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Łódź

EEMIAN AND EARLY WÜRMIAN SOILS IN LOESS OF POLAND

Abstract

Chernozem developed under steppe vegetation which overgrew the loess areas of Poland at the beginning of the Eemian Interglacial and in the older part of the Holocene. In the climatic optimum of the Eemian Interglacial the steppe plants gave way to those of the forest type under which a complete degradation of chernozem was accomplished and in consequence the soil lessivée came into being. Its development was interrupted together with the extinction of coniferous trees. Cold and humid climate at the beginning of the Würm – favourable for intensive denudation – became more continental and promoted formation of pseudomorphoses after elementary fissure ice and sedimentation of thin patches of the younger loess I. The climatic conditions during optimum of the Brörup, which was a relatively warm period, were much the same as in the older part of the Eem or in the Boreal period of the Holocene and gave rise to chernozem whose development was twice interrupted.

In the course of investigations carried out by the present author in the loess areas the most attention has been given to the fossil soils of the Nietulisko I type (Jersak, 1965, 1969a, b). Soil complexes with analogous stratigraphic position and of alike origin are regarded by many authors as leading horizons most helpful in studies on loess stratigraphy (Fink, 1964; Lieberoth, 1964; Veličko, 1965; Veličko and Morozova, 1969; Unger and Rau, 1961). In Poland this complex has been for a long time considered as one horizon of fossil soil and described as chernozem with red illuvium or with reddish weathered loess (Jahn, 1956; Kopczyńska, 1961; Pożaryski, 1956; Straszewska, Kopczyńska, 1961; Straszewska, Mycielska, 1961a, b). Grabowska-Olszewska (1963) distinguished three genetical horizons: chernozem, eluvium and rusty illuvium; she ascribed them to the soils originated under the steppe-forest conditions.

The age of the soil complex investigated has been disputable. On the basis of archaeological studies Sawicki (1932) considered this horizon as Aurignacian in age and held that it should have corresponded to the Middle Polish (Riss) glaciation. This opinion was regarded valid for a long time. Then, some scientists connected the Aurignacian interstadial with the last glaciation and compared it with the Göttweig (Grabowska-Olszewska, 1963; Jersak, 1961; Klatka, 1961; Straszewska, Mycielska, 1961), and recently it has been ascribed to the Brörup Interstadial (Mojski, 1965, 1968, 1969; Czeppe, Kozłowski, Krysowska, 1963; Jahn, 1969; Jersak, 1965; Kozłowski, 1969).

The more complicated genesis of this horizon attracted attention of many workers (Jersak, 1965, 1969a, b; Klatka, 1969, 1970; Mojski, 1965, 1968, 1969) who hold that the soil complex of the Nietulisko I type or – as Mojski (1969b) and Różycki (1967) call it – Hrubieszów fossil soil – was formed under various climatic conditions and under different vegetation communities. According to Mojski chernozem developed first under the steppe plants and later, in the warmer part of the same period the growth of forests caused its degradation. As a result of this succession of vegetation the bleaching chernozem originated during the Brörup Interstadial.

Jersak (1969a, b) and Klatka (1970) present another point of view on the origin of this horizon; soil lessivée developed under the forest vegetation in the Eemian Interglacial, then in the older part of the Würm, perhaps in the Brörup Interstadial, chernozem was formed under the herbaceous plants.

The results of the three last years' studies of the present author have revealed that the structure and origin of soils of the Eemian Interglacial and of the early Würm are much more complicated than it had been believed so far. There are also special differentiations. Soil complex of the Nietulisko I type represents somewhat another mode of development in the loess areas of Eastern and Central Poland than in some places of their northern marginal areas and in Western Poland. This fact points to some zonality of the development of fossil soils which attracted attention of Brünnacker (1956), Fink (1966) and Ložek (1966).

FOSSIL SOIL OF THE WAXING PHASE OF THE EEM

According to the present author's studies, the oldest part of the Nietulisko I soil has been preserved in the brick-kiln at Nieledew near Hrubieszów, the Lublin Upland. There, three horizons of fossil soils can be distinguished; the upper two form most probably one soil complex. The present site at Nieledew consits of two separate profiles, southern and northern, which are divided into two parts by a steep, 70 m long escarp overgrown with vegetation. In the southern excavation there is only one horizon of fossil soil, it is well preserved except for its upper part which displays slight dislocations. In the northern section there are three horizons of fossil soils, the uppermost of them is strongly denuded. Mojski (1965, 1968, 1969) ascribes the upper denuded soil to the middle Würm and compares it to the Paudorf interphase; the middle soil as well as the soil from the southern section he asigns to the Brörup Interstadial, whereas the lowermost horizon – to the Eemian Interglacial. This interpretation arouses much doubt. The most controversive is the opinion that the soil from the southern excavation corresponds to the middle soil of the northern cut (Fig. 1). The two soils differ essentially in structure. The middle soil from the northern profile consists of one genetic accumulational horizon, while the soil in the southern cut displays three genetic horizons: accumulational, leached and illuvial like the upper soil in the northern excavation. In the northern profile the upper fossil soil is strongly denuded.

The additional excavations made by the present author in the escarp separating the two exposures revealed that there is a full succession from the undestroyed fossil soil in the southern cut to the strongly denuded upper fossil soil in the northern profile. In the southern part of the northern excavation the nature of the soil is still better pronounced but northwards the destruction is advanced (Pl. 1) and all genetic horizons are intermixed. Small layers containig humus, grey or black in colour, from the accumulational horizon, alternate with the brownish-orange clayey layers from the destroyed illuvial horizon.

