Late Holocene environmental trends in the center of the Russian Plain

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Starting from Dokuchaev time scientists suggested multiple shifts of steppe and forest landscapes based on intricate borders between Chernozems, Phaeozems and Luvisols
Complicated intersection of Retisols, Luvisols, Phaeozems and Chernozems at the Southern fringe of the Forest zone (Chuvashia Republic)
Holocene landscape shifts
based on palynological assemblages in peat of raised bogs,
Serebryannaya, 1992; modified: Alexandrovskiy and Alexandrovsakaya, 2005

Periglacial formations

Forest

Forest-steppe

Steppe

Tula

Kursk

Ka BP
Sedentary tribes introduced fortifications with earth walls.

Typical position – promontories of uplands between ancient gullies.

The Early Iron Age ~2500 yr BP.
Southern Forest steppe, Belgorod region

Buried surface $^{14}$C 2540±100 years CalBP

$^{14}$C 6750±120 years CalBP

Cambic Cryosol
Calcaric

Buried soil – Chernic Luvic Phaeozem

Surface soil – Chernic Greyzemic Luvic Phaeozem
Pedogenetic stages recorded in soils of Southern Forest-Steppe

Stage 1. Cryo-arid pedogenesis.

*Late Pleistocene, MIS2 (?)*

- **a, b** - fine granular microfabric with rounded aggregates common for Upper Pleistocene paleosols
- **c, d** - carbonate neoformations and crushed grains

**Buried Cambic Cryosol in the layer of carbonate loess**

*(recorded both in surface and buried soils ~100 cm below the former surface)*
Pedogenetic stages recorded in soils of Southern Forest-Steppe Stage 2. Forest pedogenesis. Early to mid-Holocene (?)

Argic horizon:
Subangular blocky peds
Multi-layered clay cutans in a sequence of the Bt horizons.

recorded in Argic horizons both in surface and buried soils
Pedogenetic stages recorded in soils of Southern Forest-Steppe
Stage 3. Steppe pedogenesis.
(Holocene climatic optimum – $^{14}C$ 6110±100 years CalBP)

- Dark color, fine granular structure and high humus content
- Groundmass impregnated with dark humus
- Humus enriched in Humic acids ($C_{HA}/C_{FA} < 2$)
- Krotovinas
Pedogenetic stages recorded in soils of Southern Forest-Steppe
Stage 4. Pedogenesis under broadleaf forests (Early Iron Age till present)

Degradation of the upper part of Chernic horizon
Greyzemic features and Albeluvic glossae in Ah horizon
Recorded in surface soil
Central Forest-Steppe, Lipetsk region

Buried soil
Greyzemic Luvic Phaeozem, V-VI centuries BC

Buried soil
Luvic Chernozem, V century AD

Surface soil,
Greyzemic Luvic Phaeozem
Pedogenetic stages recorded in the soils of Central Forest-Steppe

- **Stage 1. Cryo-arid pedogenesis.**
  - Late Pleistocene, MIS2 (?), 140 cm

- **Stage 2. Forest pedogenesis – Argic horizon**
  - Early to mid-Holocene (?)
Pedogenetic stages recorded in the soils of Central Forest-Steppe

• **Stage 3. Steppe pedogenesis - dark Ah, krotovinas**

  – Holocene climatic optimum - $^{14}C \ 5530 \pm 80 \ years \ CalBP$
Pedogenetic stages recorded in the soils of Central Forest-Steppe

- **Stage 4.** Pedogenesis under broadleaf forests - degradation of the upper part of Chernic horizon, Greyzemic features and Albeluvic glossae in Ah horizon
  - Since the Early Iron Age
Pedogenetic stages recorded in the soils of Central Forest-Steppe

• **Stage 5. Arid pedogenesis** – dark Ah, carbonate impregnation, carbonate films above clay cutans
  – V century AD

Carbonate films over clay cutans in the Bt horizon
Pedogenetic stages recorded in the soils of Central Forest-Steppe

- Stage 6. Pedogenesis under broadleaf forests - degradation of the upper part of Chernic horizon, Greyzemetic features and Albeluvic glossae in Ah horizon
  - The last 1500 years
Broadleaf forest, Chuvashia Republic
Albic Retisols, left – surface soil; right – buried soil (¹⁴C 2068 CalBP)
Pedogenetic stages recorded in soils of broadleaf forest

Stage 1. Cryo-arid pedogenesis.

Late Pleistocene, MIS2 (?)

Buried Cambic Cryosol in the layer of carbonate loess (recorded both in surface and buried soils ~100 cm below the former surface)

Fine granular microfabric

Carbonate neoformations, crushed

Cambic Turbic Cryosol, Central Yakutia

Buried Ca

(recorded both in surface and buried soils ~100 cm below the former surface)
Pedogenetic stages recorded in soils of broadleaf forest

Stage 1. Cryo-arid pedogenesis.

*Late Pleistocene, MIS2 (?)*

**Cambic Turbic Cryosol, Central Yakutia**

**Microstructure of Stilfrid B paleosol (MIS3),**

*Terhorst et al., 2013*
Pedogenetic stages recorded in soils of broadleaf forest

Stage 2. Forest pedogenesis (clay cutans, Retic properties, Albeluvic glossae)

*Through the whole Holocene till present*

**Buried soil**

**Surface soil**

Grain size distribution pattern
Micromorphology of Albic Retisols, 
broadleaf forest, Chuvashia Republic

Surface soil  Buried soil

E

EBt

Bt
Broadleaf forest, Chuvashia Republic

Microbiomorphic data for surface (left) and buried (right) soils. a, b – ratio of taxa in the spore-pollen spectrum; c, d – ratio of major groups in the spore-pollen spectrum; e, f – composition of the phytoliths complex.

Bacterial 16S rRNA genes content in buried and surface soils estimated by qPCR.
Anthropogenic impact and diagenesis in the buried Retisol, broad-leaved forest, Chuvash Republic

a – Akhb horizon. Charcoal with the ring of diagenetic carbonates. 10II;
b - Ahkb horizon. Bone fragment. 4II;
c – AEkb horizon. Bone fragments, diagenetic carbonates and admixture of Bt horizon. 4X;
d - Ekb horizon. Diagenetic carbonates. 4X.
Shallow buried Late Pleistocene paleosols are widespread within the profile of surface soils

- Due to shallow depth of the upper loess layer on the uplands buried soils are included within the profile of surface soils

- The lower horizons (BC, C) are former Ah horizons of buried soils

- Calcaric Cryosols indicate cold and arid environment of the Late Pleistocene

- Within the steppe-forest ecotone buried soils show striking similarities indicating simplified periglacial zonality (hyper-zonality of A. Velichko, 1973)

**Dokuchaev bioclimatic zonal soil sequence**
Conclusions

- Due to a combination of more dynamic and more stable features, soils of the forest-steppe areas are polygenetic and show features of both forest and steppe pedogenesis.

- The Retisols at the southern fringe of the forest zone show landscape stability in a studied time/space range.

- Dynamic soil properties (humus and calcareous profile, Greyzemic features) are proxy of multi-directional landscape shifts.

- Clay cutans are more stable and indicate one-way soil evolution: once appeared they are then inherited by subsequent stages.