Carboniferous Disconformities, Paleosols and Paleolandscapes of the East European Craton

Kabanov P.B.,*
*Institute of Physical, Chemical, and Biological Problems of Soil Science RAS, Pushchino, Russia.
kabanovp@gmail.com

and

Alekseeva T.V., Alekseev A.O.*, Burova L.V.**, Alekseeva V.A.***, Chuhlanceva E.R.***
**RTC, Oil company "Gazprom Neft", Tyumen, Russia
***Geography, Lomonossov Moscow State University, Moscow, Russia

Summary

The East European Craton (EEC) is one of major circum-arctic continental blocks. Carboniferous "intraformational" disconformities of the EEC are as common as in other well-studied coeval shallow-marine successions of the World. Paleosols and associated terrestrial beds at disconformities unravel ancient climates and landscape processes in great detail. The middle Pennsylvanian calcimagnesian plains of the central and central-northern EEC featured harsh semiarid to arid climate, palygorskite and smectite pedogenesis, and yet were fairly vegetated. The Upper Viséan succession of southern Moscow Basin (central EEC) show presence of rhizoid paleokarsts and two levels of early-transgressive palustrine saponitic marls. Aridization trend is recorded throughout the Lower Serpukhovian by decline of Stigmaria and emergence of lagoonal and soil palygorskites.

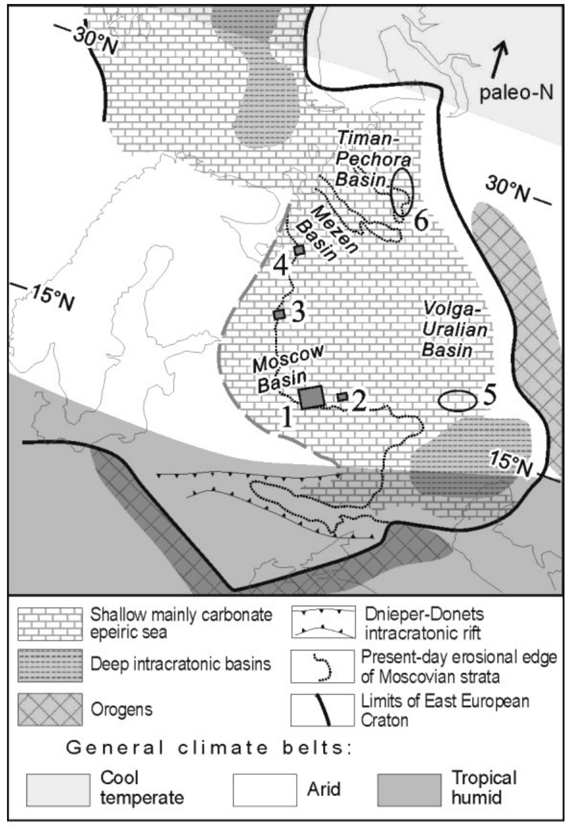

Figure 1: Moscovian-age paleogeography of the East European Craton (modified from Nikishin et al., 1996) and location of studied sections. Outcrop materiials are from rectangles: 1-southern MS, 2 – southeastern MS (Oka-Tsna Swell), 3 – northern MS, 4 – western MZ. Core from hydrocarbon fields and prospects in ellipses: 5 – Buzuluk Depression (southern VU), 6 – eastern TP.

Introduction

The East European Craton (EEC; also known as Baltica or Russian Platform) is one of major circum-arctic continental blocks with insufficiently known Paleozoic facies and paleogeography. During the Carboniferous the central and eastern EEC was covered by a succession of tropical epeiric-platform seas with predominantly carbonate sedimentation (Fig. 1). The two major Carboniferous lowstand phases are the Tournaisian/Viséan and the Mississippian/Pennsylvanian disconformities (5-8 My hiatuses in central EEC) marked by weathering crusts and deep (>100 m) incised valleys. The mid-Viséan to Serpukhovian and Moscovian to Gzhelian predominantly carbonate successions between these unconformities contain numerous subaerial surfaces, some with proven extension to distance over 1000 km (Kabanov et al., 2010). These successive disconformities (parallel unconformities) represent geologically short (mostly < 0.3 My) hiatuses that are usually below biostratigraphic resolution and define cyclothemic character of shallow-marine sections across the EEC. Paleosols and associated non-marine features at these disconformities are the topic of the ongoing interdisciplinary study. In central EEC, unusually well preserved original geochemical and mineralogical signals due to lack of significant burial, heating, and hydrocarbon migration, allow detailed landscape reconstructions. Core data from the Volga-Uralian (VU) and Timan-Pechora (TP) hydrocarbon basins of the eastern EEC confirm extensive development of "intraformational" disconformities having high yet mostly unused correlation potential.