The middle fossil soil in the brick-kiln at Nieledew which has only one black genetical, accumulational horizon is in places 1 m thick. It displays slight striation of darker and lighter interlayers containing more or less organic matter. This striation is the result of accumulation of slope material supplied slowly and simultaneously with the development of the soil. The whole material was altered by the soil processes, which is evidenced by carbonates in this horizon. The macroscopically visible concentrations of these compounds occur on the walls of small fissures as $CaCO_3$ efflorescences formed after the soil had been developed as well as pseudomycellia and small finger-like concretions in places of the former vegetation root system dissecting the darker and lighter layers formed simultaneously with the development of soil processes. The organic matter in the accumulational horizon is strongly decomposed therefore no macroscopic remains can be found here. The content of humus is various: in the middle part of the accumulational horizon it reaches up to 1.1%, while in the upper and bottom parts – 0.4%. Poor content of organic matter in the bottom parts of the horizon is due to the soil processes, but its decrease in the upper parts may be a result of a faster growth of thickness of the slope material. The more or less homogeneous accumulational horizon is overlain by sediment showing alternating small dark layers which still contain fairly large quantities of the organic matter, and lighter ones almost deprived of it. The accumulation was very intensive in the course of formation of the upper soil layer.

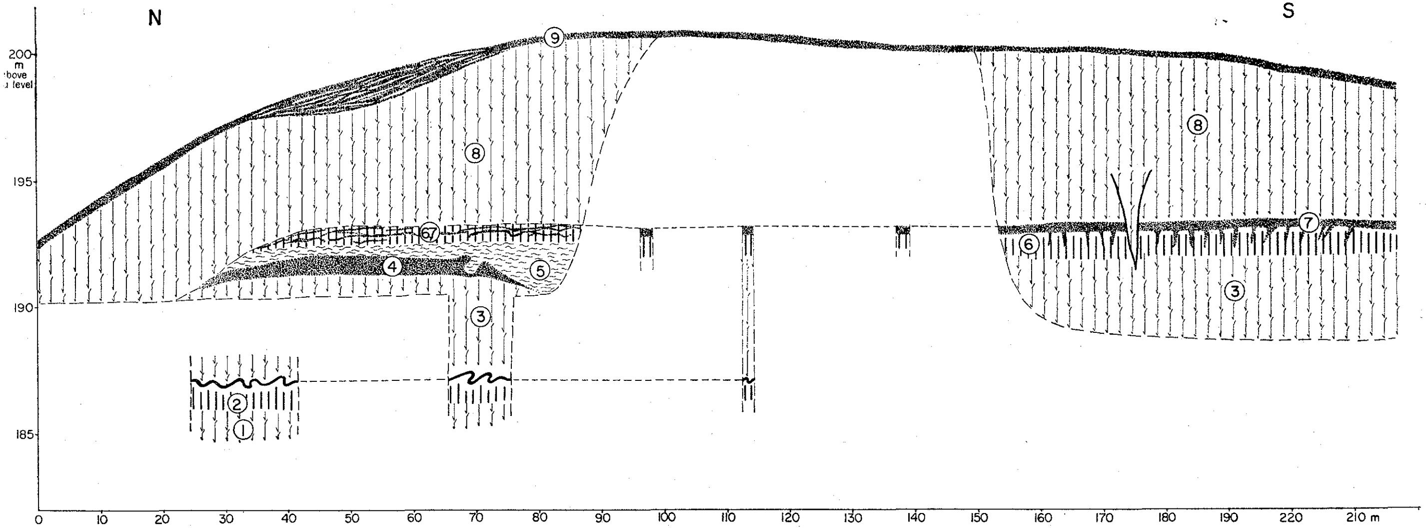


Fig. 1. Schematic section at Nieledew near Hrubieszów, Lublin Upland

1. older lower loess, strongly gleyed, decalcified; 2. soil lessivée of the Tomaszów type – lower fossil soil with 3 horizons: accumulational A_1, leached gleyed A_3g, and illuvial gleyed Bg; 3. older upper loess, calcareous, containing large $CaCO_3$ concretions, in the lower part strongly gleyed; 4. middle soil – meadow chernozem (older Eemian in age); 5. slope deposits – light striated loess intercalated with dark humus loess and tiny lumps of organic material; 6. soil lessivée of the soil complex of the Nietulisko I type with 2 horizons: A_3 – leached, and B – illuvial, non-destroyed in the southern part of the section, dissected by the pseudomorphoses after elementary fissure ice (young part of the Eem); 7. chernozem of the soil complex of the Nietulisko I type, slightly dislocated in the southern part of the section. In the northern part it is intermingled with the underlying soil lessivée (6, 7); 8. younger loess II, in the lower part strongly gleyed, upwards light "dry" loess; 9. Holocene chernozem, in places colluvial chernozem

The nature of the profile indicates that the middle horizon at Nieledew is gleyed chernozem soil which originated under the meadow herbaceous vegetation when the supply of slope material was slow. Gleying processes distinct both in the accumulational horizon and in the underlying parent material progressed upwards from the base parts under the conditions of permanent high level of ground waters. The divalent iron compounds give a grey-greenish or blueish colour to the parent material. The leaching processes are not marked here; the upper part of horizon A_1 is somewhat enriched in comparison with the lower horizon A_1/C. In the transitional horizon A_1/C there is 2.30% of Fe_2O_3, while in the upper part of the accumulational horizon A_1 – 2.70%.

The sediments, separating the middle and upper fossil soils at Nieledew, contain numerous small layers and lumps of organic matter. They are similar to the Holocene loess-like covers occurring in small concave land-forms (Jersak, 1965). These sediments 2–3 m thick, must have been formed in a warm period; they do not display any characteristics of eolian loesses *in situ*.

