ECOLOGY
AND NOOSPHEROLOGY

ISSN 1726-1112 (Print)
ISSN 2310-4309 (Online)
Ecol. Noospher., 31(2), 59–64
doi: 10.15421/032009

Palaeoecological aspects of an Ukrainian Upper Holocene chernozem

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Article info

Received 15.04.2020
Received in revised form 23.04.2020
Accepted 29.04.2020

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Recio Espejo, J. M., Kotovych, O. V., Díaz del Olmo, F., Gorban, V. A., Cámara Artigas, R., Masyuk, O. M., Borja Barrera, C. (2020). Palaeoecological aspects of an Ukrainian Upper Holocene chernozems. Ecology and Noospherology, 31(2), 59–64. doi:10.15421/032009

A physicochemical, palynological and chronological analysis of a soil profile corresponding to a Haplic Chernozem (FAO, 2015) developed in the Ukrainian steppe allow the interpretation of recent environmental changes that have conditioned its formation. Uniformed under the blackening process, its surface horizon dark color contrasts with yellowish color loessic parental material; it is decarbonated and the organic carbon content on the surface is 2.24%.The texture is silty in surface but sandy in lower horizon denoting a clear wind selection and an energy change in aeolian sedimentation processes. The clays present similar values in the three analyzed horizons. The presence of two discontinuities in the profile has made it possible to distinguish a very sandy blackened horizon of 2500 +/- 25cal BP chronologies from another silty surface and black chromas of age 1336–1256 cal BP. A total of fifteen pollen types have been identified; superficial horizon (A11) has a high presence of pollen of the *Amaranthaceae* type, the *Poaceae* are the most abundant and *Quercus* gender is identified. The sandy horizon (2A/B) shows *Poaceas, Pinus*, and *Oleaceas* presence together pollen of *Rosaceas* type (14%). Pollen data reveal vegetative changes in the three horizons with the presence of even non-existent species today, linked both to recent anthropic-climatic and holocene-type changes on a millennial scale since the last glacial period.

Keywords: steppe; Ukrainian chernozem; palaeoecology

Introduction

The present work represents a contribution to the research line maintained by the authors in relationship to the ecological factors and geomorphological conditions that motivate the blackening and tirsification processes of some pedological horizons of Vertisols, Chernozems or chilean Andosols (Núñez et al., 1997; Recio et al., 2017, 2018, 2019, a, b; Guajardo et al., 2020). The study of a polyphasic profile corresponding to a Calcic Chernozem (FAO, 2015) has allowed us to deepen this process as well as to evaluate some of the palaeocological conditions that have controlled its formation (Alexandrovskiy and Chichagova, 1998; Khokhlova and Kovalevskaya, 2001).

This soil profile (Calcic Chernozem) (FAO, 2015) studied by the authors (Fig. 1) are located to coordenates position 48° 45' 36.9"N, 35° 27' 40.5"E within the virgin steppe land of watershed plateau in a culminating position (south-eastern part of the Andreevka village).

The current majority vegetation support by the superficial horizon is constituted by *Festuca valesiaca* Schleich former Gaudin, (Poaceae), *Koeleria macrantha* (Ledeb.) Schult (Poaceae), *Thymus marschallinus* Wilid. (Lamiaceae), *Linum hirsutum* L. (Linaceae), *Salvia nemorosa* L. (Lamiaceae), *Austrian Artemisia* Jacq (Asteraceae).

Material and methods

For its morphological and physicochemical characterization have been used the guide FAO (1977), the colour parameters was determined by Munsell (1990), carbonates (Duchaufour, 1975), wet and ignition loss by M.A.P.A (1986), total organic carbon by Sims and Haby (1971), magnetic susceptibility (Dearing, 1999) and textural analysis and distribution particle size by Soil Survey England and Wales (1982) (Table 1, 2, 3, Fig. 1).

