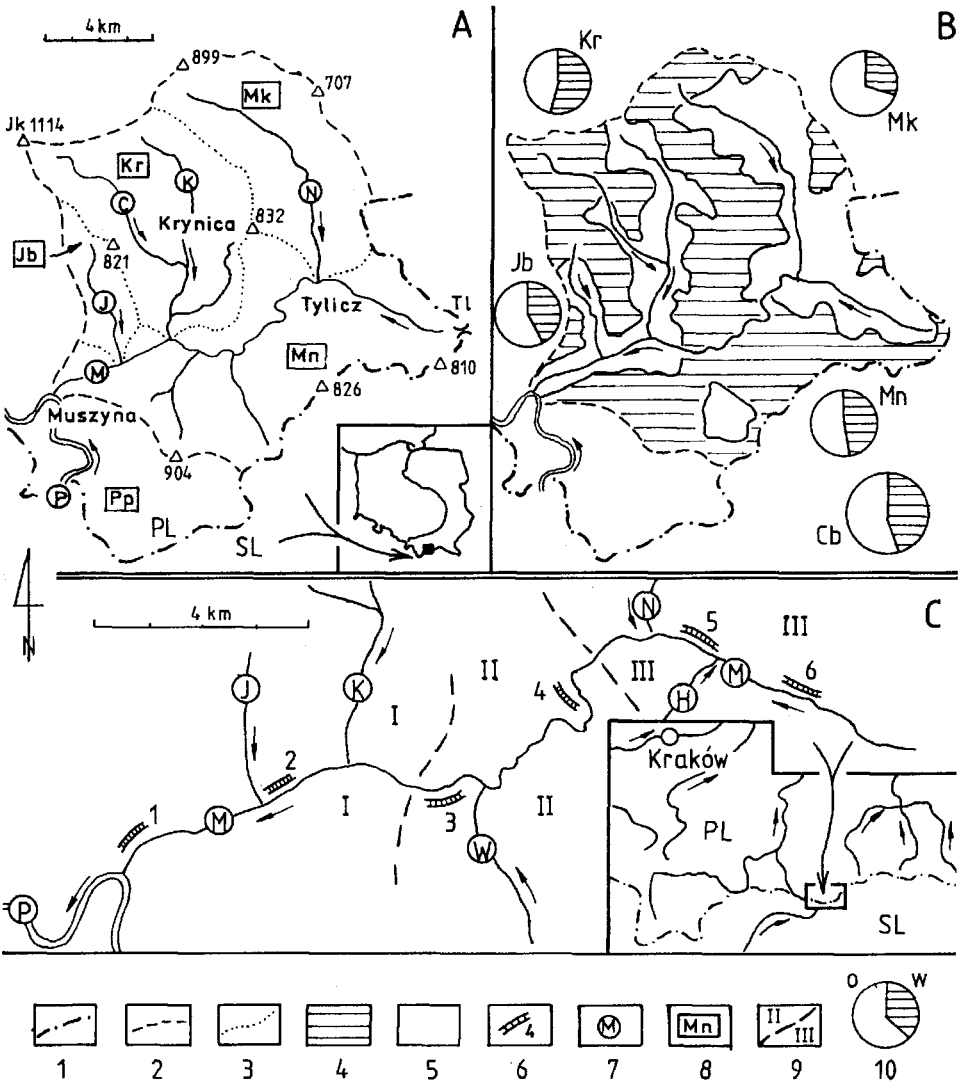


Fig. 1. The catchment basin of the Muszynka river. 1 — Polish-Slovakian border, 2 — limit of the catchment area, 3 — limits of catchment basins of the main tributaries, 4 — wooded area, 5 — open area, 4 — sites of collected thanatocenoses (1–6), 7 — rivers and streams: P — Poprad river, M — Muszynka river, N — Mochnaczka stream, K — Kryniczanka stream, J — Jastrzębik stream, W — Wojkowski stream, H — Hotarny stream; 8 — catchment basins of rivers and streams: Pp — Poprad catchment area, Mn — Muszynka catchment area, Mk — Mochnaczka catchment area, Kr — Kryniczanka catchment area, Jb — Jastrzębik catchment area; 9 — borders of particular parts of the Muszynka river valley (I–III), 10 — the percentage of wooded (W) and open (O) areas. A — location sketch of the Muszynka catchment basin: PL — Poland, SL — Slovakia, Jk — Jaworzyna Krynicka Mt, Tl — Tylicz pass; B — the afforestation of the catchment area: Cb — the whole area; C — sketch of the Muszynka river valley

Research on death assemblages of molluscs in the Muszynka river valley is the contribution to the scientific project supported by Academy of Mining and Metallurgy in Cracov. It is the first step of detail investigations on thanatocenoses undertaken by the author as a part of researches realised in Institute of Stratigraphy and Regional Geology AGH as a project 10.140.551.

## CATCHMENT AREA

Muszynka river is the right-bank tributary of the Poprad river. It drains the south-eastern part of the Beskid Sądecki Range close to the Polish–Slovakian border. The surface of their catchment basin is about 150 km$^2$ with altitudes ranging from 450 to 1,115 m a.s.l. The river is 21.4 km long with an average gradient 10.7 ‰. The valley crosses geological structures of the Magura Nappe: the Bystrica Subunit in the north-eastern part of the area and the Krynica Subunit in its south-western part. Three right-bank tributaries: Mochnaczka stream, Kryniczanka stream and Jastrzębik stream and the main ones (Fig. 1A) while four left-bank tributaries are relatively short. Three of them: Wojkowski stream, Pusta stream and Zimny stream drain the Dubne Range along the gap of the Muszynka valley.

The afforestation of the catchment basin is relatively high but distinctly differentiated reaching in the whole area — 44.8 %. The surface of the Mochnaczka stream valley is poorly wooded (29.3 %) while in the Kryniczanka stream valley and in the Jastrzębik stream valley wood covers 54.4 % and 40.8 % respectively. The catchment area of the Muszynka river valley excluding the mentioned tributaries attains 47.8 % of afforestation (Fig. 1B).

