XIV International symposium and field workshop on paleopedology

SOILS AS MEMORY OF CONTEMPORARY AND PALEO ENVIRONMENTS

PROCEEDINGS

October 7th-15th 2023

Las Cruces, New Mexico State University, USA

NM STATE

BE BOLD. Shape the Future.®
New Mexico State University

International Union of Soil Sciences

IUSS Commission 1.6
PALEOPEDOLOGY

Commission 1.2 – Soil Geography

INQUA
Founded 1928

INQUA Paleopedology Working Group

Compiled and edited by Maria Korkka and Maria Bronnikova

Oct 7, 2023

Session 1 Soil-sedimentary sequences as environmental memory: pedostratigraphy, dating, soil genesis and paleoenvironmental reconstructions

Paleosols as Essential Evidence in Dune Field and Loess Records of Holocene Environmental Change

[1]Mason, Joseph A.; [1]McDowell, Taylor M.; [2]Miao, Xiaodong; [3]Hanson, Paul R.; [4]Johnson, William C.; [5]Xu, Zhiwei; [1]Marín-Spiotta, Erika

1. Department of Geography, University of Wisconsin-Madison, 2. School of Geography and Environment, Henan University, 3. Conservation and Survey Division, University of Nebraska-Lincoln, 4. Department of Geography, University of Kansas, 5. School of Geography and Ocean Science, Nanjing University.

Stratigraphic records of episodic dune activity and loess accumulation are among the most important sources of information on Holocene environmental change in semiarid landscapes, since aeolian processes respond to changing climate, vegetation, and human land use. However, the widespread use of luminescence dating to determine the timing of dune sand or loess deposition since the 1990s led to extensive discussion and debate on how to interpret large sets of ages and whether discrete episodes of regional aeolian activity can be identified and related to specific environmental changes. The recognition that active and stable dune states can coexist in the same climate (Xu et al., 2020, https://doi.org/10.1126/sciadv.aay8020) makes this problem even more complex.

This talk will focus on two key points, using examples mainly from the Great Plains with a briefer look at northern China. The first is that documenting site-specific evidence on the relative effectiveness of pedogenesis and aeolian sedimentation or erosion is essential—along with numerical dating—for inferring site-by-site changes in aeolian system state and building up to a regional record. Though many buried soils are easily recognized, evidence of brief stabilization can be much more subtle and has not been adequately utilized. For example, in Great Plains dune fields, minimally developed surface soils occur on dunes <1000 years old with more recent reworking by blowouts. However, these soils lack sedimentary structures that are ubiquitous in underlying dune sand and have accumulated fines that alter their moisture retention curves. Buried equivalents to these soils are probably recognizable with appropriate observations and measurements. Recognizing remnants of truncated paleosols is also important.

The second point is that aggradational (also known as accumulative or upbuilding) soils are common in loess and also occur in dune fields. Such soils are important evidence of ongoing, though relatively slow, sedimentation, and are valuable sources of evidence on environmental change that occurred during their development. It can be challenging to distinguish slow upward growth of a soil from effects of deep pedoturbation, especially in grassland environments. The Brady Soil in loess of the Great Plains provides good examples of the kinds of evidence that can be used to make this distinction. Importantly, if a soil can be shown to be aggradational, it can be much easier to interpret change over time in the soil's environment, from, e.g., stable carbon isotope profiles, phytolith analysis, and micromorphology. Measurements of soil hydraulic properties and modeling of soil hydrology under a range of climatic scenarios can potentially be used to understand how the depth affected by frequent wetting, root growth, and pedogenic carbonate formation changes over time in an upbuilding soil.

Interglacial paleosol sequences in Quaternary deposits of the Sandomierska Upland in southern Poland

Jankowski Michał[1], Zagórski Zbigniew[2], Sochocka Magdalena[1], Michalak Joanna[1]
[1] Nicolaus Copernicus University in Toruń, ul. Lwowska 1, 87-100 Toruń, Poland mijank@umk.pl, madzia930908@wp.pl, asia.m@doktorant.umk.pl
[2] SGGW, Warszawa, Poland, zbigniew_zagorski@sggw.pl,

Soil-sediment sequences found in loess areas are among the most valuable paleoenvironmental archives of the Quaternary. In southern Poland, the stratigraphy of Pleistocene loess has been studied since the 1960s (Jersak, 1965). The relationship of loess deposits to other Pleistocene formations, related to particular advances of ice sheets, the development of periglacial zones and the periods of pedogenesis separating them, has not yet been precisely determined. The Sandomierska Upland is located in the zone onto which the older Pleistocene ice sheets advanced, while younger glaciations left it in their closer or further foreland. 4 previously undescribed profiles representing Pleistocene stratigraphy were analyzed from a lithological and paleopedological point of view: Szewce, Złota, Gorzyczany and Górki Klimontowskie. So far, these profiles have not been dated, but they were referred to the previously known and dated profile Polanów (Jary, 2007, Mroczek, 2008).

