Late Holocene environmental trends in the center of the Russian Plain

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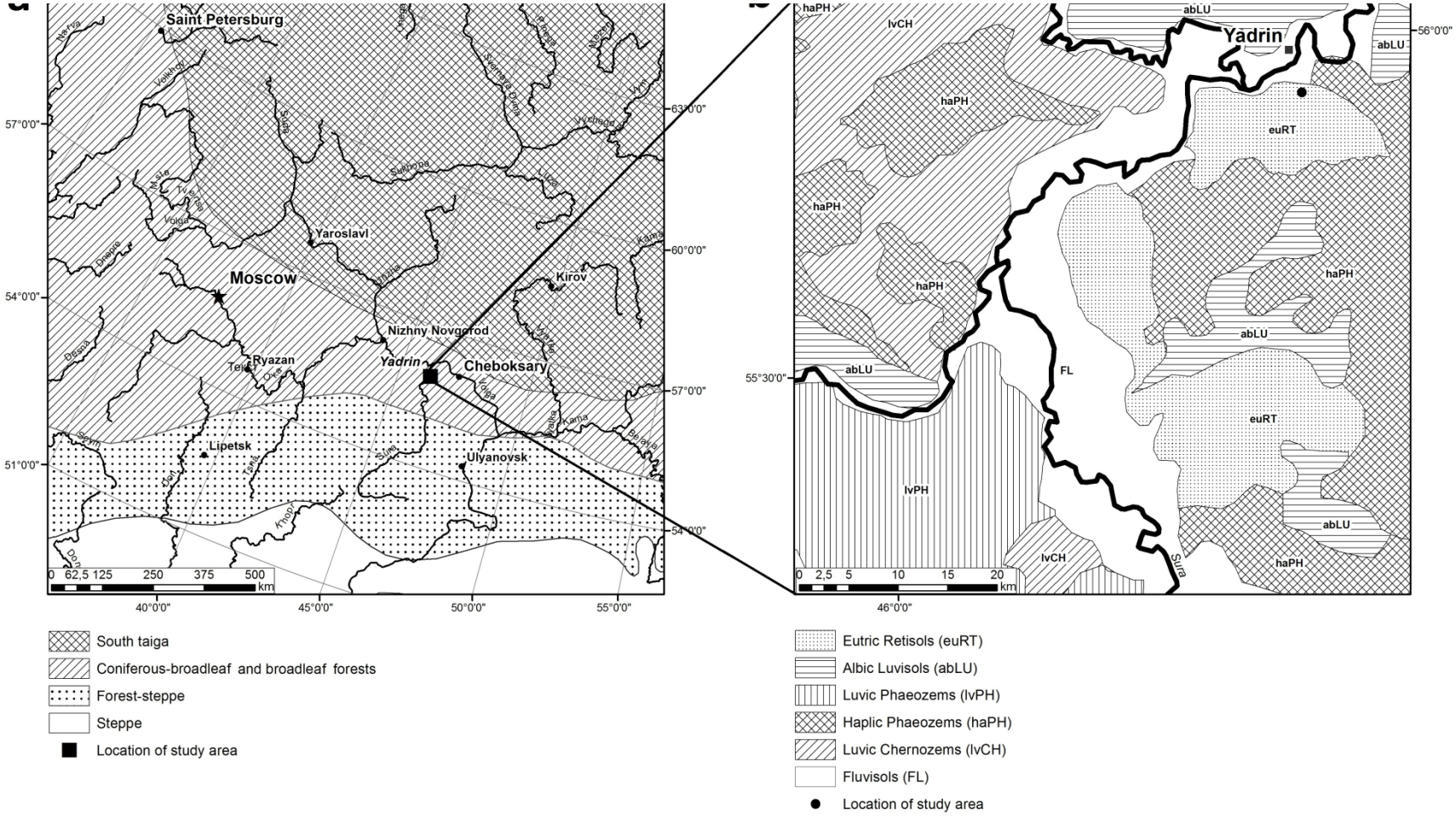
Central Forest-Steppe,

Lipetsk region

Starting from Dokuchaev time scientists suggested multiple shifts of steppe and forest landscapes based on intricate borders between Chernozems, Phaeozems and Luvisols

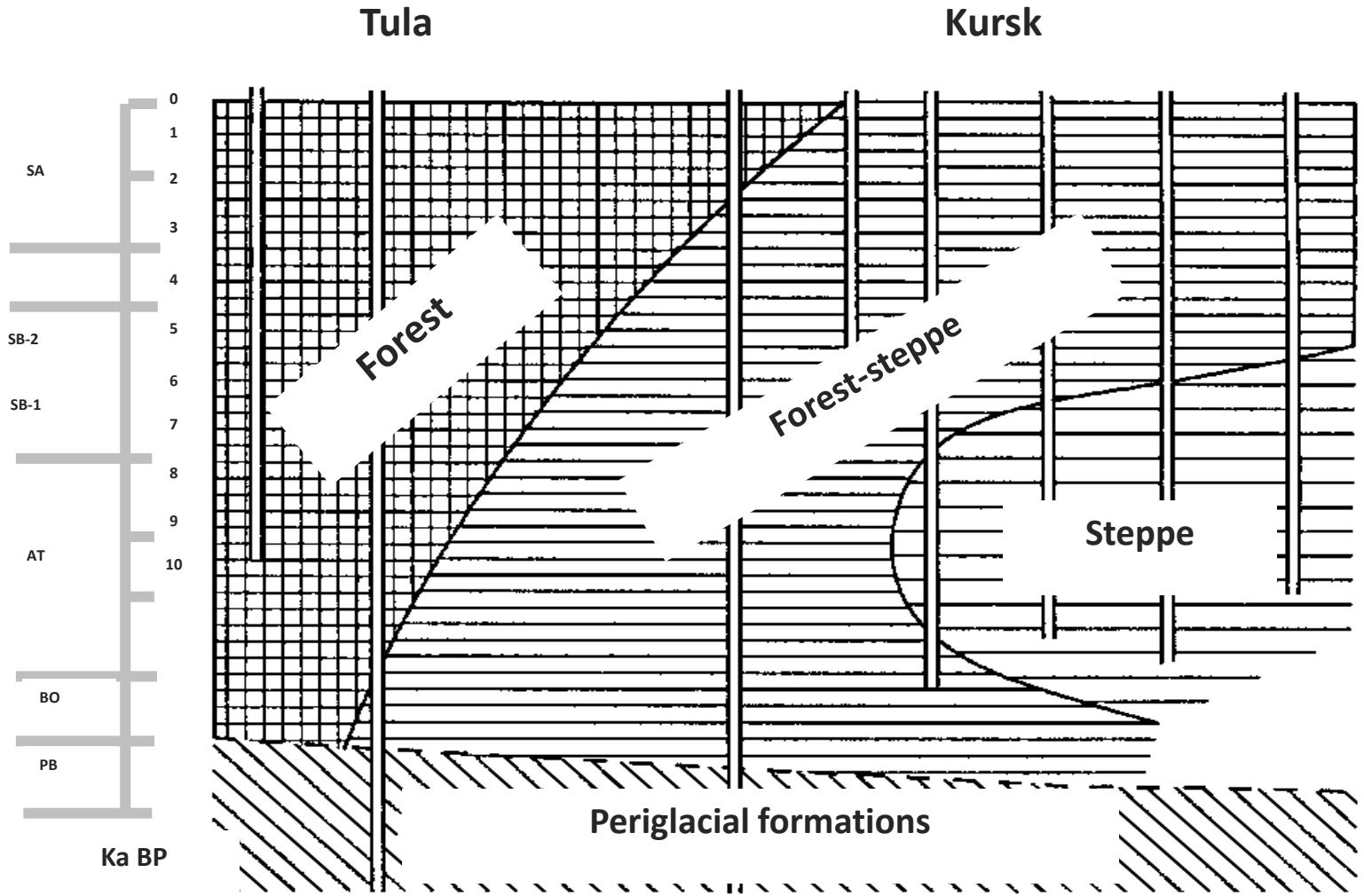
Complicated intersection of Retisols, Luvisols, Phaeozems and Chernozems at the Southern fringe of the Forest zone *(Chuvashia Republic)*