FOSSIL SOILS OF THE WANING PHASE OF THE EEM AND OF THE EARLY WÜRM

The upper fossil soil preserved in the brickfield at Nieledew has a remarkably complicated profile. It is composed of three genetical horizons: (1) accumulational A_1, (2) leached A_2, and (3) illuvial. The uppermost accumulational horizon A_1, 40–50 cm thick, is black with brownish shadow; its top part contains organic matter (1.00%) exclusively amorphic whereas in the lower part few pieces of charcoal are scattered. Secondary $CaCO_3$ crusts occur in places on the walls of small fissures in A_1 horizon.

Underneath lies the leached discontinuous horizon A_3, up to 20 cm thick, composed of white loose material, poor in colloids and in Fe_2O_3 (1.34%).

The lowermost, i.e. illuvial horizon B, 1 m thick, is strongly clayey, brownish-orange and of the aggregate structure. On the surfaces of prismatic aggregates there are colloidal glazes of soapy lustre. The Fe_2O_3 content is about 2.92%.

Two lower genetical horizons testify to very strong leaching processes characteristic of podzols or soil lessivée developed under the forest vegetation. The upper horizon of the chernozem type typical of the steppe herbaceous plants does not bear any traces of leaching. Such a pattern of the soil profile is a result of the succession of two pedogenic processes: the formation of soil lessivée under the forest communities took place prior to the development of chernozem associated with steppe vegetation.

The inverse succession of the soil forming processes suggested by Mojski (1965, 1968, 1969) seems rather unlikely. The leaching processes operate from the top of the soil profile. Had the chernozem process been prior to leaching – chernozem should have presented a strong degradation which it does not display.

The fossil soils of similar structure are very frequent in the loess series on the Lublin-, Opatów-, Sandomierz-, and Miechów Uplands (Dylik, Dylikowa, 1960; Grabowska-Olszewska, 1964; Jahn, 1956; Jersak, 1965, 1969a, b; Malicki, 1961; Malinowski, 1964; Mojski, 1965, 1968, 1969; Mycielska-Dowgiałło, 1966; Pożaryski, 1956; Sawicki, 1932).

There are another facts that bear witness for two soil forming periods in that type of fossil soil profiles. At sites Biskupie Doły, Komorniki, Nietulisko (Jersak, 1961, 1965, 1969a, b) a distinct bipartition of the accumulational horizon can be noticed. Its upper part of chernozem is underlain by an accumulational horizon associated with the formation of soil lessivée. The lower accumulational horizon, grey in colour, with numerous pieces of charcoal, is strongly leached as well as the lower horizon A_3 which in these sites reaches 20–50 cm of thickness. The lowermost illuvial horizon B is very much alike the one at Nieledew. Considerable thickness of the horizon A_3 at Biskupie Doły, Komorniki and Nietulisko Małe does not result from the intensive activity of the leaching processes. In these sites chernozem developed in the deposit overlying the soil lessivée while at Nieledew as well as in many other sites the upper parts of soil lessivée were transformed into chernozem soil and consequently the older accumulational horizon disappeared and horizon A_3 became strongly reduced.

Numerous pieces of charcoal from the accumulational horizon A_1 associated with the development of soil lessivée at Biskupie Doły represent: 104 specimens of *Coniferae*, 9 – *Pinus* sp., 3 – *Pinus silvestris* L., 4 – *Picea* or *Larix*, 1 – *Abies* sp., 1 – *Quercus* sp., 1 – *Alnus* sp.[1] Such a composition of trees is characteristic of coniferous forests of taiga; this fact together with the geological and paleopedological data have a univocal meaning. Strongly carbonized charcoal preserved in the accumulational horizon comes from the final stage of soil formation, the macro-remains from the earlier period must have been entirely decomposed. The development of intensely leached soil lessivée, particularly in calcareous loess should have been long-lasting. It probably started in the Eemian climatic optimum, when the loess uplands were completely overgrown with forests and came to the end simultaneously with the extinction of the coniferous forest of the taiga type in the final stage of the Interglacial.

[1] The analyses were made by Mrs. Pawlikowa in the Botanical Institute in Cracow. directed by Professor Środoń.

Chernozem developed in a warmer phase of the Early Würm. Between these two warm periods during which the soil lessivée and chernozem came into existence, the soil processes were hampered. The top of the soil lessivée is frequently truncated and all its horizons are sometimes destroyed, as for example in the site at Jędrzejów and in borrings at Stodoły and Kruków on the Opatów–Sandomierz Upland (Jersak, 1965, 1969a). At Kruków chernozem lies directly on the older calcareous loess; the lower horizons of this soil complex are lacking, they were denuded before the formation of chernozem. All these sites are situated in the marginal zone of the interfluve near deep tributary valleys. According to Klatka (1970), at Miechów on the Opatów–Sandomierz Upland, the illuvial horizon of soil lessivée and chernozem *in situ* is interbedded with the 20–30 cm thick, striated slope deposit coming from the destroyed upper part of soil lessivée.

At Błogocice on the Miechów Upland (Fig. 2, Pl. 2) the older soil is truncated by the pavement occurring at the base of the overlying chernozem. This older fossil soil is of a type of mixed rendzina developed on slope deposits with a high admixture of plate debris of marls. The slope deposit is regarded as grèzes litées. A horizon, composed of strongly clayey sands of brownish tint, displays horizontal lenses of gravels, lighter in colour, and numerous vertical black spots containing organic substance. Some of them are wedge-like, long up to 70 cm and 15–20 cm wide in the upper part. They are all the traces of a root system of trees vegetation and do not form fissure polygons: they are round or oval in plan. When the exposure face is being cleaned up, some spots disappear while in other places the new ones come into sight. They are very numerous and occur on various levels but never dissect the chernozem. The uppermost spots come from the pavement in the base of chernozem.

