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Loess-like deposits in Harbutowice, southern Wielickie Foreland

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Three beds of the loess-like deposits, separated by deluvial-solifluction and weathering deposits, were distinguished. The oldest loess-like deposits, together with the weathering and solifluction ones, were associated with the older Pleniglacial. The second bed of the loess-like deposits together with deluvial and solifluction ones were accumulated during the Interpleniglacial. Deposition terminated with soil forming processes, which led to development of a palaeosol during the Denekamp Interstadial, ^{14}C dated at 31 200±1000 ka BP. The youngest loess-like deposits, together with deluvial and weathering ones, represent the younger Pleniglacial.

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Key words: Polish Carpathians, Pleistocene, Denekamp Interstadial, palaeosol.

INTRODUCTION

During field studies in 1996–1997 (a part of grant projects 1344/4 and 1384/5) in the upper Harbutówka River basin — a tributary of the Skawinka River (Fig. 1) — a drilled hole Harbutowice-1 was made in slope sediments up to a depth of 14 m. An entire lithologic profile was obtained, from which 28 samples were collected and the following analysis conducted: grain size distribution, $CaCO_3$ content, palynological and heavy minerals content. Results of these analyses, particularly analyses of heavy minerals, allowed to specify an origin of the drilled slope deposits. A significant part of these sediments, interpreted so far as weathered and deluvial sediments (M. Książkiewicz, 1953), has probably an aeolian origin.

LOCATION AND GEOLOGY

The study area is located between Harbutowice and Sułkowice, at a boundary between the Beskid Makowski Mts. and the Wielickie Foreland (Fig. 1; J. Kondracki, 1994). A watershed divide, where the drilled hole Harbutowice-1 was made, is placed at 340–385 m a.s.l. (Figs. 1–3). From the west and the east, the divide is limited by river valleys of the Harbutówka and Gościbia (Figs. 1 and 3), however, from the south by slopes of the Beskid Makowski Mts. Inclinations of the divide slopes do not exceed 9°, and an inclination of the valley slopes reach up to 19°.

Distribution of the Quaternary sediments within the described area is presented on the geologic map (Fig. 2), prepared by the author based partly on the geologic map of A. Wójcik and W. Rączkowski (1994). The pre-Quaternary rocks were classified (M. Książkiewicz, 1953) to three series: the Silesian one in the northern and central part of the area, the Subsilesian Series in tectonic windows within the Silesian Series in the central part of the area, and the Magura Series in the southern part of the area. Flysch rocks are covered by the Quaternary sediments of a variable thickness.

Alluvia which occur within river valleys are predominantly composed of sandstone pebbles, forming surfaces of 5 river terraces at the following elevations above the river bed: terrace I at 0.5–2.0 m, terrace II at 2.5–5.0 m, terrace III at 6–10 m, terrace IV at 13–15 m, and terrace V at 19–22 m (D. Grabowski, 1996). Surfaces of the terraces III–V are locally covered by deluvial deposits.

The Harbutowice-1 drilling was located at the bottom of elongated, shallow depression, in the vicinity of the eastern margin of the divide (Fig. 3), at 361.5 m a.s.l.; it was made assistance of Dr. Jerzy Nitychoruk (Institute of Geology of the Warsaw University), using a mechanical auger Ejkelkamp up

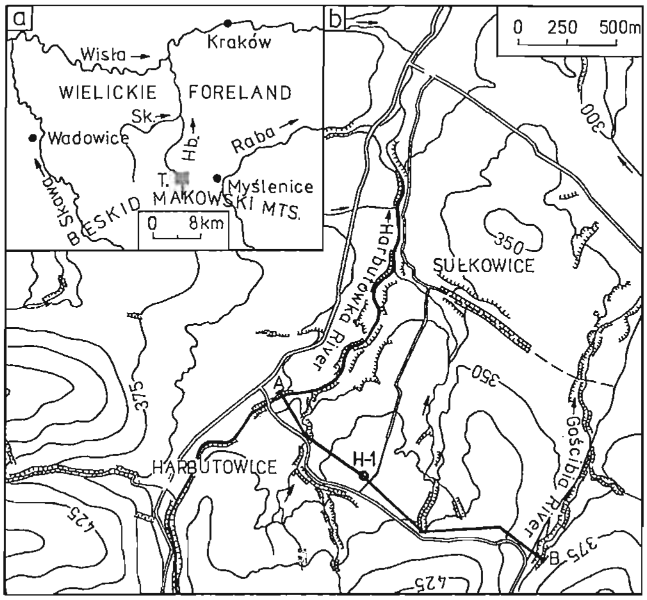

Fig. 1. Location of the study area

a: T — the study area, Sk — Skawinka River, Hb — Harbutówka River; b: A–B — geological cross-section, H-1 — drilling Harbutowice-1

to a depth of 14 m. The origin of the depression filled with the Quaternary sediments has not been entirely explained but available data indicate on the tectonic character. Glauconitic sandstones from Gorzeń at Harbutowice occur in a strongly tectonically deformed zone (M. Książkiewicz, J. Liszkowa, 1979), locally covered by soliflunctional deposits and slope deposits relocated as the result of creep (Fig. 3). Thickness of these sediments does not exceed 0.5 m. To the east from the described drilling, the elevation rises along the moderately inclined slope which gradually changes into a flat surface, and further declines along a steep slope to the terrace II of the Gościbia River (Fig. 3). In this part of the area, clayey weathered deposits of thickness of 0.5–3.0 m, locally greater, cover the flysch rocks, i.e. the Upper Cieszyn Slates (Fig. 3). Deluvial deposits of a thickness of 0.5–2.0 m occur directly above solifluction sediments (Fig. 3).

LITHOLOGY

Clayey-silty sediments with admixtures of sandy and gravely fraction, and individual rock fragments, mainly sandstones, occur in the Harbutowice-1 profile. These are macroscopically relatively uniform and only analysis of the grain size distribution of the collected samples indicated their variability and allowed to distinguish nine lithologic complexes (Fig. 4). Boundary values of fractions are given based on the Wentworth scale, modified by Krumbein and Lane, and supplemented by Urbaniak-Biernacka (E. Mycielska-Dowgiałło, J. Rutkowski, 1995). Indices of grain size distribution are determined (Table 1), based on formulas of R. L. Folk and W. C. Ward (1957).

