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Malacofauna of the Vistulian Loess in the Cracow Region (S Poland)*

Malakofauna lessów vistulianu w okolicach Krakowa (Polska S)

Abstract. More than thirty profiles and outcrops of loess abounding in shells of molluscs have been described from the Cracow region. The fauna comprises 30 taxa of snails and bivalves divided into five ecological groups. Three types of molluscan successions can be distinguished. One of them connected with sediments filling dry valleys is the most common. Changes of assemblages correspond to the development of the climate and environment during the interval 32–15 ka BP. Cold tolerant species prevail in loess deposited at the decline of the Denecamp Interstadial. The abundance of fauna in loess dated at 26–22 ka BP reflects amelioration of ecological conditions while sediments of the Pleniglacial (22–14 ka BP) contain only a few species of snails, typical of a severe climate and dry habitats.

Key words: younger loess, molluscan fauna, late Pleistocene, pleniglacial, interpleniglacial.

INTRODUCTION

Loess and related deposits are widespread in the Cracow Upland, Miechów Upland, Proszowice Hills, in the western part of the Sandomierz Basin and in the Carpathian Foothill around Cracow. Most of them are connected with the last glaciation, and only in a few outcrops older loess intercalated with fossil soils is accessible. The mentioned sediments have been described since a about hundred years by many authors (S. Zaręczny 1894, C. Kuźniar 1912, J. Lewiński 1913, W. Walczak 1956, M. Kolasa 1963). A considerable progress in stratigraphy of loess was initiated with

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detail studies basing on lithological, chemical and paleopedological methods supplemented by TL and C-14 dating (J. Jersak 1973, H. Maruszczak 1980, 1986, J. Jersak et al. 1992) as well as by investigations of archaeological sites (Lk. Sawicki 1952, J.K. Kozłowski 1966, 1969, T. Madeyska 1981). Although shells of snails were found in several places, malacofauna of loess has been little known at yet. Three species: *Succinea oblonga*, *Pupilla muscorum* and *Pupilla loessica* have been noted again and again while two other — occasionally (*Trichia hispida*, *Vallonia tenuilabris*). Sequences of molluscan assemblages were briefly described by the author in three profiles while the structure of an assemblage — in one locality only (S.W. Alexandrowicz, J. Jersak 1985, S.W. Alexandrowicz 1987b, 1989, 1991, H. Maruszczak 1991). The molluscan fauna from a profile of the Wartanian and Vistulian loess is known in Odonów near Kazimierza Wielka (S.W. Alexandrowicz 1986).

MATERIAL AND METHODS

More than thirty localities of mollusc-bearing Vistulian loess and related deposits had been found in the Cracow Region. A third of them were studied in detail as particularly interesting malacological profiles, distributed mainly between Krzeszowice and Słomniki as well as in the Vistula River Valley (Fig. 1, I). The material was collected since the first half of the eighties and it has been supplemented in almost all localities during the last year. About three hundred samples were analysed using conventional methods and procedures (S.W. Alexandrowicz 1987a) while a third of them were introduced into malacological diagrams.

Three types of loess-facies can be distinguished according to J. Jersak (1973). The upland loess is widespread and characterized by a limited thickness. It is devoid of an admixture of coarse material. The molluscan fauna is quite poor or even completely absent. The loess of the slope-facies is thicker and partly redeposited by slope-wash or solifluction. It contains intercalations enriched in quartz grains or rock debris. The fauna is locally rich and differentiated. In valleys of the Cracow and Miechów Uplands this type of sediment forms loess terraces as traces of the Vistulian dry valleys (S.W. Alexandrowicz 1989). Localities in Szklary, Korzkiew, Bibice and Januszowice are examples of profiles of the slope-facies (Fig. 1, II). The valley loess is characterized by lamination and thin intercalations of fine-grained sand. It occurs in the Vistula River Valley eastward of Cracow, forming a large terrace (Fig. 1, II–Op). Fauna with an admixture of water snails and bivalves is typical of the valley-facies of loess. In the Cracow Region

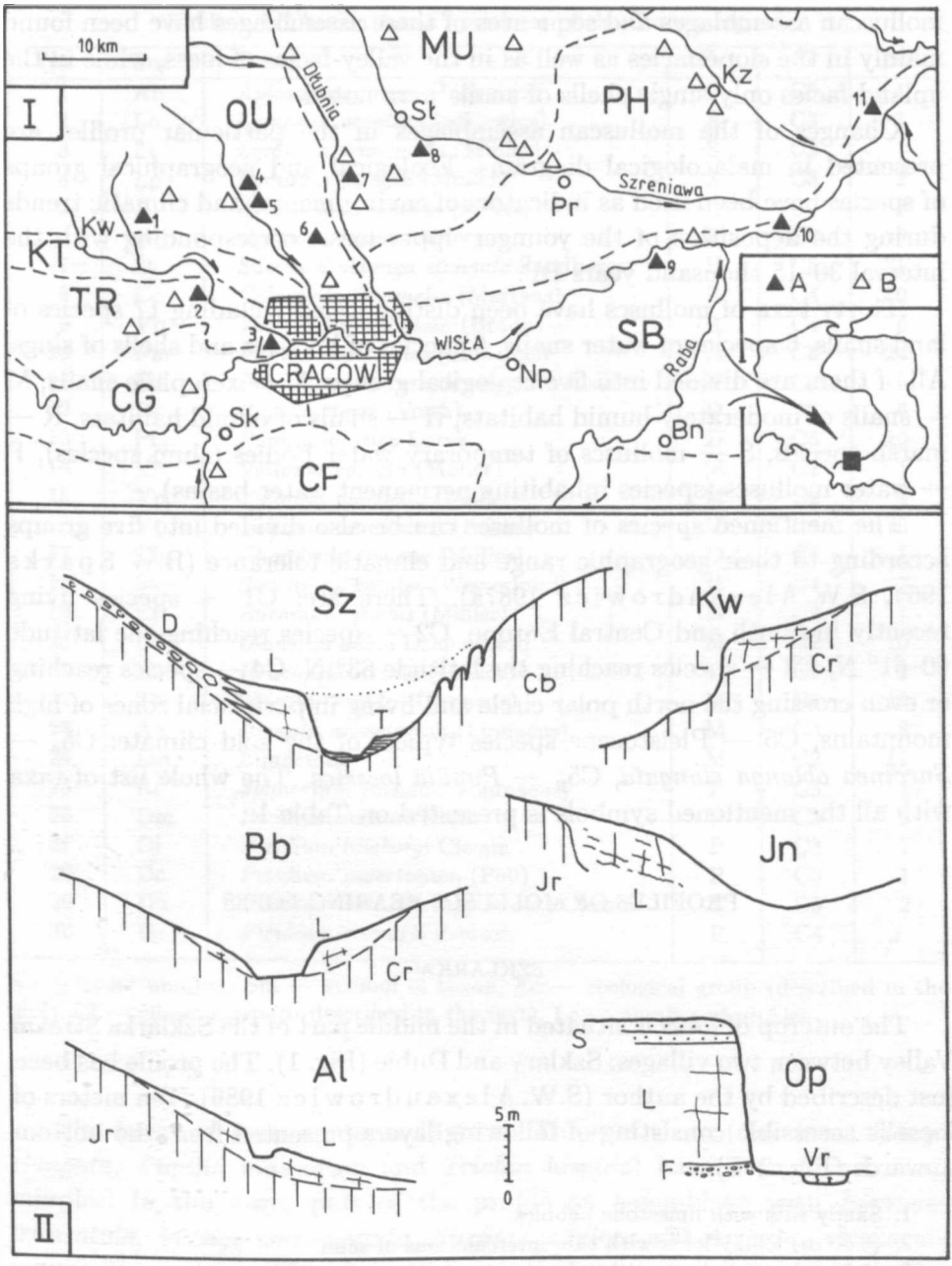

Fig. 1. Profiles and outcrops of loess in the Cracow region; I — distribution of localities; A — profiles described in the text (1–11), B — supplementary outcrops, CF — Carpathian Foothill, CG — Cracow Gate, TG — Tenczynek Range, KT — Krzeszowice Trough, OU — Ojców Upland, MU — Miechów Upland, PH — Proszowice Hills, SB — Sandomierz Basin. II — Selected outcrops of loess: Sz — Szklarka, Kw — Korzkiew, Bb — Bibice, Jn — Januszowice, Al — Aleksandrowice, Op — Opatowiec

molluscan assemblages and sequences of these assemblages have been found mainly in the slope-facies as well as in the valley-facies of loess, while in the upland-facies only single shells of snails were noted.

Changes of the molluscan assemblages in the particular profiles are presented in malacological diagrams. Ecological and geographical groups of species have been used as indicators of environmental and climatic trends during the deposition of the younger upper loess, corresponding with the interval 30–15 thousand years BP.

Thirty taxa of molluscs have been distinguished including 17 species of land snails, 6 species of water snails, 6 species of bivalves and shells of slugs. All of them are divided into five ecological groups: D — xerophile snails, M — snails of moderately humid habitats, H — snails of humid habitats, R — marsh species, S — molluscs of temporary water bodies (slum species), P — water molluscs (species inhabiting permanent water basins).

The mentioned species of molluscs can be also divided into five groups according to their geographic range and climatic tolerance (B.W. Sparks 1964, S.W. Alexandrowicz 1987a). There are: C1 — species living recently in South and Central Europe, C2 — species reaching the latitude 60–61° N, C3 — species reaching the latitude 63° N, C4 — species reaching or even crossing the north polar circle and living in periglacial zones of high mountains, C5 — Pleistocene species typical of the cold climate: $C5_s$ — *Succinea oblonga elongata*, $C5_p$ — *Pupilla loessica*. The whole list of taxa with all the mentioned symbols is presented on Table 1.

