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OUTLINE OF LOESS STRATIGRAPHY IN POLAND

Abstract

In Poland, loesses were laid down at the time of the South Polish, Middle Polish and North Polish Glaciations. The stratigraphy of the loesses that belong to the North Polish Glaciation is known more in detail. In these loesses three horizons have been distinguished. The lower horizon corresponds to the Szczecin Stage of the North Polish Glaciation, both middle and upper ones — to the Main Stage of this glaciation. The loesses of the North Polish Glaciation are separated by two fossil soils, the lower of which belongs to the Brørup Interstadial, the upper one — to the Paudorf Interphase of the Main Stage.

INTRODUCTION

In Poland loesses occur at the surface, mainly in the areas of Middle Polish Uplands, in the Carpathians and in the Sudetic foreland, together with loess loams. According to L. Sawicki (1957), the areas covered with the loesses amount to about 30 600 km², i.e. ca. 10% of the whole territory of the country. In addition, loesses are found also in the foreland of uplands, locally under a considerably thick cover of younger deposits. In such cases, however, they can be investigated by means of drilling works only.

In the areas of their occurrence, the loesses are of considerable importance to the Quaternary stratigraphy, mainly to the Younger Quaternary, constituting the most widespread deposits relatively easy for subdivision. The factors mentioned above and a considerable economical importance of this formation are responsible for a fact that loesses have for a long time been an object of study in Poland.

Researches on loess stratigraphy developed in Poland parallelly to the researches on the Quaternary stratigraphy. Numerous observations presented in the papers published in the twenties and thirthies of this century prove that in the upland areas, locally also in the north of the country, loesses can occur at several horizons (J. Samsonowicz, 1924; J. Czarnocki, 1931; B. Halicki, L. Sawicki, 1934; M. Książkiewicz, 1935). Conclusions as to the stratigraphy were based mainly on the

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analysis of lithological profiles. Fauna remains, particularly those of molluscs, occurring in stratified loesses in abundance, did not yield sufficient data for loess subdivision. Only the well developing archaeological studies, together with the results of the investigations on stratigraphical position of the intraloessial fossil soils, and on geomorphological situation of the profile in study allowed, for the first time, to synthetize the stratigraphy of loesses in Poland. This was commenced in an article written by L. Sawicki „Sur la stratigraphie du loess en Pologne" published in 1932. In that paper, based on the research works made in the areas of the Volhynia and Little-Poland Upland, L. Sawicki gave certain evidences proving the occurrence of three loess horizons intercalated by humus fossil soils. The three loess horizons were referred by him to the Riss Glaciation and to two stages of the Würm Glaciation, being at that time of different significance.

The study on loess stratigraphy in Poland developed intensely, particularly in the last decade. At first, certain opinions (A. Malicki, 1949) stressed that the loesses of the Middle Polish Uplands had originated at the time of the Middle Polish Glaciation (Riss), and the loesses and loess-like loams of the Carpathians and their foreland — during the South Polish Glaciation (Mindel). These opinions were mainly based on a general convergence of the northern boundary of these loess areas in Poland, with that of the continental glacier of both glaciations (Fig. 1).

The research works made by A. Jahn (1950, 1952, 1956a, 1956b), K. Pożaryska (1948) and W. Pożaryski (1953, 1956) within the Lublin Upland area and in the Kamienna river valley in the northern foreland of the Święty Krzyż Mts., as well as in the Middle Vistula river valley, yielded new geological evidences that speak for the existence of a connection of the youngest and commonest loess horizon with the North Polish Glaciation. Similar results were obtained during the research works made in the Carpathians and within their foreland, as well as in the foreland of the Sudetes (M. Klimaszewski, 1948; J. Łyczewska, 1948; A. Jahn, 1960b). At the same time L. Sawicki (1952, 1957) and others, conducting the study on loess stratigraphy in connection with the Palaeolithic and Pleistocene flora stratigraphy, came to somewhat different conclusions. The state of the then studies on loess in Poland was presented in two articles by J. Dylik (1954) and J. E. Mojski (1955).

Irrespective of the studies on the stratigraphy of the loesses occurring on the surface within the area of uplands, researches were made to explain stratigraphical position of the loesses occurring in the Quaternary section (mainly of the Middle Polish Glaciation) within the foreland of uplands, under the cover of glacial, or fluvioglacial deposits. Such loesses, for a long