Three zones can be distinguished along the main valley (Fig. 1C):

I — the lower reach between Muszyna and Powroźnik — the river channel is nearly straight, reinforced and partly canalized with a few low weirs, the valley bottom is 400–600 m large, partly built-up, bordered with steep, more or less wooded slopes;

II — the middle reach between Powroźnik and Tylicz — the valley is narrow (100–300 m), forming a gap with deeply incised meanders and steep, wooded slopes;

Ryc. 1. Dorzecze Muszynki. 1 — granica polsko-słowacka, 2 — granica dorzecza, 3 — granice dorzeczy głównych dopływów, 4 — obszar zalesiony, 5 — obszar niezalesiony, 6 — lokalizacja stanowisk (1–6), 7 — rzeki i potoki: P — Poprad, M — Muszynka, N — Mochnaczka, K — Kryniczanka, J — Jastrzębik, W — Wojkowski, H — Hotarny; 8 — dorzecza rzek i potoków: Pp — Popradu, Mn — Muszynki, Mk — Mochnaczki, Kr — Kryniczanki, Jb — Jastrzębika; 9 — wydzielone odcinki doliny Muszynki (I–III), 10 — stopień zalesienia dorzeczy (W — las, O — środowisko otwarte); A — szkic sytuacyjny dorzecza Muszynki: PL — Polska, SL — Słowacja, Jk — Jaworzyna Krynicka, Tl — Przełęcz Tylicka; B — zalesienie dorzecza Muszynki: Cb — całe dorzecze; C — szkic sytuacyjny doliny Muszynki

III — the upper reach between Tylicz and Muszynka (Tylicz Pass) — the valley bottom is relatively large, surrounded with gentle slopes, deforested and cultivated.

The gradient of the Muszynka river valley along its course is distinctly differentiated. In the uppermost part, close to the spring it reach 21.5 ‰ passing downwards into a more flat stretch of the zone III (8.2 ‰). The gradient of the middle part of the valley (zone II) is somewhat more steep (11.8 ‰) and in the lower part it is low, reaching 3.9 ‰ in the zone I.

The mean discharge of the river measured in Muszyna close to the outlet is about 2 $m^3$/sec. changing from about 1.75 $m^3$/sec. in the winter to 2.28 $m^3$/sec. in the summer. During floods connected with snowmelt it can be ten time as much, while summer-floods followed the prolonged heavy rainfalls reache in the short period the discharge up to 150 $m^3$/sec. In spring-floods the water level rises 0.5 to 0.8 m but during extreme floods this value attains two meters.

## MATERIAL AND METHODS

Samples of sediments deposited during the flood in may 1989 (plant detritus, wood and branches, shells of molluscs, anthropogenic remains, mineral components), weighting 2–4 kg each were taken, dried-up and sieved to pick all specimens of snails and bivalves as well as determinable fragments of shells. The material was then cleansed with the diluted perhydrol. The whole collection comprises about eight thousand specimens representing 62 taxa. Standard methods of quaternary malacology described by Ložek (1964), Evans (1972), Puissegur (1976) and the author (Alexandrowicz 1987) have been adopted to analyse the described thanatocenoses. The number of shells of each taxon is presented in logarithmic scale. Malacospectra of species and specimens (MSS, MSI) include eight ecological groups of molluscs distinguished according to the scheme defined by Ložek (1964). Taxonomic dendrogram were calculated after the Steinhaus' $d_{St}$ formula (Alexandrowicz 1987). Relations between the afforestation of the catchment area, the content of woodland snails and the number of taxa growing downstream are estimated with the rank-correlation method. The TDA index and the Shannon-Weaver formula were used to characterise the diversity of molluscan assemblages, while the index of the biotic dispersity (ADI) expresses the differentiation of the whole collected fauna. Relations between the content of shadow-loving and open-country snails were calculated according to the general diferential formula: $WDI = (S - O)/(S+O)$. Constancy and domination of each species were used to characterize the structure of assemblages. All the mentioned indices are described in detail by the author (Alexandrowicz 1987).

Molluscan thanatocenoses were collected in six sites along the Muszynka river valley between Muszyna and Muszynka (Fig. 1C):

1. Material accumulated on the right bank of the river along the edge of the low terrace near the mineral spring "Anna", close to the outlet of the Muszynka river to the Poprad river,

2. Material deposited on the reinforced right bank of the river, close to the outlet of the Jastrzębik stream near the low weir,

3. Accumulation of fragments of wood and branches on the left bank of the river just below the weir in the eastern part of the village Powroźnik,

4. Material deposited on the right bank of the river, partly reinforced and grown with bushes, about 2 km downstream of Tylicz in the narrow segment of the valley,

5. Thanatocenose sampled on the left bank of the river between root of trees close to the mineral spring in Tylicz,

6. Material accumulated on the outer border of a small meander close to the church in the village Muszynka.

The mentioned thanatocenoses were sampled with regard to the differentiation of environment and of habitats along the whole valley. Particular sites are situated below outlets of main tributaries of the Muszynka river (Fig. 1C). Samples 1 and 2 derive from the lower reach of the valley, the first one — below the outlet of the Jastrzębik stream and the other one — below the outlet of the Kryniczanka stream. Samples 3 and 4 represent the narrow, wooded gap of the valley and were collected respectively below outlets of the Wojkowski stream and the Mochnaczka stream while the remaining samples (5 and 6) characterise the upper reach of the valley.

## MOLLUSCAN ASSEMBLAGES

Thanatocenoses of the Muszynka river valley abound in shells of molluscs. The fauna comprises 62 taxa while the number of collected specimens exceed eigth thousand (Tab. 1). The main features of assemblages are illustrated by a few quantitative indices (Tab. 2). Constancy and domination of particular species (C–D) can be used to indicate the most important components of the whole thanatocenose. Several taxa are characterised by the highest value of constancy (C > 80 %). Seven of them belong to shadow-loving snails, six — to mesophile snails, four — to open-country snails, two — to marsh species and two — to water molluscs. No one species reaches the highest values of both indices (C and D) but three taxa can be counted to the class 5–4 (C > 80%, D = 10–20 %). There are: *Vallonia pulchella*, *Carychium tridentatum* and *Cochlicopa lubrica*. Together with two species belonging to the class 5–3 (*Vitrea diaphana*, *V.transsylvanica*) they can be pointed out as principal components of the fauna. Following species of the class 5–2 are supplementary elements found in each site: *Aegopinella pura*, *Vestia turgida*, *Perforatella bidentata*, *Vertigo pygmaea*, *Pupilla muscorum*, *Succinea putris* and *Lymnaea truncatula*.

