Carpathian Journal of Earth and Environmental Sciences, February 2020, Vol. 15, No. 1, p. 247 - 259; Doi:10.26471/cjees/2020/015/126

DEVELOPMENT OF SETTLEMENTS IN PODHALE BASIN AND PIENINY MTS. (WESTERN CARPATHIANS, SOUTHERN POLAND) IN LIGHT OF MALACOLOGICAL RESEARCH

Witold Paweł ALEXANDROWICZ
AGH University of Science and Technology, Faculty of Geology, Geophysics and Environment Protection, Chair of General Geology and Geotourism, Al. Mickiewicza 30, 30-059 Cracow, email: wpalex@geol.agh.edu.pl

Abstract: The analysis covered mollusc communities found in Late Holocene river sediments and calcareous tufa in Podhale Basin and Pieniny Mts. The presence of rich malacofauna was revealed in 44 sites studied. Based on the analysis of the composition and structure of fauna, it was possible to separate two types of communities. The first type is dominated by shade-loving species and the second – by open-country taxa. The progression of these communities in the profiles allowed defining three types of succession. The results of malacological research, radiocarbon dating and historical data allowed us to distinguish two stages of intensive colonization (13th – 15th centuries and from the mid-19th century to modern times) separated by a depopulation period from the 16th to the mid-19th centuries. During periods of intense colonization, there was extensive deforestation and a significant increase in anthropopressure in Podhale and Pieniny. Human activity was particularly intense within flat valleys in the northern part of Podhale and in the wide valleys of larger rivers in the Pieniny. Anthropopressure was much less intense within the hill ranges in the southern part of Podhale and Pieniny. This was undoubtedly associated with more difficult terrain conditions that did not favour farming.

Key words: human impact, environmental changes, molluscs, last millenium, Carpathians, southern Poland

1. INTRODUCTION

Human activities affecting the environment are referred to as anthropopressure. One of its most visible manifestations is deforestation, usually associated with the need to acquire suitable areas for farming (breeding cattle or cultivation). Extensive deforestation is usually caused by settlement development and/or demographic growth. The decline of forests and their replacement with much less diverse open habitats is reflected in the species composition and the diversity of the fauna and flora communities inhabiting these areas. It also significantly affects the course and intensity of geological phenomena, mainly mass movements and fluvial processes. All these aspects of changes are clearly visible in sediment sequences, particularly ones deposited in river and stream valleys. These are reflected both in lithology of sediments as well as fauna and flora complexes occurring within them.

Snails are sensitive indicators of the environment and react to changes relatively quickly. Therefore, they are well suited to the needs of paleoenvironmental reconstructions. Violent and rapid changes caused by human activity, such as extensive deforestation occurring over a short time, are very clear in malacological sequences. These are primarily manifested in the replacement of rich and species-diverse faunas with the predominance of shade-loving species with poor fauna, dominated by a share of taxa typical of open biotops. The former represents natural habitats, only slightly transformed due to human activity. The latter include malacocoenoses inhabiting areas subject to anthropopressure and largely transformed. Such analyses were conducted in many European countries and concerned various stages of settlement from the Neolith (e.g. Lososová, 2011; Alexandrowicz, 2013a; Rosin et al., 2017).

The main purpose of the paper is to reconstruct the changes in the environment of Podhale Basin and Pieniny Mts. during the last millennium, with particular emphasis on periods of intense colonization and the related anthropopressure. Meanwhile, the presented study is to indicate the possibility of using malacological analysis in reconstructions of the impact, time and intensity of human activity (anthropopressure) on the natural environment.

2. STUDY AREA

The study covered the Podhale valley and the Pieniny range. The Podhale valley is a mountain basin bounded by the Tatras to the south and the Flysch Carpathians to the north. The bottom of the valley is significantly lower than the surrounding mountain ranges. In the southern part of Podhale stretches the Spisko-Gubałowskie Foothills with relatively diverse terrain relief (Fig. 1). It is a range of hills exceeding 1000 m a.s.l. characterized by steep slopes, cut by numerous V-shaped stream valleys. This range is primarily composed of Oligocene sandstones and slate (the so-called Podhale flysch), often with a high calcium carbonate content. These rocks were folded to a limited degree in the early Miocene and are now forming a flat synclinorium, cut locally by fault zones (Mastella, 1975; Olszewska & Wieczorek, 1998). The northern part of Podhale (Orawa-Nowy Targ Basin) is characterized by less diverse relief (Fig. 1). It is a flat, sometimes wet area cut with wide, flat-bottomed valleys. There are numerous peat bogs in its western part. Its base includes Palaeogene flysch sediments belonging to the Magura unit of the Flysch Carpathians. These are covered by a thick succession of Neogene sands and gravels, as well as Quaternary deposits (Watycha, 1976; Alexandrowicz, 1997; Zuchiewicz et al., 2002). A narrow belt of Mesozoic limestone outcrops runs between the Spisko-Gubałowskie Foothills and the Orawa-Nowy Targ Basin. They form isolated, often rocky hills. This area is part of the Pieniny Klippen Belt (Klimaszewski, 1952, 1972).

The Pieniny range is characterized by very varied terrain relief. There are steep hills here, often with rocky slopes, and steep, deeply indented valleys (Fig. 1). The main range is surrounded by flatter areas with much gentler relief. The Pieniny are made of limestone representing the Jurassic and early Cretaceous periods, soft marls belonging to the late Cretaceous and Paleogene flysch (Birkenmajer, 1977). Deposits building the Pieniny were strongly folded several times in the late Cretaceous and early Neogene (Birkenmajer, 1977).

During almost the entire Quaternary, the area of Podhale and Pieniny was overgrown with dense forest complexes. This is reflected in numerous malacological (Alexandrowicz 1997, 2013b; Alexandrowicz & Rybska 2013; Alexandrowicz et al, 2014, 2016, 2018; Alexandrowicz & Skoczylas, 2017) and palynological (Obidowicz, 1990; Rybničkova & Rybniček, 2002) profiles described in this area. Nowadays, the region is characterized by a high population density, and forests cover only about 20% of its area (Zielony & Kliczkowska, 2012). The largest area in the Pieniny and higher parts of the Spisko-Gubałowskie Foothills are covered by forests, while the Orawa-Nowy Targ Basin is almost completely deforested.

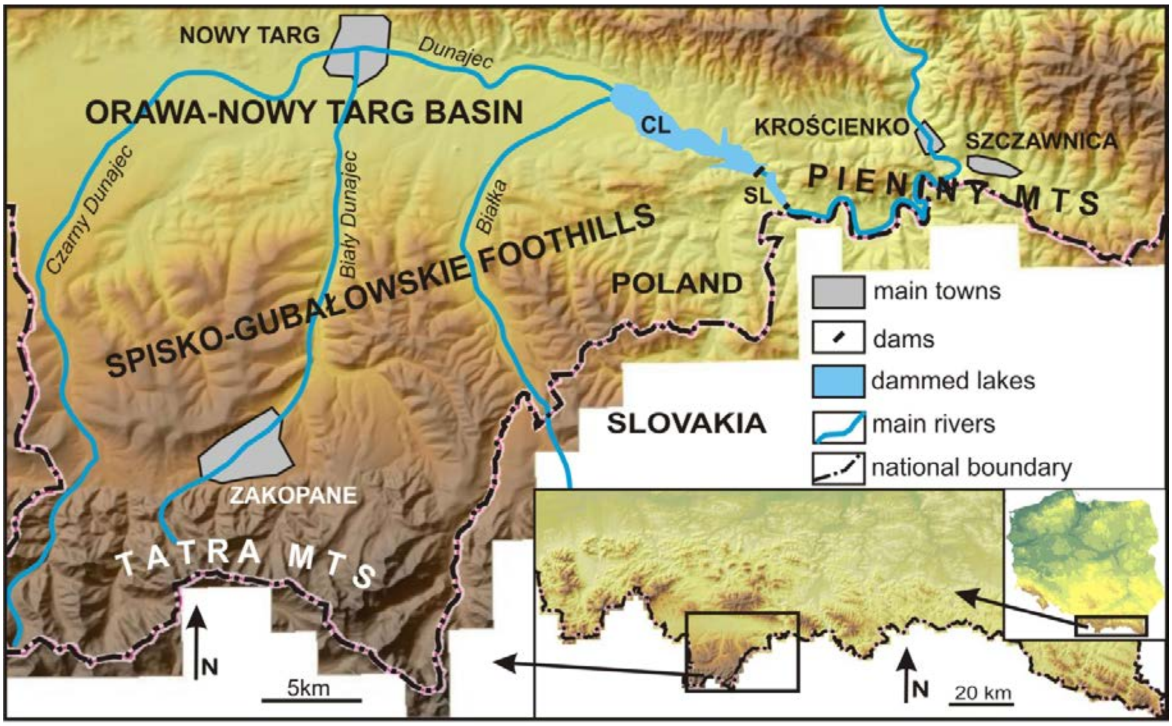

Figure 1. Localization and relief of the Podhale Basin and Pieniny Mts
CL. Czorsztyn dammed lake, SL. Sromowce dammed lake