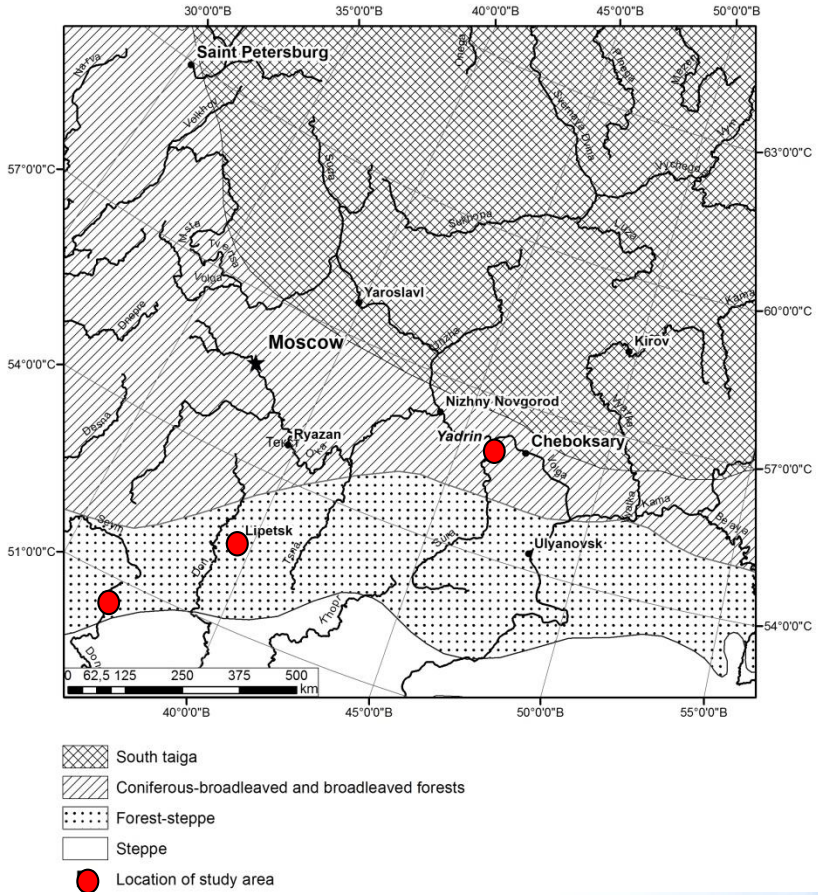


Holocene landscape shifts

based on palynological assemblages in peat of raised bogs,

Serebryannaya, 1992; modified: Alexandrovskiy and Alexandrovsakaya, 2005

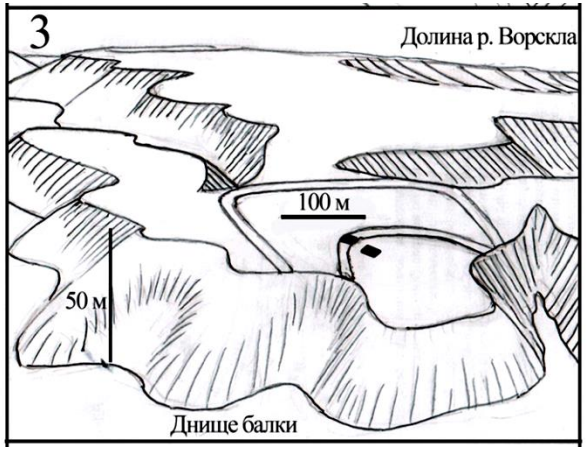




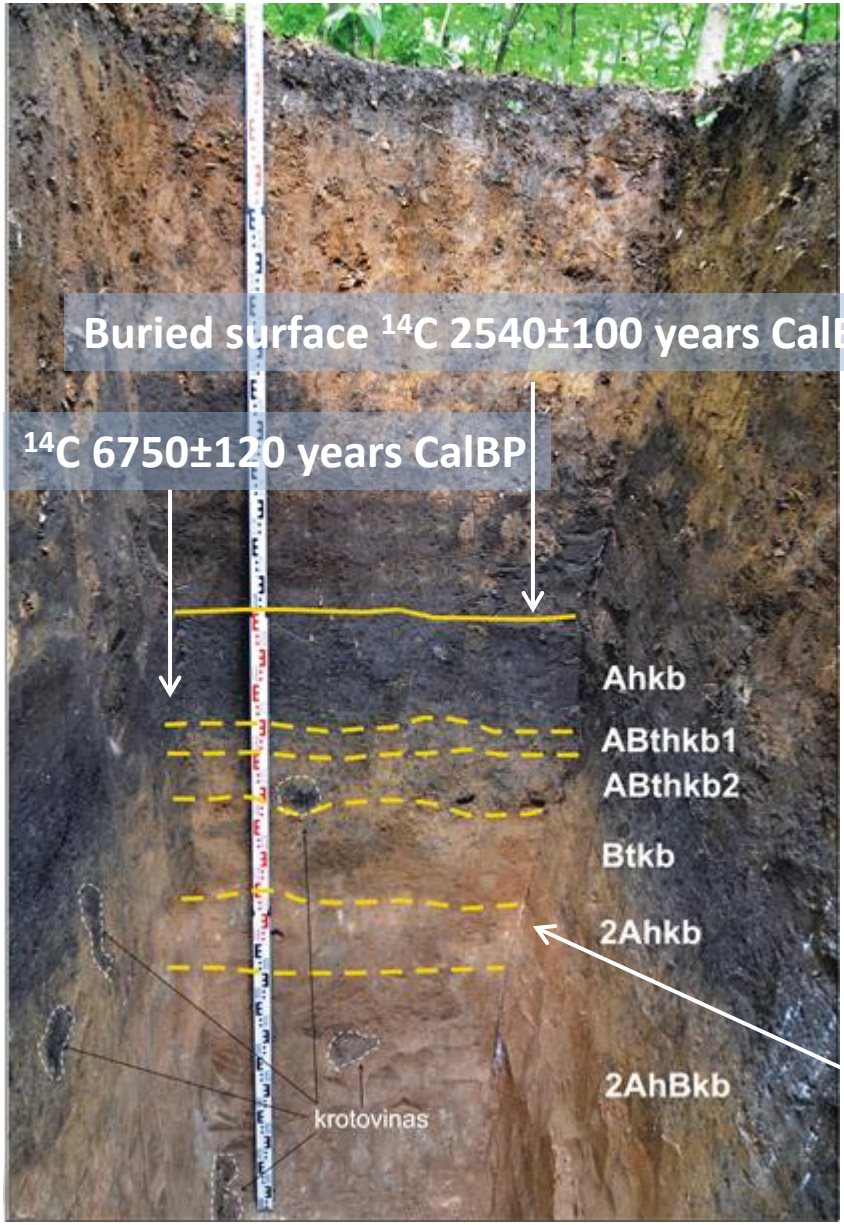
The Early Iron Age ~2500 yr BP

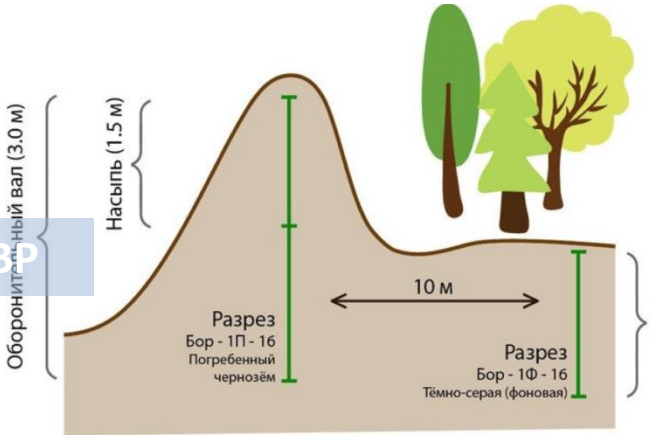
Sedentary tribes introduced fortifications with earth walls

