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Łódź

STRATIGRAPHY OF LOESSES IN POLAND ON THE BASIS OF STUDIES IN THE FORELAND OF THE ŚWIĘTOKRZYSKIE MTS.

The author presents the results of investigations carried out in the Opatów Upland, i.e. in the foreland of the Świętokrzyskie Moutains (Fig. 1, 2), and concerned the subject of numerous works recently published in Poland. Among papers produced over the last ten years dealing with loess stratigraphy in strict connection with the morphogenetic processes in the Quaternary and especially in the Younger Pleistocene, the following may be mentioned: Pożaryski (1953, 1956), Malicki (1949), Jahn (1950, 1956). Most of these papers are based on field work which enabled the authors to define the stratigraphic position of loesses in relation to other sediments, but did not afford enough lithologic data. This resulted from the fact that the workers mainly studied natural section in young erosional gullies commonly occurring in loess areas where the structure and texture of the sediments may easily be examined, but in no more than one of its facies. The young gullies are generally situated on slopes, often steep ones, in places where the present-day loess cover is entirely or at least partly on its secondary bed. Therefore, the results were sometimes accidental and one-sided. The features of one facie of loesses were ascribed to the whole cover, which in reality may exhibit striking differences depending on its geomorphologic situation. There are still gaps in our knowledge of the sediments occurring in intervalley areas because of difficulties in digging pits deep enough to penetrate through the whole loess cover, as well as because of the distribution of natural gullies mentioned above.

It should be also stressed that borings were not so commonly used in this kind of field-work as in other geological investigations. This may be due to the opinion that material obtained through borings is insufficient for defining various and sometimes minute

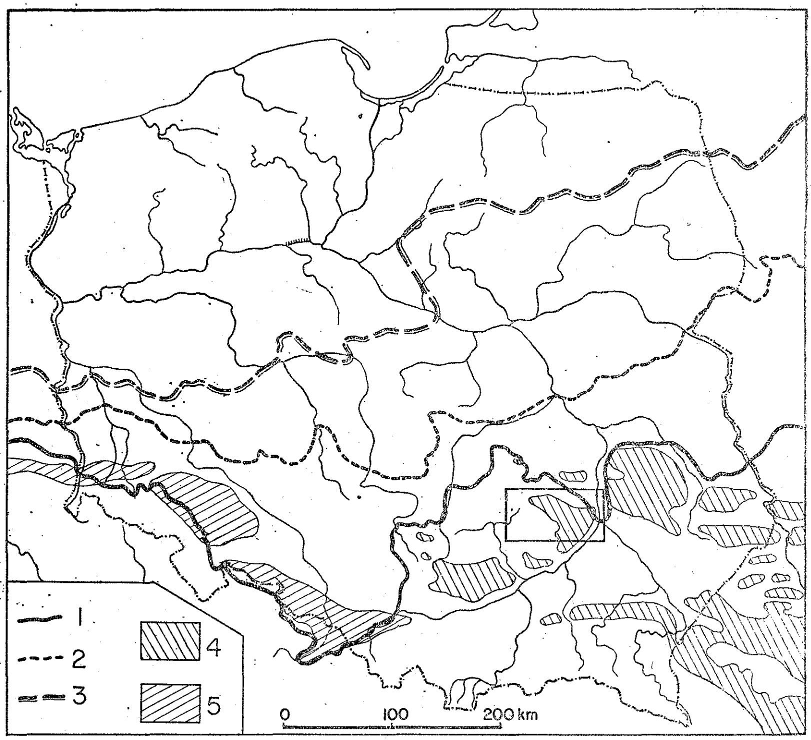


Fig. 1. Extent of the Middle-Polish (Riss) and Baltic (Würm) glaciations and loess areas in Poland (mainly after S. Z. Różycki, 1967)

limits of the Middle-Polish ice-sheet: 1. the Odra stage, 2. the Warta stage; 3. limit of the Baltic glaciation; 4. eastern loess area; 5. western loess area; the quadrangle denotes the area of detailed investigations

features of sediments, and especially of loesses which seem to be homogeneous.

The past few years have seen very intensive studies of loesses in Poland (Czeppe, Kozłowski, Krysowska, 1963; Grabowska-Olszewska, 1961c, 1963; Jersak, 1965; Malicki, 1967; Malinowski, Mojski, 1960; Malinowski, 1964, 1965; Mojski, 1961, 1965, 1968). Though the investigations have been carried out in various directions, they show a common tendency to perform more detailed studies in a relatively small area.

The research methods have also changed. In present-day investigations, there are widely performed borings together with the thorough analysis of natural gullies and artificial pits such as wells in villages etc. Systematic laboratory works permit better results

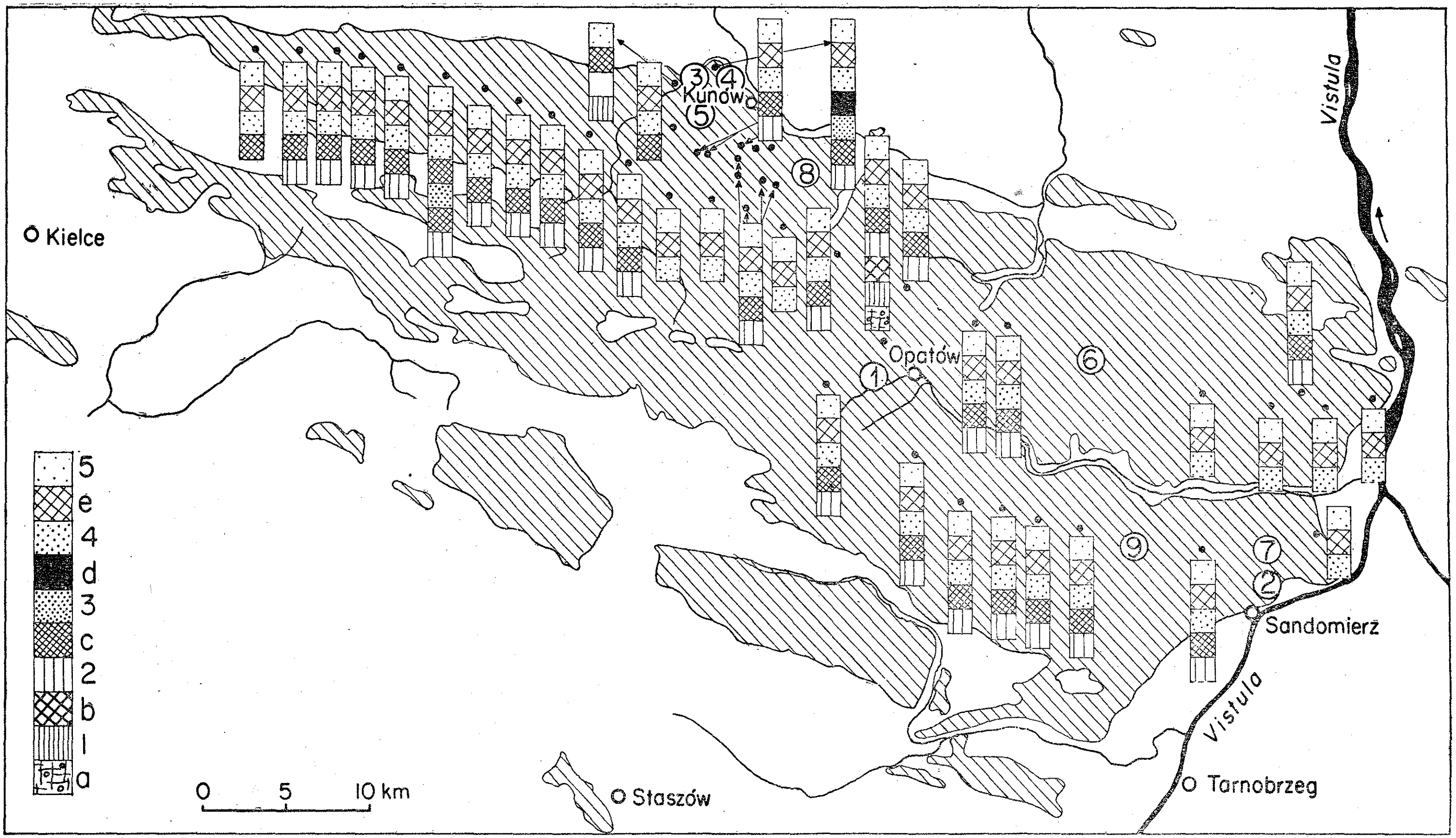


Fig. 2. Loess area in the foreland of the Świętokrzyskie Mts., and situation of the sites investigated

1. lower Older Loess; 2. upper Older Loess; 3. Younger Loess I; 4. Younger Loess II-a; 5. Younger Loess II-b; a. Cracovian (Mindel) boulder clay, decalcified; b. soil of the Tomaszów type; c—d. soil complex of the Nietulisko I type: (c) soil lessivé, (d) chernozem; e. soil of the Komorniki type; figures in circles denotes localities cited in the text

in defining the stratigraphy as well as the lithology and genesis of sediments.

As the varieties of the loess facies are strictly controlled by their geomorphologic situation, the present writer suggests the following division into 3 groups: (1) upland loess, (2) slope loess, and (3) valley loess (Jersak, 1965). These are the facies more or less synchronously originated under the arctic climate in a tundra zone overgrown with herbaceous or park-like vegetation. The upland loess, whose bedding and striation are macroscopically invisible, occurring on flat intervalley surfaces, was accumulated by winds. On slopes, it passes into a striated deposit and forms the slope loess which originated due to the initial eolian as well as to the secondary slope transportation. In the latter case the congelifluxion and downwash took place. The striated and bedded loesses of which the middle river terraces are formed, arose due to the above mentioned processes and to the river-water transport. Facies differ in grain-size and in some chemical properties (Jersak, 1965).

The present writer considers the interfluve facies the most important from the stratigraphical point of view. The original character of the loesses is best preserved on the intervalley plains, especially in the places lying far from the valley edges where the loess was not strongly exposed to denudation. Eolian erosion seems to be also of negligible importance. These areas must have been overgrown with a dense herbaceous vegetation in the time of the accumulation of the eolian dust; in such topographic situation, the accumulation of the slope-sediments cannot be taken into consideration. Therefore, the fossil soils which present the main stratigraphical criterion are best preserved in the interfluve facies. In other facies they are far less reliable as leading horizons. In loesses lying on the upper parts of slopes the soil is completely or partly eroded, whereas in the lower slope segments as well as in the valley facies, the numerous striae, with a large content of humus, are to be seen (Straszewska, Mycielska, 1961b). It is sometimes difficult to distinguish these discontinuous humus horizons occurring on the second bed from the horizons of accumulational (humus) soils *in situ* disturbed by periglacial or diagenetic processes and characterized by the profile (A)—C or A—C. Some workers consider this type of form appearing among the striated and bedded loesses as very important which raises many doubts as pointed out by Pierzchałko (1954) and Malicki (1967).

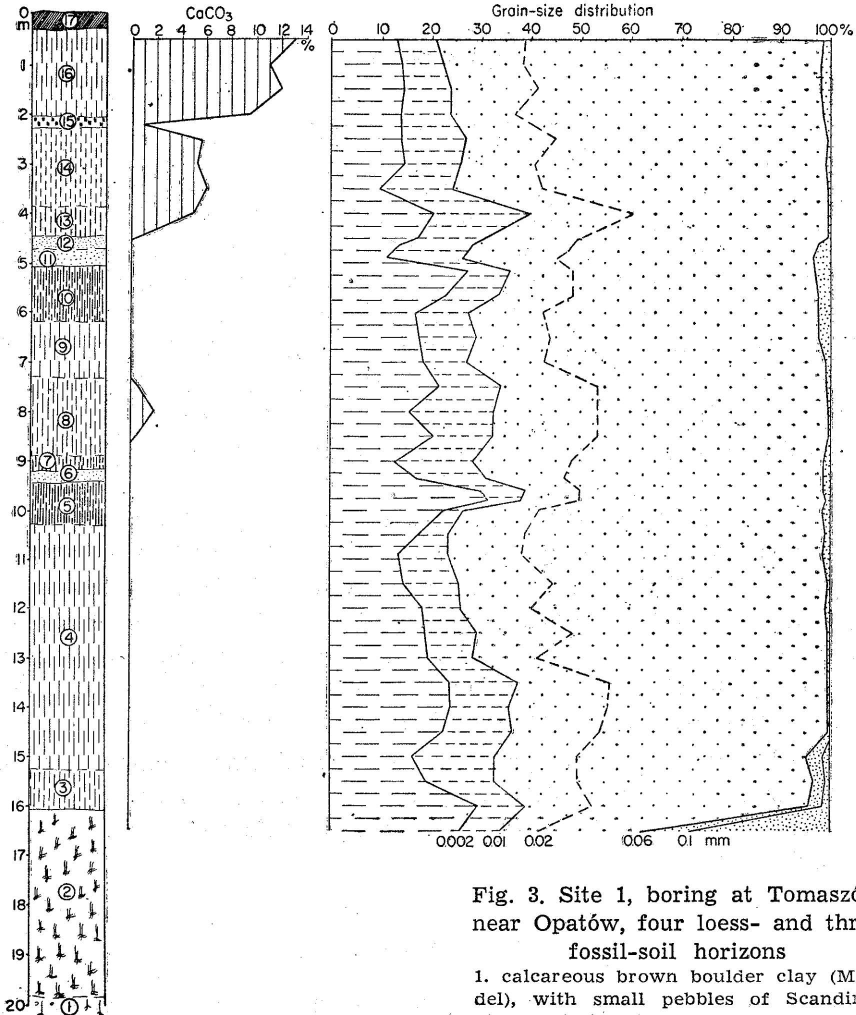


Fig. 3. Site 1, boring at Tomaszów near Opatów, four loess- and three fossil-soil horizons