PROFILES OF MOLLUSCS-BEARING LOESS

SZKLARKA

The outcrop of loess is situated in the middle part of the Szklarka Stream Valley between two villages: Szklary and Dubie (Fig. 1). The profile has been just described by the author (S.W. Alexandrowicz 1989). Ten meters of loess is accessible consisting of following layers presented from the bottom upwards (Fig. 2–L).

1. Sandy silts with limestone pebbles.
2. (0.80 m) loamy loess with thin intercalations of sand.
3. (1.00 m) yellow loess with a few laminae of silty sand.
4. (1.70 m) yellow loess.
5. (0.80 m) loamy loess with an admixture of small limestone lumps.
6. (3.00 m) yellow loess with numerous shells of snails.
7. (0.60 m) yellow loess partly laminated with loamy loess.
8. (2.10 m) loess with numerous shells of snails.

Table 1. Molluscan fauna from loess of the Cracow region

No	Sm	Taxon	Ec	Cl	Lc
1	Ah	*Aplexa hypnorum* (Linnaeus)	S	C3	1
2	Lo	*Lymnaea occulta* (Jackiewicz)	S	C3	1
3	Lt	*Lymnaea truncatula* (Müller)	S	C3	7
4	Lp	*Lymnaea peregra* (Müller)	S	C3	2
5	Al	*Anisus leucostomus* (Millet)	S	C2	2
6	Gl	*Gyraulus laevis* (Alder)	P	C3	3
7	Se	*Succinea oblonga elongata* Sandberger	H	C5	31
8	Cc	*Columella columella* (Martens)	R	C4	10
9	Vp	*Vertigo parcedentata* (Braun)	R	C4	6
10	Pm	*Pupilla muscorum* (Linnaeus)	M	C3	24
11	Pd	*Pupilla muscorum densegyrata* Łożek	H	C4	5
12	Ps	*Pupilla sterri* (Voith)	D	C1	6
13	Pl	*Pupilla loessica* Łożek	D	C5	29
14	Vc	*Vallonia costata* (Müller)	M	C2	1
15	Vp	*Vallonia pulchella* (Müller)	M	C2	4
16	Vt	*Vallonia tenuilabris* (Braun)	M	C4	19
17	Ch	*Chondrula tridens* (Müller)	D	C1	1
18	Sk	*Similimax kotulai* (Westerlund)	H	C4	7
19	Ef	*Euconolus fulvus* (Müller)	M	C3	1
20	Cd	*Clausilia dubia* Draparnaud	M	C2	10
21	Hs	*Helicopsis striata* (Müller)	D	C1	2
22	Th	*Trichia hispida* (Linnaeus)	M	C3	12
23	Aa	*Arianta arbustorum* (Linnaeus)	M	C3	8
24	Lm	*Limacidae*	M	C2	11
25	Rc	*Sphaerium corneum* (Linnaeus)	P	C3	1
26	Dm	*Pisidium milium* Held	P	C3	2
27	Dl	*Pisidium lilieborgi* Clessin	P	C3	1
28	Dc	*Pisidium casertanum* (Poli)	P	C3	1
29	Do	*Pisidium obtusale lapponicum* Clessin	S	C5	2
30	Ds	*Pisidium stewarti* Preston	P	C4	1

No — order number, Sm — symbol of taxon, Ec — ecological group (described in the text), Cl — climatic group (described in the text), Lc — number of profiles

The fauna of loess contains 14 taxa. Three of them (*Succinea oblonga elongata, Pupilla muscorum* and *Trichia hispida*) have been found in all samples. In the lower part of the profile an assemblage with *Lymnaea truncatula, Vertigo parcedentata, Euconulus fulvus* and *Arianta arbustorum* occurs. Two species: *Chondrula tridens* and *Vallonia tenuilabris* characterize the next assemblage passing upward into a rich fauna with *Pupilla loessica, P.muscorum, Trichia hispida* and *Succinea oblonga elongata.* In the upper part of the discussed profile shells of *Clausilia dubia* and *Columella columella* are noted additionally (Fig. 2–F).

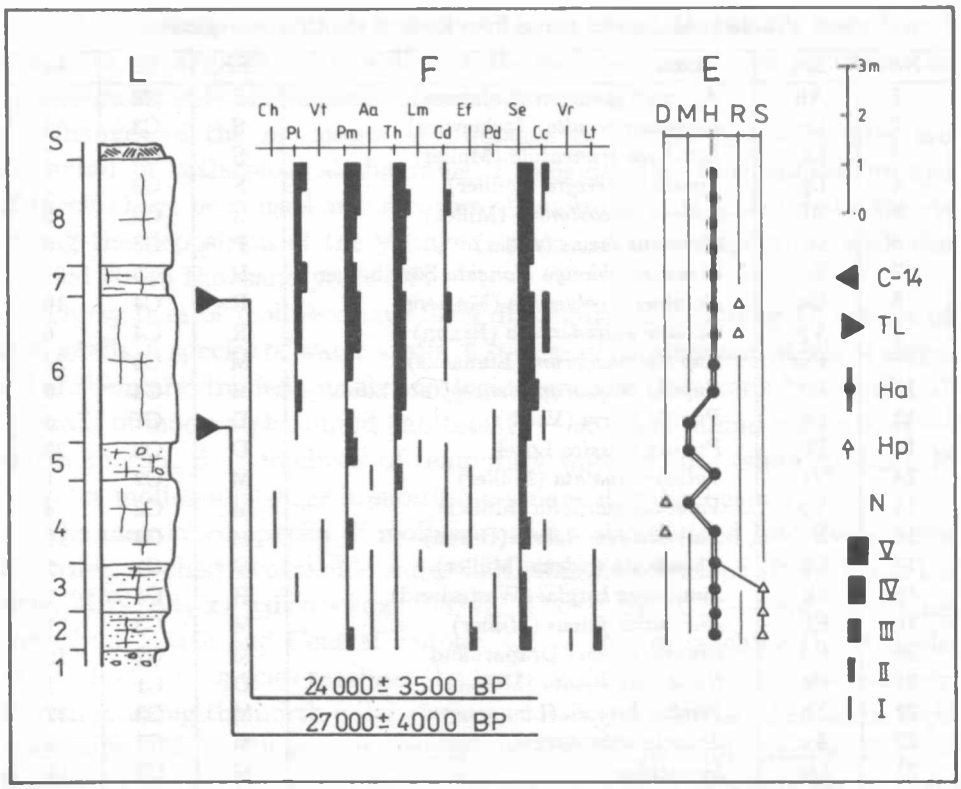

Fig. 2. Profile in the Szklarka Stream Valley; L — lithology of loess (layers described in the text), F — molluscan fauna (symbols of species as in Tab. 1), E — ecological groups of molluscs: D — xerophile snails, M — snails of moderately humid habitats, H — snails of humid habitats, R — marsh species, S — slum species, P — water molluscs; C-14 — radiocarbon dating, TL — thermoluminescence dating, Ha — main ecological type of assemblage, Hp — supplementary ecological type of assemblage, N — number of specimens: I — 1–3, II — 4–9, III — 10–31, IV — 32–99, V — 100–316

Species living in humid and moderately humid habitats are the main components of the fauna in the whole sequence mentioned. In its lowermost part they are accompanied by an amphibiotic snail — *Lymnaea truncatula*, while in the middle part by a xerophile species — *Chondrula tridens* at first and later by a marsh snail — *Columella columella*. During the deposition of loess ecological conditions had been relatively stable before the dry valley filled with these sediments was dissected in the early phase of the Late Vistulian.

SZCZYGLICE

It is an outcrop situated in the western part of the village at the side of the road leading from Zabierzów to the airport (Fig. 1). Jurassic limestones are covered with following deposits (Fig. 3–L).

1. (0.30 m) yellow loam with numerous fragments of limestones.
2. (0.40 m) loamy loess with small lumps of jurassic limestones.
3. (0.80 m) yellow molluscs-bearing loess indistinctly laminated.
4. (1.50 m) loess decalcified in the upper part of the layer.
5. (0.50 m) rock detritus with a loamy matrix.

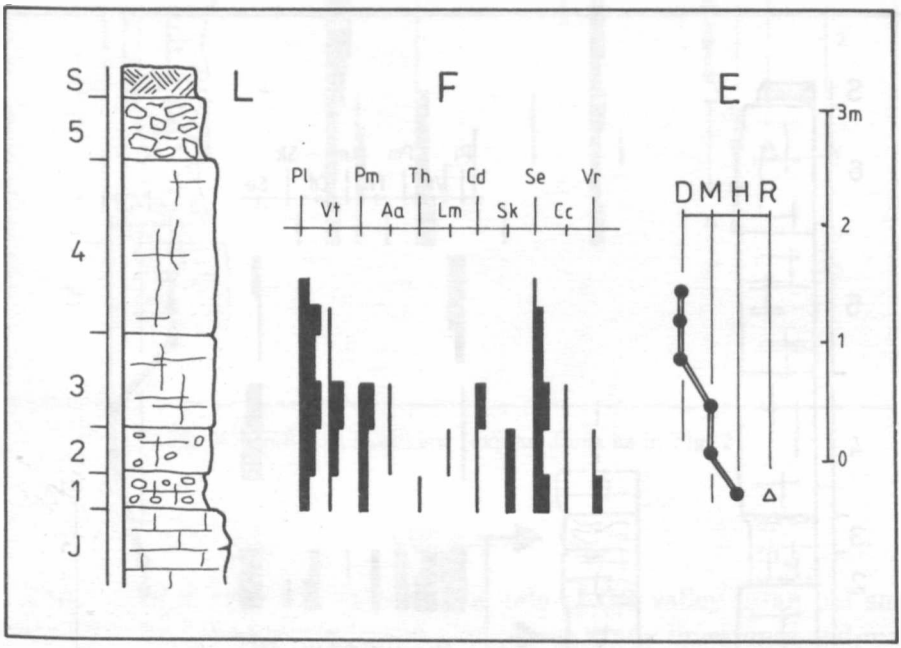

Fig. 3. Profile in Szczyglice (explanations as in Fig. 2)

Two molluscan assemblages can be distinguished in the discussed profile. *Succinea oblonga elongata*, *Semilimax kotulai* and *Vertigo parcedentata* are the most typical elements of the first assemblage, while the second one is dominated by *Pupilla loessica* (Fig. 3–F). The molluscan sequence indicates changes of the environment being initially more or less humid and subsequently more dry (Fig. 3–E).

