Geological Quarterly, Vol. 39. No. 1, 1995, p. 121–144

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Lithology and stratigraphy of Pleistocene loess-like deposits in the Załubińcze section (Nowy Sącz Basin — Outer Carpathians)

Silt loess-like deposits of a considerable thickness occur on the margins of the Nowy Sącz Basin. The most complete section is placed at Załubińcze near the northern border of Nowy Sącz. Palaeomagnetic data, TL dating and the occurrence of palaeosols allow determination of heterochronous parts of the section. The discussed loess-like deposits are covered by fluvial deposits, which can be connected with the South-Polish Glaciation. Three parts: lower, middle and upper have been distinguished in the outcropping silty deposits. Samples with negative magnetic inclination occur in the lower and middle part of the section. The lowermost has been interpreted as the Emperor event and the uppermost as the Biwa II – Chagan event. Furthermore, uppermost samples from the middle part reveal evidence of a palaeomagnetic excursion interpreted as Jamaica excursion (Biwa I ?). TL dating reveals ages between 81 and 411 ka. The deposits represent the San, Wilga, Liwiec, Odra, Vistula glaciations and the Mazovian I and II interglacials. The Warta Stage, Lublin (Zbójno) and Eemian interglacials deposits have not been discerned.

INTRODUCTION

Loess-like clayey-silty deposits from the edges of the Nowy Sącz Basin were described by V. Uhlig (1888), J. Smoleński (1918), M. Klimaszewski (1937, 1948), J. Cegła (1965, 1972), S. W. Alexandrowicz (1987), J. Butrym, W. Zuchiewicz (1985) and W. Zuchiewicz (1985*a*, *b*). In most of the described outcrops sediments lack any fossil content. Only a few profiles from the Carpathians bear malacofauna from the youngest Pleistocene (S. W. Alexandrowicz, 1987; S. W. Alexandrowicz *et al.*, 1991) and their accumulation is connected with so-called younger loesses according to H. Maruszczak (1986). S. W. Alexandrowicz (1987) stated, on the basis of malacofauna investigations, that the clayey-silty sediments were deposited during the last cold period of the Pleistocene in a cold steppe or a steppe-tundra environment. Poorly preserved palaeosol horizons in these sediments are

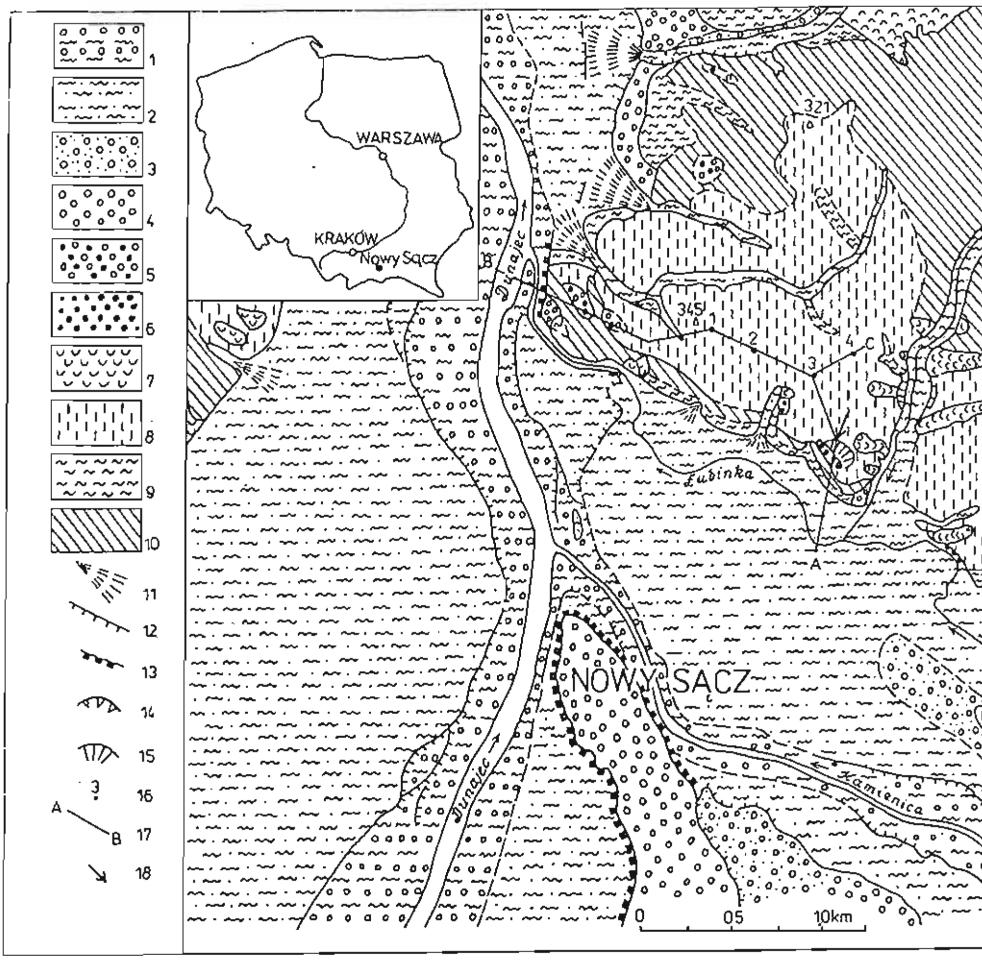


Fig. 1. Map of loess-like deposits distribution in the Nowy Sącz region

1 — clays, sands and gravels of flood terraces, 1–3 m in height; 2 — fluvial clays, muds, sands and gravels of supra-flood terraces with fen soil accumulation, 3–6 m in height; 3 — fluvial clays, sands and gravels of flood terraces, 8–12 m in height; 4 — fluvial clays, sands and gravels of flood terraces, 15–20 m in height; 5 — fluvial clays, sands and gravels of flood terraces, 25–40 m in height; 6 — fluvial clays, sands and gravel of flood terraces, 50–65 m in height; 7 — silts, clays, clays with debris, blocks and rock boulders — landslide colluvia; 8 — silty clays and loess-like muds; 9 — deluvial-solifluction clays, sands and clays with debris; 10 — clays, clays with rock debris of various origin, and outcrops of pre-Quaternary deposits; 11 — alluvial fans; 12 — low fluvial terrace escarpments; 13 — high fluvial terrace escarpments; 14 — rock landslide niches; 15 — brickwork escarpment; 16 — borehole; 17 — line of geological cross-section; 18 — section localization

Mapa rozmieszczenia utworów lessopodobnych w rejonie Nowego Sącza

1 — gliny piaski i żwiry tarasów zalewowych o wysokości 1–3 m; 2 — gliny, mułki, piaski i żwiry rzeczne tarasów nadzalewowych z nadbudową mad o wysokości 3–6 m; 3 — gliny, piaski i żwiry rzeczne tarasów o wysokości 8–12 m; 4 — gliny, piaski i żwiry rzeczne tarasów o wysokości 15–20 m; 5 — gliny, piaski i żwiry rzeczne tarasów o wysokości 25–40 m; 6 — gliny, piaski i żwiry rzeczne tarasów o wysokości 50–65 m; 7 — iły, gliny, gliny z rumoszem, bloki i głazy skalne — koluwia osuwiskowe; 8 — gliny pylaste i mułki lessopodobne; 9 — gliny, piaski

supposed to be Late Glacial (J. Cegła, 1965) or older — interpleniglacial (L. Starkel, 1984). The investigations of M. Krysowska-Iwaszkiewicz and A. Wójcik (1990) in Doły Jasielsko--Sanockie show the complex history of clayey-silty sediments occurring on slopes. They are mainly from the North-Polish (Wisła) Glaciation, and their age has been determined on the basis of the ^{14}C method on organic remains (M. Krysowska-Iwaszkiewicz, A. Wójcik, 1990; T. Gerlach, 1991; T. Gerlach *et al.*, 1993). In the vicinity of Przemyśl (edge of Carpathians), sections with loesses older than the Last Glaciation occur (A. Malicki, 1972; H. Maruszczak *et al.*, 1972; H. Maruszczak, 1991).

A large area of the northern edge of Nowy Sącz Basin is covered by loess-like clayey-silty sediments (Fig. 1), which in some parts reach a considerable thickness — up to 30 m in the vicinity of Podegrodzie (N. Oszczypko, A. Wójcik, 1993). They cover Cretaceous and Tertiary flysch deposits, Miocene marine and fresh-water deposits, as well as Quaternary fluvial deposits (Figs. 2, 3). The best outcrop of these loess-like sediments is placed in the Załubińcze brickyard (Fig. 1), which was described by W. Zuchiewicz (1985*a*) and J. Butrym and W. Zuchiewicz (1985, 1991). On the basis of TL dating, W. Zuchiewicz (1985*a*) assumed that the accumulation of a part of these deposits took place during warmer periods — interglacials, which is in total contradiction with earlier investigations carried out in other parts of the Carpathians (J. Dziewański, L. Starkel, 1967). Palaeomagnetic investigations were made for the upper part of the profile by J. Nawrocki *et al.* (1988). The following years brought further investigations of the discussed section.

LOCALITY AND SECTION CHARACTERISTICS

The exploitation area for the Załubińcze brickworks is situated at the northern border of Nowy Sącz (Fig. 1). Outcropping loess-like clayey-silty deposits have a thickness of 19 m. They occur on a flattened lobe, 320–360 m a.s.l. high, built of Magura sandstones (N. Oszczypko, 1973), covered by Quaternary fluvial deposits of the Łubinka and Dunajec rivers. The flat bottom of Nowy Sącz Basin, covered with various terraces of the Dunajec, Kamienica and Łubinka rivers (Figs. 1–3), is bordered from the northern the steep, by 60–70 m high slope of the lobe. In the southern part of the lobe the investigated loess-like deposits have the largest thickness (Figs. 2, 3). In the vicinity of Roszkowice, thickness ranges between 18 and 21 m. To the north with the rise of the lobe's height, the loess-like deposits' thickness decreases (Fig. 2). The lobe's slopes are also covered with rather thin muds and in many localities the underlying Eocene Magura sandstones are visible. Deluvial muds occur in the lower part of the slope (Figs. 1, 2).