1. calcareous brown boulder clay (Mindel), with small pebbles of Scandinavian material, in the top part numerous $CaCO_3$ concretions ca. 5 cm in diameter; 2. decalcified brown boulder clay (Mindel), with numerous strongly weathered stones — weathered horizon from the Great Interglacial (Mindel—Riss); 3. „marble-like" loess, grey, with rusty spots, partly gleyed; 4. brown loess slightly gleyed in the top, passing downwards into non-gleyed yellowish loess 5. clayey brownish-orange loess of crumble structure — illuvial horizon B; 6. strawy sandy loess — leached horizon A_3; 7. light-grey and brownish gleyed loess, accumulational horizon A_1; 8. „marble-like" loess, grey with tiny rusty spots, partly gleyed; 9. non-gleyed, ochrous loess; 10. orange loess, clayey, of platy structure — illuvial horizon B; 11. grey sandy loess with charcoals in the top part — leached horizon A_3; 12. grey, sandy loess with charcoals — accumulational horizon A_1; 13. „marble-like" loess, slightly gleyed, with rusty spots; 14. ochrous loess, non-gleyed with $CaCO_3$ concretions; 15. grey, strongly gleyed, decalcified loess — gleyed soil of the Komorniki type; 16. lightyellow non-gleyed loess, at the depth 1.0 m numerous $CaCO_3$ concretions; 17. grey loess, present-day arable horizon; 3—7 lower Older Loess; 8—12. upper Older Loess; 13—15. Younger Loess II-a; 16—17. Younger Loess II-b; 5—7. soil lessivé of the Tomaszów type

LITHOLOGIC UNITS

The present work is based on data collected from 54 sites situated on the intervalley plains and on upper terraces of the Vistula and of side valleys (Fig. 2). The material was obtained through borings and from especially dug pits. Out of 18 sites investigated in 1960—1963 some results were published in 1965 (Jersak), but the whole set examined in 1964—1967 consisting of 35 sites has not been publishsed yet. In all sites the occurrence of fossil soils was established; in 38 there are two horizons preseved, in 16 — only one.

Loesses of the Opatów Upland are in many places deposited on the boulder clay which has recently been ascribed to the Cracovian (Mindel) glaciation (Klimaszewski, 1952; Różycki, 1964, 1967; Klatka, 1962; Jersak, 1965). The boulder clay was registered in 43 sites out of 48 in which the whole loess cover was perforated. In the remaining 5 sites there were sands and silts (3) and the clayey waste of the Paleozoic rocks (2).

The boulder clay containing northern material is calcareous in its lower part where $CaCO_3$ amounts to 20%, in the upper beds it is decalcified. The leached zone varies in thickness, and is often as thick as 4 m.

LOWER OLDER LOESS

The present writer met the oldest of the loess horizons in the intervalley area only in two sites (Fig. 3). The oldest loess occurs also on the upper terrace at Opacie Doły on the Świślina river (it is the so-called "older loess" in: Klatka, 1961 and Jersak, 1965) and at Sandomierz on the Vistula (fig 4, 5).

At Tomaszów near Opatów this loess (Fig. 3) 7.1 m in thickness has varied texture: in the lower part, ca 0.8 m thick, the "marble-like loess" is clayey, plastic, grey in colour with numerous rusty spots. Upwards it becomes much less plastic, yellowish-brown in colour. The upper part of loess ca 1.5 m in thickness is weathered and altered by later soil processes.

The lower part, i.e. the "marble-like loess" was probably accumulated in a humid environment which is attested by its great plasticity and colour caused by the oxidization and reduction processes which usually take place when the subsoil is at least perio-

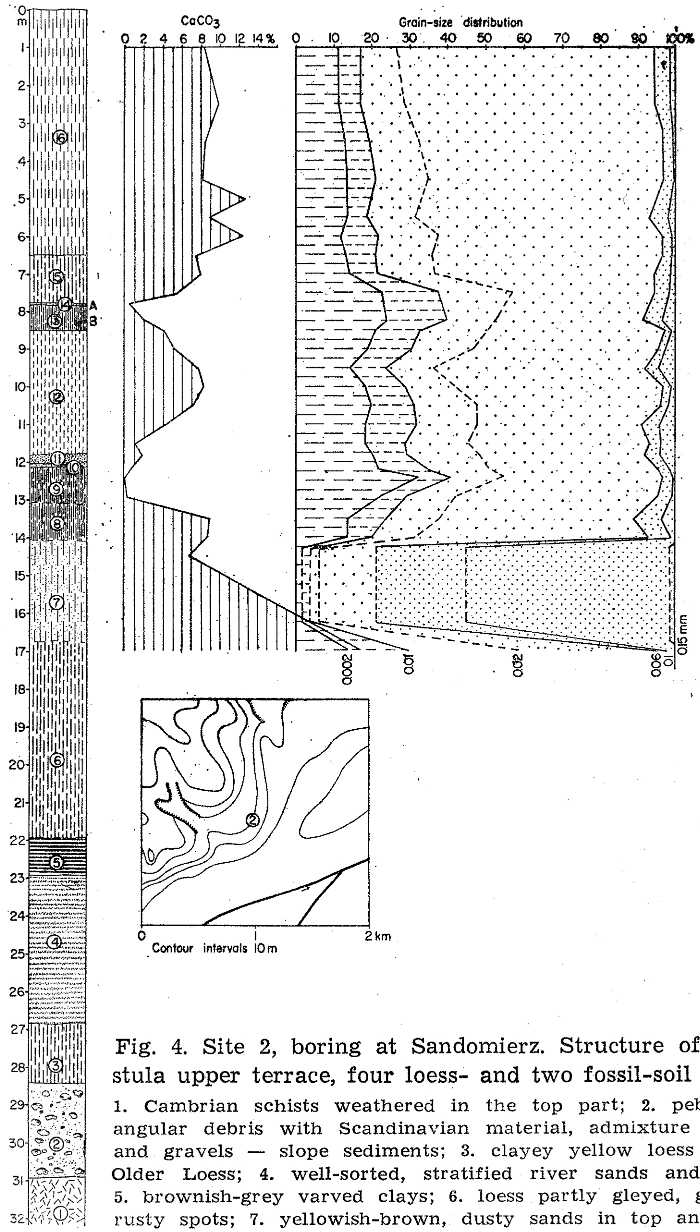


Fig. 4. Site 2, boring at Sandomierz. Structure of the Vistula upper terrace, four loess- and two fossil-soil horizons

1. Cambrian schists weathered in the top part; 2. pebbles and angular debris with Scandinavian material, admixture of sands and gravels — slope sediments; 3. clayey yellow loess — lower Older Loess; 4. well-sorted, stratified river sands and gravels; 5. brownish-grey varved clays; 6. loess partly gleyed, grey with rusty spots; 7. yellowish-brown, dusty sands in top and bottom gradually passing into loess; 8. grey loess — horizon enriched with $CaCO_3$; 9. orange loess of plate-like structure —iluvial horizon B; 10. light-grey loess — leached horizon A_3; 11. dark-grey loess with charcoals — accumulational horizon A_1; 12. ochrous loess; 13. clayey brown loess — horizon B of the forest brown soil; 14. grey loess with humus — accumulational horizon A_1; 15. „marble-like" loess partly gleyed, brown with grey and rusty spots; 16. light-yellow loess
6—11. upper Older Loess; 12—14. Younger Loess II-a; 15—16. Younger Loess II-b
8—11. lower part of the soil complex Nietulisko I, soil lessivé; 13—14. brown arctic soil of the Komorniki type

dically oversaturated with water. Free ferric oxides occur here mainly as FeO, dyeing the sediments with grey colour. The upper parts of the loess were accumulated under conditions much more arid, and therefore the deposit has a uniform yellow-brownish colour.

The grain-size composition of this horizon is characteristic of all the upland loesses on the foreland of the Świętokrzyskie Mountains. The colloidal, 0.002 mm particles amount on an average to 21%, and apart from the weathering horizon they range from 13.5 to 24.0%. The particles of 0.002—0.01 mm grain-sizes are scarce, their mean frequency amounts to some 11.0%, the limits being 4—16.3%. The most common are 0.01—0.06 mm particles, whose proportion varies from 45.7 to 74.1%, mean frequency is 62.3%. Sandy-size particles, less than 0.05 mm in diameter, are the rarest, their mean frequency is 5.7%, the minimum — 1.0%, the maximum — 15.0%; grains of more than 0.1 mm in diameter can be met only in traces, mainly in the base part of the loess where they reach 1.3%. This loess is vertically differentiated, which is characteristic of the loesses of the interfluve facies. The base parts of the loess in comparison with the upper ones are much

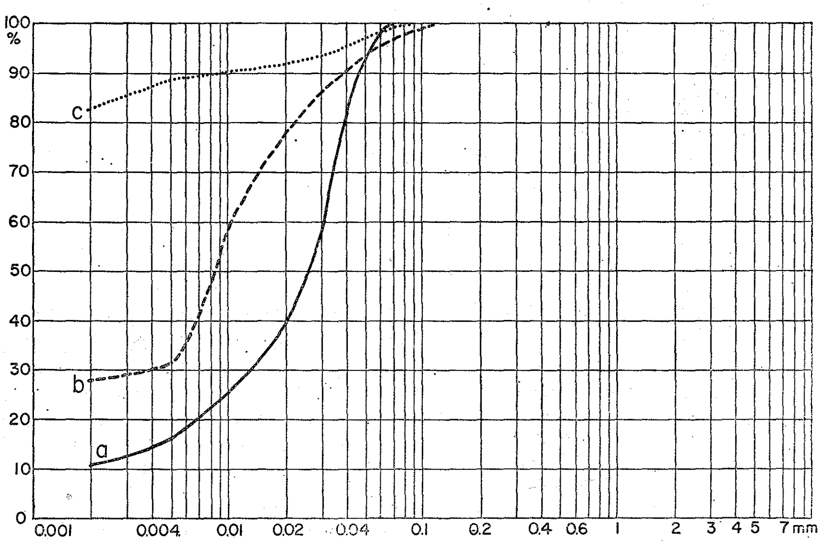


Fig. 5. Grain-size cummulative curves of lower Older Loess and varved clays: (a) the Świślina upper terrace at Opacie Doły, (b) the Vistula upper terrace at Sandomierz, (c) varved clays from the Vistula upper terrace at Sandomierz

richer in particles finer than 0.01 mm. The former contain as much as 39.0% of them, whereas in the latter they never exceed 30.0%.

The lack of calcium carbonates in the whole horizon of this loess attracts attention. They might have been leached out during the formation of the fossil soil which is preserved on the top of loess. But in such a case the carbonates should be present as secondary concretions in the bottom part of the loess or in the top-part of the underlying boulder-clay. Because of the lack of such secondary concretions, it must have been the original property of this loess since the time of the eolian dust accumulation. Calcium carbonates were either absent from the dust or leached and transported to the lower positions. The latter possibility seems to be more valid, as the loess of this age occurring on the upper terrace of the Vistula at Sandomierz is calcareous and contains as much as 12.5% of $CaCO_3$.

FOSSIL SOIL OF THE TOMASZÓW TYPE

Soil of the Tomaszów type (Fig. 3) is developed on the lower loess. Its profile shows the following genetic horizons: (1) accumulational horizon A_1, (2) leached horizon A_2 (or A_3), and (3) illuvial horizon B. Horizon A_1, ca 30 cm in thickness, is inconspicuous. It is partly altered by later oxydo-reductive processes which played an important role in the initial period of accumulation of the loess lying above. These alterations are reflected in an increased plasticity of the deposit and in a change of colour due to the rusty spots. Among all the genetic horizons preserved in this profile the horizon A_1 has the smallest amount (12.7%) of particles 0.002 mm in diameter. The content of humus and free iron oxides is also very small (humus 0.13%, free iron oxides 1.55%).

The underlying leached horizon A_2 (or A_3) ca 20 cm in thickness, is white and of loose structure, though it contains 17.1% of colloidal particles and scarcely 0.93% of free iron oxides.

Both these horizons are characterized by a strong leaching of colloidal particles and Fe_2O_3 which are abundant in the lowest horizon B where colloidal particles amount to 31.2% and Fe_2O_3 2.90%.

Horizon B, 0.9 m in thickness, has a brownish-red colour and aggregate structure; when dry the deposit falls in cubic pieces 2—3 mm across.

The profile described above is characteristic of podzols or pale soils (*lessivés*). From its strong leaching it may be inferred that this soil represents a long warm period, even though it would be assumed that it had developed on a subsoil deprived of a factor hampering leaching processes as important as $CaCO_3$. In all probability it was a period of interglacial or slightly more severe climatic conditions. The ill-preserved soil of the Biskupie Doły type, formerly described by the present writer (Jersak, 1965) has the similar stratigraphic position.

Manikowska (1966) considers the fossil soil of this type occurring in the Łódź region as having originated under interglacial conditions. It is held by many scientists that in Central Europe forest soils of the pale-type (*lessivés, Parabraunerde*) or podzols were formed in interglacial periods (Picard, 1958, 1960, 1964; Brunnacker, 1959; Stremme, 1960, Fink, 1964; Kukla, 1961; Kukla, Ložek, 1961; Ložek, 1964; Liberoth, 1962, 1964).

UPPER OLDER LOESS

The upper Older Loess is fairly common on interfluves; it was found in 38 sites. This horizon is on the whole strongly changed by the later soil processes (Fig. 6—13). The upper Older Loess is not thick and in many places varies from several tens of centimeters to 2 m. It is thicker only in 5 sites and reaches a maximum 4.5 m at Tomaszów. There, in the bottom part, the loess is plastic (Fig. 3), grey in colour with rusty spots — "marble-like loess". The traces which it bears are due to the periodical processes in the time of the accumulation of the eolian dust. Upwards the loess is brown and non-gleyed. The difference between the bottom- and upper parts of the loess and the overlying sediments might have been caused by later secondary processes. The brown loess of 1 m in thickness lying just under the weathering horizon was changed by pedogenic processes; this is evidenced by the gradual transition of this part of the deposit into the higher situated illuvial horizon of fossil soil.