Methods

In addition to field, thin-section and SEM (secondary emission mode) observations, a range of instrumental methods was applied. The mineral composition of bulk and clay-fraction samples was studied by x-ray diffraction (Cu Kά radiation). Elemental concentrations were determined by x-ray fluorescence (XRF) spectrometer "SPECTROSCAN MAKC-GV" with results calibrated to standard soil and rock samples. Total-organic-carbon content in clay fractions was determined by the potassium dichromate method. Magnetic properties were examined in dry samples using room-temperature measurements under a Newport 4" Electromagnet (Kabanov et al. 2010).

Results

Middle Pennsylvanian

Disconformities in the Podolskian through Myachkovian succession of the Moscow Basin (MS; central EEC) and the Mezen Basin (MZ; northern EEC) have been discovered in recent years (Kabanov et al., 2010). Thin (mostly < 1 m) paleosols developed at seven successive unconformities generally consist of an upper terrestrial clay layer or 'topclay,' a crust of beta calcrete beneath the topclay, and a weakly karsted substrate limestone penetrated by rhizocretions (Fig. 2).

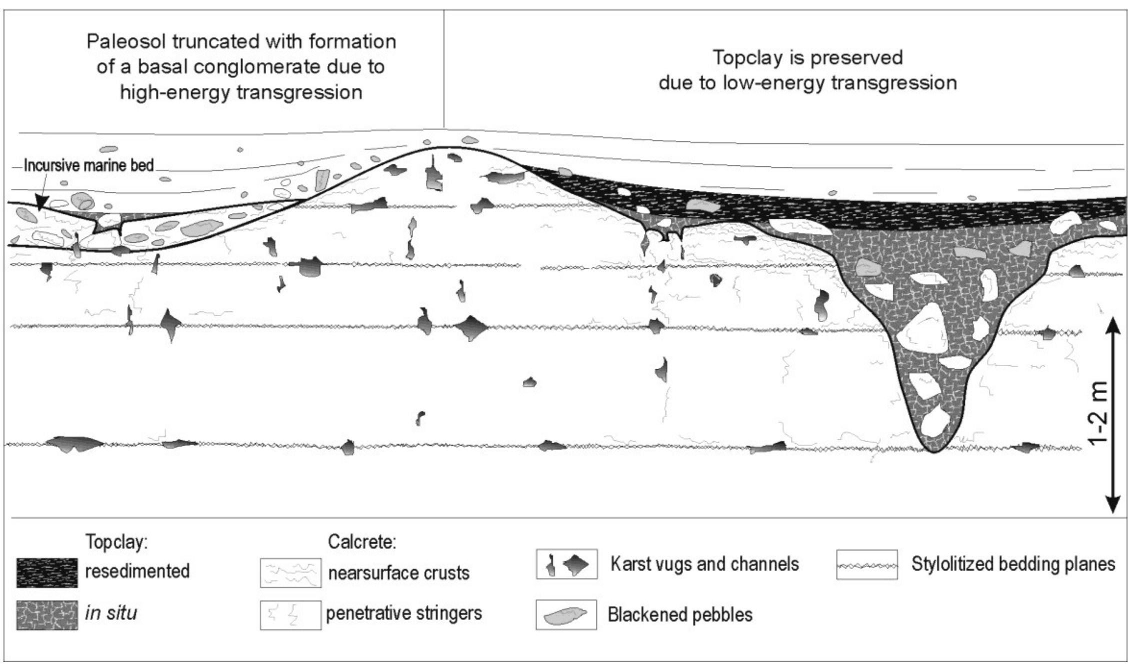

Figure 2: Major elements and variability of upper Moscovian disconformities of Moscow Basin (slightly simplified from Kabanov et al., 2010)