KRAKÓW, SPADZISTA STREET

The locality has been studied a few times by archaeologists. In the profile of the trench A described by J.K. Kozłowski (1969) younger loess intercalated with loamy loess was distinguished (Fig. 4–L, 4–6). It contains shells of molluscs identified by A. Wiktor (1969). In the trench C2 described by J.K. Kozłowski and K. Sobczyk (1987) fauna occurs only in loamy loess covered with solifluction loam and younger loess (Fig. 4–L, 1–3). Molluscan assemblages from both trenches supplement one another and can be interpreted as one succession.

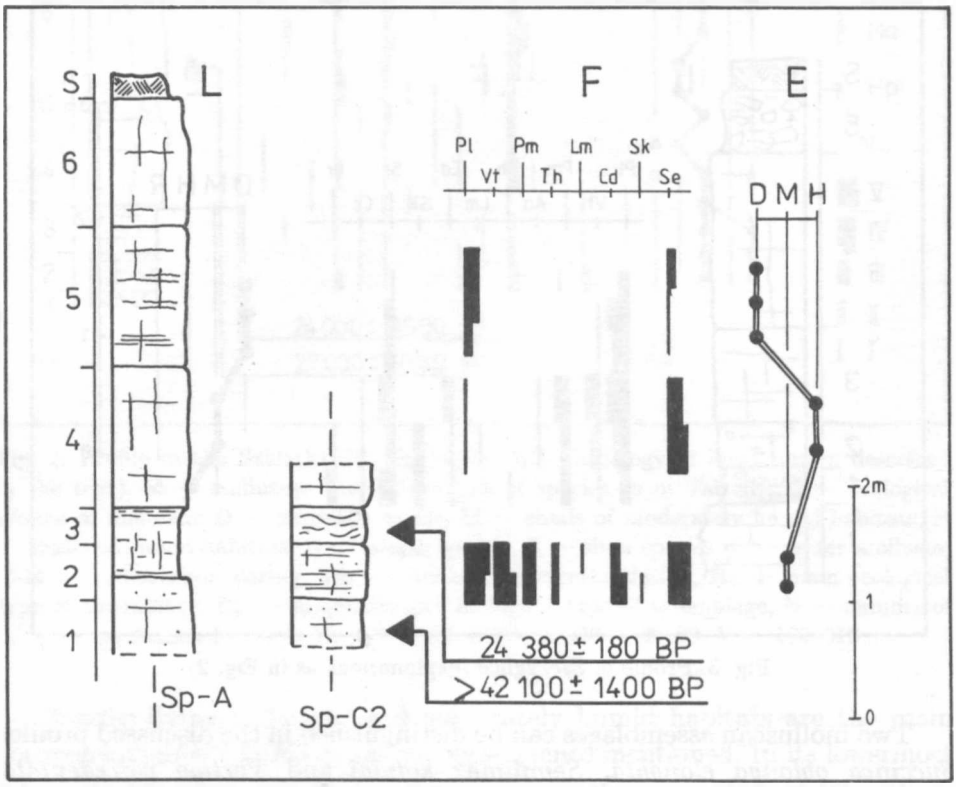

Fig. 4. Profile in Cracow, Spadzista Street. Sp-A, Sp-C2 — numbers of archaeological outcrops (explanations as in Fig. 2)

The older assemblage is relatively rich, characterized by such species as: *Vallonia tenuilabris, Pupilla muscorum, Trichia hispida* and *Clausilia dubia* (S.W. Alexandrowicz 1987b). In younger loess the fauna dominated by *Succinea oblonga elongata* passes upward into a fauna with *Pupilla loessica* (A. Wiktor 1969). Such a succession reflects changes of the environment.

Moderately humid and humid habitats favourable for different species had been replaced by dry habitats accepted only by a few of them (Fig. 4–E).

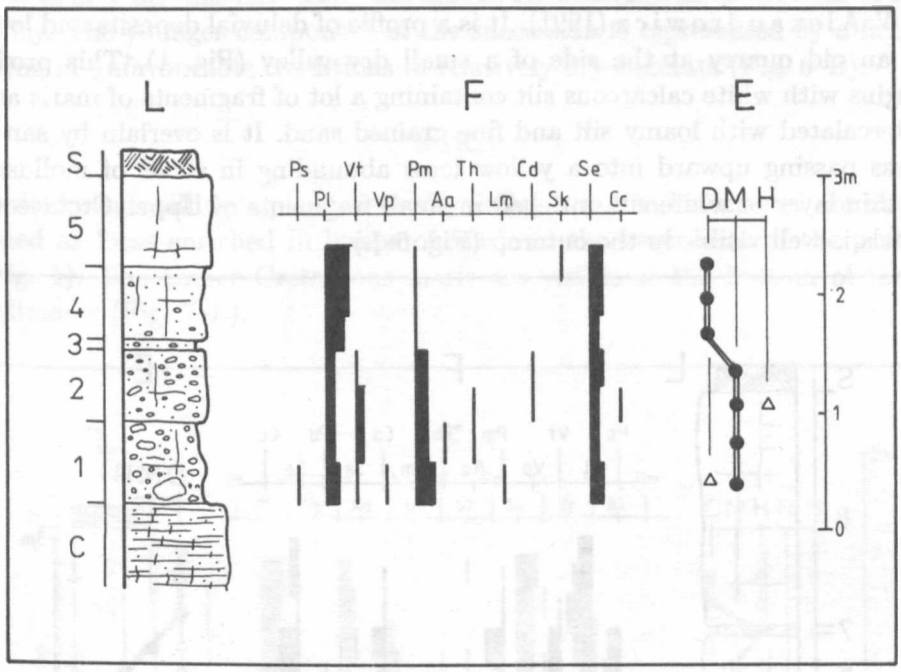

Fig. 5. Profile in Korzkiew (explanations as in Fig. 2)

KORZKIEW

The profile is localized on the right side of the valley in an old small quarry (Fig. 1). Loess covers Upper Cretaceous sandy limestones and marls (Fig. 5–L).

1. (0.70 m) sandy loess with rock detritus.
2–4. (1.30 m) loess with rock lumps intercalated with calcareous silt.
5. (0.70 m) yellow loess decalcified at the top of the layer.

A rich molluscan fauna occurs in the described profile (Fig. 5–F). An association with *Pupilla sterri* and *P.muscorum* begins the sequence passing upward into a fauna with *Pupilla muscorum, Trichia hispida, Vallonia tenuilabris* and *Arianta arbustorum*. The third assemblage includes mainly two species with predominating *Pupilla loessica*. The presented succession reflects changes of the environment. In its lower part it is a fauna of moderately humid habitats favourable for molluscs, while in the upper part it corresponds with more dry and unfavourable conditions (Fig. 5–E).

JANUSZOWICE

The outcrop was previously mentioned by S. Bukowy (1956) and S.W. Alexandrowicz (1991). It is a profile of deluvial deposits and loess in an old quarry at the side of a small dry valley (Fig. 1). This profile begins with white calcareous silt containing a lot of fragments of marls and intercalated with loamy silt and fine grained sand. It is overlain by sandy loess passing upward into a yellow loess abounding in shells of molluscs. A thin layer of white silt enriched in small fragments of Upper Cretaceous marls is well visible in the outcrop (Fig. 6–L).

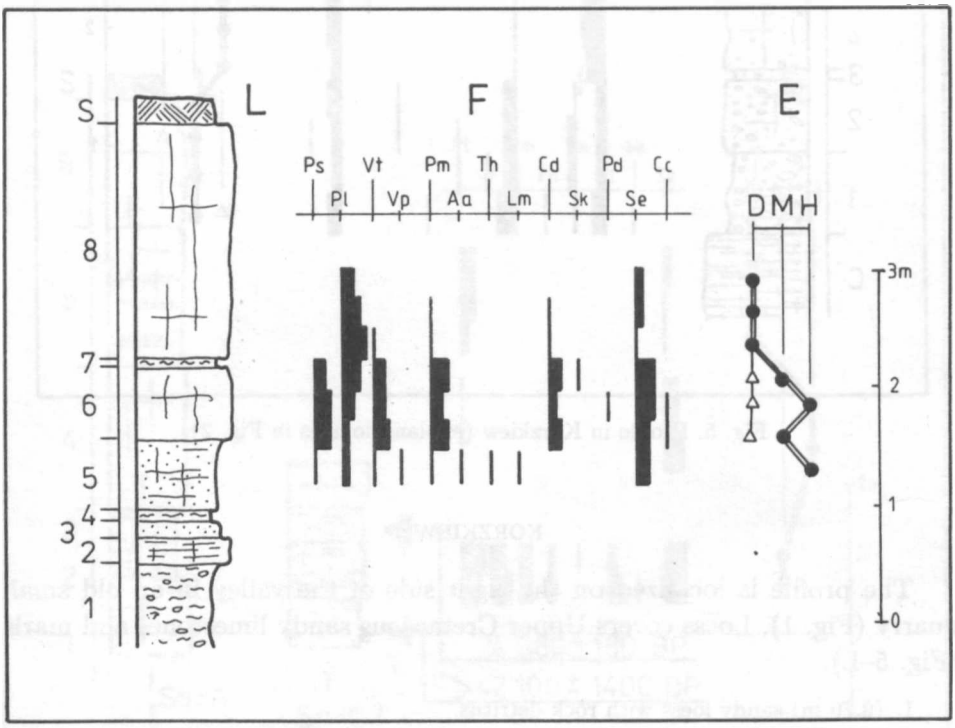

Fig. 6. Profile in Januszowice (explanations as in Fig. 2)

The molluscan fauna of the sandy loess contains 9 species of snails such as *Vallonia tenuilabris, V.pulchella, Arianta arbustorum* and *Trichia hispida*. A rich assemblage has been found in the lower layer of loess. The occurrence of numerous shells of *Pupilla sterri* beside *Vallonia tenuilabris, Pupilla muscorum, Clausilia dubia* and *Columella columella* is worth of noting. In the upper layer of loess the fauna is dominated by *Pupilla loessica* (Fig. 6–F).

