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LATE VISTULIAN AND HOLOCENE MOLLUSC ASSEMBLAGES FROM CALCAREOUS TUFA AT THE OSTRYSZ HILL (PODHALE BASIN, S POLAND)

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ABSTRACT: Late Vistulian and Holocene mollusc-bearing deposits, developed as solifluction sediments, travertines and calcareous tufa, occur in a valley of a small stream on NE slopes of the Ostrysz Hill near Małe Ciche in the Podhale Basin (S Poland). Several types of rich and differentiated mollusc assemblages, corresponding to consecutive phases of the evolution of climate and palaeogeographical conditions during the Late Vistulian and Holocene, were found in eleven profiles.

KEY WORDS: mollusc assemblages, calcareous tufa, environmental changes, Late Vistulian, Holocene, Podhale Basin

INTRODUCTION

The studied area is situated on north-eastern slopes of the Ostrysz Hill near Małe Ciche, in the south-western part of the Podhale Basin (Fig. 1A). The geological structure of the region was described by several authors (RADOMSKI 1958, GOŁĄB 1959, WATYCHA 1959, MASTELLA 1975 and others). The basement is formed of flysh deposits belonging to the Podhale Flysh, composed of shales and sandstones with carbonate matrix. Mollusc-bearing deposits were found in the upper part of a small, left-bank tributary of the Ciche Stream (Fig. 1B). Profiles Os-I – Os-IX are situated close to the head of the stream, while the remaining two profiles (Os-X and Os-XI) are located about 300 m downstream (Fig. 1C, D).

Travertines and calcareous tufa form irregular bodies of a very differentiated and complicated structure (Fig. 1E). Their maximum thickness is about 2.5 m. Five main lithological types of deposits can be distinguished:

– travertines – white or yellow, compact limestones, usually cavernous and porous;
– nodular travertines – yellowish-white calcareous sediments with angular fragments of compact travertines, reaching up to 20 cm in diameter;
– coarse-grained calcareous tufa – white, yellow or even brown deposits containing travertine gravel and calcareous sand;
– fine-grained calcareous tufa – sandy, white calcareous sediments;
– calcareous silt – white, loose and unstratifield deposits.

Calcareous sediments are underlain by slope deposits developed as mud with angular debris of sandstones.

Mollusc shells from travertines and calcareous tufa of the Ostrysz Hill were first reported by PACYGA (1982) and CISZEK (1992) and later by S. W. ALEXANDROWICZ (1985) and by S. W. ALEXANDROWICZ & W. P. ALEXANDROWICZ (1995a, b, c). Several profiles of calcareous deposits from the Ostrysz Hill were studied in detail by W. P. ALEXANDROWICZ (1997). According to these data and the results of malacological analysis carried out at new logs, a few types of mollusc assemblages can be distinguished. Their succession indicates both the age of the deposits and the main stages of climatic and environmental changes.

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MATERIAL AND METHODS

Fifty-three samples of mollusc-bearing deposits were taken from eleven profiles of calcareous tufa. The samples were washed, so as to pick out all the mollusc shells and shell fragments that could be determined. The whole analysed material comprises fifty-six species of land snails, two taxa of water snails and one of bivalves, all these being represented by a total of over five thousand specimens.

Standard methods of malacological analysis described by LOŽEK (1964) and S. W. ALEXANDROWICZ (1987a, 1999) were applied. All the taxa were divided into ecological groups representing five comprehensive categories: F – woodland snails, O – open-country snails, M – mesophile snails, H – higrophile snails and W – water molluscs. These groups were distinguished in the malacological spectra of specimens (MSI). Species of molluscs could also be divided into five groups according to their geographical range and climatic tolerance (SPARKS 1964, S. W. ALEXANDROWICZ 1987a). These are: N-1 – species living recently in South and Central Europe, N-2 – species reaching the latitude of 60–61°N, N-3 – species reaching the latitude of 63°N, N-4 – species reaching the north polar circle and living in high mountains, N-5 – species crossing the north polar circle and living in periglacial zones of high mountains. Triangular diagrams were used for the specification of mollusc assemblages described from calcareous tufa of the Ostrysz Hill. The diagrams make it possible to distinguish a succession of communities in consectuive climatic phases of the Late Glacial and Holocene.

RESULTS

Eleven profiles of mollusc-bearing calcareous tufa accessible in two localities were studied in detail. Profiles Os-I – Os-IX represent the main outcrop situated close to the source of the stream (Fig. 1B, C, E).

