Geological Quarterly, Vol. 41, No. 2, 1997, p. 251–256

New data on the Late Pleistocene deposits at Wadowice in the Carpathian Foothills

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(Received: 12.11.1996)

At the NW end of Wadowice, on the upland neighbouring the Skawa River valley, the sequence of the Vistulian deposits comprises the Older Pleniglacial solifluctional and deluvial silts, as well as the deluvial silts and clays deposited in a small and shallow depression during the Interpleniglacial and the Younger Pleniglacial loess-like silts displaced by slope processes. The ^{14}C dated Interpleniglacial deposits originated in a tree-less environment during the Hengelo and Denekamp Interstadials.

LOCATION AND IMPORTANCE OF THE INVESTIGATED DEPOSITS

Two sites of the Pleistocene deposits, both important for the Quaternary stratigraphy of the Carpathian Foothills, are described at Wadowice (Figs. 1, 2). One of them, the clay-pit of the brickyard Łazówka (M. Klimaszewski, 1936, 1937, 1948, 1967; L. Starkel, 1984, 1988) is located in the upland part neighbouring the Skawa River valley and the Choczeńka River valley. Another one, the abandoned clay-pit of the "southern brickyard" excavated near the cemetery (M. Sobolewska *et al.*, 1964; L. Starkel, 1972, 1988, 1995) includes the lowermost portion of the western slope of the Skawa River valley. The present note gives a new look on the Late Pleistocene deposits from the Łazówka clay-pit, i.e. the deposits that overlie there a loam containing erratic boulders (J. Dudziak, 1961), gene-rally considered to be a glacial till deposited during the Cracovian (Mindel Glaciation). According to M. Klimaszewski (1948), this till is overlain by the following deposits (Fig. 3, profile II, layers 5–7):

— fine-stratified silt (0.6 m thick),

— greenish-grey stratified loam and silt containing erratic pebbles (1.5 m thick),

— yellow loess-like loam (2 m thick).

The bottom of these deposits is fixed at 296 m a.s.l., their top (i.e. the present topographic surface) reaching there 300 m a.s.l. (M. Klimaszewski, 1967). They have been related to the retreat of the Cracovian ice-sheet (M. Klimaszewski, 1948); however, the geological maps of the Wadowice region mark an isolated outcrop of the glacial till surrounded by loess assigned to the last (i.e. Vistulian) glaciation (M. Książkiewicz, 1953; J. Golonka, 1981).

In a borehole located several hundred metres westward (Fig. 3, profile I), a 5.1 m thick "yellow non-calcareous loam" overlies directly the Palaeogene Menilite Beds (M. Książkiewicz, 1957). The upper surface of these layers, reaching there 300 m a.s.l., is an ancient erosional and/or denudational surface.

RECENT INVESTIGATIONS

During field investigations carried out in 1992–1994 (research theme BW-1205/15) in the eastern (recently exploited) part of the Łazówka clay-pit, the first author has studied three new lithostratigraphic profiles III, IV and V (Fig. 3). The IV one is located 90 m ENE from the III-rd, the V-th one 50 m SE from the IV-th. Between the profiles IV and V the present