The succession of molluscan assemblages is composed of two elements. The older one reflects the coexistence of different habitats close to one ano-

ther, characterized by species in moderately humid or even quite humid places and by species typical of sunny xerothermic slopes. The first component clearly prevails indicating the type of environment at the bottom of the valley. The younger component of the succession is represented by a fauna living in unfavourable conditions in relatively dry habitats (Fig. 6–E).

BIBICE

Sediments filling a pleistocene dry valley occur in Bibice and are developed as loess enriched in lumps of marls in the lower part of the profile (Fig. 1). The Upper Cretaceous marls are visible at the bottom of these sediments (Fig. 7–L).

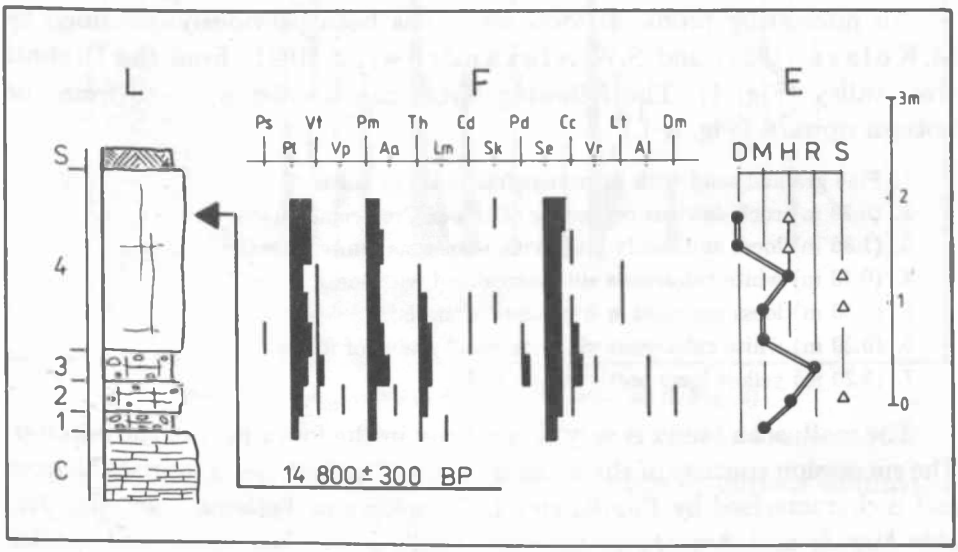

Fig. 7. Profile in Bibice (explanations as in Fig. 2)

1. (0.20 m) rock detritus with loamy matrix.
2. (0.30 m) loess indistinctly laminated with grains of marls.
3. (0.30 m) loess with numerous fragments of marls.
4. (1.40 m) yellow loess abounding in shells of snails.

The molluscan fauna is very rich (Fig. 7–F). The succession begins with an assemblage characterized by *Pupilla muscorum* and *Trichia hispida* passing upward into a fauna consisting of more than ten taxa, including two previously mentioned species. The occurrence of *Columella columella* and *Vertigo parcedentata* such as water molluscs is noteworthy. The third assemblage contains a considerable number of specimens of *Pupilla loessica*,

P. muscorum and *Succinea oblonga elongata*. The last mentioned prevail in the uppermost part of the profile and their shells were dated by the radiocarbon method (S.W. Alexandrowicz 1991).

The presented sequence of assemblages reflects both changes and differentiation of the environment during the deposition of loess. Moderately humid or humid habitats and even temporary water bodies had been developed at the bottom of the valley in the early stage of sedimentation. In the late stage humid environment was still developing at the valley bottom, while dry habitats were widespread on slopes (Fig. 7–E).

MASZKÓW

An interesting profile of loess series has been previously described by M. Kolasa (1963) and S.W. Alexandrowicz (1991) from the Dłubnia river valley (Fig. 1). The following layers can be distinguished from the bottom upward (Fig. 8–L).

1. Fine grained sand with numerous fragments of marls.
2. (0.20 m) rock detritus consisting of Upper Cretaceous marls.
3. (1.30 m) loess and sandy loess with numerous lumps of marls.
4. (0.40 m) white calcareous silt intercalated with loess.
5. (1.00 m) loess enriched in fragments of marls.
6. (0.20 m) white calcareous silt with small grains of marls.
7. (3.20 m) yellow loess partly decalcified.

The molluscan fauna is very rich mainly in the lower part of the outcrop. The succession consists of three assemblages. The first one comprises 15 taxa and is characterized by *Pupilla sterri, P.muscorum, Vallonia pulchella, Trichia hispida* and *Arianta arbustorum*. Shells of the last mentioned species were dated by the C-14 method (S.W. Alexandrowicz 1991). The occurrence of an amphibiotic snail — *Lymnaea truncatula* distinguishes this assemblage from the next one, while other components are nearly the same. The third fauna is dominated by *Pupilla loessica* accompanied by *Pupilla muscorum* and *Succinea oblonga elongata* (Fig. 8–F).

The described succession reflects both changes and the differentiation of the environment during the deposition of loess and the activity of slope processes (solifluction). The valley bottom was still occupied by humid or moderately humid habitats and, in the early stage, also by marshes or temporary water bodies, while on slopes formed of the Upper Cretaceous marls dry and xerothermic habitats existed. In the first stage of the succession ecological conditions were quite favourable for many species of

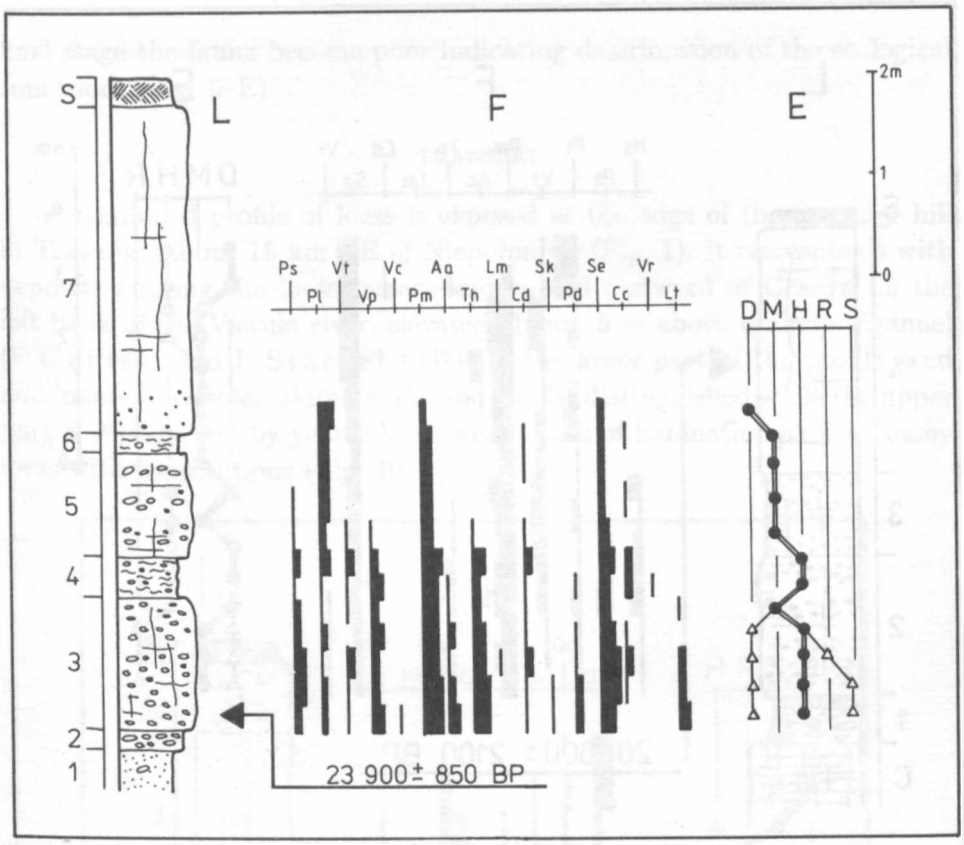

Fig. 8. Profile in Maszków (explanations as in Fig. 2)

snails while in the second stage deterioration of these conditions eliminated a considerable number of taxa (Fig. 8–E).

NIEDŹWIEDŹ

The outcrop is situated in a deep gorge in the southern part of the village Niedźwiedź-Gliniki (Fig. 1). Upper Cretaceous marls are visible in the lowermost part of the profile (Fig. 9–L).