From this profile the pollen present on the horizons (A11, 0–20 cm) and lower zone profile (2A/B and 3BC1) has been identified following the method described by Dupré Olivier (1979), with some modifications proposed by Martín Consuegra (1996) and by López et al. (2003). With the pollen extracted, its identification has been carried out under optical microscopy through the use of the reference palinoteca and different pollen atlases (Table 3).

Chronological dating by C_{14} cal. BP was performed in the humine fraction of the superficial horizon (A11) by the Beta Analytic Laboratory (Miami, Florida, USA) and the medium horizon (2A/B) by the Accelerator National Centre of CSIC-University of Seville (Seville, Spain) (Fig. 2).

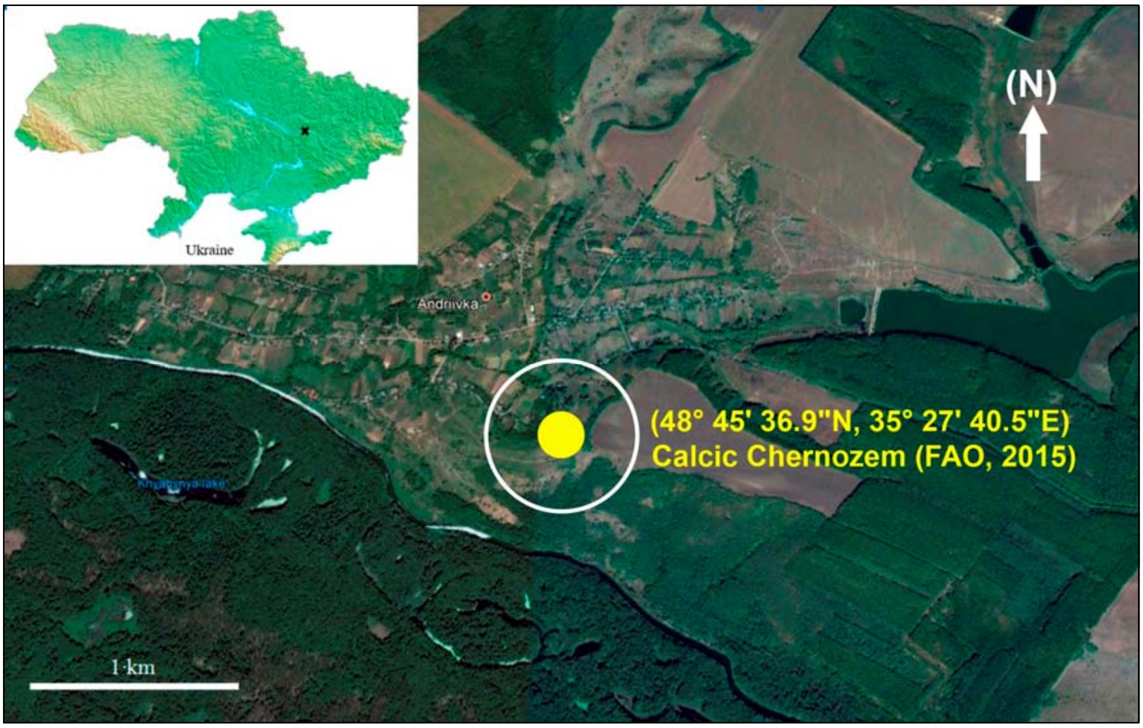

Fig. 1. Location of studied area

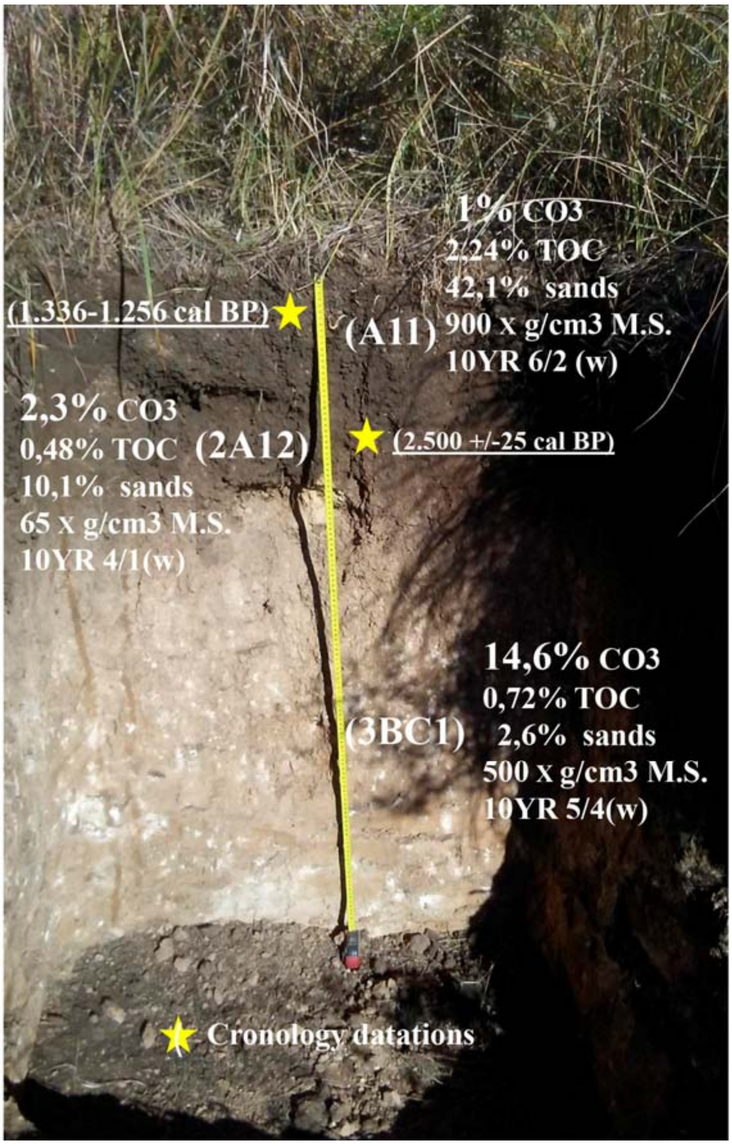

Fig. 2. Haplic Chernozem (FAO, 2015)

Results and discussion

Table 1 shows the physical-chemical characterization carried out in the profile. The dark color of the surface horizon (10YR 4/1) contrasts sharply with the yellowish tones of the parental loess (10YR 7/4), at 130cm from the surface, and equally affects the two surface horizons (A11 and 2A/B), uniformed under the blackening process.

The organic carbon content on the surface is 2.24%, and at 80 cm depth (3BC1) it becomes 0.72%, greater than in the overlying horizon. The loss on ignition is 7.88% on the surface, so we can consider that 49% of it is humidified, compared to 20% in 2A/B and 35% in 3BC1 respectively (Table 1).