Typical position – promontories of uplands between ancient gullies

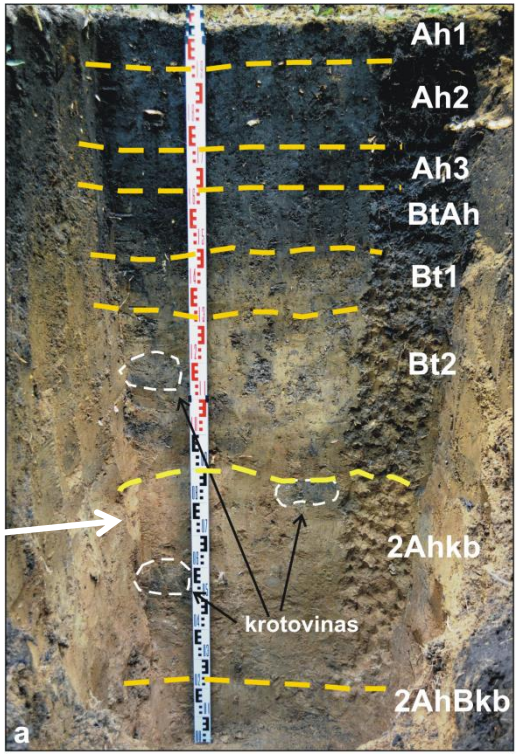


Southern Forest steppe, Belgorod region





Cambic Cryosol
Calcaric



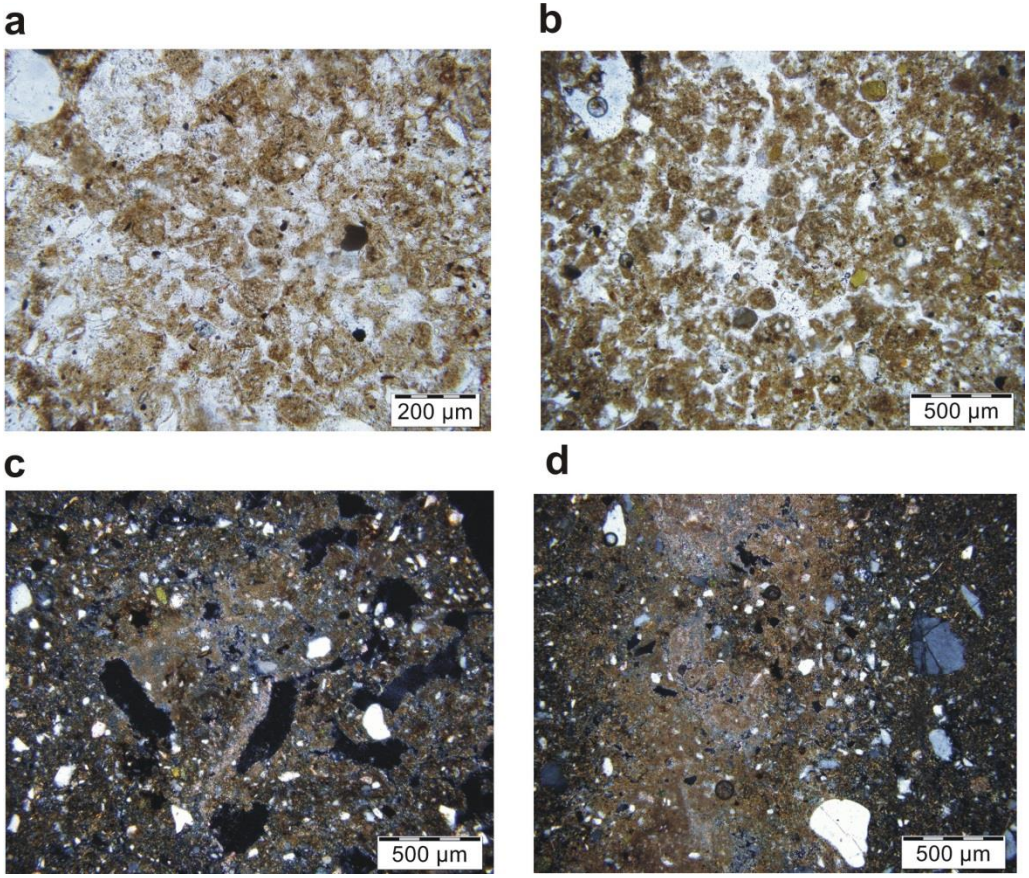
Buried soil – Chernic Luvic Phaeozem

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

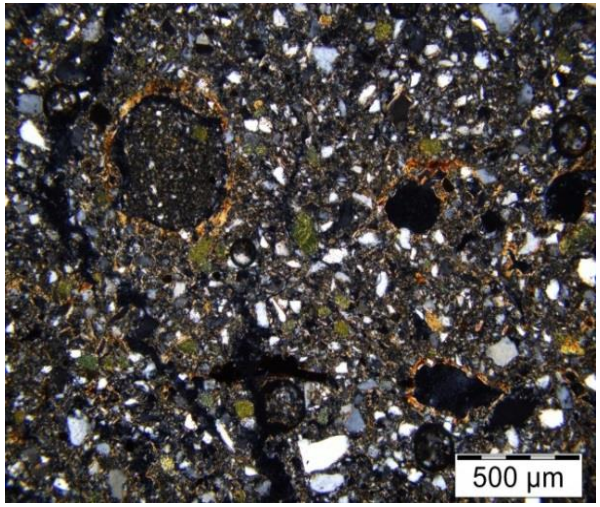
c, d- carbonate neoformations and crushed grains

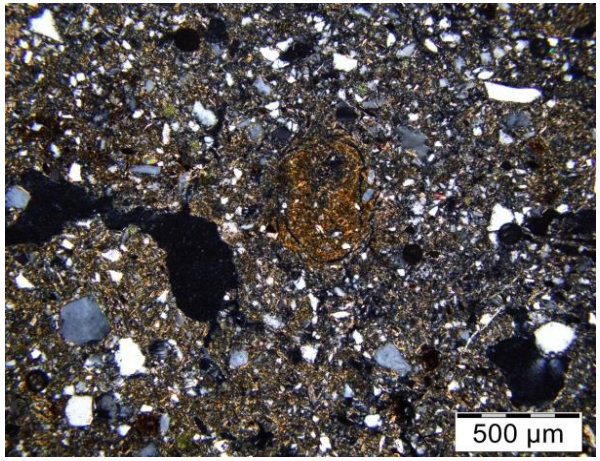
Buried Cambic Cryosol in the layer of carbonate loess

(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

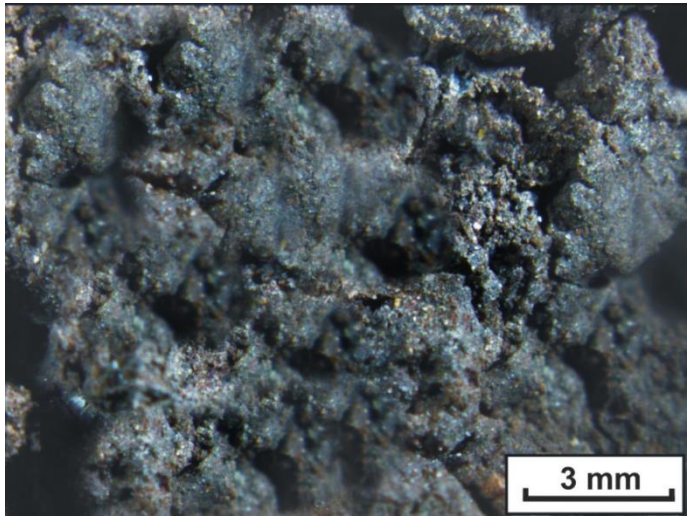
Multi-layered clay cutans in a sequence of the Bt horizons.

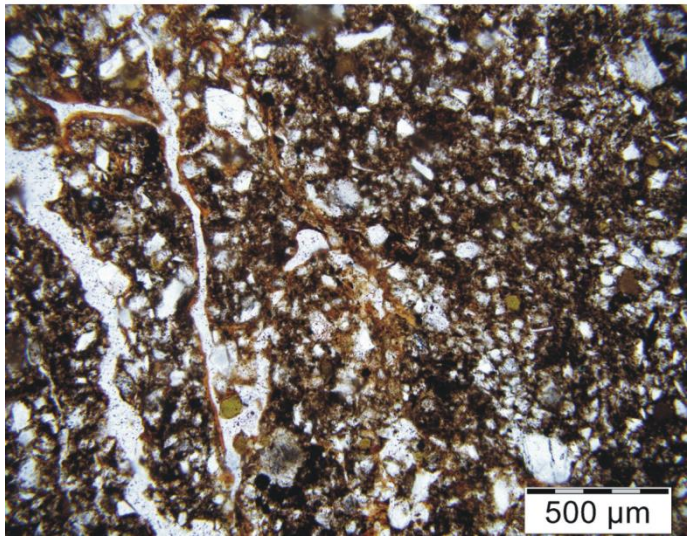
recorded in Argic horizons both in surface and buried soils

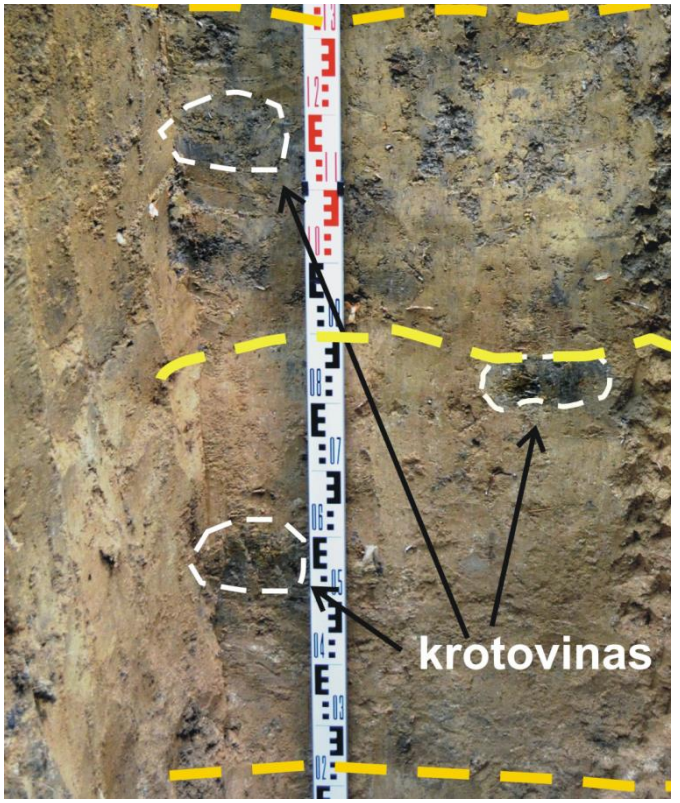
Pedogenetic stages recorded in soils of Southern Forest-Steppe

Stage 3. Steppe pedogenesis.