3. MATERIAL AND METHODS

Two genetic sediment types were analyzed. The first of these were calcareous tufa. Due to the abundance of calcium carbonate in the bedrock, numerous occurrences of these deposits are known both in Podhale and Pieniny. The vast majority of these sites represent the Late Holocene (Alexandrowicz, 2004, 2010; Alexandrowicz et al., 2014, 2016). Such deposits most often appear in spring areas and are formed as hard, highly porous travertines and loose dusty sinters. The last mentioned usually provide rich malacological material and provided a basis for detailed research. The second type of sediments analysed were fluvial deposits. These are represented by gravels (channel facies) as well as sands and muds (overbank facies). The sediments belonging to the second of the facies listed are often rich in mollusc communities. Both in the case of calcareous tufa and river sediments, the analysis only included profiles representing the period of the last thousand years, i.e. the colonization phase in Podhale and Pieniny. Long-term field studies included locating the profiles, describing lithology and sampling for analysis. In total, the material included 44 profiles (22 calcareous sinters and 22 river sediments) (Fig. 2, Table 1). Laboratory analyses included slurrying and drying, followed by extracting mollusc shells (whole specimens and quantifiable shell fragments). The shell material was marked with the use of keys (Kerney et al., 1983; Wiktor, 2004; Welter-Schultes, 2012; Horsák et al., 2013) and comparative collection. The shell material was subject to standard malacological analysis (Ložek 1964; Alexandrowicz & Alexandrowicz, 2011). Particular species were included into ecological groups. The use of malacological specimen spectra was the basis for reconstructing the environmental changes and human impact. In each of the examples presented, the ratio of the frequency of shade-loving species to open-country taxa was calculated (shadow index SI). It takes values from 0 (completely open habitats) to 1 (completely shaded habitats) and is helpful in assessing environmental changes, particularly in the case of rapid and intensive anthropogenic deforestation. The stratigraphic position of the sediments in some profiles was determined by radiocarbon dating (27 dates in total) (Table 2). The material used in dating were primarily plant remains. Radiocarbon analyses were performed in laboratories in Kijev, Gliwice and Skała. The results of age determination were calibrated using the OxCal 3.9 software (Bronk Ramsey, 2003).

4. RESULTS

4.1. Malacofauna and mollusc communities

The analysis was based exclusively on land snails. Each species was included in one of four basic ecological groups: F - shade-loving species, O - open-country species, M - mesophilous species, H - hydrophilous species.

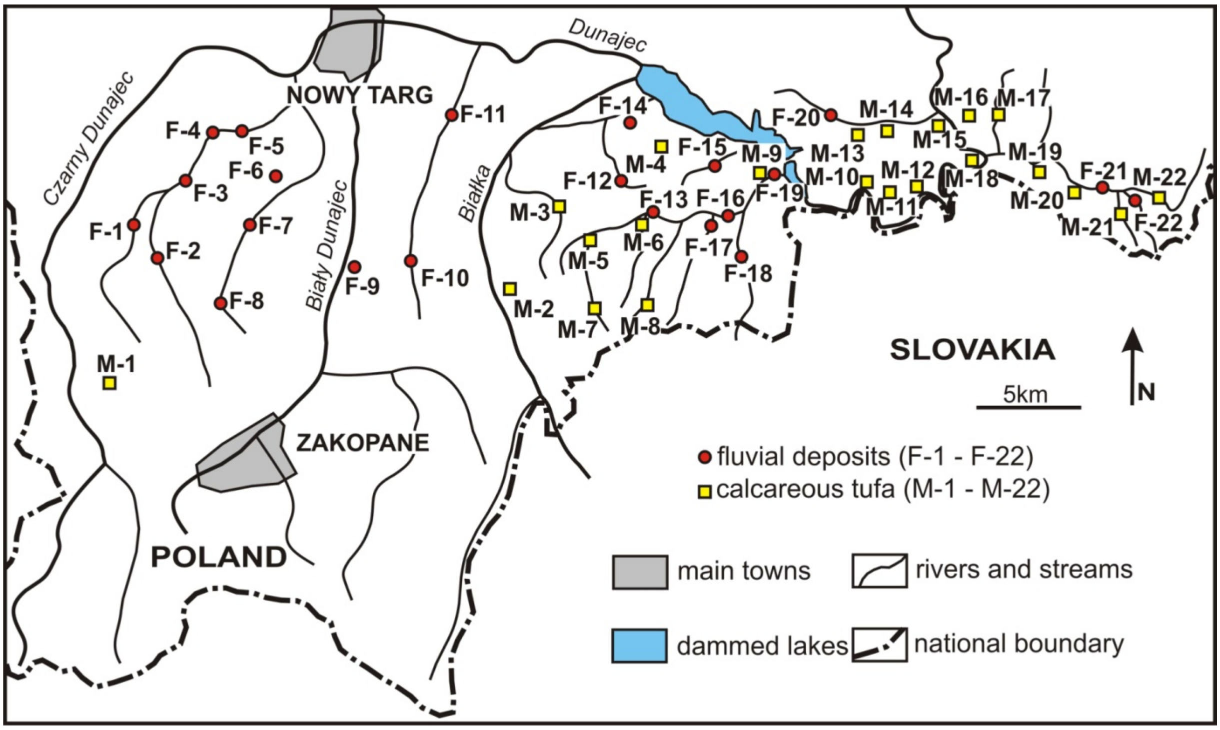

Figure 2. Localization of analyzed sites

Table 1. List of analyzed sites: M-1 - M-22. sites of calcareous tufa, F-1 - F-22. sites of river deposits

Calcareous tufa			Fluvial deposits		
Locality		References	Locality		References
M-1	Dzianisz	Alexandrowicz, 1997, 2004, 2010; Alexandrowicz et al., 2014	**F-1**	Ciche	Alexandrowicz, 2013a
M-2	Czarna Góra	Alexandrowicz, 2010; Alexandrowicz et al., 2014	**F-2**	Ratułów	-
M-3	Trybsz	Alexandrowicz, 2010; Alexandrowicz et al., 2014	**F-3**	Stare Bystre	Alexandrowicz, 2013a
M-4	Falsztyn	Alexandrowicz, 2010, Alexandrowicz et al., 2014	**F-4**	Rogoźnik I	Alexandrowicz, 2013a
M-5	Łapsze Wyżne	Alexandrowicz, 1997, 2010; Alexandrowicz et al., 2014	**F-5**	Rogoźnik II	Alexandrowicz, 2013a
M-6	Łapsze Niżne	Alexandrowicz, 1997; Alexandrowicz et al., 2014, 2018	**F-6**	Maruszyna	Alexandrowicz, 2013a
M-7	Łapszanka	Alexandrowicz, 2010; Alexandrowicz et al., 2014	**F-7**	Skrzypne	Alexandrowicz, 1997, 2013a
M-8	Stawiska	Alexandrowicz,, 1997, 2010; Alexandrowicz et al., 2014	**F-8**	Czerwienne	Alexandrowicz, 2013a
M-9	Niedzica	Alexandrowicz,, 1997; Alexandrowicz & Rybska, 2013; Alexandrowicz et al., 2014	**F-9**	Gliczarów	Alexandrowicz, 2013a
M-10	Macelowy Potok	Alexandrowicz, 1990, 2010; Alexandrowicz et al., 2016	**F-10**	Leśnica	Alexandrowicz, 2013a
M-11	Wawóz Sobczański	Alexandrowicz, 2004, 2010, 2014; Alexandrowicz et al., 2016	**F-11**	Gronków	Alexandrowicz, 2013a
M-12	Wąwóz Gorczyński	Alexandrowicz, 2004, 2010, 2014; Alexandrowicz et al., 2016	**F-12**	Dursztyn	-
M-13	Płaśnie	Alexandrowicz,, 1997, 2004, 2010, 2013c; Alexandrowicz et al., 2016	**F-13**	Łapsze	Alexandrowicz, 2013b
M-14	Tylka	Alexandrowicz, 1997, 2004, 2010, 2013c; Alexandrowicz et al., 2016	**F-14**	Frydman	Alexandrowicz, 2013b
M-15	Zawiasy	Alexandrowicz, 2004, 2010, 2014; Alexandrowicz et al., 2016	**F-15**	Falsztyński Potok	Alexandrowicz, 1997, 2019b
M-16	Potok Zakijowski	Alexandrowicz, 2004, 2010	**F-16**	Łapsze Niżne	Alexandrowicz, 1997
M-17	Potok Ścigocki	Alexandrowicz, 1993, 1997; Alexandrowicz et al., 2016	**F-17**	Zawoda	-
M-18	Długi Gronik	Alexandrowicz, 2004, 2010; Alexandrowicz et al., 2016	**F-18**	Kacwin	-
M-19	Potok Kozłecki	Alexandrowicz 2004, 2010, Alexandrowicz et al., 2016	**F-19**	Niedzica Zamek	Alexandrowicz, 2013a
M-20	Jaworki	Alexandrowicz, 2004, 2010; Alexandrowicz et al., 2016	**F-20**	Grywałd	-
M-21	Homole	Alexandrowicz, 1996, 2004; 2010, Alexandrowicz et al., 2016	**F-21**	Grajcarek	-
M-22	Biała Woda	Alexandrowicz, 2004, 2010; Alexandrowicz et al., 2016	**F-22**	Zaskale	Alexandrowicz, 2004; Alexandrowicz & Skoczylas, 2017