1. (0.80 m) rock detritus with a poor silty matrix.
2. (2.20 m) yellow loess with numerous fragments of marls.
3. (1.30 m) loess laminated with material enriched in lumps of marls.
4. (3.90 m) yellow loess with shells of snails.

An assemblage dominated by shells of *Pupilla muscorum* with an admixture of *Helicopsis striata* and *Vertigo parcedentata* begins the molluscan

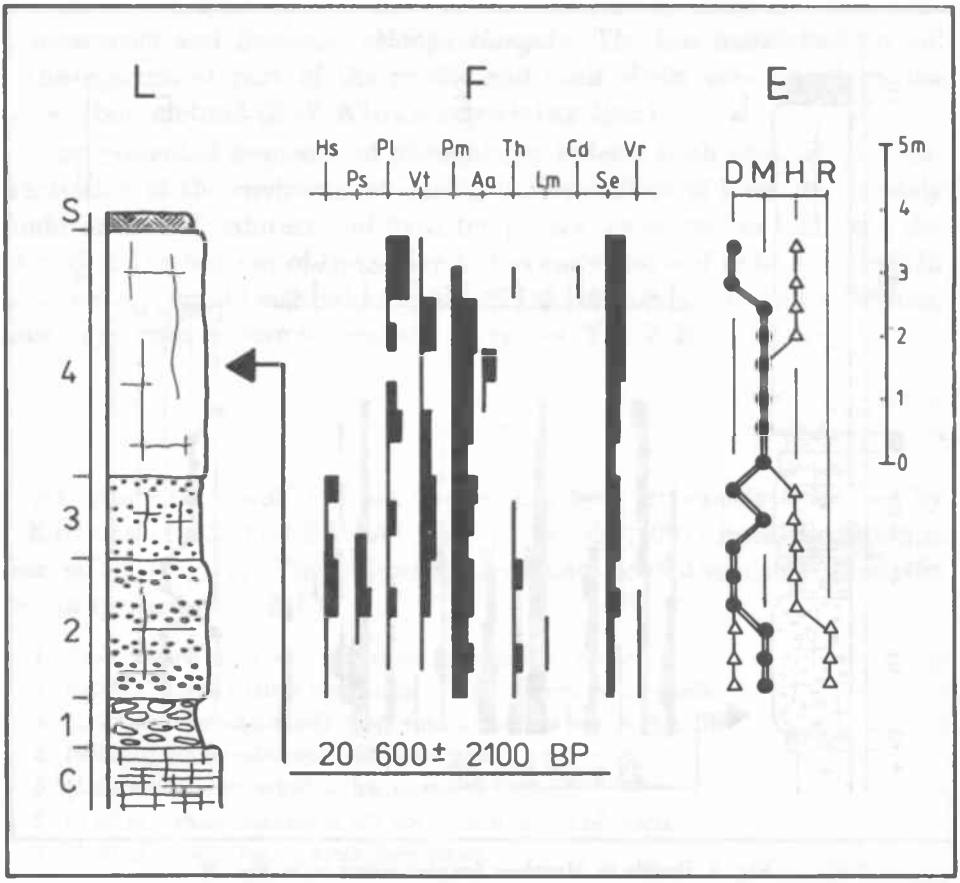

Fig. 9. Profile in Niedźwiedź (explanation as in Fig. 2)

succession. It passes upward into a rich fauna with *Trichia hispida, Helicopsis striata, Pupilla sterri, P.muscorum* and *Vallonia tenuilabris.* The next assemblage is characterized by numerous specimens of *Arianta arbustorum.* Shells of this species were dated by the C-14 method. In the uppermost part of the profile *Pupilla muscorum* and *Succinea oblonga elongata* predominate (Fig. 9–F).

The presented molluscan fauna reflects the differentiation of habitats in particular phases of the deposition of loess. The early stage of the succession is characterized by species connected with dry habitats, moderately humid places and even marshes. The first mentioned snails developed on slopes while the remaining ones — at the valley bottom. The next stage of the sequence corresponds at first with both dry and humid habitats and later — with moderately humid environment, favourable for molluscs. In the

final stage the fauna become poor indicating deterioration of the ecological conditions (Fig. 9–E).

TRAWNIKI

A combined profile of loess is exposed at the edge of the meander hill in Trawniki, about 15 km NE of Niepołomice (Fig. 1). It corresponds with deposits forming the loess terrace widespread eastward of Cracow on the left bank of the Vistula river, elevated about 15 m above the river channel (P. Gębica and L. Starkel 1987). In the lower part of the profile sand and loamy loess intercalated with sand can be distinguished while the upper part is represented by yellow loess with traces of lamination and by loamy loess with convolutions (Fig. 10–L).

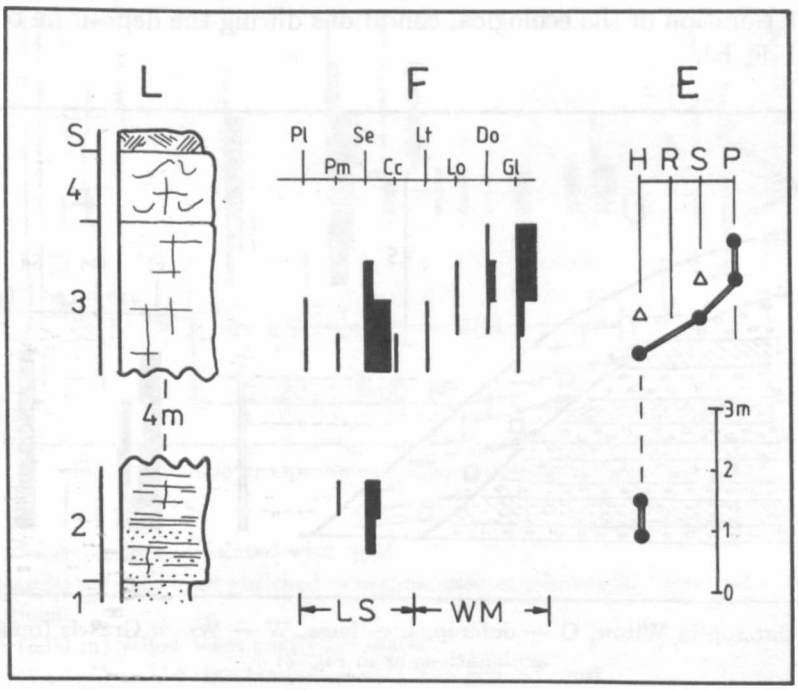

Fig. 10. Profile in Trawniki; LS — land snails, WM — water molluscs (explanations as in Fig. 2)

A poor fauna with *Succinea oblonga elongata* begins the molluscan sequence. It passes into a more rich fauna forming two assemblages (Fig. 10–F). The first of them includes numerous specimens of *Succinea oblonga elongata* being still the main component of the fauna but accompanied by water molluscs typical of temporary water bodies. The second assemblage is clearly

dominated by a water snail — *Gyraulus laevis*, characterizing water basins with a relatively rich vegetation (Fig. 10–E).

WITÓW

An outcrop of loess was found on the eastern side of the gravel pit in Witów. Loess covers a hill formed by early Quaternary gravels described by J. Rutkowski (1987). It is a yellow loamy silt with thin intercalations of sand pinching outside, connected with hillwash (Fig. 11–L). A poor molluscan fauna is visible in this outcrop. In the whole profile two species: *Pupilla loessica* and *Succinea oblonga elongata* predominate. In the lower part they are accompanied by a few other taxa, mainly *Vallonia tenuilabris*, reaching a considerable number of specimens. The sequence reflects progressive deterioration of the ecological conditions during the deposition of loess (Fig. 11–F, E).

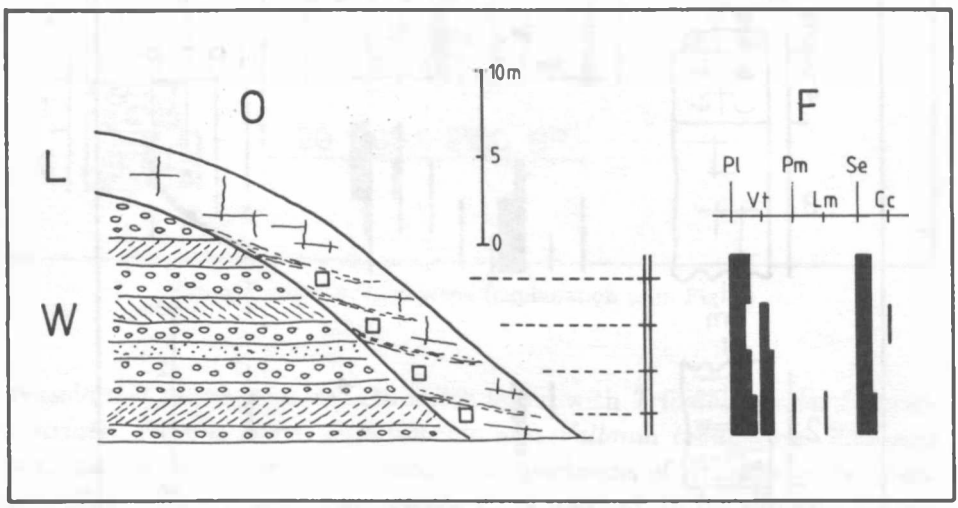

Fig. 11. Outcrop in Witów; O — outcrop, L — loess, W — Witów Gravels (remaining explanations as in Fig. 2)

OPATOWIEC

A profile of deposits forming a large loess terrace developed along the Vistula river valley eastward of Cracow is well visible at Opatowiec, close to the confluence of the Vistula and the Dunajec river (Fig. 1). It was just mentioned by J. Jersak (1973) and previously described by

S.W. Alexandrowicz, J. Jersak (1987). The sequence of layers from the bottom upward is as follow (Fig. 12-L).

