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MOLLUSCAN ASSEMBLAGES FROM DEPOSITS FILLING SMALL KARST FORMS IN THE TATRA MOUNTAINS (SOUTHERN POLAND)

ZDRUŽBE MOLUSKOV V ZAPOLNITVAH MANJŠIH KRAŠKIH OBLIK V TATRAH (JUŽNA POLJSKA)

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Witold Paweł Alexandrowicz: Združbe moluskov v zapolnitvah manjših kraških oblik v Tatrah (južna Poljska)

V zapolnitvah manjših kraških oblik in v majhnih meliščih, ki vsebujejo ilovnate sedimente, bogate z apnencem, in dolomitni grušč, so lupine številnih moluskov. Bili so analizirani z več nahajališč v Tatrah. Vodilni sestavni del živalstva so polži gozdnate in odprte pokrajine. Deleža teh dveh ekoloških skupin moluskov kažeta na klimatske spremembe in na spreminjanje gozdne meje. Opazne so tri toplejše faze, ločene z dvema fazama hladnejše klime. Pripisati jim je mogoče naslednje starosti: XIII. in prva polovica XIV. stol. po Kr. (topla faza), druga polovica XIV. stol. - XVII. stol. po Kr. (mrzla faza), XVIII. in prva polovica XIX. stol. (topla faza), druga polovica XIX. stol. (mrzla faza) in končno XX. stol. (topla faza).
Ključne besede: paleontologija, moluski, polži, kraška zapolnitev, klimatske spremembe, gozdna meja, Tatre, Poljska.

Abstract UDC: 564(438):551.583

Witold Paweł Alexandrowicz: Molluscan assemblages from deposits filling small karst forms in the Tatra Mountains (Southern Poland)

Numerous shells of molluscs were found in loamy sediments rich in limestone and dolomite scree filling small karst forms and forming debris fans. They have been analysed from several logs in the Tatra Mountains. Woodland and open-country snails are the main components of fauna. Relations between two mentioned ecological groups of molluscs indicate climatic changes and moving the timberline. Three phases of warming separated by two stages of the colder climate were recognised. They can be related to following ages: XIII and first half of XIV centuries AD (warm phase), second half of XIV - XVII centuries AD (cold phase), XVIII and the first half of XIX centuries (warm phase), second half of the XIX century (cold phase) and finally to XX century (warm phase).
Key words: palaeontology, Molluscan, snails, karst filling, climatic changes, timberline, Tatra Mts., Poland.

INTRODUCTION

The Tatra Mountains are the highest mountain massif of the Carpathian range. Their core is formed of crystalline rocks (Late Palaeozoic granite with the old metamorphic mantle) and is overlain by Mesosoic sedimentary formations. The last mentioned, represented mainly by limestones and dolomites, are widespread in the North-western part of the massif forming the bedrock particularly favourable for the development of the karst processes. Numerous small karst forms such as low and shallow rock shelters, rocky niches and pockets have been found during the field work. Some of them were filled by loam abounding in limestone of dolomite lumbs and scree. These sediments are also developed at the food of rocky walls as debris fans. They contain more or less rich assemblages of subfossil molluscs.

Assemblages of molluscs from cave sediments and debris fans have been described from several localities in the Cracow-Częstochowa Upland (Stworzewicz 1973, 1988, Bocheński et al. 1985, S.W. Alexandrowicz 1992, 2000, S.W. Alexandrowicz et al. 1992, W.P. Alexandrowicz 2000 and others), Podhale Basin (W.P. Alexandrowicz 1997) as well as in the Slovak Carpathians (Ložek 1979, 1980, 1981, 1982) and in the Moravian Karst (Svoboda et al. 2000). Subfossil molluscs were also noted in sediments filling small karst forms and forming debris fans in the Tatra Mountains (W.P. Alexandrowicz 1996) as well as in Holocene calcareous tufa and travertines described by S.W. Alexandrowicz (1985, 1988) from "Kraków Gorge" (Western Tatra).

The present study is a contribution to scientific project: Quaternary palaeogeography and palaeoecology in karstic regions of Slovenia and Southern Poland, carried out in co-operation between the Polish Academy of Arts and Sciences (PAU) and the Slovenian Academy of Sciences and Arts (SAZU).

MATERIAL AND METHODS

Molluscan assemblages have been studied in detail in fifty samples deriving from eleven logs. Samples were washed, so as to pick up all the shells of molluscs and fragments of shells that could be determined. The whole analysed material comprises fifty-six species of land snails represented by 13 759 specimens.

Standard methods of malacological analysis described by Ložek (1964) and S.W. Alexandrowicz (1987) have been used. All taxa devided into ecological groups representing four comprehensive categories: F - woodland snails, including typical forest species and taxa inhabiting partly shady habitats, O - open-country snails, including meadow species, xerophile snails and taxa living onto rocky walls, M - snails of wide ecological tolerance (mesophile) and H - snails preferring moist habitats. Water snails (ecological group W) do not occur. Two-component diagrams reflect changes of molluscan assemblages during the deposition of cave sediments. The triangular diagram has been used to illustrate the differentiation of the fauna.

LOGS OF MOLLUSCS-BEARING DEPOSITS

Small karst forms filled with sediments containing shells of molluscs are developed within the zone of occurrence of Mesosoic limestone and dolomite. They were accessible mainly in

isolated tors and rocky walls. These deposits have been studied in detail in eleven logs (Fig. 1).

Jastrzębia Turnia Tor (Js-I)

Twelve samples (Js-1 - Js-12) have been collected from the section of a debris fan developed at the food of the rocky wall. It is composed of grey loam abounding with dolomite scree intercalated by yellow sandy-loam without rubble (Figs. 1, 2 P,S). The fauna comprises 41 species and