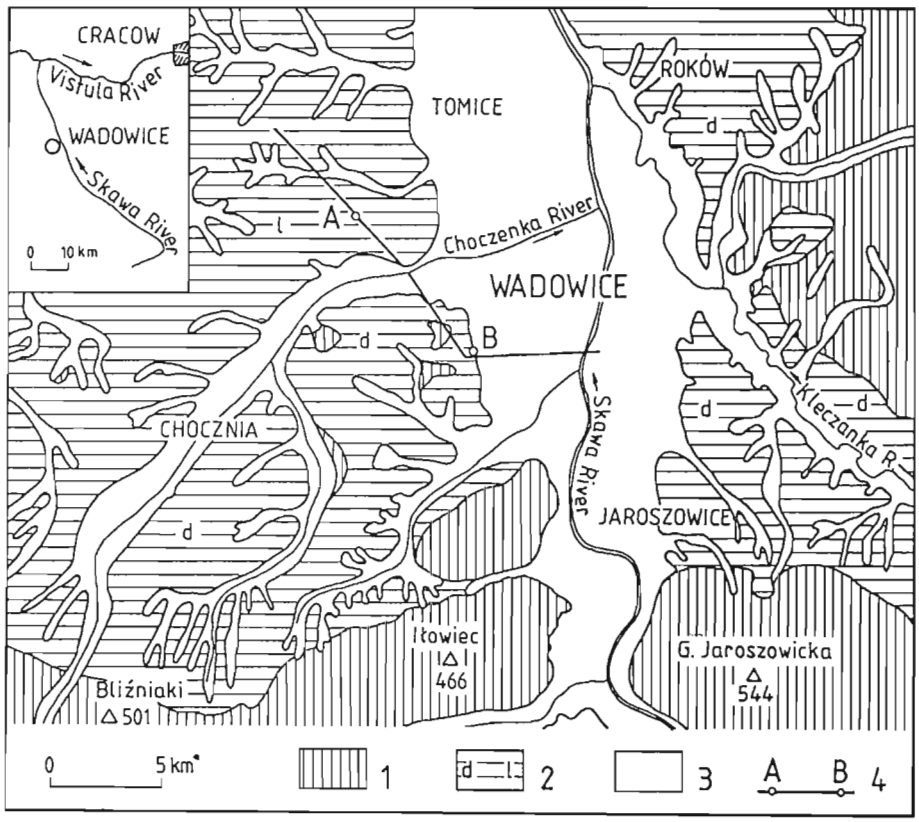

Fig. 1. Geological and geomorphological setting of the studied profiles after M. Książkiewicz (1953), simplified

Cretaceous-Palaeogene: 1 — flysch cropping out in the Beskid Mały Mts. (in the south) and in the Carpathian Foothills (mainly in the east); Quaternary: 2 — deluvia (d) and loess (l) cover in the Carpathian Foothills, 3 — alluvia in the river valleys; 4 — geological cross-section line (Fig. 2): A — location of the Łazówka brickyard, B — location of the "southern brickyard"

Sytuacja geologiczno-geomorfologiczna zbadanych profili według M. Książkiewicza (1953), uproszczona

Kreda-paleogen: 1 — flisz odsłonięty w Beskidzie Małym (na południu) i na Pogórzu Karpackim (głównie na wschodzie); czwartorzęd: 2 — pokrywa deluwialna (d) i lessowa (l) na Pogórzu Karpackim, 3 — aluwia w dolinach rzecznych; 4 — linia przekroju geologicznego (fig. 2): A — cegielnia Łazówka, B — „cegielnia południowa"

topographic surface stretches horizontally at 296.4 m a.s.l. In the profiles III and IV a mixtite[1] containing erratic cobbles (layer 3 on Fig. 3) is less thick and occurs at lower altitude than the till in the profile II, but the correspondence of these two deposits is evident. In the profile V the mixtite is lacking.

Subsequently the second author has realized the palynological analyses of several samples. Two samples have obtained the radiocarbon dates in the ^{14}C Laboratory of the Silesian Technical University at Gliwice, two other samples have been dated in the TL Laboratory at the Gdańsk University.

In the light of the above mentioned investigations, the deposits overlying the mixtite form three lithostratigraphic units namely:

— solifluctional and deluvial silts,

— deluvial clays and silts deposited in a small and local depression,

— loess-like silts, partly displaced by slope processes.

SOLIFLUCTIONAL AND DELUVIAL SILTS

The silts (layer 4a on Fig. 3,) lying in the profile IV just above the gently sloping top surface of the mixtite contain deformed sandy silt laminae, mixtite patches parallel to the bottom surface as well as quartz and crystalline rock pebbles. This deposit was most certainly displaced by the solifluction. In the same slope environment were probably deposited the sandy silts (layer 4b on Fig. 3) lying in the profile V on the denudational surface of silts older than the mixtite. The silts overlying the mixtite contain some pebbles too, but their sorting is much better: they are probably the deluvial deposit resulting from washout of the mixtite. They are TL-dated 75.8 ±11.3 ka BP (UG-1713). In the light of this date and in agreement with the palaeogeomorphologic reconstructions of other Carpathian regions (L. Starkel, 1984) the slope processes responsible for the described silts probably have taken place during the Older Pleniglacial of the Vistulian[2].

DELUVIAL CLAYS AND SILTS

The above described deluvial silts (layer 4b on Fig. 3) are overlain by bluish-grey silty clays (containing few pebbles) changing upwards into the light grey clayey silts of subhorizontal lamination. Within these silts an erosional surface was identified (surface **e** on Fig. 3). Total thickness of clays and silts is 2.5 m; most probably they represent the sedimentation in a small stagnant water basin which was not deep and became more and more shallow due to deluviation. Occasionally its bottom has been eroded by washout.

