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Development Stages of Loessial and Glacial Formations in Ukraine (Stratigraphy of Loesses in Ukraine)

Stadia rozwoju utworów lessowych i glacjalnych w Ukrainie
(Stratygrafia lessów w Ukrainie)

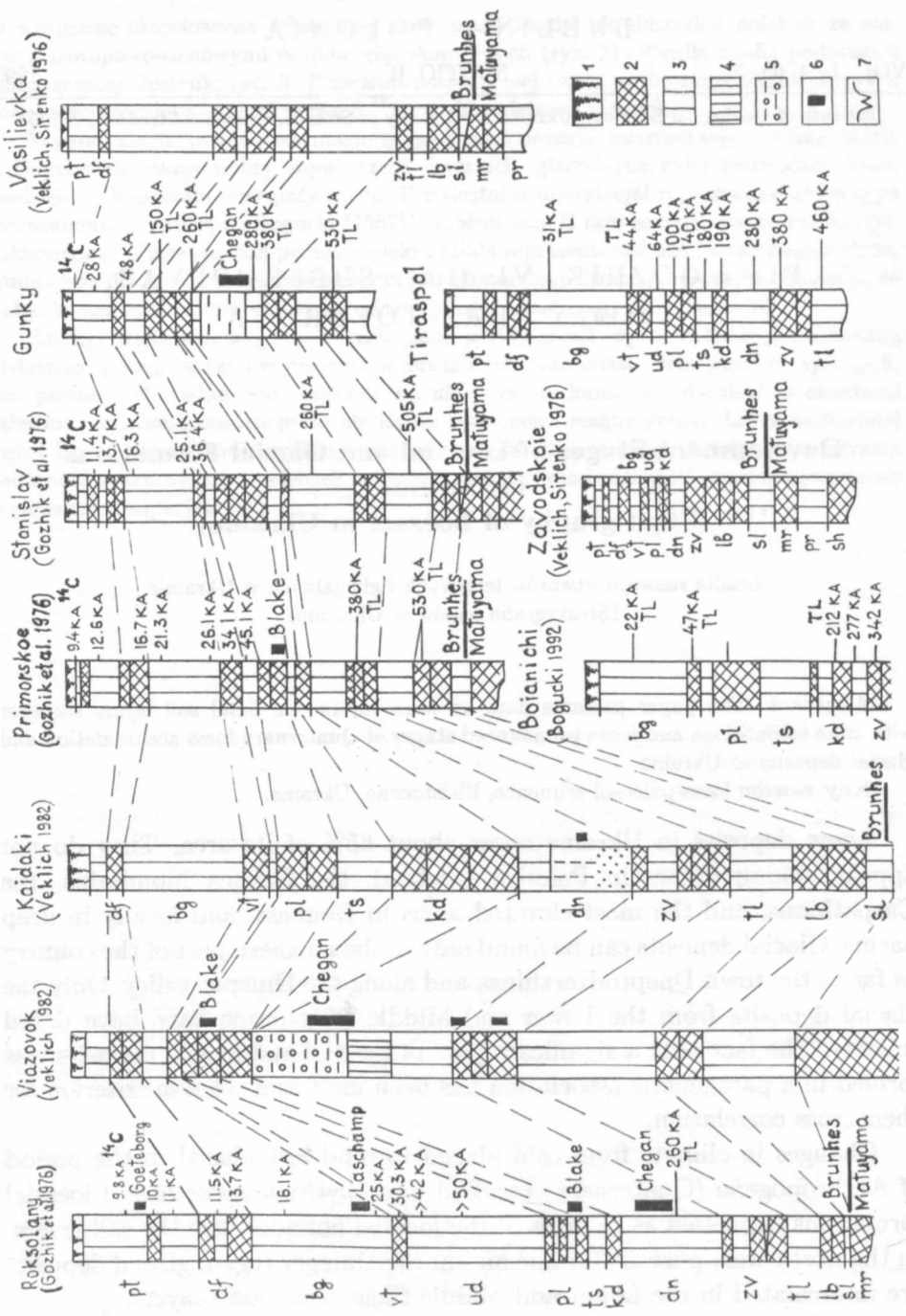
Abstract. The paper presents data on loess layers and fossil soil layers together with time estimations and more pronounced stages of Quaternary loess accumulation and glacial deposits in Ukraine.