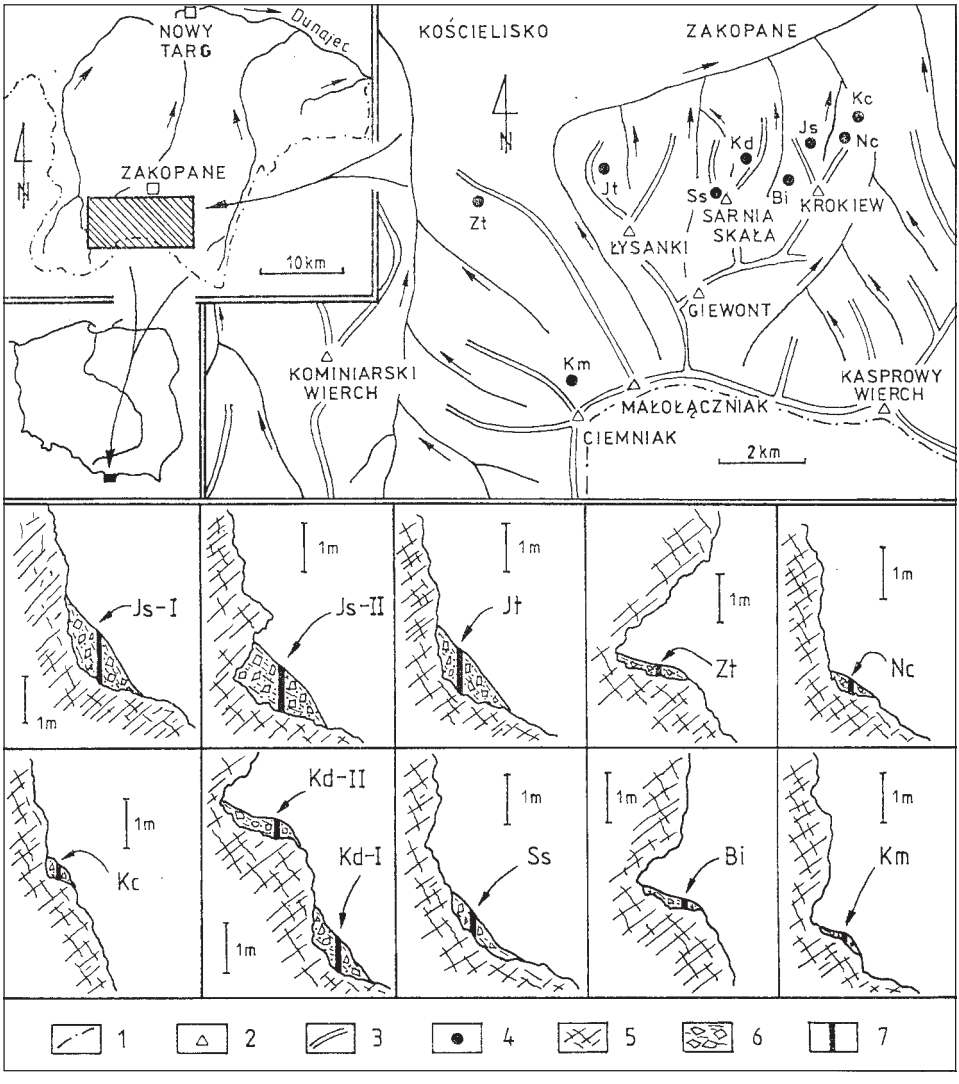

Fig. 1: Location of outcrops of cave sediments in Tatra Mountains.
1 - national border, 2 - summits, 3 - ridges, 4 - outcrops, 5 - bedrock, 6 - cave deposits, 7 - logs.

4986 specimens. Three intervals with domination of woodland species (*Vitrea subrimata* (Reinh.), *Aegopinella pura* (Ald.), *Isognomostoma isognomostoma* (Schröter) and others) are strongly marked. They are separated by phases with high content of open-country snails represented by taxa living on open rocky walls (*Pyramidula rupestris* (Drap.)). The last mentioned corresponds with layers of yellow sandy-loam. The whole community is supplemented by catholic (mesophile) snails (Fig. 2 E,D, Tab. I).

Jastrzębia Turnia Tor (Js-II)

Grey loam with admixture of sand and rubble of dolomites occurs at the bottom of a small rocky niche at the foot of the northern wall of the Jastrzębia Turnia Tor (Figs. 1, 2 P). Five samples (Js-31 - Js-17) containing 27 species and 191 specimens were collected in this section (Fig. 2 S, N). The poor fauna is dominated by woodland snails such as: *Vitrea subrimata* (Reinh.), *Trichia unidentata* (Drap.) and accompanied by mesophile and open-country taxa mainly *Pyramidula rupestris* (Drap.). The content of shadow-loving species decreases in middle interval of the log (Fig. 2 E, D, Tab. I).

Jasiowe Turnie Tors (Jt)

Five samples of mollusca-bearing deposits (Jt-1 - Jt-5) were collected from a section of a debris fan (Fig. 1). The sequence of deposits encloses grey sandy loam passing upward into grey or yellowish-grey loam enriched in angular fragments of dolomites (Fig. 2P, S). These sediments contain a relatively rich fauna of molluscs (38 species and 1049 specimens) The number of taxa is 19 to 28 per sample, whereas the number of specimens reaches 353 (Fig. 2 N). In the lower interval of the log open-country snails, mainly those inhabiting open rocky walls (*Pyramidula rupestris* (Drap.)) prevail. In the next assemblage they are replaced by shadow-loving species: *Discus ruderatus* (Fér.), *Aegopinella pura* (Ald.), *Oxychilus depressus* (Sterki), *Chilostoma faustinum* (Rossm.). In the upper part of the profile this component of the fauna reaches up to 68% of the community (Fig. 2 E, D, Tab. I).

Zawiesista Turnia Tor (Zt)

Yellow sandy loam and yellowish brown loam with limestone scree fill a small rock shelter in the lower part of the southern wall of the Zawiesista Turnia Tor. Three samples (Zt-1 - Zt-3) containing 26 species and 258 specimens have been collected from this locality (Figs. 1, 2 P, S, N). The molluscan assemblage found in the lower part of the section is dominated by the pertrophile snails: *Pyramidula rupestris* (Drap.) and by mesophile species (*Cochlicopa lubrica* (Müll.), *Punctum pygmaeum* (Müll.)). A considerable content of snails preferring wooded or partly wooded areas (*Vitrea diaphana* (Stud.), *Ena montana* (Drap.), *Oxychilus depressus* (Sterki), *Semilimax kotulai* (West.)) characterises the upper interval of the log (Fig. 2 E, D, Tab. I).