The analysis of heavy minerals was conducted by Dr. Bogusław Bagiński (Institute of Geochemistry, Mineralogy and Petrography of the Warsaw University) for 16 samples from the profile of the Harbutowice-1 drilling and samples from the weathered glauconitic Gorzeń Sandstones collected in the outcrop (sample 28) from a depth of 0.2–0.4 m (Fig. 3). Analyses were conducted for a fraction ranging from 0.063 to 0.1 mm; additionally analyses were conducted for a fraction of 0.1–0.125 mm (in cases where amount of heavy minerals in the fraction 0.063–0.1 mm was insufficient). Results of the conducted analyses were presented (Table 2) where percentage contents of all occurring groups of heavy minerals, i.e. transparent, translucent and opaque ones, are presented. Additionally, percentage amount of transparent minerals is presented against the background of the entire sample.

Lithologic complex 1 (samples 1 and 2), 0.5 m thick: these are dark grey silty sediments (silty fraction 48–52%, including "loess" fraction 19–21%) with a significant admixture of clayey fraction (19–21%) and sandy (12–24%), and individual clasts of weathered and non-weathered glauconitic sandstones — gravely fraction (7–17%). $CaCO_3$ content is about 1%. Iron carbonates predominate among heavy minerals (Table 2). The presence of glauconite (4.9%) and garnets (8.4%) brings attention among transparent minerals.

Lithologic complex 2 (samples 3 and 4), 0.4 m thick: grey-brown silty sediments (silty fraction 71–73%, including "loess" fraction content of 28–31%) with a significant content of clayey fraction (ca. 22%) and insignificant admixture of sandy fraction (4–6%). Sandstone clasts do not occur in this layer, however, some amounts of dispersed organic substance are present. $CaCO_3$ content is 1.0–1.6%. Among heavy minerals, to compare with the complex 1, a significantly higher amount of iron oxides (ca. 43%) and insignificant amount of iron carbonates (ca. 19%) are present. Glauconite (4.0%) and garnets (11.4%) are the most important among transparent minerals.

Lithologic complex 3 (samples 5 and 6), 0.8 m thick: dark grey sandy-silty sediments (sandy fraction 31–41%, silty fraction 24–47.5%, including "loess" fraction 8–20%) with a significant admixture of gravely fraction (5–21%) represented by clasts of partly weathered glauconitic sandstones of a 5 cm diameter. Clayey fraction content (14–16%) is the smallest in the entire profile. Light-coloured streaks enriched in $CaCO_3$, which content is the highest in the entire profile, are present in the characterized sediments. Composition and contents of heavy minerals are similar to the results from sediments of the complex 1 (Table 2).

Lithologic complex 4 (samples 7–12), to 2.6 m thick: light grey silty sediments (silty fraction 77–82%, including "loess" fraction 33–39%), enriched in clayey fraction (16–21%) with a minimum admixture of sandy fraction (1–2%). $CaCO_3$ content varies from 1.5 to 2.5% (the highest in the central part of the complex). The most significant feature among heavy mineral composition is the presence of amphiboles, which appear in the top of the complex 3 (sample 6 — 1.2%); the highest amount (5.9%) is reached in the upper part of the described complex (sample 11/12). A large biotite content (7.3–12.6%) and a small garnet content (sample 8/9 — 3%) bring attention in the characterized sediments.

Lithologic complex 5 (samples 13–16), 2.2 m thick: grey-green and similar to the previous complex, but contains more clayey fraction (23–29%) and less silty fraction (68–74%, including "loess" fraction 28–33%). Sandy fraction content also increases slightly to 3%. In the lowest part of the described complex (samples 13 and 14), $CaCO_3$ content is 0.1–0.9%); in higher parts the complex 5 (similarly to all younger sediments) does not contain $CaCO_3$. Composition of heavy minerals is similar to that of typical for the complex 4 — amphiboles (1.2–2.2%), biotite (1.7–11.4%) and garnets (sample 16 — 5.7%) are present.

Lithologic complex 6 (samples 17 and 18), 2.5 m thick: steel-grey colour significantly differs from two previous complexes. It is represented by clayey-silty sediments (clayey fraction 40–44%, silty fraction 49–54%, including "loess" fraction 16–18%) with an admixture of sandy fraction (6–7%) and individual clasts of sandstones of a 1 cm diameter (gravely fraction up to 0.5%). Heavy minerals are dominated in sediments of this complex by iron carbonates (mainly siderite), which contents — the highest in the entire profile — are 89.0–98.2% (samples 17 and 18). Among transparent minerals, only small amounts of resistant minerals are present — zircon (0.8%), rutile (2%), tourmaline (2.2%), and monazite (0.6%).

Lithologic complex 7 (samples 19 and 20), 0.9 m thick: clayey-silty sediments (clayey fraction 41–42%, silty fraction 43–44%, including "loess" fraction 7–12%) with an admixture of sandy fraction (ca. 15%), higher than in the complex 6. In the lower part (7a) described sediments are light grey, in the upper part (7b) they are, because of a significant admixture of organic substances, dark brown. A sample from these sediments was ^{14}C dated at 31 200±1000 years BP in the ^{14}C Laboratory of the Institute of Silesian Technical University (Gd-10 391).

Amount of transparent minerals in sediments of the characterized complex is insignificant (sample 19 — 10.4%), iron carbonates dominate (sample 19 — 60.6%). Analysis of heavy minerals was also conducted for the sample 20. Insufficient amount of grains, however, caused that content of specific minerals was only approximately estimated. Composition of heavy minerals and their contents are similar to these of the sample 19 — there was only lack of amphiboles.

Lithologic complex 8 (samples 21–25), 2.6 m thick: grey-yellow silty-clayey sediments with a significant admixture of sand, indicates also differences in grain size distribution. Clayey fraction dominates (47–48%) in some parts (8a, 8c), over silty fraction (35–36%) and sandy (16–17%). Amounts of clayey fraction (35–38%) and silty fraction (35–36%) are comparable in other parts (8b, 8d), though significant admixtures of sandy fraction are present (25–30%). "Loess" fraction content ranges from 9 to 10%. Composition of heavy minerals in sediments of the described complex is characterized by a significant amount of iron carbonates — 62.0%, and small amounts of opaque minerals — 13.5% which resembles sediments of the complexes 1, 3, and 7. There is, however, more biotite (5.3%) and tourmaline (8.9%) in sediments of the complex 8. One should indicate that only one sample was analyzed from the complex 8 (sample 22), from a lower part of this complex, and results obtained do not have to be representative for the entire complex.