(Holocene climatic optimum – ^{14}C 6110±100 years CalBP)



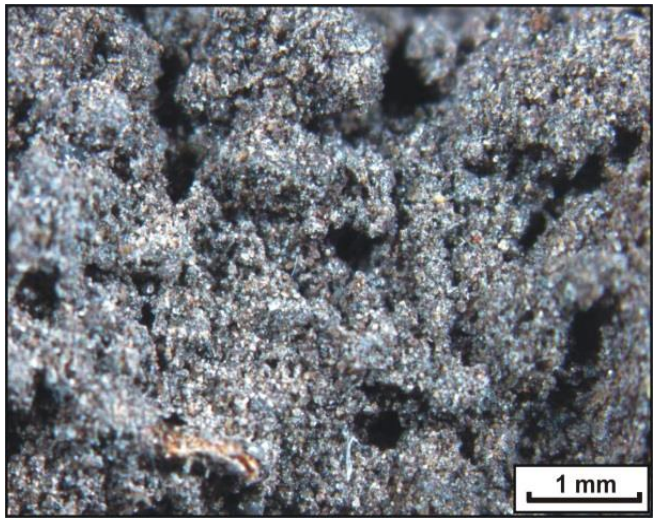


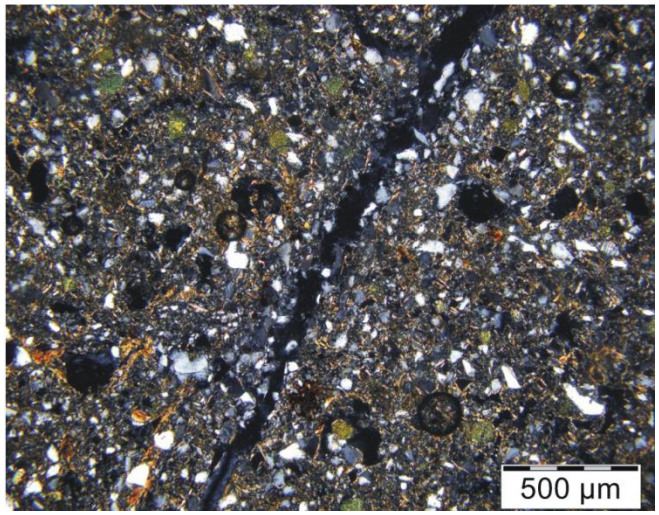


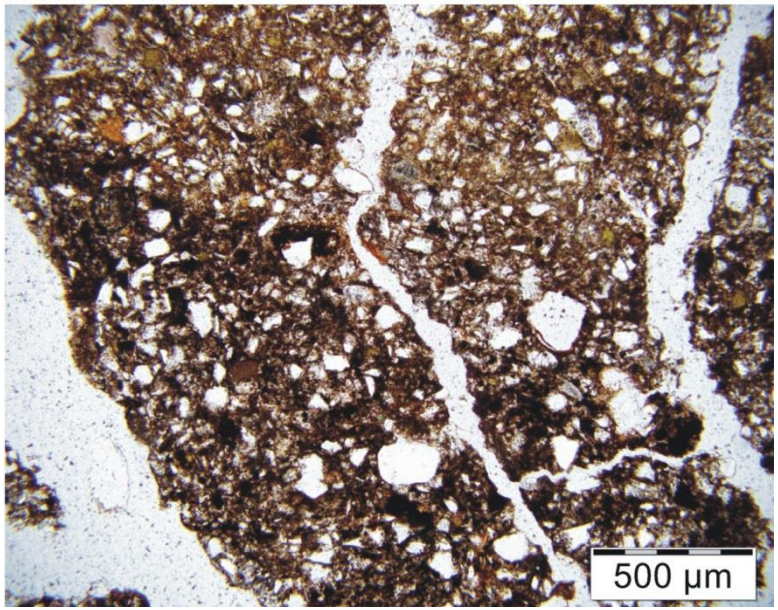
- **Dark color, fine granular structure and high humus content**
- **Groundmass impregnated with dark humus**
- **Humus enriched in Humic acids (C_{HA}/C_{FA} <2)**
- **Krotovinas**

Pedogenetic stages recorded in soils of Southern Forest-Steppe

Stage 4. Pedogenesis under broadleaf forests (Early Iron Age till present)

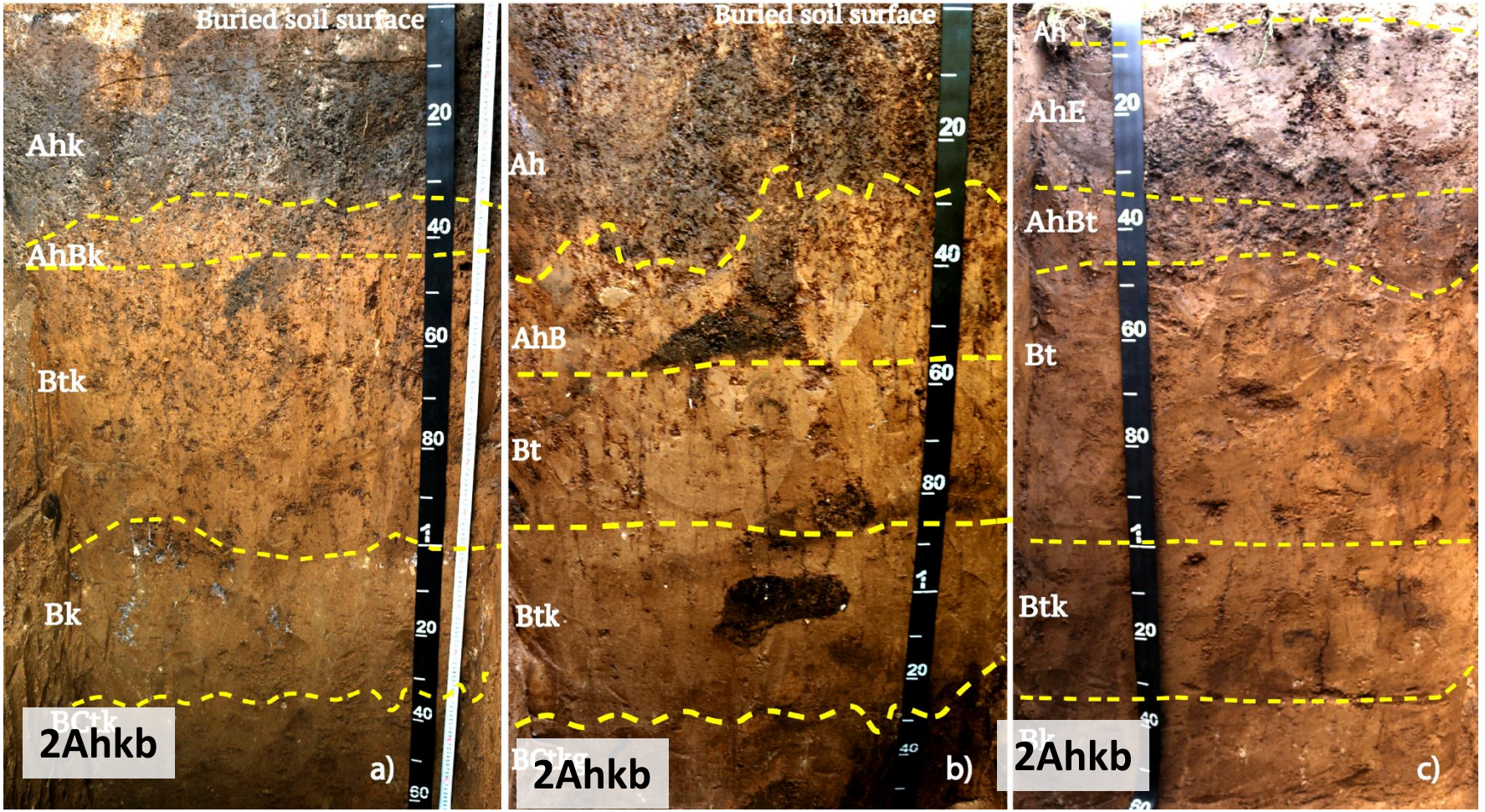






- Degradation of the upper part of Chernic horizon
- Greyzemic features and Albeluvic glossae in Ah horizon
- Recorded in surface soil