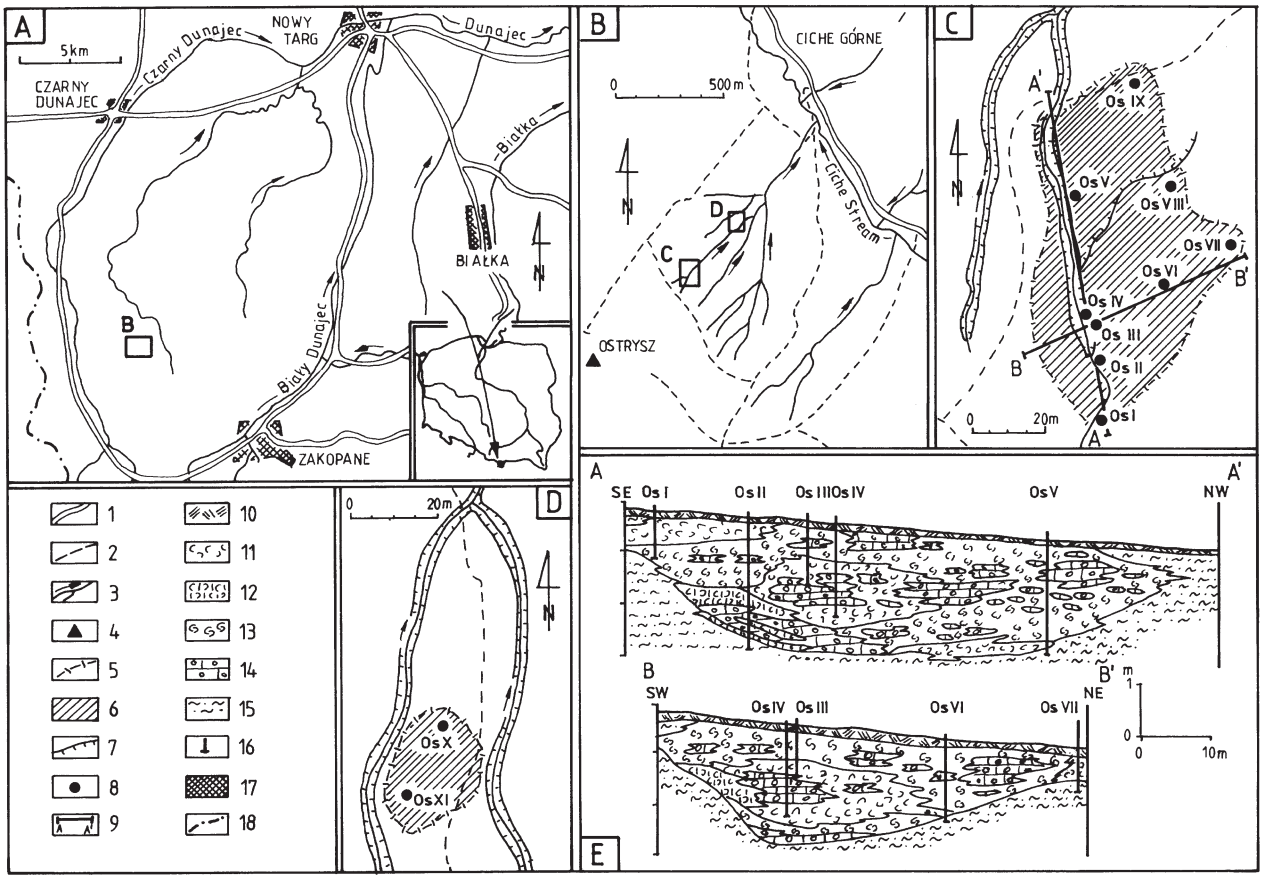

Fig. 1. Location of profiles of calcareous tufa at the Ostrysz Hill: 1 – main roads, 2 – forest roads, 3 – rivers and streams, 4 – summits, 5 – boundary of zone of accumulation of calcareous tufa and travertines, 6 – calcareous deposits, 7 – terrace risers, 8 – profiles (on maps), 9 – cross-sections, 10 – recent soil, 11 – fine-grained calcareous tufa, 12 – calcareous silt, 13 – coarse-grained calcareous tufa, 14 – travertines, 15 – solifluction loam, 16 – profiles (in cross-section), 17 – towns and villages, 18 – state boundary

Fine-grained calcareous tufa intercalated with peat were distinguished in profile Os-I. The thickness of these deposits was ca 0.9 m (Fig. 2: P). Two samples (Os-1 – Os-2) containing mollusc shells were collected (Fig. 2: S). The number of species varied from 11 to 20, whereas the number of specimens – from 39 to 87 (Fig. 2: N). Shadow-loving snails, represented mainly by cold-tolerant taxa, such as *Semilimax kotulai* (West.), and mesophile species were two main components of the fauna. The remaining ecological groups were practically absent (Table 1, Fig. 2: E).

Coarse- and fine-grained calcareous tufa with interelations of nodular travertines, calcareous silt and massive travertines occurred in log Os-II. Calcareous sediments covered solifluction deposits (Fig. 2: P). In eight samples from this log (Os-3 – Os-10), the number of species varied from 14 to 21, while the number of specimens reached up to 189 (Fig. 2: S, N). Mesophile species (*Euconulus fulvus* (O. F. Müll.), *Nesovitrea hammonis* (Ström)) accompanied by cold-tolerant woodland and higrophile snails (*Semilimax kotulai* (West.), *Vertigo genesii* (Gredl.), *Vertigo geyeri* Lindh.) were the main components of the fauna in the lowermost part of the profile. Higher up catholic species and shadow-loving taxa occurred in nearly equal proportions. Water molluscs represented by *Bythinella austriaca* (Frfld.) were found in the uppermost part of the described sequence (Table 1, Fig. 2: E).

Profile Os-III included fine-grained calcareous tufa passing upward into nodular travertines, ca 1.1 m thick (Fig. 2: P). Four samples (Os-11 – Os-14) contained a relatively rich mollusc fauna (6–15 species and 12–340 specimens per sample) (Fig. 2: S, N). Catholic taxa (*Euconulus fulvus* (O. F. Müll.), *Nesovitrea hammonis* (Ström), *Nesovitrea petronella* (L. Pfr.), *Succinea oblonga* Drap. and others) dominate in this fauna. Woodland species: *Isognomostoma isognomostoma* (Schröt.), *Ena montana* (Drap.) *Arianta arbustorum* (L.) were important components of the assemblage as well (Table 1, Fig. 2: E).

Eleven samples (Os-15 – Os-25) derived from travertines, fine-grained calcareous tufa and nodular travertines in log Os-IV (Fig. 2: P, S). The number of species varied from 12 to 30, whereas the number of specimens reached up to 541 (Fig. 2: N). In the lower and middle part of the sequence mesophile snails (*Cochlicopa lubrica* (O. F. Müll.), *Nesovitrea hammonis* (Ström), *Carychium tridentatum* (Risso), *Succinea oblonga* Drap. and others) prevailed. They were accompanied