Table 1 — Tabela 1

Molluscan assemblages forming thanatocenoses in the Muszyna river valley (sites 1–6)
Zespoły mięczaków tworzące tanatocenozy muszlowe w dolinie Muszynki (stanowiska 1–6)

| E | TAXON | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| 1 | *Acicula parcelineata* (Clessin) | | | | 1 | | 1 |
| 1 | *Acicula polita* (Hartmann) | | | | | 1 | 1 |
| 1 | *Vertigo pusilla* Müller | 2 | | 2 | 1 | 1 | 2 |
| 1 | *Ena montana* (Draparnaud) | | | 1 | 1 | | |
| 1 | *Discus perspectivus* (Mühlenfeld) | | | | 1 | | |
| 1 | *Eucobresia nivalis* (Dum. and Mort.) | | | 1 | | | |
| 1 | *Aegopinella pura* (Alder) | 3 | 2 | 3 | 2 | 2 | 2 |
| 1 | *Aegopinella epipedostoma* (Fagot) | | | 1 | 1 | | |
| 1 | *Vitrea diaphana* (Studer) | 3 | 3 | 4 | 4 | 3 | 3 |
| 1 | *Vitrea transsylvanica* (Clessin) | 3 | 3 | 4 | 3 | 2 | 3 |
| 1 | *Oxychilus orientalis* (Clessin) | 1 | 1 | 1 | | | |
| 1 | *Oxychilus depressus* (Sterki) | | 2 | 1 | 2 | | 1 |
| 1 | *Ruthenica filograna* (Rossmaessl.) | | 1 | | | | |
| 1 | *Macrogastra plicatula* (Drap.) | | 1 | | | | |
| 1 | *Macrogastra latestriata* (Schmidt) | | 1 | | 1 | | |
| 1 | *Vestia gulo* (Bielz) | 3 | 1 | 3 | 2 | | 1 |
| 1 | *Vestia turgida* (Rossmaessler) | 2 | 1 | 3 | 3 | 2 | 1 |
| 1 | *Perforatella dibothrion* (Klimak.) | | | 1 | 2 | | 1 |
| 1 | *Perforatella incarnata* (Müller) | 2 | 2 | 2 | 1 | 1 | |
| 1 | *Trichia unidentata* (Draparnaud) | | | 2 | 1 | 1 | 1 |
| 1 | *Chilostoma faustinum* (Rossm.) | 1 | 1 | | 1 | | |
| 1 | *Isognomostoma isognomostoma*. (Schröt.) | 2 | | | 2 | | |
| 2 | *Discus rotundatus* (Ferussac) | | | 1 | 1 | 1 | 1 |
| 2 | *Vitrea crystallina* (Müller) | 3 | 3 | 4 | 4 | 2 | 2 |
| 2 | *Alinda biplicata* (Montagu) | 1 | 1 | 1 | 2 | 1 | 2 |
| 2 | *Arianta arbustorum* (Linnaeus) | | | | 1 | | |
| 2 | *Helix pomatia* Linnaeus | 1 | 1 | | | | |
| 3 | *Macrogastra tumida* (Rossmaessl.) | | | | 1 | | |
| 3 | *Perforatella bidentata* (Gmelin) | 3 | 2 | 2 | 1 | 1 | 2 |
| 3 | *Perforatella vicina* (Rossmaessler) | | | | 1 | | |
| 3 | *Perforatella umbrosa* (Pfeiffer) | 1 | 1 | 1 | 1 | | |
| 4 | *Cecilioides acicula* (Müller) | 1 | 1 | | | 2 | 1 |
| 5 | *Truncatellina cylindrica* (Ferussac) | | 1 | | | 2 | 1 |

| E | TAXON | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| 5 | *Vertigo pygmaea* (Draparnaud) | 3 | 2 | 3 | 3 | 3 | 1 |
| 5 | *Pupilla muscorum* (Linnaeus) | 2 | 3 | 2 | 3 | 3 | 2 |
| 5 | *Vallonia pulchella* (Müller) | 4 | 4 | 5 | 5 | 5 | 5 |
| 5 | *Vallonia costata* (Müller) | 3 | 3 | 4 | 3 | 2 | 3 |
| 7 | *Cochlicopa lubrica* (Müller) | 4 | 4 | 5 | 4 | 4 | 4 |
| 7 | *Vertigo alpestris* Alder | | | | 1 | | 1 |
| 7 | *Punctum pygmaeum* (Draparnaud) | 2 | 3 | 3 | 4 | 3 | 3 |
| 7 | *Vitrina pellucida* (Müller) | 1 | 2 | 2 | 3 | 2 | 2 |
| 7 | *Vitrea contracta* (Westerlund) | 3 | 3 | 4 | 4 | 4 | 4 |
| 7 | *Nesovitrea hammonis* (Ström) | 2 | | 3 | 2 | 3 | 2 |
| 7 | *Limacidae* | | 1 | | | | |
| 7 | *Euconulus fulvus* (Müller) | 2 | 1 | 1 | 2 | | 2 |
| 7 | *Laciniaria plicata* (Draparnaud) | | 1 | | | | 1 |
| 8 | *Carychium tridentatum* (Risso) | 4 | 5 | 4 | 5 | 4 | 5 |
| 8 | *Succinea oblonga* (Draparnaud) | 1 | 1 | 1 | | 2 | |
| 8 | *Columella edentula* (Draparnaud) | 2 | 1 | 2 | 3 | 2 | 2 |
| 8 | *Vertigo substriata* (Jeffreys) | | 1 | | 1 | | |
| 8 | *Vertigo angustior* (Jeffreys) | | 1 | | 1 | | 1 |
| 8 | *Trichia villosula* (Rossmaessler) | 2 | 2 | 1 | 1 | 1 | 2 |
| 9 | *Succinea putris* (Linnaeus) | 2 | 3 | 3 | 3 | 3 | 4 |
| 9 | *Vertigo antivertigo* (Draparnaud) | | 1 | | | | |
| 9 | *Zonitioides nitidus* (Müller) | 2 | 2 | 2 | 3 | 2 | 3 |
| 9 | *Perforatella rubiginosa* (Schmidt) | 2 | 2 | 2 | 2 | | 1 |
| 10 | *Bythinella austriaca* (Frauenfeld) | | | 1 | 2 | 2 | 2 |
| 10 | *Lymnaea peregra* (Müller) | | | 1 | | | |
| 10 | *Lymnaea truncatula* (Müller) | 2 | 2 | 1 | 3 | 2 | 2 |
| 10 | *Anisus leucostomus* (Millet) | 3 | 2 | | 4 | | 3 |
| 10 | *Armiger crista* (Linnaeus) | | | | | | 1 |
| 10 | *Pisidium casertanum* (Poli) | 2 | 1 | 2 | 2 | 1 | 1 |