The unweathered upper Older Loess has the following grain composition: colloidal particles of less than 0.002 mm in diameter having a mean frequency of 18%, minimum 15.8%, maximum 21.6%; 0.002—0.01 mm particles vary from 8.3% to 16.9%, the

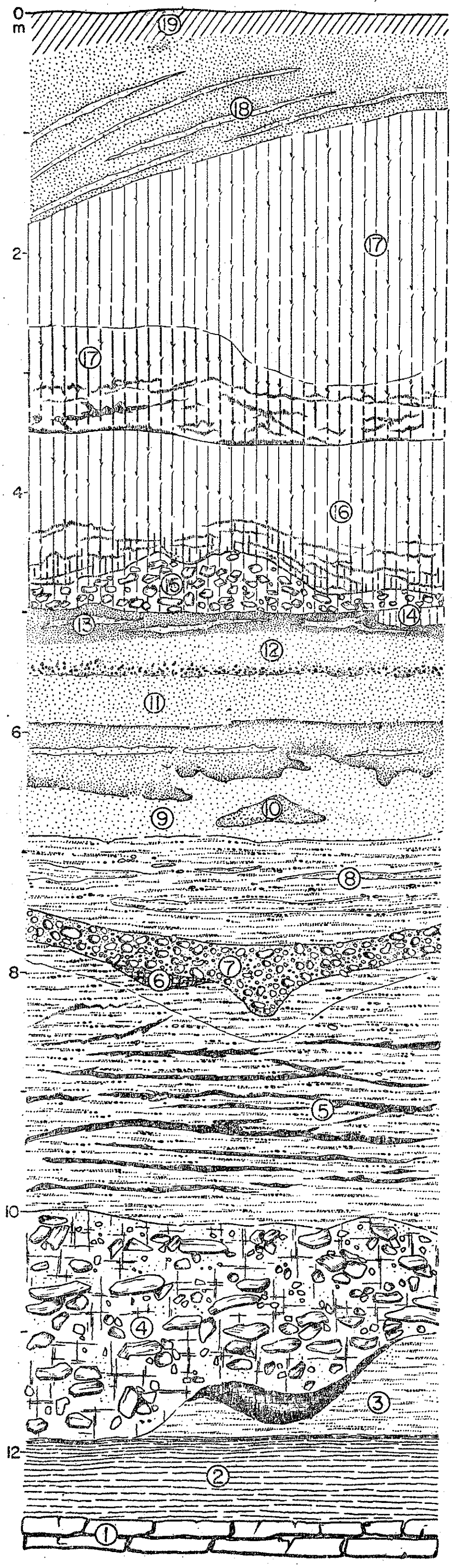


Fig. 6. Site 3, Biskupie Doły, section 1, in the right side of the Świślina valley. Structure of the upper terrace: four loess- and one fossil-soil horizons

1. Rhaetic sandstone; 2. violet and green Rhaetic clays; 3. glaciofluvial sands and gravels of the Cracovian glaciation, brownish-black in colour, strongly ferruginous; 4. clayey-sandy-debris cover with blocks up to 0.5 m across, brown in colour, structureless in the bottom part, upwards striated and sandy — slope deposits; 5. stratified river sands and gravels with ferruginous striae (4—5. sediments of the Odra stage); 6. clayey material of crumble structure, intensively brownish-red, split into angular 5 mm clods: clod faces are lustrous due to iron and manganese coatings; 7. structureless sands with angular boulders of local rocks and with strongly weathered Scandinavian pebbles; 8. striated sands with chaotically distributed small rock fragments (6—8. slope deposits of the Warta stage); 9. lumps of orange sands; 10. striated clayey loess, orange in colour, of crumble structure (9—10. illuvial horizon B); 11. light-grey sandy loess, in the lower part with ferruginous striae — leached horizon A_3; 12. dark-grey, sandy loess with numerous charcoals — accumulational horizon A_1; 13. brownish-black, clayey loess — chernozem soil; 14. brown, clayey loess; 15. grey, clayey loess with debris; 16. grey, gleyed loess; 17. loess, in lower part grey with ferruginous spots and striae, higher up light-yellow, non-gleyed; 18. cover of loess-like material, red, and light-yellow dusty striae; 19. present-day arable horizon

10—12. upper Older Loess; 14—16. Younger Loess II-a; 17. Younger Loess II-b

9—12. soil lessivé

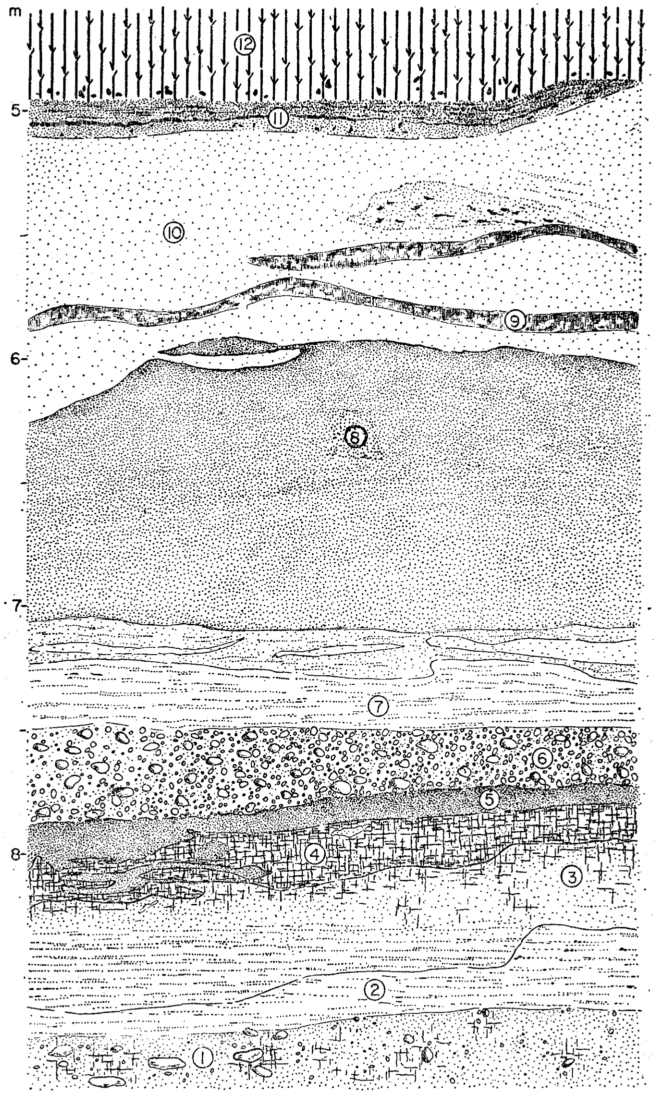


Fig. 7. Site 3 at Biskupie Doły, fragment of the section 2 in the upper terrace, some 10 m north of the section 1

1. clayey-sandy-debris cover with blocks up to 0.5 m across, brown in colour, structureless in the bottom part, upwards striated and sandy — slope deposits; 2. stratified river sands and gravels with ferruginous striae; 3. red, clayey river sands and gravels: 4. clayey material of crumble structure, intensively brownish-red, split into angular 5 mm clods, clod faces are lustrous due to iron and manganese coatings; 5. brownish-red clayey sands structureless; 6. structureless sands with angular boulders of local rocks and with strongly weathered Scandinavian pebbles; 7. striated sands with chaotically distributed small rock fragments; 8. striated, clayey loess, orange in colour, of crumble structure — illuvial horizon B; 9. sandy-loess with ferruginous striae; 10. light-grey, sandy loess; 11. dark-grey, sandy loess with numerous charcoals — accumulational horizon A_1; 12. grey gleyed loess — Younger Loes II-a

1—5. sediments of the Odra stage; 3—5. remains of illuvial soil horizon of the Tomaszów type — in former terminology: Biskupie Doły soil (J e r s a k, 1965); 6—7. slope deposits of the Warta stage; 8—11. upper Older Loess — soil lessivé, complex of the Nietulisko I type; 9—10. leached horizon A_3;

mean value is 12.2%; 0.01—0.05 mm grains amount on an average to 63.9%, their minimal and maximal frequencies being 59.4% and 68.7% respectively; 0.05—0.1 mm grains range from 0.3 to 8.3%, their mean frequency is 5.4%; grains of diameter more than 0.1 mm are detectable only in traces outside the weathering level, whereas in the weathering horizon their frequency reaches up to 1.0%. In the vicinity of larger valleys the loess of this level shows remarkably different grain-size gradation. In the neighbourhood of Kunów (Jersak, 1965), close to the large Kamienna valley the loess contains many more grains of sand-size and less dust material. In 5 sites the mean frequency of grains $>$ 0.05 mm in diameter is 23.8%, grains more than 0.1 mm always range from several to less than 20%; the amount of 0.01—0.05 mm particles is ca 48.3%. Though in the Kunów region the whole loess was changed by pedogenic processes, the colloids and fines were particularly affected. The frequency of coarser particles in the soil horizon is almost the same as in the unweathered loesses. This loess is even more sandy at Sandomierz on the Vistula (Fig. 4) where the middle parts of the upper Older Loess display a predominance of fine-sand particles 0.05—0.2 mm, whose frequency is as high as 90%, while that of the particles less than 0.05 mm is only 10%. The bottom- and top-parts in the loess at Sandomierz show the grain-size gradation characteristic of loesses.

The upper Older Loess on the interfluves is not abundant in calcium carbonate; at Kruków (Fig. 13) and at Tomaszów (Fig. 3) it contains only 6% and 2% respectively. In other localities $CaCO_3$ does not occur at all, the carbonate concretions are also absent from the underlying sediments. This suggests that the loess initially contained small amounts of $CaCO_3$. Instead, the loess of this horizon occurring in the lower places, such as river terraces, has larger quantities of calcium carbonate (up to 25%, Fig. 4).

SOIL OF THE NIETULISKO I TYPE

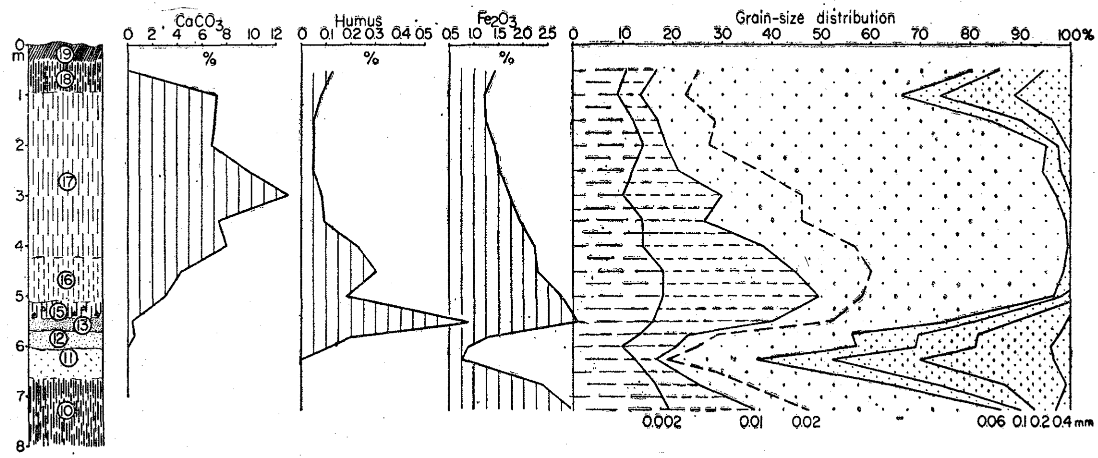
In the top-part of the upper Older Loess a soil series is composed of two different soil-types (Fig. 3, 4, 11, 12, 13, 14). The lower part of this series presents a well-developed soil lessivé (or podzol), the upper one is of chernozem type. The soil lessivé has the following genetic horizons: (1) accumulational A_1, (2) eluvial A_3, and (3) illuvial B.

The accumulational horizon A_1, of 5—20 cm in thickness, is in some places sandy, grey in colour, with a large admixture of charcoals, 2 cm in size. There may be observed strikingly small amounts of clay particles: ca 10.0—14.5% and free ferric oxides 0.9—1.3%. As for an organic horizon, it is poor in organic matter which reaches scercely up to 0.2—0.3%; presumably this figure was originally higher. Glazovskaya (1956) holds that the older a soil the less amount of organic admixture it contains. Its quantity gradually decreases due to the activity of various diagenetic processes. The accumulational horizon passes smoothly into the lower eluvial horizon A_3, whose thickness is from several centimeters to 0.5 m. It is of loose texture, sometimes sandy and white in colour. As well as the higher horizon it has a low percentage of Fe_2O_3. In the eluvial horizon the amount of colloidal particles is 9—12%, and of Fe_2O_3: 0.4—0.8%. The lowest, illuvial horizon B of 1.0—1.5 m in thickness, is orange, clayey and has a crumble structure. It is enriched with colloidal particles which range from 25 to 33%, and Fe_2O_3 from 3 to 4%. Calcium carbonate is leached from the whole weathering horizon. At Sandomierz on the upper terrace of the Vistula (Fig. 4) $CaCO_3$ appears at a depth of 1.3 m and on the interfluve at Tomaszów it was found as deep as 3 m under the top part of the fossil soil.