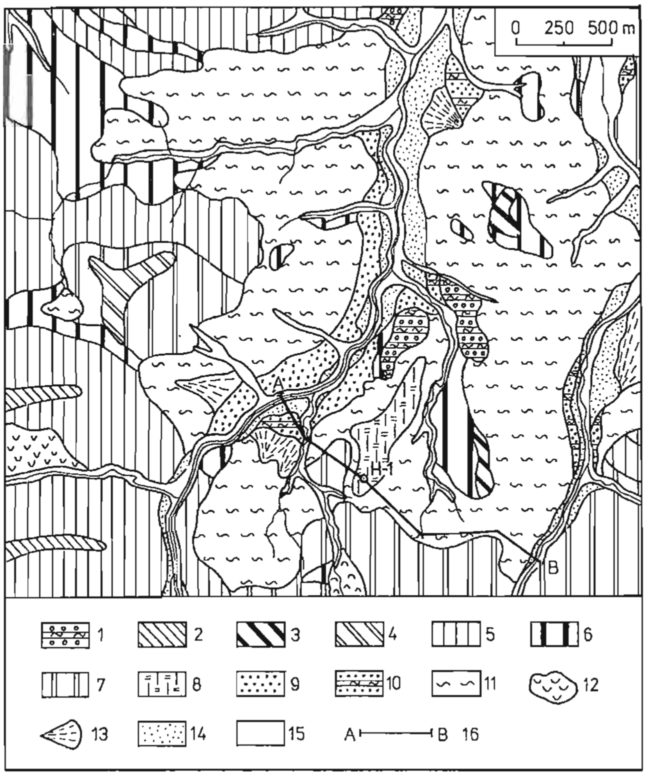

Fig. 2. Geologic map of the Quaternary deposits in the study area

Odranian Glaciation/older part of the Vistulian Glaciation: 1 — pebbles and gravels of the terrace V of the Harbutówka River (19–22 m) locally covered by deluvial deposits; **Vistulian Glaciation/Holocene**: weathered deposits: 2 — sandy-silty, 3 — sandy-clayey, 4 — clayey-silty; weathered deposits, solifluctional deposits and slope deposits relocated as the result of creep: 5 — sandy-silty, 6 — clayey-silty and clayey, 7 — sandy-clayey and gravely-clayey; **younger part of Vistulian Glaciation/early Holocene**: 8 — loess-like silty deposits, 9 — pebbles and gravels of the terrace III of the Harbutówka River (6–10 m), 10 — deluvial deposits over pebbles and gravels of the terrace III of the Harbutówka River, 11 — clayey-silty deposits and sandy-silty deluvial deposits; **Holocene**: 12 — clay, silts and sands with fragments of colluvium, 13 — sands, gravels and pebbles of alluvial fans, 14 — sands, gravels and pebbles of the terrace II of the Harbutówka River (2.5–5 m), 15 — sands, gravels and pebbles of the terrace I of the Harbutówka River (0.5–2.0 m); 16 — geologic cross-section A–B; H-1 — drilling Harbutowice-1

Lithologic complex 9 (samples 26 and 27), 1.5 m thick: dark yellow silty sediments (silty fraction 62–75%, including "loess" fraction 25–28%) with an admixture of clayey material (20–21%) and sandy (4–16%). Composition of heavy minerals of sediments in the complex 9 is similar to that of the complexes 4 and 5, due to the presence of amphiboles (0.7–7.9%) and a high biotite content (5.8–14.1%). Amounts of garnets, similarly to the complexes 4 and 5, is variable, 2.6–9.4%. Minerals which appear for the first time in the profile in amounts up to 2% are: epidote, chlorite, staurolite, sillimanite. Percentage amounts of transparent minerals, reaching up to 51%, is the highest in this complex. Iron carbo-

Table 1

Indices of grain distribution of sediments from the Harbutowice-1 profile (according to R. L. Folk, W. C. Ward, 1957)

Lithologic complexes depth [m]	Mz	δ_I	Sk_I	K_G
9 0.0–1.5	6.51–6.86	2.84–3.07	0.14–0.51	1.22–1.31
8 1.5–4.1	6.93–8.58	4.15–4.21	-0.17–0.04	0.72–0.80
7 4.1–5.0	8.09–8.30	3.68–4.06	0.02–0.08	0.85–0.91
6 5.0–7.5	8.29–8.59	3.16–3.38	0.05–0.07	0.78
5 7.5–9.7	7.23–7.60	2.77–3.18	0.48–0.57	0.85–1.08
4 9.7–12.3	6.25–7.12	2.26–3.40	0.55–0.68	1.34–1.91
3 12.3–13.1	3.00–5.07	3.81–4.74	0.10–0.28	0.82–1.08
2 13.1–13.5	7.14–7.18	2.94–3.01	0.50–0.55	1.25–1.31
1 13.5–14.0	4.80–5.76	4.43–5.36	-0.11–0.07	1.25–1.37

Mz — mean grain diameter, δ_I — standard deviation, Sk_I — skewness, K_G — curtosis

nate content in amounts of 11–26% is also similar to these of the complexes 2, 4, and 5. Heavy mineral composition of the described complex is also similar to composition of weathered glauconitic Gorzeń Sandstones (sample 28), in which only amphiboles do not occur (Table 2).

Described lithologic complexes indicate certain common features. Sediments of the complexes 1 and 3 have the highest content of sandy fraction (up to 41%) and small content of clayey fraction (14–21%). Clasts of weathered and non-weathered sandstones in a gravely fraction (5–21%) are present only in these sediments. A similar set of heavy minerals, where the presence of glauconite brings attention, occurs sediments of the complexes 1–3 whereas in sediments of younger complexes glauconite does not occur. Sediments of complexes 2, 4, 5, and 9 contain the highest amounts of silty fraction (62–83%) and small amounts of sandy fraction (1.5–5.0%, only in the case of sample 26 — 16%). In composition of heavy minerals in sediments of complexes 4, 5, and 9, amphiboles and significant amounts of biotite appear. Sediments of the three following complexes, i.e. 6–8, are characterized by the highest content of clayey fraction (42–56%) and significant admixtures of sandy fraction (16–30%), particularly in sediments of the complex 8. Composition of heavy minerals is not diversified and dominated by iron carbonates. Described similarities of the successive complexes are confirmed by determined indexes of grain size distribution.