E — ecological groups of molluscs: 1 — woodland snails, 2 — species of partly shady habitats, 3 — snails of humid forests, 4 — xerophile snails, 5 — open-country species, 7 — mesophile snails of moderately humid habitats, 8 — mesophile snails of humid habitats, 9 — marsh-species, 10 — water molluscs; number of specimens: 1 — 1–3, 2 — 4–9, 3 — 10–31, 4 — 32–99, 5 — 100–316

E — grupy ekologiczne mięczaków: 1 — ślimaki leśne, 2 — gatunki siedlisk częściowo zacienionych, 3 — ślimaki wilgotnych lasów, 4 — gatunki kserofilne, 5 — ślimaki środowiska otwartego, 7 — gatunki mezofilne siedlisk umiarkowanie wilgotnych, 8 — gatunki mezofilne siedlisk wilgotnych, 9 — ślimaki wilgociolubne, 10 — mięczaki wodne; ilość okazów: 1 — 1–3, 2 — 4–9, 3 — 10–31, 4 — 32–99, 5 — 100–316

Table 2 — Tabela 2

Selected indices characterizing thanatocenoses of the Muszynka river
Wybrane wskaźniki charakteryzujące tanatocenozy w dolinie Muszynki

| | site 1 | site 2 | site 3 | site 4 | site 5 | site 6 |
|---|---|---|---|---|---|---|
| $n_t$ | 36 | 33 | 40 | 48 | 34 | 41 |
| $n_s$ | 516 | 453 | 945 | 903 | 558 | 643 |
| TDA | 0.854 | 0.802 | 0.813 | 0.768 | 0.772 | 0.780 |
| SWI | 4.35 | 4.14 | 4.08 | 4.02 | 3.91 | 3.90 |
| sls (%) | 29 | 23 | 31 | 17 | 17 | 13 |
| ocs (%) | 26 | 25 | 24 | 35 | 31 | 27 |
| WOI | +0.05 | –0.04 | +0.13 | –0.35 | –0.29 | –0.35 |

$n_t$ — number of species, $n_s$ — number of specimens, TDA — normalised differentiation index, SWI — Shannon-Weaver differentiation index, sls (%) — content of shadow-loving snails, ocs (%) — content of open-country snails, WOI — relation between woodland and open-country snails
$n_t$ — ilość gatunków, $n_s$ — ilość okazów, TDA — znormalizowany wskaźnik różnorodności, SWI — wskaźnik Shannona-Weavera, sls (%) — udział ślimaków leśnych, ocs (%) — udział ślimaków środowiska otwartego, WOI — wskaźnik ilościowej relacji ślimaków cieniolubnych i gatunków typowych dla siedlisk otwartych

On the other hand a third of all taxa are accessory components falling into C–D classes: 1–1 and 2–1.

The occurrence of a few species is noteworthy. There are snails living exclusively or mainly in Eastern Carpathians, such as *Oxychilus orientalis* and *Perforatella dibotryon* as well as *Acicula parcelineata* and *Discus perspectivus*. Species connected with Carpathians are represented by: *Chilostoma faustinum*, *Vestia turgida*, *V. gulo*, *Vitrea transsylvanica* while following taxa have been repeatedly noted in the mentioned region: *Acicula polita*, *Vertigo alpestris*, *V.substriata*, *Ena montana*, *Ruthenica filograna*, *Macrogastra plicatula*, *M.latestriata*, *Alinda biplicata*, *Trichia unidentata*, *Isognomostoma isognomostoma* and *Arianta arbustorum* (Riedel 1988). Snails immigrated from the south, followed the human activity and land occupation are represented by *Cecilioides acicula* and probably also by *Truncatellina cylindrica* (Tab. 1). A quite similar molluscan fauna is known from the nature reserve Obrożyska near Muszyna (Alexandrowicz 1984) as well as from ruins of medieval castles situated in the Poprad river valley in Muszyna and Rytro (Alexandrowicz 1995).

The analysed thanatocenose is fairly differentiated as the biotic dispersity index do not exceed 0.5 (ADI = 0.43). According to the taxonomic dendrogram the whole set of samples can be divided into two subsets. The first one comprises samples from the lower part of the valley (sites 1 and 2) while the other — all remaining samples from sites 3–6. Values of taxonomic distances ($d_{St}$) between