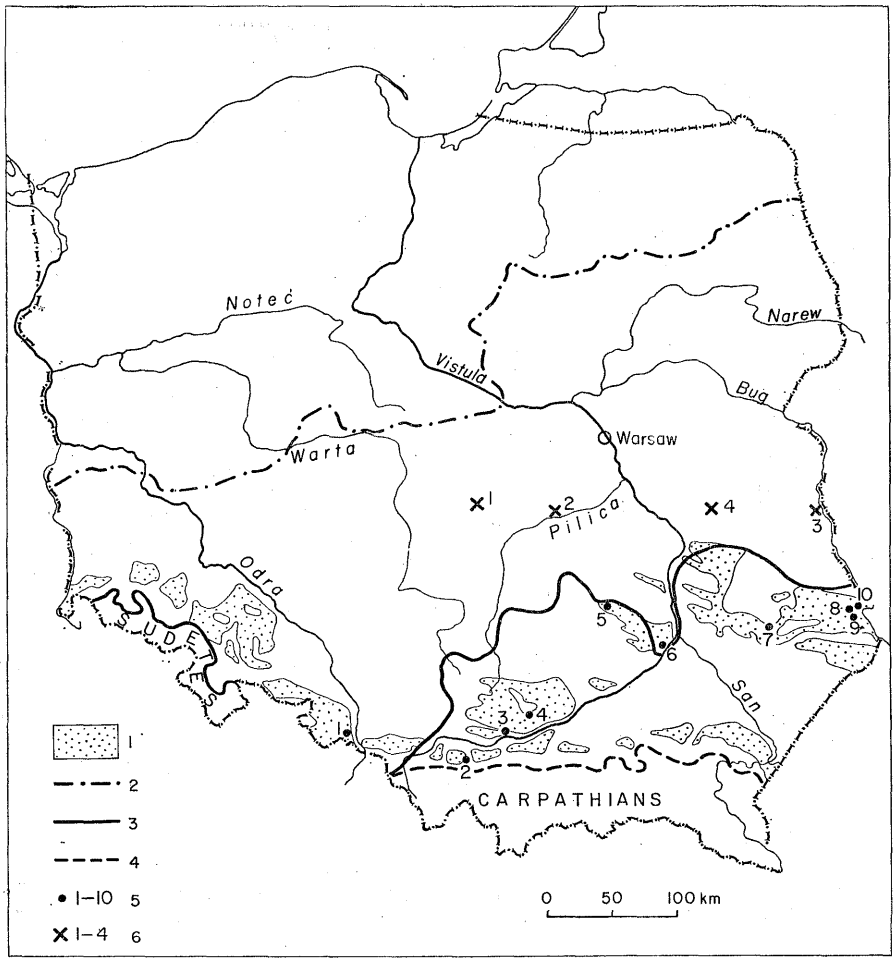

Fig. 1. Map of loess occurrence in Poland

1. loess; 2. boundary of continental glacier of the North Polish Glaciation; 3. boundary of continental glacier of the Middle Polish Glaciation; 4. boundary of continental glacier of the South Polish Glaciation; 5. some more important profiles of the loess not covered with glacial deposits: (1) Racibórz — Ocice, (2) Wadowice, (3) Zwierzyniec, (4) Topola, (5) Biskupie Doły and Komorniki, (6) Gołębice, (7) Sąsiadka, (8) Nieledew, (9) Michałówka, (10) Hrubieszów; 6. some more important profiles of the loess covered with glacial deposits: (1) Łódź, (2) Niemojewice, (3) Suszno, (4) Ferdynandów

time known from the Święty Krzyż Mts. (J. Samsonowicz, 1924; J. Czarnocki, 1931), were ascertained also in the Pilica (W. Karaszewski, 1952), Uniejówka (H. Ruszczyńska, 1961a), Kamienna (K. Pożaryska, 1948) and Bug (J. E. Mojski, J. Trembaczowski, 1961) river basins, as well as in the vicinities of Łódź (F. Różycki, 1961), and in other localities.

Recently, a series of papers were published, in which conclusions concerning loesses were based not only on a detailed field documentation, but also on exhaustive laboratory examinations. This, to certain degree, was also stimulated by the VIth INQUA Congress held in 1961 in Poland, and by the Loess Symposium of this Congress, held at the same time in Lublin, where mainly stratigraphical problems were discussed. It should be emphasized here that simultaneously a Sub-Commission for Loess Stratigraphy of the INQUA Congress was also called into existence.

As a result of the last researches, the opinions on loess age became more precise. The fossil soils occurring in loesses are thought to be main stratigraphical criterion here. The purpose of these researches was also to investigate these soils typologically. Certain index features of each soil horizon have been defined. Relation of the individual loess horizons to the Pleistocene deposits, whose age can be defined by other methods, is an important factors facilitating stratigraphical correlation (L. Baraniecki, 1965; B. Grabowska-Olszewska, 1963; J. Jersak, 1965; A. Malicki, 1961; J. Malinowski, 1964, 1965; J. E. Mojski, 1965a, b, 1967; H. Maruszczak, 1956). In a close connection with the stratigraphical loess profile, the evolution of the Upper Palaeolithic cultures of the whole Central Europe was presented by J. K. Kozłowski (1965).

The present article shows an outline of loess stratigraphy in Poland, according to the Quaternary subdivision by J. E. Mojski and E. Rühle (1965), with some supplements introduced into the subdivision of the North Polish Glaciation (J. E. Mojski, 1968). In this subdivision, the Quaternary is divided into Eo-Pleistocene (from the beginning of the Pleistocene to the Günz Glaciation), Meso-Pleistocene (from the Cromer Interglacial to the Masovian Interglacial, Mindel—Riss), and Neo-Pleistocene (from the Middle-Polish Glaciation, or Riss Glaciation, to the close of the Pleistocene). The North Polish Glaciation (Würm) has been subdivided into two stages, i.e. Szczecin Stage and Main Stage separated by the Brørup Interstadial.

The present author is of the opinion that the acceptance of the aeolian origin of loess is right (A. Jahn, 1950). Loess was laid down at the Pleistocene time under conditions of arctic climate in the form of three syngenetical types of sediment, i. e. as subaerial (upland) loess, solifluction (slope) loess, and alluvial (valley) loess. Each of these types bears its own structural and textural features, and is characterized by various occurrence conditions, as compared with the forms of relief (J. E. Mojski, 1965a). Such a subdivision was applied also in other papers dealing with loess stratigraphy (J. Jersak, 1965; J. Malinowski, 1964).

The formation of loess-like loams in the areas of the Carpathians and

Sudetes was synchronous with that of the loesses. They were formed as a result of slope processes acting under periglacial conditions during the successive glaciations, mainly during the North Polish Glaciation.

EO-PLEISTOCENE AND MESO-PLEISTOCENE LOESSES

So far, no sufficiently evidenced Eo-Pleistocene loess profiles were known to occur in Poland. The so-called „Old-Pleistocene silts" described for the first time by A. Jahn (1952) from the Lublin Upland, and referred by him to the oldest (Günz) Glaciation (A. Jahn, 1956a, 1960), represent, as proved by the recent investigations, the deposits of various age, and may be connected with the loess forming processes in part only.

The Meso-Pleistocene loesses, in turn, occur in several sites. South of the Święty Krzyż Mts., there are found thick silt mantles characterized by certain features of solifluction loess, covered with glacial deposits of the South Polish Glaciation (J. Czarnocki, 1931). In a similar stratigraphical situation are the loess silts occurring in the Kierdonka river valley, north of Raków, near Kielce. Here, as described by E. Rühle (1952), are found white-grey, slightly stratified silts, over 1 m in thickness, covered with boulder clay. Since this clay can belong to the South Polish Glaciation only, the loess silts might have been formed at latest at the of beginning of that glaciation. Similar deposits occur probably in the area of the Upper Pilica river (H. Ruszczyńska, 1961a), appearing as alluvial loess, up to 2 m in thickness. It has been ascertained that they are in a close connection with the glacial deposits of the South Polish Glaciation.