The loess-like deposits' sequence is underlain by a palaeoterrace (Figs. 2, 3) built of muds, sandstones and gravels, mainly sandy with single boulders of granite and quartzite from the Tatra Mts. Alluvial deposits crop out in the bottom of the exploited area and in

oraz gliny z rumoszem deluwialno-soliflukcyjnym; 10 — gliny, gliny z rumoszem skalnym różnej genezy oraz wychodnie utworów przedczwartorzędowych; 11 — stożki napływowe; 12 — krawędzie tarasów rzecznych — niskie; 13 — krawędzie tarasów rzecznych — wysokie; 14 — nisze osuwisk skalnych; 15 — skarpa wyrobiska; 16 — otwór wiertniczy; 17 — linia przekroju geologicznego; 18 — lokalizacja profilu

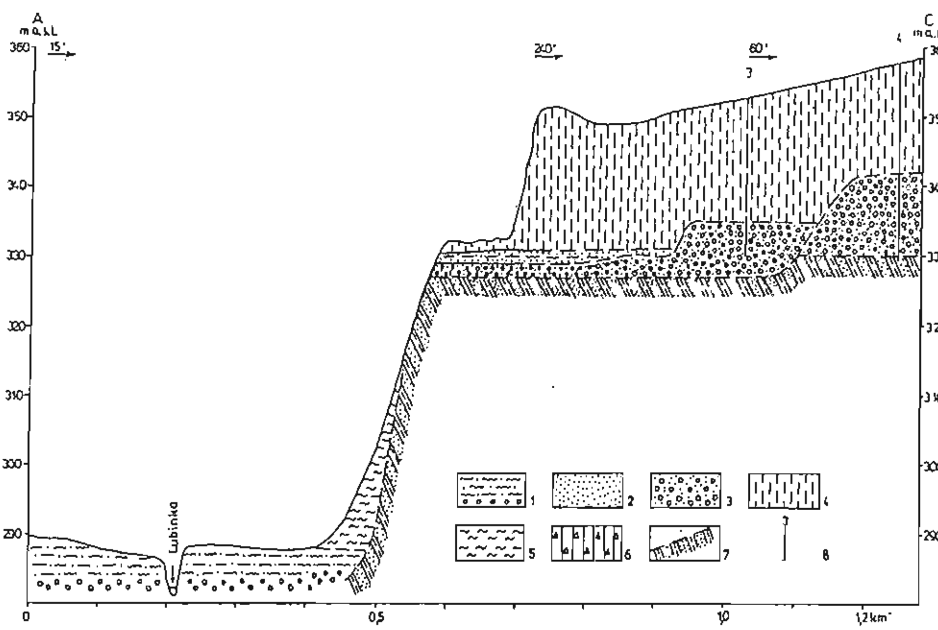


Fig. 2. Geological cross-section A–C

1 — fluvial clays, muds, sands and gravels of present river beds; 2 — fluvial sands; 3 — high fluvial terrace gravels, sands and clays; 4 — loess-like clays and muds; 5 — deluvial clays and sands; 6 — clays and clays with rock debris of various origin; 7 — sandstones and shales of the Magura beds; 8 — borehole section

Przekrój geologiczny A–C

1 — gliny, mułki, piaski i żwiry rzeczne współczesnych den dolin; 2 — piaski rzeczne; 3 — żwiry, piaski i gliny rzeczne tarasów wysokich; 4 — gliny i mułki lessopodobne; 5 — gliny i piaski deluwialne; 6 — gliny i gliny z rumoszem skalnym różnej genezy; 7 — piaskowce i łupki warstw magurskich; 8 — profil otworu wiertniczego

road cuts. The Magura sandstone base lies 55–57 m above the present Dunajec river bed. N. Oszczypko (1973) and N. Oszczypko and A. Wójcik (1992, 1993) associated the accumulation of fluvial deposits with the South-Polish Glaciation, whereas W. Zuchiewicz (1985*a*, 1992) dated this as the Günz Glaciation.

The Załubińcze outcrop is composed of silty deposits, mainly loess-like silty muds and muds and silty clays, yellowish-brown in colour, separated by ashy, grey and ashy-yellow horizons (J. Nawrocki *et al.*, 1988). The dry outcrop wall showed a few lighter horizons, interpreted as fragments of illuvial pedohorizons (N. Oszczypko *et al.*, 1985; W. Zuchiewicz, 1985*a*). The morphological position of these deposits testifies to their aeolian origin. Their occurrence on top of a flattened lobe (Figs. 2, 3) excludes a deluvial origin. Similar outcrops occur in the eastern part of the Carpathians at Orzechowce and Pikulice (A. Malicki, 1972; H. Maruszczak *et al.*, 1972). Their accumulation is connected with colder spells of the Pleistocene. Laboratory tests by J. Cegła (1972) show that loess accumulation depends not only on vegetation cover but also on soil humidity, which had influence on loess sedimentation during the Pleistocene in Poland.

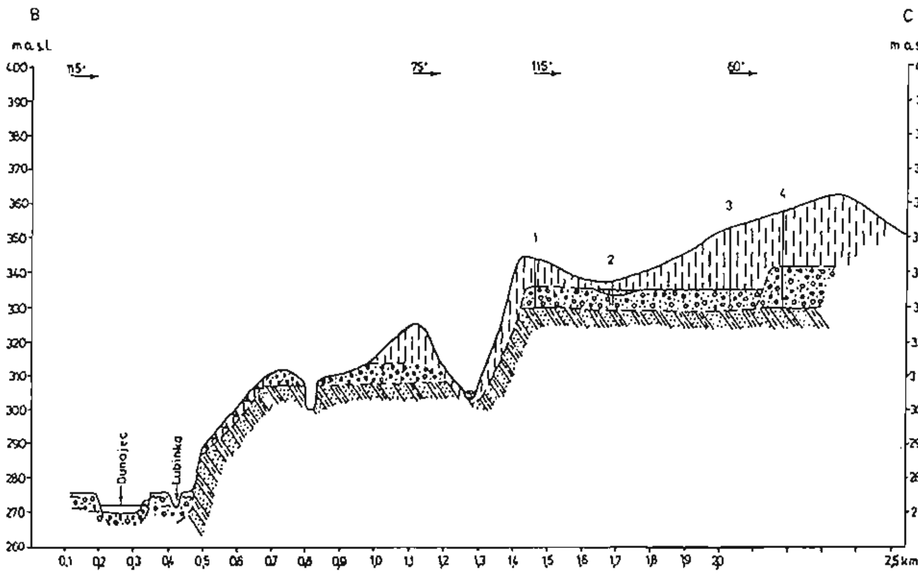
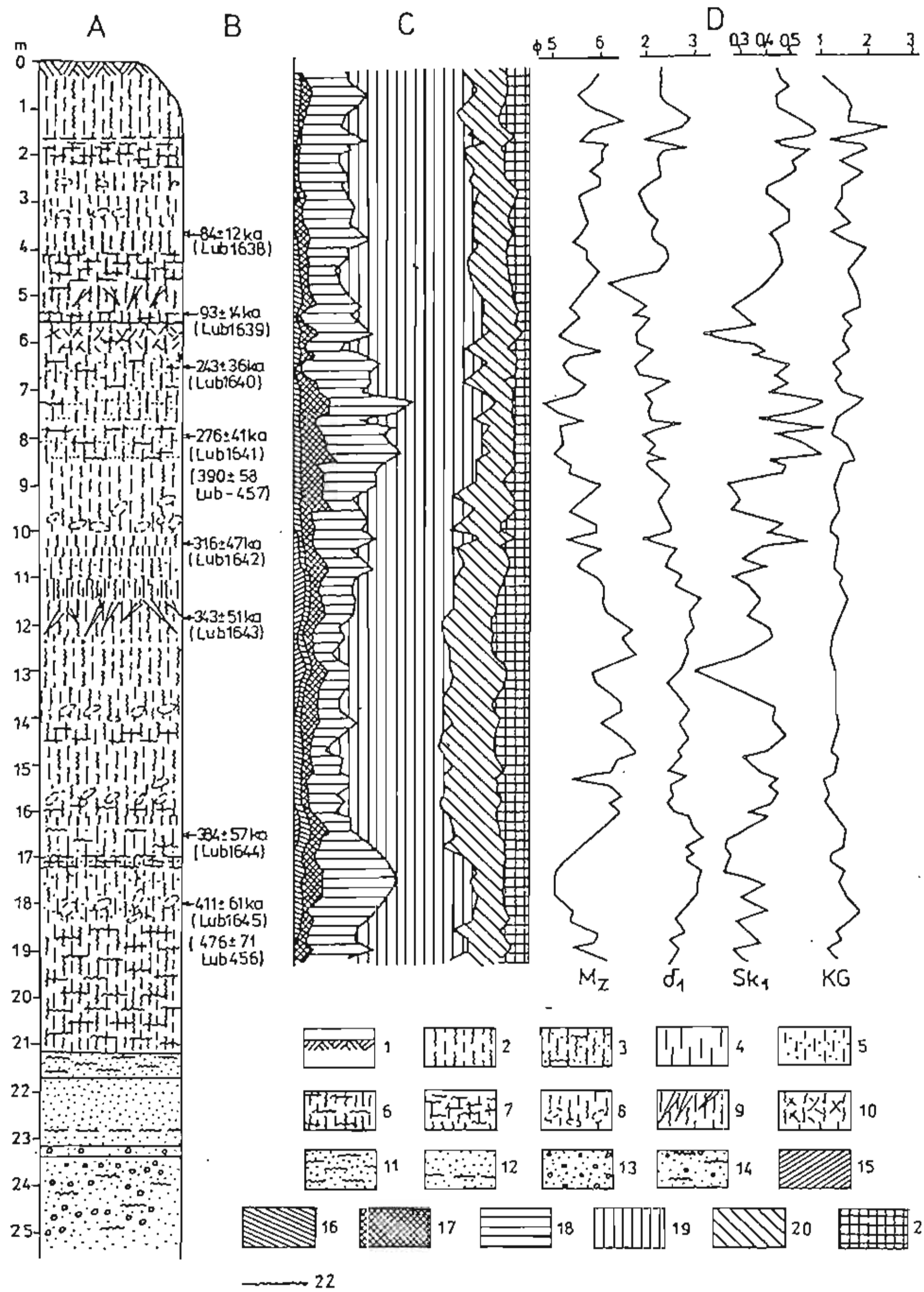