Several dark grey laminae bearing plant detritus occur within the described deposits, mostly in the silts. A sample taken from a silt lamina just above mentioned erosional sur-

[1] This mixtite and the underlying Pleistocene deposits will be discussed by the second author in another article, in the light of the TL dates they seem younger than the Cracovian Glaciation.

[2] The subdivision of the Vistulian after L. Starkel (1995), slightly modified.

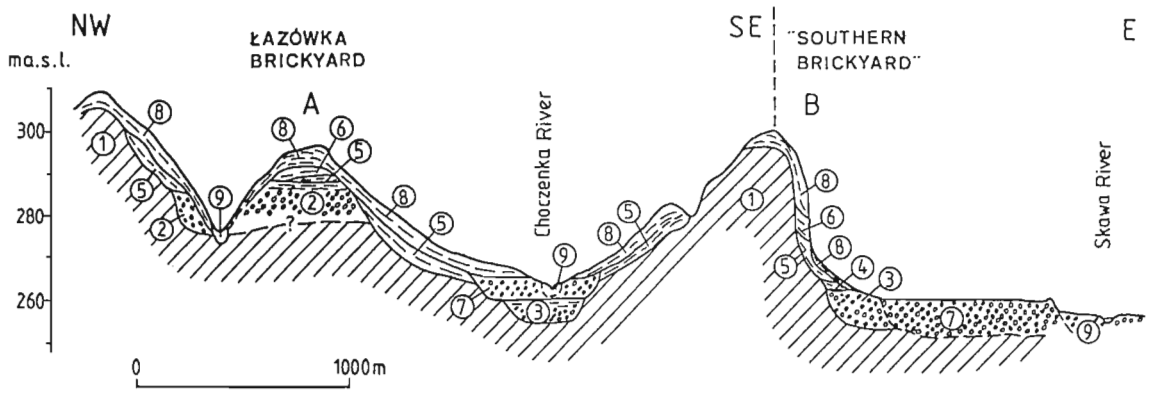

Fig. 2. Schematic cross-section in the area of Wadowice

Cretaceous-Palaeogene: 1 — flysch; Quaternary prior to the Vistulian, locally Miocene possible: 2 — gravels, sands, silts and clays; Early Vistulian: 3 — alluvia; Brörup Interstadial: 4 — alluvia and peats; Older Pleniglacial: 5 — solifluctional and deluvial silts; Interpleniglacial: 6 — lacustrine-deluvial clays and silts; Pleniglacial *sensu lato* and/or Late Vistulian: 7 — alluvia; Younger Pleniglacial: 8 — loess-like silts; Holocene: 9 — alluvia

Schematyczny przekrój geologiczny w rejonie Wadowic

Kreda-paleogen: 1 — flisz; czwartorzęd starszy od vistulianu, lokalnie być może miocen: 2 — żwiry, piaski, mułki i iły; wczesny vistulian: 3 — aluwia; interstadiał brörup: 4 — aluwia i torfy; starszy pleniglacjał: 5 — mułki soliflukcyjne i deluwialne; interpleniglacjał: 6 — mułki i iły deluwialne; pleniglacjał *sensu lato* i/lub późny vistulian: 7 — aluwia; młodszy pleniglacjał: 8 — mułki lessopodobne; holocen: 9 — aluwia

face contains: *Pinus* — 3.8%, *Picea* — 0.5%, *Gramineae* — 16.2%, *Cyperaceae* — 76.3%, *Compositae Tubuliflorae* — 0.6%, *Compositae Liguliflorae* — 0,9%, *Cruciferae* — 0.3%, *Caryophyllaceae* — 0.3%, *Chenopodiaceae* — 0.3%, *Cerastium* t. — 0.6%, *Botrychium* — 0.6%. This pollen spectrum makes it possible to conclude that during the sedimentation of the analyzed lamina the Carpathian Foothills in the vicinity of Wadowice were covered by the open communities. A sample taken from the same lamina was a ^{14}C dated 28.9 ± 0.77 ka BP (Gd-9221), therefore the sedimentation of this lamina can be related to the close of the Denekamp Interstadial. In two samples from the upper part of the silts the pollen frequency is low, nevertheless, these samples can be also related to the tundra vegetation.