It is decarbonated, these being accumulated in the form of powdery spots on the 3BC1 horizon (14.6%). Magnetic susceptibility values are low, highlighting those found in 2A12 much lower than the rest of the horizons. In relation to the density and porosity that the horizons present, coincide with the values previously found by Nuñez et al. (1997) and very different from those presented by blackening horizons Andosol (FAO, 2015) studied by Guajardo et al. (2020) and developed on yellowish ash of volcanic origin.

Its texture is silty except in the 2A12 horizon where the sand fraction is the dominant one with 42.1% and where very thick fractions are represented (Table 2). In the superficial horizons, the dominant sand fraction is that of diameter 0.25–0.125 mm. denoting a clear wind selection. On the contrary, the 3BC1 horizon shows a loamier character, with a dominant fraction (74%) in the fraction with the smallest diameter (0.125–0.063 mm. In this silt fraction, the largest fractions (0.063 to 0.015 mm) are always the most representative (Table 2), denoting their wind selection. The clays present values around 40% in the three analyzed horizons (Table 1).

Another hand a total of 15 pollen types has been identified. The quantity has been expressed in pollen grains per gram of soil horizon (Table 1). Superficial horizon A11 (0–20 cm) has a high concentration with 473 pollen grains per gram, 45 are in 2A/B, while BC1 (40–130 cm) has 64 pollen grains per gram (Table 3). The 2A/B horizon presents only 4 pollen types, compared to 12 of the other horizons.