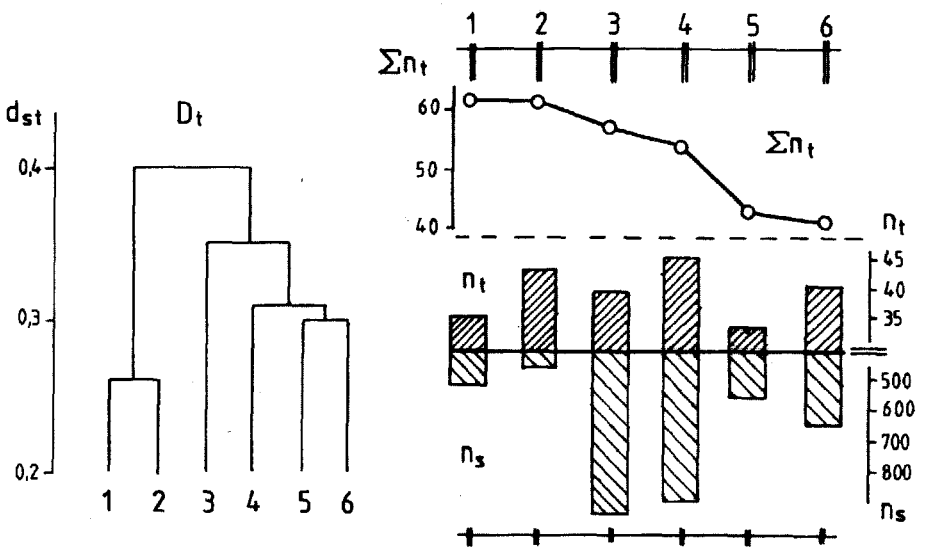


Fig. 2. Diagrams illustrating selected features of molluscan assemblages. $D_t$ — taxonomic dendrogram, $d_{st}$ — taxonomic distance, $\Sigma n_t$ — increasing number of species in the whole thanatocenose, $n_t$ — number of taxa, $n_s$ — number of specimens, 1–6 — collected samples

Ryc. 2. Diagramy wybranych cech zespołów mięczaków. $D_t$ — dendrogram taksonomiczny, $d_{St}$ — odległość taksonomiczna, $\Sigma n_t$ — przyrost ilości gatunków w tanatocenozie, $n_t$ — ilość gatunków, $n_s$ — ilość okazów, 1–6 — numery próbek

assemblages are relatively low because the diagram is closed with the $d_{St} = 0.40$. The shape of the dendrogram indicates scarcely marked differences between thanatocenoses deposited along the course of the river, assemblages from the lower reach of the valley are separated in particular (Fig. 2 — $D_t$). Faunal diversity indices (TDA, SWI) are simultaneously similar in all samples however they indicate, that assemblages from the lower part of the valley are somewhat more differentiated as these from the upper part (Tab. 2).

The number of taxa and specimens oscillates from one sample to the other. The richest fauna occur in sites situated along the gap of the valley between Powroźnik and Tylicz (the middle reach of the river). These assemblages comprise 40–48 taxa and more then 900 specimens each (Fig. 2 — $n_t$, $n_s$). In relation to the whole thanatocenose the number of species summarized progressivelly grows unevenly from the uppermost site downstream reaching respectively following values: 41–43–54–57–62–62 (Fig. 2 — $\Sigma n_t$). The highest growth-rate corresponding with the enrichment of the molluscan fauna is noted between sites 5 and 4. In the site situated in the lowermost part of the valley (1) no one new species was found. Namely the middle part of the valley along the gap between Tylicz and Powroźnik seems to be particularly important for the formation of the described molluscan thanatocenose.

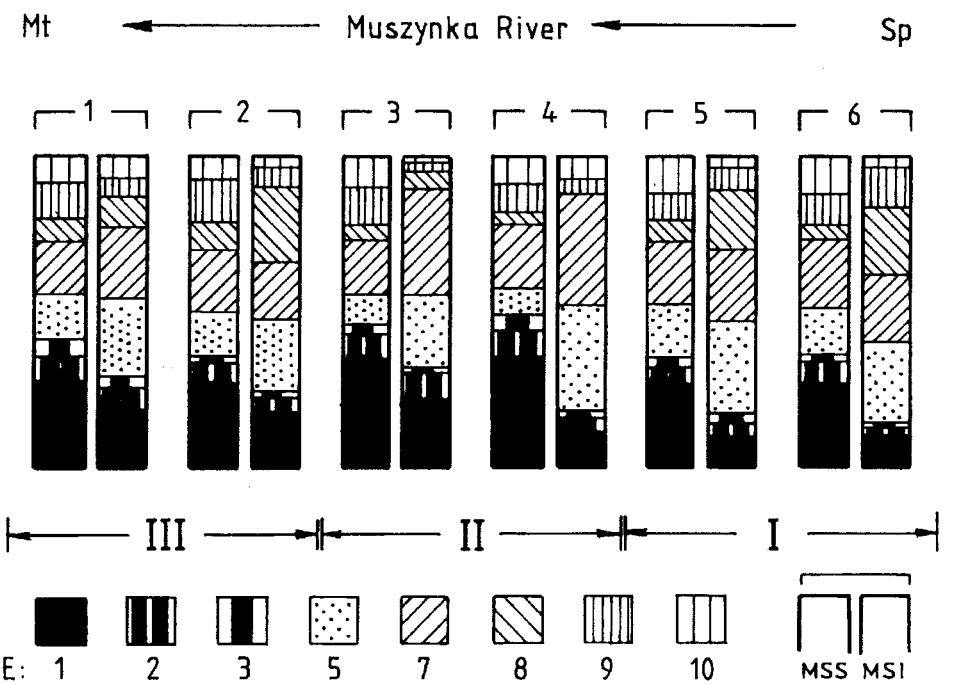


Fig. 3. Malacological spectra of thanatocenoses from the Muszynka river valley. Sp — spring, Mt — mouth, 1–6 — samples collected in particular sites, I–III — parts of the Muszynka river valley, MSS — spectra of species, MSI — spectra of specimens; E — ecological groups of molluscs: 1 — woodland snails, 2 — species of partly shady habitats, 3 — snails of humid forest, 5 — open-country snails, 7 — mesophile species of moderately humid habitats, 8 — mesophile species of humid habitats, 9 — march species, 10 — water molluscs

Ryc. 3. Spektra malakologiczne tanatocenoz muszlowych z doliny Muszynki. Sp — źródło, Mt — ujście rzeki, 1–6 — próbki pobrane w poszczególnych stanowiskach, I–III — wyróżnione odcinki doliny Muszynki, MSS — spektra gatunkowe, MSI — spektra osobnicze; E — grupy ekologiczne mięczaków: 1 — ślimaki leśne, 2 — gatunki siedlisk częściowo zacienionych, 3 — ślimaki wilgotnych lasów, 5 — gatunki środowiska otwartego, 7 — ślimaki mezofilne siedlisk średnio wilgotnych, 8 — ślimaki mezofilne siedlisk wilgotnych, 9 — gatunki wilgociolubne, 10 — mięczaki wodne