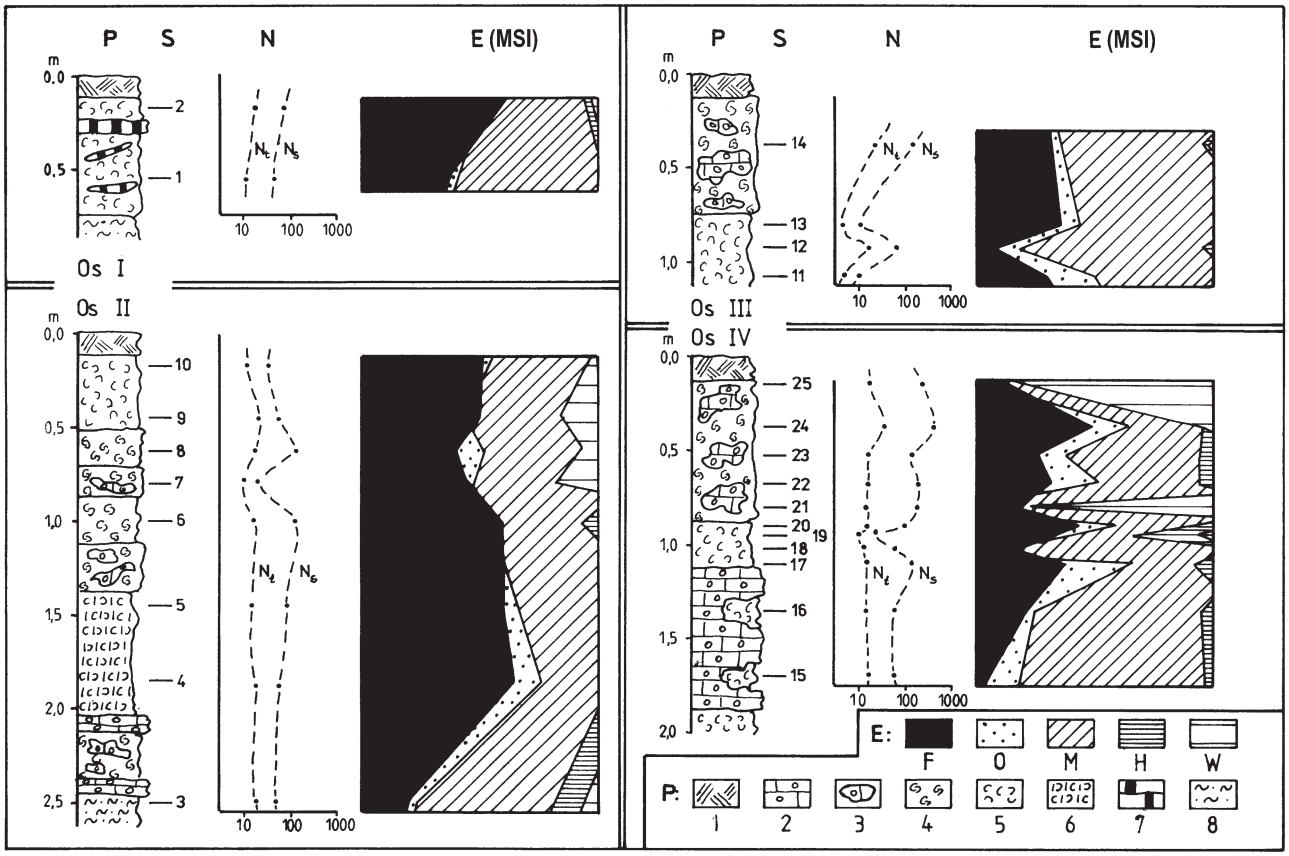

Fig. 2. Lithology and malacofauna of profiles Os-I – Os-IV. E. ecological groups of molluscs (based on LOŽEK 1964 and S. W. ALEXANDROWICZ 1987a) (MSI – malacological spectrum of species): F – shadow-loving species, O – open-country species, M – mesophile species, H – higrophile species, W – water species; P – lithology: 1 – recent soil, 2 – travertines, 3 – nodular travertines, 4 – coarse-grained calcareous tufa, 5 – fine-grained calcareous tufa, 6 – calcareous silt, 7 – peat, 8 – solifluction loam; S – samples; N – number of taxa (n_t) and number of specimens (n_s)

Table 1. Malacofauna of calcareous tufa from the Ostrysz Hill (profiles Os-I – Os-IV). E. ecological groups (based on LOŽEK 1964 and S. W. ALEXANDROWICZ 1987a): 1 – typical forest species, 2 – species inhabiting mainly forests, 3 – species of humid forests, 5 – open-country species, 7 – mesophile species of moderately humid habitats, 8 – mesophile species of humid habitats, 9 – higrophile species, 10 – water molluscs; number of specimens (based on S. W. ALEXANDROWICZ 1987a); 1 – 1–3, 2 – 4–10, 3 – 11–32, 4 – 33–100, 5 – 100–316, 6 – 317–1000

E	TAXON	OsI		Os II								Os III				Os IV										
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1	*Acicula polita*									2					1			3				1		1	4	1
1	*Acanthinula aculeata*																									1
1	*Ena montana*		1							1					2			1				1			1	2
1	*Discus ruderatus*	2	3	1	2	1		1			1	1	1	1	2	1		2		2	3		3	3	4	
1	*Eucobresia nivalis*				1	1	1		2									1				1			2	2
1	*Semilimax semilimax*										2						1	1			1		1	1	1	1
1	*Aegopinella pura*									2	2							2				1			4	1
1	*Aegopinella nitidula*														1							2				2
1	*Oxychilus depressus*																								2	
1	*Vitrea diaphana*		1						1						1							2				2
1	*Vitrea transsylvanica*														1							2				
1	*Vitrea subrimata*									1				1								1				
1	*Clausilia cruciata*																	1								1
1	*Macrogastra plicatula*														1											1
1	*Monachoides incarnata*								1													1				
1	*Trichia unidentata*	1						1	1	1					1			1		1	1	2	1	1	2	1
1	*Chilostoma faustinum*				1		1		2	1								1				1				
1	*Isognomostoma isognomostoma*				1	2			2	1				3	2							2	3	2	2	1
2	*Semilimax kotulai*	2	3	1	1	3	4		2	1	1	1	1		2	1	2	1		1	2		3	3	3	
2	*Aegopinella minor*								1						1											
2	*Vitrea crystallina*		1		2	2		1	3	3								3			1	2	3	2	3	1
2	*Bradybaena fruticum*		2						3		2							2	1							1
2	*Arianta arbustorum*		2	1	3	3		2	3	1	1	1	1		2	1	1	2		1	2		2	1	2	2
3	*Macrogastra ventricosa*														1											
3	*Monachoides vicina*		1					1	3	1	1							2		1		1	1		2	1
5	*Vertigo pygmaea*										1														1	
5	*Pupilla muscorum*												1													
5	*Vallonia costata*			2	2	2		1	3	2		1	1	1	2	2	1	4		1	3		4		4	
5	*Vallonia pulchella*	1	1										1											3		
7	*Cochlicopa lubrica*	2	2	2	1	2	1		3	1	1		2	1	2	2	2	3			1	1	2	1	2	
7	*Columella columella*	1	1										1		2	2	1	1			1		1	1	1	
7	*Vertigo arctica*											1			1											
7	*Vertigo alpestris*								1																	
7	*Punctum pygmaeum*	1		2	1	1	1		1				1		2	2	2	1			2		2	2	2	
7	*Vitrina pellucida*	1	1												1			1				1	1			
7	*Nesovitrea hammonis*	2	2	3	1	2	1	1	2	1			1		2	3	1	2		1	2	1	2	2	3	
7	Limacidae	1	1	1		2	2	1	2	1	2	1	2		3	1	1	1		2	3	1	1	1	2	1
7	*Euconulus fulvus*		1	2	2	2	2		3	1		1	2		2	2	2	1	1	1		1	2	2	2	
7	*Clausilia dubia*									1	1						1						1		1	
8	*Carychium tridentatum*		2		2	2	3	1	3	1	1				1		1	3			1	2	3	4	4	2
8	*Columella edentula*			1		2			1		2															
8	*Vertigo substriata*	1	2	2	1	1				1			2		1	2	1				1	1	1	2	2	
8	*Succinea oblonga*			1	1		1						3		3	3	3		1		1		3		1	
8	*Nesovitrea petronella*								2				2	1	1		1	2	1		1		1		1	
9	*Carychium minimum*						2			2								3					2	1	2	
9	*Vertigo genesii*			2									1		1	1	2			1			1			
9	*Vertigo geyeri*			1												1	1									
9	*Succinea putris*																			2				1	2	
9	*Monachoides rubiginosa*		1																							
10	*Bythinella austriaca*		1		1			2	3	1	1			1	1	1		1		1		4			2	6
10	*Lymnaea truncatula*															1	1									
10	*Pisidium personatum*		1																							