Fig. 3. Geological cross-section B–C
Explanations as in Fig. 2
Przekrój geologiczny B–C
Objaśnienia jak na fig. 2

The discussed section is one of few with loess-like deposits in the Carpathians, recently termed Carpathian loess (T. Gerlach *et al.*, 1993) or mountain — Carpathian loess (H. Maruszczak, 1991), of a considerable thickness and with deposits older than the Last Glaciation. Over a dozen layers varying in characteristics, among them horizons of fossil soil at different stages in the of pedogenetic process, have been distinguished in the section. The latter are partly visible in the outcrop as lighter horizons. The loess-like deposits profile at Załubińcze is as follows:

Depth in metres	Lithologic description
0.00–0.30	Grey clayey soil.
0.30–1.65	Silty loess-like muds, yellow, gradually passing into yellow-brownish with ashen irregular spots. Horizontally stratified below 1.20 m.
1.65–1.80	Silty loess-like muds, dark yellow, distinctly laminated with light yellow silt. Distinct transition in upper part.
1.80–2.30	Silty loess-like muds, dark yellow, partially passing into light brown with poorly visible, irregular lamination (1–5 mm) of light yellow silt and with light brown spots.
2.30–2.76	Silty loess-like muds, light yellow, with single brown spots. Brown silty deposits in lower part (below 2.66 m).
2.76–3.40	Muds and silty loess-like muds, yellow. Below 3.10 m with yellowish-green spots with brown contour (gleyization traces).
3.40–3.66	Silty loess-like muds, ashen-yellow, with poorly visible, discontinuous ashen and brownish-black lamination, and with single concretions.


A
B
C
D
m
84±12 ka (Lub1638)
93±14 ka (Lub1639)
243±36 ka (Lub1640)
276±41 ka (Lub1641)
(390±58 Lub-457)
316±47 ka (Lub1642)
343±51 ka (Lub1643)
384±57 ka (Lub1644)
411±61 ka (Lub1645)
(476±71 Lub456)
Mz
σ1
Sk1
KG
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22

3.66–4.05	Loess-like muds, yellowish-brown, with single concretions (1–3 cm in diameter).
4.05–4.70	Silty loess-like muds, yellow and yellowish-brown, with horizontal light ashen and rusty lamination and with black spots.
4.70–5.24	Silty loess-like muds, brownish-yellow, occasionally with vertical and diagonal narrow ashen spots (root gleyization traces) and with traces of horizontal lamination.
5.24–5.50	Loess-like muds, yellowish-brown, with poorly visible lamination.
5.50–6.20	Silty loess-like muds (in lower part silty-sandy muds), light ashen and yellow, with a mixed block-clotty (marble) structure, with signs of lamination. Distinct upper boundary — erosional surface. Lower part reveals distinct brownish-rusty and ashen lamination. Layer with distinct turbulence occurring as a system of fissures and polygons filled with brown, ashen and rusty silt.
6.20–7.00	Silty and silt-sandy loess-like muds, brownish-yellow, with poorly visible ashen, light brown and rusty lamination and spots, gradual transition.
7.00–7.65	Silty loess-like muds, light yellow with nests of clayey sand.
7.65–7.70	Silty loess-like muds, light brown.
7.70–8.30	Silty-sandy loess-like muds, yellow, laminated with dark yellow aleuritic sand. Single ashen and rusty spots below 8.00 m.
8.30–8.60	Silty-sandy loess-like muds, yellow. Distinct transition. Occasionally, poorly visible lamination.
8.60–9.95	Silty and silty-sandy loess-like muds, yellowish-brown with delicate horizontal lamination in the upper part (up to 8.57) and light ashen spots in the lower part (gleyization traces) and black spots (manganese?).
9.95–10.28	Silty muds and loess-like muds, light yellow with black spots.
10.28–10.55	Silty muds and silty-sandy loess-like muds, greyish-yellow, with brownish-black and blackish-grey spots (humus) and rusty lamination in the lower part.
10.55–10.97	Silty-sandy loess-like muds, yellowish-grey with black spots.
10.97–11.40	Silty muds and silty-sandy loess-like muds, grey with black spots.
11.40–12.20	Silty muds and silty-sandy loess-like muds, dark yellow, with diagonal narrow light ashen spots resembling a root system (root gleyization?).
12.20–13.20	Silty muds and silty-sandy loess-like muds, yellowish-brown and brownish with black spots, lighter in the lower part (below 12.50 m).
13.20–13.95	Silty muds and silty-sandy loess-like muds, brownish-yellow with ashen spots in the lower part.
13.95–14.45	Silty-sandy loess-like muds, yellowish-brown with poorly visible ashen lamination.

Fig. 4. Załubińcze loess-like deposits section

A — lithology and structure: 1 — recent soil, 2 — loess-like silty muds, 3 — loess-like muds with stripes or nests of silty sand, 4 — loess-like silty clays, 5 — sandy clays, 6 — clays, 7 — loess-like muds or silty clays with stripes or lamination, 8 — gleyization, 9 — root gleyization, 10 — loess-like muds with a block-clotty structure, 11 — clayey sands, 12 — sands, 13 — sands with gravels, 14 — rounded boulders and fluvial gravels with sandy clay; B — TL datings in ka (dates from J. Butrym and W. Zuchiewicz (1985) are given in brackets); C — grain composition of deposits (diameter of grains in millimetres): 15 — > 0.5, 16 — 0.5–0.25, 17 — 0.25–0.1, 18 — 0.1–0.05, 19 — 0.05–0.01, 20 — 0.01–0.0013, 21 — < 0.0013; 22 — discontinuity surfaces — larger stratigraphic hiatuses; D — diversion of grain indexes in vertical section after formulas by R. L. Folk and W. C. Ward: *Mz* — median grain diameter, δ_1 — standard deviation, Sk_1 — kurtosis index, *KG* — graphic flattening

Profil utworów lessopodobnych Załubińcze

A — litologia i struktura: 1 — gleba współczesna, 2 — mułki ilaste lessopodobne, 3 — mułki lessopodobne ze smugami lub gniazdami piasku pylastego, 4 — gliny pylaste lessopodobne, 5 — gliny piaszczyste, 6 — gliny, 7 — mułki lub gliny pylaste lessopodobne, smugowane lub laminowane, 8 — oglejenie, 9 — oglejenie pokorzeniowe, 10 — mułki lessopodobne o strukturze bloczkowo-gruzełkowej, 11 — piaski zaglinione, 12 — piaski, 13 — piaski ze żwirami, 14 — obtoczone głaziki i żwiry rzeczne z gliną piaszczystą; B — datowania termoluminescencyjne w ka BP (w nawiasach podano daty z pracy J. Butryma i W. Zuchiewicza, 1985); C — skład ziarnowy osadów (średnice ziarn w milimetrach): 15 — > 0,5, 16 — 0,5–0,25, 17 — 0,25–0,1, 18 — 0,1–0,05, 19 — 0,05–0,01, 20 — 0,01–0,0013, 21 — < 0.0013; 22 — powierzchnie nieciągłości — większe luki stratygraficzne; D — zmienność wskaźników uziarnienia w profilu pionowym według wzorów R. L. Folka i W. C. Warda: *Mz* — średnia średnica ziarna, δ_1 — odchylenie standardowe, Sk_1 — skośność graficzna, *KG* — spłaszczenie graficzne

14.45–15.27	Silty loess-like muds, yellow with black spots, occasionally with sand admixture.
15.27–15.98	Silty loess-like muds, yellow with ashen, ashen-black and greyish-brown lamination and spots in the upper part (up to 15.32 m). Deposit lighter in colour in the lower part with ashen spots (gleyization traces) and ashen lamination.
15.98–16.30	Silty muds and silty-sandy loess-like muds, brown, in lower part light brown.
16.30–16.85	Silty loess-like muds, light yellow with black spots (manganese spots?) and poorly visible rusty and brownish lamination. Gradual transition.
16.85–17.10	Sandy-silty loess-like clays, yellow with distinct brown and rusty lamination.
17.10–18.28	Silty clays and sandy-silty loess-like muds, yellowish-brown with nests and spots, ashen with a rusty border (gleyization traces).
18.28–18.40	Silty-sandy loess-like muds and silty clays, ashen, with rusty lamination, sediment yellowish-rusty in lower part.
18.40–21.00	Silty loess-like muds and silty clays, yellowish-grey with ashen lamination, occasionally sandy.
21.00–21.50	Sandy clays, yellowish-ashen.
21.50–22.60	Poorly sorted sand, yellow.
22.60–22.70	Sandy clays, ashen-yellow.
22.70–23.00	Coarse-grained sand, yellow.
23.00–23.20	Sand with fine gravel.
23.20–25.00	Rounded boulders and gravels of flysch sandstones and crystalline rocks from the Tatra Mts., with clayey sand.

The described loess-like section can be divided into three parts on account of distinct erosional surfaces and pedohorizons: upper, middle and lower. The border between the upper and middle parts of the section lies at a depth of about of 5.5 m, and between the middle and lower parts of the section at about 11 m.