Malacospectra of species (MSS) are nearly the same in the whole described collection. The content of taxa representing ecological groups 1, 5 and 7 is relatively high and equalised while taxa of snails connected with humid and moist habitats as well as of water molluscs are less numerous (Fig. 3). Malacospectra of specimens (MSI) are more distinctly differentiated. The number of shadow-loving snails and open country ones (Tab. 1 — sls, ocs) in assemblages from the lower and upper segment of the valley is quite different (Tab. 1). In the lower reach of the river the number of specimens of both mentioned components is nearly the same while in the upper reach shells of open-country snails clearly prevail. These differences are also illustrated by values of the WOI index ranging from –0.04 to +0.13 in samples 1–3 and from –0.29 to –0.035 in samples 4–6 (Tab. 1). The content of

mesophile snails is less interesting then it is similar in each sample. The same refers to specimens from the remaining two ecological groups (9 and 10).

Relations between the degree of afforestation growing downstream along the catchment area and the content of the most important components of molluscan assemblages are quite distinct (Fig. 4). The afforestation is positively

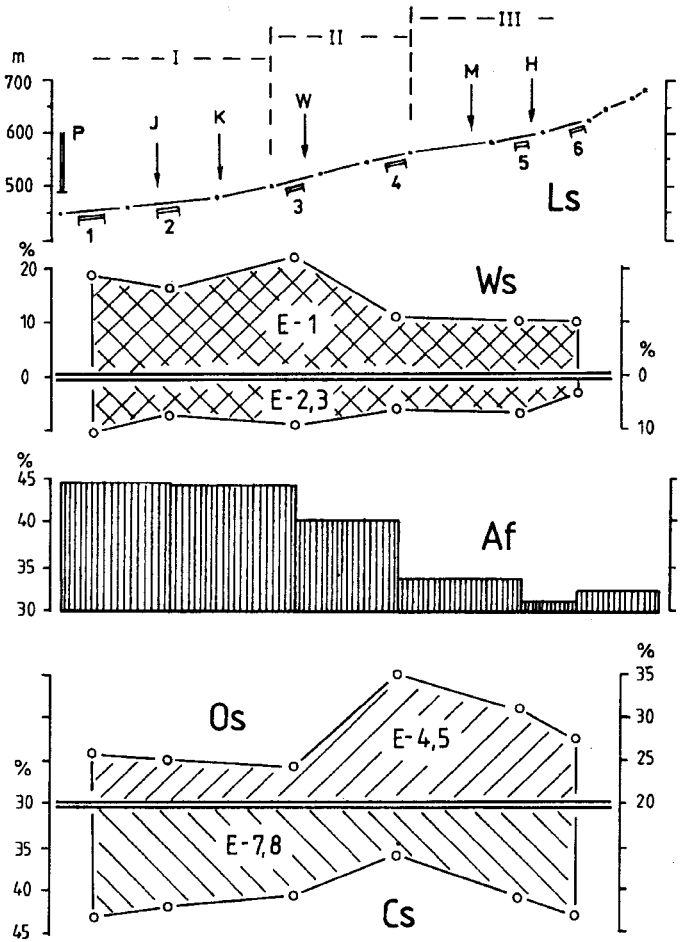


Fig. 4. Changes of thanatocenoses along the Muszynka river valley. Ls — longitudinal section of the valley, Ws — content of shadow-loving snails (ecological groups E — 1–3), Af — the afforestation in particular parts of the valley between sites, Os — content of open country snails (ecological groups E — 4–5), Cs — content of catholic species (ecological groups E — 7–8). Remaining explanations as in Fig. 1

Ryc. 4. Zmiany tanatocenoz wzdłuż biegu Muszynki. Ls — przekrój podłużny doliny, Ws — udział ślimaków cieniolubnych (grupy ekologiczne E — 1–3), Af — przyrost zalesienia dorzecza między stanowiskami, Os — udział gatunków typowych dla środowiska otwartego (grupy ekologiczne E — 4–5), Cs — udział ślimaków mezofilnych (grupy ekologiczne E — 7–8). Pozostałe objaśnienia jak na ryc. 1

correlated with number of shadow-loving snails in particular thanatocenoses. The rank-correlation index is significant on the confidence level 0.05 and reaches r = 0.77. On the other hand the number of open-country snails is negatively correlated with the afforestation, but the coefficient r = –0.60 and this relation is not significant on the same level (Fig. 4; Af, Ws, Os).

## BIOMETRY OF COCHLICOPA LUBRICA

Numerous specimens of *Cochlicopa lubrica* slightly differentiated in size occur in the described material. The height (h) and the breadth (b) of 208 shells were measured with the accuracy of 0.1 mm. Simple statistical indices such as arithmetic mean (X), standard deviation (S), standard error (E), differentiation index (V) and standardised values (T) have been calculated to characterise the whole analysed set as well as subsets representing particular samples. The elongation index (h/b) was established additionally (Tab. 3). The mean size of shells (h = 5.60 mm, b = 2.49 mm, h/b = 2.25) is contained within interval of variability quoted by Ložek (1964), Kerney et al. (1983) and other authors, but it corresponds to the lowest part of this range. However the population of *Cochlicopa lubrica* from the Muszynka river valley can be compared with populations living in Cracow, as nearly the same ones (Alexandrowicz 1988, 1990).

The largest specimens of *Cochlicopa lubrica* occur in samples collected along the narrow, wooded part of the described valley (samples 3 and 4). Standardised values of the shell height (h) reach +0.52 and +0.78 (mean values are 5.89 mm and 5.79 mm respectively). In sites surrounded by open habitats specimens are relatively small, characterized by standardised values of h ranging between +0.02 and –0.41 (5.61–5.45 mm). These differences are connected neither with the flood competence nor with sedimentary conditions, because shells of other species considerably both smaller and larger then these of *Cochlicopa lubrica* occur in the same thanatocenoses. Therefore the mentioned diversity can be explained by the distribution of populations developed in more or less shady habitats, supplying death assemblages. According to data described from the Cracow region specimens living in shady, partly shady and humid places are somewhat more large then those living in less shady or even open habitats (Alexandrowicz 1988, 1990).