by woodland and open-country snails (*Acicula polita* (Hartm.), *Discus ruderatus* (Fér.), *Aegopinella pura* (Ald.), *Trichia unidentata* (Drap.), *Vitrea crystallina* (O. F. Müll.) *Vallonia costata* (O. F. Müll.)). In samples Os-21 and Os-25 a high proportion of *Bythinella austriaca* (Frfld.) is notheworty (Table 1, Fig. 2: E).

Nodular travertines intercalated with coarse-grained calcareous tufa and travertines were present in profile Os-V (Fig. 3: P). Five samples (Os-26–Os-30) containing a poor mollusc fauna (Fig. 3: S, N) were collected. Woodland snails (*Acicula polita* (Hartm.), *Oxychilus depressus* (Sterki), *Arianta arbustorum* (L.)), catholic taxa (*Vitrina pellucida* (O. F. Müll.), *Euconulus fulvus* (O. F. Müll.)) and water molluscs (*Bythinella austriaca* (Frfld.)) were the main components of this fauna (Table 2, Fig. 3: E).

Six samples (Os-31 – Os-36) were taken from calcareous deposits cropping out in profile Os-VI (Fig. 3: P, S). The ecological composition of this fauna was similar to that of the assemblages described from profile Os-V (Table 2, Fig. 3: N, E).

Fine-grained calcareous tufa were present in profile Os-VII. The thickness of these deposits is ca 0.9 m (Fig. 3: P). Four samples (Os-37 – Os-40) containing rich and differentiated mollusc fauna were taken in this log (Fig. 3: S). The number of taxa varied from 31 to 34, and the number of specimens from 349 to 743 (Fig. 3: N). Woodland snails (*Acicula polita* (Hartm.), *Aegopinella pura* (Ald.), *Cochlodina laminata* (Mont.), *Isognomostoma isognomostoma* (Schröt.), *Vitrea crystallina* (O. F. Müll.), *Aegopinella minor* (Stab.) and many others) were the main component of this fauna. They were accompanied by species of the remaining ecological groups (Table 2, Fig. 3: E).

Profile Os-VIII comprised fine-grained calcareous tufa intercalated by nodular travertines and underlain by massive travertines (Fig. 3: P). Two samples (Os-41, Os-42) derived from this log contained a relatively poor fauna (Fig. 3: S, N). Woodland taxa (*Discus ruderatus* (Fér.), *Ena montana* (Drap.), *Trichia unidentata* (Drap.) and others) were numerous, particulary in the upper part of the sequence, while in its lower interval water molluscs (*Bithynella austriaca* (Frfld.)) prevailed (Table 2, Fig. 3: E).

The last profile from the main outcrop of calcareous tufa at the Ostrysz Hill (Os-IX) was composed of fine-grained calcareous tufa covering the solifluction loam and passing upward into nodular travertines (Fig. 4: P). Three samples contained a poor mollusc fauna (11–17 species per sample and 72–98 specimens) (Fig. 4: S, N). In the lower interval cold-tolerant species occurred commonly (*Semilimax kotulai* (West.), *Vertigo genesii* (Gredl.), *Vertigo geyeri* Lindh. and *Columella columella* (G. Mart.). Catholic species were the main component of the fauna. In the upper part of the log woodland species (*Discus*