INVESTIGATION METHODS

Palaeomagnetic methods were used to determine the stratigraphic position of the discussed sediments. Palaeomagnetic data was correlated with the standard magnetic polarity scale. While analysing changes in palaeodeclination and palaeoinclination, the reconstruction of the environment of sedimentation was also pursued (J. Nawrocki *et al.*, 1988). The whole 19 m thick section was continuously sampled, giving a total of 573 samples oriented towards magnetic north. Samples were demagnetized using an alternating magnetic field of 23 mT intensity. The optimal demagnetising field intensity value was determined by gradual and complete demagnetization of 20 random samples. Thermomagnetic analyses of samples reveal that magnetite is the main magnetization carrier in the discussed sediments. Magnetic susceptibility was also measured in all of the collected samples. The section was also tested for granulometric composition using the aerometric method on 96 samples collected directly from the outcrop down to 19.1 m, as well as for organic C and calcium carbonate. TL dating in the Lublin laboratory was done twice, before only first time (J. Butrym, W. Zuchiewicz, 1985). Results of these datings gave an age very much earlier in comparison to the result obtained in this paper (Fig. 4). The reliability of the method (H. Maruszczak, 1991) and of the obtained results is an open matter. New TL datings for this section are comparable to results from similar aeolian deposits in Poland (H. Maruszczak, J. Nawrocki, 1991) and are consistent with absolute datings of palaeomagnetic events within Quaternary marine deposits (U. Bleil, G. Gard, 1989).

GRANULOMETRIC ANALYSIS RESULTS

In vertical section the granulometric composition of the discussed sediment does not vary distinctly (Fig. 4). The sediment can be referred to as loess-like silty muds and silty-sandy muds as well as silty clays, or according to pedologic terminology — clayey dust and silty dust, occasionally clayey sand. The aleuritic fraction (0.05–0.01 mm) dominates in the whole section (31 to 57%). For typical loesses the aleuritic fraction content is 30–50% and according to A. Malicki (1967) the content of 0.05–0.02 fraction should go up to 50–60%. The greatest variability occurs within the sand fraction. Content of this fraction within the section distinctly increases between 7 and 9.6 m depth, 10 and 14 m depth and below 16.5 m (Fig. 4). On the other hand the finest silt fraction (< 0.0013 mm) content is constant, only in the lower part of the section is there a slight increase in grains from 0.01–0.0013 mm in diameter.

Four main granulometric indices were calculated after formulas by R. L. Folk and W. C. Ward (*fide* E. Rühle, 1973; E. Mycielska-Dowgiałło, 1980). The median grain diameter (*Mz*) for the upper part of the section varies from 5.5 to 6.0 Φ and tends to decrease with depth to 7.4 m where it amounts to 4.7 Φ. Below that depth *Mz* values increase, which means that the grain diameter decreases. For the depths 12.7 and 14.7 m, the largest *Mz* values were calculated 6.7 Φ. Between 11 and 16 m from the surface occur sediments with grain diameter below 6 Φ. In the lower part the median diameter (*Mz*) again increases up to 5 Φ. These results indicate a larger fine material content in the sedimentation of this loess-like section. In parts with palaeosol horizons a relative increase of *Mz* values can be observed (Fig. 4), which can be connected with a decrease of transportation energy or with chemical decomposition of host rock in consequence of pedogenetic processes. Grain composition, as well as calculated median grain diameter (*Mz*) in the section, are close to typical loesses.

Graphical standard deviation index (δ_1), which numerically represents sediment sorting (R. Gradziński *et al.*, 1976), for the discussed section varies from 2 to 3, which means that the sediment is poorly sorted (Fig. 4). A low sorting index for aeolian sediments is possibly connected with varying dynamics in the depositional environment and with a nearby source of material. Slight differences are visible in the discussed profile within the upper and lower part. The δ_1 value tends to increase with depth. For the upper part, δ_1 values are within 2–3, at the same time tending to decrease with depth. The lowest δ_1 value, 1.1, was obtained for samples from 4.8 m. Below that δ_1 ranges from 2.5 to 3.2. On the basis of calculated standard deviation it can be stated that the worst sorting occurs in the lower part of the section. Lower values of δ_1 for the middle part of the section testify to better sorting and possibly indicate long transport from distant source areas. According to R. Racinowski and T. Szczypek (1985) standard deviation for loesses is between 1–2. The trend of *Mz* and δ_1 change through the section is similar, especially in the middle part (Fig. 4), which suggests an interdependence of both parameters.

Skewness index (Sk_1) for loess-like deposits in the section is positive, and shows predominance of finer fraction over coarse-grained fraction (Fig. 4). Obtained results are usually over 0.3. Kurtosis index (*KG*) ranges from 1 to 2 and indicates a leptokurtosic distribution with a monofraction gradation arrangement. The highest values were calculated for the upper part of the section, the lowest for the lower part. High kurtosis index values are supposed to indicate a monopopulation system (E. Mycielska-Dowgiałło, 1980). Most

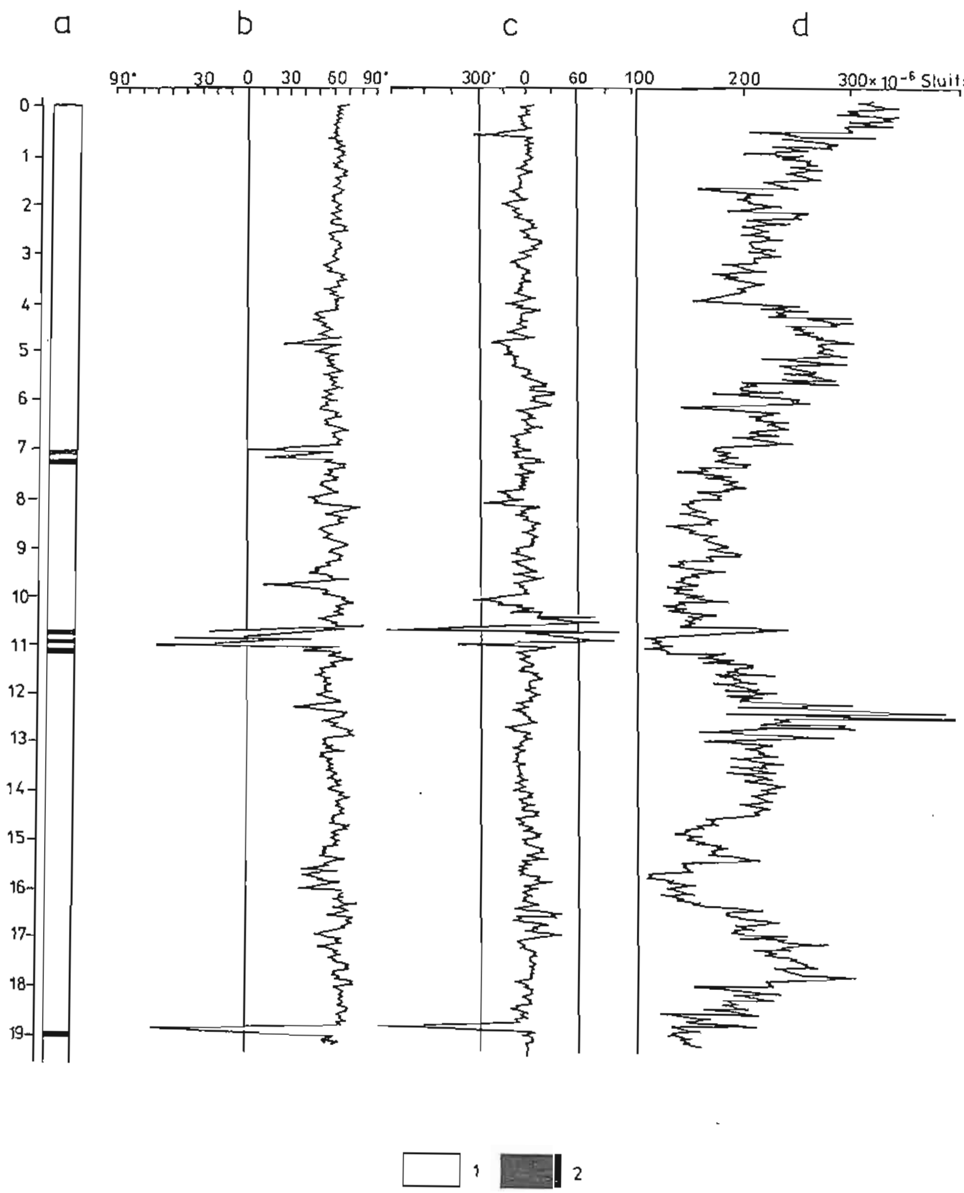


Fig. 5. Palaeomagnetic data for Załubińcze section

a — magnetic polarity: 1 — normal, 2 — reversed; b — palaeomagnetic inclination; c — palaeomagnetic declination; d — magnetic susceptibility

Dane paleomagnetyczne dla profilu Załubińcze

a — polarność magnetyczna: 1 — normalna, 2 — odwrotna; b — inklinacja paleomagnetyczna; c — deklinacja paleomagnetyczna; d — podatność magnetyczna samples from the section reveal a unimodal frequency curve. In most cases the modal value occurs in the aleuritic fraction, with a maximum at 5 Φ diameter. Occasionally in the middle part of the section a second mode for the fraction 7–7.5 Φ appears. A monomodal gradation arrangement with sharp peaks indicates an aeolian origin of sediments. If the section included sediments of a different genesis, i.e. deluvial clays or solifluxion clays, the frequency curves would be polymodal, and the modal values would have varied (M. Krysowska-Iwaszkiewicz, A. Wójcik, 1990). The middle part of the section differs from the lower and upper parts of the section on gradation index charts.