The top of all four studied profiles is loess accumulated during the Weichselian (Wisconsinan) glaciation, divided into two parts by interstadial Gleyic Cryosol (Lohner/Farmdale paleosol). Below the Weichselian loess, there are three layers of deposits representing glacial and interglacial events (Saalian/Illinoian – Elsterian/Kansan), of various lithological characteristics: glacial tills, glaciofluvial sandy-gravel materials, ice-dam reservoir silty-clay sediments, loess. These sediments are divided by two pedostratigraphic units, representing periods of advanced pedogenesis, of interglacial rank (Eemian/Sangamonian, Holstenian/Yarmouthian).

The upper pedostratigraphic unit is a complex of two welded soils, corresponding to the complex known from the literature as e.g. Mezin and Ryshkovo (e.g. Velichko *et al.* 1992), Nietulisko I (Poland; Jersak 1965). The basic part of the complex are well-developed Luvisols formed in Saalian sediments with different texture and origin (till, sand, loess) - so they constitute a lithosequence that can be considered representative of the zonal conditions of Central Europe during the Eemian interglacial. At the Szewce site, the Eemian is represented by intrazonal Mollic Gleysol occupying a local depression and together with Luvisols creating a toposequence depicting a fragment of the integlacial soil-scape. Eemian paleosols are overlain by colluvial and loess pedo-sediments, related to the cooling and warming of the climate in the early Weichselian phase. In those sediments cryogenic Chernozems, Colluvial Regosols and Gleysols developed, also forming a toposequence.

The older pedostratigraphic unit is another topo-lithosequence of soils formed in periglacial conditions at the end of the Holsteinian interglacial. It is represented by a lithosequence of Turbic Cryosols developed in various sediments (sandy, gravely and loamy), turning into Histic Cryosols in the lower relief position. The whole sequence of Pleistocene paleosols and sediments is underlain by (glacio?)tectonically disturbed marine sands and clays of the late Tertiary age.

References:

Jary Z., 2007. Zapis zmian klimatu w górnoplejstoceńskich sekwencjach lessowo-glebowych w Polsce i w zachodniej części Ukrainy. Inst. Geografii i Rozwoju Regionalnego Uniwersytetu Wrocławskiego, Wrocław.

Jersak J., 1965. Stratygrafia i geneza lessów okolic Kunowa. Acta Geographica Lodzensia 20.

Mroczek P., 2008. Interpretacja paleogeograficzna cech mikromorfologicznych neoplejstoceńskich sekwencji lessowo-glebowych. Wydawnictwo UMCS, Lublin.

Velichko A.A., Morozova T.D., Nechaev V.P., Udartsev V.P., Tsatskin A.I., 1992. Problems of stratigraphy and correlation of loess-soil formation of Russian Plain. Stratigraphy and palaeogeography of the Quaternary period of Eastern Europe. IG RAS: 115–140.

Pleistocene paleosols in North-Western Siberia: new source of information for paleogeographical reconstruction and gaining into environmental evolution

[1]Sheinkman Vladimir, [1,2]Sedov, Sergey
[1]Tyumen Science Center, SB RAS, Tyumen, Russia;
[2]National Autonomous University of Mexico,Mexico;
E-mail: vlad.sheinkman@mail.ru; serg_sedov@yahoo.com

Recent development of non-glacial scenario for the Quaternary landscape evolution in North-Western Siberia (Sheinkman, 2016) stimulated search for the paleopedological archives in this region. During the last decade field there are carried out surveys identified and studied 3 major Late Pleistocene pedostratigraphic levels in the sedimentary sequences of the high terraces in the river valleys which run to the north and south from the Siberian Uval – the sub-latitudinal highland divided along the Arctic Circle, approximately, northern and southern parts of West Siberia.

The present authors have received reliable materials allowed us to create already some soil-permafrost paleorecords for the region in respect to the Late Pleistocene. The compound regional pedostratigraphic scheme will be presented in common features below.

The lowest level identified in the Middle Ob' terrace sections Kiryas and Belaya Gora yielded U/Th dates 100-120 kyr BP and thus is attributed to the MIS-5 – Kazantsevo stadial thermochron. It is represented by a pedocomplex in which the lower paleosol unit has signs of clay illuviation (indicative of taiga pedogenesis) whereas the upper one consists of the peat and gleyic horizons which suppose cryohydromorphic pedogenesis. Palynological characteristics of this pedocomplex recorded the climate fluctuations during MIS-5 from the Picea-Larix taiga environment during MIS-5e to the establishment of tundra-steppe environment due to the cooling of MIS-5d and/or MIS-5b – that agrees with the paleopedogenetic results.