Key words: loess-paleosol sequence, Pleistocene, Ukraine.

Loess deposits in Ukraine cover about 65% of its area. They do not appear among others in Polesiye Lowland, the Crimea Mountains, the Carpathians, and the most elevated areas in Donbass, and locally in deep basins. Glacial deposits can be found only in the northern part of the country as far as the town Dneprodzerzhinsk and along the Dnieper valley. Only the glacial deposits from the Lower and Middle Pleistocene have been dated reliably. The fact that a significant part of loessial and glacial deposits was formed in a paragenetic association has been used as a reliable criterion for their cross correlation.

Changes in climate from cold glacial to mild interglacial in the period of Anthropogene (Quaternary) resulted in a rhythmic structure of loessial formations expressed as changes of the loessial horizons into the soil layers. In the north-west part of Ukraine and in the Dnieper region glacial deposits are intercalated in the Lower and Middle Pleistocene loess layers.

The Lower Pleistocene loesses appear as a rather thin series with some traces of geochemical alterations resulting from soil-forming processes. The


Roksolany (Gozhik et al. 1976)
Viazovok (Veklich 1982)
Kaidaki (Veklich 1982)
Primorskoe (Gozhik et al. 1976)
Boianichi (Bogucki 1992)
Stanislav (Gozhik et al. 1976)
Zavodskoie (Veklich, Sirenko 1976)
Gunky
Tiraspol
Vasilievka (Veklich, Sirenko 1976)
Brunhes
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earliest loesses overlay red brown Eopleistocene clays (Shirokino buried soil — vide Fig. 1) that have been classified as the Azov horizon (M. Veklich 1965). In the present paper, however, we named the horizons according to the Ukrainian Geological Survey.

The Lower Pleistocene loesses vary in their thickness from 0.3 to 2.0 m. Most often loess layers of the Azov horizon are highly altered by the pedogenetic processes. These are usually medium and sandy loams, dove pale yellow or brownish pale yellow in colour. They are overlaid by 2 or 3 horizons of brown buried soils up to 3 m thick classified as Martonosha horizon (M. Veklich 1965). Judging from the soil types and spore-pollen data, they were formed in the subtropic conditions.

The second Lower Pleistocene loess horizon, i.e. Sula loess, has been distinguished by V. Krokos (1927). It is represented by medium, or, less frequently, light and sandy loams, greyish pale yellow in colour and 0.5 to 4.0 m thick. The first unquestionably cryogenic structures occur in the Sula loesses which suggest periglacial sedimentation. They are overlaid by the Lubny soils (one or two horizons) of meadow type similar to subtropic ones. The soils of the Lubny horizon vary in thickness from 1.2 to 3.2 m.

The Lower Pleistocene section is completed by a 0.4 to 3.8 m thick loess horizon (V. Krokos 1927). It is characteristic of the distinct cryogenic structures, especially in the Middle Dnieper Region. This Tiligul loess is interbedded with sands; near Vyazovok village inclusions of crystalline rock gravels can be found. Contemporaneously with Tiligul loesses there was accumulation of Krukenichi till in the north-west part of Ukraine correlated with the Oka (=South Polish) glaciation. In the north of Volhynia this till covers lacustrine-alluvial deposits of Bialowieza Interglacial and is overlaid by the lake sediments of the Great Interglacial (=Holsteinian). In a well known section of Boianichi village (West Volhynia) till is transformed by the pedogenetic processes.

Fig. 1. Reference sections of the loessial formation in the Black Sea Region (Roskolany, Stanislav, Primorskoye), in the Middle Dnieper Region (Gunki, Viazovok, Kaidaki), in the Lower Dnieper Region (Vasilievka), at Kerch Peninsula (Zavodskoie), in the Lower Dniester Region (Tiraspol), in Volhynia (Boianichi); 1 — recent soil; 2 — fossil soils; 3 — loess and loess-like deposits; 4 — loams; 5 — glacial deposits; 6 — reverse magnetic polarity events; 7 — cryogenic structures. Stratigraphic symbols for the loessial formation horizons in Ukraine: pr — Azov, mr — Martonosha, sl — Sula, lb — Lubny, tl — Tiligul, zv — Zavadovka (Sokal and Lutsk), dn — Dnieper, kd — Kaidaki (Korshev), ts — Tiasmin, pl — Priluki (Horokhov); ud — Udai, vt — Vitachev (Dubno), bg — Bug, df — Dofinovka, pt — Prichenomor (Peripontian)