Central Forest-Steppe, Lipetsk region



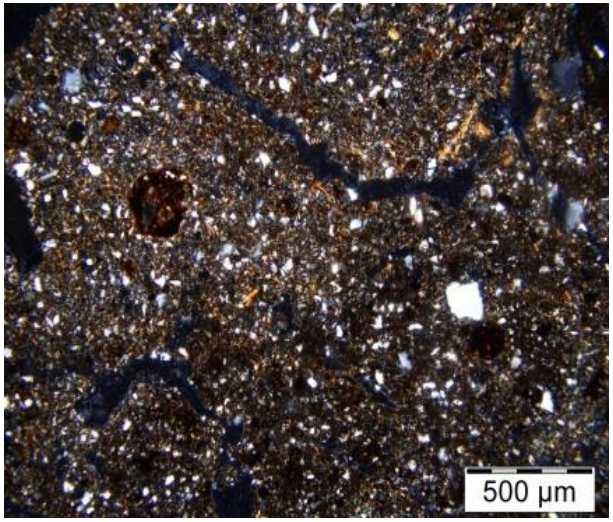
Buried soil
Greyzemic Luvic Phaeozem,
V-VI centuries BC

Buried soil
Luvic Chernozem,
V century AD

Surface soil,
Greyzemic Luvic
Phaeozem

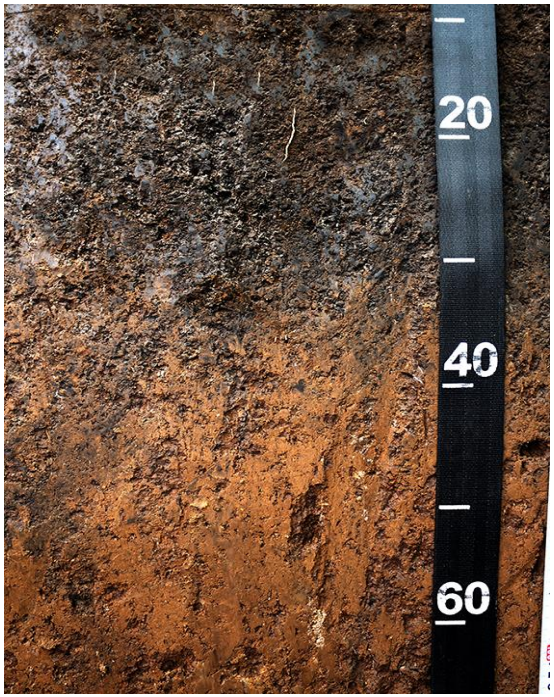
Pedogenetic stages recorded in the soils of Central Forest-Steppe

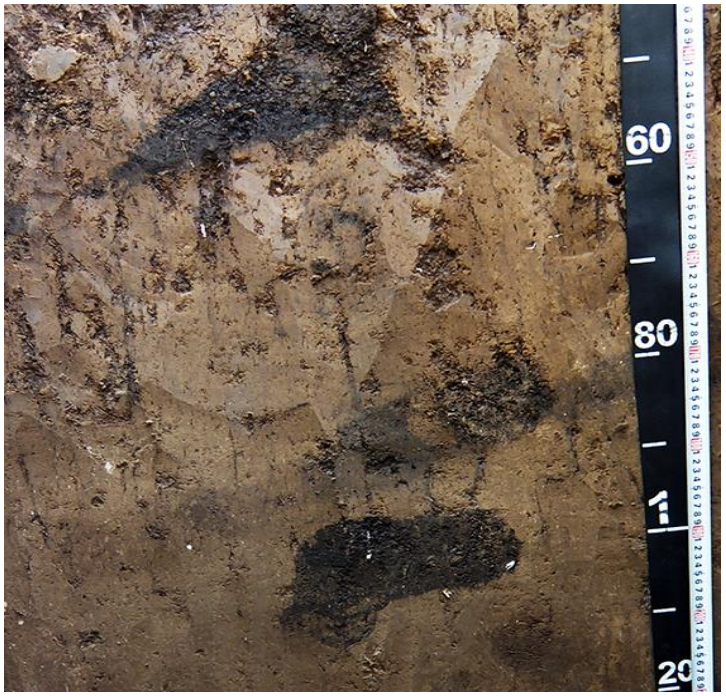
- **Stage 1. Cryo-arid pedogenesis.**
  - Late Pleistocene, MIS2 (?), 140 cm
- **Stage 2. Forest pedogenesis – Argic horizon**
  - Early to mid-Holocene (?)



Pedogenetic stages recorded in the soils of Central Forest-Steppe

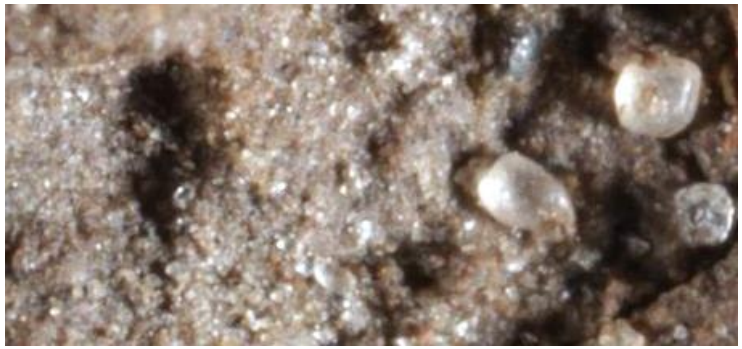
- **Stage 3. Steppe pedogenesis - dark Ah, krotovinas**
  - Holocene climatic optimum - ^{14}C *5530±80 years CalBP*





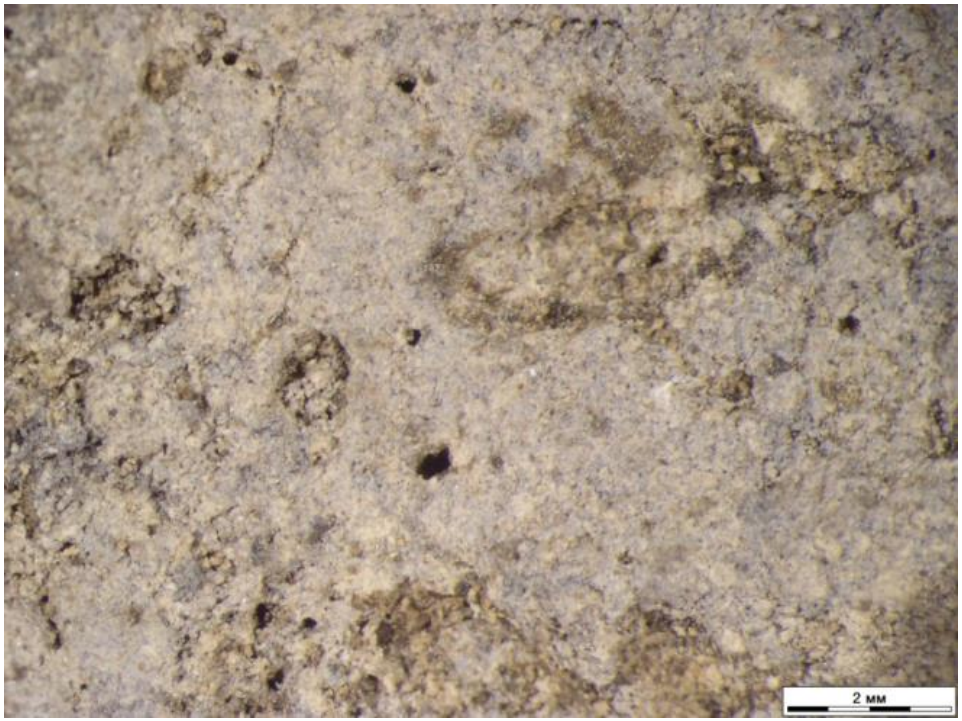
Pedogenetic stages recorded in the soils of Central Forest-Steppe