Chernozem soil

The chernozem of 0.2—0.4 and even up to 0.6 m in thickness is not so common as the pale-soil (lessivé) (Fig. 6, 8—14). It presents one genetic accumulation horizon A_1; it is clayey, brownish-black and comprises 0.6—1.0% of strongly decomposed organic matter. This chernozem is of the type of soil developed under the cover of meadow-steppe vegetation growing under the interstadial climatic conditions.

The formation of chernozem did not start immediately after the development of the lower soil lessivé. In the site at Stodoły, near the valley edge (Fig. 12) the chernozem overies the illuvial horizon of the soil lessivé, while at Kruków (Fig. 13), in the similar topographic situation, it is underlain by the calcareous loess. Such a sequence proves that after the warm interglacial period there immediately started: (1) intensive erosion which completely or partly destroyed the soil lessivé near the valley edges, and la-



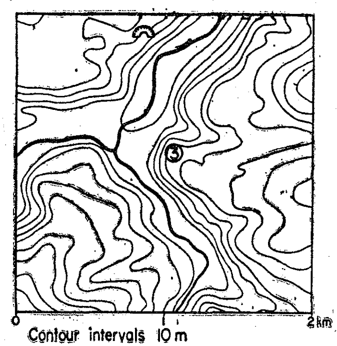


Fig. 8. Site 3 at Biskupie Doły, section 1. Curves of chemical changes and grain-size gradation

Explanations see fig. 6

ter (2) eolian accumulation produced the thin and discontinuous cover of the Younger Loess I (Fig. 6, 8—14), on which chernozem developed. This sequence of processes is evidenced by the difference in grain-size gradation as well as in the content of free iron oxides in the upper horizons of soil lessivé, on one hand, and of the chernozem on the other. There is as much as 9—14% of colloidal particles in the top of soil lessivé, whereas in chernozem they are much more abundant and amount to 16—32%. The vertical differentiation of free iron oxides is very much alike; their frequency is 0.4—1.3% in the horizon A_1 and A_2 of soil lessivé while in chernozem 2—3%. It is hardly probable that the loess was secondarily enriched with such an amount of colloids and Fe_2O_3 by processes associated with the formation of chernozem. The eolian accumulation could have taken place in the time span between the formation of two soil horizons. This seems to be supported by the profile at Jędrzejowice (Fig. 14) where the lower soil is developed on the boulder clay, and the chernozem — on the loess.

YOUNGER LOESS II-a

The Younger Loess II-a (Fig. 3, 4, 6, 8—15) is fairly common on the upland plains where it forms a continuous cover from several tens of centimeters to 5 m in thickness, but usually it is 2—4 m thick. The loess is various in its lithologic character. In many places the whole bed is gleyed (Fig. 15). The steel-bluish colour of the sediments proves that its sedimentation took place under very strong reductive conditions, i.e. in an environment where the surface dried up only sporadically in the summer-time. In another place only the bottom parts of the sediments are gleyed (Fig. 4, 11—14) and here it is the „marble-like loess", grey in colour with numerous rusty spots and tiny ferruginous concretions. This proves that the accumulation occurred under oxydo-reduction conditions when the ground was periodically oversaturated with water. Topward loess, ochre in colour, developed in an oxidative environment.

The bottom-part of the Younger Loess II-a is mostly deprived of calcium corbonate, but upwards the loess becomes gradually calcareous. In the site of Kruków (Fig. 13) the maximum of $CaCO_3$ is 8.0%, in other sites the content of calcium carbonate is smaller and does not exceed 4.0—6.0%.

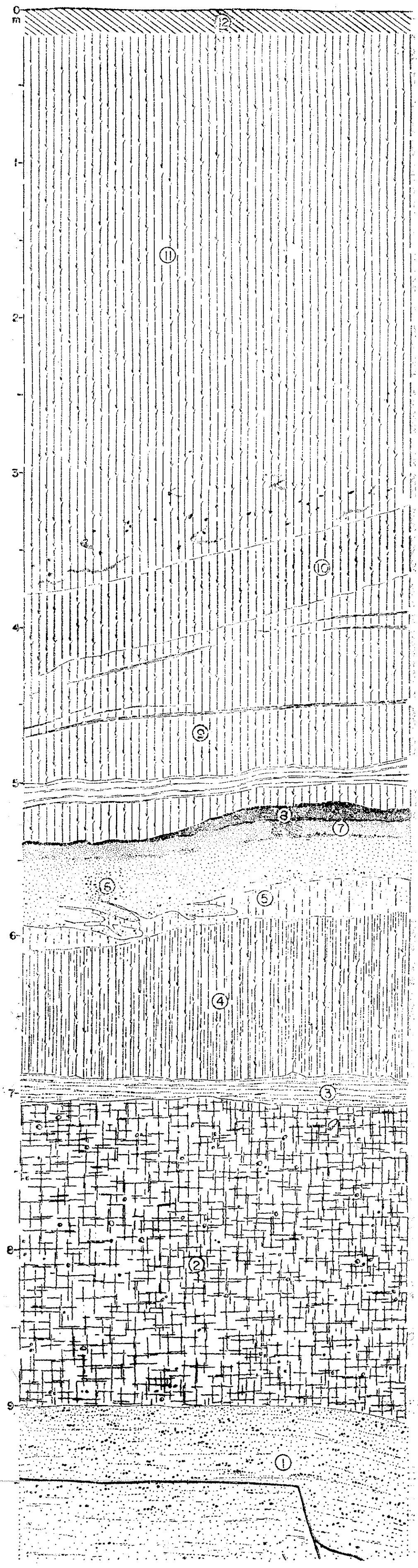
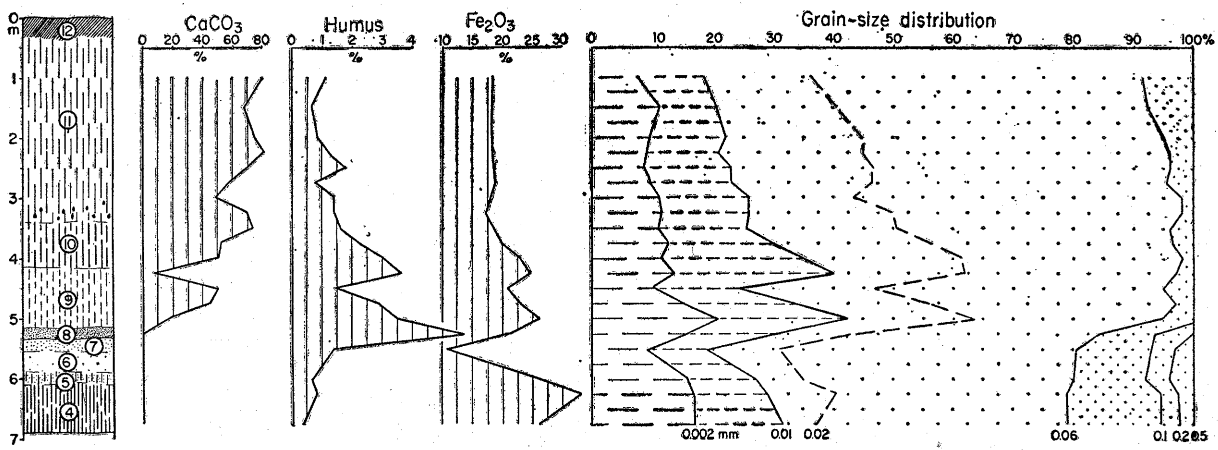


Fig. 9. Site 4, Nietulisko Małe, four loess horizons, one fossil soil horizon

1. light-grey sands and silts horizontally stratiffied with small faults; 2. boulder clay of the Cracovian (Mindel) glaciations on the secondary bed; 3. striated clayey sands — slope deposits; 4. orange claye loess of plate-like structure — illuvial horizon B; 5. light grey loess with clayey orange striae — horizon As/B; 6. light-grey sandy loess — leached horizon As; 7. grey sandy loess with charcoals — accumulational horizon A1; 8. clayey brownish-black loess — chernozem; 9. clayey loess, in some places slightly striated; 10. grey loess, partly gleyed; 11. light-yellow loess, non-gleyed; 12. grey loess — present-day arable horizon

4—7. upper Older Loess; 9. Younger Loess II-a; 10—12. Younger Loess II-b

4—8. soil complex of the Nietulisko I type



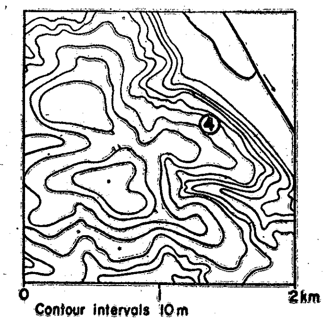


Fig. 10. Site 4, Nietulisko Małe. Curves of chemical changes and grain-size gradation

Explanations see fig. 9

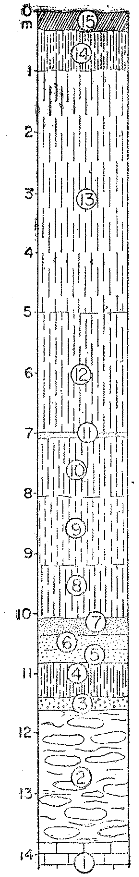
The bottom- and top-parts of the Younger Loess II-a are abundant in the finest particles: 32—42% of <0.01 mm grains and 58—68% of grains >0.01 mm in size, whereas in the middle horizons the percentage of particles <0.01 mm is only 25—30%, and 70—75% of coarser sizes.

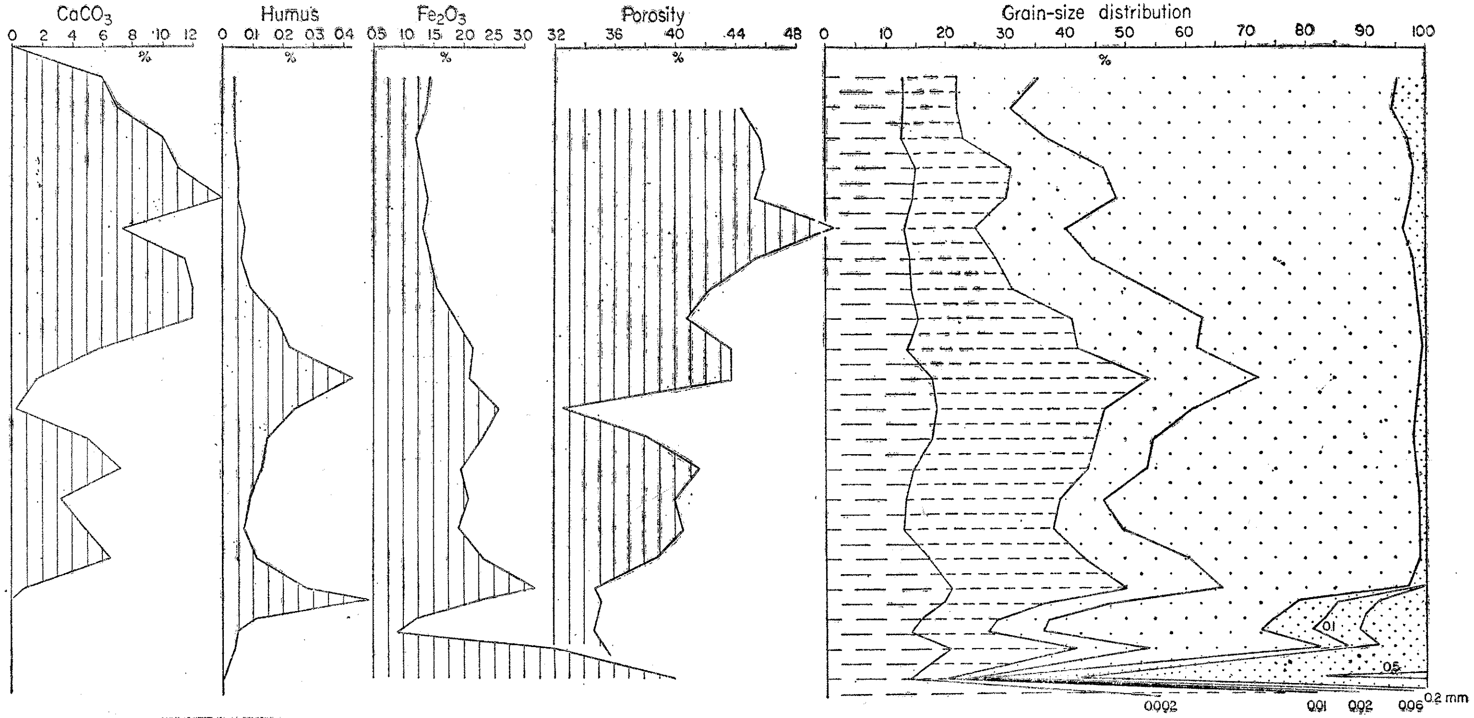
SOIL OF THE KOMORNIKI TYPE

Widely spread on the interfluves, the soil of the Komorniki type (Jersak, 1965) is either gleyed or boggy soil, or even the brown arctic soil (Fig. 3, 4, 11, 12, 13, 15). It the top of the Younger Loess II-a, where the sediment is ochre in colour, there is preserved either the accumulational horizon (A_1) (Fig. 4, 11) or the strongly gleyed horizon (G_{or}) (Fig. 3, 12, 13). The brownish--black accumulational horizon is poorly developed and no more than several centimeters thick. The gleyed horizon is about 0.3 m in thickness its colour is changeable but generally light-grey with scarce rusty spots and a slight admixture of the vertically oriented tube-like ferruginous concretions of over ten centimeters in length and 2—3 cm in diameter. The gleyed horizons contain 0.35% of organic matter and an insignificant amount of Fe_2O_3 (Fig. 11). On the steel-bluish loesses a boggy soil developed (Fig. 15); its 0.5 m thick organic horizon, black-bluish in colour, contains 1.8% of organic matter.