Nad Capkami Valley (Nc)

Grey loam with limestone rubble covered by black rendsina-type soil occur in a flat part of the South-eastern slope of the small tor in lower part of the Nad Capkami Valley (Figs. 1 ,3 P). Three samples (Nc-1 - Nc-3) containing a relatively rich molluscan fauna (32 species, 701 specimens) were collected from this log (Fig. 3 S, N). Woodland snails (*Ena montana* (Drap.), *Discus ruderatus* (Fér.), *Vitrea diaphana* (Stud.)) and taxa living in bushes (*Vitrea crystallina* (Müll.),

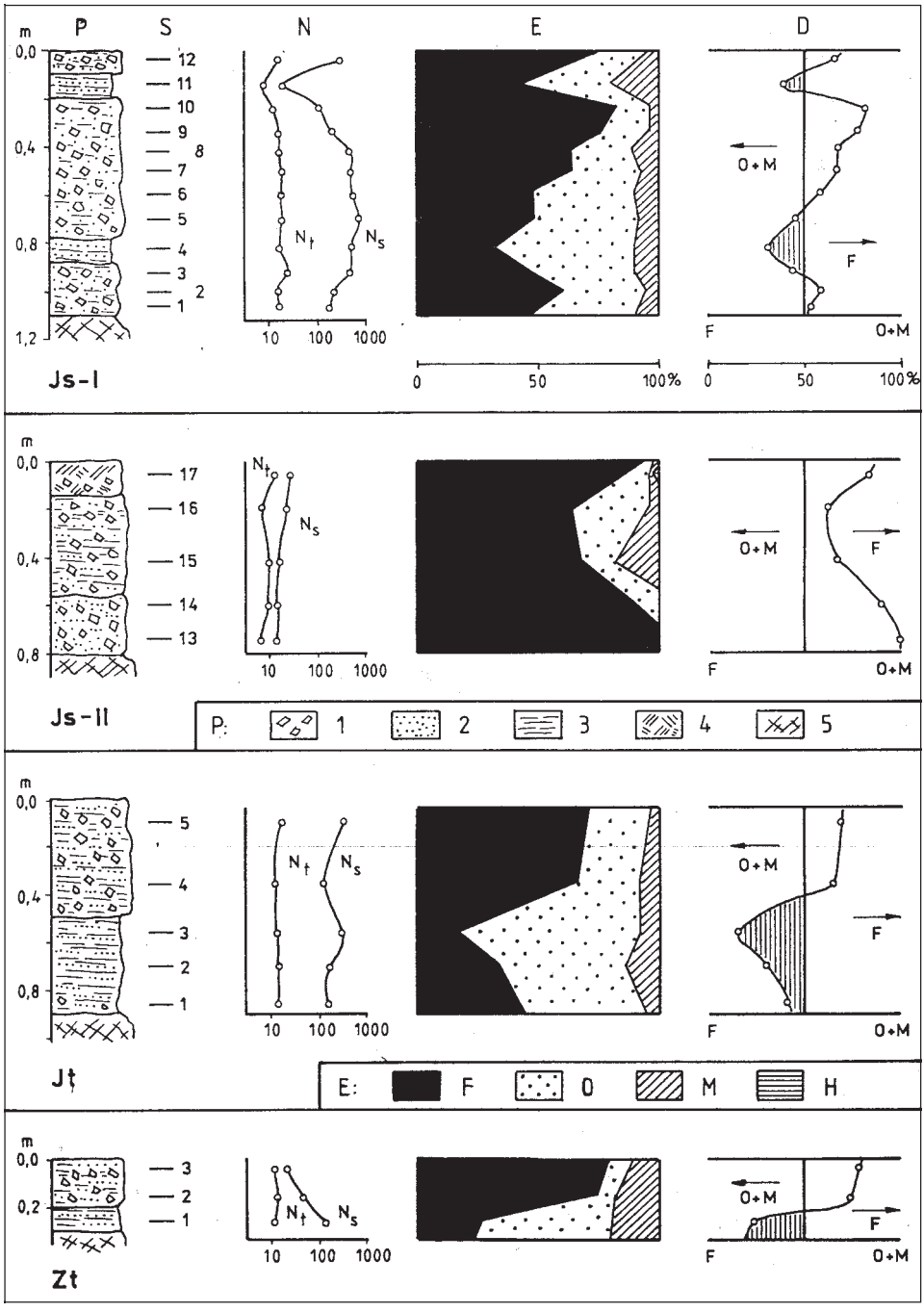
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Fig. 2

Fig. 2: Profiles and malacofauna of the cave sediments in Tatra Mountains (logs: Js-I, Js-II, Jt, Zt) (on the page 130).
P: Profiles; 1 - limestone or dolomite scree, 2 - sand, 3 - loam, 4 - soil, 5 - bedrock;
E: Ecological groups of molluscs (based on Ložek (1964) and S.W. Alexandrowicz (1987));
F - woodland snails, O - open-country snails, M - mesophile snails, H - higrophile snails.

Arianta arbustorum (L.)) as well as species inhabiting shady rocky walls (*Argna bielzi* (Rossm.)) are the main component of this community. Mesophile species (*Carychium tridentatum* Risso) supplement the described fauna (Fig. 3 E, D, Tab.-II).

Nad Capkami Quarry (Kc)

Three samples (Kc-1 - Kc-3) of loam enriched in limestone scree have been collected from the flat ledge on the northern wall of the Nad Capkani quarry (Figs. 1, 3 P, S). A poor molluscan fauna is composed of 21 species and 195 specimens (Fig. 3 N). Woodland snails (*Vitrea diaphana* (Stud.), *Aegopinella pura* (Ald.), *Trichia unidentata* (Drap.) and others) are a most important components of this community. A few shells of mesophile taxa are to be noted (Figs. 3 E, D, Tab. II).

Ku Dziurze Valley (Kd-I)

The profile (Kd-I) represents the debris fan developed at the food of the rocky wall. It encloses yellow loam abounding in limestone rubble intercalated by sandy loam without scree (Figs. 1, 3 P). A rich molluscan fauna (43 species and 2274 specimens) occur in five samples (Kd-1 - Kd-5) (Fig. 3 S, N). Snails inhabiting open rocky walls (*Pyramidula rupestris* (Drap.), *Chondrina clienta* (West.)) dominate in the lower interval of the section. They are accompanied by woodland taxa (*Argna bielzi* (Rossm.), *Eucobresia nivalis* (Dum et Mort.), *Vitrea subrimata* (Reinh.) and others) as well as by catholic snails (*Orcula dolium* (Drap.), *Euconulus fulvus* (Müll.)). In the upper part of the log the prevailing content of shadow-loving taxa (*Aegopinella pura* (Ald.), *Vitrea diaphana* (Stud.)) is noteworthy (Fig. 3 E, D, Tab. II).

Ku Dziurze Valley (Kd-II)

The loam with limestone scree occurs on the flattening of the rocky wall (Kd-II). It contains numerous shells of molluscs found in four samples (Kd-6 - Kd-9) (Figs. 1, 3 P, S). The fauna is composed of 44 species and 2062 specimens (Fig. 3 N). The malacological composition and succession of the fauna are similar to those described from log Kd-I (Fig. 3 E, D, Tab. II).