PALAEOMAGNETIC RESULTS

Palaeomagnetic analysis of the discussed section shows two places with reversed magnetization (Fig. 5). Polarity reversal of the geomagnetic field has been noted at depths between 10.75 and 11.1 m and between 18.9 and 19 m. The upper episode occurs in the upper part of the palaeosol horizon, which is the best developed pedohorizon in the section, and in the overlying layer. The episode is threefold (Fig. 5) and can be compared to similar episodes within Quaternary deposits. It has been interpreted as the Biwa II – Chagan – Dniepr episode. This is testified by the multipartite character of the discovered inversion (Fig. 6), not exactly opposite position of inversion palaeopoles (A. N. Tretjak, 1983; F. Wiegank *et al.*, 1990), as well as occurrence within both warm and cold climate deposits. It has to be stated that the age of this episode is questionable. Sea logs from the Norwegian-Greenland Sea yield an inversion, connected by U. Bleil, G. Gard (1989) with the nearest palaeomagnetic event Biwa II (dated in Japan at 292–298 ka, N. Kawai *et al.*, 1972) — Fig. 6 — which in turn is dated at 318–347 ka in the Norwegian-Greenland Sea and correlated with the 9/10 oxygen horizon. On the other hand, in Eastern Europe the Chagan – Dniepr event is TL dated at 240–280 or 270–300 ka (Fig. 6, A. N. Tretjak, 1983; F. Wiegank *et al.*, 1990). TL date for the Załubińcze section, between 316 and 343±51 ka (Fig. 6), are very much closer to Norwegian-Greenland Sea date obtained by U. Bleil, G. Gard (1989). Similar results have been obtained for a soil with palaeopole inversion in its upper part when compared to results in interglacial soil from Nieledew (TL age 341–327 ka) (J. Butrym, H. Maruszczak, 1983; H. Maruszczak, 1986; H. Maruszczak, J. Nawrocki, 1991). In the Nieledew section H. Maruszczak (1986) places the Chagan palaeomagnetic event above the palaeosol from the Mazovian Interglacial. Similar to its position in the Załubińcze section, the palaeomagnetic event within the loesses occurs in the Korolevo section (Ukraine) and, dated at about 360 ka, is correlated with the Biwa II event (G. A. Pospelova, 1990; O. M. Adamenko *et al.*, 1987, 1989). Furthermore, in Ukraine and Moldavia, within the loess-palaeosol complex, A. N. Tretjak (1983) distinguishes a *y*-zone, dated 315–350 ka, which is correlated with the Biwa III event (F. Wiegank *et al.*, 1990).

Inversion in the lower part of the section is much more difficult to interpret. It is situated below the 411±61 ka date (Figs. 4, 5). It is older than the Biwa III inversion and can be connected with the Emperor event dated by U. Bleil and G. Gard (1989) at 470–484 ka (Fig. 6) and linked with the 12 or 12/13 oxygen-isotope horizon. On the other hand, F. Wiegank *et al.* (1990) date the Emperor event at 410 ka, setting the Eluniano V event at 470 ka (Fig. 6).

Besides parts with inverse magnetization, several places with significant variation of inclination values, compared to values characteristic for the Quaternary dipole field, occur within the section. The most important magnetic field excursion has been recorded at a depth of 7.1–7.3 m. The magnetic inclination value drops down to 0° here (Fig. 5). In deposits younger than 300 ka this magnetic event, bearing the characteristics of a magnetic excursion, has been noted in the Greenland Sea between 180 and 200 ka and termed the Biwa I excursion (U. Bleil, G. Gard, 1989) or Jamaica excursion (J. P. Valet, L. Meynadier, 1993). H. Maruszczak (1991) places the Jamaica excursion in the lower part of the younger loesses and in the lower part of the palaeosol from the Lublin Interglacial. A palaeomagnetic event, TL dated at 220–260 ka in the Korolevo section (G. A. Pospelova, 1990) and termed the Jamaica excursion, occurs in a similar stratigraphic position as in the Załubińcze section. In the latter, the recorded magnetic excursion is TL dated at 220–270 ka (243±43 and 276±41 ka — Figs. 4, 7) and is closest to events known as Jamaica excursion — Biwa I. The palaeomagnetic event in this interval noted in some loess sections of the Ukrainian Carpathians is known as the Chagan – Dniepr event, whereas in other localities this event has been dated as much older (G. A. Pospelova, 1990).

Record of palaeodeclination and palaeoinclination changes within the discussed section reveals a number of discontinuities. Obtained data show that the sedimentation of the disussed sediments was not continuous. The middle part of the section has a particularly large number of discontinuities. Sedimentation continuity can be observed only in small sections where the values of declination and inclination gradually rise describing secular variation loops. In the discussed section, larger sedimentation gaps are visible as distinct changes of declination and inclination values, i.e., in the upper part between 4.5 and 4.7 m, and below that at 7.0, 8.3, and 12.4 m of depth (Fig. 5). One of the larger sedimentation gaps has been recorded at a depth of 5.5 m, estimated to last between 100 and 150 ka. At this point inclination has a distinct transition, and declination value is between 10 and 30°, while above it ranges between 300 and 310° (Fig. 5). The latter testifies to different magnetic field direction during the accumulation of underlying deposits. In other parts of the section other abrupt changes in the inclination record indicate sedimentation gaps, reaching up to 30 in number.

Climatic conditions and depositional environment can be determined by examining magnetic susceptibility (J. Nawrocki, 1990, 1992; H. Maruszczak, J. Nawrocki, 1991). For Chinese loesses, increase of magnetic susceptibility is connected with a break in accumulation and soil formation in warm climate conditions (G. Kukla *et al.*, 1988). Fossil soils within Alaskan loesses have a low magnetic susceptibility (J. Beget, 1990; J. Beget *et al.*, 1990), whereas much higher values have been noted in colder spells of loess accumulation. In our study section, part of pedohorizons have much lower magnetic susceptibility values than the underlying loesses. The lowest values have been noted in the upper part of palaeosol occurring at 11–12 m of depth (Fig. 5). In zones of silty clay and silt occurrence where no palaeosol traces have been recorded, susceptibility values are the highest (Fig. 5). The magnetic susceptibility record here is more similar to the record of J. Beget (1990) for Alaskan loesses. It is worth noting that the largest stratigraphic gap within the Załubińcze section occurs in a similar position on the susceptibility chart as in the stratotype section in Nieledew (see: H. Maruszczak, J. Nawrocki, 1991). This testifies to a relatively correct TL dating.

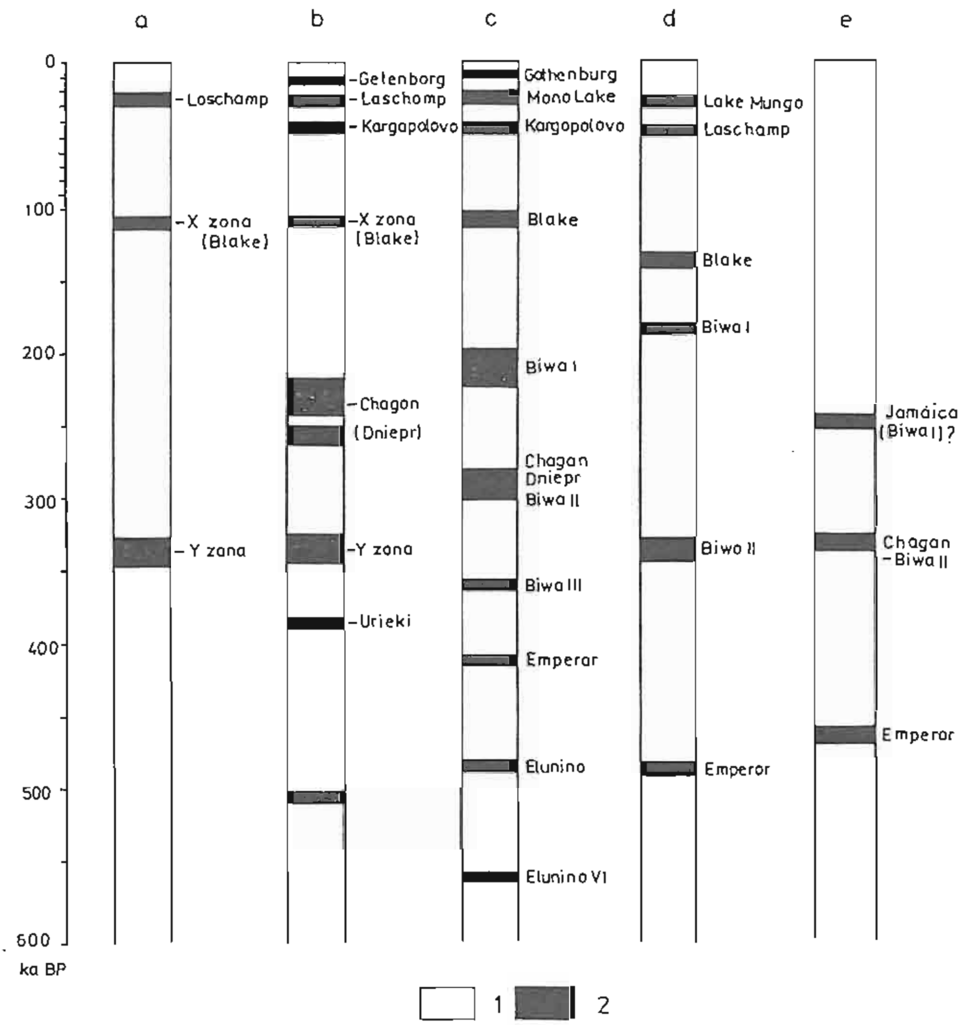


Fig. 6. Occurrence of palaeomagnetic events during the last 600 ka after various authors

a — after A. Cox (1969); b — after A. N. Tretjak (1983); c — after F. Wiegank *et al.* (1990); d — after U. Bleil and G. Gard (1989); e — palaeomagnetic events and excursions recorded in the Załubińcze section; magnetic polarity: 1 — normal, 2 — inversed

Występowanie zdarzeń paleomagnetycznych w czasie ostatnich 600 ka według różnych autorów

a — według A. Cox (1969); b — według A. N. Tretjaka (1983); c — według F. Wieganka i in. (1990); d — według U. Bleila i G. Garda (1989); e — zdarzenia i wycieczki paleomagnetyczne zarejestrowane w profilu Załubińcze; polarność magnetyczna: 1 — normalna, 2 — odwrotna

STRATIGRAPHY OF THE ZAŁUBIŃCZE SECTION IN LIGHT OF GEOLOGICAL AND GEOPHYSICAL DATA

Stratigraphic interpretation of the outcropping section is difficult because of lack of organic remains. Its stratigraphic position has been determined jointly with aid of palaeomagnetic studies and TL date. With reference to studies of palaeosols in loess covers (J. Jersak, 1976; H. Maruszczak, 1976; J. E. Mojski, 1965) it is assumed that fossil soils developed each time during warmer spells of interglacials or interstadials before loess accumulation. Loess accumulation on the other hand took place during cold and cool periods. Silty deposits were captured by vegetation, i.e., arctic moss (J. Jersak, 1965), or on damp surfaces (J. Cegła, 1972). Figure 7 shows an attempted stratigraphic subdivision of the discussed section.