In the upper part of the valley between Muszynka and Tylicz surrounded by deforested and cultivated environment, the size of shells washed from slopes corresponds with types of habitats (small specimens in samples 6 and 5). In the middle segment of the valley the molluscan fauna live within mixed forest and shrubs growing slopes along the gap. Relatively large shells of the mentioned species connected with such habitats are washed downslope and deposited just in the same part of the valley (specimens in samples 4 and 3). Thanatocenoses from the lower reach of the valley enclose small shells of *Cochlicopa lubrica*

Table 3 — Tabela 3

Statistical features of population of *Cochlicopa lubrica*
Wskaźniki statystyczne populacji *Cochlicopa lubrica*

| | | N | X | S | E | V | T |
|---|---|---|---|---|---|---|---|
| Σ1–6 | h | 208 | 5.598 | 0.369 | 0.027 | 6.59 | — |
| | b | | 2.488 | 0.154 | 0.011 | 6.19 | — |
| | h/b | | 2.254 | 0.139 | 0.010 | 6.17 | — |
| site 1 | h | 48 | 5.544 | 0.346 | 0.050 | 6.24 | -0.147 |
| | b | | 2.477 | 0.143 | 0.021 | 5.77 | — |
| | h/b | | 2.240 | 0.092 | 0.013 | 4.11 | — |
| site 2 | h | 30 | 5.663 | 0.436 | 0.034 | 7.70 | +0.175 |
| | b | | 2.247 | 0.171 | 0.033 | 7.61 | — |
| | h/b | | 2.299 | 0.191 | 0.037 | 8.31 | — |
| site 3 | h | 32 | 5.790 | 0.330 | 0.065 | 5.70 | +0.519 |
| | b | | 2.500 | 0.229 | 0.045 | 9.16 | — |
| | h/b | | 2.331 | 0.204 | 0.040 | 8.75 | — |
| site 4 | h | 38 | 5.889 | 0.346 | 0.058 | 5.88 | +0.787 |
| | b | | 2.494 | 0.105 | 0.017 | 4.21 | — |
| | h/b | | 2.241 | 0.112 | 0.019 | 5.00 | — |
| site 5 | h | 29 | 5.607 | 0.314 | 0.058 | 5.60 | +0.024 |
| | b | | 2.520 | 0.127 | 0.023 | 5.04 | — |
| | h/b | | 2.227 | 0.104 | 0.019 | 4.67 | — |
| site 6 | h | 31 | 5.446 | 0.368 | 0.071 | 6.76 | -0.412 |
| | b | | 2.467 | 0.141 | 0.027 | 5.72 | — |
| | h/b | | 2.208 | 0.075 | 0.014 | 3.40 | — |

N — number of shells, X — arithmetic mean, S — standard deviation, E — standard error, V — differentiation index, T — standardized values, h — height of the shell, b — breadth of the shell, h/b — elongation index

N —ilość skorupek, X — średnia arytmetyczna, S — odchylenie standardowe, E — błąd standardowy, V — współczynnik zmienności, T — wartości znormalizowane, h — wysokość skorupki, b — szerokość skorupki, h/b —·współczynnik elongacji

again (samples 2 and 1). The presented data indicate, that shells of molluscs washed by floods are deposited after a short transport. It can be estimated at a few hundred meters or at a few kilometres to the maximum. Accordingly in mountain valleys (such as the Muszynka river valley) molluscan thanatocenoses reflect living populations of molluscs in a high degree and are usual to paleogeographical interpretations.

## INTERPRETATION

The analysis of molluscan assemblages forming thanatocenoses along the Muszynka river valley suggests some conclusions about both the fauna of the Beskid Sądecki Range and the accumulation of shell material within fluviatile sediments in relation to present-day environmental conditions. The latter aspect requires special attention as a key to palaeogeographic interpretations of quaternary and particularly Holocene mollusc-bearing fluviatile flood deposits.

The molluscan fauna of the Krynica–Muszyna region has been not studied at yet. It is known mainly as a part of the fauna of Polish Western Carpathians (Riedel 1988). Only the assemblage inhabiting the nature reserve Obrożyska in Muszyna and the subfossil assemblage from the landslide in Piwniczna were described in detail by the author (Alexandrowicz 1984, 1985). Thanatocenoses of the Muszynka river valley enclos 62 taxa and significantly supplement the list of snail species living in this region. The occurrence of species typical of Eastern Carpathians is the feature of this fauna.

Two ecological groups of molluscs are the main elements of the described death assemblages. Shells of woodland snails and related shadow-loving species (ecological groups 1, 2, 3) accompanied by some mesophile snails (groups 7, 8) derive from wooded and partly shady slopes as well as from patches of trees and shrubs distributed at the valley bottom. Specimens of open-country snails (groups 4, 5) are coming from meadows, pastures, fields and waste land. The content of both mentioned components depends not only upon the afforestation of the catchment area but also on a few other factors. One of them is the intensity of hillwash being much less effective on wooded slopes then in open or deforested environments. In consequence thanatocenoses are usually enriched in shells of snails living in open habitats, mainly in cultivated areas.

The breath of a valley is another factor controlling the structure of death assemblage. Shells of snails washed downslope together with plant remains and fine-grained mineral material are accumulated on the river terrace or on the floodplain. In narrow valleys they are easily and quickly incorporated into flood-material while in large valleys they can rest a long time outside the influence of the river transport. Finally thanatocenoses formed in large valleys are usually impoverished in shells of molluscs living on slopes and enriched in species connected with different habitats widespread on floodplains and river terraces. These are mainly open-country or mesophile snails and particularly marsh-species as well as molluscs inhabiting temporary water bodies.

Shells of molluscs such as plant remains and mineral grains are transported, sorted and deposited in relation to their size and weight as well as to the flow competence. The whole material is displaced downstream on a more or less long distance. In consequence organic remains forming thanatocenoses or incorporated

in fluviatile sediments can be related either to habitats dominating around the site either to environments widespread in preceding segments of the valley.