In the Quaternary section at Ferdynandów, approximately 100 km south-east of Warsaw (Fig. 1), the Meso-Pleistocene loesses have been pierced by three bore holes at a depth from 67 m to 100 m. The deposit under discussion was from 3.75 m to 11.5 m in thickness. It is overlain with fluvioglacial and glacial deposits of the South Polish Glaciation, which, in turn, are covered with the deposits belonging, as proved by pollen analysis made by Z. Janczyk-Kopikowa (1963), to the Masovian Interglacial (Mindel—Riss), and with those of the Middle Polish (Riss) Glaciation (Fig. 2). The loess from Ferdynandów contains a 0.01—0.05 mm fraction from 45.8% to 80.1% (98 samples examined). $CaCO^3$ contents range from 2.6% to 11.5%, mean contents for each bore hole being 4.3%, 4.4% and 7.0%, respectively.

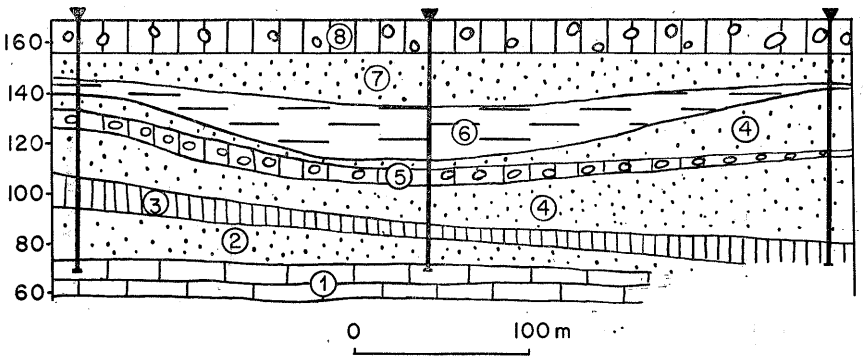

Fig. 2. Loess section at Ferdynandów

1. Cretaceous and Palaeocene formations; 2. fluvial and fluvioglacial sands of the South Polish Glaciation; 3. loess; 4. fluvioglacial sands of the South Polish Glaciation; 5. boulder clay of the South Polish Glaciation; 6. lacustrine deposits of the Masovian Interglacial; 7. fluvioglacial sands of the Middle Polish Glaciation, 8. boulder clay of the Middle Polish Glaciation

NEO-PLEISTOCENE LOESSES

The Neo-Pleistocene loesses belong to the Middle Polish and North Polish Glaciations.

MIDDLE POLISH GLACIATION

The loesses of the Middle Polish Glaciation are known to occur in the areas, where glacial deposits of this age are found to cover them almost completely. Loesses of this kind are reported from the foreland areas of the Middle Polish Uplands, where they are commonly called „submoraine loesses". Moreover, the loesses of the Middle Polish Glaciation are found in the upland areas, south of the extent of the glacial deposits of that age, where they are covered with the soil of the Eemian Interglacial and with the loesses, younger than this soil.

The loesses covered with the glacial deposits are known mainly from exposures along the Pilica river valley (Fig. 3). The first evidences were presented by W. Karaszewski (1952), who described the profiles occurring in the vicinities of Warka, where stratified alluvial loesses, at places also subaerial loesses, over 2 m in thickness, occurred under the boulder clay, locally also under the varved clays. The loesses contain molluscan fauna with such representatives as *Succinea oblonga*, *Pupilla muscorum* and *Vallonia tenuilabris*. Content of the loess fraction grains, i.e. of those from 0.02 mm to 0.05 mm, amounts to 47—55%. Other information on

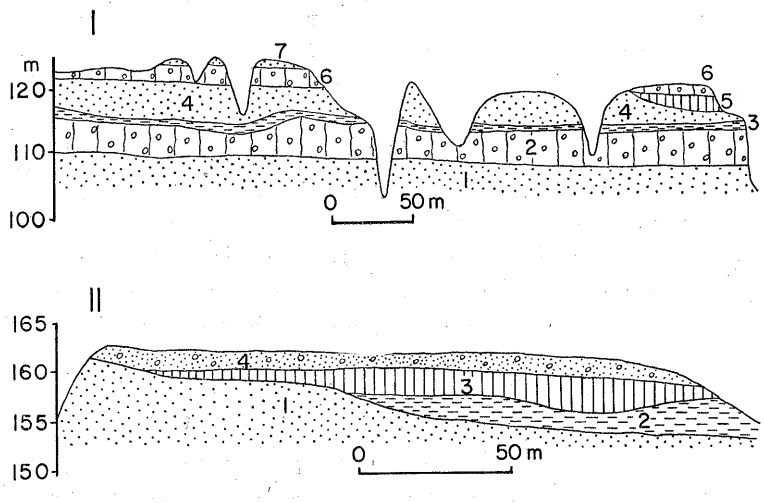

Fig. 3. Loess profiles at Niemojewice on Pilica, and at Suszno on Bug, near Włodawa

I. Niemojewice (geological cross section according to S. Z. Różycki, 1961): 1. fluvioglacial sands, 2. boulder clay of the Maximum Stage of the Middle Polish Glaciation, 3. ice-marginal lake clays, 4. fluvioglacial sands, 5. loess, 6. boulder clay of the Masovian-Podlasie Stage of the Middle Polish Glaciation, 7. sands

II. Suszno (according to J. E. Mojski, J. Trembaczowski, 1961): 1. fluvioglacial sands and gravels of the South Polish Glaciation, 2. lacustrine deposits of the Masovian Interglacial, 3. loess, 4. sands with boulders — residua of glacial deposits of the Middle Polish Glaciation

the loesses from the vicinities of Warka can be found in the guide-books to the excursions of the VIth INQUA Congress.

There is not much doubt about the Middle Polish age of these loesses, but a more detailed dating seems here to be highly disputable. The loesses, together with the overlying deposits, have been referred by W. Karaszewski to the Maximum Stage of the Middle Polish Glaciation, whereas S. Z. Różycki (1961) tends to connect them with the younger, Masovian-Podlasie Stage. The latter opinion seems to be more substantiated, particularly in the light of the recent results of the researches made by A. Makowska in the Geological Institute, and of the research works conducted by M. Rosłaniec-Chodnikiewicz (1966). This author informs that e.g. in the vicinities of Stara Warka, the loess is developed in an alluvial facies, has 89% of grains below 0.06 mm in size, is strongly calcareous, contains concretions of calcium carbonate at the top part, and is 2 m in thickness. Moreover, it rests between two horizons of glacial deposits, the lower of which belongs to the Maximum Stage, the upper one — to the Masovian-Podlasie Stage of the Middle Polish Glaciation.