Sarnia Skała Mountain (Ss)

The log of yellowish-brown sandy loam enriched in dolomite scree have been found in flat rocky niche near the top of the Sarnia Skała Mountain (Figs. 1, 3 P). Six samples (Ss-1 - Ss-6) collected in this locality contain a rich fauna (34 species and 1181 specimens) (Fig. 3 S, N). Open-country snails connected with open rocky walls (*Pyramidula rupestris* (Drap.)) and species inhabiting meadows (*Vallonia costata* (Müll.), *Chilostoma cingulellum* (Rossm.)) are the important components of the fauna, mainly in the middle and uppermost part of the section. The assem-

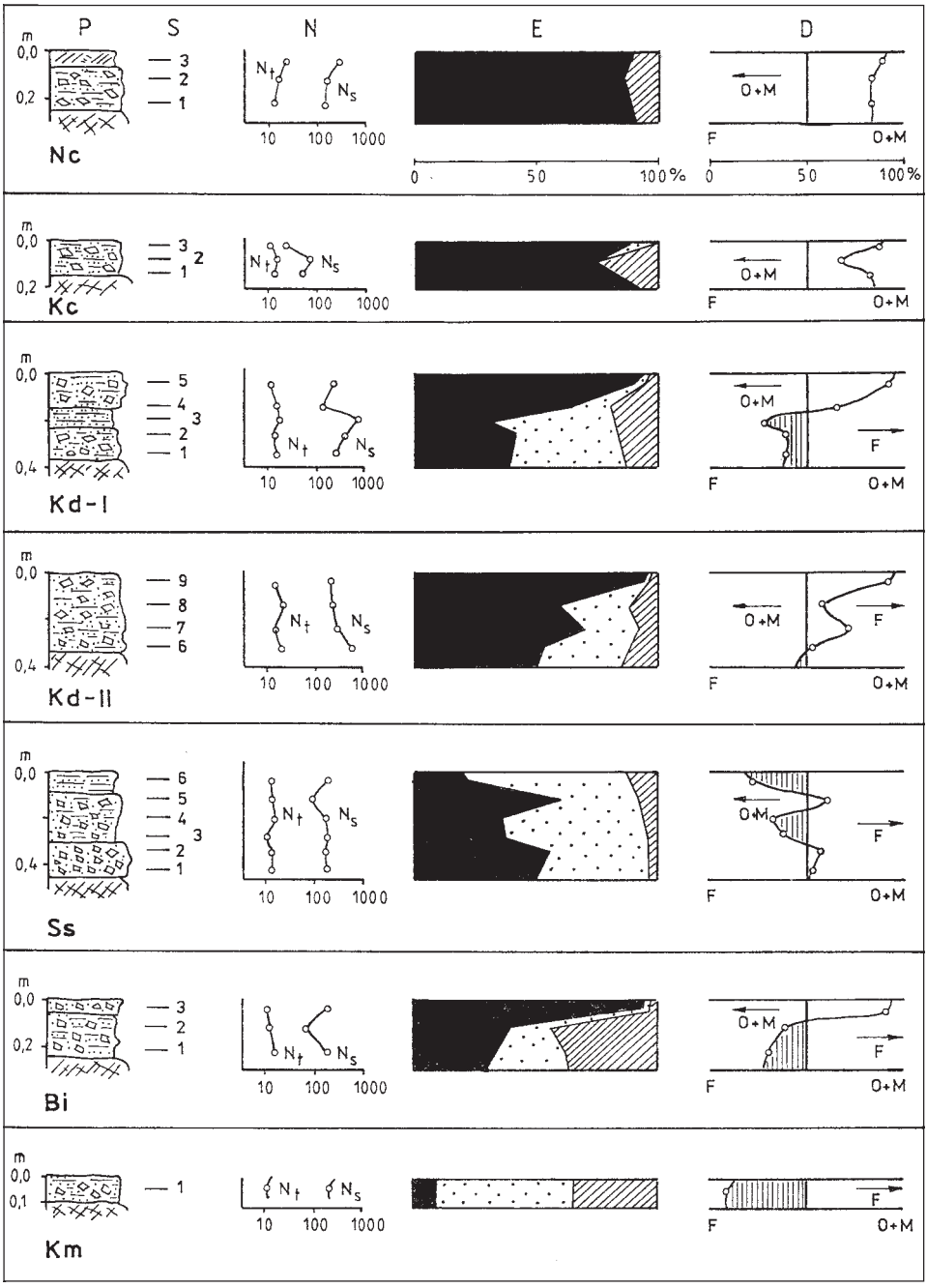

Fig. 3: Profiles and malacofauna of the cave sediments in Tatra Mountains (logs: Nc, Kc, Kd-I, Kd-II, Ss, Bi, Km). For explanations see fig. 2.

blage is completed by shadow-loving and catholic taxa (*Aegopinella pura* (Ald.), *Vitrea crystallina* (Müll.)) (Fig. 3 E, D, Tab. II).

Białego Stream Valley (Bi)

Grey sandy loam with dolomite scree fill a small rock shelter developed within the tor situated on the western slope of the Biały Stream Valley (Figs. 1, 3 P). Three samples of molluscs-bearing deposits were collected from this log (Bi-1 - Bi-3) (Fig. 3 S). The fauna contains 35 species and 430 specimens (Fig. 3 N). In the lower part of the section numerous shells of mesophile snails have been found (*Punctum pygmaeum* (Drap.), *Vitrina pellucida* (Müll.), *Carychium tridentatum* Risso). Open-country taxa (*Pyramidula rupestris* (Drap.)) and woodland species (*Vitrea subrimata* (Reinh.), *Aegopinella pura* (Ald.)) occur additionally. In the upper interval of the log shadow-loving taxa (*Isognomostoma isognomostoma* (Schröter), *Causa holosericum* (Stud.)) prevail, reaching up to 94% of the assemblage. Snails representing the remaining ecological groups are only a subordinate component of the fauna (Fig. 3 E, D, Tab. II).

Mułowy Kocioł (Km)

Sandy loam abounding in limestone scree and rock detritus covers the flat part of the North-western rocky slope of the Ciemniak Mountain (Figs. 1, 3 P). In sample Km-1 the poor molluscan fauna (11 species and 250 specimens) were found (Fig. 3 S, N). Open-country species inhabiting mainly rocky walls (*Pyramidula rupestris* (Drap.), *Chilostoma cingulellum* (Rossm.)) are commonly noted. Catholic taxa (*Clausilia dubia* Drap., *Vertigo alpestris* Ald., *Columella columella* (G.Mart.)) are a second important component of the fauna. Shadow-loving snails typical of areas overgrown with bushes (*Semilimax kotulai* (West.), *Vitrea crystallina* (Müll.)) are supplementary elements of this assemblage. The occurrence of glacial relicts such as: *Columella columella* (G.Mart.), *Semilimax kotulai* (West.) is noteworthy (Fig. 3 E, D, Tab. II).