The percentage share of individual ecological groups in the profiles or their sections clearly changed. These fluctuations were the basis for defining two basic types of fauna. The types characterized by a species composition and ecological structure closely correspond to the environmental conditions in which sedimentation of deposits containing them took place. The first of the distinguished types shows a large species diversity and the dominance of shady habitat forms (F-FAUNA). There are taxa typical of forests, mainly coniferous or mixed ones (e.g. *Aegopinella pura*, *Vertigo pusilla*, *Fruticicola fruticum*) and mesophilous snails (*Euconulus fulvus*, *Perpolita hammonis* and others). Shade-loving forms preferring environments with high humidity are important (*Perforatella bidentata*, *Monachoides vicinus*). In total, shade-loving species can make up over 70% of the community. On the other hand, the share of taxa characteristic of open and drier habitats is very small (up to 10% of the community).

The presented community is typical for shady habitats with quite significant humidity. Such environments develop particularly often at the bottom of river and stream valleys. Sediments accumulating at the rock walls include petrophilous taxa, though their share rarely exceeds 20%. The second of the distinguished types of fauna (O_{FAUNA}) has different characteristics. This community is much poorer in terms of species composition. Its ecological structure is also different. The dominant group are open-country snails, especially meadow taxa (*Vallonia pulchella*, *Vallonia costata*). Noteworthy is the presence of snails considered characteristic of arable fields. The share of the ecological group in question usually reaches 80% of the community. Mesophilous and hygrophilous forms complement the fauna, while shade-loving species are virtually absent. The community is characterised by open, dry, grassy habitats or semi-arable areas.

4.2. Molluscs community successions

The differentiation in the composition and structure of mollusc communities observed in vertical profiles is closely linked to changes occurring in the environment during sediment deposition. The analysed materials allow defining three types of malacological successions (Fig. 3).

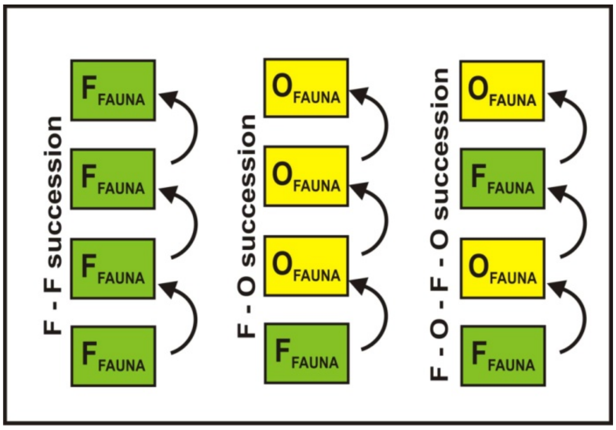

Figure 3 Types of mulluscan successions, F_{FAUNA}, O_{FAUNA}. molluscan assemblages (described in text)

F - O succession. It was revealed at three calcareous tufa sites (M-4, M-13, M-14) and in thirteen fluvial deposits (F-3 - F-6, F-11 and F-14 - F-21) (Fig. 2, Table 1). This succession shows a clear, usually a rapid change in the characteristics of mollusc communities. A good example illustrating this type of succession is the profile of river sediments exposed in the Grajcarek stream near Szczawnica (F-21) (Figs 2, 4, Table 1). It is a low terrace profile formed of alternating layers of fine-grained gravel and dark sandy silts. These silts contain numerous mollusc shells and plant debris that allow dating using the c-14 method. In the lower section of the sequence, a rich and diverse malacofauna was revealed, with a predominant share of shade-loving species, mainly forest ones, accompanied by fewer mesophilous taxa. Open-country snails are very rare or absent. The SI index value is high and ranges between 1.0 and 0.9. Two radiocarbon dates are associated with this stage: 4550±70 BP (3513-3424, 3384-3023 cal BC) and 940±30 BP (1125-1160 cal AD) (Fig. 4, Table 2). In the upper section of the profile there is a very clear change in the composition and structure of the mollusc community. Shadow-loving snails disappear almost completely and are replaced by taxa preferring open grasslands. *Ceciloides acicula* – a typical taxon for agricultural areas – also appears (Alexandrowicz et al., 1997, Alexandrowicz, 2013a, 2019a; Alexandrowicz et al., 2019). The SI index value drops rapidly to the value of 0.2-0.1 (Fig. 4). Dating plant remains found in the upper section of the profile gave the result: 370±30 BP (1447-1528; 1390-1450 cal AD) (Fig. 4, Table 2). Similar progressions were found in a number of other profiles in the Podhale Basin and Pieniny (Alexandrowicz, 1997, 2004, 2013a). This type of succession is typical of fluvial sediments deposited in relatively wide, flat-bottomed valleys.

F - F succession. It was revealed at nineteen calcareous tufa sites (M-1 - M-3, M-5 - M-12 and M-15 - M-22) and seven river sediment sites (F-1, F- 2, F-7 - F-9, F-12 and F-13) (Fig. 2, Table 1). The dominance of shade-loving taxa persists throughout the entire profile. The share of snails typical for open environments is minute and usually does not exceed 10%. This type of succession is typical mainly of modern-day precipitated calcareous tufa. An example is the Zawiasy site (M-15) (Figs 2, 5, Table 1). The share of shade-loving taxa is very high and reaches 80% of the community. In the lower section, hygrophilous taxa are slightly more numerous, and in the upper section – mesophilous taxa (Fig. 5). Open-country snails are few and make up to 5% of the community. The SI idex value remains at a similar level (0.9) throughout the entire sequence. In the middle interval of the profile in question, age determination was carried out using the radiocarbon method (320±40 BP (1496-1646 cal AD) (Fig. 5, Table 2). Similar progressions are observed in nearly all calcareous tufa sites in the studied area. In fluvial deposits, the F-F succession appears only in deeply indented, narrow, V-shaped valleys with steep slopes. An example of such a site is the mud and gravel profile exposed in the low terrace of the Skrzypne stream (F-7) (Fig. 2, Tab. 1). As in the previously described site, the dominant role of shade-loving species is seen throughout the entire profile. This is completed by mesophilous snails,