The lower part occurs between the 11 and 21 m depths, the lowest part of which (below 19.3 m) is known from a borehole in the bottom of the outcrop. It is topped by a palaeosol horizon and palaeomagnetic event Biwa II (Chagan – Dniepr ?), while the lower part is built of fluvial deposits from the South-Polish Glaciation (San II). Fluvial deposits from the vicinity of Brzeźna, occurring in a similar position over the Dunajec river as the ones in Załubińcze (Fig. 2), have been TL dated at 470–516 ka (J. Butrym, W. Zuchiewicz, 1991). Glacial deposits connected with maximum expansion of the Scandinavian glacier in the Carpathians and their foreland were TL dated at 490–580 ka (J. Wojtanowicz, 1985; J. Butrym, T. Gerlach, 1985; J. Nitychoruk, 1991). Rocky-accumulation terraces in the Nowy Sącz Basin occurring at 45–60 m over the present Dunajec river bed are most probably connected with this time interval.

Over half of the outcropping sediments occurring on alluvial deposits correspond to oldest loesses (LN) according to terminology of H. Maruszczak (1986). The discussed lower part of the section between 343–411 ka (476 ka according to J. Butrym and W. Zuchiewicz, 1985) corresponds in older terms to the Great Interglacial (E. Rühle, 1973; S. Z. Różycki, 1978) and includes oxygen stages (^{18}O) from 12 to 9 (N. J. Shackelton, N. G. Opdyke, 1973).

In the lowest part of the discussed section, 3.9 m thick loess-like deposits occur on fluvial deposits. They are composed of silty clay and silty-sandy mud, yellow with ashen, yellowish-rusty and rusty lamination. A layer of brownish-yellow clays with ashen spots with rusty borders occurs at a depth 17.10–18.28 m from the surface and indicates pedogenetic processes (Figs. 4, 7). This poorly pronounced pedohorizon bears signs of pseudogleyization. It is covered by 1.83 m thick, yellow, silty clays and loess-like muds with rusty-brown and ashen lamination and brown, silty muds to 15.27 m from the surface. This series has been TL dated at 384±57 ka. It seems that accumulation of these sediments took place in damper conditions, which is pointed out by a more frequent occurrence of rusty lamination and a decrease in magnetic susceptibility values (Fig. 5).

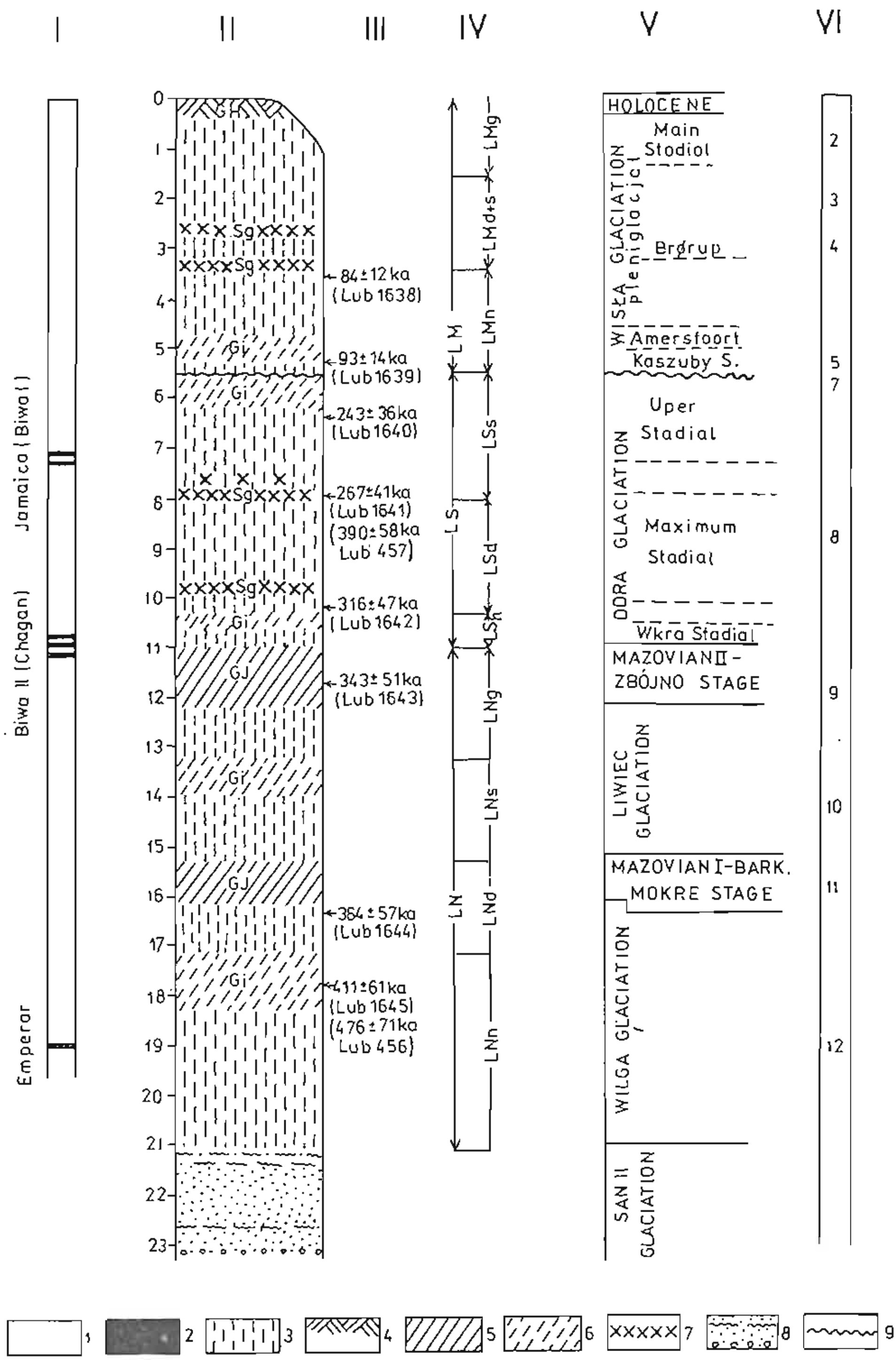
Accumulation of loess-like deposits overlying fluvial sediments corresponds to the postmaximum phase of the South-Polish Glaciation and a coolness period, which in Poland is termed as the Wilga Glaciation by J. E. Mojski (1985), and correlated with oxygen stage (^{18}O) 12 (L. Lindner, 1992). The Emperor palaeomagnetic event has been noted at the 18.9–19.0 m depth. It is older than 410 ka (Figs. 5, 6) and occurs in oxygen stage 12 (U. Bleil, G. Gard, 1989), TL dated at 440–472 ka (N. J. Shackelton, N. G. Opdyke, 1973).

Sedimentation of this part of the section took 70–100 ka, which has been determined on basis of TL dating. The palaeosol (?) occurring here corresponds to a break in sedimentation or a considerable decrease in sedimentation rate. This is also testified by a distinct transition of inclination and declination values (Fig. 5). The susceptibility curve for this part indicates an increase of magnetic susceptibility with a slight decrease in the gleyization zone (Figs. 4, 5). TL date show that accumulation of these deposits terminated about 380 ka. According to the terminology of H. Maruszczak (1986, 1991) for loesses, the described part of the section can be referred to as lowermost oldest loess (LNn) and lower oldest loess (LNd), separated by a poorly developed palaeosol with gleyization signs (Fig. 7).

A palaeosol with a poorly preserved humus horizon (C organic 0.9–1.04% — in the form of ashen-black, greyish-brown lamination and spots) as well as pedolization and gleyization horizons (in the form of light ashen spots) occurs in the upper part of the discussed series at 15.27–15.87 m from the surface. According to TL dating the palaeosol is younger than 384 ka and older than overlying deposits, TL dated at 343 ka (Figs. 4, 7). These results link its development with a warm period termed the Barkowice Mokre Stage — Mazovian I Interglacial in stratigraphic subdivisions, correlated by L. Lindner (1992) with ^{18}O horizon 11, or corresponding to the Holsteinian Interglacial dated by M. Sarnthein *et al.* (1986) at 350–370 ka. The climatic optimum of this interglacial lasted, according to R. Müler (1974), not longer than 15–16 ka. The discussed fossil soil is older than the oldest palaeosols from the Nieledew and Orzechowce sections (H. Maruszczak, 1991). It probably corresponds to palaeosol PK VI in the Czerwony Kopiec section near Brno (Moravia) (J. Macoun, 1985). Magnetic susceptibility values reach their minimal values in the part of the section with the palaeosol horizon.