MOLLUSCAN ASSEMBLAGES

The fauna of molluscs found in deposits filling small karst forms and forming debris fans encloses 56 taxa of land snails. The number of species in particular samples varies between 6 and 34, while the number of specimens ranges between 22 and 877.

The triangular malacological diagram illustrates the diversity of molluscan communities (Fig. 4). Five types of the fauna can be distinguished:

- Assemblage with domination of woodland snails was recognised in 26 samples. Typical forest species such as: *Vitrea subrimata* (Reinh.), *Aegopinella pura* (Ald.), *Isognomostoma isognomostoma* (Schröter) and many others are the most important component of this community. They are accompanied by taxa living in partly shady habitats: *Arianta arbustorum* (L.), *Vitrea crystallina* (Müll.). Relatively high content of snails inhabiting open rocky bedrock (*Pyramidula rupestris* (Drap.)) also to be noted. The remaining ecological groups occur rarely.
- Mixed assemblage containing woodland and open-country species has been distinguished in eighteen samples. It is the fauna of petrophile snails connected with rocky bedrock: *Pyramidula rupestris* (Drap.), *Chondrina clienta* (West.) with considerable admixture of shadow-loving

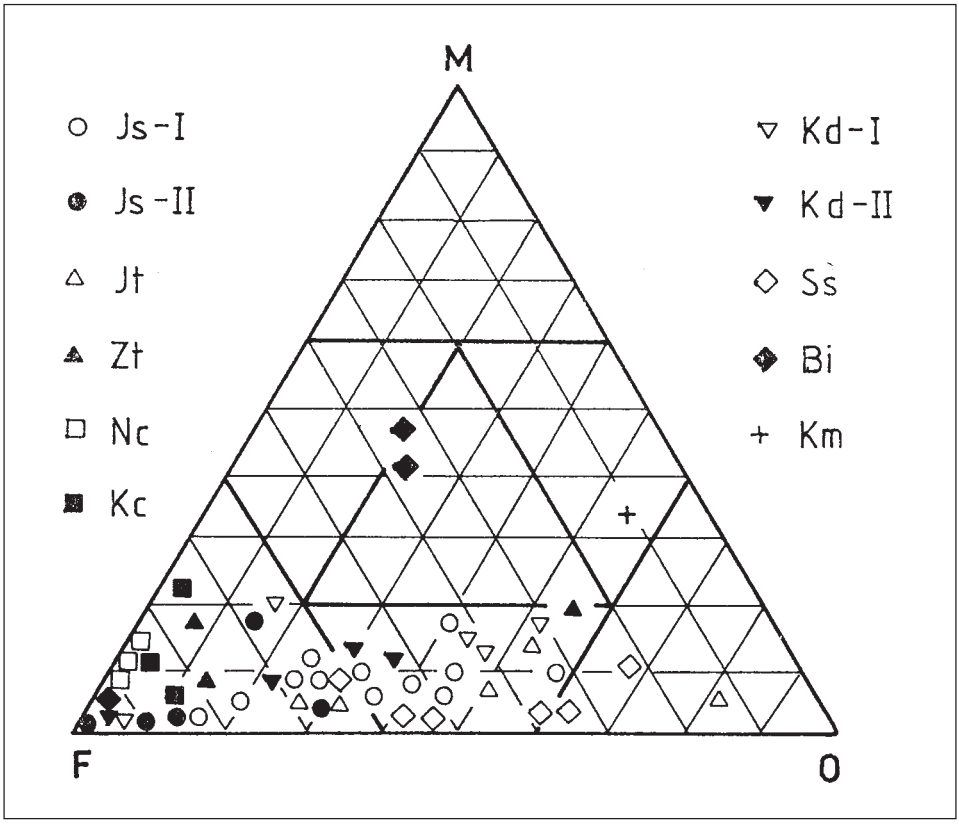

Fig. 4: Ecological types of molluscan assemblages.
F - woodland snails, O - open-country snails, M - mesophile snails.

snails like: *Vitrea subrimata* (Reinh.), *Aegopinella pura* (Ald.) and few others. Species inhabiting meadows and mesophile ones are a subordinate component of the fauna.

- Assemblage dominated by open-country snails is represented in three samples. It contains numerous shells of *Pyramidula rupestris* (Drap.), while shadow-loving snails are the second important component of this community.
- Mixed assemblage with woodland and catholic snails was distinguished only in two samples. The fauna is dominated by mesophile species (*Carychim tridentatum* Risso, *Puncrum pygmaeum* (Drap.) and others) and woodland taxa (*Vitrea subrimata* (Reinh.), *Aegopinella pura* (Ald.)). Open-country snails are a subordinate component of the fauna.
- Mixed assemblage with open-country and mesophile snails was recognised only in one sample. It is the fauna with numerous shells of catholic species such as: *Columella columella* (G.Mart.), *Punctum pygmaeum* (Drap.), *Vertigo alpestris* Ald.. Taxa preferring rocky, open habitats: *Pyramidula rupestris* (Drap.), *Chilostoma cingulellum* (Rossm.) are another important component of this assemblage. Shadow-loving snails occur only as an admixture.

VERTICAL DIFFERENTIATION OF THE FAUNA

The relief and types of the bedrock, plant communities and the degree of afforestation as well as the hipsometric gradient and climatic condition are the main factors controlling the differentiation of molluscan assemblages. The Tatra Mountains are a typical massif with strongly marked arrangement of vegetational zones. Five zones of plant formations can be distinguished: the lower mountain forest (700 - 1250 m a.s.l.), the upper mountain forest (1250 - 1550 m a.s.l.), the zone of dwarf pine (1550 - 1800 m a.s.l.), the alpine grassland zone (1800 - 2300 m a.s.l.) and the summit zone (2300 - 2655 m a.s.l.) (Fabianowski 1962). The timberline ranges the altitude of about 1500 - 1550 m a.s.l. The present-day vertical distribution of mollusc species and assemblages distinctly corresponds with arrangement of vegetational zones (Kotula 1884, Hudec & Brabanec 1960, Kroupova 1986, Dyduch-Falniowska 1991).