Thus, the Lower Pleistocene depositis are characteristic of the three distinct loess accumulation stages, i.e. Azov, Sula, Tiligul, separated by soils of subtropic type. The loesses were dated back using paleomagnetic, thermoluminescence and paleonthological methods. Conclusions drawn from the data obtained (Fig. 1) suggest that the boundary between Bruhnes and Matuyama paleomagnetic epochs goes over the bottom of Sula loesses (Roksolany, Primorskoye, Vyazovok, Kaidaky, Zavodskoye, Stanislav sections). Consequently, their lower boundary can be dated back to 700 ka BP. This latter conclusions is also confirmed by the thermoluminescence (TL) datings for the Sula loesses near the villages of Zavadovka (642±85 ka BP), Rozhki (653±70 ka BP), Primorskoye (658±91 ka BP) and for the loess top layer near the village of Novo-Petrovka (607±65 ka BP) (V. Shelkoplyas et al. 1986). Martonosha soil in Roksolany section was dated back to 800±98 ka BP, and Azov loess near the village of Potyagailovka to 923±106 ka BP. Tiligul loess was dated using samples from various age levels and for that reason the results are not very reliable. The above can also explain scatter in datings (from 440±55 ka BP near Potyagailovka village to 470±52 ka BP near Rozhki village, 480±60 ka BP near Zavadovka and 510±60 ka BP near Chigirin). This suggests that accumulation of Tiligul loesses lasted for about 70 ka. Till near Boianichi was dated back to 510±60 ka BP and heavy loams overlying this till to 496± 74 ka BP and 473±70 ka BP. Thus, it seems quite feasible to correlate Tiligul loess with Lower Pleistocene till from the Ciscarpathian Region and Volhynia.

Two Middle Pleistocene brown soils — 1.7 m thick and 3.5 m thick similar to Lower Pleistocene buried soils occur mainly in the bottom of the Middle Pleistocene loess formations. This type of basic soil formation was classified as Zavadovka horizon (M. Veklich 1965). There are also thin layers of loess (10 to 25 cm thick) that occur in-between the soils. In some sections the Zavadovka horizon is overlaid by a thin loess layer (0.5 to 1.6 m thick) that is called Orel loess after V. Krokos (1927). It is, in turn, overlapped by a layer of brown soil 0.5–1.1 m thick. In majority of places, however, Zavadovka soils are overlaid by the Dnieper loess horizon that is the second in thickness (from 2 to 6 m) of all the loess formations in Ukraine. These horizons are usually light, pale yellow medium or, less frequently, sandy loams with the interbed of the Dnieper till (in the glaciated zone; see Fig. 1.). The Dnieper loess is usually overlaid by one or two horizons of meadow chernozems of the thickness from 1.0 to 2.5 m (up to 5.0 m maximum) that are classified as the Kaidak horizon (M. Veklich 1965). The Middle Pleistocene section is then completed by the third horizon of

Tyasim loess (M. Veklich 1965). It is a rather thin horizon that vary in thickness from 0.2 to 1.5 m or is absent in many sections.

We have dated the loessial horizons of Middle Pleistocene on the basis of their inter-relations with the paleontologically characterized layers, TL datings and paleomagnetic data. The datings of Dnieper loesses and till are quite reliable (V. Shelkoplyas et al. 1986). The minimum and maximum loess datings are equal to 230 ka and 290 ka, respectively these for the till to 260 ka and 280 ka BP. The Dnieper till and the lower part of the Dnieper loess have been related to the Chegan event dated to 260 to 280 ka BP at the paleomagnetic scale. Estimation of the age and period of the Zavadovka stratigraphic horizon presents a more complicated problem. The TL dating available range from 340±52 ka BP to 440±48 ka BP. It should be noted, however, that there is a single dating for Potyagailovka soil (between Orel and Dnieper loess) at 304 ka BP that may be arbitrarily dated to the upper part of the Zavadovka horizon (i.e. Great Interglacial).