The loess on which the soil of the Komorniki type developed is always rich in colloidal particles and entirely decalcified. In various places the percentage of colloids is as high as 20—30%, the greatest being in the gleyed horizons developed on the ochrous loess. The thickness of the decalcified zone varies from several tens of centimeters to 1.5 m.

The soil of the Komorniki type represents a short period of slight amelioration of climate, but fairly common occurrence of gley processes on the interfluves attests the presence of permafrost. As an impermeable layer, permafrost and some influences of climate, promoted strong moisture of the top part of loess and activity of oxydo-reduction processes. The increased admixture of the organic matter in this horizon is probably due to a rich





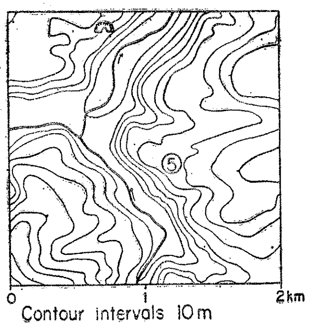


Fig. 11. Site 5, Komorniki, four loess- and two fossil-soil horizons

1. Muschelkalk limestone — Triassic; 2. clayey waste containing local rock fragments; 3. glaciofluvial sands and gravels of the Cracovian (Mindel) glaciation — illuvial horizon B; 4. orange, clayey loess of crumble structure — illuvial horizon B; 5. light-grey, strongly sandy loess-leached horizon A_3; 6. dark-grey, sandy loess with charcoals — accumulational horizon A_1; 7. brownish-black, clayey loess — chernozem — Younger Loess I; 8. "marble-like" loess, grey, with rusty spots, partly gleyed; 9. ochrous loess, non-gleyed; 10. brown loess partly clayey — horizon (B) of forest brown soil; 11. dark-grey loess with humus — accumulational horizon A_1; 12. "marble-like" loess, partly gleyed, grey with tiny rusty spots; 13. light-yellow loess non-gleyed; 14. brown, clayey loess — horizon **(B)** of forest brown soil; 15. grey loess with humus — present-day arabia horizon

4—6. upper Older Loess; 8—11. Younger Loess II-a; 12—15. Younger Loess II-b

4—8. soil complex of the Nietulisko I type Nietulisko I type

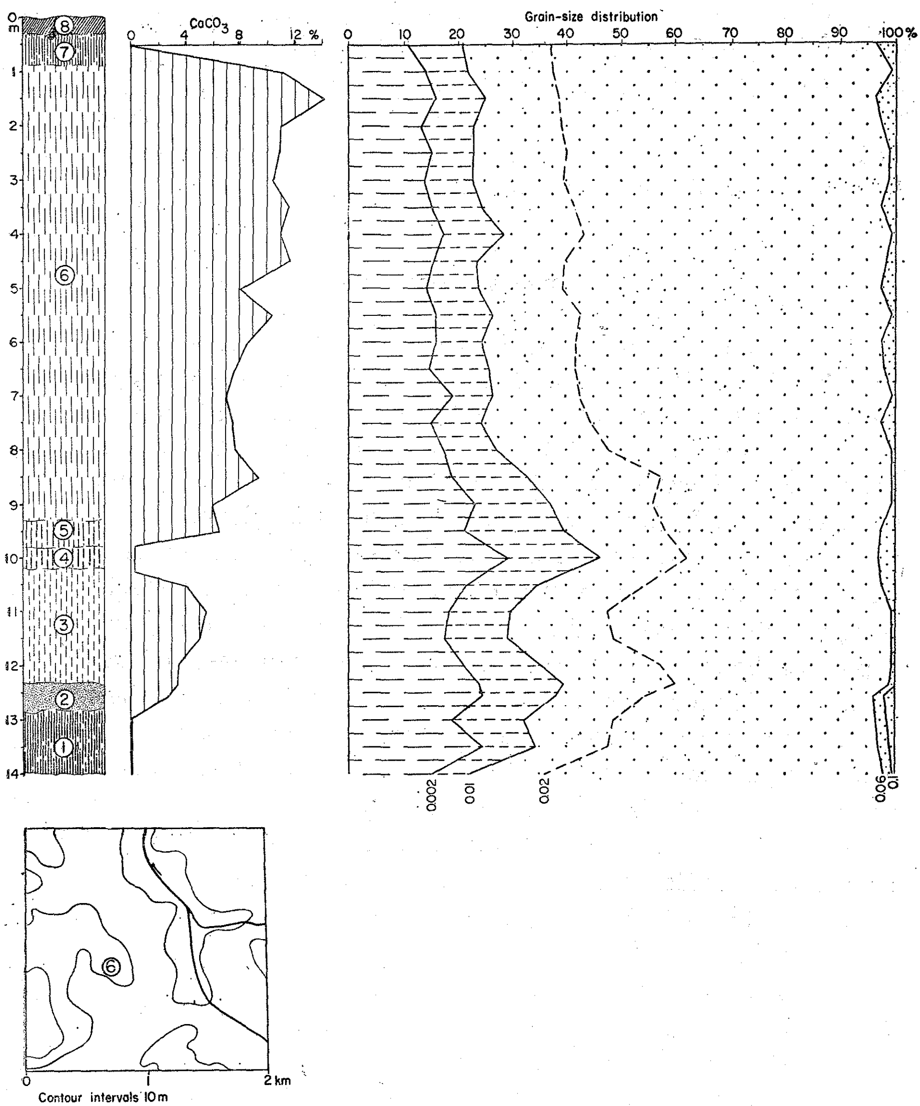


Fig. 12. Site 6, boring at Stodoły, four loess horizons and two fossil-soil horizons

1. orange, clayey loess of plate-like structure — illuvial horizon B of soil lessivé — upper Older Loess; 2. brownish-black clayey loess — chernozem soil — Younger Loess I; 3. ochrous loess slightly gleyed in the bottom part; 4. strongly gleyed loess, bluish-grey, with rusty spots — soil of the Komorniki type; 5. greyish-brown loess with tiny rusty spots partly gleyed; 6. light-yellow, non-gleyed loess; 7. brown, gleyed loess — horizon (B) of the forest brown soil; 8. grey loess, present-day arable horizon

3—4. Younger Loess II-a; 5—8. Younger Loess II-b

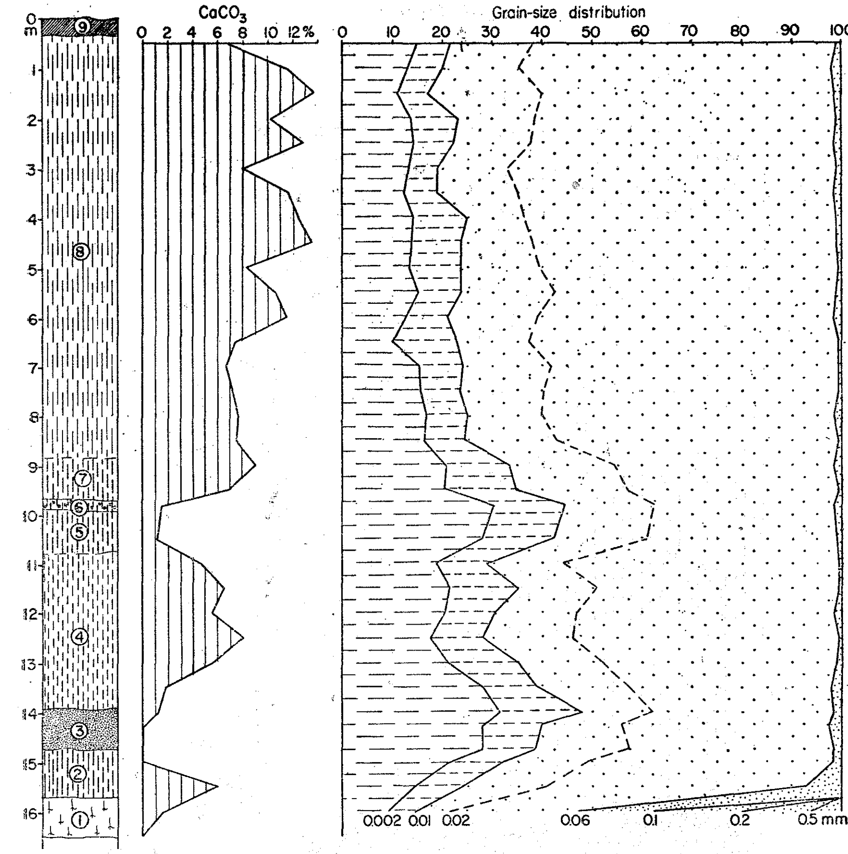
1—2. soil complex of the Nietulisko I type growth of vegetation. Beside the then existing herbaceous plants there also appeared shrubby vegetation. These changes contributed to an intensive leaching of $CaCO_3$, but it seems improbable that this process could cause the formation of such a thick decalcified zone. In all likelihood the slope accumulation of eolian dust took place simultaneously with leaching of $CaCO_3$.

YOUNGER LOESS II-b

The youngest continuous cover in the intervalley area is the Younger Loess II-b (Fig. 3, 4, 6, 8—15), which represents the biggest thickness, especially in the eastern part of the Opatów Upland in the close vicinity of the Vistula where the loess bed attains to a thickness of 13.5 m. It is, like all the older horizons, differentiated. In the lower parts the loess is gleyed, steel-bluish in colour with numerous rusty spots, so called „marble-like loess"; upwards it becomes non-gleyed and light-yellow. The steel-bluish, boggy sediment occurs in places where a deposit of analogous type lies beneath (Fig. 15), whereas the „marble-like" sediment is on the Younger ochrous Loess II-a. The thickness of the gleyed loesses which originated under reductive conditions, as well as of those originated under oxido-reduction ones, is 2 m at most. The sedimentation of the yellowish loess lying higher up took place in a definitely continental climate. It is non-gleyed with the grey or rusty sporadic spots appearing only in places where the present-day table of ground water remains high due to geological structure.

The gleyed loess in comparison with the upper one contains less $CaCO_3$ and is composed of finer grains. The content of calcium carbonate in the bottom parts is either insignificant or does not exist at all, but it increases topwards and ranges from 7.0 to 14%.

The grain-size composition of the Younger Loess II-b is variable, which is characteristic of the horizons occurring in the intervalley areas (Fig. 3, 4, 8, 10—13, 15). In the lower part, the non-gleyed deposit contains 32—44% of particles < 0.01 mm in diameter, the upper ones have 20—30% of the analogical grains; of coarser grains, $> 0,01$ mm, there are 56—68% and 70—80% respectively.



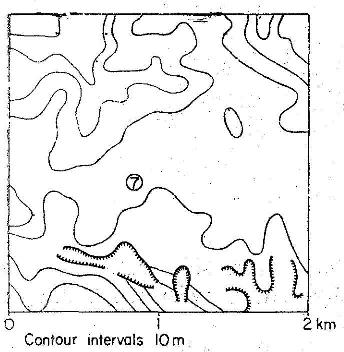


Fig. 13. Site 7, boring at Kruków, four loess horizons and two fossil-soil horizons

1. boulder clay of the Cracovian (Mindel) glaciation, brown, decalcified in the top part; 2. gleyed, greenish-grey loess with rusty spots — upper Older Loess; 3. black, clayey loess — chernozem — Younger Loess I, upper part of soil complex of the Nietulisko I type; 4. ochrous, non-gleyed loess; 5. partly gleyed, brown loess with rusty spots; 6. greenish-grey loess with rusty spots, plastic — gley soil; 7. grey loess with rusty spots, partly gleyed; 8. light-yellow loess, non-gleyed; 9. grey loess — present-day arable horizon