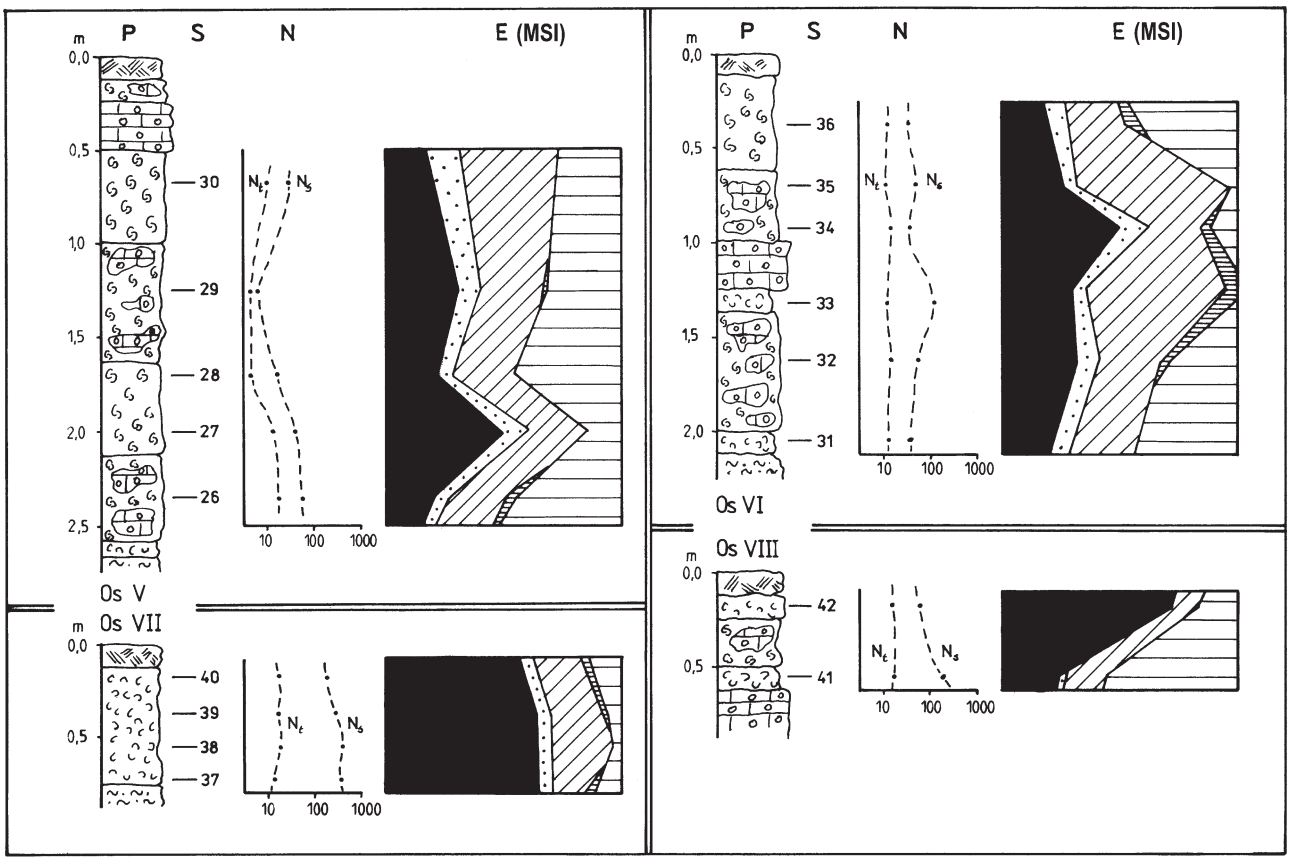

Fig. 3. Lithology and malacofauna of profiles Os-V – Os-VIII. For explanations see Fig. 2

Table 2. Malacofauna of calcareous tufa from the Ostrysz Hill (profiles Os-V – Os-IX). For explanations see Table 1.

E	TAXON	Os V					Os VI						Os VII				Os VIII		Os IX			Os X				Os XI			
		26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53
1	*Acicula polita*	1	1	1			1						3	3	3	2		3			1				1				1
1	*Vertigo pusilla*												1		1														
1	*Ena montana*	1					1	1		1				3	1	2	2	1					1				1		
1	*Discus ruderatus*							1		2			3	2	2	2	2	1		1	2		2	2		1	3	3	2
1	*Eucobresia nivalis*											1	2	1	2	2	1	1			1							2	
1	*Semilimax semilimax*								1	1	2	1																	
1	*Aegopinella pura*	1								1			4	4	3	3		3					1		2			2	1
1	*Oxychilus depressus*	2					1				1			2	1	1							1						
1	*Vitrea diaphana*		1						1				2	1	1								1						
1	*Vitrea transsylvanica*						1									1									1				
1	*Vitrea subrimata*				1											1	1								1	1			
1	*Cochlodina laminata*												1	1	2	2	1										2		
1	*Cochlodina orthostoma*														1														
1	*Clausilia cruciata*													1															
1	*Macrogastra plicatula*													1	1	1													
1	*Perforatella incarnata*													1				1					1						
1	*Trichia unidentata*	1					1	2	1				2	2	2	2	3	2			1	1	1	1				1	2
1	*Chilostoma faustinum*												2	2	3	1	2	1		1	1		2						
1	*Isognomostoma isognomostoma*						1	1					3	3	3	2	1	1			1				1				
2	*Semilimax kotulai*		1			1	1	1	2	1			2	1	2	1	1	1	2	1	2	1	1	1	1	2	2	1	
2	*Aegopinella minor*												1	1	2	2	1												
2	*Vitrea crystallina*	1						1		1		1	3	3	3	3	1	2					1	1	2				1
2	*Bradybaena fruticum*				1		1		2					1			1												
2	*Arianta arbustorum*	2	2	3		2		3	3	2	3	2	2	3	2	1		1	2	3	3	3	3	2	1	2	2	2	
3	*Vestia turgida*												1			1													
3	*Perforatella vicina*								1	1		1	2	2	3	1	1				2				1				
5	*Pupilla muscorum*	2				1		1	2			1								1							1		
5	*Vallonia costata*	1	1				1	2		1	2	1	3	3	3	3	1	2			1								
5	*Vallonia pulchella*						1			1							1											1	1
7	*Cochlicopa lubrica*	1	1	1				2	3	1	2	1	2	2	2	2	2	1	2	2	1	1	1		2	1	2	2	
7	*Columella columella*		1		1	1	1		2										1	1		1				3			
7	*Vertigo arctica*									1												1				2	1		
7	*Vertigo ronnebyensis*																					2				2	2		
7	*Vertigo alpestris*												1	1															
7	*Punctum pygmaeum*	1	1			1		1	2		2		1	2			1		1	1		1	1				1		1
7	*Vitrina pellucida*	2	1				1	1	1	1	1	1																	
7	*Nesovitrea hammonis*	1			1	1	1	1	3		2	1		2	2	2	2	1	2	2	2			2	2	1		1	
7	Limacidae	1				2	1	2	3	1	2	1	1	2	1	1	2		2	2	1	1	1		2	1	2	1	1
7	*Euconulus fulvus*	1	1			2		1	2	1	2		1	1	1		2	1	1	2	2	1	1	1		2		2	
7	*Clausilia dubia*	1					1					1	1	1	1	1		1	1								1		
7	*Trichia hispida*													2															
8	*Carychium tridentatum*						1	1		1		1	3	4	3	3	1	2			1				3				2
8	*Columella edentula*												1		1	1	1				1			1					
8	*Vertigo substriata*		1			1			1	1	2		1	1	2	1	2	1	1		1			2		1	2	2	
8	*Succinea oblonga*		1				2				3	1					2		2	2				2					
8	*Nesovitrea petronella*	1	1						2		1		3											1					
9	*Carychium minimum*												2	1	2	2									1				
9	*Vertigo genesii*					1			1										2	2		1	1			2	1		
9	*Vertigo geyeri*																		1	2		3	1			1	1		
9	*Succinea putris*							1	2	1															1				
9	*Zonitioides nitidus*											1																	
10	*Bythinella austriaca*	3	3	2	2	1	3	3		2	1	3	4	3	3	3	4	1		2		2	2	2	5			1	5
10	*Lymnaea truncatula*						1						1													1	1		
10	*Pisidium personatum*					1							1	1														1	

ruderatus (Fér.), *Eucobresia nivalis* (Dum. et Mort.) and a few others) prevailed (Table 2, Fig. 4: E).