Grabowska-Olszewska (1963), Klatka (1970), Różycki (1967), Staszewska and Kopczyńska (1961) describe the fossil root system occurring in the soil complex of the Nietulisko I type. However, the pseudomorphoses after root system in sites at Grocholice, Żurawica (Pl. 3), Gołębice and Lenarczyce show fairly remarkable differences from those occurring at Błogocice. Only at Lenarczyce a part of these structures may be regarded as former root system because they are oval or round in the horizontal section (Klatka, 1970). In the rest of sites mentioned above, they have wedge-like shape in the vertical section. The present author has met similar structures in other regions, e.g. Nieledew on the Lublin Upland (Pl. 4) and Donosy near Kazimierza Wielka (Pl. 5). All these wedge-like structures are truncated by the chernozem. Very characteristic is the regular spacing of the individual forms being 2–4 m in cross-profile. They are infilled with the vertically striated material derived from the older accumulational horizon, grey in colour with

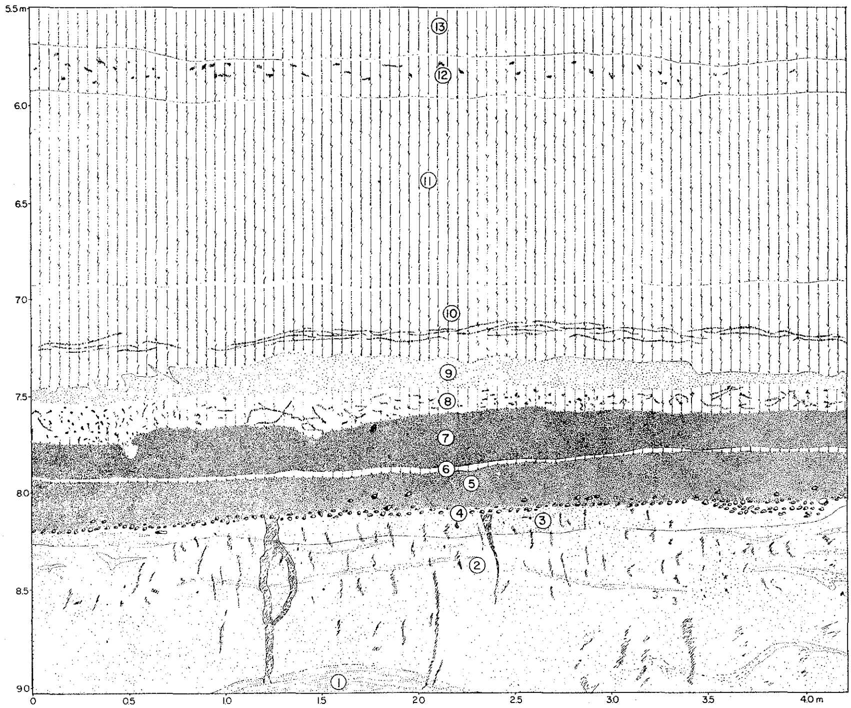


Fig. 2. Section at Błogocice, Lublin Upland

1. light yellow, fine-grained sands intercalated with lenses of Cretaceous marl debris - deposits of the grèze litée type; 2. brown-rusty ferruginous clayey sands with scattered small pebbles up to 3 cm in size and with light striae of sands – brown soil horizon B. Vertical humus striae after a tree-root system. The Eemian para-rendzina; 3. transitional horizon A_1/B developed on sands, brown and grey in colour; 4. pavement composed of pebbles, 2–3 cm and even 8 cm in size; 5. chernozem horizon – in the upper part developed on loess, in the lower one – on the sandy material; 6. ochre-yellow clayey loess with rusty ferruginous patches and small grey humus striae; 7. chernozem horizon developed fully on loess, black in colour, calcareous; 8. ochre-yellow calcareous loess with numerous small patches and humus striae after a former root system of herbaceous vegetation; 9. dark grey accumulational horizon of chernozem type, calcareous, poorly developed; 10. light grey loess, gleyed, calcareous, with ochre and rusty striae; 11. ochre loess, non-gleyed with light grey striae; 12. grey blue loess strongly gleyed, calcareous with tiny rusty patches of the Komorniki type (?); 13. light yellow loess, slightly gleyed in the bottom part, higher up "dry"

numerous charcoals and from the white-coloured deposit from the leached horizon. The striae within the wedge structures intersect each other and in the bottom part the individual striae penetrate into the surrounding material outside the wedge itself and form there a pattern similar to the ramified root system. The wedge-like structures reach the depth of 1–1.5 m. The most cogent proof that they are no fossil root system structures is the presence of fissures in the horizontal section. Their regular spacing in the vertical profile suggests that they form a system of polygon fissures, about 4 m in