- **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



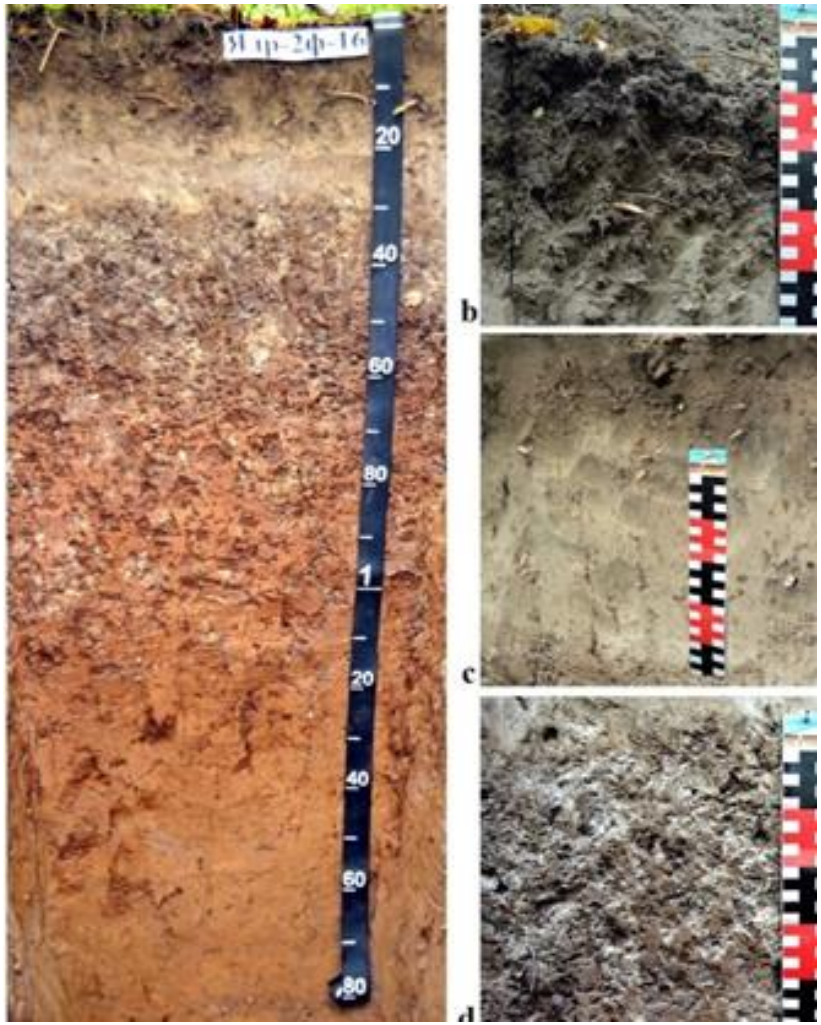
Carbonate films over clay cutans in the Bt horizon

Pedogenetic stages recorded in the soils of Central Forest-Steppe

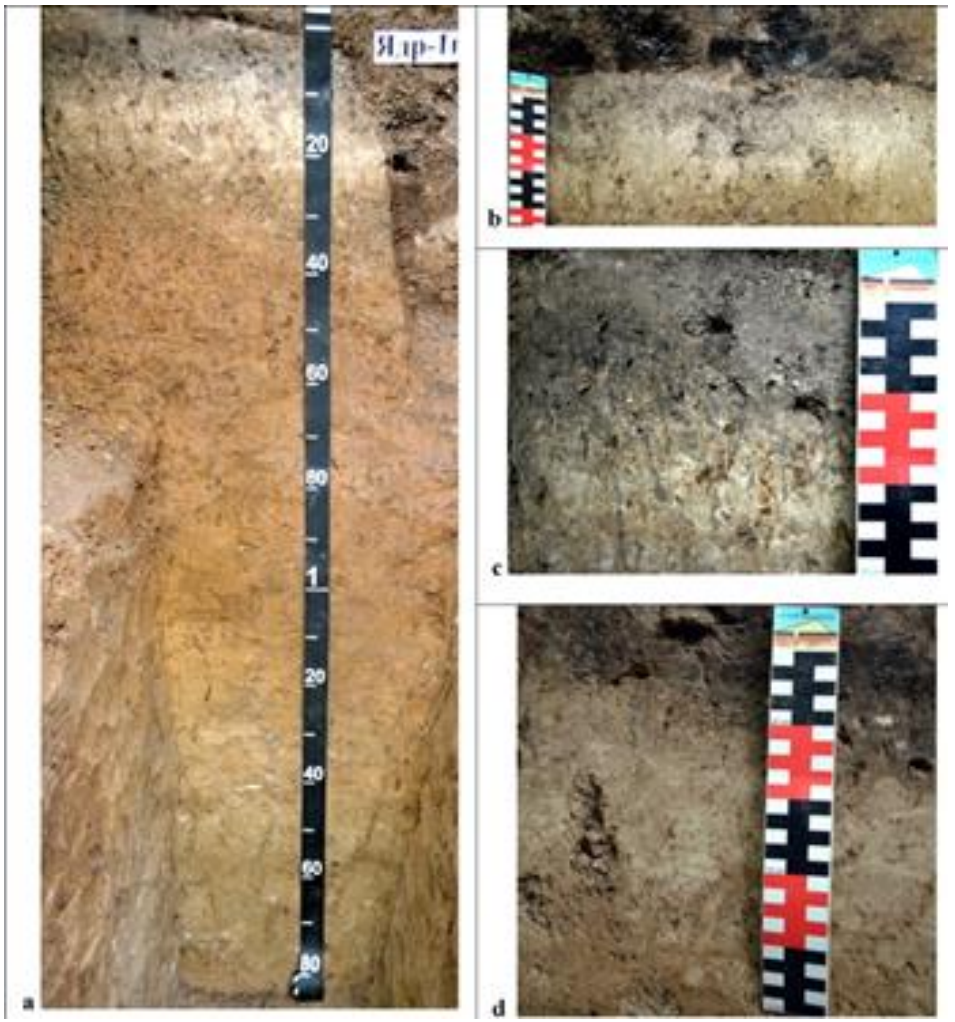
- **Stage 6. Pedogenesis under broadleaf forests - degradation of the upper part of Chernic horizon, Greyzemic features and Albeluvic glossae in Ah horizon**
  - The last 1500 years

Broadleaf forest, Chuvashia Republic

Albic Retisols, left – surface soil; right – buried soil (^{14}C 2068 CalBP)



Surface soil

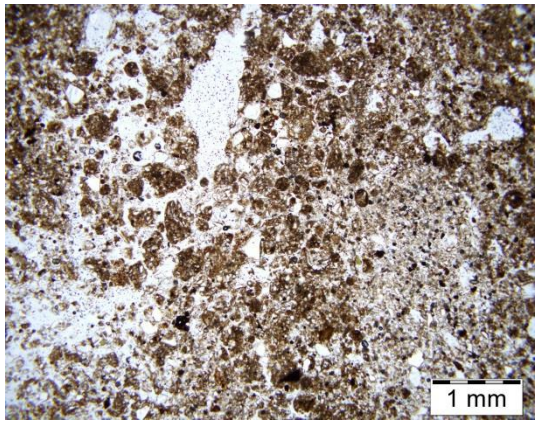


Buried soil

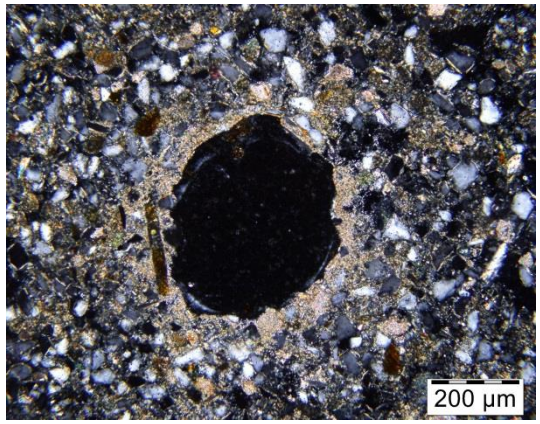
Pedogenetic stages recorded in soils of broadleaf forest

Stage 1. Cryo-arid pedogenesis.

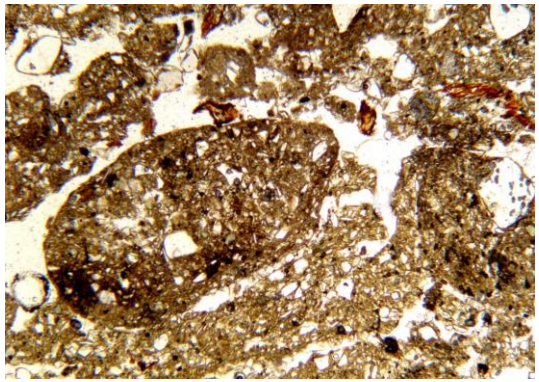
Late Pleistocene, MIS2 (?)