Between the profiles IV and V the bottom surface of the described deposits slopes toward SE, in the profile V its position is 1.5–2.5 m below that one of the profile IV. In this profile the dark grey laminae containing plant detritus are also present. In upper part of the silts, these dark grey laminae (as well as all the laminae below) contain no more than 20% of the 0.02–0.05 mm fraction (roughly 1/4 of the total mud), while in the alternating light grey laminae this fraction reaches 45% (nearly 2/3 of the total mud), similarly as in the loess (J. Cegła, 1972; A. Malicki, 1950). It seems that the material of the lower part of the unit and of the dark grey laminae of the upper part was furnished by washout waters, while the grains of the upper part of light grey laminae came from eolian transport. The rhythmic lamination of the upper part of the silts most probably reflects alternation of more humid and more arid periods (possibly seasons).

The palynologic analysis of the deposits occurring in the profile V deals with three samples. A sample from the lower part of these deposits contains: *Pinus* — 13.7%, *Alnus* — 0.4%, *Salix* — 0.4%, *Betula* — 5.2%, *Picea* — 0.2%, *Juniperus* — 0.4%, *Gramineae* — 21.9%, *Cerastium* t. — 0.8%, *Cruciferae* — 3.0%, *Thalictrum* — 0.45%, *Plantago maior/media* — 0.4%, *Cyperaceae* — 49.8%, *Compositae Tubuliflorae* — 2.5%, *Compositae Liguliflorae* — 0.4%, *Polypodiaceae* — 0.4%, *Botrychium* — 0.8%, *Selaginella selaginoides* — 0.4%. In the middle part there were found: *Pinus* — 18.8%, *Betula* — 2.3%, *Alnus* — 4.1%, *Picea* — 1.5%, *Ericaceae* — 0.6%, *Gramineae* — 14.7%, *Cyperaceae* — 56.9%, *Cruciferae* — 1.2%, *Cerastium* t. — 1.8%, *Thalictrum* — 0.6%, *Selaginella selaginoides* — 3.5%, *Sphagnum* — 0.5%, *Polypodiaceae* — 0.6%. A sample taken from the upper part has a similar character but, in this case, the pollen frequency is very low. Similarly to those of the profile IV, the samples of the profile V most certainly represent open communities. The higher percentage of the arboreal pollen may come from a long eolian transport, but we cannot exclude that it gives evidence of few forest patches.

A sample taken at the profile V from the uppermost part of the described deposits was ^{14}C dated 35.4 ±1.6 ka BP (Gd-9229), therefore this part of the unit can be related to the Hengelo Interstadial of the Vistulian. In the light of this date and of the above mentioned altitude differences, the described deposits of the profile V should correspond to the lower part of the deposits of the same unit occurring in the profile IV (below the erosional surface) in the profile V we have no equivalent of the upper part of the unit, related in the profile IV to the Denekamp Interstadial.

The described deposits of the two interstadials represent the Interpleniglacial of the Vistulian. It is possible that the loess-like laminae occurring in the profile V announce a cooling between the Hengelo and the Denekamp Interstadials. The involved washout erosion is related rather to the Denekamp Interstadial.

These Interpleniglacial deposits are cut by a denudational surface (surface **d** on Fig. 3) that seems larger than the former erosion and denudation phenomena. In the profile IV this surface is subhorizontal (0–1°), its inclination increases slightly towards the profile V where it appears 1 m lower (that's why, in this profile, the Denekamp Interstadial deposits are lacking). Further southwards (following the clay-pit wall in

1994) this surface continue to go lower to the bottom of the Interpleniglacial deposits. Its slope inclination, as measured in the wall, is roughly 5°, the true slope toward the SE is a little greater.

This denudational surface is diversified by rill forms, several to several dozen centimetres deep. In the wall (stretching N–S) the width of these rill sections reaches several dozen centimetres, in reality the rills (descending to the SE) are somewhat narrower.

The described surface reflects activity of linear washout which probably increased at the close of the Interpleniglacial because of reduction of vegetation.

LOESS-LIKE SILTS

In the profiles IV and V the upper unit consists of the clayey silts (layers 6–8 on Fig. 3) located above the denudational surface up to the present topographic surface. Because of slope inclination of the denudational surface, thickness of these silts increases from 3.6 m in the profile IV to 4.7 m in the profile V and to full 8 m more southwards.