Alluvial loess occurring in a similar situation has been found at numerous exposures along the northern marginal area of the Pilica river valley, between Warka and Nowe Miasto. At Pacew, near Białobrzegi,

this formation discloses a fine stratification, is calcareous and contains few clayey and sand intercalations (H. Ruszczyńska-Szenajch, 1966). The loess appearing at Góra, near Nowe Miasto on Pilica, represents an analogous deposit. It consists of subaerial loess divided by solifluction loess and loess-like silts, with an admixture of sand. Content of 0.05—0.002 mm fraction in the solifluction loess amounts to 50%, that in the subaerial loess — 87% (H. Ruszczyńska, 1961b).

On the Uniejówka river, in the upper part of the Pilica river basin (H. Ruszczyńska, 1961a) there occurs a horizon of both subaerial and alluvial loesses, several metres in thickness. The loesses show a close connection with the river terrace that corresponds to the Middle Polish Glaciation, whose boundary runs not far away in the north.

In the neighbourhood of the loesses occurring in the Pilica river valley there are found other loesses in the vicinities of Łódź (F. Różycki, 1961). It seems that the loesses, several metres in thickness, pierced by bore holes, usually rest under the boulder clay of the Masovian-Podlasie Stage of the Middle Polish Glaciation. As a rule, the content of 0.05—0.002 mm particles is over 50%, and that of $CaCO_3$ exceeds 5%. Although the grain-size, mineralogic and chemical compositions and the porosity are frequently approximate to the values characteristic of loesses, a decision of F. Różycki to refer certain deposits to these loesses must be called in question. Profiles that are without any reservations point to the analogous position occupied by the loesses from both the Łódź and the Lower Pilica river areas in stratigraphical profile.

Within the Kamienna river basin, to the Middle Polish Glaciation can belong the loess in certain sites only described by K. Pożaryska (1948). Here belongs the profile from Wólka Pętkowska. In some sites the loess is covered not only with the glacial deposits *in situ*, but also with the periglacial talus formations originating from the destroyed glacial deposits. Profiles of this kind are frequently found in the upland areas, where they occur at the marginal region of the loess that belongs to the North Polish Glaciation, thus being often a cause of wrong stratigraphical interpretation of the profiles of Pleistocene deposits (e.g. profile at Góra Puławska).

Loess covered with the glacial deposits belonging to the Middle Polish Glaciation occurs in the Bug river valley, as well (Fig. 3). In the vicinities of Włodawa (J. E. Mojski, J. Trembaczowski, 1961) the loess appears in an alluvial facies, within the lake deposits, several metres in thickness. According to pollen analysis, these latter correspond to the decline period of the Masovian Interglacial. In the grain-size composition there prevails fraction from 0.01 to 0.05 mm.