PALYNOLOGY

Based on the palynological analysis conducted for a part of the profile (from depth of 4–14 m), mostly on the basis of the content variability of significant components AP and NAP, Dr. Krzysztof Bińka (Institute of Geology of the Warsaw University) distinguished two cooler periods (Fig. 5: content of grass and sedge pollen about 80–90%) and two warmer periods (content of tree pollens up to 45%). In a lower part of the profile, at depth of 13.1–13.3 m (sample 4 within the lithologic complex 2), a decided domination of NAP pollen (Cyperaceae — about 77%, Gramineae — about 10%) over AP pollen (mainly *Pinus* — about 7%) indicates a colder period. Tree pollen occurs occasionally from a secondary source and sporomorphs older than the Tertiary and Quaternary are present. Content of AP pollen (*Pinus* — about 40% and *Betula* — about 5%) increases significantly within the lithologic complex 4 (sample 10 from a depth 10.6–10.8 m) with respect to NAP (Gramineae — about 37%, Cyperaceae — about 11%), which may indicate presence of warmer climatic conditions. Successive cooling occurred during accumulation of sediments of the lithologic complex 5 (sample 15 from a depth 8.6–8.8 m), which is supported by a decided domination of NAP (Gramineae — about 53%, Cyperaceae — about 31%) over AP (*Betula* — about 7%, *Pinus* — about 1.5%). The warmest period occurred during accumulation of sediments of the lithologic complex 7 (samples 19 and 20 from a depth 4.2–4.8 m), which is indicated by variable NAP content (Gramineae — about 34–43%, Cyperaceae — about 25–30%) and AP (*Pinus* — 27–40%, *Betula* — 2–4%, *Juniperus* — about 1.5%, *Larix* — about 1%).

DISCUSSION

Detailed analyses of grain size distribution (Fig. 4, Table 1), composition and content of heavy minerals (Table 2) and palynological analysis (Fig. 5) allow to relate a part of the drilled sediments to weathering processes, solifluction and washout — but some of these deposits have most probably aeolian origin and may be considered as loess-like sediments. The greatest difficulty to explicitly determine the origin of these sediments is associated mainly with:

— lack of outcrops, where characteristic structures for the solifluction-deluvial and loess deposits could be identified;

— simultaneous occurrence of effects of slope and aeolian processes and post-sedimentary processes (e.g. soil-forming), which partly altered the original character of the sediments, making an interpretation more difficult.

Interpretation of the origin presented below, based mostly on the drilled material, may raise some doubts, hence the author also considered the area morphology and detailed analysis of the geologic cross-section A–B (Fig. 3), in addition to analyses conducted being the foundation of genesis conclusions.

Table 2

Composition of heavy minerals in sediments of the profile Harbutowice-1

Sample no.	Minerals [%]														
	Semi-, non-transparent		Transparent												
	Fe*	Fe and Cr**	total	C	R	T	M	Gr	E	St	Sl	Ch	A	B	Gl
28	29.0	39.0	32.0	10.9	8.0	3.6	–	1.5	1.5	0.5	–	0.7	–	5.3	–
27	11.0	38.0	51.0	2.1	18.0	1.0	–	2.6	2.0	1.0	1.0	1.3	7.9	14.1	–
26	16.0	39.0	35.0	6.8	8.0	1.9	–	9.4	1.4	1.0	–	–	0.7	5.8	–
22	62.0	13.5	24.5	0.6	9.7	8.9	–	–	–	–	–	–	–	5.3	–
19	60.6	29.0	10.4	1.7	2.0	4.6	–	0.9	–	–	–	–	0.5	0.7	–
18	89.0	6.0	5.0	0.8	2.0	2.2	–	–	–	–	–	–	–	–	–
17	98.2	1.2	0.6	–	–	–	0.6	–	–	–	–	–	–	–	–
16	68.0	12.1	19.9	5.8	11.2	–	–	–	–	–	–	–	1.2	1.7	–
14	18.0	47.9	34.1	2.8	7.5	4.5	–	5.7	–	–	–	–	2.2	11.4	–
11/12	24.0	40.5	35.5	11.4	8.0	2.9	–	–	–	–	–	–	5.9	7.3	–
8/9	17.2	41.4	41.4	7.8	8.6	4.9	–	3.0	–	–	–	–	3.1	12.6	1.4
6	51.3	18.4	30.3	7.4	7.6	3.2	–	6.6	–	–	–	–	1.2	2.2	2.1
3/4	19.3	43.4	37.3	3.8	14.2	2.0	–	11.4	–	–	–	–	–	1.9	4.0
1	52.1	16.9	31.0	4.4	6.7	4.5	–	8.4	–	–	–	–	–	2.1	4.9

* Fe carbonates — mainly siderite and ankerite; ** Fe and Cr oxides — chromite, ilmenite, magnetite; resistant minerals: C — zircon, R — rutile, T — tourmaline, M — monazite; moderately resistant minerals: Gr — garnets, E — epidote, St — staurolite, Sl — sillimanite; poorly resistant minerals: Ch — chlorite, A — amphibole, B — biotite, Gl — glauconite

Sediments of the lithologic complexes 1 and 3 have similar grain size distributions, characterized by a significant content of gravely and sandy fractions. Gravely fraction, undoubtedly originated from disintegration of weathered glauconitic sandstones (surely also of the Magura and Ciężkowice Sandstones) does not occur in the upper part of the profile in such big quantity. A large content of sandy and gravely fractions and the presence of numerous, typically strongly weathered clasts of glauconitic sandstones and most of all the presence of glauconitic grains, allow to consider these sediments as products of weathering of glauconitic Gorzeń Sandstones. There is though a possibility that these deposits are solifluctional as glauconite grains occur also in the Magura Sandstones and the drilling has not reached the bedrock. Some doubts may be risen by lack of glauconite in the weathered glauconitic Gorzeń Sandstones (sample 28). The sample 28, collected from a depth of 0.2–0.4 m, has been subjected for a long time to mechanical and chemical weathering. Probably, it caused decomposition of unstable glauconite or its leaching. Hence, a next conclusion results that since glauconite is preserved in weathered glauconitic sandstones represented by the complexes 1 and 3, the activity of weathering factors was either weaker or shorter. Most probably the weathered glauconitic sandstones were relatively quickly covered by younger sediment and separated from the external factors. It is not entirely out of the question that existing then climatic conditions were less favourable for the chemical weathering then presently (it was cooler — which is indicated by the palynologic analysis).