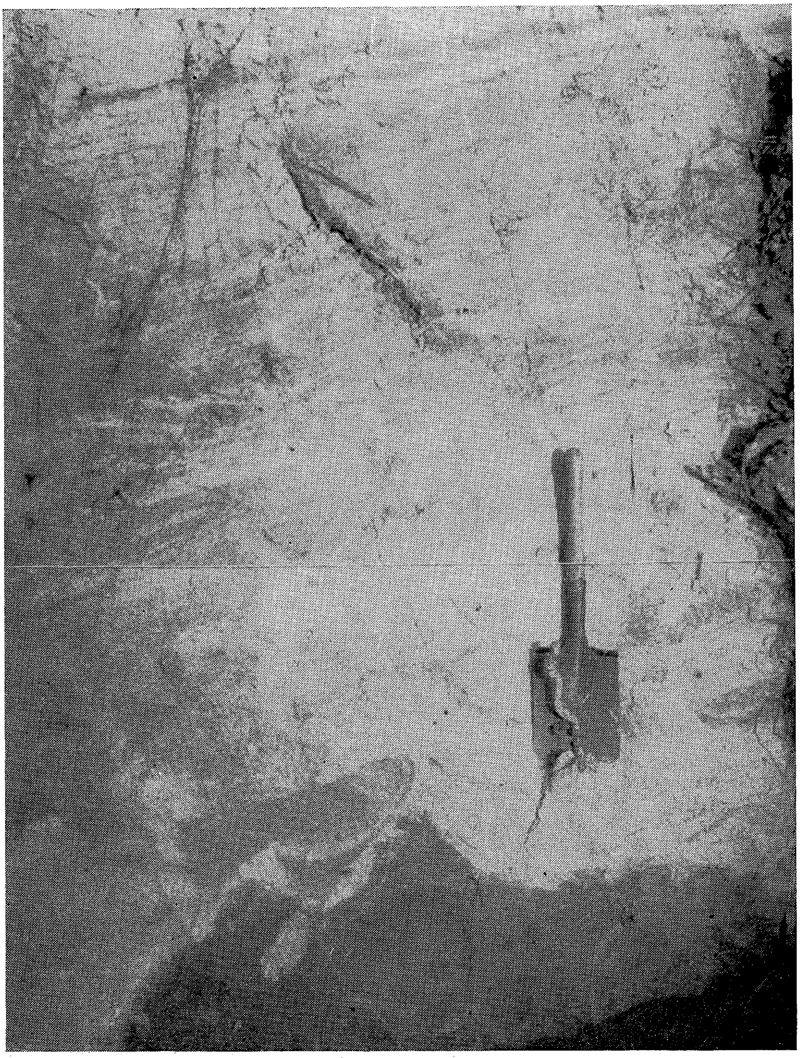
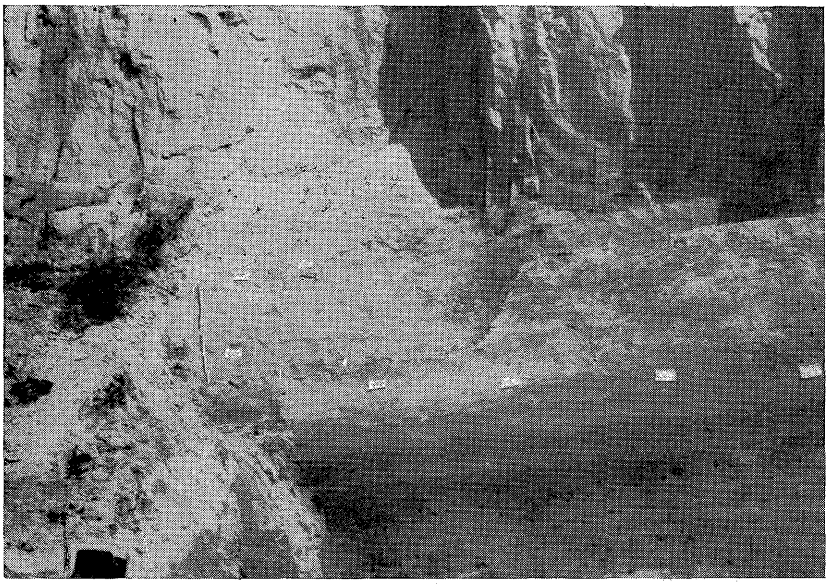


Photo by the author

Pl. 1. Nieledew N – part of exposure. Soil Nietu complex of the lisko I type on the secondary bed

Chernozem intermixed with illuvial horizon of soil lessivée. In the lower part visible meadow chernozem – older part of the Eemian Interglacial



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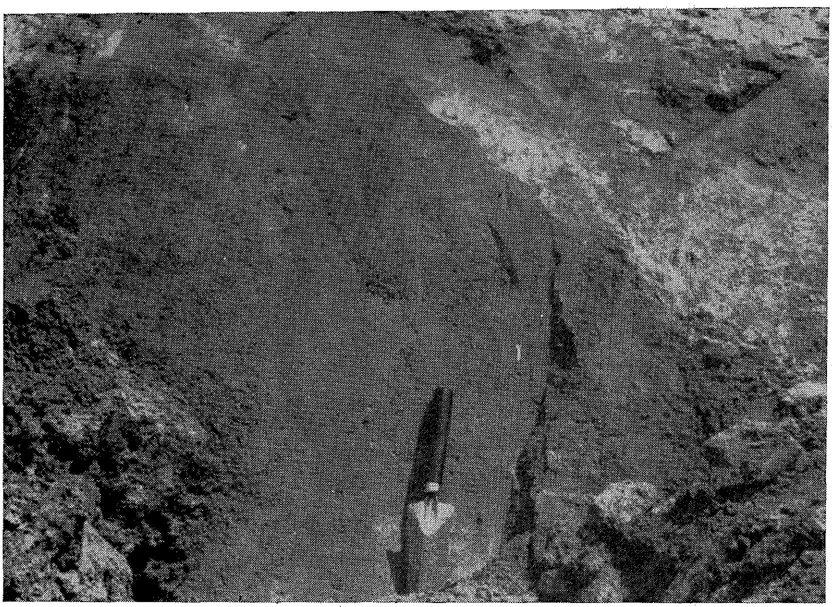
Pl. 2. Błogocice. Soil complex of the Nietulisko I type with chernozem horizons