4—6. Younger Loess II-a; 7—9. Younger Loess II-b

5—6. soil of the Komorniki type

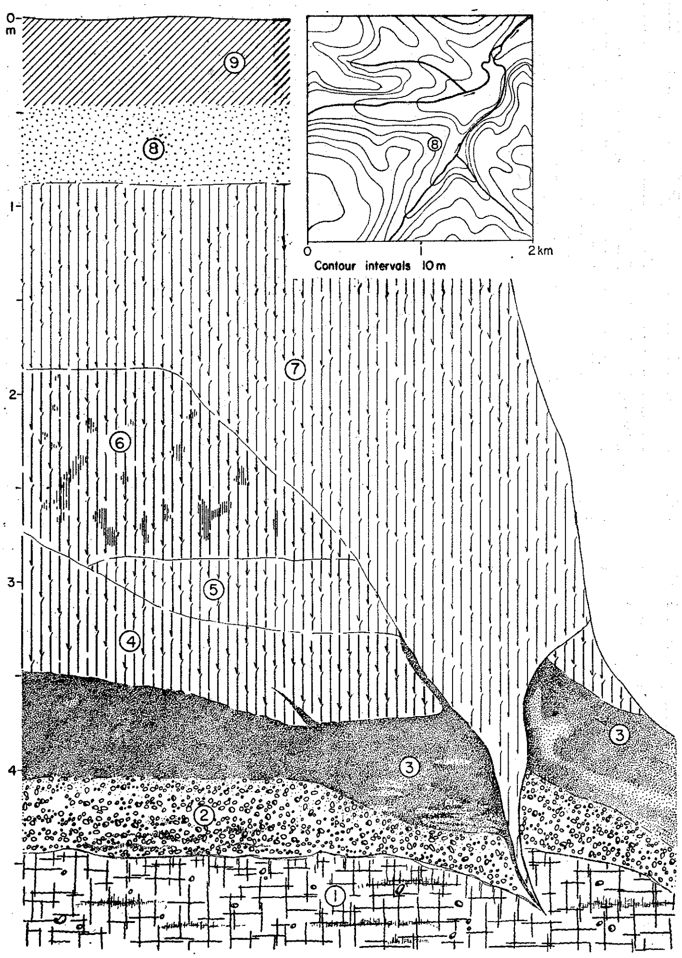
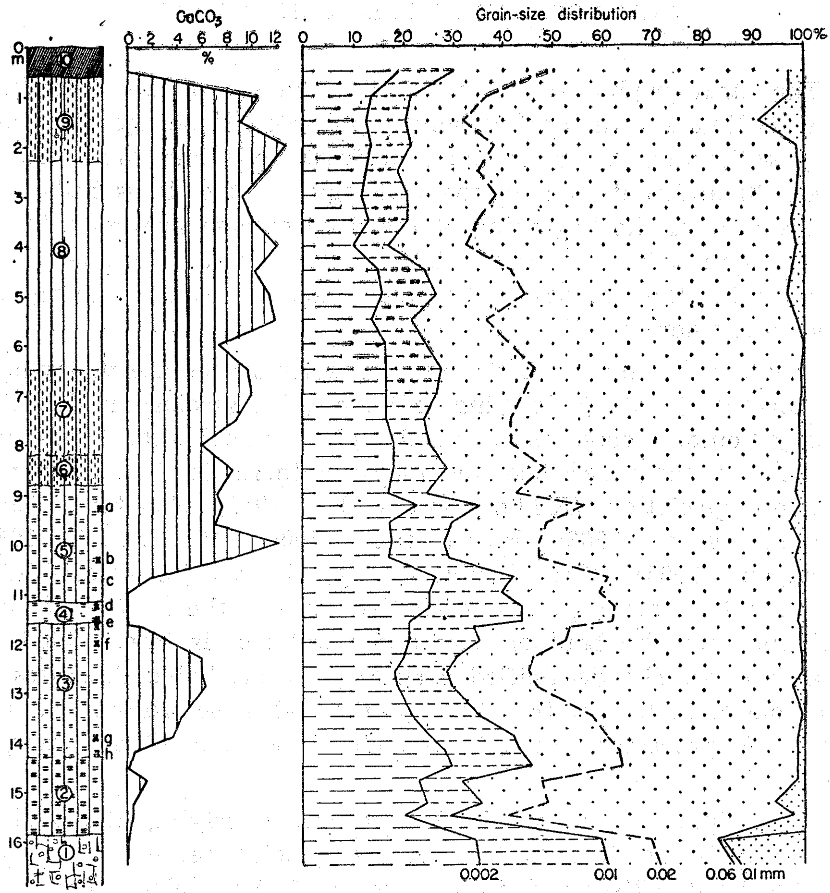


Fig. 14. Site 8, Jędrzejowice. Section of the slope of a side valley; three loess horizons, one fossil soil horizon, ice-wedge filled with the Younger Loess II-b

1. boulder clay (5 m thick) of the Cracovian (Mindel) glaciation in the top part leached and enriched with clay particles (26.0%) and Fe_2O_3 (2.72%) — illuvial horizon; 2. light-yellow clayey sands with small boulders — leached horizon A_3; 13.0% of clay particles, 2.0% of Fe_2O_3; 3. clayey brownish-grey loess — 22.5% of 0.002 mm particles, 0.92% of humus compounds, 2.22% of Fe_2O_3 — chernozem — Younger Loess I; 4. loess indistinctly striated, gleyed, calcareous (3.8%); 5. brown, non-gleyed loess; 6. grey, gleyed loess with rusty spots, in the top part enriched with organic matter (0.22%); 7. light-yellow loess, structureless, calcareous (7.0%); 8. clayey loess, brown with light-yellow striae, entirely decalcified — illuvial horizon B; 9. grey decalcified loess — present-day arable horizon

4—6. Younger Loess II-a; 7—9. Younger Loess II-b

1—3. soil complex of the Nietulisko I type; 8—9. Holocene soil



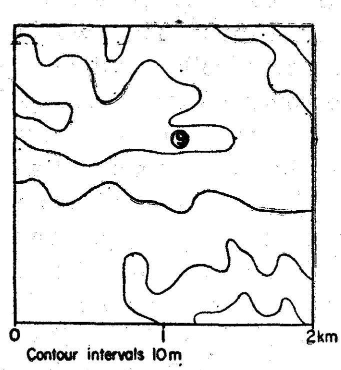


Fig. 15. Site 9, boring at Rożki, two loess horizons, one fossil soil horizon

1. boulder clay of the Cracovian (Mindel) glaciation, steel-bluish, with Scandinavian material and fragments of local Cambrian schists; 2. steel--bluish, decalcified, gleyed loess; 3. steel-bluish, calcareous and gleyed loess; 4. steel-bluish loess with humus striae — boggy soil of the Komorniki type; 5. gleyed loess, steel-greyish with bluish tint; 6. clayey loess, yellow with blue spots; 7. yellow loess with grey, blue and rusty striae and spots; 8. greyish loess with rusty spots, at the depth of 5.5 m numerous $CaCO_3$ concretions; 9. light-yellow loess with rusty and greyish spots; 10. strongly clayey loess, black — Holocene chernozem;
2—4. Younger Loess II-a (2. upper Older Loess ?); 5—10. Younger Loess II-b
a, b,... h, places where samples were taken for palynologic analysis (see Tabl. I)

STRATIGRAPHY OF THE LOESS COVERS

The stratigraphic situation of the loesses of the interfluve facies is linked with the following problems: (1) the age of underlying sediments, (2) the number of fossil soils and their genetic types, (3) differentiation in the lithology of the loess beds, and (4) the time of the beginning of the deep erosion processes. These questions may be answered solely when they are considered together with the course of the morphogenetic events during the Quaternary period.

The lower boundary of the age of loesses in the intervalley area is indicated by the underlying sediments, i.e. glaciogenic deposits, mainly boulder clay, more rarely glaciofluvial silts, sands and gravels, recently ascribed by many authors to the Cracovian (Mindel) glaciation (Klimaszewski, 1952; Klatka, 1962; Radłowska, 1963; Bartosik, 1964; Różycki, 1967; Jersak, 1965). The boulder clay, brown or steel-bluish in colour is in many places decalcified even in the area where e.g. at Tomaszów, the boulder clay and fossil soil is interbedded by a thick loess. The decalcified zone has a remarkable thickness in some places up to 4 m. (Fig. 3). It seems that these are the traces of pedogenic processes active in the Great (Mindel—Riss) Interglacial.

The origin of the whole loess-cover, overlying the boulder clay, may be ascribed to the two last glaciations, namely to the Middle-Polish (Riss) and to the Baltic (Würm) glaciations. This cover is separated by four fossil soils developed in the periods when the eolian accumulation was interrupted. The two lowest well-developed soils are podzols or pale-type soils (*lessivés, Parabraunerde*) which originated under the cover of forest vegetation; the two upper soils — chernozem and tundra soil — represent shorter sub-stages, and developed under the herbaceous and shrubby vegetation. The best-developed is the second soil from the bottom: part of a soil complex of the Nietulisko I type. Thus, it may be considered as a counterpart of the Eemian Interglacial, while the lower soil of the Tomaszów type (in the nomenclature formerly used by the present writer — the soil of the Biskupie Doły) belongs to a warmer period of the Middle-Polish (Riss) glaciation.

The soil of the Tomaszów type is best-preserved at Tomaszów near Opatów, where its weathering profile shows the following horizons: (1) accumulational A_1, (2) eluvial A_2 and (3) illuvial B. Horizon A_1, partly changed by later processes, contains a small amount of the organic matter which is not completely decomposed, and numerous charcoals. Horizon A_2, ca 0.2 m thick, is loose and white-yellowish in colour. The illuvial horizon, ca 0.7 m in thickness, is clayey, orange in colour and of aggregate structure. The traces of an intensive leaching may be seen in the vertical differentiation of the colloidal particles and free ferric oxides.

The age of the Tomaszów type soil is best determined by its position in the excavation at Biskupie Doły: the remnants of the illuvial horizon are developed in the top-part of the upper terrace which originated at the time of the maximum extent of the Middle-Polish (Riss) ice-sheet (L e n c e w i c z, 1934; P o ż a r y s k a, 1949; J e r s a k, 1961; K l a t k a, 1961; 1962; R a d ł o w s k a, 1963; B a r t o s i k, 1964). Such a stratigraphic position of the soil proves that it originated during a longer warm period after the maximum of the Middle-Polish (Riss) glaciation, before the Warta stage, i.e. during the Odra stage (K l i m a s z e w s k i, 1961).

The nature of this period is defined by paleobotanical and pedological studies. In Germany it is called the Ohe interstadial. Formerly this period was considered as the interstadial (W o l d s t e d t, 1955), but now most authors agree in regarding it as the interglacial period (B r e l i e, 1955). Of the same opinion are P i c a r d (1958, 1960) and S t r e m m e (1960). They both found in Schleswig-Holstein the fossil podzols passing in some places into peats. These soils developed on the boulder clay of the Drenthe stage and are covered with solifluxion sediments of the Warta stage.

The counterpart of this period on the Russian lowland may be the Odintzovo Interglacial separating the sediments of the Dniepr and Moscow glaciations (M o s k v i t i n, 1954, 1959, 1961a, b; S h i k, 1959, 1960, 1961; G r i c h u k, M o n o s h o n, S h i k, 1961). The organic sediments of this interglacial were particularly well examined in the Smoleńsk region, where they were found in 17 localities. The palynological studies revealed that in the climatic optimum there was a predominance of deciduous forests (*Quercetum mixtum*). According to S h i k (1959) the Odintzovo Interglacial was not colder but more arid than the other interglacials.

In Poland no typical fossil flora from this period has been so far discovered. Such sites as Brzozowica near Będzin (Gilewska, Stuchlik, 1958) and Łabędy (Ralska-Jasiewiczowa, 1958) are of an uncertain geologic position. Środoń (1961) holds that these sediments belong to the Brörup interstadial. The paleobotanical site in Warsaw, with so-called Żoliborz interstadial flora (Rühle, 1954; Raniecka-Bobrowska, 1954) is also uncertain and requires new geological and palynological studies.

Manikowska (1966) observed the traces of washing (*lessivage*) in the fossil soil of the warm period separating the Middle-Polish (Riss) glaciation preserved in the Łódź region. In her opinion this fact shows that the area in question was overgrown with the forest vegetation at that time.

Of all the loess regions of Poland, the oldest fossil soil on the Lublin Upland (Malinowski, 1964; Mojski, 1965, 1968) should perhaps be ascribed to the warm period mentioned above. According to these authors the soils are of the podzol type originated in the Eemian Interglacial. However, they are ill-preserved and occur almost entirely on the secondary bed. Hence, their typological nature and stratigraphic position are not clear enough. This particularly concerns the fossil soils in the Roztocze Hills and Zamość depression (Malinowski, 1964). At Nieledew near Hrubieszów (Mojski, 1965) the lowest fossil soil, relatively well-preserved, has an analogous stratigraphic position to the soil of the Tomaszów type in the foreland of the Świętokrzyskie Mountains. It developed in the top of the lowest loess lying on the sediments of the Great Interglacial (Mindel—Riss); above on the upper loess the fossil weathering horizon developed under the forest vegetation again occurs.

In the loess regions of Czechoslovakia the horizons of the warm period separating the Middle-Polish (Riss) glaciation always represent the well-developed soils lessivés (Kukla, Ložek, 1961; Kukla, Ložek, Barta, 1962; Ložek, 1964, 1966). They originated, as in Poland, under the forest vegetation during a long warm period under the conditions similar to the interglacial ones.

The lower Older Loess, on which the soil of the Tomaszów type developed, originated — according to Klimaszewski (1961) — during the Odra stage. In the foreland of the

Table I

Rożki. Pollen grains and spores

Signatures — cf. Fig. 15	Depth in m	pollen grains and spores	*Pinus* t. *silvestris*	*Pinus* t. *haploxylon*	*Betula*	*Picea*	*Alnus*	*Salix*	*Frangula*	*Thalictrum*	*Chenopodiaceae*	*Ericaceae*	*Ephedra distachya*	*Ephedra fragilis*	*Cyperaceae*	*Gramineae*	*Artemisia*	*Rumex*
a	9.25	37	*18*	*4*	*1*	*1*						*1*						
b	10.30	310	38.5	3.0	14.5	4.5	7.2	5.3	0.4	1.9	1.9	0.8		1.1	10.9	6.8	3.4	0.4
c	10.70	29	*4*			*1*	*1*							*1*		*1*		
d	11.30	233	55.4	1.3	11.5	0.6	1.9				2.5	1.6		3.2	3.8	6.4	12.1	
e	11.60	402	24.8	2.6	14.7	0.3	2.9	2.9		1.6	2.6	0.6	0.3	0.3	11.3	20.3	14.0	
f	12.00	Horizons deprived of pollens																
g	13.90																	
h	14.20																	

Signatures — cf. Fig. 15	*Cruciferae*	*Botrychium*	*Caryophyllaceae*	*Compositae tubiflorae*	*Rosaceae*	*Umbelliferae*	*Polypodiaceae*	*Polemonium*	*Valeriana*	*Saxifraga*	*Selaginella*	*Linum* cf. *cathafticum*	*Rubiaceae*	*Lycopodium annotinum*	*Polygonum* t. *bistorta*	*Labiatae*	*Composita liguliflorae*	*Lycopodium selago*
a		*4*					*1*											*1*
b	1.5	1.5	1.1	1.5		1.1	2.5			0.4				0.8	0.4	0.9	1.9	
c		*18*																
d	1,6	30.6	3.2	1.3	1.3	1.6	1.9	0.6		0.6	0.3	0.3	0.6					
e	3.6	14.0	3.9	1.3	1.0	0.6	0.3	0.6	0.3						0.6			
f	Horizons deprived of pollens																	
g																		
h																		

Signatures — cf. Fig. 15	*Varia*	*Sphagnum*	*Pediastrum*	*Pterocarya*	*Corylus*	*Liquidambar*	*Quercus*	*Ulmus*	*Elaeagnaceae*	*Tsuga*	*Nyssa*	*Carpinus*	*Platycaria—Engelhardtia*	*Pteridophyta of Tertiary spores*
a	*1*	*2*	*8*	*1*	*2*									
b	3.4	4.1	*25*	1.9	1.9	0.4	0.4	1.1	0.4	0.4	0.4	0.4		1.1
c			*4*										*1*	*2*
d	3.8	2.5	*1*	0.6										1.9
e	1.6	0.3	2						0.6	0.3			0.3	0.6
f	Horizons deprived of pollens													
g														
h														

100% = AP + NAP, anemophilous
absolute numbers — in italics

Świętokrzyskie Mts. this loess lies some 20—30 km outside the end moraines of the maximum extent of the Middle-Polish (Riss) ice-sheet, whereas the northern boundary of the loess of the last (Würm) glaciation is separated from the Würm end moraines by a much larger zone, whose width according to B ü d e l (1951) is always more than 100 km. Presumably, the accumulation of eolian dust also in the time of the Middle-Polish (Riss) glaciation occurred at a remarkable distance outside the glacier front.