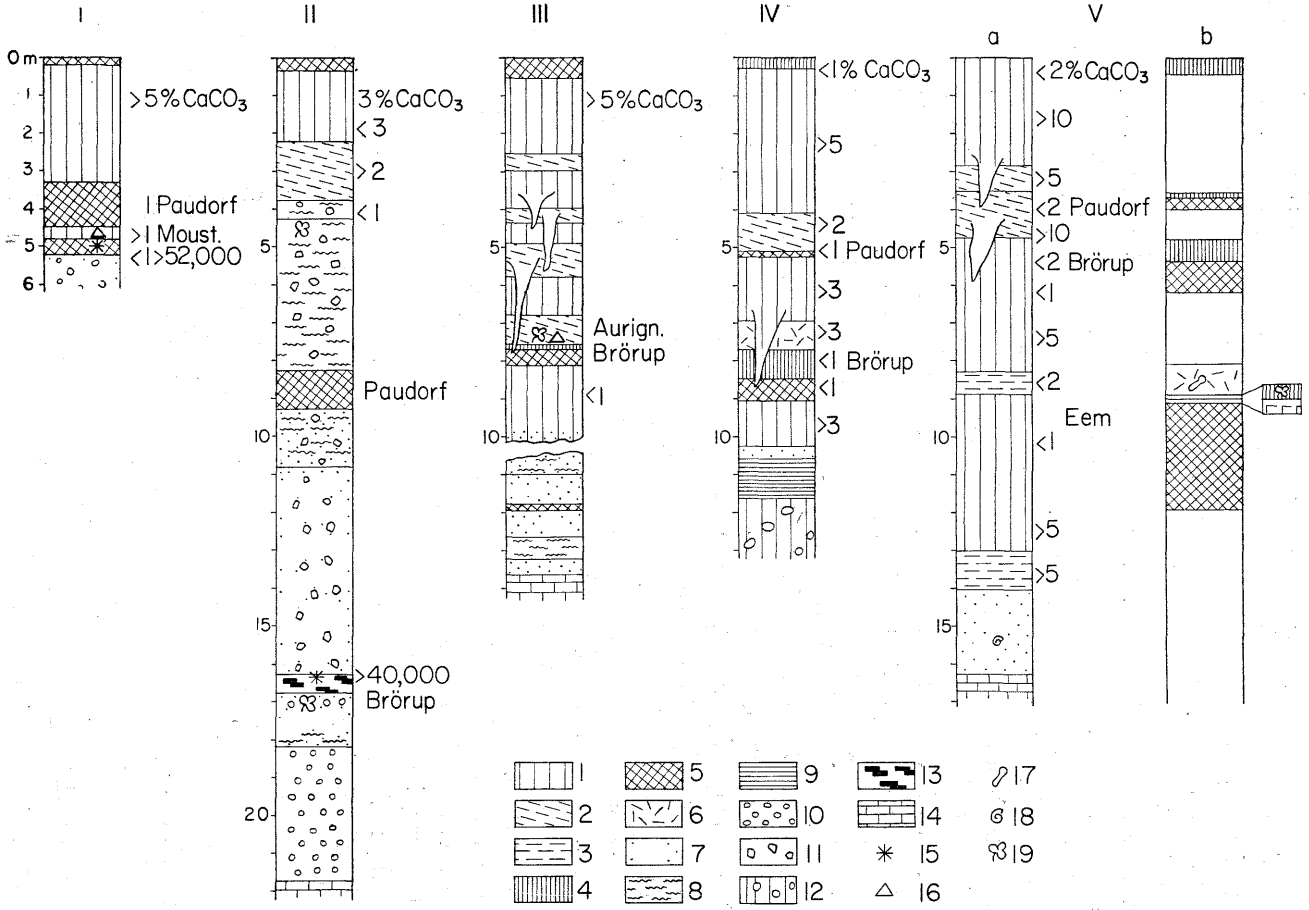

Fig. 4. Certain more important loess profiles in Poland

I. Racibórz—Ocice (according to Czeppe, Kozłowski, Krysowska, 1963); II. Wadowice (Sobolewska, Starkel, Środoń, 1964); III. Zwierzyniec (Sawicki, 1952); IV. Gołębice (Grabowska-Olszewska, 1963). V. Nieledew: a — lithological profile, b — soil profile (Mojski, 1965a)
1 — subaerial loess; 2. solifluction loess; 3. alluvial loess; 4. soil accumulation (humus) horizon (in the Nieledew profile in lowermost soil also eluvial horizon); 5. soil illuvial horizon; 6. gleyed loess; 7. sands; 8. silts; 9. clays; 10. gravels; 11. rock debris; 12. boulder clay; 13. peats; 14. pre-Quaternary marls and limestones; 15. dates of C^{14}; 16. Palaeolithic sites; 17. mammalian fossil bones; 18. molluscs; 19. flora

The profiles mentioned above prove that loesses also constitute the deposits of the Middle Polish Glaciation in the areas, where the glacial deposits of this age occur. However, most loesses of this glaciation stretch in an area south of its extent, i.e. in the areas of the Lublin, Opatów and Miechów Uplands.

Within the Lublin Upland area the loess of the Middle Polish Glaciation is known to occur in the Hrubieszów vicinity and in the Roztocze region (Figs. 1 and 4). In the vicinity of Hrubieszów, in the profile of Nieledew and in other profiles, the loess is developed in both alluvial and subaerial facies that coincide with the lower part of the thick loess cover (J. E. Mojski, 1965a). Here, it rests on the palaeontologically dated fluvial sands of the Masovian Interglacial, and is covered with the soil of the Eemian Interglacial. The thickness of this loess amounts to 7 m.

In the Roztocze region, the loess of the Middle Polish Glaciation is found in depressions (J. Malinowski, 1964), where it forms mainly alluvial deposits, 1.1—14.2 m in thickness, disclosing certain traces of subaerial loess at the top. The upper portion of the loess is strongly weathered. The content of grains 0.01—0.05 mm in size does not exceed 50%, whereas, in relation to the younger loesses, the fraction smaller than 0.01 mm increases.

In the Opatów Upland, the loess of the age under discussion, is represented by an alluvial loess that rests on the fluvioglacial deposits of the Maximum Stage. The thickness of this loess reaches up to 4 m (Złota near Sandomierz, B. Grabowska-Olszewska, 1963).

In the Miechów Upland, the loess of the Middle Polish Glaciation can occur as a solifluction loess containing sand admixture and talus debris. However, its stratigraphical position has not so far been sufficiently cleared up, mainly due to a lack of connections with the Pleistocene deposits of other facies, mostly with glacial deposits.

EEMIAN INTERGLACIAL

The soil of the Eemian Interglacial may be thought to represent key horizon of the loess profiles in the Middle Polish Uplands. The soil has been reported to occur at numerous places in the area of the Lublin, Opatów and Miechów Uplands, as well as in the Roztocze region. Complete and best developed soil profiles are found in the Lublin Upland and in the Roztocze. In the eastern part of the Lublin Upland the soil bears some features of bleached and gleyey soil. It is characterized by a 3.2 m deep illuvial horizon, and by an accumulation horizon 0.3 m in thickness. In the alluvial horizon there are found single pollen grains of *Betula* and

Carpinus. Loess structure in the soil is obliterated, and calcium carbonate completely leached out. In the upper part of the illuvial horizon siliceous-ferruginous concretions occur at certain exposures. Both accumulation and eluvial horizons are cryogenically disturbed and form an involution zone up to 0.5 m in thickness.

In the western area of the Roztocze region the soil of the Eemian Interglacial is over 4 m thick (J. Malinowski, 1964), and the soil profile consists of illuvial and eluvial horizons. The soil itself is completely decalcified, contains rich ferruginous concretions and is brown or bronze in colour. Such a colour is typical of the remaining sites of the Eemian Interglacial soil.

In the loess areas of both the Opatów and the Miechów Uplands, the presence of the soil belonging to the Eemian Interglacial is dubious. Maybe, the Eemian age can be referred to the marshy soil that occurs in the profile at Topola and is characterized by a gley formation process. The soil rests on the gravels and alluvial loess (?), and is covered with solifluction loess of the North Polish Glaciation (Z. Klajnert, 1961). Age of the oak remains found in the soil, determined by means of C^{14} method, amounts to over 37,000 years (oral information by J. Dylik during the VIth INQUA Congress, 1961). Additional evidences that could help in a more detailed age definition of the fossil soil from Topola are lacking, however.

The absence of the Eemian Interglacial soil in the western part of the Middle Polish Uplands can be substantiated by its destruction during successive denudation processes. Due to a higher humidity of climate these processes must have developed on a larger scale than in the eastern, more continental part of the uplands.

NORTH POLISH GLACIATION

Szczecin Stage

The loess of the Szczecin Stage is known to occur in the area of the Lublin, Opatów and Miechów Uplands, and in the Roztocze region.

The profiles from the eastern part of the Lublin Upland (J. E. Mojski, 1965a) yield numerous data allowing to determine the position of the loess of the Szczecin Stage in stratigraphical profile, and to obtain some evidences concerning its lithological character and extent, in relation to the relief. The loess of the Szczecin Stage rests here on the fossil soil of the Eemian Interglacial, and is covered with a soil of Brørup Interstadial. Such a position is characteristic of this loess at Nieledew, Michałówka and Trzeszczany, where it is represented by alluvial and subaerial loesses;

the alluvial loess constitutes here the lower part, and the subaerial one mainly the upper part of the profile. As a rule, the alluvial loess is fine-bedded, its grain size changing markedly. The grain-size composition is characterized by the predominance of 0.1—0.05 mm fraction amounting to 45—84%. Apart from the weathered portions of the profile, the percentage of calcium carbonate is from 2.8 to 20.2. Quartz is the main mineral constituent. In the lower part of the profiles the quantity of the fine-grained and medium-grained sand laminae increases. In the alluvial loess, mainly in its upper portion, are found common, short and narrow fissures, probably frost cracks, as well as certain structures determinaed as involutions, that have an amplitude of disturbances up to 20 cm.