In both profiles these silts are tripartite: the lower part (layer 6) bears abundant discontinuous streaks that are inclined subparallelly to the bottom surface; the middle part (layer 7) consists of homogeneous clayey silt, the upper part (layer 8) contains a small amount of gravels associated with a slight increase of sandy fraction. In all the deposits of the described unit the amount of 0.02–0.05 mm fraction is higher than below, generally exceeding 25%, in some cases up to 40%. This feature of the silts probably reflects their eolian origin (J. Cegła, 1972): the silts of the middle part of the unit can be considered as subaerial loess, those of the lower and upper parts are slope (solifluctional and/or deluvial) loesses.

Similarly to the underlying deposits, the described silts show generally light tints of yellow-grey or grey-yellow in colour, excepting the lowermost part of the unit, 0.3–0.5 m thick, covering evenly the inclined bottom surface, that is dark yellow, locally rusty-yellow in colour due to the increased limonite content. This part of the silts, characterized by the largest amount of clay (up to 40%), is evidently transformed by illuviation. The limitation of this transformation just on the top of the interpleniglacial silts, which are apparently more permeable, evokes the ancient permeability of these silts diminished by freezing (J. Stochlak, 1978), possibly the illuviation had taken place above the permafrost.

Some discontinuous laminae of the described unit (mainly of its upper part) are grey in colour due to small admixture of plant detritus. Samples of these laminae show a very low pollen frequency but they involve the tundra assemblages.

A sample taken from the upper part of the unit (profile IV, depth 1.5–1.8 m) was TL-dated 28.7 ±4.3 ka BP (UG-1714). Basing on this date and taking into consideration the ^{14}C dates of the underlying interpleniglacial deposits, we can relate the sedimentation of the described loess-like silts to the Younger Pleniglacial (Main Stadial) of the Vistulian.

PALAEOGEOGRAPHIC RELATIONS

In the light of the data here presented, in the Łazówka brickyard clay-pit the Vistulian is represented by the deposits originated during the Older Pleniglacial, the Interpleniglacial and the Younger Pleniglacial. These deposits reflect importance of the solifluction and of the washout in the pleniglacial environment and an increased activity of washout in the Interpleniglacial. The loess-like deposits episodically appear in the Interpleniglacial (the uppermost part of the layer 5 in the profile V), but their development corresponds mainly to the Younger Pleniglacial.

The vegetation remains recorded in the deposits of the Hengelo and Denekamp Interstadials indicate tundra assemblages, eventually with some isolated arboreal patches (namely in the Hengelo Interstadial). The cooling that separated these interstadials, palynologically argued in the site Brzeźnica in the Wisłoka River valley (K. Mamakowa, L. Starkel, 1974), roughly 130 km eastwards, can be suggested at Łazówka on sedimentological grounds (episodes of the loess accumulation).

During the Interpleniglacial, in the vicinity of Wadowice the vegetation was probably meagrer than in the Wisłoka River valley (K. Mamakowa, L. Starkel, 1974; K. Mamakowa, A. Wójcik, 1987). It was evidently meagrer than the vegetation covering the Wadowice region earlier, during the Brörup Interstadial, as described in the "southern brickyard" by M. Sobolewska *et al.* (1966).

The interpleniglacial deposits of Łazówka correspond to the deposits occurring in the "southern brickyard" between the Brörup deposits and the "proluvial dusty silts with a Dryas flora". A close relation certainly joins the interpleniglacial deposits of Łazówka with the "loams and clays with organic material" underlying the loesses some kilometres northwards (L. Bober *et al.*, 1980) and with the Vistulian deposits of Kęty (J. Butrym *et al.*, 1988) and Myślenice (L. Starkel, 1969) but the details of this correlation need some complementary studies.

Lack of the Early Vistulian deposits at Łazówka may be connected with the location of this site near the upland margin where topography and vegetation favoured denudation processes. The denudational surface assigned to the close of the Interpleniglacial has originated as the upper part of the northern slope of the Choczenka River valley. The silts occurring in the lower part of this slope, corresponding probably to the Older and Younger Pleniglacial deposits of Łazówka (Fig. 2), are related to the evidently bipartite gravels of the valley floor. The lower part of these gravels may represent the Early Vistulian, the upper one can be assigned to the Pleniglacial *sensu lato* (Interpleniglacial?).