The conclusion on the protracted period of soil formation during the Great Interglacial era is indisputable. On the basis of the TL datings available it may be gathered that the Orel stage of loess accumulation corresponding to the climate deterioration during the Great Interglacial (Mindel-Riss, Likhvin, Holstein) lasted from 360 to 340 ka BP. As to the optimum of the Interglacial fixed in the loess formation it should be dated at 400–380 ka BP. Judging on the TL datings and a reverse paleomagnetic event in the bottom of the soil formation the beginning of the interglacial period dates to 440 ka BP. Correlation between the Zavadovka horizon and the Great Interglacial is proved by numerous paleontological materials, especially those about the terrace complexes of the Dniester, Prut and Danube together with their conjugated marine terraces. The TL datings for the Kaidak chernozems worked out by the Institute of Geological Sciences of the National Academy of Sciences of Ukraine were clustered within the 225 to 233 ka BP time span. It is worth mentioning that the datings of the Korshov buried soil comparable with the Kaidak horizon by the Lublin Univerisity (V. Shelkoplyas 1986) are within 213 to 235 ka BP time range.

The upper horizon of the Middle Pleistocene loesses, specified as the Tyasmin horizon by M. Veklich (1965) is, as a rule, rather thin and not as widely spread as the Dnieper loesses. Its sediments consist of pale yellow loams and, less often, of sandy loams. However, unlike the thin Orel horizon, the Tyasmin loesses are separated by frost wedges and show well developed cryoturbations that point to the periglacial conditions. The few TL datings available range from 180 to 211 ka BP.

The Upper Pleistocene loesses are wide-spread even in Polesiye where they occur as "loess islands". Features such as column-like structure, prevailing pale yellow colour and their considerable thickness ranging from a few to 20–30 m are distinctive of these loesses. The buried soils divide the Upper Pleistocene loesses into three major horizons. There are a lot of sections that fully show changes in the sedimentation that took place in the Late Pleistocene. In the bottom layer they consist of thick soil formation classified as the Priluki horizon (M. Veklich 1965) or as the Horokhov pedocomplex in Volhynia–Podolia (A. Bogucki 1986). In the most complete sections (Fig. 1) the above mentioned horizon consists of three layers of buried soil separated by thin loess interbeds. As a rule, the lowermost brown forest soil was formed during the optimum climatic conditions, and the two upper ones consist of meadow chernozem. The uppermost soil is broken by frost wedges. There are numerous TL datings for the Priluki soils in the ranges of 100±10, 115±13, 120±16 ka BP to 144±18, 150±18, and 167±13 ka BP. The Horokhov pedocomplex was dated back to about 160 ka BP. It should be stressed that the Blake event within the period 110–115 ka BP was fixed in the middle and bottom part of the Priluki soil formation. Considering its position at the lower loess interbed/lower soil boundary, it may be gathered that the Priluki soil complex began to form at 130–140 ka BP. As can be seen, the TL datings are somewhat too high since they specify the commencement of accumulation of the mother rock, not the soil-formation process itself.

The Udai loess (V. Krokos 1927) appears as a thin layer (0.5 to 2.0–3.0 m, or less often, up to a few meters) overlaying the Priluki soil formation and is represented by medium and sandy loams, brownish pale yellow or off-white yellow in colour, with frost deformations. The radiocarbon method yielded more recent datings of Udai loess, i.e. about 45 ka BP for the top layers, 58±8 to 67±9 ka BP for various middle layers, and from 80±12 to 100±17 ka BP at the bottom. The Vitachev buried soil (M. Veklich 1965) overlaying the Udai loess is represented by two horizons of buried soils 0.8 to 2.2 m thick. They were dated by means of radiocarbon method in several sections. The datings (28, 30, 34, and 36 ka BP) point to a differentiated character of these soils in relation to their age; even though age underestimation cannot be ruled out. The TL datings are also ambiguous and vary from 35±6, 38±7 ka BP to 43±8 and 44±5 ka BP. The Dubno soil from the section near Boianichi village was dated at the Lublin Laboratory. The dating was 47±7 ka BP. Thus, the formation period for the soils of the interpleniglacial interstadials can be dated at 28 to 46 ka BP.