The logs of mollusc-bearing deposits filling a small karst forms derives from different altitudes (Fig. 5 A, B). The richest communities of subfossil molluscs are associated with logs situated in the lower mountain forest zone. Localities indicated as: Kc, Nc, Kd-I, Kd-II, Bi, Js-I, Js-II and Jt belong to this group (Fig. 5 A, B) and are characterised by the fauna dominated by typical

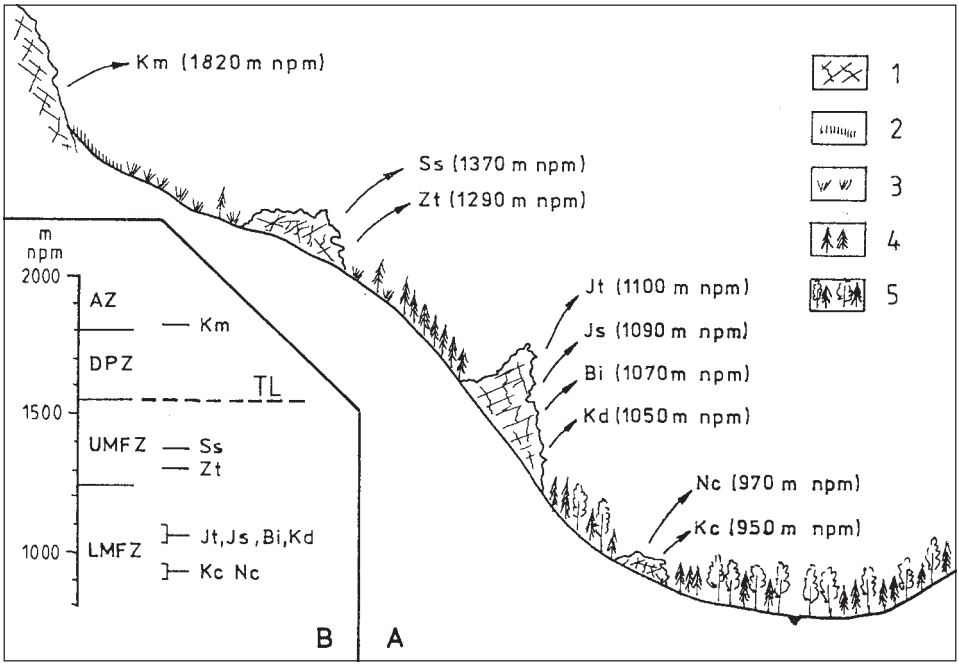

Fig. 5: Vertical distribution of molluscs-bearing cave deposits in Tatra Mountains.
A: 1 - summits zone, 2 - alpine grassland zone, 3 - dwarf pine zone, 4 - upper mountain forest zone, 5 - lower mountain forest zone;
B: AZ - alpine zone, DPZ - dwarf pine zone, UMFZ - upper mountain forest zone, LMFZ - lower mountain forest zone, TL - timber line.

woodland snails. The occurrence of species inhabiting more or less open rocky walls is noted, too while mesophile taxa are a subordinate component only. Logs Ss and Zt are situated in the upper mountain forest zone. The fauna found there contains woodland species and additionally also open-country ones (Fig. 5 A, B). The assemblage collected in the remaining locality (Km) situated within the summit zone is dominated by catholic and open-country species with an admixture of snails preferring partly shady habitats (Fig. 5 A, B).

STRATIGRAPHIC INTREPRETATION

Mollusc-bearing deposits developed in small karst forms such as rock shelters and rocky niches as well as forming debris fans at the foot of the rocky walls reaches a relatively low thickness. It varies in particular logs between 10 and 110 cm. The molluscan assemblages found in these deposits are closely similar to the fauna living recently in related zones of the Tatra Mountains (Kotula 1884, Hudec & Brabanec 1960, Kroupova 1989, Dyduch-Falniowska 1991). It indicates that the molluscan fauna described above corresponds with Late Holocene, namely with the last several hundred years. Calcareous tufa with a rich molluscan assemblage from the Kraków Gorge corresponds with this age, too (S.W. Alexandrowicz 1988).

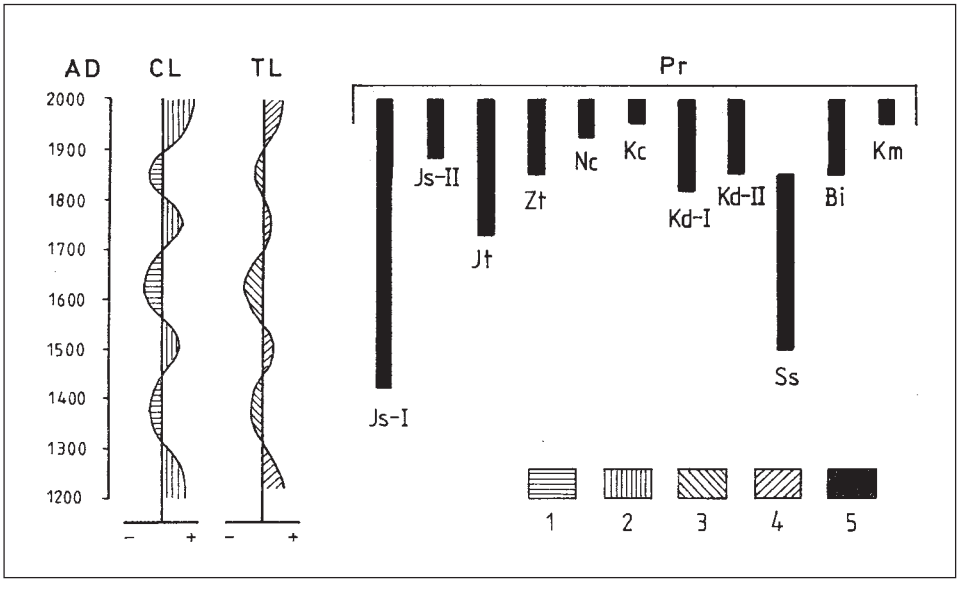

Fig. 6: Changes of climate, fluctuation of the timber line and stratigraphy of molluscs-bearing cave sediments in Tatra Mountains.
AD - age, CL - climatic changes, TL - fluctuations of the timber line, Pr - stratigraphical range of the profiles; 1 - cold phases, 2 - warm phases, 3 - rise of the timber line, 4 - lowering of the timber line, 5 - stratigraphical range of the profiles.

Changes of the climate are the main factor determining the level of the timberline. They are also reflected by the succession of the molluscan assemblages corresponding with the moving of the timberline. Three phases of warming separated by two phases of a colder and more severe climate can be distinguished. The raising of the timberline was connected with warm periods, and the lowering with cold episodes (Fig. 6 CL, TL).