Table 3
Type polinics and its frequency in the different horizons

Type polinics (%)/ Horizons	**A11**	**2A/B**	**3BC1**
Corylus	2.33 (O)	0.00 (–)	8.57 (F)
Pinus	3.72 (O)	14.29 (C)	5.71 (F)
Oleaceae	3.26 (O)	14.29 C)	11.43 (C)
Myrtaceae	0.00 (–)	0.00 (–)	2.86 (O)
Cupressaceae	0.00 (–)	0.00 (–)	2.86 (O)
Castanea	0.93 (R)	0.00 (–)	8.57 (F)
Quercus	10.70 (C)	0.00 (–)	20.00 (C)
Poaceae	16.28 (C)	57.14 (A)	5.71 (F)
Amaranthaceae	55.81(A)	0.00 (–)	11.43 (C)
Urticaceae	1.40 (O)	0.00 (–)	2.86 (0)
Echium	2.33 (O)	0.00 (–)	2.86 (O)
Apiaceae	1.40 (O)	0.00 (–)	0.00 (–)
Salix	0.47 (R)	0.00 (–)	0.00 (–)
Rossacea	0.00 (–)	14.29 (C)	0.00 (–)
Compositae	0.93 (R)	0.00 (–)	5.71 (F)
No determinated	0.47	0.00	11.43
Types polinic	**12**	**4**	**12**
Grains by sample grams	**473**	**45**	**64**
Abundant		>25.0% (A)	
Common		10.1–25.0 (C)	
Frequent		5.1–10.0 (F)	
Occasional		1.1–5.0 (O)	
Rare		0.3–1.0 (R)	
Very rare		< 0.3% (VR)	
Absent		(–)	

Note the high presence of pollen of the *Amaranthaceae* type followed by *Poaceae* on the surface horizon with values of 55% (A, abundant) and 16% (C, commont) respectively. The *Quercus* gender is also represented (10%) in both horizons with a common character (C). The 3BC1 sample has a lower concentration of pollen grains and its largest representative is *Quercus (C)* followed by *Amaranthaceae* and *Oleaceae.* (F, frequent and C, common). In this deepest level the grains of pollen from cherries are the best represented, presenting two pollen types not present in the previous one (*Myrtaceae* and *Cupressaceae*) with an occasional (O) frecuency (2.86%).

The intermediate sandy horizon shows, like the others, the presence of *Poaceas*, *Pinus*, and *Oleaceas*, and pollen belonging to the *Rosaceas* family 14% (C) are only represented here. The majority vegetation supported by the current soil superficial horizont is *Poaceae;* some specific genders determinates are not currently represented in the area.

In view of these results, there seems to be a clear disagreement in the profile linked to an energy change in eolian sedimentation processes. Erosive-sedimentary processes of a sandy nature have come to interrupt the initial and final silt-loessic sedimentation processes found in the profile, and which have shaped changes in the starting parental material linked to anthropization (agricultural erosion) or to environmental humidity-aridity changes related to Bond cycles (Bond et al., 1997). This palaeoenvironmental conditions and the profile chronology obtained may suggest this formation under the influence of millennial-scale climate cycles. The dating has revealed a chronology of 1336–1256 cal BP to horizon upper silty superficial horizon (A11), and 2500 +/-25 cal BP for the middle horizon (2A12) developed on sandy parental material (Fig. 3).