Considering composition and content of heavy minerals, sediments of the lithologic complex 2 are almost identical to sediments of the described complexes 1 and 3. The difference between these complexes is indicated in the granulometric characteristics — silts are dominant sediments of the complex 2 — and in respect to grain size distribution are equivalent to sediments of the complexes 4 and 5. Sediments of the described complex were most probably associated with aeolian accumulation, which is supported indirectly by indices of grain size distribution (Table 1), similar to indices obtained in other profiles of loess sediments (J. Nowak, 1977/1978; S. W. Alexandrowicz *et al.*, 1991; M. Łanczont, 1995). Accumulation of the loess-like deposits was relatively quickly disrupted by slope processes and accumulation of solifluction deposits (lithologic complex 3). A small thickness of loess-like deposits and simultaneous contribution of slope processes in their accumulation caused that composition of heavy minerals in complexes 1 through 3 is very similar, and since accompanied by lack of amphiboles, it indicates rather a short transport of the material.

In sediments of lithologic complexes 4 and 5 (of a combined thickness almost 5 m) the most significant is the presence of amphiboles and biotite, minerals considered (in sedimentary rocks) as allogenic (R. Chlebowski, 1988, and others). Particularly the presence of amphiboles in sediments with a large content of so-called "loess" fraction may be associated with aeolian transport. In the profile of deposits the last glaciation in nearly Wadowice, amphiboles were not found in

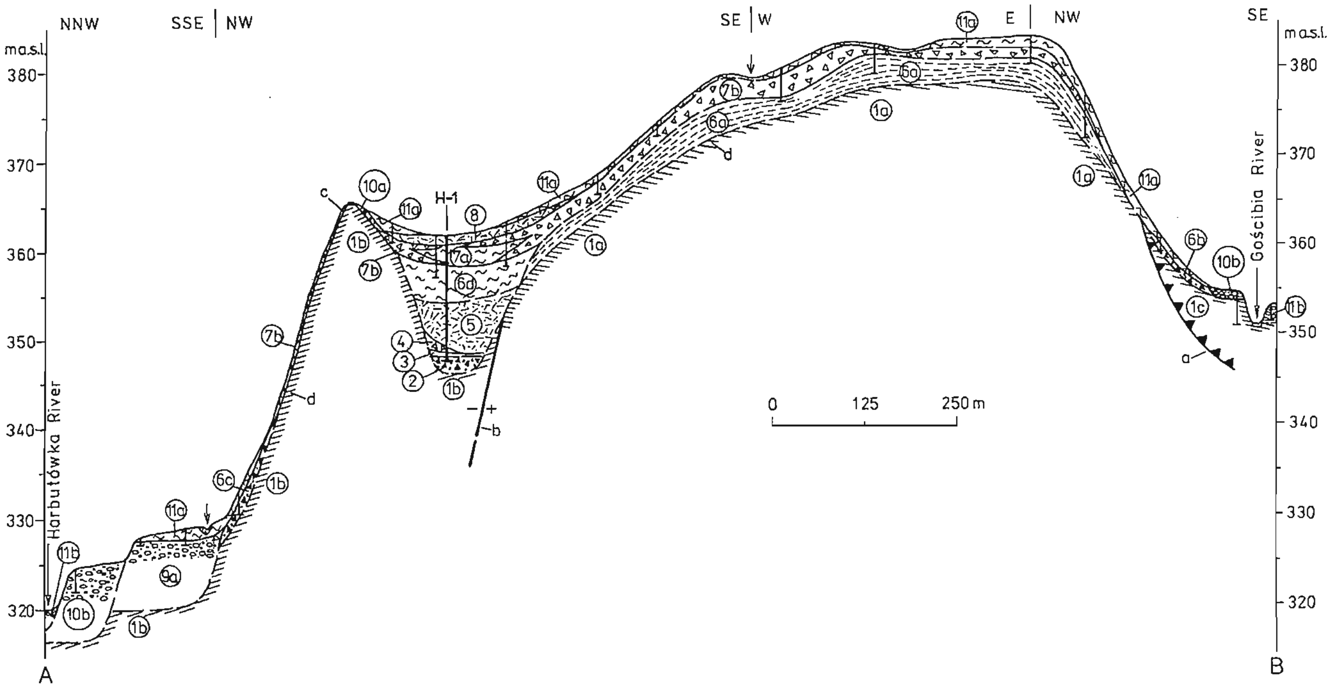

Fig. 3. Geologic cross-section A–B: flysch rocks according to M. Książkiewicz (1953) and M. Książkiewicz, J. Liszkowa (1979)

Lower Cretaceous — Valanginian: 1a — Upper Cieszyn Slates of the Subsilesian Series; **Lower Cretaceous — Albian**: 1b — glauconitic sandstones from Gorzeń of the Silesian Series; **Tertiary — Palaeogene**: 1c — Ciężkowice Sandstones of the Magura Series; **Quaternary: Vistulian Glaciation: older Pleniglacial**: 2 — weathered deposits and sandy-clayey solifluctional deposits, 3 — loess-like silty deposits, 4 — solifluctional sandy-clayey deposits; **Interpleniglacial**: 5 — loess-like silty deposits, 6a — clayey weathered deposits of the Upper Cieszyn Slates, 6b — weathered deposits and solifluctional deposits, gravely-clayey, 6c — solifluctional sandy-clayey deposits, 6d — clayey-silty deluvial deposits and solifluctional deposits; **younger Pleniglacial**: 7a — silty-clayey deluvial deposits, 7b — sandy-clayey solifluctional deposits and slope deposits replaced by creep, 8 — loess-like silty deposits; **decline of Vistulian Glaciation/early Holocene**: 9a — gravels and pebbles of the terrace III of the Harbutówka River (7–10 m); **Holocene**: 10a — weathered deposits and solifluctional sandy-clayey deposits, 10b — sands, gravels and pebbles of the terrace II of the Harbutówka and Gościbia Rivers (2.5–5 m), 11a — clayey-silty deposits and sandy-silty deluvial deposits, 11b — gravels and pebbles of the terrace I of the Harbutówka and Gościbia Rivers (0.5–2 m); H-1 — Harbutowice-1 drilling; a — boundary of the Magura Series over the Subsilesian Series, b — fault (+ — hanging wall, – — footwall), c — location of sample 28, d — flysch rocks schematically indicated

weathered flysch sandstones, and amphibole content (4%) in overlying loess-like deposits was associated with a distant transport (M. Sobolewska *et al.*, 1964). The relationship between amphiboles occurring in silty covers with aeolian transport — possibly blown away from glaciofluvial deposits — may be indicated in other profiles of the borderland between the Beskidy Mts. and the foreland (K. Grzybowski, oral information). Determined indices of grain size distribution (Table 1) and the presence of $CaCO_3$ in sediments of the complex 4 and a lower part of the complex 5 ($CaCO_3$ in a lower part was possible leached away), may also support loess-like characteristics of the described sediments.