The MIS-3 Karginian paleosols (with $^{C}14$ dates from the soil organic materials in the range of 25-35 ka BP) lie above the MIS-5 level being separated by the alluvial sediments containing dropstones identified as a result of ice-river transfer from the right-hand bank of the Yenisei River. These paleosols demonstrate strong morphological evidence of gleysation and accumulation of plant residues, both processes suppose water logging and reduced environment. We suppose that permafrost was the main factor of hampering percolation and switching redoximorphic processes in the paleosol, which thus was classified as Reductaquic Cryosol.

Presence of permafrost implies colder climate than the present one. Furthermore, neutral reaction, presence of neoformed calcium carbonate and abundance of silt fraction, which points to eolian sedimentation, suggest drier conditions. Paleobiological proxies such as pollen, plant macroremains, phytoliths and fossil insects indicate tundra or tundra-steppe ecosystem (possibly with some forest stands), in good agreement with the paleopedological and sedimentary records.

The paleosol level corresponding to the terminal phase of the Late Pleistocene – end of MIS-2 (^{14}C dates of 10-12 ka BP) was identified in the uppermost parts of the high terrace sections of the basins of the rivers Taz and Nadym. This strongly gleyed paleosol is associated with a cryogenic horizon and partly is presented by pedosediments filling large ice wedge pseudomorphs. The present authors suppose that it is associated with the warming events at the end of the last Pleistocene cryochron – Sartanian,. Paleoenvironmental interpretation of the paleosols agrees with the palinological and paleontological records showing paleovegetation of swampy tundra type.

All Pleistocene soils differ sharply from the recent surface soils that are Podzols, formed in under conditions of perfect soil drainage and no water excess, in agreement with current geological and geomorphological conditions of the Holocene. However paleocryogenic morphostructures inherited from MIS-2 influence Podzol development: the latter shows large pockets both of E and Bf horizons above ice wedge pseudomorphs. Paleosols of the MIS-2 cryochron are often located close to the surface and comprise the lower part of the recent soil profile.

So, an important massive of capacious information has received at present already and can be useful in different researches. It is possible to conclude that revelation of buried palaeosols in

North-Western Siberia and obtaining the data concerning their genesis and development allow us to considerably widen our knowledge in respect to the environmental evolution of that area.

Paleosol Narratives: Reading Diagenetic and Pedogenic Imprints in the Lameta Formation

Anjali Kumari
Department of Geology, Panjab University, Chandigarh (INDIA)

Paleosols are ancient soils with a variety of geological applications. The reconstruction of paleo-landscape and paleoenvironment is one of the important applications of paleosols. The spatial distribution of different kinds of paleosols indicates the variation in the landscape on which they developed. The maturity of the paleosol is directly proportional to landscape stability. A prolonged period of landscape stability will lead to the formation of more mature paleosols. Thick, well-developed paleosols might indicate a stable landscape with little erosion, while thin or discontinuous paleosols might suggest more active erosion or sediment deposition. However, the influence of post-burial geological processes has a significant impact on the preservation of pedogenic features. With increasing burial pressure and temperature, the evidence of pedogenesis gets modified and destroyed.

The present study discusses the pedogenic features and diagenetic modification of paleosols preserved in the Late Cretaceous dinosaur-bearing Lameta Formation in Central India. The Lameta sediments are widely recognized for their abundant Maastrichtian dinosaur eggshells and extensive fossil records. However, there remains ongoing debate concerning their depositional landscape.

Only a few paleosol profiles exhibit diagenetic features, such as distorted clay coating, microcrystalline silica, suturing of quartz grains, and recrystallization of micromass. The observed diagenetic characteristics lack the intensity to impede paleoenvironmental interpretations. Therefore, we utilized the pedogenic characteristics to reconstruct the paleo- landscape. Based on paleosol features, including obliteration of bedding, soil horizonation, soil structures, rhizoconcretions, Fe-Mn/clay/calcite coatings and hypocoatings, infillings, Fe- Mn/calcite nodules, organic material, and crystallitic/striated b-fabrics, the thirteen paleosol profiles were categorized into five pedotypes. The observed pedotypes are interpreted as compound and composite paleosol profiles ranging from poorly to moderately drained, and encompassing weakly to well-developed paleosols. This diversity in palaeosol formation leads to the creation of a soil catena, where better-drained palaeosols form the highlands and poorly drained palaeosols form the lowland areas. Based on varying degrees of development and drainage, the paleo-landscape is constructed as a blend of periodic wetlands and arid terrains.