Subaerial loess is characterized by a random texture, at the lower part locally banded. It is built up of quartz grains that predominate in a 0.01—0.05 mm fraction, from 45% to 64%. The percentage of calcium carbonate is from 2.8 to 20.2. In the profile from Nieledew, a strong gley formation process can distinctly be traced mainly at the lower part of the subaerial loess. However, this occurs only at places, in a low position of the fossil soil of the Eemian Interglacial. In the eastern part of the Lublin Upland the thickness of the loess belonging to the Szczecin Stage averages approximately 3 m.

The loess of the Szczecin Stage, that occurs within the area of the Roztocze region, is developed mainly in the form of subaerial loess underlain, in the neighbourhood of valleys, by alluvial one (J. Malinowski, 1964). Grain-size composition shows the predominance of 0.01—0.05 mm fraction that ranges from 44.3% to 77.0%. An absolute predominance of this fraction can be observed in the alluvial loess. Here, the content of calcium carbonate amounts to 0.6—10.1%. Lower values are characteristic of the solifluction loess which, however, is rarely found here. In the western area of the Roztocze region, the loess of the Szczecin Stage is several metres thick, at least, the maximum values being observed at the lower parts of slopes.

In the Wieprz river valley, between Łęczna and the Bystrzyca river mouth, the Szczecin Stage may embrace, according to A. Jahn (1956a, b), the so-called Spiczyn silts that consist of alluvial loess, mainly fine-stratified and calcareous. They contain molluscan fauna with *Gyraulus*, *Sphaerium corneum* and *Pisidium* sp.

In the Vistula river valley, between Zawichost and Puławy, the deposits of the Szczecin Stage are built up of slope loess, thus of solifluction loess (W. Pożaryski, 1953). The profile consists here of strongly weathered loess, 5 m in thickness, known from Podgórze, Kwaskowa Góra and Parchatka.

In the Opatów Upland, to the Szczecin Stage corresponds the lower bottom loess (B. Grabowska-Olszewska, 1963). At the lower part of the profile this consists of both alluvial and solifluction loesses. The latter one contains a sand and gravel admixture in the form of thin layers derived from the underlying fluvioglacial sands. At the upper part of the profile there occurs subaerial loess revealing a random structure. At Chobrzany (K. Straszewska, E. Mycielska, 1961) the alluvial loess consists of loess silts of varved type stratification, underlain by fine-grained sands with few laminae of clayey loess. In the vicinities of Kunów, in the north-western part of the Opatów Upland (J. Jersak, 1965) light-grey, sandy loess occurs having iron hydroxide concretions (section at Biskupie Doły). The percentage of 0.01—0.05 mm grains amounts in the deposit to 59.3. In the Opatów Upland the loess of the Szczecin Stage is up to 4 m in thickness.

Both the loess of solifluction type with humus streaks from Klemencice and the solifluction loess containing weathered debris and humus layers from Parkoszowice situated within the Miechów Upland area, may tentatively be regarded as those belonging to the Szczecin Stage. In the profile known from Zwierzyniec, Cracow area (L. Sawicki, 1952), the loess called by L. Sawicki „the lower loess" corresponds to the deposits described above. This is a subaerial loess with sand admixture at the lower part, revealing a calcium carbonate content of 1.35% on an average (M. Kolasa, 1963), and a thickness amounting to 2.5 m. At the top part of this loess, young Aurignacian flint implements, probably redeposited, have been found by L. Sawicki.

So far, both vertebrate and molluscan faunas appearing in the loess of the Szczecin Stage have been examined unsufficiently, thus the fauna representatives cannot be of index significance.

Brørup Interstadial

The Brørup Interstadial occurs in loess profiles in the form of fossil soil. The completely developed soil is known to exist in the Lublin Upland area, particularly in its eastern part (J. E. Mojski, 1965a), and in the western area of the Roztocze region (J. Malinowski, 1964). The soil occurs also in the loesses of the Opatów Upland (J. Jersak, 1965), the Miechów Upland, the Cracow area, at Zwierzyniec (L. Sawicki, 1952), as well as at many other places, also in the vicinities of Racibórz (Z. Czeppe, J. K. Kozłowski, M. Krysowska, 1963).

A complete soil profile occurring in the Lublin Upland and in the Roztocze region consists of an accumulation and an illuvial horizon, which

are separated at places by an eluvial one. The accumulation horizon, up to 0.8 m in thickness, is represented by a non-calcareous, humus loess, dark-grey and violet-grey in colour. The illuvial horizon, up to 1.5 m in thickness, consists of a non-calcareous brown and bronze loess that disclose a crumb and polyhedral structure. The eluvial horizon appears as a light-grey lamina of quartz grains 0.1 mm in thickness. The whole thickness of the soil is approximately 2.5 m. Towards the west the thickness gradually decreases (Fig. 4), as it can be observed in the vicinities of Kunów, in the north-western part of the Opatów Upland. The soil of the Brørup Interstadial has been defined as that of „Nietulisko type" (J. Jersak, 1965). In the *locus typicus* profile, i.e. at Nietulisko Małe, the soil consists of bleached, brown, forest soil, about 2 m in thickness, consisting of illuvial, eluvial and humus horizons. The illuvial horizon, orange in colour, contains about 20—22% of clay particles and 3.5% of Fe_2O_3. The eluvial horizon, characterized by an infrequently observed thickness to about 0.5 m, reveals small quantity of clay particles and contains a small amount of Fe_2O_3 (below 1%). The humus horizon is brown in colour and contains coal fragments up to 1 cm in diameter. Above the humus horizon there rests a chernozen soil, 30 cm in thickness, containing approximately 0.9% of humus, up to 3% of Fe_2O_3 and 19% of clay particles. According to J. Jersak, the soil profile from Nietulisko Małe represents two different typological soils (forest soil overlain by chernozem soil), and, therefore, the profile of both soils has been called by this author „the soil complex".