The Vitachev soil in Ukraine is overlaid by the thickest Bug loess horizon

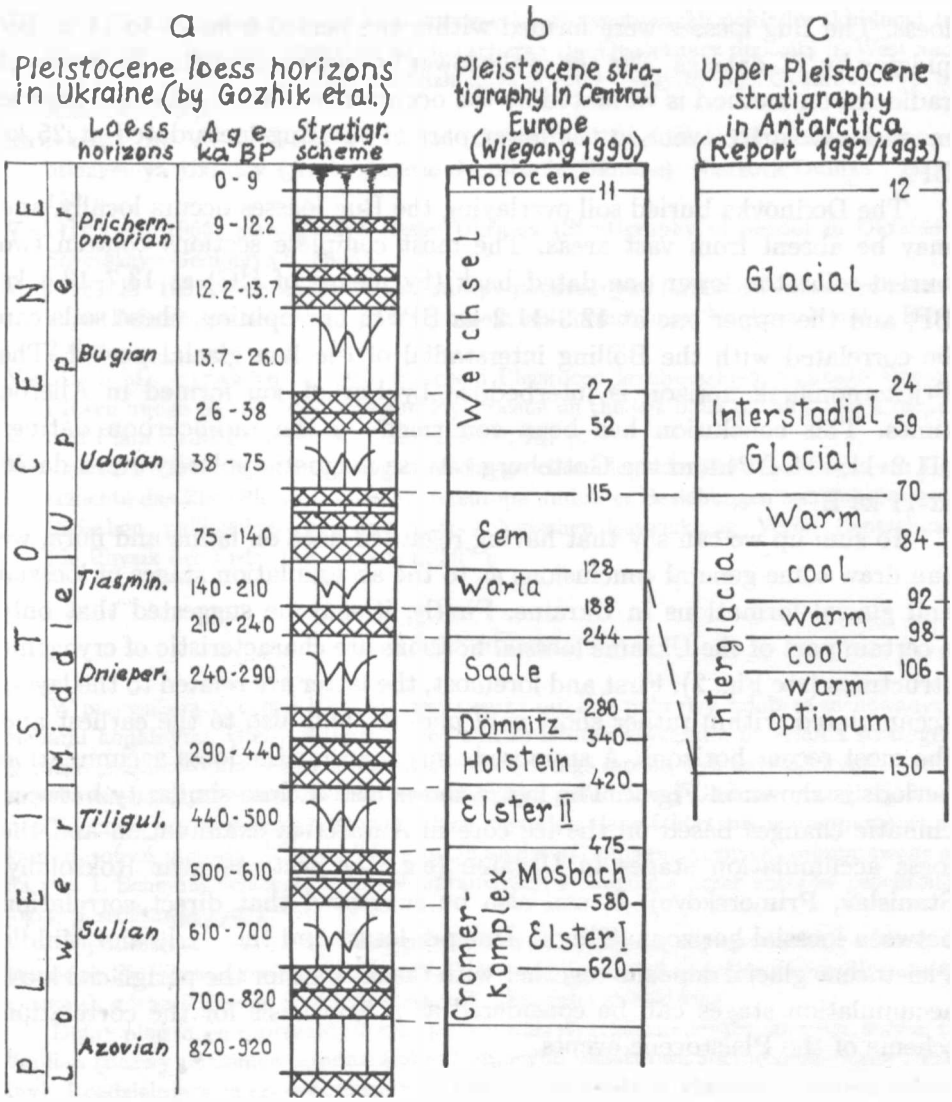

Fig. 2. Pleistocene loessial formations in Ukraine (a) and its correlation with the scheme of Pleistocene stratigraphy in Central Europe (b) and Upper Pleistocene stratigraphy in Antarctica (c). Explanations — see Fig. 1

(V. Krokos 1927). It consists of pale to light pale yellow loess with the thickness of 10 m or more (5 to 8 m on the average). According to the earlier concepts, this loess represents the final stage of loess accumulation corresponding to the most recent glaciation. M. Veklich (1965) succeeded in separating the overlaying Dofinovka fossil soil and the Prichernomorsk

loess. The Bug loesses were formed within the period from 26 to 14 ka BP judging by TL datings. The age of the lower boundary estimated by means of radiocarbon method is validated by the occurrence of the Lachampe reverse magnetic polarity event in the lower part of the Bug loess dated at 25 ka BP.

The Dofinovka buried soil overlaying the Bug loesses occurs locally, and may be absent from vast areas. The most complete sections contain two buried soils; the lower one dated back (by means of ^{14}C) at 13.7–13.4 ka BP, and the upper one at 12.3–11.2 ka BP. In our opinion, these soils can be correlated with the Bölling interstadial of the late glacial period. The Prichernomorsk horizon is interbedded by buried soil formed in Alleröd times. This conclusion has been confirmed by the radiocarbon datings (11.2–11.4 ka BP) and the Gotteborg reverse magnetic polarity event dated at 11 ka BP.