The oldest stage of development of cave sediments corresponds with a warm period. It has been distinguished in the lowermost intervals of logs Jastrzębia Turnia Tor (samples Js-1 - Js-3) and Sarnia Skała Mountain (samples Ss-1, Ss-2). Woodland snails dominate in mollusc communities reaching up to 60% (Figs. 2 E, D, 3 E, D). In the second stage the climate became colder (Jastrzębia Turnia Tor Js-4 - Js-6, Sarnia Skała Mountain Ss-3, Ss-4, Ku Dziurze Valley Kd-6). This episode is characterised by a considerable content of open-country species and by limited differentiation of woodland taxa (Figs. 2 E, D, 3 E, D). The next stage corresponds with warming of the climate. It can be observed in logs: Jastrzębia Turnia Tor (Js-7 - Js-10 and Js-13, Js-14), Ku Dziurze Valley (Kd-7) and Sarnia Skała Mountain (Ss-5). The fauna is rich and differentiated. It comprises numerous shells of forest snails. Species belonging to the remaining ecological groups are only a subordinate component of assemblages (Figs. 2 E, D, 3 E, D). The last cold phase is characterised by the prevailing of open-country taxa recognised in profiles: Js-I (Js-11), Js-II (Js-15, Js-16), Jt (Jt-1 - Jt-3), Kd-I (Kd-1 - Kd-3), Ss (Ss-6) and Bi (Bi-1,Bi-2) (Figs. 2 E, D, 3 E, D). The last phase corresponds with warming of the climate. It is connected with uppermost intervals of all logs except Sarnia Sakła Mountain and Mułowy Kocioł (Figs. 2 E, D, 3 E, D). The last mentioned is situated recently above the timberline so the fauna is dominated by open-country and catholic species.

CONCLUSIONS

The succession of molluscan assemblages reflects climatic changes during the last seven hundred years. Particular profiles have different stratigraphical ranges (Fig. 6 Pr). The sequence of climatic phases as well as movement of the timber line was described by several authors (Stachlewski 1978, Maruszczak 1991, Obidowicz 1993 and others). According to this data the molluscan communities found in the Tatra Mountains in cave and slope deposits correspond with the following climatic stages:

- The first warm phase - the Middle Ages climatic optimum (XIII and first half of XIV centuries AD) (Fig. 6 CL, TL).
- The first cold phase - the oldest episode of the Little Ice Age (second half of XIV - XVII centuries AD) (Fig. 6 CL, TL).
- The second warm phase - the warming of the climate in the second half of the XVIII and the first half of the XIX centuries (Fig. 6 CL, TL).
- The second cold phase - the late stage of the Little Ice Age in the second half of the XIX century (Fig. 6 CL, TL).
- The third warm phase - the warming falling to the XX century (Fig. 6 CL, TL).

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Tab. I: Malacofauna of the deposits filling small karst forms in Tatra Mountains (logs: Js-I, Js-II, Jt, Zt) (on the page 140).
E: ecological groups (based on Ložek 1964 and S.W. Alexandrowicz 1987); 1 - typical forest species, 2 - species inhabiting forests and bushes, 3 - species of moist forests, 4 - species inhabiting rock walls and xerotermic snails, 5 - open-country species, 6 - mesophile species of dry environments, 7 - mesophile species of moderately dry environments, 8 - mesophile species of moist environments, 9 - higrophile species. Number of specimens: 1. 1-3, 2. 4-10, 3. 11-32, 4. 33-100, 5. 101-316.

Tab. II. Malacofauna of the deposits filling small karst forms in Tatra Mountains (logs: Nc, Kc, Kd-I, Kd-II, Ss, Bi, Km) (on the page 141). For explanation see tab. I.

E	TAXON	Js - I									Js - II								Jt					Zt		
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	1	2	3	4	5	1	2	3
1	Acicula parcelineata										1	1	1					1								
1	Acicula polita	2	2	3	3	1	3	3	3	3			2	1					1	1	2		2		1	1
1	Argna bielzi		1	2	2	3	4	2	2	1	1		2		1			1				1	1		2	
1	Acanthinula aculeata				2	2	2		1									1	1							
1	Ena montana	1		1	1	1	2	1	1	2			1		1									1	2	2
1	Discus ruderatus	1	2	1	1	2	1	1	1	1	1		1			1			2	1	2	1	2			1
1	Eucobresia nivalis		1		1	1	1	1	1	1			1						1	1	1	1	1	2		
1	Vitrea diaphana	1	3	2	2	2	3	2	2	1	2		2	1	2			3	2		1	1	2	3	2	2
1	Vitrea transsylvanica			1	1	2		1		1	1		1	1						1	1		2		1	
1	Vitrea subrimata	4	4	5	4	5	5	5	5	4	3	1	5	3	1	2	2	2		1		1	3		1	1
1	Aegopinella pura	3	2	3	4	3	4	3	3	2	1	1	3						2	2	2	2	3		1	
1	Aegopinella nitens						2		2	2	1												2	1	2	
1	Oxychilus orientalis																						1			
1	Oxychilus depressus	2	3	3	2	2	3	3	3	2			3		1	1		1	2	2	1	2	3	1	3	1
1	Cochlodina laminata	1		1	2	1	1	1	1	1			1	1	1				2		2	2	3			
1	Cochlodina orthostoma		1	1		1			1																	
1	Macrogastra plicatula	1	1	2	2	2	3	2	2	2	1		2	1	1	1	1	1	1				2			
1	Macrogastra latestriata																						1			
1	Clausilia cruciata			1									1							1			1			
1	Perforatella incarnata																							1		
1	Trichia unidentata	2	2	3	3	3	3	2	3	3	3	1	3	2	1	1	3	2	1	1		2	2		2	
1	Cheliostoma faustinum	2	3	3	2	2	2	3	2	2	2	1	3	1		1			3	3	3	3	4		2	
1	Isognomostoma isogn.	3	3	4	2	3	4	4	3	2	3		4			1	1	3	1	1		2	3		1	1
1	Causa holosericeum				1			1	3	2	2	1	2		1	1	1	1								
2	Semilimax kotulai										1		1	1										3	2	1
2	Vitrea crystallina	1		1				1		1								2		1						1
2	Aegopinella minor							1		1			3													
2	Alinda biplicata																					1				1
2	Arianta arbustorum		1			1	1			2								1	1		1		2			
3	Macrogastra tumida	1																								
3	Vestia turgida	1		1			2		1											1	1	1	2			
3	Perforatella vicina		2	1	1	1	2	1	1	1			2						1		1	2	3			1
4	Pyramidula rupestris	4	4	5	6	5	5	5	5	4	3	2	5		1	2	3	2	4	4	5	3	4	4	2	1
5	Vallonia costata																			1						
5	Vallonia pulchella																			1	1	1				
6	Cheliostoma cingulellum			2																		2	2			
7	Cochlicopa lubricella			1																1	1					
7	Cochlicopa lubrica	1																1	1					1	2	1
7	Vertigo alpestris	1	1	2	2	2	2	1	1	1			2						1	1	2	1	1	2		1
7	Orcula dolium	1	2	3	3	3	4	3	3		2	1	2			2				1		1	2			
7	Punctum pygmaeum				1	1	1	1	1				2				1		2	2	3		1	2	1	
7	Nesovitrea hammonis			1	1		1	2	2	1			1			1				1		1				
7	Limacidae		1	1	1	1	2	1	2	1		1	2				1				1		1	2	2	1
7	Euconulus fulvus	1	1	2	1	1	2	1	1									1		1	1			2		
7	Clausilia dubia																				1				1	
8	Carychium tridentatum	2	1	2	3	3	3	3	3	2			3						2	2	1	2	2			
8	Columella edentula							1																		
8	Vertigo substriata					1	1			1																
9	Carychium minimum																	1								