Buried paleosoils interbedded with Early Pleistocene lavas and tephra: a key for the environment during the initial hominid dispersal in Eurasia

Kust Pavel[1], Belyaeva Elena[2], Elizabeth Solleiro-Rebolledo[3] and Sedov Sergey[3]
[1]Independent researcher; [2]Institute for the History of Material Culture, RAS, St. Petersburg, Russia; [3]Instituto de Geología, Universidad Nacional Autonoma de Mexico, Ciudad Universitaria, Mexico

The Yagdan study site (41.01°N; 44.51°E) located in the northern part of Modern Armenia (The Lori Basin) offers a unique archive for understanding volcanism, paleoenvironment and landscape development, and Palaeolithic occupation during the Early Pleistocene. Through detailed geomorphological mapping, archaeological survey and soil studies with absolute dating, we demonstrate that sediments interbedded with Early Pleistocene lavas preserve *in situ* formed soils. These Early Pleistocene pedosediments are very well conserved under the products of volcanic activity which have been dated: lavas layers stack above the upper soil – earlier than 2.08 ± 0.10 Ma (K-Ar; Belyaeva, 2022).

Studied buried soils has been developed between two lava emplacements. The observed Yagdan section formation can be subdivided into several stages: (1) emplacement of younger lavas as subhorizontal layers in stack of more than 40 m thickness in contact with mountain ridge slope – a Hovnadzor River pre-existing river valley slope. This stack of lavas are usually dated as ~3.25–2.05 Ma (Sheth et al., 2015); (2) water erosion of younger lava sediments and formation of a local depression of more than 7 m depth and at least 75 m length; (3) consequent filling of the formed depression by the (a) mountain ridge colluvial material with subhorizontal orientation of layers at the bottom and (b) hillside deposits with uneven surface at the top; (4) soil formation in the deposited material in accordance to relic landscape and paleoenvironment with forming a catena of soil profiles typical for local streamflow floodplain – soils are very well stratified by the thickness of upper Umbric horizon which increases its thickness down to the slope; (5) erosion and cutting of upper soil horizons on the topmost positions and elevating of uneven surface in accordance to the mountain ridge slope inclination; (6) burying of lower part of slope sediments with formed soils (by thin tephra and thick molted lava layer, up to 1,301 m a.s.l and possibly with blockage of the paleo local streamflow and lake formation in the lea of upper soils); (7) further soil formation in the slope sediments higher than 1301 m a.s.l.; (8) burying of upper part of slope sediments (up to the 1,316 m a.s.l) with longer formed soils by thin tephra and thick molted stack of lava layers. Single layers are underlined by thin tephra interlayers with signs of weathering, so that we assume a long time period of 10ka*n-100ka*n between stage 6 and 8. This is possible, since at least 4 phases of effusive volcanism are described for that region in the Late Miocene - Early Pleistocene transition (Triphonov et al., 2015).

The reference soil profile was chosen in the lower part of the slope, in which the hillside deposits were minimal, and during stage 5 it has been minimally eroded, since it is almost completely developed in the deposits with subhorizontal orientation. Signs of the formation of the studied soils in a humid warm (subtropical) climate were found, which is consistent with the results of early studies (Revunova et al. 2021). Based on the field morphology the Yagdan section buried soils were classified as Argic, Vitric, Chromic Umbrisol. However, a very complicated set of diagenetic processes, typical for soils buried under the volcanic sediments (i.e., exposure to molten lava solutions resulted in red-colored layers), enhanced by long time burying, make a challenge for the further study of such soils. Mexican young analogs of paleosols under lavas, already well studied, can be model objects for a comparison (Solleiro et al., 2011).

Studied paleosoils buried under the pyroclastic sediments are very important in terms of Quarternary paleosols research as they are well conserved, can be well-dated, can provide paleopedological records for large time intervals like loess-paleosoil sequences, but so far much less studied. We have mentioned that the Hovnadzor River basalts are intracanyon flows filling pre-existing river valleys, and in such environment there is an opportunity for inter-flow sedimentation, and even more sites can be recognized during further studies.

Few studies of Lower Palaeolithic prehistory in Armenia have been conducted previously. This soil survey was adjoined to the survey of Paleolithic sites along the valley of the Hovnadzor River. Hominin populations exploiting the floodplains also occupied the surrounding valley sides with the studied buried soils. Within buried soils and soil parent material the lithic material artifacts have been found and identified as of Lower Paleolithic manufacture. So, it is now clear, that such sites provide a novel Early-Middle Pleistocene stage of occupation of the Caucasus in the region. The studied site is located in a critical region for Lower Paleolithic research - at the crossroads of Europe, Africa, and Asia. Further studies, including precise geomorphology and absolute dating of the deposits should shed the light on the role of Modern Armenia Lower Paleolithic sites in the understanding of the Palaeolithic occupation of Eurasia. This work has been supported by the project grant PAPIIT IN110323 “Paleosuelos en secuencias volcánicas del Cuaternario: paleoambientes y geoarqueología”.