The remaining two profiles (Os-X and Os-XI) derived from a supplementary outcrop of calcareous tufa situated about 300 m downstream (Fig. 1B, D).

Coarse-grained calcareous tufa underlain by travertines, calcareous silt and solifluction loam passing upward into fine-grained ones were exposed in profile Os-X (Fig. 4: P). In four samples (Os-46 – Os-49) the number of taxa varied from 13 to 18, whereas the number of specimens was 79–621 (Fig. 4: S, N). In the lowermost part of the profile catholic and higrophile species with numerous shells of cold-tolerant snails (*Vertigo arctica* (Say), *Vertigo ronnebyensis* (West.), *Vertigo genesii* (Gredl.), *Vertigo geyeri* Lindh., *Columella columella* (G. Mart.)) occurred. In the middle interval of the sequence woodland taxa (*Discus ruderatus* (Fér.), *Semilimax kotulai* (West.), *Arianta arbustorum* (L.)) were the main component of the fauna while water molluscs, represented by *Bythinella austriaca* (Frfld.) dominated in the upper part of the log (Table 2, Fig. 4: E).

Four samples (Os-50 – Os-53) were taken from calcareous deposits outcropping in profile Os-XI (Fig. 4: P, S). The ecological composition of this fauna as well as lithology of the log were similar to those of the assemblages described from profile Os-X (Table 2, Fig. 4: N, E).

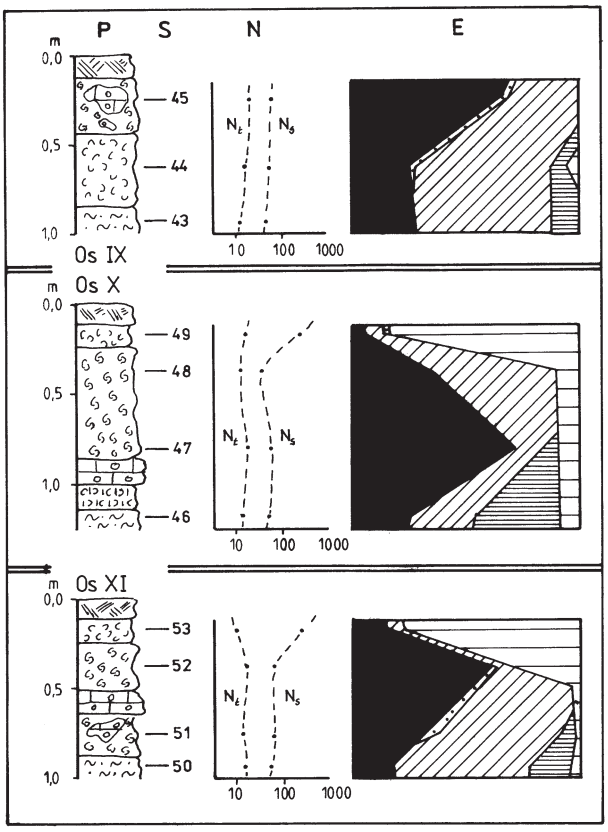

Fig. 4. Lithology and malacofauna of profiles Os-IX – Os-XI. For explanations see Fig. 2

The following types of mollusc assemblages, recognised in calcareous sediments as well as in solifluction loam at the Ostrysz Hill, could be distinguished. The succession of these communities corresponds with environmental and climatic changes in the Podhale Basin during the Late Vistulian and Holocene.

ASSEMBLAGE WITH *SEMILIMAX KOTULAI*

It is a relatively poor fauna composed of two groups of molluscs. One comprises cold-loving species, such as *Semilimax kotulai* (West.), *Vertigo genesii* (Gredl.), *Vertigo geyeri* Lindh., *Columella columella* (G. Mart.). Shadow-loving taxa typical for coniferous forests (*Discus ruderatus* (Fér.), *Arianta arbustorum* (L.)) and catholic snails of wide ecological tolerance (*Euconulus fulvus* (O. F. Müll.), *Nesovitrea hammonis* (Ström)) represent the second group. The described assemblage was found in the solifluction loam underlying calcareous deposits in the lowermost parts of logs Os-II and Os-XI (Figs 2, 4).

The community described above is associated with wooded areas and a cold climate. A similar assemblage was reported from slope deposits underlying calcareous tufa in Gliczarów. The first period of accumulation of travertines and calcareous tufa in this locality was dated by radiocarbon method at 10,850±1,800 and 10,940±1,830 years BP (PAZDUR 1987, W. P. ALEXANDROWICZ 1997). According to these data the assemblage with *Semilimax kotulai* can be assigned to the upper part of the Alleröd Phase (Fig. 5: MA).

ASSEMBLAGE WITH *VERTIGO GENESII*

The fauna was found in the lower parts of profiles Os-IV, Os-IX and Os-X (Figs 2, 4). *Vertigo genesii* (Gredl.), accompanied by other cold-tolerant taxa (*Vertigo geyeri* Lindh., *Columella columella* (G. Mart.)), and catholic molluscs are the main components of this assemblage while woodland snails occur sporadically. This fauna is typical for humid, woodless environment developed under a cold climate (S. W. ALEXANDROWICZ 1987a, LIMONDIN & ROUSSEAU 1991, LIMONDIN 1992).

The assemblage with *Vertigo genesii* occurs in the oldest calcareous tufa at Gliczarów, dated by radiocarbon method at 10,850±1,800 and 10,940±1,830 years BP (PAZDUR 1987, W. P. ALEXANDROWICZ 1997). The dating indicates a Young Dryas age of this assemblage (Fig. 5: MA). Similar assemblages are known from deposits of Young Dryas age from the Cracow Upland (S. W. ALEXANDROWICZ 1983, 1984a, 1987b, W. P. ALEXANDROWICZ & KOBOJEK 1997), Polish Carpathians (S. W. ALEXANDROWICZ & CHMIELOWIEC 1991, S. W. ALEXANDROWICZ & W. P. ALEXANDROWICZ 1995a, b, c, W. P. ALEXANDROWICZ 1997) and from northern Poland (W. P. ALEXANDROWICZ 1999).