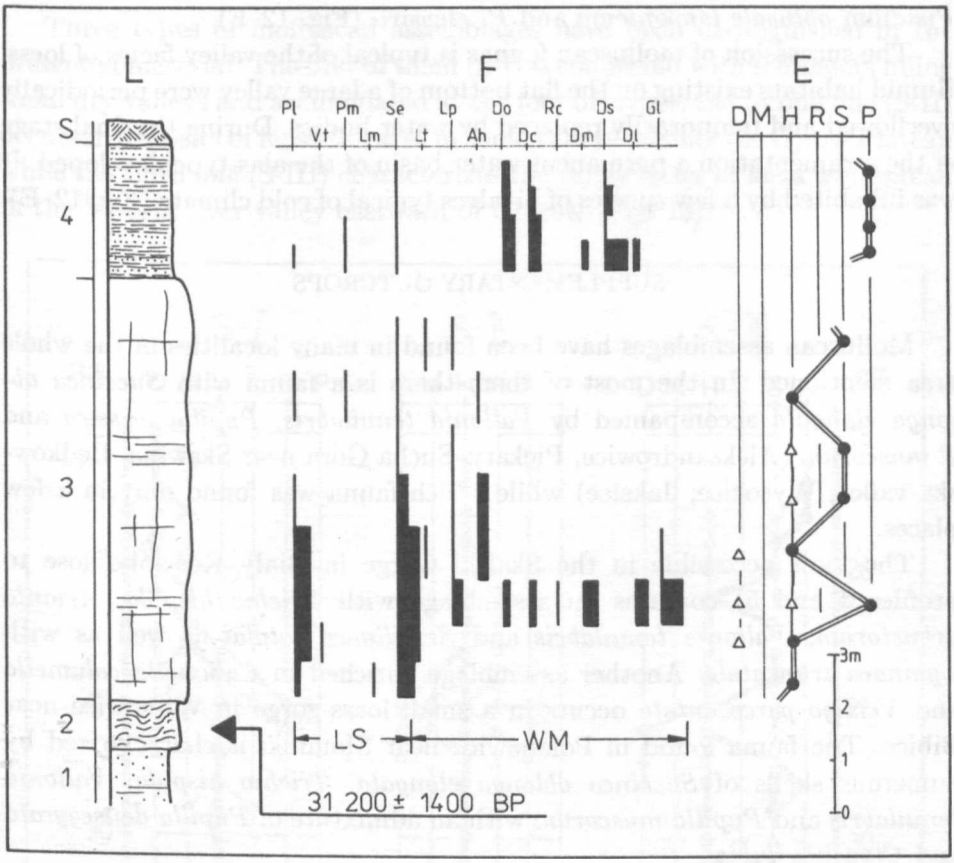

Fig. 12. Profile in Opatowiec (explanations as in Figs. 2 and 10)

1. Sandy loam intercalated with sand.
2. (0.90 m) sandy silt enriched in organic matter (the initial fossil soil) with involutions.
3. (8.00 m) yellow loess partly laminated.
4. (2.60 m) yellow silts laminated with fine grained sand.

The molluscan fauna contains both land and water species. The succession comprises five assemblages. It begins with a *Succinea — Pupilla* fauna dominated by *Succinea oblonga elongata*, devoid of water molluscs. The second assemblage is the richest one. Beside numerous shells of *Gyraulus laevis*, five species of bivalves occur while the two previously mentioned taxa are still represented. A water snail — *Aplexa hypnorum* accompanied by *Succinea oblonga elongata* and *Pupilla loessica* characterizes the third

assemblage while, the next is a poor one. The last fauna found in the upper part of the profile is dominated by water molluscs, mainly by bivalves: *Pisidium obtusale lapponicum* and *P. stewarti* (Fig. 12–F).

The succession of molluscan faunas is typical of the valley facies of loess. Humid habitats existing on the flat bottom of a large valley were periodically overflowed and temporarily replaced by water bodies. During the final stage of the sedimentation a permanent water basin of the alas-type developed. It was inhabited by a few species of bivalves typical of cold climate (Fig. 12–E).

SUPPLEMENTARY OUTCROPS

Molluscan assemblages have been found in many localities in the whole area mentioned. In the most of them there is a fauna with *Succinea oblonga elongata* accompanied by *Vallonia tenuilabris, Pupilla loessica* and *P.muscorum* (Aleksandrowice, Piekary, Sucha Góra near Skawina, Będkowska valley, Wysocice, Jaksice) while a rich fauna was found only in a few places.

The loess accessible in the Skalski Gorge in Biały Kościół (close to profiles 4 and 5) contains an assemblage with *Trichia hispida, Arianta arbustorum, Vallonia tenuilabris* and *Semilimax kotulai* as well as with *Lymnaea truncatula.* Another assemblage enriched in *Columella columella* and *Vertigo parcedentata* occurs in a small loess-gorge in Witkowice near Bibice. The fauna found in Polanowice near Słomniki is characterized by numerous shells of *Succinea oblonga elongata, Trichia hispida, Vallonia tenuilabris* and *Pupilla muscorum* with an admixture of *Pupilla densegyrata* and *Clausilia dubia.*

Several outcrops of loess are known in the Proszowice area. A relatively rich fauna comprising assemblages with *Succinea oblonga elongata, Pupilla muscorum, Vallonia tenuilabris, Arianta arbustorum, Trichia hispida* and *Clausilia dubia* have been found in this region. The mentioned species can be accompanied either by *Helicopsis striata* or by *Anisus leucostomus, Lymnaea peregra* and *L.truncatula.* A fauna enriched in species connected with wet habitats has been found in Kazimierza Wielka. It contains *Succinea oblonga elongata, Columella columella, Vertigo parcedentata, Lymnaea truncatula* and even two species of bivalves: *Pisidium obtusale lapponicum* and *P.stewarti.*

The mentioned molluscan assemblages corresponds with the previously described ones. They confirm the differentiation of the molluscan fauna of the Vistulian loess series connected with mosaics of habitats still existing during the whole interval analysed.

SUCCESSIONS OF MOLLUSCAN ASSEMBLAGES

Three types of molluscan assemblages have been distinguished in the presented material. The first of them (S-I) is connected with sediments filling small dry valleys and accumulated at the foot of slopes, the second one (S-II) occurs in deposits of loess-terraces in some valleys passing the Ojców Plateau while the third one (S-III) characterizes the valley facies of loess widespread in the Vistula river valley eastward of Cracow (Fig. 13).

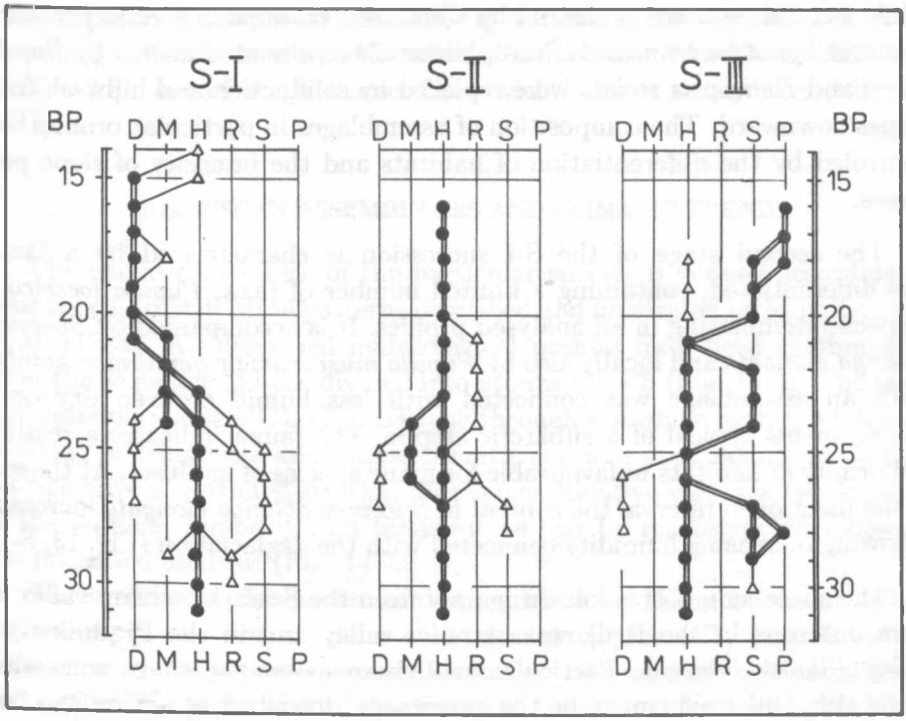

Fig. 13. Successions of molluscan assemblages; BP — age in thousands of years, S-I, S-II, S-III — types of molluscan successions (explanations as in Fig. 2)

The succession S-I is represented in most of the described profiles (Szczyglice, Korzkiew, Januszowice, Bibice). It contains two main elements. The first of them can be related to the late phase of the Interpleniglacial, namely with the interval of 31–22 000 BP, while the second — to the Last Pleniglacial (21–15 000 BP). Particular assemblages comprise species of different ecological groups. Such assemblages can be regarded as allocenoses composed of species living synchronously in habitats distributed close to one another.