A net of frost wedge polygons is a highly characteristic feature of the soil belonging to the Brørup Interstadial. The wedges stick in younger loesses, but due to their depth exceeding 2 m, locally also 3 m, they penetrate, in the lower parts, also the older deposits. As an interesting example of such structures might serve here numerous profiles observed in the Lublin Upland area, among others at Nieledew, Lipice, Hrubieszów, Sąsiadka, a.o.

The soil profile of the Brørup Interstadial from the Lublin Upland is thought to be bleached chernozem. Probably, the process of formation of the soil profile was here highly complex and long-lasting. We may assume that the chernozem developed at the beginning of the interstadial and, during the thermal optimum, the loess areas were covered with deciduous forests, resulting in bleaching of the soil profile under discussion. At the time of the last interstadial phase, the plant cover changed again and, probably, at that period the accumulation horizon was enriched in humus substances. A similar sequence of events can be observed in the soil of Nietulisko type. The forest soil proves here the existence of a long

and considerable warming up, and the presence of coniferous tree forests, whereas the chernozem is an evidence of predominance of steppe conditions (J. Jersak, 1965).

Main Stage

Two loess horizons occur in the Main Stage of the North Polish Glaciation. The lower horizon belongs to the pre-Paudorf Phase, the upper one to the Leszno, Poznań and Pomeranian Phases. The horizons are separated by a soil of the Paudor Interphase.

Pre-Paudorf Phase

Loesses belong to the better investigated deposits of the pre-Paudorf Phase in Poland. Their occurrence is defined by their position above the soil of the Brørup Interstadial and below the soil of the Paudorf Interphase. Profiles of this type occur in the eastern part of the Lublin Upland (J. E. Mojski, 1965a), in the western area of the Roztocze region (J. Malinowski, 1964), in the Vistula river valley (W. Pożaryski, 1953) in the Opatów Upland (L. Sawicki, 1932; B. Grabowska-Olszewska, 1963; J. Jersak, 1965), and in the Miechów Upland areas (Guide-book of the VIth INQUA Congress, 1961). The loess of the pre-Paudorf Phase is represented mainly by the solifluction loess that consists of wind-borne dust, and of substratum rock fragments that come from various genetical horizons of the soil profile of the Brørup Interstadial.

At places, e.g. in the north-western part of the Opatów Upland, the loess of the pre-Paudorf Phase frequently shows, at its bottom part, an intense gley formation process. At the contact with the overlying not-gleyed loess, there are found frost fissure polygonals (J. Jersak, 1965).

As a rule, the thickness of the loess belonging to the pre-Paudorf Phase ranges from 2 m to 4 m to increase widely in the western area of the Roztocze region.

Paudorf Interphase

In the loess profiles, to the Paudorf Interphase belongs fossil soil developed as not-calcareous, or slightly calcareous brown loess of scarcely definite origin and typology. Such a soil is found at all places, where the loess of the pre-Paudorf Phase does occur. In the Lublin Upland, at Nieledew, a layer of scattered humus loess rests above the brown loess. In

the vicinity of Kunów, the Opatów Upland, the Paudorf Interphase embraces the soil of „Komorniki type". It consists of brown coloured loess with a slightly greater amount of clay fraction at the bottom, and of a humus horizon several centimetres in thickness (J. Jersak, 1965).

The thickness of the soil here considered is from 0.2 m to 0.8 m. For the most part of the loess profiles the soil is eroded by solifluction processes, and the Paudorf Interphase is here expessed by a buried denudation surface of the loess of the pre-Paudorf Phase, or of the older deposits.

Leszno Phase — Pomeranian Phase

Loess is an important deposit that in the area of the Middle Polish Uplands constitutes the stratigraphical profile of the Main Stage and embraces a part of this latter, from the Leszno Phase to the Pomeranian Phase inclusive. The loess of this age constitutes the surface of loess patches in the areas of the Lublin, Opatów and Miechów Uplands, and in the Roztocze region. In addition, the loess, together with the loess-like deposits, occurs also in the forelands of the Carpathians and Sudetes. The loess of the phase under discussion is of aeolian origin, and appears in the form of three types as alluvial, solifluction and subaerial.

On account of the lack of mineral and petrographical synthetic elaborations, characteristic, as far as the youngest loess deposits are concerned, of the whole country, the author presents a characteristic of this kind, giving, as an example, the loess of the Lublin Upland area (J. Malinowski, 1964; J. E. Mojski, 1965a). The loess under discussion is of a uniform mineral composition, in which quartz predominates, amounting to more than 90%, feldspars, calcium carbonate, clay minerals (mainly illite), iron oxides and heavy minerals being, however, scarcely represented. In the vertical profile the quartz content undergoes a slight change only, whereas the amount of the remaining minerals, particularly that of calcite and clay minerals, frequently varies. Among heavy minerals are: zircon, garnet, tourmaline, rutile, hornblende, staurolite, disthene and epidote. As a rule, resistant minerals prevail (50%—75%), and those being less resistant to weathering are scarcely represented. The content of calcium carbonate is from 1.2% to 17.8%, the greatest one being found in the subaerial loess (from 5.2% to 17.8%). In the alluvial loess in turn the $CaCO_3$ content is from 5.2% to 11.0%, and that in the solifluction loess from 1.2% to 13.2%.

Grain-size composition of both alluvial and subaerial loesses is characterized by a predominance of 0.01—0,05 mm fraction appearing from 47% to 78% (in the subaerial loess — from 47% to 74%, in the alluvial

one — from 50% to 78%). In the solifluction loess, the main loess fraction can be reduced almost twofold, being from 27% to 61%. The data mentioned above prove that the best graded grains are found in the alluvial loess, the feebly separated ones — in the solifluction loess. Moreover, as compared with the remaining area, the alluvial loess is characterized, in the profiles occurring in the eastern part of the Lublin Upland, by a decrease in sand contents.

In the loess of the southern part of the Miechów Upland, the $CaCO_3$ content is from 1.4% to 17.9% (M. Kolasa, 1963). In granulometric composition the fraction from 0.006 mm to 0.06 mm prevails, amounting to 66.5—88.0%. The youngest loess of the north-western part of the Opatów Upland is characterized by a calcium carbonate content from 0.5% to 14.0% (J. Jersak, 1965).