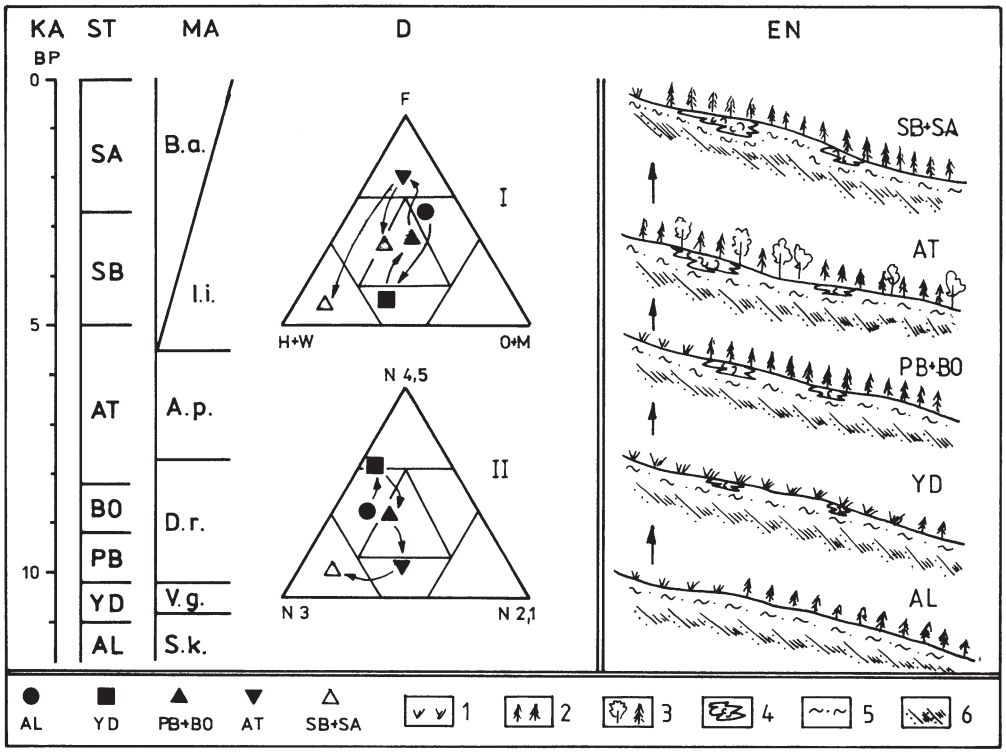

Fig. 5. Succession of mollusc assemblages and environmental changes. KA – age BP; ST – stratigraphy: AL – Alleröd Phase, YD – Young Dryas, PB – Preboreal Phase, BO – Boreal Phase, AT – Atlantic Phase, SB – Subboreal Phase, SA – Subatlantic Phase; MA – mollusc assemblages: S.k. – with *Semilimax kotulai*, V.g. – with *Vertigo genesii*, D.r. – with *Discus ruderatus*, A.p. – with *Aegopinella pura*, I.i. – with *Isognomostoma isognomostoma*, B.a. – with *Bythinella austriaca*; D – triangular diagrams: D-I (ecological changes of the fauna: ecological groups of molluscs, based on LOŽEK 1964 and S. W. ALEXANDROWICZ 1987a): F – shadow-loving species, O – open-country species, M – mesophile species, H – higrophile species, W – water species; D-II (paleogeographic changes of the fauna): N-1 – species living recently in South and Central Europe, N-2 – species reaching the latitude of 60–61°N, N-3 – species reaching the latitude of 63°N, N-4 – species reaching the north polar circle and living in high mountains, N-5 – species crossing the north polar circle and living in periglacial zones of high mountains (based on SPARKS 1964 and S. W. ALEXANDROWICZ 1987a); EN (environmental changes): 1 – bushes, 2 – coniferous forests, 3 – mixed forests, 4 – calcareous deposits, 5 – solifluction loam, 6 – bedrock

ASSEMBLAGE WITH *DISCUS RUDERATUS*

Woodland snails associated with coniferous forests (*Discus ruderatus* (Fér.), *Arianta arbustorum* (L.), *Eucobresia nivalis* (Dum. et Mort.), *Trichia unidentata* (Drap.) and others) accompanied by mesophile taxa (*Euconulus fulvus* (O. F. Müll.), *Cochlicopa lubrica* (O. F. Müll.), *Nesovitrea hammonis* (Ström), *Vertigo substriata* (Jeffr.)) are two main components of this fauna, although shadow-loving molluscs prevail. The occurrence of cold-tolerant species, typical of Late Glacial (*Semilimax kotulai* (West.), *Vertigo genesii* (Gredl.), *Columella columella* (G. Mart.)), is noteworthy. The community described occurs in logs Os-I, Os-II (middle part), Os-IV (middle part), Os-IX (upper part), Os-X (middle part), Os-XI (middle part) (Figs 2, 4).

The community with *Discus ruderatus* indicates a phase of forest expansion and amelioration of climatic conditions. This fauna corresponds with the "Ruderatus-fauna" described by DEHM (1967) and regarded as typical for the Preboreal and Boreal Phases of the Holocene (Fig. 5: MA). Similar assemblages were mentioned from numerous localities in the Carpathians (S. W. ALEXANDROWICZ & CHMIELOWIEC 1991, S. W. ALEXANDROWICZ & W. P. ALEXANDROWICZ 1995a, b, c, W. P. ALEXANDROWICZ 1997) and in the Cracow Upland (S. W. ALEXANDROWICZ 1983, 1984a, 1987b, W. P. ALEXANDROWICZ & KOBOJEK 1997).

ASSEMBLAGE WITH *AEGOPINELLA PURA*

It is a rich and differentiated fauna, characterised by the dominance of shadow-loving species, such as *Aegopinella pura* (Ald.), *Acicula polita* (Hartm.), *Cochlodina laminata* (Mont.), *Vitrea crystallina* (O. F. Müll.), *Isognomostoma isognomostoma* (Schröt.) and many others. Molluscs of the remaining ecological groups are subordinate components of this assemblage. Cold-tolerant taxa were represented only by single specimens. This assemblage was found in logs Os-II (upper part), Os-IV (middle part) and Os-VII (Figs 2, 3).

The described community inhabiting mixed forests is typical for a relatively warm climate. The fauna

corresponds with the climatic optimum of the Holocene (Atlantic Phase) (Fig. 5: MA). Similar assemblages are known from numerous localities in southern Poland (S. W. ALEXANDROWICZ 1983, 1984a, b, 1987b, S. W. ALEXANDROWICZ & W. P. ALEXANDROWICZ 1995a, b, c, W. P. ALEXANDROWICZ 1997, W. P. ALEXANDROWICZ & KOBOJEK 1997).