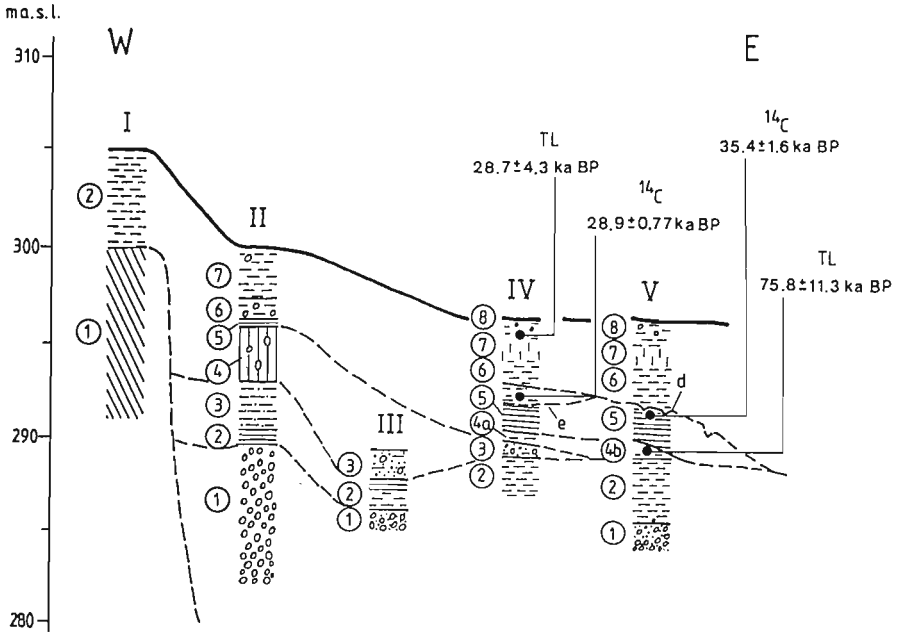

Fig. 3. Geologic profiles in the Łazówka brickyard and in the neighbourhood

I — after M. Książkiewicz (1957): Palaeogene: 1 — flysch; Quaternary: 2 — yellow non-calcareous loam; II — after M. Klimaszewski (1967): Pleistocene deposits: 1 — flysch gravels, 2 — varved clays, 3 — clays, 4 — till, 5 — silty clays, 6 — clays with erratic cobbles, 7 — stratified loam with flysch cobbles in its upper part; III–V — new profiles: Quaternary pre-Vistulian deposits: 1 — fluvial gravels containing flysch cobbles, 2 — lacustrine silts and clays, 3 — mixtite; Vistulian deposits: 4a — solifluctional silts (Older Pleniglacial), 4b — deluvial silts (Older Pleniglacial), 5 — deluvial clays and silts (Interpleniglacial), 6 — solifluctional and/or deluvial loess-like silts (Younger Pleniglacial), 7 — loess-like silts (Younger Pleniglacial), 8 — deluvial loess-like silts (Younger Pleniglacial); **d** — denudational surface; **e** — erosional surface

Profile geologiczne w cegielni Łazówka i w jej sąsiedztwie

I — według M. Książkiewicza (1957): paleogen: 1 — flisz; czwartorzęd: 2 — glina żółta bezwapienna; II — według M. Klimaszewskiego (1967): osady plejstoceńskie: 1 — żwiry fliszowe, 2 — iły warwowe, 3 — iły, 4 — morena denna, 5 — iły mułkowate, 6 — iły z otoczakami eratycznymi, 7 — glina warstwowana, w górnej części z otoczakami fliszowymi; III–V — nowe profile; osady czwartorzędowe starsze od vistulianu: 1 — żwiry rzeczne z otoczakami skał fliszowych, 2 — mułki i iły jeziorne, 3 — mikstyt; osady vistulianu: 4a — mułki soliflukcyjne (starszy pleniglacjał), 4b — mułki deluwialne (starszy pleniglacjał), 5 — iły i mułki deluwialne (interpleniglacjał), 6 — mułki lessopodobne, soliflukcyjne i/lub deluwialne (młodszy pleniglacjał) 7 — mułki lessopodobne (młodszy pleniglacjał), 8 — mułki lessopodobne deluwialne (młodszy pleniglacjał); **d** — powierzchnia denudacyjna; **e** — powierzchnia erozyjna

The Vistulian gravely alluvia of the Skawa River valley (Fig. 2) must be interpreted in another way. In the outer part of the valley they are covered by the Brörup deposits and are no younger than the Early Vistulian (M. Sobolewska *et al.*, 1964; L. Starkel, 1995). In the inner part of this valley, in the result of erosion and redeposition, they represent the Pleniglacial *sensu lato* and/or the Late Vistulian.