Solution pits and small (< 3 m deep) karst sinkholes are rare. Non-truncated topclays commonly consist of two layers: *in-situ* clayey epipedons and resedimented terrestrial clays. The latter are interpreted as playa sediments. The Myachkovian unconformities of the MZ (Fig. 1) lack beta calcrete and root traces, and the limestone beneath these unconformities is sepiolitized. In Podolskian paleosols of the southern Moscow Basin, the topclays are predominantly palygorskitic. he Myachkovian paleosol clays are smectitic-illitic with occasional chlorite admixture. The majority of late Moscovian paleosols surveyed formally conform to lithic (rendollic) haplocalcids. A detailed study of a lower Podolskian Sennitsa Creek paleosol at Gory reveals development of shallow soil carbonate, low alumina/bases and Ba/Sr ratios, enhanced Mn and Sr, presence of soil gypsum and opal, and a characteristic peak in magnetic susceptibility, all suggesting a semiarid to arid pedogenic environment. The palygorskite clay of this paleo-pedon retains 1.1-1.5 % of connate organic matter in the form of covalently bound organo-mineral complexes (Fig. 3), and is fulvate-dominated resembling organic matter from extant dryland soils (Alekseeva et al., 2009). Palygorskitic composition of Podolskian topclays and shallow (< 30 cm) pedogenic carbonates is interpreted to reflect hot well-drained semi-desert conditions with precipitation less than 300 mm/yr. The transition from palygorskitic to smectitic soil clays across the Podolskian/Myachkovian boundary and other features record a general increase in humidity such that annual precipitation may have exceeded 300-400 mm.

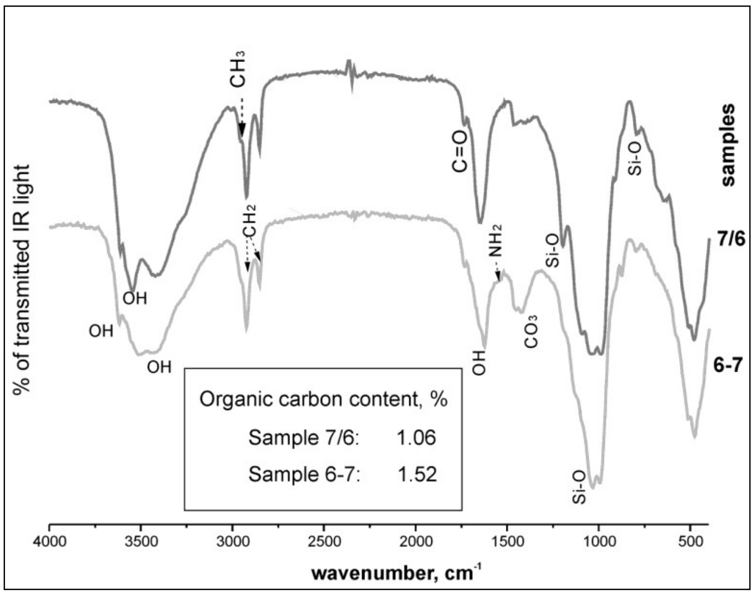

Figure 3: IR spectra and TOC of clay fractions indicating organic molecules attached to palygorskite, Sennitsa Creek paleosol, Podolskian, Gory (slightly modified from Kabanov et al., 2010).

Data from Moscovian paleosols reconstruct *"great calcimagnesian plain"* landscapes formed during low sea level phases across tens of thousands of km^2. This non-actualistic system apparently lacked fluvial network and was covered by uniform soils and playas. The primary productivity of this early (310-305 My old) dryland ecosystem inferred from high TOC and rhizogenic beta-calcretes was not markedly different from present-day steppe/savanna grasslands and semi-deserts. In MZ outcrops, drier conditions probably limited colonization by higher plants. The available data open a 'hidden chapter' in the Paleozoic evolution of terrestrial ecosystems which is not recorded by paleobotany and urges modifications in the concept of low-productivity character of pre-Miocene dry landscapes (Kabanov et al., 2010).