The loesses of the Leszno, Poznań and Pomeranian Phases reveal certain structural features that prove its periglacial origin. The commonly found ice-wedge and frost-fissure polygons, as well as frost heaving structures belong to the features mentioned above. The polygons are found in various intervals of the profile of both alluvial and subaerial loesses. In the alluvial loess shorter and narrower fissures prevail, whereas a large number of wide wedges, usually over 1 m in depth, are characteristic of the subaerial loess.

The frost heaving structures resemble upright or inclined folds, locally over 2 m in height. The core of fold is built up of a deposit that forms the bottom part of the profile of the loess in study, or of older deposits at places. In these structures, the loess is distinctly fractured, parallelly to the outline of the form. Farther off the core, the fractures disappear, similarly as does it the stratification that frequently appears in the fold. In all probability, structures of this kind are found mainly on slopes, thus in places, where the subaerial loess is underlain by solifluction one. So far, a small number of the investigated frost heaving structures did not allow to detect any regularity in their regional distribution. We may, however, ascertain that the amount of frost wedges increases towards the east. Such a relationship can easily be explained by a more continental character of climate in the east, and by a greater oceanity in the west during the formation of both the loess and the structures under consideration.

So far, the character of the loess profiles belonging to the Leszno, Poznań and Pomeranian Phases does not permit to distinguish here any intervals that might correspond to the successive phases and interphases. Thus, it may be assumed that differences in climate conditions of phases and interphases were insignificant and did not exert any considerable influence on the character of the profile. This does not mean, however,

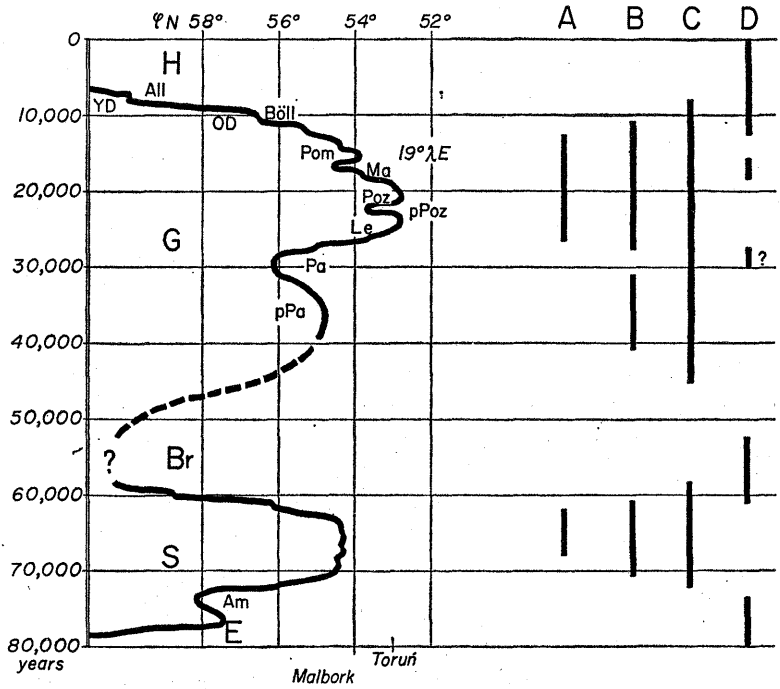

Fig. 5. Loess accumulation in the light of continental glacier extent curve of the North Polish Glaciation. Thick and black line shows the extent of the continental glacier

A — accumulation of glacial and fluvioglacial deposits; B — loess accumulation; C — formation of periglacial eluvial and talus covers; D — organogenic accumulation in lakes, under conditions of forest vegetation development; E — Eemian Interglacial; S — Szczecin Stage; Am — Amersfoort oscillation; Br — Brørup Interstadial; G — Main Stage; pPa — pre-Paudorf Phase; Pa — Paudorf Phase; Le — Leszno Phase; pPoz — pre-Poznań Interphase; Poz — Poznań Phase; Ma — Masurian Interphase; Pom — Pomeranian Phase; Bøll — Bølling Interphase; OD — Older Dryas Phase; All — Alleröd Interphase; YD — Younger Dryas Phase; H — Holocene

that the profile is completely homogeneous. At places, in the subaerial loess profiles, a change can be observed, consisting in a fact that several layers occur in the loess, being from some to several dozen of centimetres in thickness. The layers are built up of grey, or green-grey, more clayey and irregularly stratified loess with brown spots caused probably by plant detritus. Such beds described and for the first time interpreted by L. Sawicki (1952) at Zwierzyniec, Cracow area, are known to occur also in the loesses of the Lublin Upland. In the profile at Zwierzyniec there occur over 10 layers of this character, whereas in the Lublin Upland solely 3 layers have been found, in one profile. The character of development seems to point to a fact, stressed also by L. Sawicki (1952) and J. Siuta (1960), that the grey loess layers have been formed in a relatively humid environment, favourable to an exuberant growth of tundra vegetation, and to an

increased congelifluction and gley processes reflected in the structure. It has so far not been explained, to what rank of change of climatic conditions correspond the periods of greater humidity. It is possible that some of them can be referred to the interphases reflected in the deposits and in the relief of the lowland area.

The thickness of the loesses belonging to the Leszno, Poznań and Pomeranian Phases is greater than that of the older loesses. It ranges from several to about 20 m. In relation to the morphological and topographical situation, the greatest thickness of loesses has been observed at the bottom parts of slopes. A thickness of this kind is reported to occur also within the intervalley areas, in certain parts of the Lublin Upland, in the western area of the Roztocze region, a.o.

So far, vertebrate and molluscan fauna has only fragmentarily been examined, thus faunal assemblage cannot be regarded as that of index significance. To the most popular remains of vertebrates belong fossil bones of mammoth (*Elephas primigenius*). Moreover, there are also found bones of *Rhinoceros tichorhinus*, *Bos priscus*, *Equus caballus fossilis* and *Sus scrofa fossilis*, mainly in the Vistula river gap (W. Pożaryski, 1953). The molluscan fauna is mainly represented by *Pupilla muscorum*, *Succinea oblonga*, *Limnaea*, *Vallonia tenuilabris*, *Columella edentula columella*, and others (W. Pożaryski, 1953; A. Jahn, 1956a; J. Jersak, 1965; M. Prószyński, 1952).

Fig. 5 shows a relation between the periods of loess accumulation and curve of continental glacier extent during the North Polish Glaciation.

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