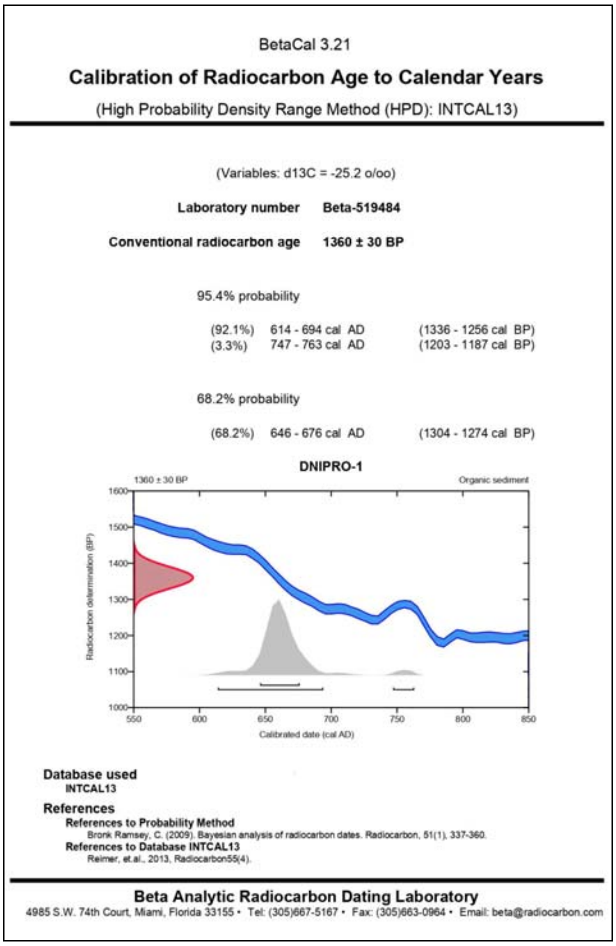

Fig. 3. Chronology dating

Table 1
Physicochemical characterization of Chernozem soil profile studied

Horiz./Depth (cm)	Colour (d)	Colour (w)	$CO_3^{=}$ (%)	Wet (%)	TOC (%)	O.M. (%)	L. Ign. (%)	M.S. ($X10^{-9}$)	Dap. (g/cm3)	Dreal. (g/cm3)	Porosity (%)	Sand (%)	Silt (%)	Clay (%)
A11 (0–20)	10YR 4/1	10YR 6/2	1	4,61	2,24	3,85	7,88	900	1,13	1,94	41,75	10,1	47,4	42,5
2A/B (20–40)	10YR 6/2	10YR 4/1	2,3	3,88	0,48	0,82	4,01	65	1,23	2,01	38,50	42,1	20,4	37,5
3BC1 (40–130)	10YR 7/4	10YR 5/4	14,6	3,01	0,72	1,23	3,51	500	1,17	2,1	44,28	2,6	59,9	37,5

Table 2
Particle size distribution of sand and silt fraction of Chernozem soil profile studied

Horiz./Depth (cm)	2,0–1,0 (%)	1,0–0,5 (%)	0,5–0,25 (%)	0,25–0,125 (%)	0,125–0,063 (%)	0,063–0,031 (%)	0,031–0,015 (%)	0,015–0,007 (%)	0,007–0,0039 (%)	0,0039–0,0019 (%)
A11 (0–20)	0	0	3,55	63,95	32,48	7,5	22,5	5	5	2,5
2A/B (20–40)	1,09	3,03	23,15	63,27	9,45	n.d	n.d	n.d.	n.d.	n.d.
3BC1 (40–130)	0	0	2	24	74	17,5	25	10	5	5

To explain the vegetation climate changes with the initial deepest horizon, we could use the Types of Bioclimatic Regimes of Cámara (2004) applied in other geographic regions (Cámara et al., 2005) from the Worldclim climate database (Hijmans et al., 2005). The change from dry-subhumid mesocryo-mesophylle conditions (16) with the presence of pines and deciduous forests towards the current subhumid-dry and semiarid cryo-mesophylle conditions (7 and 8) corresponding to the steppe could explain the presence of some of the pollen types found (Fig. 4).