ASSEMBLAGE WITH *ISOGNOMOSTOMA ISOGNOMOSTOMA*

It is a rather diverse assemblage dominated by shadow-loving species (*Isognomostoma isognomostoma* (Schröt.), *Discus ruderatus* (Fér.), *Arianta arbustorum* (L.) and others), accompanied by catholic and higrophile snails (*Succinea oblonga* Drap., *Euconulus fulvus* (O. F. Müll.), *Cochlicopa lubrica* (O. F. Müll.), *Carychium tridentatum* (Risso), *Carychium minimum* O. F. Müll.). The fauna developed in forested areas during the Subboreal and Subatlantic Phases of Holocene. It was found in profiles Os-III and Os-IV (upper part) (Figs 2, 5: MA).

ASSEMBLAGE WITH *BYTHINELLA AUSTRIACA*

The community is associated with calcareous sediments accumulated by streams, particulary near springs. *Bythinella austriaca* (Frfld.) dominates, constituting even up to 90% of the assemblage. Woodland, catholic and higrophile snails occur in various proportions. The fauna was found in the uppermost part of profiles Os-IV, Os-X, Os-XI and in logs Os-V, Os-VI and Os-VIII (Figs 2, 3, 4).

The mentioned assemblage is typical of the Upper Holocene, mainly the Subatlantic Phase and recently accumulated travertines (Fig. 5: MA). It was described from several localities in the Carpathians (S. W. ALEXANDROWICZ 1984b, 1985, 1987a, W. P. ALEXANDROWICZ 1997).

CONCLUSIONS

Various mollusc communities are associated with various climatic conditions. The assemblages described above reflect the evolution of environment in the western part of the Podhale Basin during consecutive climatic phases of the Late Vistulian and Holocene.

The deposition of calcareous tufa at the Ostrysz Hill was initiated during the Young Dryas. In southern Poland travertines of this age are known only from a few localities (S. W. ALEXANDROWICZ 1985, S. W. ALEXANDROWICZ & W. P. ALEXANDROWICZ 1995a, b, c, W. P. ALEXANDROWICZ 1997, W. P. ALEXANDROWICZ & KOBOJEK 1997).

The Alleröd Phase was the first stage of afforestation. This is well reflected by both malacological and palynological sequences (KOPEROWA 1958, 1962, OBIDOWICZ 1990, W. P. ALEXANDROWICZ 1997). Shadow-loving snails, mainly *Semilimax kotulai* (West.), are important components of assemblages dominated by catholic species (Fig. 5: D-I). The fauna includes North European, cold-tolerant taxa accompanied by Central European or even South European elements (Fig. 5: D-II). The assemblage with *Semilimax kotulai* corresponds with this period. It was found in solifluction loam underlying calcareous deposits and preceding the first phase of accumulation of tufa and travertines at the Ostrysz Hill (Fig. 5: EN).

At the end of the Alleröd Phase the climate became colder. That was the reason for the deforestation during the Young Dryas, well reflected in palynological profiles (KOPEROWA 1958, 1962, OBIDOWICZ 1990). Mollusc assemblages were dominated by cold-tolerant species preferring humid habitats, while the occurrence of woodland snails was reduced (W. P. ALEXANDROWICZ 1997) (Fig. 5: D-I, EN). The assemblage with *Vertigo genesii* is typical of this period. Palaeogeographical structure of the fauna is characterised by the dominance of Central European taxa, with a considerable proportion of North European ones, while South European species are practically absent (Fig. 5: D-II). The first stage of accumulation of calcareous tufa in Gliczarów, Groń and at the Ostrysz Hill fell on the mentioned phase (S. W. ALEXANDROWICZ 1985, S. W. ALEXANDROWICZ & W. P. ALEXANDROWICZ 1995a, b, c, W. P. ALEXANDROWICZ 1997) (Fig. 5: EN).

In the Preboreal and Boreal Phases of the Holocene, a rapid warming of the climate was followed by the expansion of coniferous forests (KOPEROWA 1958, 1962, OBIDOWICZ 1990) (Fig. 5: EN). Calcareous deposits at the Ostrysz Hill contain an assemblage with *Discus ruderatus* dominated by woodland and catholic species typical of the Lower Holocene (Fig. 5: D-I). A limited number of cold-tolerant species regarded as glacial relicts is a characteristic feature of this fauna. Central European species accompanied by North European ones are its prevailing components (Fig. 5: D-II).

The Atlantic Phase was a period of the maximum expansion of mixed forests (KOPEROWA 1958, 1962, OBIDOWICZ 1990) (Fig. 5: EN). Increased chemical denudation in the Podhale Region promoted precipitation of calcium carbonate and accumulation of calcareous tufa. These processes are well visible in Gliczarów and Niedzica (S. W. ALEXANDROWICZ 1985, S. W. ALEXANDROWICZ & W. P. ALEXANDROWICZ 1995a, b, c,

W. P. ALEXANDROWICZ 1997). Deposition of carbonate sediments at the Ostrysz Hill became slower. This was probably associated with local conditions. The mollusc assemblages are dominated by woodland species, constituting up to 70% of the community (Fig. 5: D-I). The cold-tolerant taxa, except *Semilimax kotulai* (West.), disappeared. Central European snails are the main components of the fauna, but South European ones comprise up to 25% of the assemblage (Fig. 5: D-II). The assemblage with *Aegopinella pura* corresponds with the mentioned phase.

At the beginning of the Subboreal Phase, a cooling of the climate took place. Mollusc assemblages became poorer and less diverse. During the last two phases of the Holocene shadow-loving snails living in mixed forests were replaced by mesophile taxa and woodland species typical for coniferous forests. Central European molluscs dominated, constituting up to 85% of the fauna (Fig. 5). The community with *Isognomostoma isognomostoma* characterises this period. The assemblage dominated by *Bythinella austriaca* occurs in several samples from the youngest calcareous tufa. It can be regarded as typical for the Upper Holocene and was described from numerous localities in the Carpathians (S. W. ALEXANDROWICZ 1984b, 1985, 1987a, S. W. ALEXANDROWICZ & W. P. ALEXANDROWICZ 1995a, b, c, W. P. ALEXANDROWICZ 1997).

The calcareous tufa from the Ostrysz Hill were accumulated in the upper part of a narrow stream valley. Human impact was quite limited in this zone and environmental changes were controlled by natural processes, mainly climate. The sequence of mollusc assemblages described above fully corresponds with environmental changes in the Podhale Basin reconstructed on the basis of palynological data (KOPEROWA 1962, OBIDOWICZ 1990), the two methods of investigation being thus supplementary to each other.

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