Features of Quaternary pedogenesis in loess-paleosol sequence of Tajikistan (Obi-Mazar section)

Tokareva O.A.[1,4,5]*, Lebedeva M.P.[2], Sosin P.M. [3], Khormali F.[4], Kurbanov R.N.[3,1]
[1]Institute geography RAS, Moscow, Russia. *tokareva@igras.ru.
[2]Dokuchaev Soil Science Institute, Moscow, Russia.
[3]Institute of water problems, hydropower and ecology, TNAS, Dushanbe, Tajikistan.
[4]Gorgan University of Agricultural Sciences and Natural Resources, Gorgan, Islamic Republic of Iran.
[5]Institute Institute of Archaeology and Ethnography of Siberian Branch of the Russian Academy of Sciences, Novosibirsk, Russia.

Loess-paleosol sequences of Tajikistan contain more than 40 paleosols covering the period for the last 2-2,5 million years. The most complete and detailed loess-paleosol series are located in Afghan-Tajik depression in the Khovaling Loess Plateau. Series of outcrops were actively studied over the past 40 years by V.A. Ranov, A.E. Dodonov, I. Shaefer and others. These studies were mainly focused on description of general regional stratigraphy and palaeolithic archeology. There is a shortage of data on the structure and formation of major stratigraphic pinpoints – pedocomplexes, with which the main findings of stone tools are connected. For the first time we conducted detailed study of structure of paleosols and pedogenic processes in the upper part of the Obi-Mazar section that formed during the MIS several last glacial-interglacial cycles. Studied section is located on the right band of the Obi-Mazar river just opposite the Lakhuti village in Khovaling region of Tajikistan. There are a number of unique palaeolithic sites with abundant collection of stone tools in pedocomplexes 4, 5 and 6. Based on the micromorphology and chemical analysises, grain size measurement and magnetic susceptibility data we reconstruct stages of loess accumulation and paleosols development in pedocomplexes. The detailed stratigraphic chart and main properties of studied horizons of paleosols will be reported in our presention.

This study was supported by of RSF (project № 22-18-00568) and NordForsk (project № 96926).

Pedogenesis of the MIS 5 paleosols of the Otkaznoye Section (Ciscaucasia)

Kurbanova Fatima, Konstantinov Evgeniy, Panin Pavel
Institute of Geography, RAS

A problem of numerous hard-to-date events synchronization in the Late Quaternary history of the south of the East European Plain can be solved through correlation with loess-palesol sequence (LPS), which are reliably dated by luminescence methods. The loess paleoarchives of Ciscaucasia contain a detailed and almost continuous record of landscape changes for the last 800 ka (Velichko et al., 2012).

LPS of the Ciscaucasia are unevenly studied from the paleosol point of view. In the west of the region (in the Sea of Azov), pleistocene paleosols in the LPS have been studied in dozens of sections, detailed morphological and physicochemical characteristics of paleosols and long series of luminescent dates have been obtained (Velichko et al., 2012; Mazneva et al., 2021). In the east of the region (in the Tersko-Kuma lowland), the level of knowledge is significantly lower, especially for Late Pleistocene paleosols, which were not previously studied in outcrops, but were recovered only in cores (Konstantinov et al., 2022). At the same time, in the east of the region, as a result of higher rates of sedimentation, the thickness of the LPS is significantly higher, which makes the paleosols thicker and more preserved.

For the first time for the key section Otkaznoye (Tersko-Kuma lowland), the structure of the Mezin pedocomplex (MIS 5) was uncovered in profile, which is 4.3 m thick. Morphological features of the Krutitsa (MIS 5c) and Salyn paleosols (MIS 5e) were studied. The Krutitsa paleosol (1.0-2.7 m) developed according to the type of modern *Calcic Gypsic Kastanozem Cambic Siltic*

Tephric (WRB, 2015). In the microstructure of this paleosol, iron-manganese nodules, a weak striated b-fabric, and thin allochthonous coatings are visible, which indicate illuvial-migration processes characteristic of leaching regimes and a humid climate (Targulian, 2019).

The Salyn paleosol (3.1-4.2 m) was formed in alternating wet and arid environment, as evidenced by the abundance of carbonate formations and large iron-manganese nodules and spots (Stiles, et al., 2001). At the same time, the number of visible forms of calcium carbonates are higher than in the Krutitsa paleosol. The Salyn paleosol could have developed according to the *Calcic Gypsic Kastanozem Cambic Siltic* type and is similar to the Holocene soil.