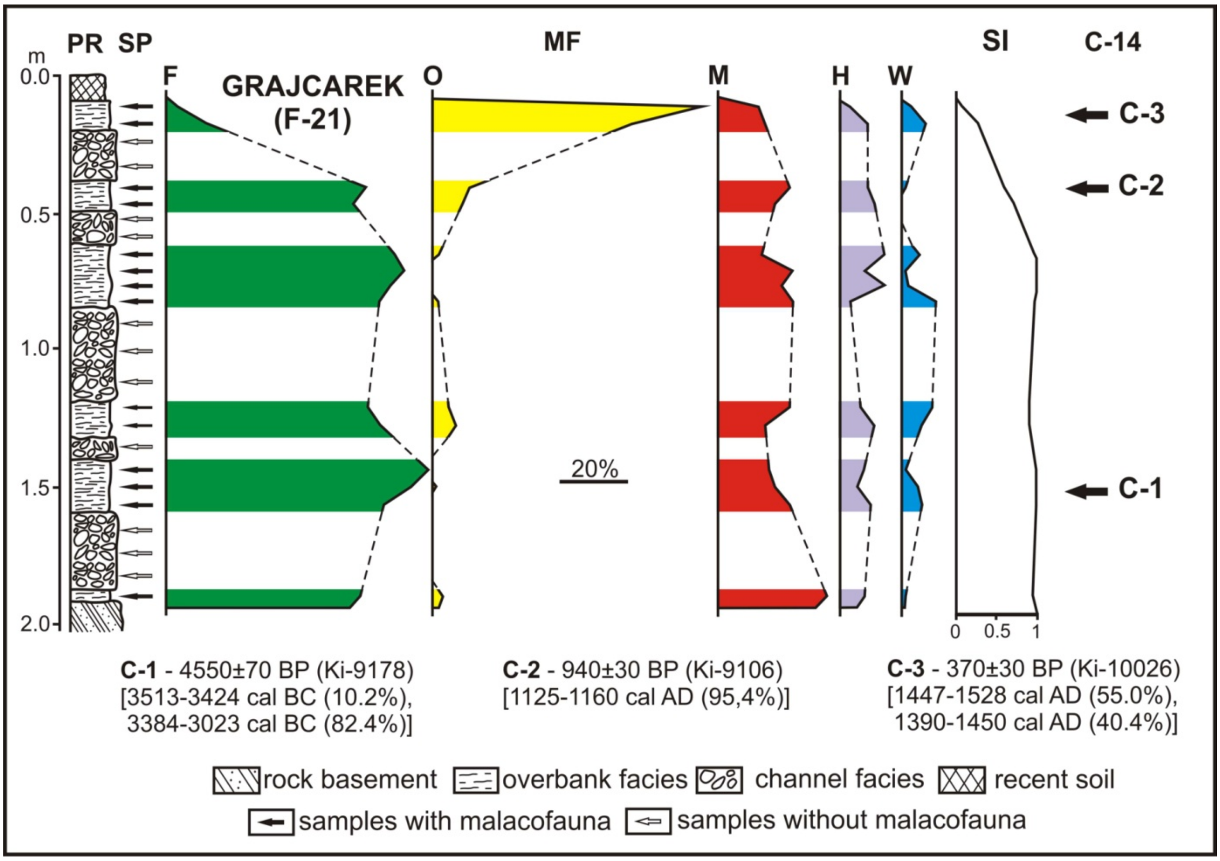

Figure 4. Profile and malacofauna of river deposits from Grajcarek site
PR. lithological profile, SP. samples, MF. malacofauna: F. shade-loving species, O. open-country species, M. mesophilous species, H. higrophilous species, W. water species, SI. shade index, C-14. radiocarbon dating

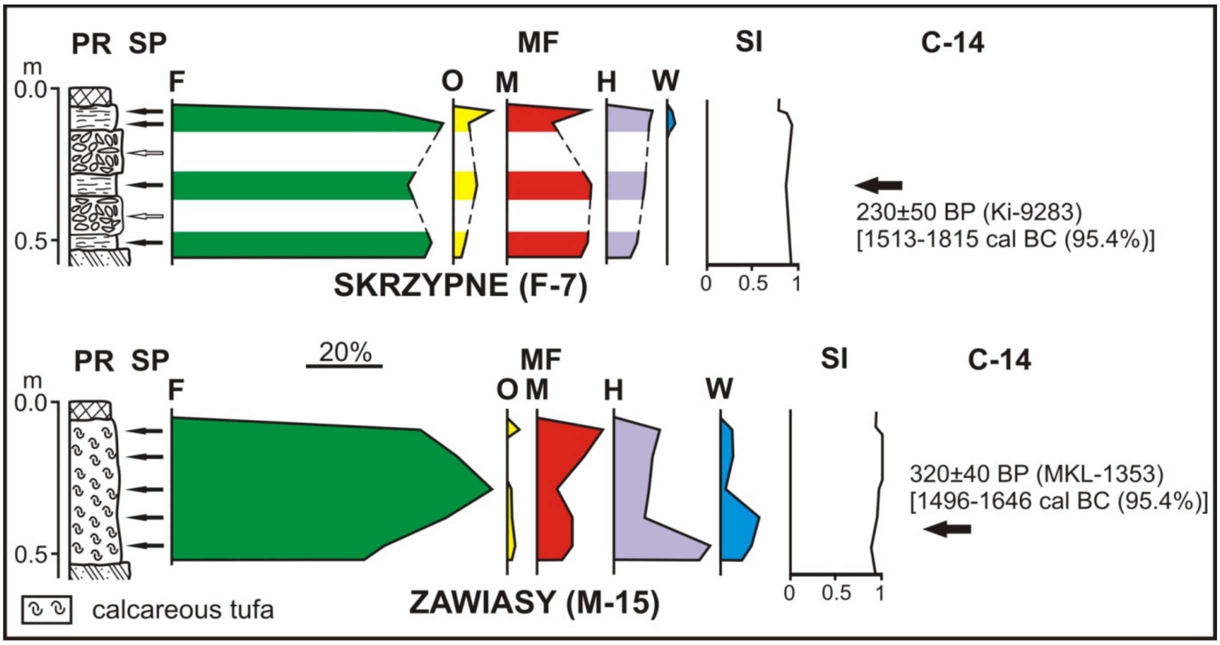

Figure 5. Profile and malacofauna of river deposits from Skrzypne site and calcareous tufa from Zawiasy.
For exaplanations see Figure 4

whose share reaches up to 25% of the community. The frequency of open-country taxa is low and does not exceed 10% (Fig. 5). The SI index has high values (1.0-0.9), typical of shaded environments. A decrease in the SI value in the upper section of the sequence (to the level of 0.8) may indicate that the density of forests in the immediate vicinity of the profile is being limited. The age of the analysed sediments was determined using the radiocarbon method at 230±50 BP (1513-1815 cal AD) (Fig. 5, Table 2). Similar progressions were observed at several fluvial sediment sites in the studied area (Alexandrowicz, 1997, 2004, 2013a).

F-O-F-O succession. It is a type of succession revealed only in two fluvial sediment profiles (F-10 and F-22) (Fig. 2, Table 1). It is characterised by the presence of two intervals with a large share of shade-loving taxa. the best example illustrating the discussed progression is the river sediment site in Leśnica (F-10) (Figs 2, 6, Tab. 1). The profile exposed here is made of gravel and dark mud. Malacofauna and plant remains were found within the mud. There are two intervals with a dominant share of shade-loving species. High values of the SI index (0.9-0.8 in the lower part and 0.7 in the upper part) indicate the presence of shady habitats: forests or at least compact thickets of shrubs in the vicinity of the site. The younger stage of forestation is associated with the radiocarbon date: 230±30 BP (1530-1539, 1635-1684, 1736-1805, 1953-... cal AD) (Fig. 6, Table 2). The profile in question included two visible stages characterized by the predominance of open habitat species. The older one separates the forest stages and corresponds to C-14 dating: 360±40 BP (1450-1636 cal AD) (Fig. 6, Table 2). The younger one represents the profile's ceiling interval. The SI values are low in both these stages: 0.3-0.4 in the older stage and 0.9 in the younger one (Fig. 6). Both sites representing this type of succession are located in stream valleys with relatively steep slopes, but flat bottoms.

5. DISCUSSION

Environmental changes in a given area are usually a product of a number of factors. On the one hand, these factors are associated with natural large-scale processes: continental or regional, modified to some extent by local conditions. The second group of factors includes human activity. It always involves settlement and development of the human population in a given area.