Above the palaeosol in the interval between 11 and 15.27 m occurs a 4.3 m thick series of yellow, yellowish-brown and grey, silty, loess-like muds (silty clays), within which gleyization signs in the form of light ashy spots appear at a depth of 13.20–13.95 m. TL dating for the upper part of this loess-like deposit gives an age of 343±51 ka. Accumulation of the discussed loess-like deposits from this part of the section corresponds to the cold period referred to by L. Lindner (1992) as the Liwiec Glaciation and correlated with oxygen horizon 10 dated at 345–367 ka (N. J. Shackelton, N. G. Opdyke, 1973). This part of the section possibly corresponds with the oldest loesses from the Nieledew section (H. Maruszczak, J. Nawrocki, 1991) and TL dated at 336–368 ka. The highest values of magnetic susceptibility have been noted in this part of the section (Fig. 5), which indicates out a considerable cooling of climate (H. Maruszczak, J. Nawrocki, 1991). Possibly the accumulation of aeolian dust in the Nowy Sącz Basin corresponds to ice-dammed sands and till from the vicinity of the Wieprz estuary to the Vistula river, dated at 354–372 ka (M. Żarski, 1994).

A fully documented 1.2 m thick palaeosol (A–C horizons) occurs on loess-like deposits connected with the Liwiec Glaciation. It is the best developed palaeosol horizon in the discussed section. It includes a grey silty deposit with black spots (humus horizon, C organic 0.7–1.4%), a layer of loess-like muds with signs of pedolization and occasionally with signs of root gleyization in the form of slanting narrow spots, sometimes resembling a root system. Distinct transition between the palaeosol and the overlying deposit is visible in the upper part of the pedohorizon. TL dating of the palaeosol determined by the dating of over- and underlying deposits is at 316–344 ka (Figs. 4, 7). In its upper part a distinct change of


I
II
III
IV
V
VI
Jamaica (Biwa I)
Biwa II (Chagan)
Emperor
GH
Sg
Gi
GJ
84±12 ka (Lub 1638)
93±14 ka (Lub 1639)
243±36 ka (Lub 1640)
267±41 ka (Lub 1641)
(390±58 ka Lub 457)
316±47 ka (Lub 1642)
343±51 ka (Lub 1643)
364±57 ka (Lub 1644)
411±61 ka (Lub 1645)
(476±71 ka Lub 456)
LMg
LMd+s
LMn
LM
LSs
LSd
LSh
LS
LNg
LNs
LNd
LNn
LN
HOLOCENE
WISŁA GLACIATION
pleniglacial
Main Stadial
Brørup
Amersfoort
Kaszuby S.
ODRA GLACIATION
Uper Stadial
Maximum Stadial
Wkra Stadial
MAZOVIAN II - ZBÓJNO STAGE
LIWIEC GLACIATION
MAZOVIAN I-BARK. MOKRE STAGE
WILGA GLACIATION
SAN II GLACIATION
2
3
4
5
7
8
9
10
11
12
1
2
3
4
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6
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9

inclination and declination values occurs (Fig. 5), possibly connected with palaeomagnetic event Biwa II – Chagan. Palaeosol VII in the Korolevo section occurs in a similar position. Above this palaeosol the Biwa III event has been noted, TL dated at 360 ka (O. M. Adamenko *et al.*, 1989). The discussed palaeosol horizon in the Załubińcze section occurs in a comparable stratigraphic position and has an age similar to the oldest palaeosol in the Nieledew section (J. Butrym, H. Maruszczak, 1983; H. Maruszczak, 1986; H. Maruszczak, J. Nawrocki, 1991). Development of this palaeosol is connected with the Zbójno Interglacial according to L. Lindner (1992), which is supposed to correspond with ^{18}O horizon 9 (N. J. Shackelton, N. G. Opdyke, 1973).

After a distinct break in aeolian accumulation connected with palaeosol development, a 5.5 m thick series of sandy loess-like muds was deposited (silts and sandy silts), TL dated at 243–316 ka (Figs. 4, 7). These results place the accumulation of sediments in the Odra Glaciation (J. E. Mojski, 1993; L. Lindner, 1992). During accumulation of the lowermost part of these sediments an inversed magnetization event took place. It can be correlated with the Chagan – Biwa II event (Figs. 5, 7) and the loesses correspond to the lowermost older loesses (LSn — H. Maruszczak, 1986, 1991) and the Fore-maximal Stadial — Krzna (J. E. Mojski, 1993).

A 0.3–0.5 m thick palaeosol developed on the silts between 10.28–10.55 m. It includes silty grey clay with black and grey spots in the upper part and with rusty lamination in the lower part (Figs. 4, 7). The percentage of coarser silt and sand fraction increases towards the surface (Fig. 4). Signs of slight gleyization in the form of ashen spots in yellow silts were observed between 6.2 –7.0 and 8.5–9.5 m depth. They probably correspond to lower older loesses (LSd) of H. Maruszczak (1986), in which slight gleyization signs are noted (H. Maruszczak, 1991). Accumulation of these loesses took place between TL dates 276 and 316 ka (Fig. 4). On the other hand the overlying deposits can be referred to as middle older loesses (LSs), TL dated at 243–276 ka. They are separated by a poorly developed soil

Fig. 7. Stratigraphic section of loess-like deposits at Załubińcze

I — chart of palaeomagnetic events recorded within the section: magnetic polarity: 1 — normal, 2 — reversed; II — schematic lithostratigraphic section: 3 — loess-like deposits, 4 — recent soil, 5 — interglacial palaeosols, 6 — interstadial (?) palaeosols, 7 — soil sediments, 8 — fluvial clays, muds, sands and gravels, 9 — larger stratigraphic gaps; palaeosols: Gi — interstadial, GJ — interglacial, Sg — soil sediments and signs of pedogenesis development; III — TL datings (in brackets ages after J. Butrym and W. Zuchiewicz, 1985); IV — diagram of loess stratigraphy after H. Maruszczak (1986): LN — oldest loess: LNn — lowermost, LNd — lower, LNs — middle; LS — older loess: LSd — lower, LSs — middle; LM — younger loess: LMn — lowermost, LMd+s — lower and middle, LMg — upper; V — diagram of Quaternary stratigraphy after various authors; VI — oxygen isotope stages after N. J. Shackelton and N. G. Opdyke (1973)

Profil stratygraficzny utworów lessopodobnych w Załubińczach

I — diagram zdarzeń paleomagnetycznych zarejestrowanych w profilu: polarność magnetyczna: 1 — normalna, 2 — odwrotna; II — schematyczny profil litostratygraficzny: 3 — utwory lessopodobne, 4 — gleba współczesna, 5 — gleby kopalne interglacjalne, 6 — gleby kopalne interstadialne (?), 7 — poziomy glebowe, 8 — gliny, mułki, piaski i żwiry rzeczne, 9 — większe luki stratygraficzne; gleby kopalne: Gi — interstadialna, GJ — interglacjalna, Sg — osady glebowe i oznaki rozwoju pedogenezy; III — wyniki datowań termoluminescencyjnych (w nawiasie podano wyniki według J. Butryma i W. Zuchiewicza, 1985); IV — schemat stratygrafii lessów według H. Maruszczaka (1986): LN — less najstarszy: LNn — najniższy, LNd — dolny, LNs — środkowy; LS — less starszy: LSd — dolny, LSs — środkowy; LM — less młodszy: LMn — najniższy, LMd+s — dolny i środkowy, LMg — górny; V — schemat stratygraficzny czwartorzędu według różnych autorów; VI — poziomy izotopowo-tlenowe według N. J. Shackeltona i N. G. Opdyke (1973) sediment and between 7.1–7.3 m of depth a distinct change of inclination and declination values bearing the character of a magnetic excursion, corresponding with Jamaica excursion (Figs. 5, 7). This palaeomagnetic episode is supposed to occur in the upper part of the interglacial palaeosol and in the lower part of the lowermost upper older loesses (LSg4) according to the stratigraphy of Polish loesses by H. Maruszczak (1991). In the discussed section there are no conditions of setting a younger age for the deposits and noted palaeomagnetic excursion. There are also no sediments corresponding to the upper older loesses, the accumulation of which took place during the Warta Glaciation.

A layer of silts and silty clays occurs at 5.5–6.2 m depth in the top of the middle part of the section. The sediments have a distinct turbulence and a block-clotty (marble) structure with frequent traces of fissures in different directions. Traces of turbulence occur in the form of polygons infilled with ashen, brown or rusty clay or silt. These are probably traces of ground ice activity. This layer is bipartite. It is divided by a 1–2 cm thick rusty layer. In the upper part the block structures are smaller and the turbulences are more frequent and more distinct. The whole layer is much harder than the under- and overlying deposits. It can be interpreted as an interstadial palaeosol with a pedolization and an illuvial horizon. The palaeosol was exposed to thermal-frost changes and to dessication. In the upper part it is erosionally truncated. It probably developed in colder periods than the interglacial.

A large stratigraphic gap occurs at a depth of 5.5 m. It is distinct in paleomagnetic charts as an abrupt change in declination and inclination values (Fig. 5). The TL data show lack of sediments from about 150 ka, including two interglacials (Eemian and Lublin – Lubawa according to L. Lindner, 1992) and separating them the Warta Glaciation cold period.

The upper 5.5 m of the section includes deposits accumulated during the last cold period — the Wisła (North-Polish) Glaciation. According to classification of loesses by H. Maruszczak (1991) these deposits include the so-called younger loesses accumulated during the last 100 ka. In this part of the section horizons with faint traces of pedogenesis probably represent warmer interstadial periods. Stratigraphic gaps have been noted on palaeodeclination and palaeoinclination charts (Fig. 5).

Directly above the erosional transition occurs a 0.8 m thick layer of loess-like silts, on which a palaeosol developed. The lower part was TL dated at 93 ka (Fig. 4), which places the accumulation of the loess-like deposits in the oldest part of the Last Glaciation in the Fore-Amersfoort Stadial (Fig. 7), termed by J. E. Mojski (1993) as the Kaszuby Stadial, and by L. Lindner (1992) as the Toruń Stadial. By analogy they can be correlated with the lowermost younger loesses (H. Maruszczak, 1991). In the upper part of this section fragment, a distinct change in palaeomagnetic parameters is noted, which testifies to a break in accumulation and palaeosol development, corresponding probably to the Amersfoort Interstadial. It is a palaeosol fragment, brownish-yellow with horizontal lamination and with distinct traces of root gleyization in the form of narrow and diagonal ashen spots. However, it cannot be excluded that the fissures are a result of thermal contraction. The sediment infilling them differs in colour and type from the host deposit.