Upper Mississippian

New data are obtained from five disconformities of the Late Viséan to Serpukhovian carbonate sections of the type Serpukhovian region of the southern MS. Late Viséan Stigmaria-rich subaerial profiles reveal pedogenally formed smectites. The "rhizoid microkarst" profiles occur at three successive unconformities in the Mikhailovian to Venevian (upper Viséan). The longest hiatus (supposedly > 0.5 My) is recorded close to Mikhailovian/Venevian boundary by prominent karst with occasional man-size caverns and the karren relief of 2.5 m local amplitude with lapies, residual boulders, and small towers. This surface is transgressively covered by 0.2-2.5 m thick "black Stigmaria limestone" which appears to be a saponitic marl with numerous internal discontinuities (Fig. 4). This marl lacks siliciclastic admixture implying authigenic origin of saponite and contains humate-type organic matter characteristic of paludal soils. The $\delta^{13}C$ of micritic calcite matrix is -3.1 to -10.7‰ suggesting passage through photosynthetic cycle. Traces of kaolinite are present. The transition to Venevian limestone is conformable, marked by lighter color and recurrence of mass marine bioclasts. This bed is interpreted as a subhumud to subarid palustrine facies comparable to classical examples of the Florida Everglades. Small lenses of the "initial-transgressive" palustrine saponitic marl also occur at the V/S boundary. An aridization trend across the V/S is recorded by decline of Stigmaria in the basal Serpukhovian and emergence of palygorskite in mid-Sephukhovian basinal-to-lagoonal shales. A paleosol in top of the Lower Serpukhovian is an arid-style palygorskitic calcrete.

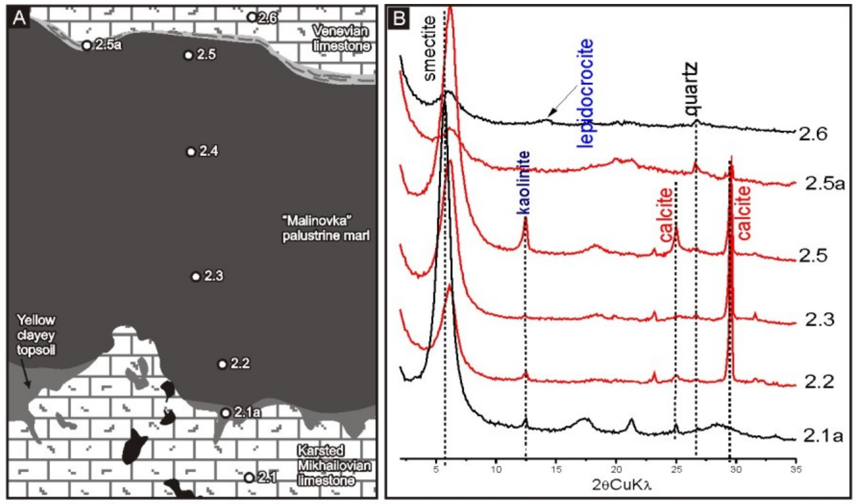

Figure 4: Composite Mikhailovian/Venevian disconformity, Malinovka: A – trace of a field photo with sample positions. B – XRD of clay fractions, Mg- saturated.

Core from Volga-Uralian and Timan-Pechora Basins

Numerous previously unknown disconformities have been detected in Tournaisian, Late Viséan, Serpukhovian, Bashkirian, and lower Moscovian shallow-platform carbonate formations. Most developed profiles with thick beta calcretes were observed in shallow (middle to upper ramp) Bashkirian carbonates of the southern VU. Tournaisian "intraformational" disconformities expressed by alveolar Karren surfaces, vuggy porosity beneath and pebbles above these surfaces. Root-like structures are rare. Crusts of beta calcrete are notably absent. No root-like structures were observed under similar surfaces in the Famennian core. Beta calcretes first appear in the carbonate core just above the Bobrikian (mid-Viséan) siliciclastic unit. We suppose that this change from barren to root-modified subaerial surfaces may be an evolutionary signal of the advance of higher plants onto juvenile carbonate plains.

Conclusions

Subaerial disconformities in the Carboniferous platform carbonates of the EEC are just as common as elsewhere in properly studied coeval successions. Paleosols and associated terrestrial beds at disconformities unravel ancient climates and processes in great detail.

Acknowledgements

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References

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