Grains of amphiboles and biotite, present in the described sediments, probably originated from the Quaternary sediments present to the west, north-west and north from Sułkowice — accumulation of loess-like deposits could be attributed to western, northwestern, and northern winds. If, however, a pine pollen found in sediments of the complex 4 comes from transport — a possible importance of the southern winds (probably in some periods) should be also considered.

Accumulation of sediments of complexes 4 and 5 occurred under cool climatic conditions, similar to conditions present here ealier. The presence of grains of the pine pollen in the sample 10 (depth 10.6–10.8 m) is quantities similar to these of the samples 19 and 20 (depth 4.2–4.8 m) indicates rather warmer conditions somewhere to the south from Sułkowice. An upper part of loess-like deposits of the complex 5 (1.5 m thick) lacks $CaCO_3$, probably as the result of decalcification. Processes of decalcification most probably occurred during a warmer period, favourable to particularly chemical weathering. This period has not been confirmed in the preserved sediments, a possibility of the occurrence of a stratigraphic unconformity exists at the boundary between the complexes 5 and 6 — a similar situation was determined in the Wadowice profile (K. Grzybowski, K. Bińka, 1997).

Sediments of the complexes 6 and 7 contain a lot of clayey fraction and significant admixtures of sandy fraction, which may indicate a change of sedimentation character. Contribution of so-called "loess" fraction is insignificant and decreases toward the top of the profile (Fig. 4). Determined indices of

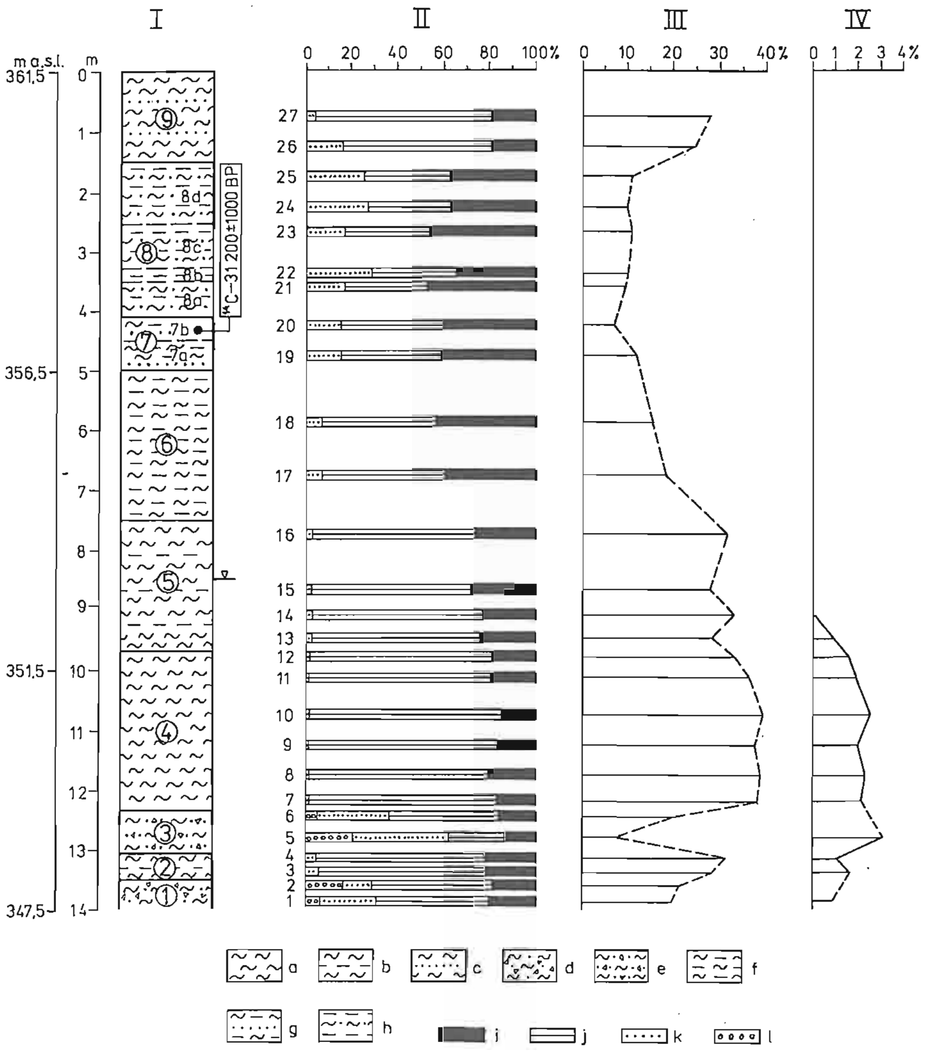

Fig. 4. Lithologic profile of the drilling Harbutowice-1 with results of grain size distribution

I — Harbutowice-1 profile: 1–9 — lithologic complexes, a — silty deposits, b — silty deposits with admixture of clayey fraction, c — silty deposits with admixture of sandy fraction, d — sandy-silty deposits, e — sandy-silty deposits with admixture of gravely fraction, f — clayey-silty deposits, g — clayey-silty deposits with admixture of sandy fraction, h — silty-clayey deposits with admixture of sandy fraction; II — grain size distribution: 1–27 — sample numbering, i — clayey fraction (<0.002 mm), j — silty fraction (0.002–0.0625 mm), k — sandy fraction (0.0625–2 mm), l — gravely fraction (>2 mm); III — diagram of "loess" fraction (0.02–0.05 mm); IV — $CaCO_3$ content; 7a, b, 8a–d — described in the text

the grain size distribution significantly differ from indices obtained for "loess-like" deposits (Table 1). Also composition of heavy minerals is significantly different from that of sediments of older complexes (Table 2). Grain size distribution and composition of heavy minerals in the described sediments are similar to these of the weathered Upper Cieszyn Slates, occurring in the direct neighbourhood of the Harbutowice-1 profile.

Based on the listed above features of grain size distribution, and also on the spatial relations among sediments of the complexes 6 and 7 with weathered rocks occurring in the vicinity (Fig. 3), the described sediments may be considered as deluvial deposits or solifluctional deposits. They were certainly in a big part formed as the result of washout and relocation of the weathered material from the Upper Cieszyn Slates (hence described similarities in the graining and composition of heavy minerals), bordering the described sediments from the east.

Relocation of the slope deposits and washout could be a result of a gradual climate warming, with beginning of which is associated the end of accumulation of loess-like deposits (an upper part of the complex 5), and with which optimum, the development of soil processes corresponds (the complex 7). In the result of the suggested climate warming, supported by the palynological analysis, a soil layer (0.8 m thick) developed on the deluvial and solifluctional deposits. The humus layer A, 0.4 m thick and a dark brown (complex 7b), and weekly marked the leaching layer B of a similar thickness (complex 7a), can be distinguished in this soil.