Overlying deposits are difficult to determine. At first, laminated loess occurs with a silty sediment yielding pipe concretions and a 20 cm thick humus horizon in the upper part. The brownish-black lamination between 3.40 and 3.66 m can be interpreted as humus deposits during pedogenesis. TL dating at a depth of 3.5 m gave a value of 82 ka (Fig. 4), which puts the palaeosol development within the Brörup Interstadial (Fig. 7), corresponding to the accumulation of lowermost younger loesses of H. Maruszczak (1991). Transitional changes in palaeomagnetic parameter values within the palaeosol, particularly an increase of magnetic susceptibility value in the overlying deposit, indicate a different aeolian accumulation cycle for the overlying deposits (Fig. 5).

Above the Brörup Interstadial palaeosol, a series of silty loess-like deposits with signs of gleyization and lamination occurs (Fig. 4), the accumulation of which probably took place during the Fore-Grudziądz Stadial (J. E. Mojski, 1993) or Lower Pleniglacial (L. Starkel, 1977). A layer with distinct lamination is visible in the upper part. Laminated loess is supposed to develop in damp conditions (J. Cegła, 1972). According to H. Maruszczak (1991) these correspond to lower and middle younger loesses. In this interval numerous gaps and breaks occur on palaeomagnetic parameter charts (Fig. 5). In most of sections described in Poland, loesses from this interval bear distinct signs of gleyization (H. Maruszczak, 1986, 1991).

The youngest deposits include the upper part of the outcrop to 1.65 m depth and represent deposits accumulated during the main stadial of the last cold period. It is separated from underlying deposits by distinctly laminated loess-like muds, corresponding to accumulation in damper conditions. A small thickness of aeolian deposits from the Last Glaciation in comparison to other sections is connected probably with the placement of the section on a lobe at the northern border of the Nowy Sącz Basin, where a smaller amount of sediment was accumulated, and probably a large amount was removed during Late Glaciation and Holocene times.

FINAL REMARKS

The Załubińcze section can serve as a stratotype section of silty deposits for the Carpathians because of well recognized aeolian deposits from the Middle Pleistocene. A series of oldest loesses occurs here, within which the palaeomagnetic Emperor event has been noted. In the lower part of the lowermost older loesses occurs the palaeomagnetic Biwa II – Chagan event and in the upper part of this interval the palaeomagnetic Jamaica (Biwa I) excursion. The method applied here for testing magnetic susceptibility in connection with palaeosols seems to be a good indicator of palaeoclimatic changes in silty deposits. On the other hand, studies of declination and inclination gives evidence of stratigraphic gaps. A feature distinguishing the discussed section from typical loesses is lack of carbonates.

The setting of the discussed section on a flattened lobe testifies against any other origin than aeolian for loess-like deposits. The magnetic susceptibility record in the section is typical for loess sections in the Lublin region, which directly indicates an aeolian origin of sediments. Grain composition also testifies to the aeolian origin. It seems that transport of sediment was rather short, which is indicated by low gradation indices and placement of loess covers along the northern border of Nowy Sącz Basin. The largest thicknesses of these sediments occur along the axes of main river valleys (Kamienica Nawojowska, Poprad).

Evidence indicates that winds blowing from the south had the largest influence on silt accumulation within the Nowy Sącz Basin as controlled by the axes of major morphologic elevations.

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STRATYGRAFIA PLEJSTOCEŃSKICH UTWORÓW PYLASTYCH W PROFILU ZAŁUBIŃCZE W ŚWIETLE BADAŃ SEDYMENTOLOGICZNYCH I PALEOMAGNETYCZNYCH

Streszczenie

Na północnym obrzeżeniu Kotliny Sądeckiej znaczne powierzchnie zajmują lessopodobne utwory eoliczne, określane w rejonie Brzozowa przez T. Gerlacha (1991) również jako karpacka odmiana lessu. Najlepiej odsłonięty profil znajduje się na terenie wyrobiska Załubińcze (obrzeże Nowego Sącza) (fig. 1), gdzie eksploatowane są gliny do wyrobu cegły. Profil ten był opisany i datowany termoluminescencyjnie przez J. Butryma i W. Zuchiewicza (1985), a następnie zbadany paleomagnetycznie przez J. Nawrockiego i in. (1988). Występujące tu osady o miąższości do 21 m przykrywają żwiry i piaski rzeczne, leżące na cokole skalnym o wysokości 55–57 m zbudowanym z piaskowców magurskich (fig. 1–3). Odsłaniająca się ok. 19-metrowa seria utworów pylastych (fig. 4) została opróbowana do badań paleomagnetycznych, uziarnienia, oznaczeń termoluminescencyjnych i innych. Występujące tu osady można podzielić na 3 części: dolną, środkową i górną. Stwierdzono kilka poziomów gleb kopalnych o różnym stopniu rozwoju i różnej randze stratygraficznej. W składzie ziarnowym dominuje frakcja pylasta (0.05–0.01 mm). Niewielka zmienność w składzie ziarnowym zaznacza się w środkowym odcinku profilu w stosunku do górnego i dolnego (fig. 4). Datowania termoluminescencyjne wykonane dla omawianego profilu zawierają się w granicach od 81 do 411 (489) ka. W dolnej i środkowej części znajdują się miejsca z osadem namagnesowanym odwrotnie (fig. 5). Dolne zdarzenie paleomagnetyczne, występujące na głębokości ok. 19 m od powierzchni, zostało zinterpretowane jako Emperor, górne zaś na głębokości 10,8–11,0 m jako Biwa II – Chagan. Na głębokości 7,1–7,3 m stwierdzono zapis epizodu paleomagnetycznego zinterpretowanego jako Jamajka (Biwa I). Zanotowane epizody paleomagnetyczne zostały dowiązane do zdarzeń paleomagnetycznych rejestrowanych w osadach czwartorzędowych (fig. 6). Wyniki badań paleomagnetycznych dały również podstawy do stwierdzenia licznych luk stratygraficznych.

Na podstawie wyników badań paleomagnetycznych, datowań termoluminescencyjnych i gleb kopalnych wyróżniono kilka cykli akumulacji eolicznej w środkowym i młodszym plejstocenie.

C z ę ś ć d o l n a profilu obejmuje interwał poniżej głębokości 11 m. W stropie ogranicza ją gleba i stwierdzone zdarzenie paleomagnetyczne Biwa II — Chagan, a w spągu — osady rzeczne zlodowacenia południowopolskiego (San II). Obejmuje ona blisko połowę odsłaniających się osadów, których górna część odpowiada lessom najstarszym (LN — H. Maruszczak, 1986). Najniższą część profilu poniżej głębokości 15,27 m można powiązać z pomaksymalną fazą zlodowacenia południowopolskiego lub okresem, który na terenie Polski jest określany jako zlodowacenie Wilgi (J. E. Mojski, 1985). W tej części profilu stwierdzono zdarzenie paleomagnetyczne Emperor korelowane przez U. Bleila i G. Garda (1989) z 12 poziomem tlenowym ^{18}O datowanym na 440–472 ka (N. J. Shackelton, N. G. Opdyke, 1973). W stropie omawianej serii występuje gleba kopalna ze słabo zachowanym poziomem próchnicznym i wyraźnym poziomem oglejenia. Gleba ta jest młodsza od 382 ka i może odpowiadać interglacjałowi mazowieckiemu I — Barkowic Mokrych, korelowanym z 11 poziomem tlenowym. Powyżej znajduje się seria glin pylastych, których górną część datowano termoluminescencyjnie na 343 ka. Akumulację ich powiązano ze zlodowaceniem Liwca (L. Lindner, 1988, 1992) korelowanym z 10 poziomem tlenowym. W stropie dolnej części profilu występuje 1,2-metrowej miąższości gleba kopalna o pełnym profilu, której wiek datuje się na 316–343 ka, oraz występujące w stropie zdarzenie paleomagnetyczne Biwa II — Chagan. Jej powstanie może odpowiadać ciepłemu interglacjałowi mazowieckiemu II — Zbójna korelowanemu z 9 poziomem tlenowym.

C z ę ś ć ś r o d k o w a profilu jest datowana termoluminescencyjnie w przedziale 243 i 316 ka (fig. 2), odpowiadającym akumulacji utworów lessopodobnych w czasie zlodowacenia Odry (J. E. Mojski, 1993; L. Lindner, 1992). Ta część profilu wyraźnie różni się od części dolnej i górnej uziarnieniem i składem minerałów ciężkich. Część środkową od górnej oddziela gleba z wyraźną granicą erozyjną w stropie z luką stratygraficzną przypadającą na interglacjał lubelski, zlodowacenie Warty i interglacjał eemski.

C z ę ś ć g ó r n a profilu o miąższości do 5,5 m obejmuje osady młodsze od 100 ka, których akumulacja odbywała się w ostatnim piętrze zimnym i przez analogię można je korelować z lessami młodszymi. Cechą odróżniającą je od typowych lessów jest brak węglanów w całym omawianym profilu. Wydaje się, że jest to zjawisko pierwotne.

Położenie omawianego profilu na spłaszczonym garbie wyklucza inną genezę niż eoliczną. Również zapis zmian podatności magnetycznej jest tu typowy dla plejstoceńskich osadów eolicznych. Transport materiału odbywał się na niezbyt duże odległości, na co wskazują niskie wskaźniki wysortowania osadów oraz rozmieszczenie pokryw lessopodobnych wzdłuż północnego obrzeżenia Kotliny Sądeckiej. Największe miąższości osady te mają w osi dolin większych rzek, takich jak Kamienica Nawojowska czy Poprad. Jest to przesłanka do przyjęcia tezy, że największy wpływ na akumulację pyłów w Kotlinie Sądeckiej miały wiatry z kierunku południowego, uwarunkowane przebiegiem osi dolin większych rzek.