In the bottom part visible denudational pavement



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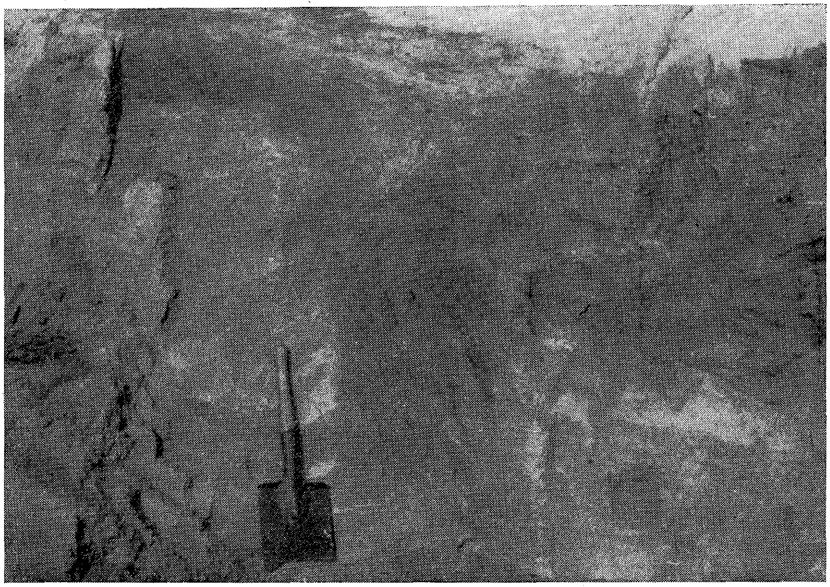
Pl. 3. Żurawica. Wedge-like pseudomorphosis after elementary fissure ice



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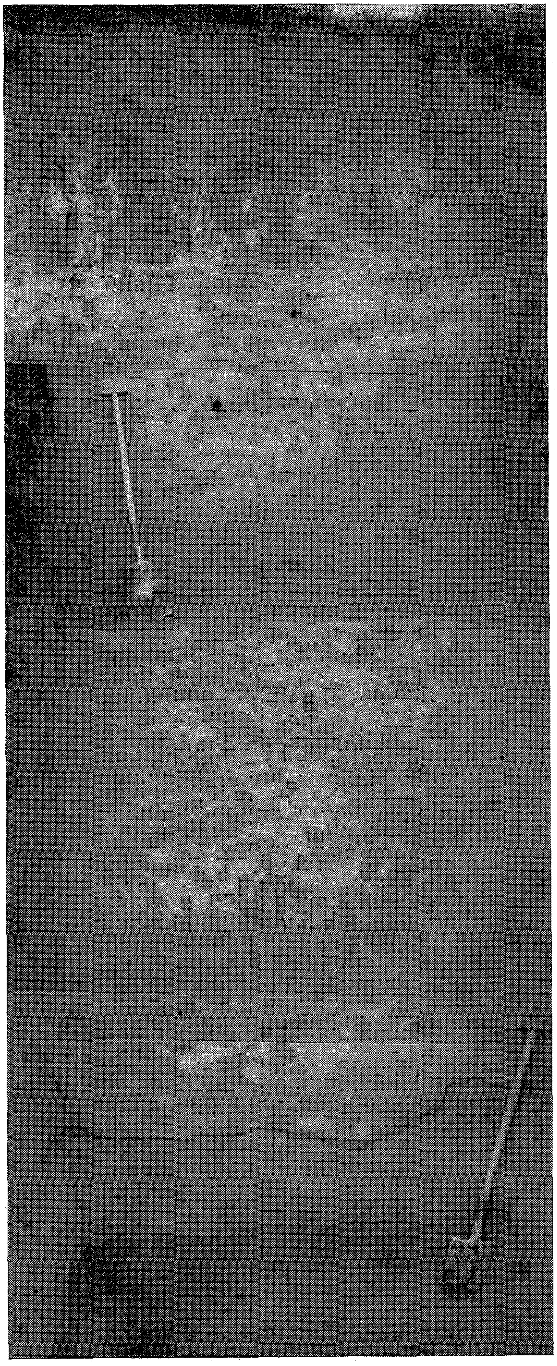
Pl. 4. Nieledew S – part of exposure. Wedge-like pseudomorphosis after elementary fissure ice with vertical stratification

Photo by the author

Pl. 5. Donosy. Wedge-like pseudomorphosis after elementary fissure ice



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Pl. 6. Racibórz — Ocice. Chernozem of the soil complex of the Nietulisko I type (in the lower part of the exposure) diameter. Vertical lamination is characteristic of pseudomorphoses after elementary vein ice in the present-day permafrost Siberian areas (Romanovskij and Boyarskij, 1966; Katasonov, 1971). Goździk (1971) suggests the term *wedges with complex infilling* for the structures of this type. The Soviet authors hold that such phenomena are formed in the active zone of permafrost due to thermal contraction. Every autumn small fissures are filled with water from polygons, the water is instantly frozen and during the spring thawing the fissure ice is replaced by the mineral material derived from the upper part of the active layer. Thus, the elementary vertical layer comes into being. During the years to follow, the process is repeated, cracks are formed in the same places and vertical layers increase in number. Pseudomorphoses after elementary vein ice develop under rigorous continental climatic conditions though they may be also formed within the periferies of permafrost areas.

The formation of frost-fissure structures was associated with a slight eolian activity. Loess, on which chernozem developed, displays in some localities somewhat different character from that in the upper part of soil lessivée (Jersak, 1969a; Klatka, 1970). In some sites, e.g. at Jędrzejów on the Opatów–Sandomierz Upland, at Błogocice on the Miechów Upland and at Racibórz–Ocice in the Racibórz Basin, chernozem has developed on the loess material underlain by other sediments with the pavement in the top part.