E	TAXON	Nc			Kc			Kd - I					Kd - II				Ss						Bi			Km
		1	2	3	1	2	3	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	1	2	3	1
1	Acicula parcelineata			2							1				1								1	1		
1	Acicula polita		2	2				2	2	2			3	2	2	2	3	2	2	2	2	1			1	
1	Vertigo pusilla							1	2	2	1		1									2				
1	Argna bielzi	1	1	3				3	3	4	1	2		4	3	2	2		1		1					
1	Acanthinula aculeata		1				1	3	3	3	1		3	2	1				1				1	1		
1	Ena montana	3	3	1				1				1	1	1	1	1							1		1	
1	Discus ruderatus	2	3	1							1							1		1						
1	Eucobresia nivalis	1		1				3	3	3	1	3	4	3	2	3		1		1	4					
1	Semilimax semilimax			1											1											
1	Vitrea diaphana	3	1	3	2	3	1	1	1	1	1	4	2	2	2	3		1			1		2		2	
1	Vitrea transsylvanica			1		1		1	1		1		1	2	1	3		1		1	1		1	1		
1	Vitrea subrimata	3	4	4				4	5	4	3		5	5	5	4		1		1	1	1	2	2		
1	Aegopinella pura	1	2	1	3	3	2	2	2	3	3	2	3	3	3	1	3	3	3	3	2	2	3	3		
1	Aegopinella nitens	2			2		2		2	2	2	5	1		1	2						1		1		1
1	Oxychilus depressus	2	2	2	1	1		1	2	1	2	4	3	2	3	3	4	3	2	2	3	3			2	
1	Cochlodina laminata	1	1	1					1			1	1	1	1	3				1					1	
1	Cochlodina orthostoma						1					1	1	1											1	
1	Macrogastra plicatula	1	2	3	1	1		1	1	1	1	1	1	1	1	3							2		1	
1	Trichia unidentata	2	2	3	3	2	1	1	2	3	3	2	3	2	2	3						1	2	1	1	
1	Cheliostoma faustinum	2	2	3	3	1	2	2	2	1	3	2	3	1	2	4	1	2				2	1		2	
1	Isognomostoma isogn.	2	3	4			1	2		1	2	4	3	2	2	4					1		1		4	
1	Causa holosericeum			3							1	1				4									4	
2	Semilimax kotulai		1	2						1				1				1								2
2	Vitrea crystallina	2	1	2	1						1					1	4	4	4	3	2	2	1	1		3
2	Aegopinella minor				1	1		1				3		1	1								1			
2	Alinda biplicata														1											
2	Arianta arbustorum	2	1	3		1		1	1	1	2			2	1	1							1		1	
3	Macrogastra tumida										1													1	1	
3	Vestia turgida	1	1	1		1			1				1	1	1	1						1			1	
3	Perforatella vicina	1	2	1	2	2		1	1	2		2	2		1	2	2						1	1		
4	Pyramidula rupestris			1			1	5	5	6	3	2	5	4	5	3	4	3	4	4	3	5	4	3	1	5
4	Chondrina clienta							2	2	2			2		2						1	1				
5	Truncatellina cylindrica							1	1	2			1		2											
5	Pupilla muscorum																1									
5	Vallonia costata									1			1				3	3	3	3	2	2				
5	Vallonia pulchella					1									1			1								
6	Cheliostoma cingulellum										1		1				3	3	4	3						3
7	Cochlicopa lubrica							1									1			1	1		1			
7	Columella columella																									4
7	Vertigo alpestris	1		1				2	1	3	2		1	1	2		1		1	1	1	2	2	1		3
7	Orcula dolium							3	3	3	2	3	2	2	3	2		1		1	1	3	1	1	2	
7	Punctum pygmaeum				2	2		2	3	3	2		3	1	1	1	1	1	1	1			3	2		3
7	Vitrina pellucida				1	1									1								3	1		
7	Nesovitrea hammonis		1	1					1	1			2		1		1	1	2	1						
7	Limacidae	1	3	3				1	1	2	1		2	1		2	2	1		1		1			1	
7	Euconulus fulvus	1	1		1	1	1	3	3	3	1	1	3	1	1	1	1		2	1	1		1	2		2
7	Clausilia dubia																1	1							1	2
8	Carychium tridentatum	3	3	3		1		3	4	4	2		4	3	3	1							4	3		
8	Columella edentula				1	2	1			1			1										1	1		
8	Vertigo substriata			1						2			1	1									2	1		2

ZDRUŽBE MOLUSKOV V ZAPOLNITVAH MANJŠIH KRAŠKIH OBLIK V TATRAH (JUŽNA POLJSKA)

Povzetek

V zapolnitvah manjših kraških oblik in v majhnih meliščih je avtor naštel vsega skupaj 56 različnih vrst kopenskih polžev, ki jih je mogoče razdeliti v pet tipov združb:

- s prevlado gozdnih polžev,
- mešane združbe gozdnih polžev in polžev odprtega sveta,
- združbe s prevlado polžev odprtega sveta,
- mešane združbe gozdnih in mezofilnih vrst polžev,
- mešane združbe polžev odprtega sveta in mezofilnih vrst polžev.

Te združbe moluskov odražajo klimatske spremembe zadnjih sedem sto let. Posamezni raziskani profili imajo različen stratigrafski obseg. Potek klimatskih faz in spreminjanje gozdne meje je opisalo več avtorjev. Skladno z njihovimi podatki združbe moluskov, najdenih v spodmolih in v pobočnih sedimentih v Tatrah, odgovarjajo sledečim klimatskim fazam:

- XIII. in prva polovica XIV. stol. po Kr. (prva topla faza),
- druga polovica XIV. stol. - XVII. stol. po Kr. (prva mrzla faza, najstarejši del t.im. Male ledene dobe),
- XVIII. stol. in prva polovica XIX. stol. (druga topla faza),
- druga polovica XIX. stoletja (druga mrzla faza, pozni stadij Male ledene dobe),
- XX. stol. (topla faza - ogrevanje).