During the first stage of the described succession humid and moderately humid environments developed at the bottom of dry valleys and ephemeral water bodies had been among them. The surrounding slopes formed mainly of Jurassic limestones or of Upper Cretaceous marls were covered with dry and xerothermic habitats. Snails typical of woodless humid/moderately humid places are the main components of molluscan assemblages. Such species as *Arianta arbustorum, Trichia hispida, Clausilia dubia* as well as *Pupilla muscorum, Vallonia tenuilabris, Semilimax kotulai* and *Succinea oblonga elongata* were connected with environments favourable for the vegetation, while wet habitats are evidenced by *Columella columella, Vertigo parcedentata* and *Lymnaea truncatula.* Xerophile snails represented mainly by *Pupilla sterri* and *Helicopsis striata* were replaced by solifluction and hillwash from slopes downward. The composition of assemblages in particular profiles was controled by the differentiation of habitats and the intensity of slope processes.

The second stage of the S-I succession is characterized by a fauna less differentiated, containing a limited number of taxa. *Pupilla loessica* is a species dominating in all analysed profiles. It is accompanied by *Succinea oblonga elongata* and locally also by *Pupilla muscorum* or *Semilimax kotulai.* Such an assemblage was connected with less humid or even dry open environments typical of a subarctic steppe. The fauna indicates a relative uniformity of habitats unfavourable for many species of molluscs. At the end of the mentioned interval the content of *Succinea oblonga elongata* increased following increasing humidity connected with the deglaciation (Fig. 13, S-I).

The succession S-II is known mainly from the Szklarka stream valley as from outcrops in the Będkowska stream valley and in the Prądnik river valley (Skalski Gorge). Particular molluscan assemblages are somewhat more rich and uniform as in the previously described sequence and are dominated by species living in humid or moderately humid places. In its early stage the succession is characterized by a fauna with *Succinea oblonga elongata* passing upward into an assemblage enriched in *Pupilla muscorum, Arianta arbustorum* and *Trichia hispida* as well as in an amphibiotic snail — *Lymnaea truncatula.* The occurrence of two taxa connected with temperate climate (*Euconulus fulvus, Vallonia costata*) is noteworthy. In the second stage water snails are replaced by a xerophile species — *Chondrula tridens* and by another species — *Clausilia dubia*, while the third stage is defined by a fauna composed of four species: *Pupilla loessica, P. muscorum, Trichia hispida* and *Columella columella.* This assemblage corresponds with more or less humid habitats still existing on the valley bottom, and with the

development of dry habitats on the surrounding slopes (Fig. 13, S-II). These places can be regarded as refugees for species of limited climatic tolerance.

The succession S-III has been distinguished in the valley facies of loess represented a.o. by the Opatowiec profile. The first stage of this sequence is characterized by a fauna with numerous shells of *Succinea oblonga elongata* accompanied by *Pupilla loessica* and several species of water moluscs. Such an assemblage can be interpreted as a mixocoenose composed of species inhabiting both open environments widespread on the valley bottom and water bodies existing temporarily on the flood plain. In the next stage the fauna is distinctly impoverished, while in the final stage it is replaced by an assemblage of water snails and bivalves. This last mentioned fauna indicates the development of water basins filled with loess or sandy silts (Fig. 13, S-III).

MOLLUSCAN ASSEMBLAGES AND CLIMATIC TRENDS

The climatic tolerance of the particular species is defined according to their specific distribution patterns described and illustrated by M.P. Kerney et al. (1983). All described malacological profiles have been combined to show the sequence of taxa divided into groups C1–C5 (Fig. 14–I). The most cold-tolerant species (C4, C5) continue through the whole profile, while snails living in temperate and boreal climatic zones or even mainly in Central Europe have a restricted stratigraphic range. Relative values of two features of the climate: humidity and temperature can be reconstructed following the presented analysis (Fig. 14–II).

Three climatic phases can be distinguished according to the described sequences. In the first of them cold-tolerant species (C5) prevail but an admixture of snails spread recently up to Central Scandinavia is noted again and again. The percentage of specimens of *Succinea oblonga elongata* ($C5_s$) still exceed those of *Pupilla loessica* ($C5_p$). The mentioned phase corresponds with the interval 32/31–26/25 thousand years BP. A relatively high humidity of the environment and changing but quite low temperatures characterize this period (Fig. 14–II).

The second phase is marked by the occurrence of snails living in Central Europe and reaching South or Central Scandinavia (C2, C3). Termophile snails (C1) occur additionally in a few profiles. The mentioned phase corresponds with the interval 26/25–22/21 thousand years BP. Rich molluscan assemblages connected with a relatively dense vegetation indicate both adequate humidity and warming of the climate (Fig. 14–II). According to radiocarbon dating of shells, the species *Arianta arbustorum* can be

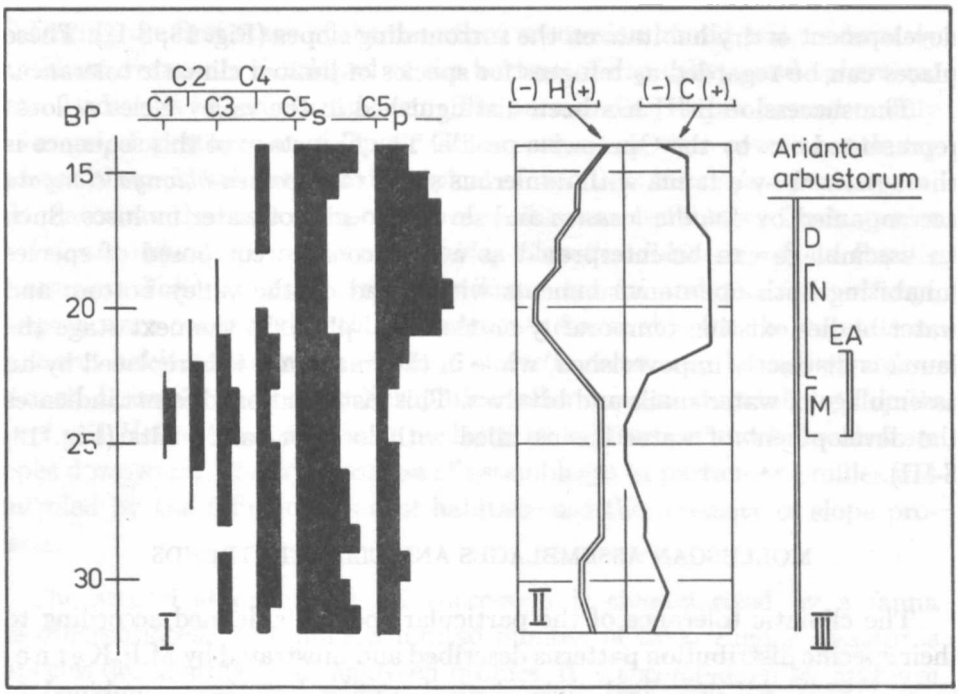

Fig. 14. Climatic interpretation of molluscan assemblages; BP — age in thousands of years, I — stratigraphic range of particular climatic groups of molluscs (C1-C5 — groups of molluscs described in the text); II — changes of the climate: H — humidity, C — cooling; III — dating of molluscan shells (*Arianta arbustorum*): D — ranges of dating, N — shells from Niedźwiedź, M — shells from Maszkow, EA — joint range of dating

pointed out as a noteworthy component of the fauna living in the mentioned interval (Fig. 14–III).

The third climatic phase corresponds with the Last Pleniglacial. Two species of loess snails (C5) clearly predominate in molluscan assemblages. They are accompanied by taxa reaching recently the north polar circle (C4). At the beginning of this phase the content of *Pupilla loessica* ($C5_p$) increases markedly in relation to the content of *Succinea oblonga elongata* ($C5_s$) while at the end an inverse relation between the two mentioned species can be observed. These changes are connected with the Upper Vistulian glaciation and with the invasion of subarctic steppes in the Małopolska Upland. Dry habitats had been widespread rapidly about 22–21 thousand years ago, subsequently to the deterioration of the climate while 5–6 thousand years later the environment became more humid again, following the deglaciation (Fig. 14–II).

Differentiation of molluscan assemblages has been noted in several pro-

files of loess in Europe as indicators of climatic trends (E. Jacobshagen et al. 1963, V. Ložek 1964, 1965, 1976, H. Remy 1968, 1969, J.J. Puissegur 1976, 1978, S.W. Alexandrowicz 1988, 1991). A detailed stratigraphic correlation between the particular profiles and malacological sequences is not advanced enough. On the other hand, the geographical differentiation of the Upper Vistulian faunas can be pointed out between localities from Central and Western Europe as well as from both sides of the Carpathian range. A very limited number of radiocarbon dating of sediments and molluscan shells makes difficulties in comparison of synchronous assemblages. However, a few similarities of molluscan successions can be noted. The fauna of the Last Pleniglacial is in general quite poor and contains only a small number of species, while the sediments deposited just before comprise more rich and differentiated assemblages, characterized by taxa living recently in the temperate climatic zone. Similar species are found in the top part of the profiles as indicators of the deglaciation.

Changes of the climate during the interval 35–15 thousand years BP, reflected by molluscan assemblages, are verified by both palynological analysis and lithological indicators. Three main episodes were distinguished by J. Jersak (1973, 1991), H. Maruszczak (1980) and a few other author. Accordingly, the first mentioned loess series of the Vistulian age deposited in uplands, on slopes and valley terraces can be divided into three parts: the younger loess II A (about 75–35 ky BP), the Komorniki Soil Complex (35–25 ky BP) and the younger loess II B (25–14 ky BP). These lithostratigraphic members have been described by J. Jersak (1973, 1991) in a lot of profiles and localities. The stratigraphic subdivision presented by H. Maruszczak (1980) comprises the younger middle loess (42–33 ky BP), the interstadial soil Gi/LMs or sg-Gi/LMs (33–29 or 32–28 ky BP) and the younger upper loess LMg accumulated during the interval 29/28–12 ky BP (Fig. 15–Str J,M).