5.1. Development of settlements in Pieniny Mts. and Podhale Basin

The area of the Carpathians, and especially the northern part, was settled relatively late. Undoubtedly, this was related to climate and terrain conditions unfavourable for human settlements. The oldest traces of the human groups settled in Podhale are associated with the Late Palaeolithic (Obłazowa Cave site (Valde-Nowak et al., 2003). These were probably small groups of nomad hunters. Their activities did not affect the course of natural processes significantly. For almost the entire Holocene, Podhale and Pieniny were not settled intensively (Kołodziejski et al., 1982; Rydlewski & Valde-Nowak, 1982; Czepiel, 1999; Krupa, 2016). The development of settlements only began leaving its mark in the early Middle Ages. Undoubtedly, it was favoured by climate warming which started in the second half of the 13th century (Medieval Climate Optimum) (Grove & Switsur, 1994; Huges & Diaz, 1994; Bradley, 2000; Briffa, 2000; Jones & Mann, 2004). Settlement was intense in the 13th–15th centuries (Czepiel, 1999; Krupa, 2016). Numerous villages and cities founded in the northern part of the analysed area are associated with this period (Fig. 7). It is a flat area with little variety in the way of relief, cut by flat, wide river valleys. This topography was conducive to the development of farming. The need to secure new areas for cultivation and new pastures was the main reason behind widespread deforestation,

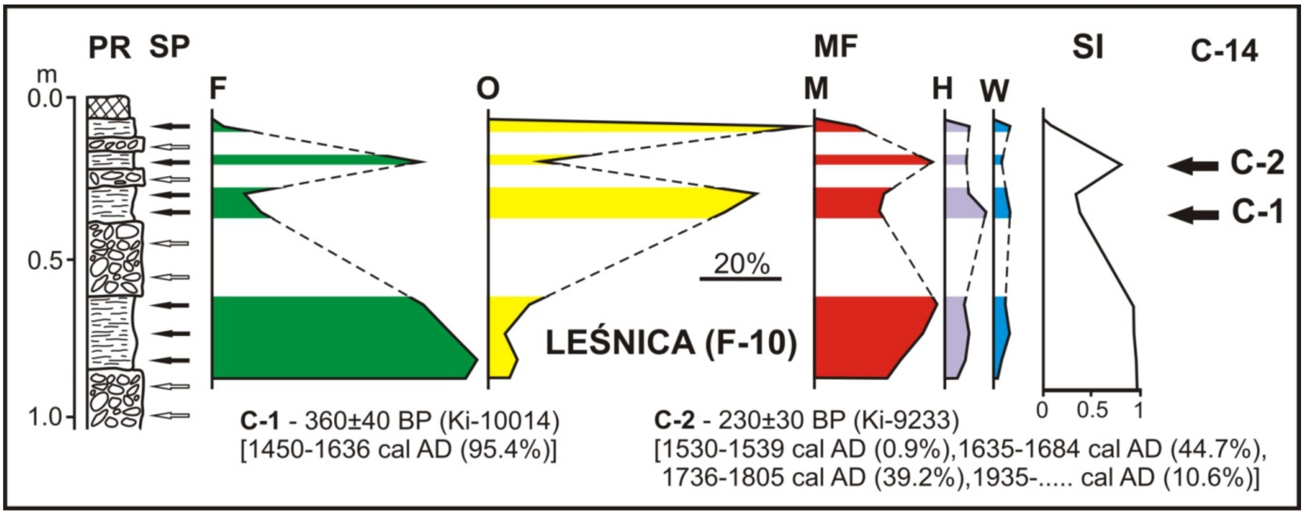

Figure 6. Profile and malacofauna of river deposits from Leśnica site For exaplanations see Figure 4

Table 2. List of radiocarbons datings
Lo. location (see Figure 2 and Table 1), Su. type of molluscan succession, 14-C. radiocarbon datings

Lo	Su	14-C	Lo	Su	14-C
M-1	**F-F**	-	F-1	**F-F**	-
M-2	**F-F**	-	F-2	**F-F**	-
M-3	**F-F**	-	F-3	**F-O**	-
M-4	**F-O**	**250±50** BP (1483-1690, 1729-1810, 1926-... cal AD)	F-4	**F-O**	-
M-5	**F-F**	**180±50** BP (1647-1710, 1717-1891, 1906-... cal AD)	F-5	**F-O**	-
M-6	**F-F**	**1080±70 BP** (770-1050 cal AD)	F-6	**F-O**	-
M-7	**F-F**	-	F-7	**F-F**	**230±50** BP (1513-1815 cal AD)
M-8	**F-F**	**390±40** BP (1436-1529, 1544-1634 cal AD)	F-8	**F-F**	-
M-9	**F-F**	**620±60** BP (1275-1415 cal BP)	F-9	**F-F**	-
M-10	**F-F**	**900±50** BP (1032-1235 cal AD) **1460±30** BP (444-661 cal AD)	F-10	**F-O-F-O**	**230±30** BP (1530-1539, 1635-1684, 1736-1805, 1953-... cal AD) **360±40** BP (1450-1636 cal AD)
M-11	**F-F**	**60±30** BP (1697-1916 cal AD) **620±80** BP (1253-1431 cal AD)	F-11	**F-O**	-
M-12	**F-F**	**140±70** BP (1650-1973 cal AD)	F-12	**F-F**	-
M-13	**F-O**	**680±80** BP (1206-1423 cal AD)	F-13	**F-F**	-
M-14	**F-O**	**535±30** BP (1330-1423 cal AD)	F-14	**F-O**	-
M-15	**F-F**	**320±40** BP (1496-1646 cal AD)	F-15	**F-O**	**120±30** BP (1679–1765, 1800–1940 cal AD) **150±40** BP (1666–1785, 1795–1893, 1907–…. cal AD) **480±40** BP (1327–1343, 1394–1476 cal AD) **510±40** (1318–1352, 1390–1450 cal AD)
M-16	**F-F**	-	F-16	**F-O**	-
M-17	**F-F**	**250±40** BP (1515-1805 cal AD)	F-17	**F-O**	-
M-18	**F-F**	**480±50** BP (1388-1499 cal AD)	F-18	**F-O**	-
M-19	**F-F**	**140±50** BP (1666-1784, 1796-... cal AD)	F-19	**F-O**	-
M-20	**F-F**	**450±30** BP (1415-1479 cal AD)	F-20	**F-O**	-
M-21	**F-F**	**480±40** BP (1298-1527 cal AD)	F-21	**F-O**	**370±30** BP (1447-1528; 1390-1450 cal AD) **940±30** BP (1125-1160 cal AD) **4550±70** BP (3513-3424, 3384-3023 cal BC)
M-22	**F-F**	-	F-22	**F-O-F-O**	-

which covered northern Podhale and the slopes of the Pieniny. The southern part of the Podhale Basin is characterised by more varied relief. There are hill ranges up to 1000 m above sea level with steep slopes cut by numerous deep valleys. It is therefore a difficult area for agricultural use. Its settlement took place in the 16th and early 17th century and was not very intense (Czepiel, 1999; Krupa, 2016) (Fig. 7). The population of Podhale decreased significantly in the 17th and 18th centuries. This is a period of numerous epidemics and subsequent famine periods. These events correlate with a major climate cooling (Little Ice Age) (Bradley & Jones, 1993; Bradley, 2000; Briffa, 2000; Jones & Mann, 2004). Depopulation in some cities reached 40%. Another influx of people into Podhale took place in the second half of the 19th century and the 20th century (Czepiel, 1999; Krupa, 2016). Nowadays, the area is inhabited by over 250,000 people.

5.2. Stages of environmental changes

The mollusc communities found in Late Holocene calcareous tufa and river sediments in Podhale Basin and Pieniny Mts. point to the existence of several stages of environmental change. Human activity, particularly agriculture, should be considered the main factor causing these changes. The severity of anthropopressure correlates to some extent with the stages of climate fluctuations. Warm periods are more favourable to settlement development and demographic growth, and are therefore usually associated with intense anthropopressure. During the cold periods, limiting settlements and a decline in population results in the weakening of human impact on the environment. Such changes are particularly visible in mountain areas. Podhale and Pieniny are areas that illustrate these relationships well.

Stage I: until the 13th century. The area of Podhale and Pieniny was almost completely forested since the beginning of the Holocene. The dominance of tree pollen during this period was documented in several peatbog profiles in Podhale (Obidowicz, 1990; Rybničkova & Rybniček, 2002). Malacological studies carried out at many river sediments sites, slopes and calcareous sinters in Podhale and Pieniny also indicate a very large proportion of shade-loving forms ranging between 50 and 80% of the community (Alexandrowicz, 1997, 2013b; Alexandrowicz & Rybska 2013; Alexandrowicz et al., 2014, 2016, 2018; Alexandrowicz & Skoczylas, 2017). This period is characterized by a lack of anthropopressure in Podhale and Pieniny. Human groups arriving there were few, and their activities did not affect the course of natural processes.

Stage II: 13th–15th century. This is a period of warm climate – the Medieval Climate Optimum (Grove & Switsur, 1994; Huges & Diaz, 1994; Bradley, 2000; Briffa, 2000; Jones & Mann, 2004). Favourable conditions were conducive to demographic growth and migration in search of new settlements. This period is associated with the influx of human groups into the northern Carpathians.