Acknowledgements. Sincere thanks are due to Prof. L. Starkel for the critical review of the manuscript of this note, to Prof. A. Pazdur for the ^{14}C datings and to Dr. S. Fedorowicz for the TL-datings. The authors are also indebted to K. Drynda M. Sc. for the grain-size analysis of the described deposits and to Mr Kubica, chief of the Łazówka brickyard, for his kind and helpful assistance during the field investigations.

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NOWE DANE O OSADACH MŁODOPLEJSTOCEŃSKICH Z WADOWIC NA POGÓRZU KARPACKIM

S t r e s z c z e n i e

Osady czwartorzędowe, znajdujące się w gliniance cegielni Łazówka na NW krańcu Wadowic (w brzeżnej części Działu Wadowickiego, w pobliżu dolin Skawy i Choczeńki, fig. 1, 2), są znane od dawna (M. Klimaszewski, 1936). Dotychczasowe opracowania dotyczyły głównie dolnej części tych osadów. Przedmiotem artykułu są osady leżące w Łazówce powyżej mikstytu uznawanego za glinę lodowcową zlodowacenia południowopolskiego (M. Klimaszewski, 1967).

W profilach III–V (fig. 3) osady te obejmują:

— mułki (4a i 4b) z domieszką frakcji piaskowej, z głazikami i płatami mikstytu — soliflukcyjne i deluwialne, osadzone podczas starszego pleniglacjału vistulianu[3],

— mułki (5) w części górnej ilaste, miejscami z domieszką substancji organicznej — deluwialne, reprezentujące interpleniglacjał, rozdzielone kopalną powierzchnią erozyjną (fig. 3, **e**) i rozcięte przez kopalną powierzchnię denudacyjną (fig. 3, **d**) obniżającą się ku SE (ku dolinie Choczeńki),

— mułki lessopodobne (6–8), częściowo przemieszczone przez procesy stokowe, związane z młodszym pleniglacjałem.

Na podstawie datowań ^{14}C (fig. 3) mułki interpleniglacjalne znajdujące się poniżej kopalnej powierzchni erozyjnej (e) zostały uznane za osady interstadiału hengelo, a mułki interpleniglacjalne leżące na tej powierzchni — za osady interstadiału denekamp.

W próbkach mułków związanych z interstadiałem hengelo zdecydowanie przeważa pyłek NAP (m. in. *Cyperaceae* — ok. 60%, *Gramineae* — ok. 20%, *Selaginella selaginoides* — 3,5%). Udział pyłku drzew jest niewielki (*Pinus* — ok. 18,8%, *Betula* — 5,2%, *Alnus* do 4,1%). W interstadiale hengelo okolice Wadowic pokrywała zapewne roślinność miejsc otwartych — bezleśna. Pyłek drzew pochodzi zapewne z transportu powietrznego, aczkolwiek nie można całkowicie wykluczyć istnienia w okolicach Wadowic niewielkich płatów lasu borealnego.

W spektrach interstadialu denekamp przewaga pyłku NAP jest jeszcze większa (*Cyperacerae* do 76,3%, *Gramineae* do 16,2%), spektra te wskazują jednoznacznie na środowiska bezleśne.

Interpleniglacjalna szata roślinna okolic Wadowic była niewątpliwie uboższa niż roślinność interstadiału hengelo w odległych o ponad 130 km odcinkach doliny Wisłoki (K. Mamakowa, L. Starkel 1974; K. Mamakowa, A. Wójcik, 1987). Była też ona znacznie uboższa niż szata roślinna interstadiału brörup opisana w „cegielni południowej" (fig. 1, 2) w Wadowicach (M. Sobolewska i in., 1964)

Mułki interpleniglacjalne z omówionego profilu odpowiadają osadom interstadialnym znajdującym się w „cegielni południowej" nad osadami interstadiału brörup. Brak osadów brörupu w Łazówce można wiązać z działalnością procesów denudacyjnych, niszczących brzeżne części Działu Wadowickiego w starszym vistulianie.

[3]Podział vistulianu według L. Starkla, 1984.