Chernozem was probably formed at warmer climatic intervals. At Błogocice (Fig. 2, Pl. 2) there occur three humus horizons separated by thin loess beds. The humus horizons are *in situ*, they do not display any traces of striation and the loess which separates them is dissected by numerous tiny humus streaks occurring in places of former root system of herbaceous plants. The fossil traces of a root system, particularly frequent between the upper and middle accumulational horizons, could not have been preserved at the postgenetic displacement. The two lower accumulational horizons are the best whereas the upper one is poorly developed. The lower horizons are black, 20-30 cm thick and rich in organic matter; the upper 10-cm horizon is grey and contains less organic substance. Very striking is the fact that all these horizons contain large quantity of $CaCO_3$ in the initial form. In other sites, where only one horizon of chernozem is preserved, the carbonates – if present – occur in secondary form and cover the walls of tiny cracks. In many cases chernozem soil overlies immediately the soil lessivée from which calcium carbonate was leached. There are also sites with chernozem developed on the unweathered parent material, but its development was longstanding and the carbonates were also leached. In the Błogocice profile the loess is exceptionally rich in $CaCO_3$ (20%); the chernozem processes

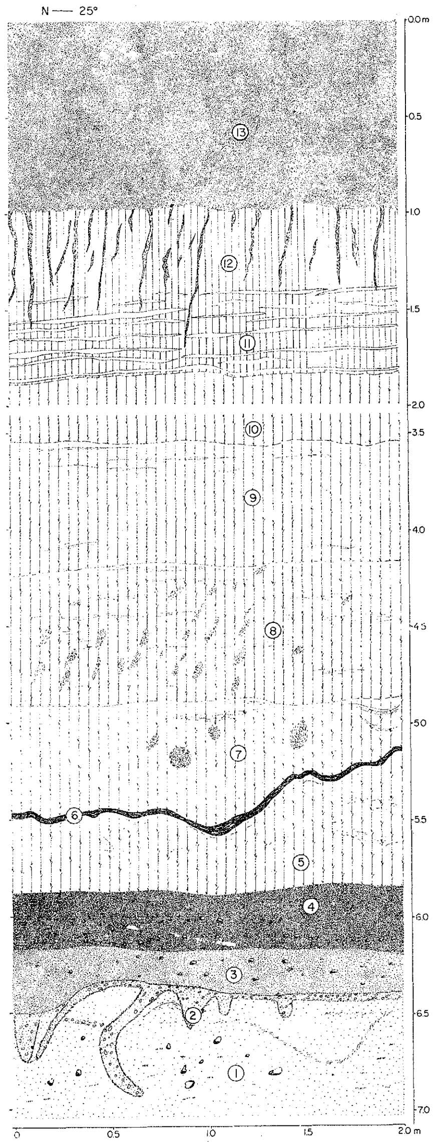

Fig. 3 Section at Racibórz–Ocice

1. terrace sands, with pebbles some cm in diameter, light-grey in colour with rusty spots, compact aggregate structure, horizon of gleying from the bottom G; 2. sand and gravel, brown-rusty in colour, with individual small pebbles; 3. dusty material, grey yellow, with humus and small pebbles 1–2 cm in size; 4. accumulational horizon of the chernozem type, dark-grey, with numerous charcoals, dusty material, underlying pavement is composed of small pebbles; 3–4 chernozem soil – upper part of the soil complex of the Nietulisko I type; 5. yellow loess with grey and rusty spots and with small lenses of fine sands; 6. iron pan, rusty in colour, in the lower part sometimes black, iron-mengenous; 7. yellow loess with individual large ferruginous Liesegang rings; 8. lightgrey loess with rusty and black spots, numerous ferruginous rings and concentrations, strongly gleyed – horizon of the Komorniki type; 9. poorly gleyed loess, yellow with grey-blueish and rusty striae, 10. light, structureless loess, non-gleyed; 11. loess with horizontal yellow and brownish striae – soil horizon B/C; 12. illuvial horizon B brown in colour with vertical grey humus striae, strongly clayey; 13. accumulational horizon A_1 of chernozem, black in colour, of nut-like structure; 11–13. Holocene soil – degraded chernozem

operating in three recurrences every time developed on new material and therefore leaching of $CaCO_3$ could not be entirely accomplished.

On the northern margins of the loess areas of the Lublin and Opatów–Sandomierz Uplands the profile of soil complex of the Nietulisko I type presents more simple structure. Jahn (1956) points to the fact that in the northern parts of the Lublin Upland, i.e. in the Kazimierz–Lublin segment this soil has relatively thin humus horizon, while on the Plateaus of Sokal, Hrubieszów and Zamość it displays much thicker layer of chernozem. In the northern part of the Opatów–Sandomierz Upland the chernozem occurs sporadically (Jersak, 1969a: p. 117, Fig. 2). In this area the most frequent is full profile of soil lessivée and the lack of upper chernozem. Sometimes soil lessivée is slightly gleyed. In the Racibórz Basin out of 7 sites known to the present author, in which the complex of the Nietulisko I soil occurs, only at Racibórz–Ocice chernozem can be found, but it is poorly developed. In other sites only soil lessivée represents this complex: in the brick-kiln at Piotrowice Wielkie, in the profile some 500 m long, this soil does not contain any chernozem horizon. Here, as well as in other sites in this area the soil is strongly gleyed. The illuvial horizon is of marble texture and the higher horizons contain numerous tiny ferruginous concretions which originated as a result of the oxidation–reduction processes. Poorly developed accumulational horizon, grey in colour, containing charcoals, is less than 20 cm thick and does not appear everywhere. At Racibórz–Ocice chernozem (Fig. 3, Pl. 6) overlies a stony pavement derived from the washing off an older soil. In this site the type of the soil beneath chernozem is difficult to define; there is preserved only the horizon strongly gleyed by upward movement; the upper part of this soil was denuded. Probably it was a stagnant gleying due to high ground-water level. The site is situated on the Odra terrace, the top of the fossil soil lying some 15 m above the present-day valley bottom. Chernozem developed on loess underlain by sand and gravel of the Odra terrace, originated here, as well as in other areas, during the older part of the Würm.