The results of X-ray fluorescence analysis showed that the Ba/Sr index correlates with the frequency dependence of magnetic susceptibility and with the clay fraction (r=0.6) <2.0 μm, which can be used as an additional indicator of the intensity of soil formation in loess. At the same time, the Zr/Y ratio correlates with an increase in the coarse dust fraction of 31-63 μm (r=0.74), which can be used as an additional indicator of dust input.

References:

Konstantinov E.A., Mazneva E.A., Sychev N.V., Zakharov A.L., Filippova K.G. Variability in the structure and composition of the Upper Quaternary loess of Ciscaucasia (south of the European part of Russia). Geomorfologiya. 2022; 53(3):107-116. (In Russ.)

Mazneva E. et al. Middle and Late Pleistocene loess of the Western Ciscaucasia: Stratigraphy, lithology and composition //Quaternary International. 2021. 590. 146-163.

Panin P. G. et al. Morphology and micromorphology of the loess-paleosol sequences in the south of the East European plain (MIS 1–MIS 17). Catena, 2018, 168. 79-101.

Stiles C. A., Mora C. I., Driese S. G. Pedogenic iron-manganese nodules in Vertisols: A new proxy for paleoprecipitation? Geological Society of America. Geology, 2001, 29. 10. 943–946.

Targulian V.O. Theory of pedogenesis and soil change in time. Moscow: Publishing house GEOS, 2019, 297 p.

Velichko A. et al. Development of the steppe zone in southern Russia based on the reconstruction from the loess-soil formation in the Don-Azov Region //Doklady Earth Sciences. – SP MAIK Nauka/Interperiodica, 2012. 445. 999-1002.

Funding: Present work was supported by a grant from the RSCF, Project No 21-77-10104 «Dust flux in Ciscaucasia for the last 250 ka: sources, accumulation rates, forcings».

Pleistocene paleosols of West Transbaikalia, Tarbagatay key section.

Golubtsov, V.[1,2], Pogosyan, L.[3], Ryzhov, Y.[1,2,4], Smirnov, M.[4]

[1] V.B. Sochava Institute of Geography SB RAS, Irkutsk, Russia, 664033, Ulan-Batorskaya str., 1

[2] Institute of Geography RAS, Moscow, Russia, 119017, Staromonetny per., 29

[3]Red de Ecología Funcional, Instituto de Ecología A C, Carretera Antigua a Coatepec 351, 91073, Xalapa, México; lilit.pogosyan@inecol.mx

[4]Institute of Earth's Crust SB RAS, 664033, Lermontova str., 128

Soil memory of Quaternary deposits is an important source of information about environmental conditions of the past. In Baikal region such sources of information are mostly related to the Late Pleistocene, meanwhile the earliest stages are not so well studied. The Tarbagatay soil-sedimentary archive is located on the left bank of the Kuytunka river and contains records of approximately 1 million years. The section stratigraphy was described by Erbajeva et al. (2019), however, the conditions of soil formation were not studied in detail. Therefore, in 2022 we conducted a field description and sampling. During our field work we have determined 17 paleosol levels, 9 of them probably refer to the Early-Middle Pleistocene and the rest to the Late Pleistocene.

The oldest deposits (from 23 to 15.4 m of the described sequence) consist of silty-loam sediments with reddish colored paleosols, morphologically similar to Terra Rosa soils. At the macromorphological level these paleosols have accumulations of carbonates at the lower part of the profile, including one horizon of dense caliche, they also contain weak clay coatings and soft small iron-manganese concretions. The micromorphological observations of these paleosols showed compact silty material with few large angular feldspar inclusions (first millimeters). Such matrix organization with angular inclusions incorporated into fine material points to the mudflow origin of the sediment. In general, these paleosol have properties of *cambic* horizon.

The upper 15.4 m of the studied soil-sedimentary sequence is composed of sandy and sandy-loam deposits and macromorphologically are difficult to classify between soil and sediment levels. The most distinguished paleosols were found at the depth of 6.9-8 (paleosol 3 and 4) м. Both mentioned levels are characterized by cryogenic disturbances and solifluction patterns, as well as by high amount of disperse soft carbonate accumulations. The sediment is represented by sandy grains of quartz, feldspar, biotite and hornblende. Angular shapes of mineral grains and their poor sorting possibly are result of colluvial sedimentation. There soils contain micrite coatings and compound iron nodules with clear in paleosol 3 and gradual in paleosol 4 boundaries. The degree of mineral grain weathering in paleosol 4 is higher than in paleosol 3, paleosol 4 sample also contains some biogenic pores and biogenic aggregates, being therefore a paleo AC horizon possibly similar to a modern topsoil.