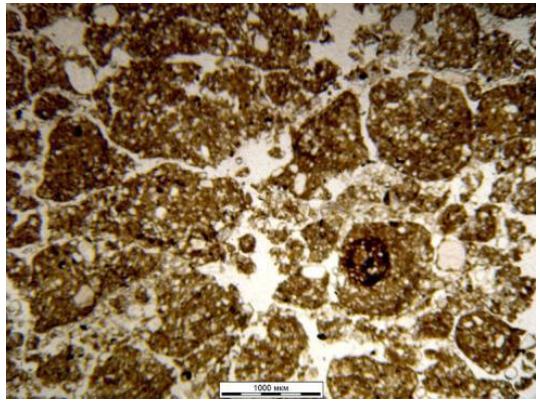


Fine granular microfabric



Carbonate neoformations, crushed





Cambic Turbic Cryosol, Central Yakutia

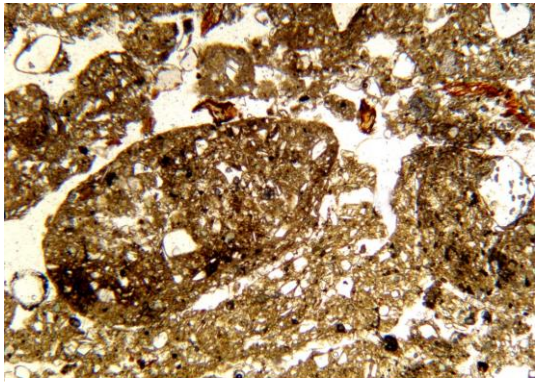
Buried Ca

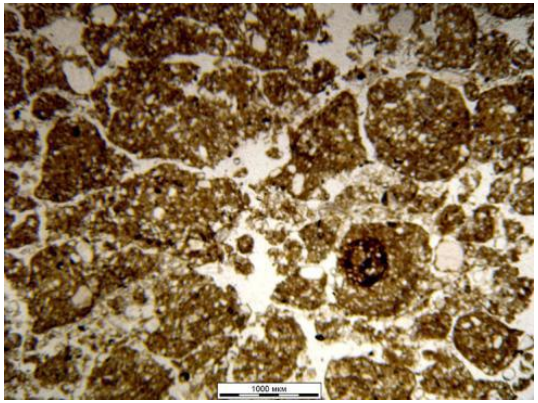
(recorded both in surface and buried soils ~100 cm below the former surface)

Pedogenetic stages recorded in soils of broadleaf forest

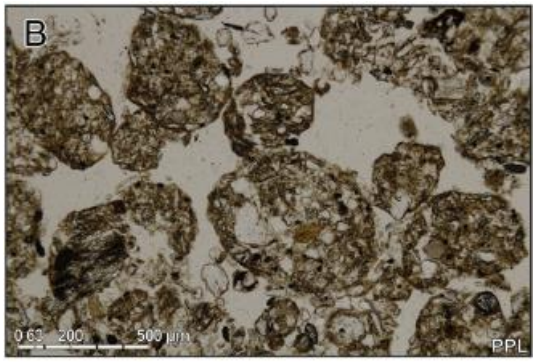
Stage 1. Cryo-arid pedogenesis.

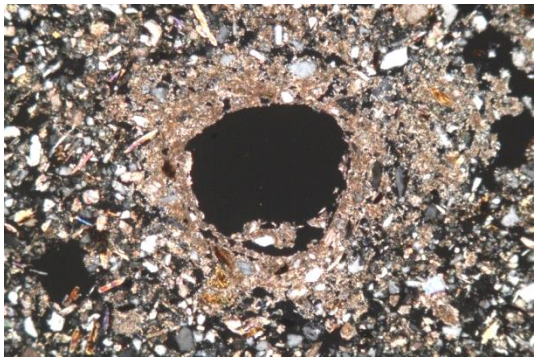
Late Pleistocene, MIS2 (?)





Cambic Turbic Cryosol, Central Yakutia





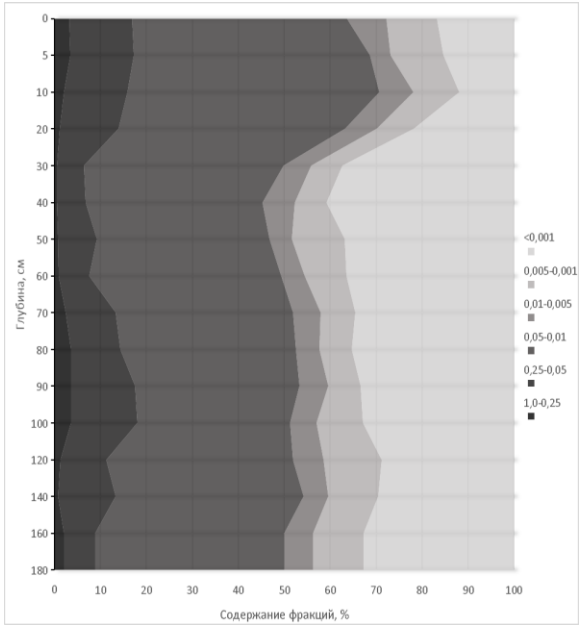
Microstructure of Stilfrid B paleosol (MIS3),

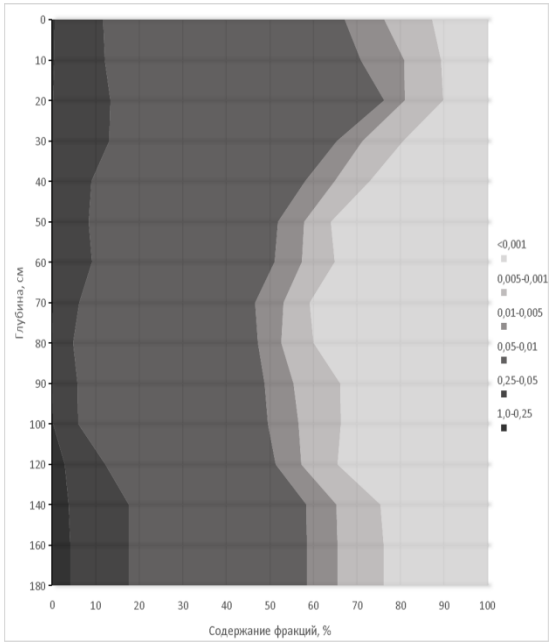
Terhorst et al., 2013

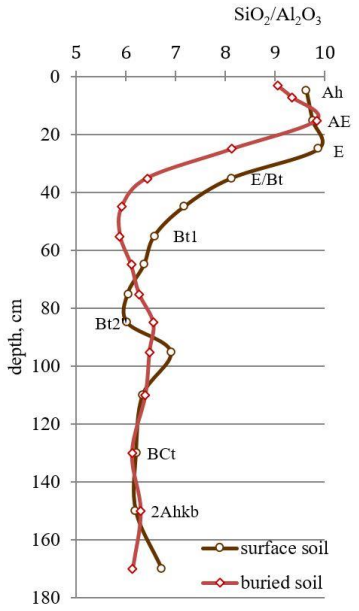
Pedogenetic stages recorded in soils of broadleaf forest

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

Through the whole Holocene till present





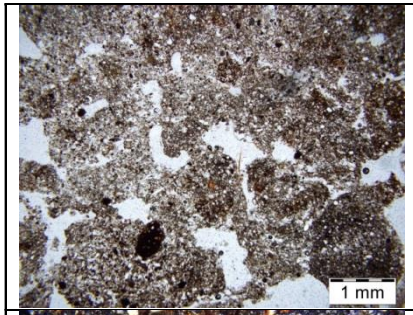
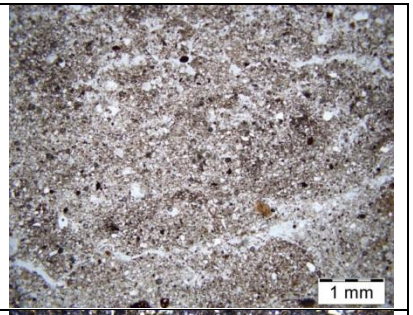
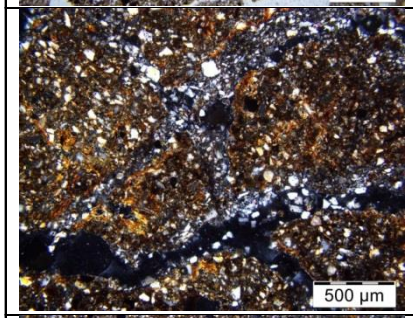
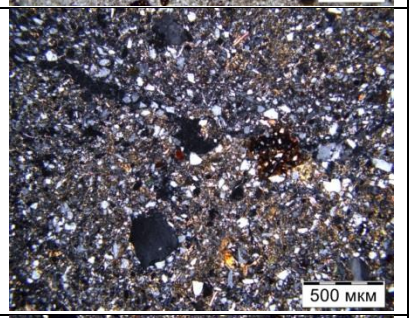
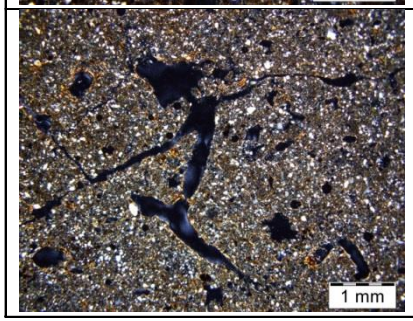
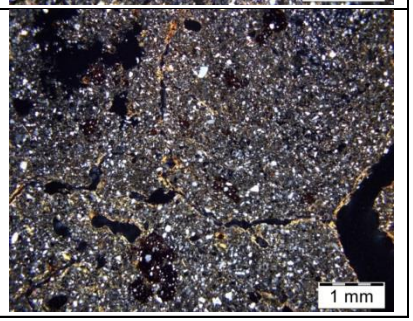