To sum up we can say that having regarded data on fauna and flora, we can draw some general conclusions as to the accumulation stages of loessial and glacial formations in Ukraine. Firstly, it may be suggested that only a certain part of the Ukraine loessial horizons are characteristic of cryogenic structures (see Fig. 2). First and foremost, the latter are related to the layers accumulated within rather short cold periods, and also to the earliest and the most recent horizons. A supposed time span for the loess accumulation periods is shown in Fig. 2. The figure shows also a close similarity between climatic changes based on the ice core in Antarctica examination and the loess accumulation stages in Ukraine (e.g. the sections near Roksolany, Stanislav, Primorskoye). It can also be suggested that direct correlation between loessial horizons (Tiligul, Dnieper loess) and the Early and Middle Pleistocene glacial deposits together with the datings for the periglacial loess accumulation stages can be considered as a firm basis for the correlation scheme of the Pleistocene events.

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STRESZCZENIE

W przeważającej części Ukrainy lessy tworzą miąższe pokrywy z dobrze zachowanymi glebami kopalnymi. Gleby stanowią więc bardzo istotne kryterium określania stratygraficznego zróżnicowania lessów ukraińskich. Oprócz tego można wykorzystać wyniki badań współwystępujących z lessami osadów morskich w południowej Ukrainie oraz glacjalnych w północnej. Uzyskane na podstawie takich kryteriów dane faktyczne, uzupełnione wynikami datowań metodą ^{14}C oraz TL, a także analiz paleomagnetycznych, prezentowane są na ryc. 1. Schemat stratygrafii lessów ukraińskich, z określoną przez autorów geochronologią, przedstawia ryc. 2.

W podłożu lessów w regionach południowych występują eoplejstoceńskie czerwonobrunatne iły ("krasnocwietnaja formacija" rozwijająca się od pliocenu do schyłku eoplejstocenu); górna ich część wyodrębniana jest jako gleba shirokińska.

Dolny plejstocen reprezentują trzy poziomy stratygraficzne lessów: azovian, sulian, tiligulian (nazwy poziomów zgodne z obowiązującymi państwową służbę geologiczną Ukrainy). Rozdzielające je czerwonobrunatne gleby powstawały w klimacie o cechach subtropikalnych. Pierwszy z wymienionych poziomów lessowych jest mało miąższy, z oznakami wyraźnego przekształcenia geochemicznego. Dopiero drugi ma cechy lessu właściwego, jest bardziej miąższy i zawiera pierwsze (najstarsze) oznaki zaburzeń kriogenicznych. Trzeci less dolnoplejstoceński paralelizowany jest z gliną zwałową, znaną m.in. z profilu Krukienice (na Płaskowyżu Sańsko-Dniestrzańskim) z okresu zlodowacenia oki (= zlodowacenia sanu).

Środkowy plejstocen rozpoczynają dwie gleby o cechach podobnych do dolnoplejstoceńskich, rozdzielone cienką (do 25 cm) warstwą lessu. Nad nimi występują dwa poziomy stratygraficzne lessów: dnieperian i tiasminian. Rozdziela je gleba typu czarnoziemnego, a więc wyraźnie różniąca się od dolnoplejstoceńskich. Less poziomu dnieperian paralelizowany jest z gliną zwałową z okresu zlodowacenia dniepru (= zlodowacenia odry), dość powszechnie występującą w środkowej Ukrainie.

Górny plejstocen rozpoczyna gleba z okresu ostatniego interglacjału — czarnoziemna na południu i brunatna leśna na północy. W najwcześniejszych etapach ostatniego zlodowacenia na glebę leśną na północy Ukrainy nałożone zostały poziomy typu czarnoziemnego; tak powstał horochowski pedokompleks wyróżniany na Wołyniu i Podolu. Wyżej wyodrębniono trzy poziomy stratygraficzne lessów — udaian, bugian, prichernomorian; ten ostatni wyróżniany jest tylko w profilach nadczarnomorskich i paralelizowany jest z późnym glacjałem (= późnym vistulianem). Pomiędzy lessami poziomów udaian i bugian występuje gleba interstadialna — na południu poziom humusowy szaro zabarwiony, a na północy gleba zmarzlinowo-glejowa (gleba dubieńska na Wołyniu).