The displacement distance of fruits and seeds in the Dunajec river valley was estimated by Pelc (1983). Remains of plants growing in Pieniny Mountains along the narrow part of the valley are usually deposited 5–10 km downstream of Szczawnica, in the gap within the Beskid Sądecki Range in Kłodne. Similar as plant remains shells of molluscs are only exceptionally transported far away (Klemm 1973). Species living in the upper reach of a river are not found in thanatocenoses forming in the lower reach (Czogler and Rotarides 1938). According to the opinion of Clessin (1908a, 1908b, 1911), Geyer (1908), Grahle (1954) and Zeissler (1963) shells of snails taken by flood-water are transported up to 30 km but usually they are accumulated after a short way. As such death assemblages correspond with the fauna living in the surrounding part of the catchment basin and can be used in faunistic studied.

Thanatocenoses of the Muszynka river valley indicate, that during the flood the deposition of molluscan shells begins just a few hundred meters or 1–3 km downstream of the alimentation point and continues in following sites (Fig. 4). Death assemblages found in succeeding localities enclose species coming with the flow but the number of taxa distinctly depends upon types of surrounding habitats. The differentiation of molluscan thanatocenoses, their composition and connections with the environment can be quite another in streams and rivers in mountain, upland and lowland rivers, in narrow and large valleys as well as in wooded and cultivated areas.

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## STRESZCZENIE

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## TANATOCENOZY MUSZLOWE W OSADACH POWODZIOWYCH MUSZYNKI (KARPATY POLSKIE)

Nagromadzenia szczątków organicznych, w tym skorupek mięczaków we współczesnych osadach rzecznych, określane jako tanatocenozy były opisywane w pracach malakologicznych, jako bogate materiały uzupełniające dane o rozmieszczeniu poszczególnych gatunków. Mało uwagi poświęcano natomiast aktualistycznym aspektom badań tafonomicznych, które mogą być podstawą dla wnioskowania o warunkach tworzenia się nagromadzeń subfosylnej fauny, cechującej charakter dawnych środowisk. Cykl badań nad tanatocenozami rozpoczynają studia przeprowadzone w dorzeczu Muszynki. Materiały do badań zostały pobrane po wiosennej powodzi w roku 1989. Powierzchnia dorzecza Muszynki ma około 150 km$^2$, długość rzeki wynosi 21.4 km, jej średni spadek — 10.7 ‰, a średni przepływ — 2.02 m$^3$/sek (w powodziach wiosennych wzrasta on dziesięciokrotnie). Stopień zalesienia dorzecza wynosi 44.8 %, ale waha się on w znacznych granicach: w górnym biegu nie przekracza 30 %, a w przełomowym odcinku między Tyliczem a Powroźnikiem wzrasta do ponad 50 % (ryc. 1).

Materiały do badań zostały pobrane w 6-ciu stanowiskach rozmieszczonych na całej długości doliny. Zostały one opracowane z zastosowaniem standardowych metod analizy malakologicznej, opisanych przez autora (Alexandrowicz 1987). Tanatocenozy obejmują w sumie 62 taksony, uszeregowane według grup ekologicznych (tab. 1). Najwyższe wskaźniki stałości i dominacji osiągają gatunki, cechujące omawianą malakofaunę: *Vallonia pulchella*, *Carychium tridentatum* i *Cochlicopa lubrica*. Charakterystyczną jej cechą jest występowanie gatunków wschodnio-karpackich, takich jak: *Oxychilus orientalis* i *Perforatella dibotryon*. Stopień zróżnicowania fauny jest średni, a wyraża go wartość wskaźnika ADI = 0.43. Diagram taksonomiczny dzieli cały zbiór próbek na dwa podzbiory, z których pierwszy obejmuje stanowiska w dolnym biegu rzeki (1 i 2), a drugi — wszystkie pozostałe. Zespoły pierwszego podzbioru mają wyższe wskaźniki różnorodności (TDA, SWI) niż zespoły drugiego podzbioru. Ilość taksonów i ilość okazów w poszczególnych zespołach waha się w znacznych granicach (tab. 2). Przyrost ilości gatunków w całej tanatocenozie licząc od źródła jest nierównomierny, a największe jej wzbogacenie następuje między stanowiskami 5 i 4. Malakospektra gatunkowe (MSS) są znacznie mniej zróżnicowane niż osobnicze (MSI), a ślimaki leśne i gatunki typowe dla środowiska otwartego przeważają (ryc. 2, 3). Udział pierwszego z wymienionych składników jest istotnie skorelowany ze stopniem zalesienia poszczególnych części dorzecza, wyrażonym przez przyrost lesistości (ryc. 4).

Badania biometryczne nad populacjami *Cochlicopa lubrica* występującymi we wszystkich próbkach wykazały zróżnicowanie wielkości skorupek tego gatunku, wyrażone najwyraźniej przez cechy znormalizowane (tab. 3). Zróżnicowanie to odzwierciedla cechy populacji, żyjących w mniej lub bardziej zacienionych siedliskach. Ich rozmieszczenie świadczy, że materiał muszlowy był transportowany przez wody powodziowe tylko na małą odległość, nie przekraczającą paru kilkometrów.

Analiza składu i zróżnicowania tanatocenoz muszlowych w dolinie Muszynki świadczy, że skład zespołów mięczaków, które tworzą się w osadach powodziowych zależy m.in. od takich czynników jak stopień zalesienia dorzecza i szerokość dna doliny w poszczególnych jej odcinkach. Istotne znaczenie ma rozmieszczenie malakocenoz w dnie doliny i otaczających stokach, a różnice między fauną żyjącą a deponowaną przez wody powodziowe wynikają z różnej efektywności procesów spłukiwania w lasach i obszarach nie zalesionych (zwłaszcza rolniczo użytkowanych). Przeprowadzone badania sugerują, że większość skorupek mięczaków jest deponowana po krótkim transporcie, nie przekraczającym odległości 1–3 km, a często ograniczonym zaledwie do kilkuset metrów. W związku z tym można uznać, że tanatocenozy dobrze odzwierciedlają charakter środowiska otaczającego dolinę, ale przy interpretacji subfosylnych zespołów mięczaków należy brać pod uwagę szereg czynników modyfikujących.