Mainly foothills, large river valleys, as well as mountain valleys, are being settled (e.g. Starkel et al., 1996; Starkel, 2005; Gębica, 2013; Gębica et al., 2013; Alexandrowicz et al., 2019). Groups of settlers have been flowing into the Podhale and Pieniny region since the early 13th century and establishing the earliest permanent settlements. Along with the increase in population, there was a need to secure land suitable for agricultural use. As a result, deforestation occurred in the northern part of Podhale and on the Pieniny slopes. The decline of forests led to significant changes in fauna and flora. Palynological profiles show a decrease in the frequency of tree pollen, accompanied by the appearance of crop pollen (Obidowicz, 1990). Very significant changes are visible in malacological profiles. The initial, rich and

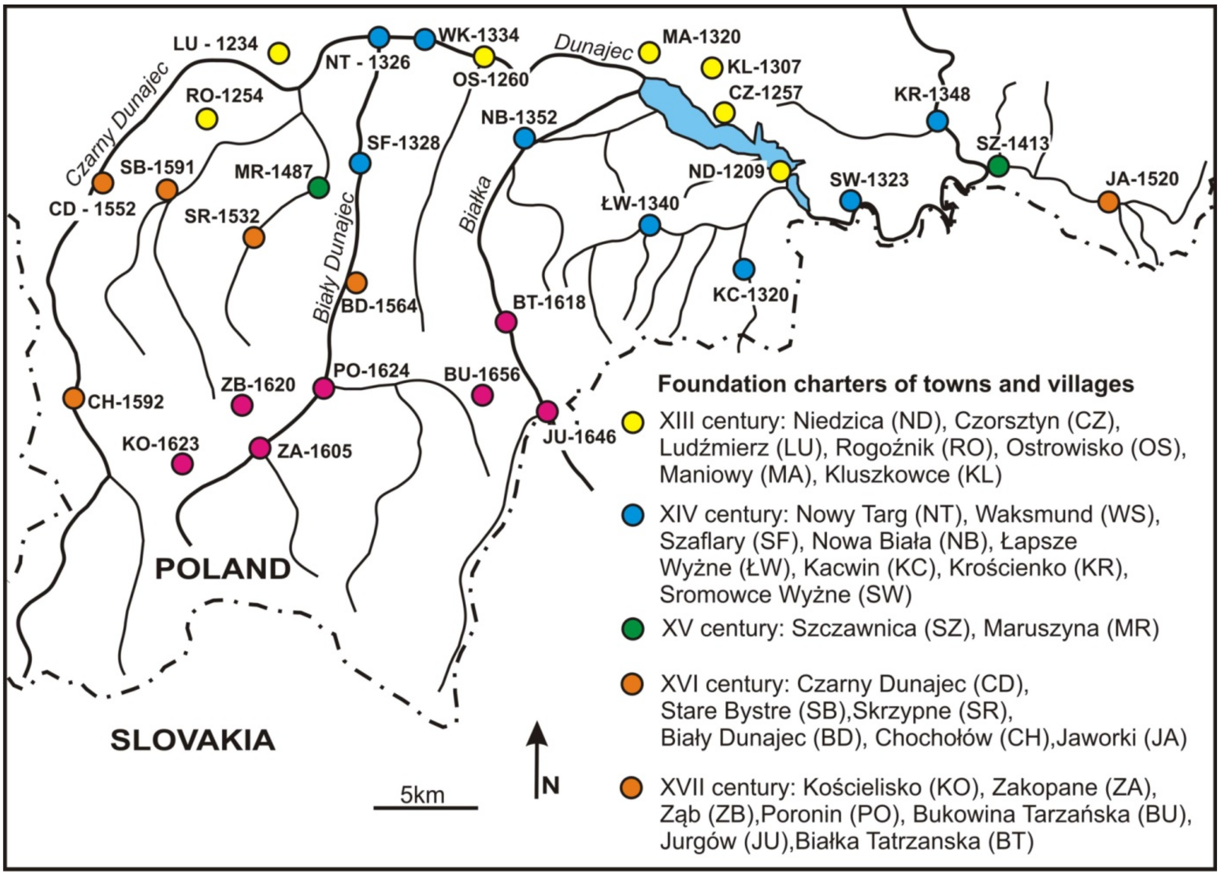

Figure. 7. Colonization of Podhale Basin and Pieniny Mts during last millenium

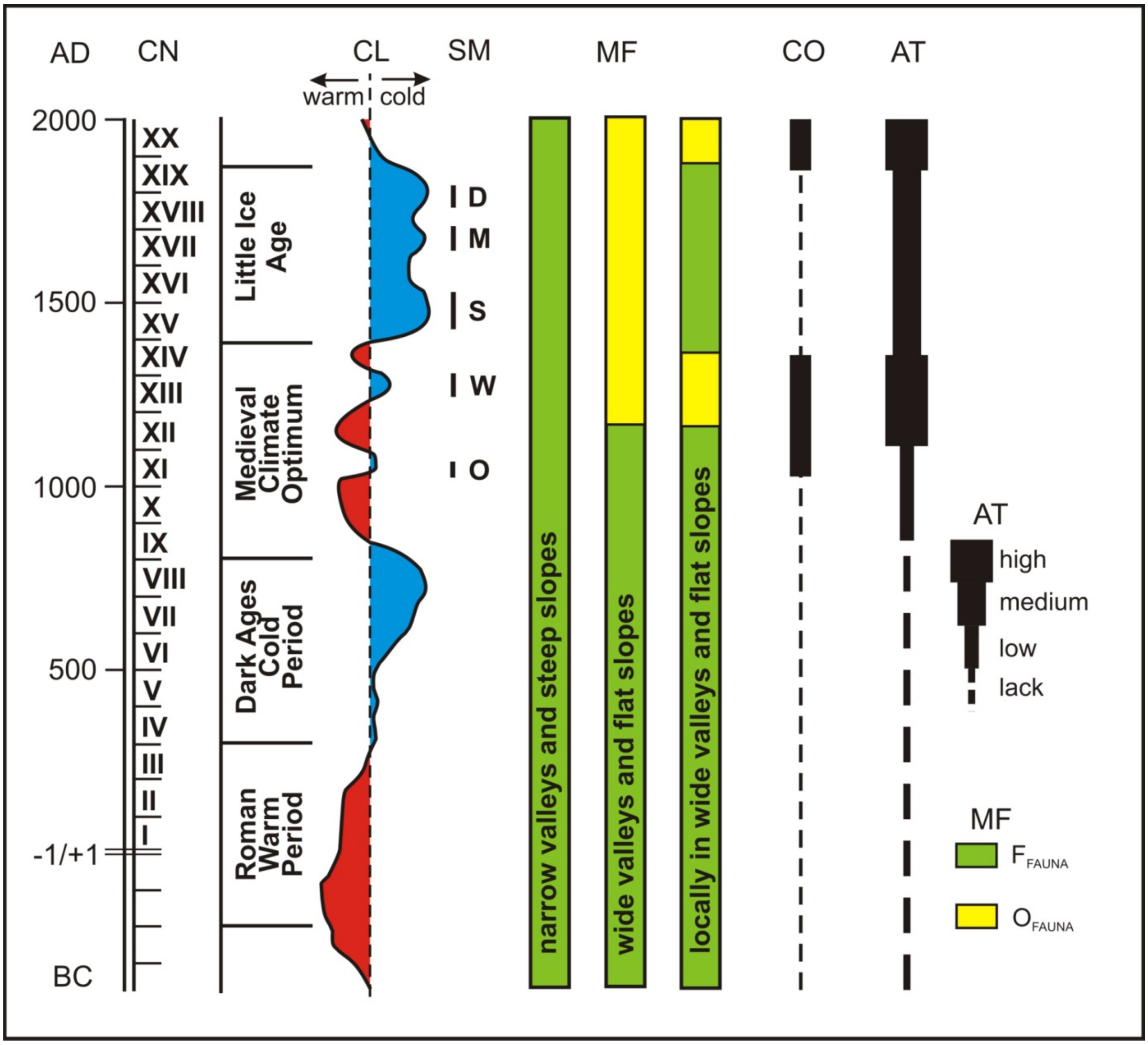

Figure 8. Climate, malacofauna and anthropogenic changes of environment of the Podhale Basin and Pieniny Mts. during historical times.
AD-BC. calendar years, CN. centuries, CL. climate, SM. solar minima: O. Oort, W. Wolf, S. Spörer, M. Maunder, D. Dalton, MF. malacofauna: F_{FAUNA}, O_{FAUNA}. molluscan assemblages (described in text), CO. colonization, AT. anthropopressure

varied malacocoenoses with a large share of shade-loving species were replaced by poor fauna with open-environment species (Alexandrowicz, 1997, 2013a; Alexandrowicz et al., 2014, 2016). This change in the features of faunal communities is dated in several profiles by the radiocarbon method (Fig. 8, Table 2). Replacement of shade-loving faunas by communities with a dominant share of open-country species is typical for the northern part of Podhale Basin and for the wide valleys of the Pieniny Mts. (F-O succession) (Fig. 8). These are areas with gentle relief and favourable conditions for the development of farming. The area of southern Podhale and the Pieniny massif is characterised by less favourable conditions for settlement and agricultural development. For this reason, this area was colonized later, and anthropopressure was less severe. Thanks to this, this area was not deforested, and the fauna and flora communities inhabiting it have largely retained their natural character during whole Late Holocene (F - F succession) (Fig. 8).