The lower Older Loess (older loess in: J e r s a k, 1965) in the excavation at Opacie Doły (K l a t k a, 1961) is truncated by congelifluxion deposits overlain by river sands and gravels which form the upper terrace. The sands and gravels are regarded as deposits originated in the time when the lower Kamienna valley was dammed by the glacier front during the maximum extent of the Middle-Polish (Riss) ice-sheet (L e n c e w i c z, 1934; P o ż a r y s k a, 1949; P o ż a r y s k i, 1953; K l a t k a, 1961, 1962; J e r s a k, 1961, 1965; R a d ł o w s k a, 1963; B a r t o s i k, 1964) The stratigraphic position of this loess indicates that its accumulation occurred in the period when the glacier front was still far from the Opatów Upland and the climate was decidedly continental. This supported by the presence of the ice wedges found by B a r t o s i k at Zębiec, 30 km north of Opatów in the zone of end moraines of the Odra stage (oral information). The wedges cut the glacifluvial sediments and the top of the underlying Jurassic ferruginous sands; the wedges are overlain by a thin layer (1—2 m) of the Odra stage boulder clay.

When the glacier front of the Odra stage attained its maximum extent, conditions on the Opatów Upland were unfavourable for the eolian accumulation. The herbaceous vegetation must have been withdrawn farther to the south and the newly formed loess cover underwent intensive solifluxion and deflation processes.

The short period of eolian accumulation and subsequent long-lasting denudation under periglacial conditions caused the destruction of the lower Older Loess which is preserved only in fragments.

Loesses of similar age are described from the Opatów Upland by G r a b o w s k a (1961b). These sediments are so-called „varved loesses" occurring at Złota, SW of Sandomierz, on the left side of the Vistula valley. Though this deposit contains, in some parts, mainly dusty particles, this can hardly be referred to losses. It presents a facial variety of varved clays deposited in the dammed lake formed by the glacier front choking the outflow of the Vistula waters during the maximum extent of the Middle-Polish (Riss) ice-sheet (Różycki, 1967). This may be inferred from the following facts: (1) the sediments occur in the Vistula valley, several kilometers along, in some places they are not composed of such coarse grains as Grabowska (1961b) asserts (Fig. 5), (2) their top attains to more or less the same altitude, about 168—196 m above sea level, i.e. some 25 m above the present-day valley bottom, (3) they show very distinct varved rhythm. The „varved loesses" distinguished by Grabowska (1961b) cannot be treated as the counterpart of the lower Older Loess because they are somewhat younger. They lie above the sands and gravels which form the upper terrace, whereas the loess lies below.

The upper Older Loess, unlike the older loess beds, forms an almost continuous cover on the Opatów Upland (Fig. 2), though its thickness is rather small and except for some places like Tomaszów, Gojców and Sandomierz it does not exceed 2 m. In many places this loess is strongly weathered due to its small thickness. On the upper terrace it always occurs above the river sands and gravels, varved clays and even above the congelifluxion sediments. This stratigraphic position proves that the loess was deposited during the Warta stage of the Middle-Polish (Riss) glaciation.

In the top part of the upper Older Loess there is a soil complex of the Nietulisko I type, which was formerly ascribed to the Aurignacian interstadial (Grabowska-Olszewska, 1963; Mojski, 1956, 1961, 1965, 1968; Malinowski, 1964, 1965; Malinowski, Mojski, 1960; Klatka, 1961, 1962; Nakonieczny, 1961a, b; Straszewska, Mycielska, 1961a, 1961b, Straszewska, Kopczyńska, 1961; Jahn, 1950, 1952, 1956; Malicki, 1961b; Klajnert, 1961; Sawicki, 1952, 1954; Jersak, 1961, 1965). Recently it has been paralleled with the Brörup interstadial (Jersak, 1965; Malinowski, 1964, 1965; Mojski, 1965, 1968). A number of authors assert that this soil is 2—3 m thick and consists of two or three genetic horizons: (1) accumulational A_1, (2) eluvial A_2, and (3) illuvial B. It is determined as chernozem, either the chernozem with rusty illuvial horizon or leached chernozem. Leached chernozem was recognized among others by Malinowski (1964) and Mojski (1965).

M o j s k i (1968) discerns the following sequence of the pedogenic processes: chernozem developed under the complex of herbaceous vegetation; next, the forest invaded this area and promoted the soil-leaching and subsequently the formation of the eluvial horizon. This opinion seems, however, improbable because leaching processes always start from the soil top, hence, first of all the chernozem should have been completely destroyed, especially under such intensive processes as gave rise to the eluvial horizon A_2 under the accumulational A_1, 0.9 m thick.

The present writer believes that the soil complex of the Nietulisko I type represents two warm periods interrupted by a colder one, during which the formation of a discontinuous loess cover took place. The soil-complex consists of two different soil-types. In the lower part there is the 2.0 m thick soil lessivé showing three genetic horizons: (1) a c c u m u l a t i o n a l A_1 — of several cms in thickness, grey in colour, of loose structure and with numerous charcoals; (2) e l u v i a l A_2 — up to 0.5 m in thickness, white in colour and loose; (3) the lowest i l l u v i a l h o r i z o n B — ca 1.5 thick, clayey, redish-orange and of crumble-structure. Traces of leaching processes are very conspicuous. Horizons A_1 and A_2 contain only 9—14% of colloids and 0.4—0.9% of Fe_2O_3, whereas in the illuvial horizon the colloidal particles (25—33%) and Fe_2O_3 (3—4) are abundant. From these data it may be concluded that this soil developed under the forest vegetation over a long and warm period such as the Eemian Interglacial probably was.

The c h e r n o z e m lying above is of 0.2—0.4 m, and in some places even of 0.6 m in thickness. It has only one, accumulational horizon A_1, which shows 0.6—1.0% of strongly decomposed organic matter occurring as colloids. The soil developed under the complex of herbaceous, meadow- and steppe-like plants at the time when the forest vegetation did not spread over the whole area. This opinion is supported by the lack of any traces of the chernozem degradation which would certainly have taken place if the forests had predominated for a longer time. Presumably, this chernozem originated in the Brörup interstadial, which on the basis of investigations so far performed could hardly be regarded as an interglacial period as M o j s k i suggests (M o j s k i, 1961, 1965, 1968). Paleobotanical studies as well as C^{14} dating show that the Brörup interstadial falls in the older part of the last cold period (A n d e r s e n, de V r i e s, Z a g w i j n, 1960; van der Hammen, Maarleveld Vogel, Zagwijn, 1967; Zagwijn, 1961). Dylik (1967), Ložek (1964) and others have pointed out the uniformity of the whole last cold period, and warmer phases might only be regarded as minor climatic oscillations, i.e. interstadial oscillations.

Pollen diagrams show that the Brörup interstadial is characterized not only by the warmth-loving trees but also by a growth of shrubs and herbaceous vegetation with light-requiring plants; this may be due to the long intervals in the growth of mainly coniferous forests which did not yet invaded the whole area (Sobolewska, Starkel, Środoń, 1964). Jańczyk-Kopikowa asserts that the period of the development of forest vegetation in the Brörup interstadial was very short (Jańczyk-Kopikowa, Mojski, 1964). In the foreland of the Świętokrzyskie Mountains the Brörup pedogenic processes were preceded by vigorous denudation operating at the beginning of the Würm. The activity of these processes led to complete or partial denudation of the soil lessivé as it is observed at Stodoły and Kruków. Later, the eolian accumulation took place and subsequently the Younger Loess I originated. Considering the course of morphodynamic events occurring in the early Würm, it seems justified to assume that this loess was deposited rather in the second interstade, younger than the Amersfoort interstadial. The eolian processes of the same age are also known in the Łódź region (Dylik, 1961, 1967). The wind activity must have been rather weak, as in the foreland of the Świętokrzyskie Mts. only a discontinuous and thin loess cover was deposited (Fig. 2). In all probability, in the first stades there was still fairly rich vegetation which protected the dust against blowing away from the deflation area and the material was only locally transported by wind.

Analogous stratigraphic situation is known from the loess regions in Austria, Czechoslovakia, Germany and in the European part of the Soviet Union, where above the weathering horizons of soil lessivé occur the thin loess beds overlain by chernozem soils. These are such horizons as Stillfried A, pedocomplex II and III, and the Mikulino (Eemian) soil (Fink, 1962, 1964; Frenzel, 1964; Kukla, Ložek, 1961; Ložek, 1964; Ložek, Kukla, 1964; Unger, Rau, 1961; Liberoth, 1963, 1964).

After the Brörup interstadial, when the climate became more severe, permafrost was rejuvenated or formed afresh and the

Younger Loess II-a gradually accumulated. On the interfluves the bogs and numerous lakes appeared due to an impermeable subsoil (permafrost) and to the humid climate which still prevailed at the beginning of this stade. The „marble-like loess" with rusty, grey and bluish spots and with small ferruginous concretions developed in the swampy places, which periodically dried up. In depressions filled for a longer time with water, there was formed a compact, plastic sediment, steel-bluish in colour, containing the remnants of algae of genus *Pediastrum*. At the same time, congelifluxion and downwash processes operated very intensively on the slopes and interfluves near the valleys. Later on, due to increasing severity of climate the surface partially dried up, vegetation was reduced and slope denudation decreased, while the increasing eolian activity led to the accumulation of a coarse-grained, calcareous and in some places non-gleyed loess. In those depressions which still existed, the steel-bluish deposit continued its sedimentation. In the present writer's opinion the climate of the period of the Younger Loess II-a accumulation was not fully continental. This conclusion is supported by such periglacial structures as tiny fissures of polygonal soils, spotted tundra structures and others, preserved in this horizon (Jersak, 1965) as well as by the lack of ice wedges which can arise only in a severe continental climate. The occurrence of the Younger Loess II-a in the intervalley area is fairly common, its maximum thickness 6—7 m on the east decreasing gradually to the west.

The fossil soil of the Komorniki type, developed on the top of the Younger Loess II-a, represents a small climatic oscillation. At that time, permafrost persisted and the climate became humid, more oceanic. This is evidenced by strong activity of the gley processes, which produced the pseudo-gleyed and boggy-peaty soils. The pseudo-gleyed soils show the oxydo-reduction horizons of several tens of centimeters in thickness, light-grey in colour with rusty spots, rich in humus; the boggy-peaty soils have a brownish-black or bluish-black horizon with the organic matter slightly decomposed and consisting mainly of the moss remnants. The nongleyed brown arctic soil is preserved in few places only. In its profile can be distinguished the brownish-grey accumulational horizon of several centimeters in thickness underlain by a horizon gradually turning brown.

Palynological analysis of the material from the site at Różki

(Fig. 15) made by Sobolewska[1] revealed the slight climatic changes occurring in this period (Tab. I). Here, in the lower part of the Younger Loess II-a no pollens were found but in the soil of the Komorniki type (2 samples from the depth of 11.3—11.6 m) and above this level in the Younger Loess II-b (1 sample from the depth of 10.3 m) the amount of sporomorphs was great enough for their percentage to be calculated. The small number of sporomorphs in the samples taken at the depth of 10.7 and 9.25 m in the Younger Loess II-b permits only the real values to be given. A predominance of the *Pinus* (56.7%) and *Betula* (11.5%) was established. Bearing in mind the fact that some of the sporomorphs were corroded, and that they occurred together with a few sporomorphs of the Tertiary plants, the sediment might be supposed to have originated through the washing of some Tertiary deposits. However, such an assumption seems unlikely for the following reasons: (1) the Tertiary is only of marine facies in this area; (2) glacial sediments form here a compact cover above which the 4—5 m thick loess coat already existed at that time. The boring was performed on the interfluve plain where the possibility of wash-accumulation of the older sediments is out of question. It may perhaps be assumed that few sporomorphs of the Tertiary plants and warmth-loving trees, as well as of *Pinus* and *Betula,* were transported by wind together with the mineral particles. Therefore, the present writer considers the participation of sporomorphs on the secondary bed as quite insignificant. This is attested by the small frequency of pollen seeds in the remaining loess horizons originated in the boggy area. The wide spread of the light-requiring plants such as *Artemisia* (12.1%), *Chenopodiaceae* (2.5%), *Ephedra* (3.2%) and *Botrychium* (30.6%) proves that the pines and birches were widely dispersed. The predominant type of vegetation of that time was the park-like tundra. It was perhaps the result of the neighbourhood of the area being densely overgrown by these trees.

In the face of these facts it may be established that in the period when the Komorniki soil originated there was a slight amelioration of climate, permafrost persisted, only its active zone increased in thickness, and the herbaceous tundra vegetation was re-

[1] The author wishes to thank Dr. Maria Sobolewska for making the palynological analysis.

placed by the park-like tundra during the accumulation of the Younger Loess II-a.