We conclude that the complete Tarbagatay sequence is divided into two mayor sedimentary units of colluvial sediments, each of them contains several paleosols with weak pedogenic features. Probably the lower paleosols were developing as Cambisols, while the upper soils were developed in colder conditions and are more similar to the modern soil. Even so, paleosols of both blocks contain iron nodules that are an indicator of temporal saturation with water during the pedogenesis.
This study was funded by RSF, project № 22-17-00265.
Erbajeva M.A., Khenzykhenova F.I., Namzalova O.D.-T., Shchetnikov A.A., Filinov I.A., Nechaev I.O., Kazansky A.Y., Matasova G.G. The new Pleistocene Ulan-Zhalga key section in Western Transbaikalia // Doklady Earth Science. 2019. Vol. 488. № 1. P. 1035-1038. DOI: 10.1134/S1028334X1909023X.

Paleoenvironmental reconstruction of the Pleistocene loess-paleosol sequences in the southern Tajikistan (Khonako II section)

Talebi. F[1], Khormali. F[1], Karimi. A.R. [2], Tazikeh. H[1], Kurbanov. R[3], Sosin. P.M[3], Buylaert. J.P[4], Tokareva . O.A[5]

1 Gorgan University of Agricultural Sciences and Natural Resources, Gorgan, Iran
2 Ferdowsi University of Mashhad, Mashhad, Iran
3 Institute of Water Resources, Hydro Energy and Ecology, National Academy of Sciences of Tajikistan, Dushanbe, Tajikistan
4 Technical University of Denmark, Department of Physics, Roskilde, Denmark
5Institute geography RAS, Moscow,Russia. Gorgan University of Agricultural Sciences and Natural Resources, Gorgan, Islamic Republic of Iran. Institute of Archaeology and Ethnography of Siberian Branch of the Russian Academy of Sciences, Novosibirsk, Russia.

The southern Tajikistan is an area highly sensitive to Pleistocene climate changes which can reach thicknesses of 200 m- is a key regin for reconstructing past climate. Loess-paleosols sequences of the southern Tajikistan provide detailed paleoenvironment record in Central Asia. Recently, micromorplological and physico-chemical studies have not been published from this area. Here, we present micromorphological investigation and also physico-chemical properties of the samples from the Khonako II section, southern Tajikistan. The micromorphological index of soil development (MISECA) explain either accurate infoemation of the degree of soil development or pedological changes in the past in different horizons. The physico- chemical properties (e.g. soil organic content, calcium carbonate equivalent and soil pH) sensitively reacted to environment and climate changes whereby, this approach can be useful for climate interpretation. Modern soil and four representive pedocomplexes (PC1, PC2, PC3 and PC4) have been represented to study paleoenvironment and past pedogenic processes. These pedocomlexes are covered by (~5800 cm) loess sediments, divided by different types of interglacial paleosol.

The soil pH and calcium carbonate contents show a decreasing trend due to increase in precipitation and available soil moisture during the formation of paleosols. The appearance of different kinds of calcite pedofeatures, consisting of coating, hypocoating, infilling and needle shaped calcite in these soils indicate later recalcification processes. micromorphology provides evidence for the downward decalcification and subsequent clay mobilization and accumulation of clay as indicated by b-fabric with increasing rainfall which is proven by increasing the degree of calcite depletion pedofeatures. Based on the MISECA index the studied soils are categorized into weakly to moderately developed soil. Variations of MISECA index values of modern soil compared to paleosols demonstrates that paleosols were formed in the more humid conditions. PC1 and PC3 with high MISECA values (MISECA=15 and 17 respectively), the best developed and preserved clay coating along channels and also calcite depletion pedofeatures (>50%) confirm the favorable pedochemical conditions for the clay mobilization and the availability of more moisture during the formation of these soils. This study was supported by of INSF (Iran National Science Foundation Project № 99006758) and NordForsk (THOCA project № 96926).

Soil development on a fluvial system, Central Botswana: preliminary observations with implications for carbonate palaeosol interpretation in the pedostratigraphic sections.

Dina Ebouel Ferdinand J. [1*], Bineli -Betsi Thierry O. [2], N. Eze Peter [1]

[1]Department of Earth and Environmental Science, Botswana International University of Science and Technology, Private Bag 16, Palapye, Botswana

[2]Department of Geological and Mining Engineering, Botswana International University of Science and Technology, Private Bag 16, Palapye, Botswana.