Stage III: 16th – first half of the 19th century. This is a period of climate cooling – Little Ice Age (Bradley & Jones, 1993; Bradley, 2000; Briffa, 2000; Jones & Mann, 2004). During this period, it is possible to distinguish several particularly cool episodes coinciding with episodes of decreasing solar activity (Eddy, 1976; Usoskin et al., 2004). Deterioration of climate conditions and the related decline in agricultural output combined with political factors (period of war) caused a significant decrease in the population living in the Pieniny and Podhale region (Czepiel, 1999). Consequently, some previously used agricultural areas were abandoned

(Fig. 8). This enabled a local expansion of forests. In a few malacological sequences, the appearance of strata with shade-loving fauna separating the intervals characterised by the predominance of open-country species is observed (F-O-F-O sequence) (Fig. 8).

Stage IV: the second half of the 19th century – present day. This is a period of gradual warming. The population of Podhale and Pieniny is increasing rapidly (Czepiel, 1999; Krupa, 2016). The second stage of deforestation is taking place, covering almost the entire analysed area. Malacocoenoses found in the upper sections of the profiles and associated with several radiocarbon dates (Fig. 8, Table 2) usually consist mainly of open-country species (F - O and F - O - F - O sequences) (Fig. 8). Anthropogenic deforestation was not exclusive to Pieniny and parts of hill ranges in the southern part of Podhale. Forest communities remained there, together with the shade-loving snail communities (F-F succession) (Fig. 8). Nowadays, forests cover less than 20% of the area (Zielony & Kliczkowska, 2012)

6. CONCLUSIONS

The results of the above analyses allow a reconstruction of the environmental changes and diversifying the severity of anthropopressure in Podhale Basin and Pieniny Mts. in the period from the 13th century to modern times. It is possible to distinguish two stages of intense human activity; whose main manifestation was the extensive and rapid deforestation occurring over a short period of time. Both stages clearly coincide with warm climate periods: the older one with the Medieval Climate Optimum, and the younger one with the modern warming. Environmental changes caused by anthropogenic deforestation associated with the Middle Ages are marked in many profiles in the Polish part of the Carpathians, particularly in the foothills and in the mountain valleys (e.g. Starkel et al., 1996; Starkel, 2005; Gębica, 2013; Gębica et al., 2013; Alexandrowicz et al., 2019), and the Podhale area is a great example of this. Radiocarbon dating indicates that the most intensive deforestation took place during 13th and 14th centuries. This period was marked by numerous foundation acts of villages in the northern part of Podhale and in the Dunajec valley. The younger stage of settlement is also documented by numerous sites. Usually, however, changes in the nature of habitats were not so pronounced there. The cooling associated with the Little Ice Age was manifested by the expansion of forests in some areas, and available historical sources indicate a significant reduction in the population of Podhale.

Malacological studies also provide an opportunity to reconstruct the diversity of anthropopressure in geographical regions. The acquired results indicate that a much stronger impact of human activity was noted in flat areas with little variety in terms of terrain relief. Such areas create favourable conditions for the development of agriculture and shepherding. And they were the first ones to be settled. In Podhale and Pieniny, these areas were deforested in the 13th and 14th centuries and were continually used as agricultural areas up to modern times. The F-O succession stands out here. Demographic growth forced the acquisition of new areas for agriculture, and consequently, areas with more varied relief were put to use. During periods of population decline, these areas were abandoned and natural plant succession occurred, leading to the emergence of shady habitats. The F-O-F-O progression is a typical malacological succession, with the forest stage dated to the 16th–18th century. Areas with diverse relief characterised by the presence of steep slopes and deep, V-shaped valleys were unfavourable when it came to agricultural use. Therefore, the degree of anthropogenic transformation in these areas is low. There is also no sign of deforestation during the last 700 years (the F-F malacological succession).

Due to their prevalence, specific ecological requirements and sensitivity to environmental changes, mollusc communities can be successfully used to characterize the impact of human activities on the natural environment. This method works particularly well as an indicator of violent and rapid changes related to deforestation and the development of a farming and shepherding economy.

This study has been sponsored by the AGH University of Science and Technology through subvention no. 16.16.140.315.

REFERENCES

Alexandrowicz, S.W., 1990. *The malacofauna of Late Holocene sediments of Sromowce (the Pieniny Mountains, Southern Poland).* Folia Malacologica, 4, 7-24.

Alexandrowicz, S.W., 1993. *Late Quaternary landslides at eastern periphery of the National Park of the Pieniny Mountains, Carpathians, Poland.* Studia Geologica Polonica, 192, 209-225.

Alexandrowicz, S.W., 1996. *Holocene dated landslides in the Polish Carpathians.* In: Frenzel, B. (Ed.), Rapid mass movement as a source of climatic evidence for the Holocene. Palaeoclimate Research 19, 75-83.

Alexandrowicz, S.W. & Alexandrowicz, W.P., 2011. *Malacological analysis – methods of investigation and interpretation.* Rozprawy Wydziału