More than thirty radiocarbon datings can be quoted to arrange the particular indicators of the climate and environmental conditions (Fig. 15–L-P Ind.). Eight of them refer to sediments of fossil soils (Sl-Os). All but one are connected with the interval 35–23 ky BP including two samples of peat from the outcrop in Kotlarnia (the western margin of the Upper Silesia), two samples of the Komorniki Soil Complex (Opatowiec and Głogówek) and three samples of organic sediments from Podgrodzie, Biskupi Dwór and Kraków–Spadzista Street (J. Jersak et al. 1992). The remaining sample of peat (about 17 ky BP) comes from a profile of the peat-bog Smerek in the Bieszczady Mts (M. Ralska-Jasiewiczowa 1980).

Molluscs-bearing sediments of snail shells were dated in six localities.

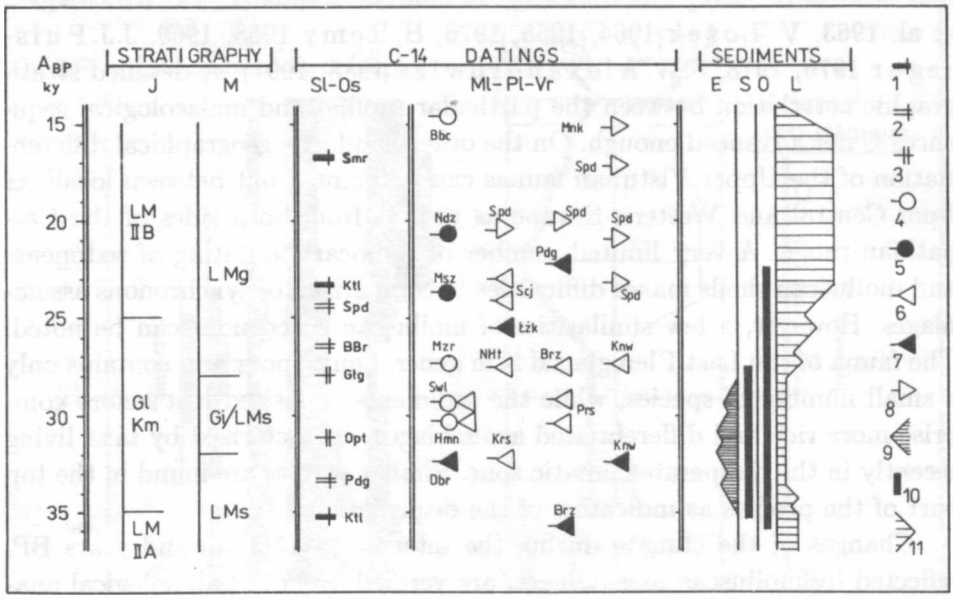

Fig. 15. Changes of sedimentation evidenced by radiocarbon dating. Stratigraphy of loess: J — after Jersak (1973, 1991), LM IIA — younger loess IIA, Gl Km — Soil Complex Komorniki, LM IIB — younger loess IIB; M — after Maruszczak (1980, 1986), LMs — middle younger loess, Gi/LMs — interglacial soil, LMg — upper younger loess. Sl-Os — dating of soil and organic sediments, Ml-Pl-Vr — dating of molluscs, plants and bones of mammals: Smr — Smerek, Ktl — Kotlarnia, Spd — Spadzista Street, BBr — Biskupi Bór, Glg — Głogówek, Opt — Opatowiec, Pdg — Podgrodzie, Bbc — Bibice, Mnk — Mników, Ndz — Niedźwiedź, Msz — Maszków, Scj — Ściejowice, Lzk — Lężek, Mzr — Mizerna, NHt — Nowa Huta, Brz — Brzeźnica, Knw — Kaniów, Swl — Sowliny, Hmn — Humniska, Prs — Pierściec, Krs — Kryspinów, Dbr — Dobra. Stratigraphic range of geological processes: E — erosion; S — forming of soil; O — deposition of organic sediments; L — deposition of loess; 1 — peat, 2 — organic sediments, 3 — fossil soil, 4 — cold-tolerant molluscs, 5 — molluscs of limited climatic tolerance, 6 — tundra, 7 — park tundra, 8 — bones of mammals, 9 — erosion, 10 — soil-forming processes and deposition of organic sediments, 11 — intensity of loess accumulation

Three of them connected with the interval 31–27 ky BP are characterized by a fauna dominated by species tolerating the cold climate and habitats of the tundra-type. In two localities molluscan assemblages dated at 24–21 ky BP comprise a few species of rather limited climatic tolerance (*Arianta arbustorum, Clausilia dubia*). In the remaining locality a fauna with typical loess snails: *Succinea oblonga elongata, Pupilla loessica* and *P.muscorum* corresponds with the age of about 15 ky BP.

Sediments documented by palynological analysis or by plant macrofossils

were dated in 15 localities. Two types of plant communities have been distinguished: one of them — typical of the woodless tundra with a more or less dense vegetation, and the other one — richer, typical of park tundra. The last mentioned is connected with two intervals: 36–31 ky BP and 26–22 ky BP, while during the interval 31–26 ky BP communities indicating quite severe climatic conditions were found (Fig. 15–Ml-Pl-Vr).

Dated sediments with plant remains and shells of molluscs correspond with the decline of the Interpleniglacial. Deterioration of the climatic conditions was not regularly progressive at that time. The Interstadial Denecamp was followed first by a more severe and then by a more mild phase preceding the last coldest period of the Vistulian.

The presented data are supplemented by six datings of bones of big mammals (mammoths), corresponding mainly with the Pleniglacial. Five of them are related to the interval 21–15 ky BP and only one is about two thousand years older (Fig. 15).

The evolution of the climate was responsible for the course of aggradation and denudation. A phase of erosion can be distinguished during the Late Interpleniglacial, and a weakly developed subarctic soil is connected with the same period (J. Jersak 1973, 1991, J. Jersak et al. 1992, H. Maruszczak 1980, S.W. Alexandrowicz 1989). In a few localities organic deposits enriched in plant detritus or even layers of peat have been found (Fig. 15–E-O-S).

During the whole mentioned period the rate of loess accumulation changed markedly. It increased at the termination of the Interpleniglacial. In many places the upper younger loess (loess IIB) underlain by layers enriched in rock detritus, redeposited by solifluction covers Upper Jurassic or Upper Cretaceous marls. This loess is just markedly more widespread than the younger middle/lower loess (loess IIA). It reaches a considerable thickness in comparison to the loess deposited before the Last Pleniglacial (Fig. 15–L).

The molluscan fauna of the Upper Vistulian reflects both the evolution of the climate and the differentiation of habitats developed in the upland with deep narrow valleys of short streams and with river valleys characterized by large terraces. Assemblages dominated by cold-tolerant snails were connected mainly with flat areas, while in the diversified landscape patches of dense vegetation influenced by more favourable mesoclimatic conditions enabled the survival of a few less tolerant species. Such assemblages of molluscs, rich in relation to others, are typical of the Late Interpleniglacial of the Cracow Upland.

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STRESZCZENIE

W okolicach Krakowa znane są liczne odsłonięcia lessów, związanych w większości z okresem ostatniego zlodowacenia. W lessach tych występuje dość bogata fauna mięczaków, obejmująca w sumie 30 taksonów. Zostały one pogrupowane według tolerancji ekologicznej i klimatycznej, co umożliwiło rekonstrukcje zmian warunków środowiska, które następowały w czasie depozycji pyłów eolicznych. W opisanych 11 profilach i 20 odsłonięciach można było wyróżnić trzy typy sekwencji zespołów mieczaków. Pierwsza z nich,

najczęściej spotykana, występuje w lessach wypełniających małe, suche dolinki i rozłogi. Rozpoczyna się dość bogatą fauną, obejmującą gatunki o różnych wymogach ekologicznych, od form kserofilnych do wilgociolubnych, a nawet amfibiotycznych, a kończy fauną ubogą, zdominowaną przez takson wskazujący na suchy i zimny klimat — *Pupilla loessica*. Druga sekwencja malakologiczna odznacza się mniej wyraźnym zróżnicowaniem fauny i dużym udziałem gatunków związanych z siedliskami wilgotnymi (*Succinea oblonga elongata*). Trzeci typ sekwencji został znaleziony w dolinie Wisły poniżej Krakowa; obejmuje on zespoły mięczaków wodnych.

Dzięki licznym datowaniom osadów, a także skorupek mięczaków i kości ssaków, w przedziale czasu obejmującym schyłek interpleniglacjalu i ostatni pleniglacjał (32–15 000 lat BP) wydzielone zostały trzy fazy klimatyczne, odpowiadające przedziałom czasu: 32–25, 25–21 i 21–15 tys. lat BP. W pierwszej panował klimat zimny i dość wilgotny, w drugiej zaznaczyło się słabe ocieplenie i poprawa warunków ekologicznych, a trzecia reprezentuje suchy i surowy, zimny klimat pleniglacjału. W okresie poprzedzającym depozycje lessów młodszych górnych, przypadającym na interpleniglacjał, w tym na Denekamp, w rejonie Krakowa panowały warunki sprzyjające tworzeniu się gleby tundrowej (poziom glebowy Komorniki). Nastąpiła również znaczna intensyfikacja procesów erozyjnych, w wyniku których usunięta została część starszych pokryw lessowych. Dzięki temu lessy młodsze górne (less IIB) leżą w większości profilów wprost na podłożu mezozoicznym, a w początkowej fazie ich depozycji na dużą skalę rozwijały się procesy soliflukcyjne.