Buried soil **Surface soil**

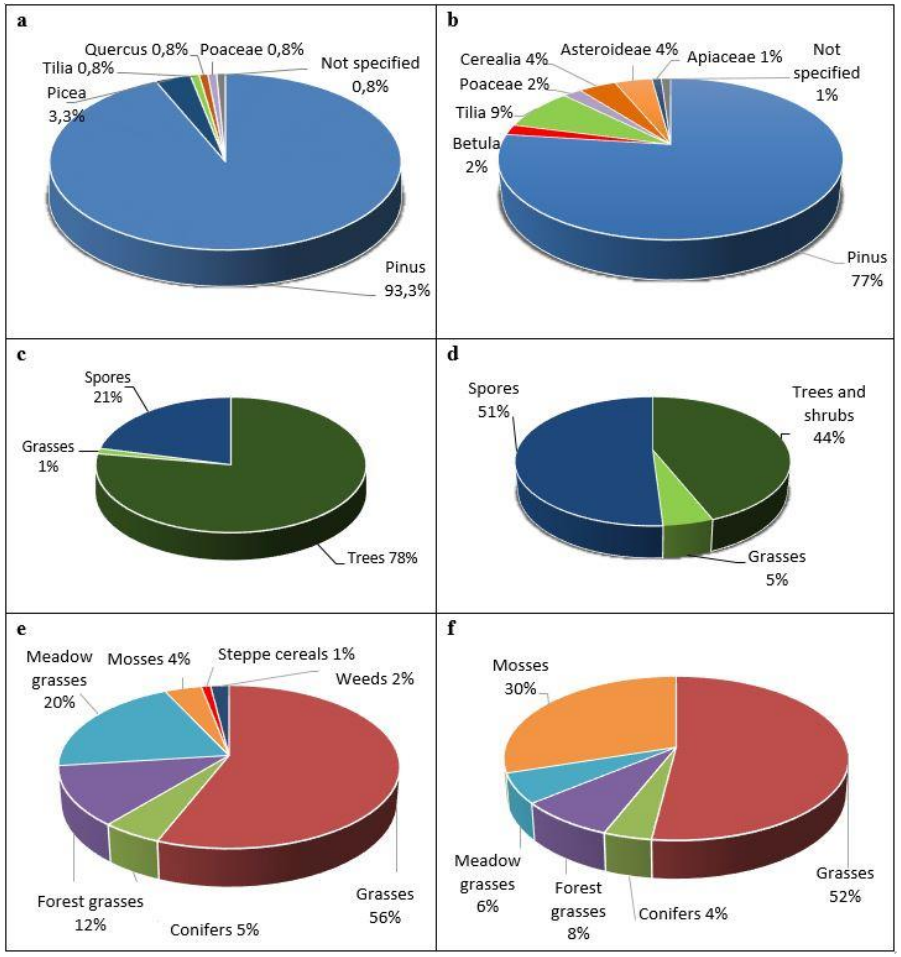
Grain size distribution pattern

Micromorphology of Albic Retisols,

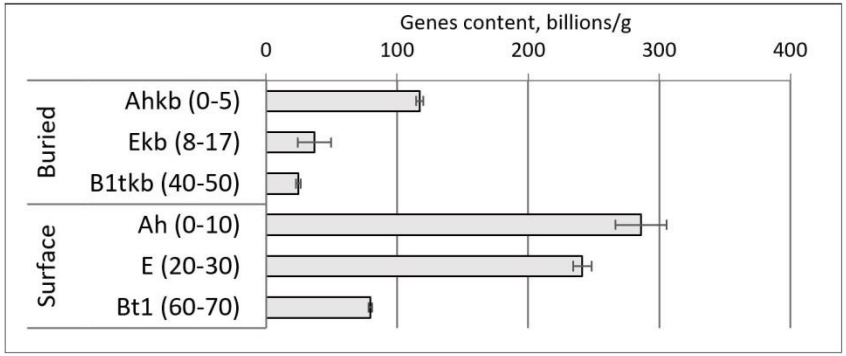
broadleaf forest, Chuvashia Republic

	Surface soil	Buried soil
E		
EBt		
Bt		

Broadleaf forest, Chuvashia Republic

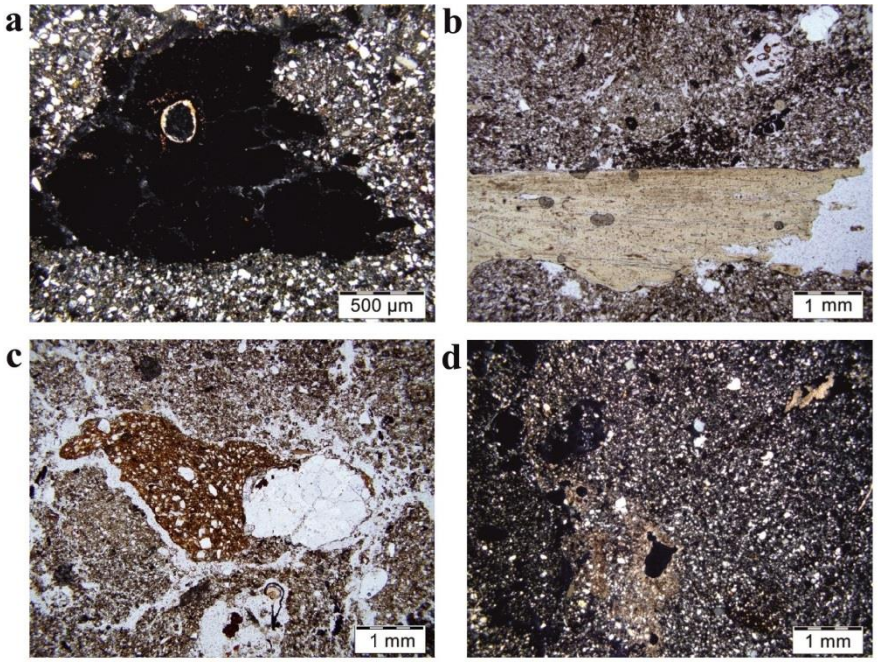


Microbiomorphic data for surface (left) and buried (right) soils. a, b – ratio of taxa in the spore-pollen spectrum; c, d – ratio of major groups in the spore-pollen spectrum; e, f – composition of the phytoliths complex.

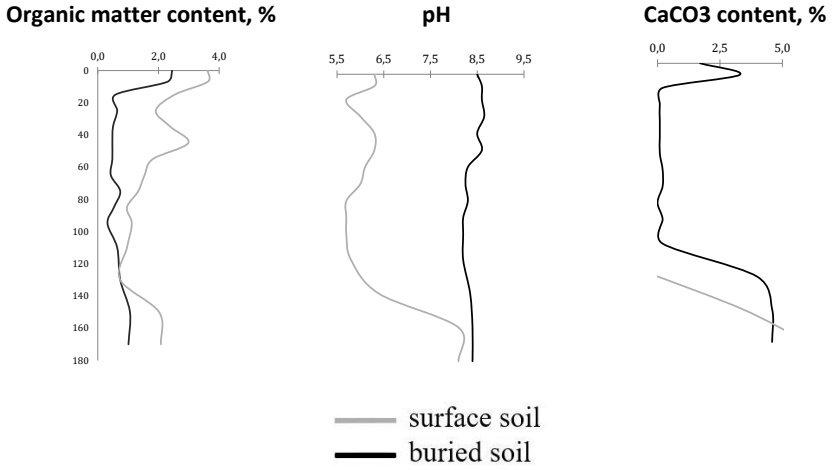


Bacterial 16S rRNA genes content in buried and surface soils estimated by qPCR.

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

Dokuchaev bioclimatic zonal soil sequence

- 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)

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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 porperties (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