DEVELOPMENT OF SOIL PROCESSES AND THE COURSE OF MORPHOGENETIC EVENTS

Pedogenetic processes during the interglacials and in the Holocene were generally similar. During the older part of the Eemian Interglacial as well as in the Holocene the soil developed as chernozem. From that part of the Eemian probably comes the middle fossil soil at Nieledew, near Hrubieszów (Fig. 1). The Holocene chernozem of the present-day inter-valley surfaces is developed on sediments containing warm-loving molluscs that display remarkably different species from those found in the underlying late Würmian sediments. In the concave land-forms the soil is covered with deposits of the Holocene Climatic Optimum and of later period (Jersak, 1965). Unlike the present-day chernozem, the fossil one does not show any traces of degradation. In the first part of the interglacials which fell on the boreal climate, in the loess areas predominated vegetation of steppe or park types. The forests failed to overgrow those relatively arid and warm surfaces though in the areas of other parent rocks and in depressions they must have formed compact covers. This is evidenced by the results of palynological investigations carried out by Szczepanek in the area of the Świętokrzyskie Mts. Szczepanek (1961) states that in the sites situated outside the loess area the share of the sporomorphs of herbaceous vegetation was fairly large in the early Holocene. In Preboreal time there was 48.4% of herbaceous plants, and in Boreal time – 56.8 - 43.2%. The forest communities became preponderant in the Boreal period. Forests overgrew loess areas at the beginning of the Holocene Climatic Optimum or a little earlier. Borowiec (1968, 1969) also accepts such succession of vegetation and soil forming processes. In his opinion the herbaceous plants persisted much longer on loesses than on some other surfaces.

Together with the growth of forests the degradation of chernozem started. In the Holocene it was not accomplished yet; forests overgrew the areas for a too short time owing, to a great extent, to man activity destroying natural vegetation in loess areas.

During interglacials the degradation of chernozem lasted longer and was more intense, especially in the final stage of those warm periods when there were coniferous forests with scarce relics of warm-loving trees. At Biskupie Doły the charcoals from the final stage of the soil formation are mainly of coniferous trees. Intensive leaching processes operating under forest complexes destroyed entirely the chernozem in early phase of the interglacial and gave rise to the forest soil lessivée.

The chernozem of early phase of the interglacial could have been preserved only in concave land-forms which were relatively soon filled with slope deposits and therefore unaffected by denudation. Such a course of events took place at Nieledew where the middle soil of the chernozem type had been overlain by slope deposits before its development was accomplished. The analogous profile of fossil soil is also at Litomeríce on the Elbe; according to Ložek and Kukla (1959) chernozem comes here from the older part of the Eemian Interglacial and soil lessivée (*Parabraunerde*) – from its younger part.

Most authors concerned with the European loesses hold that chernozem which developed in the top of soil lessivée belongs to the last cold period. The representatives of another opinion are Veličko (1965), Veličko and Morozova (1969) who consider that it originated in the final phase of the Eemian Interglacial. According to these authors the interglacial can be divided into the older and younger climatic phases. The older, longer, phase was characterized by the distinctly oceanic climate in the whole area of Central and Eastern Europe whereas the younger, shorter phase had continental climate. In the oceanic climate the soil lessivée developed under the complexes of forest vegetation, but during the phase of continental climate in the European loess areas there were steppe communities under which chernozem was formed.

In the light of the present author's studies the latter opinion is hardly probable. The formation of soil lessivée having been accomplished the soil forming processes extincted. Due to the deterioration of climate the activity of slope processes increased and the interglacial soil became gradually destroyed. In a number of sites chernozem occurs on the erosional surface. Soil lessivée is partly or entirely truncated (Jersak, 1969a), as for instance at Jędrzejów, Kruków, Błogocice (Fig. 2, Pl. 2), Racibórz—Ocice (Fig. 3, Pl. 6). At Mychów, chernozem overlies slope deposits which originated during the interphase between the formation of soil lessivée and chernozem (Klatka, 1970). This initial phase of the Würm was most probably cold and humid. Later the climate became more continental and favourable for the formation of pseudomorphoses after elementary vein ice which are very frequent in this stratigraphical position (Żurawica, Nieledew, Lenarczyce, Grocholice, Pls. 3, 4, 5). Some of these sites have been described (Dylik and Dylikowa, 1960; Klatka, 1970; Kopczyńska and Straszewska, 1961). During that period of a more continental climate the eolian processes of small intensity were operating and the younger loess I was formed (Błogocice, Jędrzejów, Racibórz—Ocice). Probably the formation of permafrost started at that time. The oldest interstadials interrupted the rigorous regime of the last cold period. The amelioration of climate gave rise to the formation of chernozem. The oldest interstadials, the Amersfoort and the Brörup, or probably only the Brörup, were twice broken by colder periods; in consequence three horizons of chernozem were formed (Fig. 2, Pl. 2).

According to paleobotanical investigations the forests dominated during the oldest interstadials of the last cold period – Brörup and Amersfoort (Borówko-Dłużakowa, 1967; Dylik, 1968; Jańczyk-Kopikowa, 1969; Sobolewska, Starkel, Środoń, 1964). The Brörup interstadial was of remarkably high rank. Środoń (1964) holds that it had the mean annual temperature some 2–3°C lower than at present. The paleobotanical analyses have revealed that during the Climatical Optimum of this period the pine and spruce forests grew in Poland. However, there are no traces of those forest complexes in the loess profiles. It seems that the Brörup interstadial was in its character very similar to the initial stage of interglacials. Forests grew mainly on moist grounds. On the loess uplands of Middle and Eastern Poland the steppe vegetation developed during the whole period discussed, only the northern margins of the country and the Racibórz Basin were the areas where the forest occurred. In the Racibórz Basin the steppe plants could subsist only in patches. On the Opatów—Sandomierz Upland, and especially on the Lublin Upland, where the continental character of the climate has always been more distinct, forests invaded the northern border of the loess areas.

In the loess areas remaining under the influence of humid climate, chernozem does not usually occur in the top of soil lessivée either in Poland or in other countries (Brunnacker, 1956; Haase, Lieberoth, Ruske, 1969; Fink, 1966; Ložek, 1966).

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