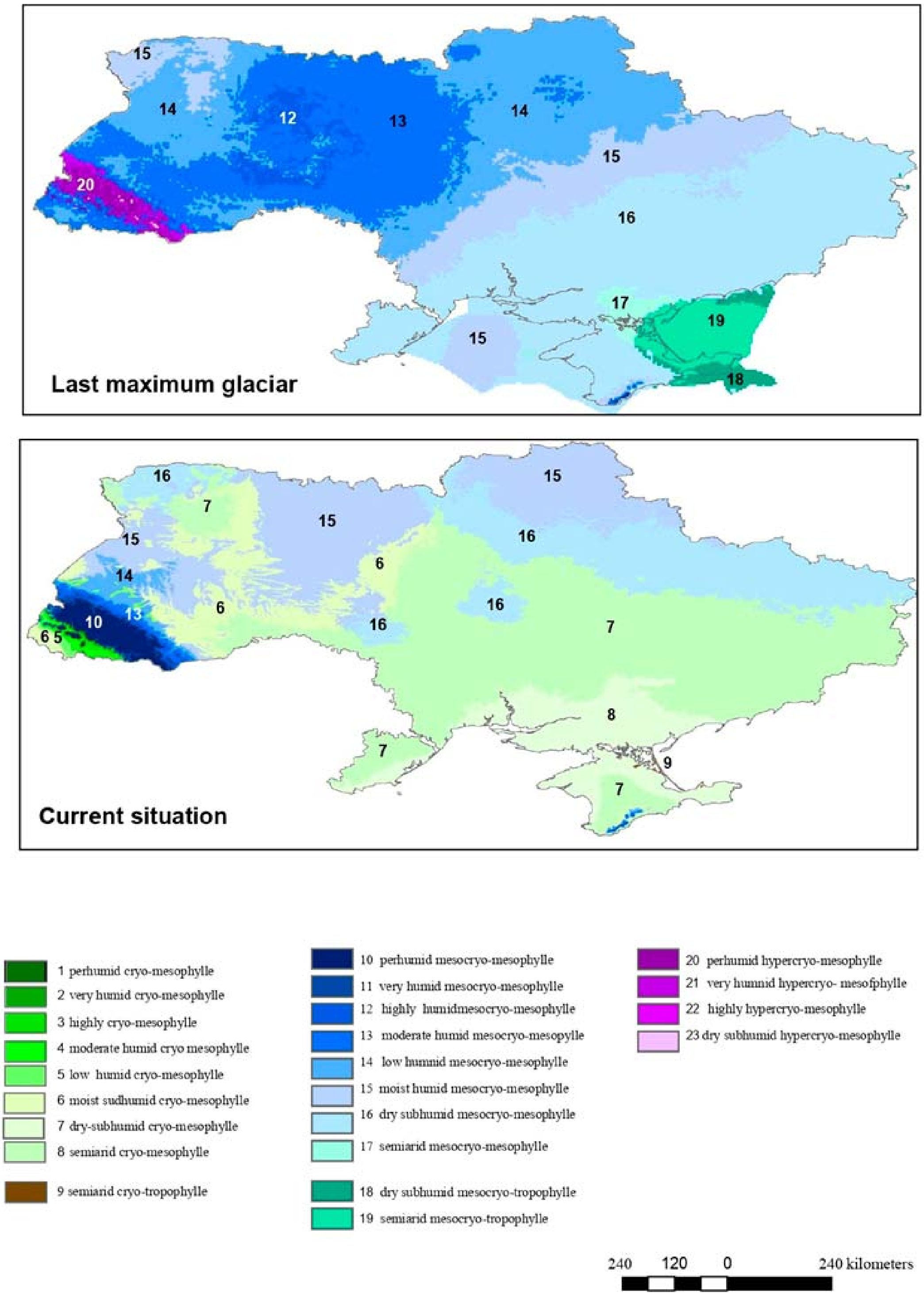

Fig. 4. Types of bioclimatic regimen changes zones (Cámara, 2004) from climate data base wordclim (Hijmans et al., 2005)

Conclusions

The blackening process that affects the upper part of the profile studied comes to mask the presence of two very different horizons formed under different environmental conditions. As a consequence of these erosive phases, the pedogenesis that affects the initial parental loessic material appears independent of that of these higher horizons. These changes have occurred on a historical scale with ecological significance for the last 2500 years BP derived from anthropogenic and/or climatic action with the presence of different species from those currently present.

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