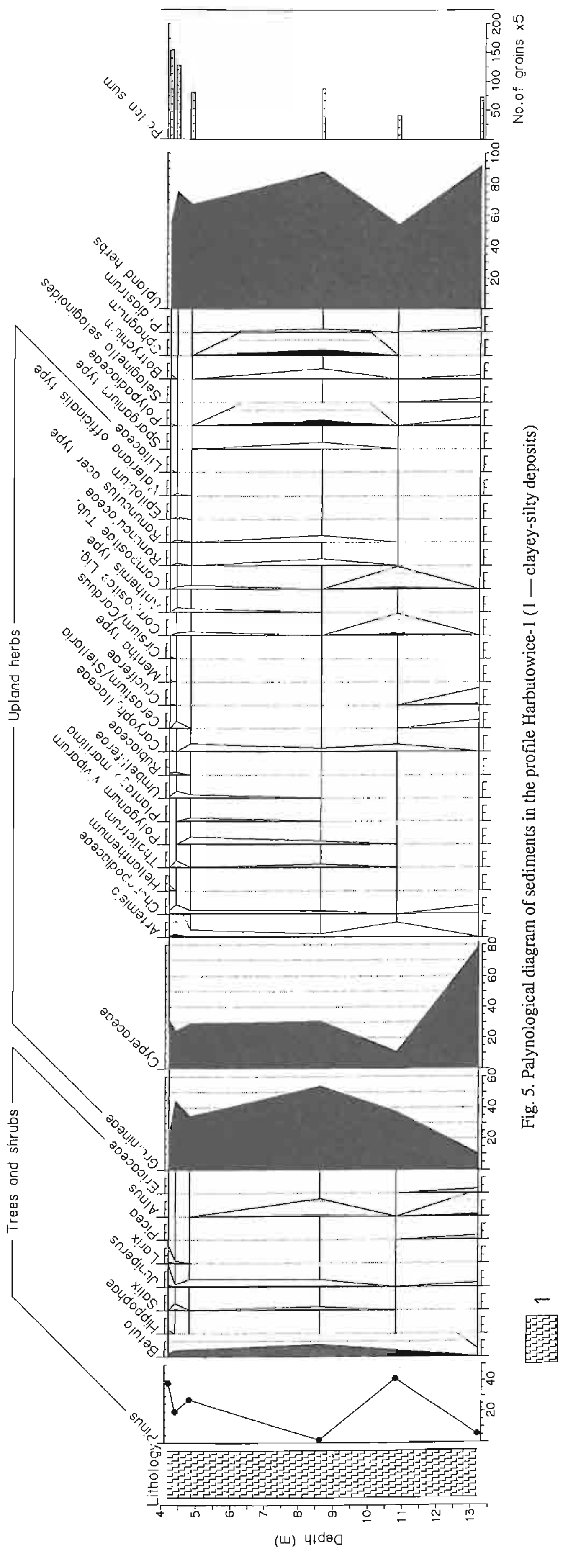

Fig. 5. Palynological diagram of sediments in the profile Harbutowice-1 (1 — clayey-silty deposits)

In a zone with a dominant content of iron carbonates (about 1.1–1.2 m beneath the palaeosol), about 1.5 m thick, concentrating of Fe^{2+} compounds occurred (mainly siderite) under reducing conditions and to decomposition and leaching of other minerals by processes of chemical weathering. Such high contents of iron carbonates and a grey-blue colour of sediments indicate simultaneously a strong gleization of the described zone. It is difficult to verify whether this gleization was caused by an upper level of soil waters, or by accumulation of rain precipitation in this zone. The gleization also affected the top of loess-like deposits (the complex 5), which is indicated by a significant content of iron carbonates (sample 16). The described iron-rich zone indicates similarity to pseudogleyey soils, described in other profiles in Poland (J. Jersak, 1976; K. Konecka-Betley, 1976; K. Konecka-Betley, H. Maruszczak, 1976).

Sediments of the lithologic complex 8, characterized by a grain size distribution similar to sediments of the complex 7 — and occurring in a similar geologic situation (Fig. 3) — are probably deluvial deposits. A greater contribution of the sandy material in their composition as compared to sediments of the complexes 6 and 7 is associated with a more intensive washout of slopes covered with solifluctional deposits, which means from the south (Fig. 2). It is not impossible that a partial contribution to accumulation of the described sediments was also caused by solifluctional processes. The occurrence of slope sediments, particularly deluvial, covering palaeosols from the Hengelo or Denekamp Interstadials, was also determined in loess profiles of the Przemyśl Foreland (M. Łanczont, 1995).

The lithologic complex 9 (the youngest in this profile), indicating grain size distribution, graining indexes and composition of heavy minerals similar to these of the complexes 4 and 5, may be also considered as a loess-like deposit. The similarity of composition of heavy minerals of the described complex and weathered material of glauconitic Gorzeń Sandstones (sample 28 — the presence of epidote, chlorite, sillimanite and staurolite in both situations) suggests that the material of the complex 9 could be blown in (periodically washed in as the result of the wash out) from this type of weathered deposits.

Stratigraphy of sediments in the Harbutowice-1 profile, based on the results of palynological analysis and on results of absolute dating, includes a significant part of the Vistulian Glaciation. The palaeosol (the lithologic complex 7) was ^{14}C dated at 31 200±1000 years BP. This date, together with the palynological results, allow to refer the development of the fossil soil to the Denekamp Intestadial.

Loess-like deposits of the complexes 4 and 5 (4.8 m thick), underlying the palaeosol associated with the Denekamp Interstadial, may be correlated with the younger middle loess (S. W. Alexandrowicz *et al.,* 1991; M. Łanczont, 1995). Accumulation of the loess-like deposits ended by processes of washout and solifluction, and later by accumulation of deluvial deposits and of solifluctional deposits of a thickness of 3.4 m. The washout and decalcification of the upper part of loess-like deposits indicate warmer climatic conditions, which could be referred to as these of the Hengelo Interstadial; it is not impossible though, that decalcification was younger.

Accumulation of loess-like (complexes 4 and 5) occurred during cooler fragments of the Interpleniglacial; accumulation of deluvial deposits and solifluctional deposits existed during warmer fragments (Hengelo, Denekamp — the complexes 6 and 7), ended by the development of the palaeosol.