Soil of the Komorniki type has the analogous stratigraphic position to the soil complex I in Czechoslovakia and the Paudorf soil and the complex Stillfried B in Austria as well as the Bryansk soil in the European part of the Soviet Union (Velichko, 1965). These soils are paralleled by Ložek (1964) with the Göta Älv interstadial in Sweden (Brotzen, 1961). The organic sediments of similar stratigraphic position dated by means of the radioactive carbon are known also in the Netherlands. They come from two slight and warm oscilations of climate: the Hengelo and the Denekamp (van der Hammen, Maarleveld, Vogel, Zagwijn, 1967).

Soil of the Komorniki type is overlain by the youngest horizon — the Younger Loess II-b — which reaches a thickness of 14 m. Its initial accumulation must have been slow, the climate relatively humid, and some water basins from the preceding period still preserved. Then, in the interfluves, the gleyed „marble-like loess" and the fine-grained loess, steel-bluish in colour, slightly calcareous were being formed. When the climate became severely continental, the rate of accumulation increased and the non-gleyed, coarse-grained yellowish loess was deposited. The periglacial phenomena such as ice-wedges and injection structures occurring in this horizon also argue in favour of a strongly continental climate (Jersak, 1965). The accumulation of loess in this area came to the end in the period preceding the Alleröd interstadial (Jersak, 1965).

The above presented results of the investigations permit to distinguish the following loess horizons originated in cold periods under the influence of a more or less continental climate, characterized by the herbaceous tundra vegetation as well as by the horizons of fossil soils which, being formed in the warmer and warm periods, separated the loess horizons:

1° The lower Older Loess from the Odra stage (after Klimaszewski, 1961) of the Middle-Polish (Riss) glaciation. The dust accumulation in the area investigated fell in the period preceding the maximum extent of the ice-sheet of this stage.

2° In the top part of the lower Older Loess the fossil soil of the Tomaszów type developed. Genetically, it belongs to

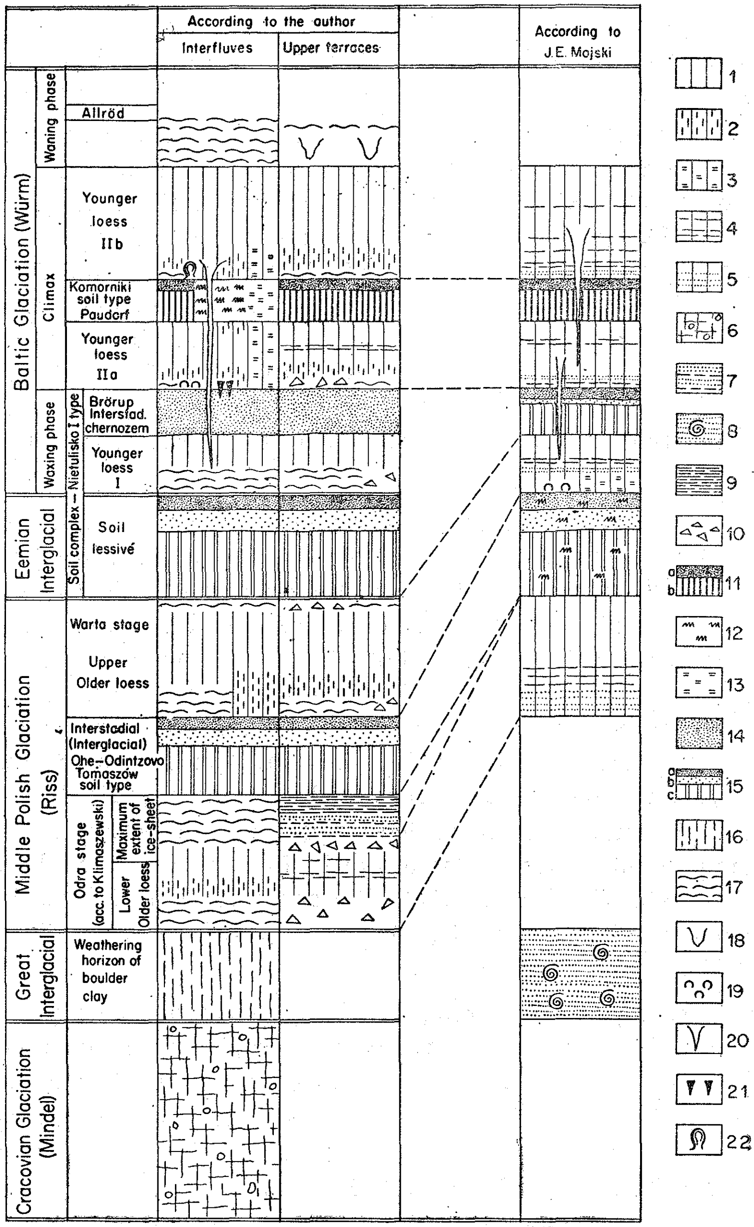


Fig. 16. Stratigraphy of loesses

1. structureless, non-gleyed loess; 2. „marble-like" loess, partly gleyed, grey with rusty spots; 3. boggy loess; 4. striated loess, displaced by slope processes; 5. stratified valley loess; 6. calcareous boulder clay; 7. river sands and gravels of upper terraces; 8. river sediments with mollusca; 9. varved clays; 10. congelifluxion- and downwash-slope deposits; clayey-sandy-loessy debris; 11. brownish arctic soil: a — accumulational horizon A_1, b — horizon (B) of forest brown soil; 12. gley soil; 13. boggy soil; 14. soil lessivé (podzol): a — accumulational horizon A_1, b — leached horizon A_3, c — illuvial horizon B; 16. weathered, decalcified boulder clay; 17. denudational processes; 18. erosional processes; 19. spotted tundra; 20. frost wedges; 21. polygonal soils; 22. injection structures

podzol or pale- (lessivé)-type soil originated in a fairly warm period, similar to an interglacial. The period of its development was earlier than the stage of the maximum extent of the Middle--Polish (Riss) ice-sheet (the Odra stage) but preceded the Warta stage. In all probability it was the period which is called the Ohe interstadial in the Western countries and the Odintzovo interglacial in the East.

3° In the intervalley area the upper Older Loess deposited during the Warta stage forms a continuous though thin cover, whose thickness does not exceed 2 m.

4° The upper Older Loess, in many places strongly weathered, is overlain by the lower part of the soil complex of the Nietulisko I type. It is well-developed soil from the warm period of the Eemian interglacial and belongs to the podzol- or soil lessivé-type, and bears distinct traces of strong leaching processes. It originated under the cover of the forest vegetation.

5° The Younger Loess I which forms a discontinuous cover several tens of centimeters thick, comes from the early phase of the Baltic (Würm) glaciation, from the stage which separated the Amersfoort and the Brörup interstadials.

6° On the Younger Loess I, the upper part of the soil complex Nietulisko I developed as chernozem from the older part of the last cold period, presumably from the Brörup interstadial.

7° The Younger Loess II-a, 2—6 m thick, originated in the older part of the climax of the last glaciation, very likely under conditions of the cold continental climate though with distinct influence of the oceanic climate.

8° Soil of the Komorniki type developed in the top-part of the Younger Loess II-a in a period of slight climatic amelioration when the humidity was a little greater than during the Younger Loess II-a accumulation. It is brown arctic or gleyed soil that rose under the park-like tundra vegetation, most probably in the Paudorf interstadial.

9° The Younger Loess II-b, up to 14 m thick, is the youngest horizon. Its sedimentation started after the Paudorf interstadial and was over before the Alleröd interstadial, when the climate was severely cold and continental.

Figure 16 shows the stratigraphy of individual loess and fossil soil horizons.

STRATIGRAPHY OF THE LOESSES IN POLAND

To discuss the problem of the stratigraphy and genesis of the loesses, the notion of loesses should be elucidated. In recent Polish as well as foreign literature, we meet such terms as *proper loess, subaeral loess, upland loess, solifluxion loess, slope loess, sub-aqueous loess-like formations, loess-like silts,* etc. The sediments corresponding to these notions may be roughly divided into two groups: (1) proper loesses, subaeral loesses and upland loesses, and (2) loess-like silts, alluvial loesses and sub-aqueous loess-like deposits. These two groups of sediments originated either through direct or indirect eolian accumulation. The origin of the first group does not rise any doubt, its direct wind accumulation being asserted by most authors. Instead, there are often ascribed to the latter some genetically different sediments which have only one or two traces in common with the former group, these are: the presence of calcium carbonate and similar grain-size gradation. The grain-size is the essential criterion. The most striking characteristics of loesses are large amounts of the pulverulent material but there is a disagreement in regarding various grains as dust, so that the range of sizes is very large: 0.05—0.01 mm (0.06—0.02 mm) 0.05—0.002 mm and even 0.1—0.002 mm. Moreover, this characteristic, which should be representative of the whole thickness of a deposit sometimes occurs only partially. This leads to such expressions in the descriptions of lithology as "loess-like sediments intercalated by sands, gravels or clays". The result of all this is the inclusion in the same group of the river, lacustrine and glacifluvial sediments along with the facies closely connected with the loess.

In Poland, the loesses ascribed to the first group occur in the areas of the Middle Polish Uplands. Generally, either two horizons are distinguished (J a h n, 1950, 1956) or four (M a l i n o w s k i, 1964, 1965; M o j s k i, 1965, 1968) which are referred to the Baltic (Würm) glaciation and to the Warta stage of the Middle-Polish (Riss) glaciation. M a l i c k i (1949) and R u s z c z y ń s k a (1961b) are representative of a different opinion, they discern three horizons and parallel them with the three separate glaciations: the Cracovian (Mindel), Middle-Polish (Riss) and Baltic (Würm) glaciations. This theory is not sufficiently supported by geological data.

The "loess-like formations" described from the Middle Polish

Uplands as well as from the areas extending N-ward are ascribed to the Odra stage of the Middle Polish (Riss), glaciation. These sediments are frequently found amidst the glacifluvial gravels, boulder- and varved-clays (Łyczewska, 1948; Karaszewski, 1952; Falkiewicz, 1961; Lamparski, 1961; Laskowska-Wysoczyńska, 1961; Mojski, Trembaczowski, 1961; Różycki F., 1961; Rühle, 1952; Różycki S. Z., 1967; Ruszczyńska, 1952). The present writter believes that the data which have been so far obtained do not permit us either to compare the „loess-like deposits" with the eolian accumulation or — even less — to attribute to them a paleogeographic importance.

On the basis of the studies of the loesses in the border area of the Świętokrzyskie Mountains and the analysis of the extent of the individual glaciations as well as of the northern limits of the loess horizons, there may be distinguished in Poland two regions (Fig. 1) — eastern and western — which distinctly differ with regard to the number and to the age of the loess horizons. The boundary between the eastern and western regions is marked by the end moraines running along the western scarps of the Silesian Upland and Cracow—Częstochowa Jura.

In the eastern region uninvaded by the Middle-Polish ice-sheet, there are probably the following loess horizons: (1) the lower Older Loess preserved only in fragments, which belongs to the stage of the maximum extent of the Middle-Polish ice-sheet (the Odra stage — according to Klimaszewski, 1961); (2) continuous horizon of the upper Older Loess from the Warta stage of the Middle-Polish (Riss) glaciation, and (3) three horizons of the Younger Loess of the Baltic (Würm) glaciation, one of which (from the older phase) is poorly developed, and two of its climax are continuous and fairly thick. Such conclusions Mojski (1961, 1965, 1968) draws from his investigations carried on in the Lublin Upland and in the Hrubieszów region. Especially interesting is the site at Nieledew near Hrubieszów where there are preserved two fossil soils representing long and warm periods resembling the interglacial conditions.

In the eastern area the two oldest horizons are probably slightly differentiated, according to their position in relation to the end moraines of the Middle-Polish (Riss) glaciation. On the border of the Świętokrzyskie Mts. the loesses, which lie nearer to the end moraines of the Odra and the Warta stages, are much thinner than the same lower horizons more remote from these moraines in the

Hrubieszów neighbourhood. It may be inferred that on the south-east part of the Lublin Upland at the time of the Middle-Polish (Riss) glaciation, the conditions were more favourable for loess accumulation than in the northern part of the Lublin Upland and of the border of the Świętokrzyskie Mts.

In the western area, at the time of the maximum extent, the ice-sheet of the Middle-Polish (Riss) glaciation advanced far to the south, its front reaching the northern border of the Sudetes. Such a range of the glacier extended the tundra zone — where the accumulation of the eolian dust was going on — farther to the south, as far as Czechoslovakia. In western Poland the loess sedimentation could not have started before the Warta stage. Presumably, the loesses of this period as well as the oldest horizon in the eastern area are preserved only in fragments. The loesses of the last cold period are frequently found throughout this area, which is confirmed by the investigations carried out there by many workers (Walczak, 1952; Piasecki, 1961; Czeppe, Kozłowski, Krysowska, 1963; Jahn, Szczepankiewicz, 1967).

This deduction also accords with the results of studies on the loesses in Czechoslovakia and in Eastern Germany. In Czechoslovakia, far to the south of the maximum extent of each glaciation, the loesses of the two last glaciations and even the older horizons are present (Kukla, Ložek, 1961; Ložek, Kukla, 1961; Kukla, Ložek, Barta, 1962; Ložek, 1964, 1965).

In Eastern Germany, where the loess areas are, in relation to the end moraines, in a position analogous to that in western Poland, the oldest horizon — the loess of the Odra stage — is preserved only in fragments, whereas the loess horizons of the last cold period are widespread (Unger, Rau, 1961; Ruske, Wünsche, 1961; Lieberoth, 1962, 1963, 1964; Hasse, 1963; Mojski, 1965).

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