Przyrodniczego PAU 3, 5-302. (in Polish).
Alexandrowicz, S.W., Alexandrowicz, W.P., Krąpiec, M. & Szychowska-Krąpiec, E., 1997**.** *Environmental changes of Southern Poland during historical period.* Geologia Kwartalnik AGH, 23, 339-387. (in Polish with English summary).
Alexandrowicz, W.P., 1997. *Malacofauna of Quaternary deposits and environmental changes of the Podhale Basin during the Late Glacial and Holocene*. Folia Quaternaria, 68, 7-132. (in Polish with English summary).
Alexandrowicz, W.P., 2004. *Molluscan assemblages of Late Glacial and Holocene calcareous tufas in Southern Poland.* Folia Ouaternaria, 75, 1-309.
Alexandrowicz, W.P., 2010. *Molluscan assemblages of recent calcareous tufas in the Podhale Basin and Pieniny Mts (S. Poland).* Folia Malcologica, 18, 99-112.
Alexandrowicz, W.P., 2013a. *Molluscan communities in Late Holocene fluvial deposits as an indicator of human activity. A study in Podhale Basin (South Poland).* Ekologia Bratislava, 32, 111–125.
Alexandrowicz, W.P., 2013b. *Malacological sequence from profile of calcareous tufa in Groń (Podhale Basin, southern Poland) as an indicator of the Late Glacial/Holocene boundary*. Quaternary International, 293, 196-206.
Alexandrowicz, W.P., 2013c. *Molluscan assemblages in the deposits of landslide dammed lakes as indicators of late Holocene mass movements in the Polish Carpathians.* Geomorphology, 180-181, 10-23.
Alexandrowicz, W.P., 2014. *Molluscan assemblages in Late Holocene tufa cones in the Pieniny Mountains (southern Poland).* Geological Quarterly, 58, 269-280.
Alexandrowicz, W.P., 2019a. *Malacological evidence of the natural and anthropogenic changes of the environment in the eastern part of the Carpathian Foreland: the studies in the Glinne stream valley near Rzeszów (southern Poland).* Carpathian Journal of Earth and Environmental Sciences, 14, 367-384.
Alexandrowicz, W.P., 2019b. *Record of environmental changes and fluvial phases in the Late Holocene within the area of Podhale (the Carpathians, southern Poland): studies in the Falsztyński valley*. Geological Quaterly, 63, 629-642.
Alexandrowicz, W.P. & Rybska E., 2013. *Environmental changes of intramontane basins derived from malacplogical analysis of profile of calcareous tufa in Niedzica (Podhale Basin, Southern Poland).* Carpathian Journal of Earth and Environmental Sciences, 8, 4, 13-26.
Alexandrowicz, W.P. & Skoczylas, S., 2017. *Molluscan assemblages from calcareous tufa in the Skalski Stream Valley (Pieniny Mountains, southern Poland) and their application for reconstruction of natural and anthropogenic environmental changes.* Carpathian Journal of Earth and Environmental Sciences, 12, 583-594.
Alexandrowicz, W.P., Szymanek, M. & Rybska, E., 2014. *Changes to the environment of intramontane basins in the light of malacological research of calcareous tufa: Podhale Basin (Carpathians, Southern Poland)*. Quaternary International, 353, 250-265.
Alexandrowicz, W.P., **Szymanek M. & Rybska E.,** 2016. *Molluscan assemblages from Holocene calcareous tufa and their significance for palaeoenvironmental reconstructions. A study in the Pieniny Mountains (Carpathians, southern Poland).* Carpathian Journal of Earth and Environmental Sciences, 11: 37-54.
Alexandrowicz, W.P., Szymanek, M. & Rybska, E., 2018. *Application of malacological analysis in local and regional palaeoenvironmental reconstructions – a study from the Holocene of Łapsze Niżne (Podhale, southern Poland).* Acta Geologica Polonica, 68, 89-105
Alexandrowicz, Z., Alexandrowicz, W.P. & Buczek K., 2019. *Conservation of the Natura 2000 Areas in the Context of Environmental Changes in Past and Present: a Case from the Polish Carpathians Geoheritage.* Geoheritage, 11, 517-529.
Birkenmajer K., 1977. *Jurassic and Cretaceous lithostratigraphic units of the Pieniny Klippen Belt.* Studia Geologica Polonica, 45, 1-158.
Bradley, R.S., 2000. *Past global changes and their significance for the future.* Quaternary Science Reviews, 19, 391-402.
Bradley, R.S. & Jones, P.D., 1993. *‚Little Ice Age‘summer temperature variations: their nature and relevance to recent global warming trends.* The Holocene, 3, 367-376.
Briffa, K.R., 2000. *Annual climate variability in the Holocene: interpretating the message of ancient trees*. Quaternary Science Reviews, 19, 87-105.
Bronk Ramsey, C., 2003. OxCal Program 3.9. University of Oxford. Radiocarbon Accelerator Unit.
Czepiel, J., 1999. *Z dziejów osadnictwa na Podhalu.* pp. 111. Abrys, Kraków. (in Polish).
Eddy, J.A., 1976. *The Maunder minimum.* Science, 192, 1189-1202.
Gębica, P., 2013. *Geomorphological records of human activity reflected in fluvial sediments in the Carpathians and their foreland.* Landform Analysis, 22, 21-31.
Gębica. P., Starkel. L., Jacyszyn. A. & Krąpiec, M., 2013. *Medieval accumulation in the Upper Dniester River Valley: the role of human impact and climate change in the Carpathian Foreland.* Quaternary International, 293, 207-218.
Grove, J.M. & Swistur, R., 1994. *Glacial geological evidence for the Medieval Warm Period.* Climatic Change, 26, 143-169.
Horsák, M., Juřičková, L. & Picka, J., 2013. *Molluscs of the Czech and Slovak Republics*. 264 pp. Kabourek, Zlín.
Hughes, M.K. & Diaz, H.F., 1994. *Was there a ‚Medieval Warm Period‘ and if so, when and where?* Climatic Change, 26, 109-142.

Jones, P.D. & Mann, M.E., 2004. *Climate over past millennia*. Reviews of *Geophysics*, 42, 1-42.
Kerney, M.P., Cameron, R.A.D. & Jungbluth, J.H., 1983. *Die Landschnecken Nord- und Mitteleuropas*. 384 pp. Verlag P. Parey, Hamburg-Berlin.
Klimaszewski, M., 1952. *The relief of Podhale Basin*. Czasopismo Geograficzne, 21-22, 237-250. (in Polish, English summary).
Klimaszewski, M., 1972. *Goemorphology of Poland, Southern Poland – mountains and uplands*. 384 pp. PWN Warszawa. (in Polish).
Kołodziejski, S., Parczewski, M., Rydlewski, J. & Valde-Novak, P., 1982. *Dzieje osadnictwa w Pieninach od czasów najdawniejszych do połowy XIV wieku.* In: K.Zarzycki, K., (Ed.), Przyroda Pienin w obliczu zmian. Studia Naturae, B, 30, 403-421. (in Polish).
Krupa, M., 2016. *Cultural landscape of Nowy Targ region – selected issues.* Journal of Heritage Conservation, 47, 61-70. (in Polish with English summary).
Lososová, Z., Horsák, M., Chytrý, M., Čejka, T., Danihelka, J., Fajmon, K., Hájek, O., Juřičková, L., Kintrová, K., Láníková, D., Otýpková, Z., Řehořek, V. & Tichý, L., 2011. *Diversity of Central European urban biota: effects on human-made habitat types on plants and land snails.* Journal of Biogeography, 38, 1152-1163.
Ložek, V., 1964. *Quartärmollusken der Tschechoslowakei.* Rozpravy Ustředniho Ustavu Geologického, 31, 1-374.
Łajczak, A., 2006. *Raised peatbog Bór na Czerwonem (Podhale, South Poland) – development, degradation, renaturalisation*. Nature Conservation, 62, 89-103.
Mastella, L., 1975. *Flysch tectonics in the eastern part of the Podhale Basin, Carpathians, Poland.* Annales Societatis Geologorum Poloniae, 45, 361-401. (in Polish with English summary).
Obidowicz, A., 1990. *Eine pollenanalytische und moorkundlische Studie zur Vegetationgeschichte des Podhale-Gebietes (West-Karpaten).* Acta Palaeobotanica, 30, 147-219.
Olszewska, B. & Wieczorek, J., 1998. *The Paleogene of the Podhale Basin (Polish Inner Carpathians) - micropaleontological perspective.* Przegląd Geologiczny, 46, 721-728. (in Polish with English summary).
Rosin, Z. M., Lesicki, A., Kwieciński, Z., Skórka, P & P. Tryjanowski, P., 2017. *Land snails benefit from human alterations in rural landscapes and habitats*. Ecosphere, 8, 1-15.
Rybníček, K. & Rybníčková, E., 2002. *Vegetation of the Upper Orava region (NW Slovakia) in the last 11000 years.* Acta Palaeobotanica, 42, 2, 153-170.
Rydlewski, J. & Valde-Novak, P., 1982. *Z najdawniejszej przeszłości Orawy.* Wierchy, 51, 7-25. (in Polish).
Starkel, L., 2005. *Role of climatic and anthropogenic factors accelerating soil erosion and fluvial activity in Central Europe.* Studia Quaternaria, 22, 27-33.
Starkel, L., Kalicki, T., Krąpiec, M., Soja, R., Gębica, P. & Czyżowska, E., 1996. *Hydrological changes of valley floors in the upper Vistula basin during Late Vistulian and Holocene*. In: Starkel, L., (ed.), Evolution of the Vistula river valley during the last 15000 years. Geographical Studies, 4, 9, 1-158.
Usoskin, I.G., Mursula K., Solanki, S., Schüssler, M., & Alanko, K., 2004. *Reconstruction of solar activity for the last millennium using ^{10}Be data.* Astronomy and Astrophysics, 413, 745-751.
Valde-Nowak, P., Nadachowski, A. & Madeyska, T., 2003. *Oblazowa Cave human activity, stratigraphy and palaeoenvironment.* Institute of Archaeology and Ethnology Polish Academy of Science, pp. 176, Cracow.
Walter-Schultes, F., 2012. *European non-marine molluscs, a guide for species identification*. pp. 674. Planet Poster Editions, Göttingen.
Watycha, L., 1976. *The Neogene of the Orawa-Nowy Targ Basin*. Kwartalnik Geologiczny, 20, 575-587. (in Polish with English summary).
Wiktor, A., 2004. Land snails of Poland. pp. 302. Mantis, Olsztyn. (in Polish).
Zielony, R. & Kliczkowska, A., 2012. *Regionalizacja przyrodniczo-leśna Polski 2010*. 3-356 pp. CILP, Warszawa. (in Polish).
Zuchiewicz, W., Tokarski, A.K., Jarosiński, M. & Márton, E., 2002. *Late Miocene to present day structural development of the Polish segment of the Outer Carpathians.* Stephan Mueller Special Publication, 3, 185-202.

Received at: 27. 01. 2020
Revised at: 21. 02. 2020
Accepted for publication at: 26. 02. 2020
Published online at: 28. 02. 2020