Sediments of the lowest part of the profile (lithologic complexes 1–3) were most probably formed during the older Pleniglacial; loess-like deposits of the complex 2 (of a thickness about 0.5 m), covered by solifluctional deposits, should be thus considered as the younger lower loess.

Sediments occurring above the fossil soil from the Denekamp Interstadial (complexes 8, 9 of a thickness 4.1 m) formed during the younger Pleniglacial; loess-like deposits of the complex 9 thus represent the younger upper loess. Accumulation of loess-like deposits was disrupted by the washout. A small thickness of the youngest loess-like deposits (about 1.5 m), with respect to their equivalents in the Rożnów Foreland (S. W. Alexandrowicz *et al.*, 1991), is probably associated with a different geomorphologic-accumulative situation within the depression, which used to be in a big part filled by older deposits before deposition of the described sediments.

CONCLUSIONS

1. In the Wielickie Foreland located between Sułkowice and Harbutowice, some deposits which have been considered so far as weathered material and deluvial deposits, indicate features of loess-like sediments.

2. A silty fraction, including the so-called "loess" fraction dominate in the studied loess-like deposits, however, sandy and clayey fractions with small admixtures of a gravely fraction dominate in the weathered deposits.

3. The presence of amphiboles and a large content of biotite brings attention in composition of heavy minerals of loess-like deposits. Amphiboles do not occur in the weathered deposits and deluvial deposits, and biotite content is significantly smaller; iron carbonates dominate here (mainly siderite) and iron oxides.

4. Within deposits considered as loess-like (lithologic complexes 2, 4, 5 and 9), the content of transparent minerals as compared to opaque minerals increases upward in the profile, similarly to the content of weakly resistant minerals with respect to moderately resistant and resistant minerals.

5. Accumulation of loess-like deposits occurred during cooler periods of the Interpleniglacial; accumulation of deluvial deposits and solifluctional deposits occurred during warmer periods and ended with soil-forming processes (Denekamp Interstadial).

6. The fossil soil ^{14}C dated at 31 200±1000 years BP represent the Denekamp Interstadial. Loess-like deposits and slope deposits, occurring beneath the fossil soil, formed during the Interpleniglacial (the younger middle loess) and the older Pleniglacial (the younger lower loess). Slope deposits together with loess-like deposits, overlying the fossil soil, represent a period of the younger Pleniglacial (the younger upper loess).

7. Sediments of the Harbutowice-1 profile accumulated in a morphological depression, most probably associated with the flysch tectonics; such a configuration of the topography of the area enhanced the development of slope processes (deluvial and solifluctional), often disrupting the loess accumulation.

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UTWORY LESSOPODOBNE W HARBUTOWICACH W POŁUDNIOWEJ CZĘŚCI POGÓRZA WIELICKIEGO

Streszczenie

Na obszarze Pogórza Wielickiego w zlewni górnej Harbutówki, między Sułkowicami a Harbutowicami, wykonano otwór wiertniczy Harbutowice-1, zlokalizowany na powierzchni działu, na wysokości 361,5 m n.p.m. (fig. 1–3). Osady z profilu tego otworu — o głębokości 14 m — zostały poddane szczegółowym analizom granulometrycznym, mineralogicznym, palinologicznym oraz datowaniom wieku bezwzględnego. W oparciu o uzyskane wyniki ustalono genezę i stratygrafię osadów profilu Harbutowice-1.

Na podstawie wyników uziarnienia osadów i wyznaczonych wskaźników uziarnienia (tab. 1) wydzielono dziewięć zespołów litologicznych (fig. 4). Analizy wykazały zróżnicowany zestaw minerałów ciężkich w wydzielonych zespołach; w obrębie samych zespołów różnice w składzie były znacznie mniejsze (tab. 2). W oparciu o wyniki analizy palinologicznej stwierdzono w profilu Harbutowice-1 występowanie czterech poziomów pyłkowych: dwóch wskazujących na warunki chłodniejsze (poziomy pyłkowe A i C — fig. 5), a pozostałych dwóch — na warunki cieplejsze (poziomy pyłkowe B i D — fig. 5).

Zespoły litologiczne 1 i 3, charakteryzujące się największymi w całym profilu zawartościami frakcji piaskowej i żwirowej (fig. 4), uznano za zwietrzeliny piaskowców glaukonitowych (zespół 1) i utwory soliflukcyjne (zespół 3). Taką genezę potwierdza także podobny w obu zespołach zestaw minerałów ciężkich, a zwłaszcza obecność glaukonitu, który w zespołach młodszych nie występuje (tab. 2).

Zespoły litologiczne 2, 4, 5 i 9 uznano za utwory lessopodobne na podstawie dużych zawartości frakcji pyłowej (wśród której dominuje tzw. frakcja lessowa — fig. 4), wskaźników uziarnienia (tab. 1) oraz występowania, w zestawie minerałów ciężkich, amfiboli (tab. 2). Obecność amfiboli, uznawanych w skałach osadowych za minerały allogeniczne, może wskazywać na transport eoliczny. Za taką interpretacją przemawia również obecność $CaCO_3$ zespołach 4 i 5.

Zespoły litologiczne 6, 7 i 8 zostały uznane za deluwia i/lub utwory soliflukcyjne głównie na podstawie sytuacji geologicznej, w której występują omawiane osady (fig. 3). Źródłem materiału dla procesów spłukiwania i soliflukcji były zwietrzeliny łupków cieszyńskich górnych — stąd duża zawartość frakcji iłowej w osadach tych zespołów.

Pod względem stratygrafii osady profilu Harbutowice-1 obejmują znaczny odcinek zlodowacenia wisły. Gleba kopalna, występująca w stropie zespołu 7, została wydatowana metodą ^{14}C na 31 200±1000 lat BP. Wynik ten, poparty analizą palinologiczną (poziom pyłkowy D), pozwala odnieść utworzenie się tej gleby do interstadiału denekamp. Utwory lessopodobne znajdujące się poniżej gleby kopalnej (zespoły 4 i 5) powstały w interpleniglacjale, można je zatem uznać za less młodszy środkowy. Osady trzech najstarszych zespołów (1, 2 i 3) zostały prawdopodobnie utworzone w starszym pleniglacjale; utwory lessopodobne zespołu 2 można więc uznać za less młodszy dolny. Osady dwóch najmłodszych zespołów (8 i 9), występujące powyżej gleby kopalnej interstadiału denekamp, były akumulowane w młodszym pleniglacjale; utwory lessopodobne zespołu 9 reprezentują zatem less młodszy górny.