Email: ef22017760@studentmail.biust.ac.bw

Palaeosol preserve good memories of past climate and environmental conditions and when they contain pedogenic carbonate, they represent a window into the atmospheric carbon sequestration, especially in arid and semi-arid environments. Here, we present the preliminary results of the investigation of a prominent ~8.4 m thick pedostratigraphic section on the northern bank of Metsimasweu River, Central Botswana with the aim of understanding soil development and the implications of its palaeosol carbonates. So far, the methods used include pedostratigraphic observation and description, determination of soil organic carbon (SOC) and inorganic carbon (SIC) content, soil pH and electrical conductivity, soil particle size distribution and X-ray diffraction. Our preliminary result shows a total of 8 different layers in the section. The section presents a mixture of fluvial and aeolian deposits, together with an accumulation of pedogenic carbonate of varying shape and size. The soil pH varies from 7.6 to 9.3, which corresponds to an alkaline environment. In the upper part of the section, the carbonates components are in the form of nodules and diffuse powders, while in the lower part they are in the form of rhizolites. The SOC content in the fine soil (fraction less than 2 mm) is higher than the SIC content, except for B_{kk1} and B_{kk2}. On the other hand, the SIC content in the coarse fraction is higher than the SOC content, except for A_{11}. X-ray results show that calcite is the main type of carbonate mineral, but in some layers, dolomite has also been identified. More laboratory studies, such as geochronological dating, elemental geochemistry, carbon and oxygen stable isotopes, and strontium isotope ratios, would provide more insight on the pedogenetic processes, chronology and paleoclimate and paleoenvironments of the fluvial system environments.

New Chronology Confirms the Duration of Last Interglacial Pedogenesis Extended for at Least 100 ka: Impact on Sangamon Geosol morphology and mineral weathering in southern Indiana

Peter Jacobs[1,2], Henry Loope[2], and Jose Luis Antinao[2]
[1] University of Wisconsin – Whitewater, Whitewater, WI 53190
[2] Indiana Geological and Water Survey, Bloomington, IN 47405

Documenting the duration of interglacial-scale pedogenesis is critical for understanding the impact of long-term pedogenesis on the magnitude and variability of morphological expression and mineral weathering of soils. The Sangamon Geosol is a soil stratigraphic unit used to correlate Quaternary deposits and interpret interglacial climates of the midcontinental United States for over 100 years. Historically, the Sangamon Geosol has been assigned to the last interglacial, and its presence in a stratigraphic section was used to recognize marine isotope stage (MIS) 6 or older sediments. However, few independent age control techniques were available to validate this conclusion. In this study, we apply optically stimulated luminescence (OSL) and cosmogenic isotopic age control to determine the timing of glaciogenic sedimentation along the outer margin of glaciation in southern Indiana. Results from 11 sites confirm that MIS 6 glaciation reached its southern limits between 160 and 130 ka. The Sangamon Geosol developed in those sediments until the slow aggradation of the Roxana Silt led to the development of silt-enriched and overthickened upper solum that together forms the Farmdale-Sangamon Geosol Complex. New radiocarbon ages show that the Roxana Silt aggraded between 38 and 29 ka in Indiana, confirming the duration of pedogenesis is a minimum of 100 ka. The Farmdale-Sangamon Geosol Complex is buried by MIS 2 loess deposited from 29 to 16 ka.

We present data from 13 well-drained profiles of the Farmdale-Sangamon Geosol that occur along the MIS 6 glacial margin in southern Indiana. We focus on profiles developed in outwash, but include some examples from profiles developed in till. Profiles were described in pedologic detail; lab analyses include particle size, dithionite Fe, clay mineralogy, and 8 to 63 µm silt mineralogy (XRD) and geochemistry (pXRF). Morphologically, the Sangamon Geosol is a humid subtropical climate soil with an eluvial upper solum and an illuvial lower solum. The polygenetic nature of the complex is primarily reflected as silt-enriched A and E horizons resulting from slow aggradation of MIS 3 loess that over-thickened the eluvial upper horizons relative to soils developed during the Holocene. Profiles developed in outwash have Bt horizons averaging 3.5 m ± 0.8 m thick, with total sola thickness averaging 4.4 m ± 1 m. Leaching depths > 6 m in all cases routinely extend throughout the thickness of outwash and till. Maximum clay content in Bt horizons average 27 ± 3%, an average of 22% increase relative to the parent material. Dithionite soluble Fe averages 3 ± 1% in Bt horizons. Silt-size plagioclase is depleted in Bt horizons, averaging 9 ± 8% loss relative to C horizons, which is supported by differences in paired Bt-C horizon geochemical ratios. Geochemical values and ratios indicate loss of CaO, Fe_2O_3, and relative gains of TiO_2 and Zr, largely due to plagioclase and other silicate mineral depletion in Bt horizons. Clay minerals show marked depletion of illite in most profiles, averaging 22 ± 13% loss. Illite is replaced by expandable minerals and kaolinite (increasing 10 ± 6%) and through interstratification, including kaolinite/expandable minerals in all profiles. All measures of profile morphology and weathering support the interpretation of progressive mineral weathering-producing clays through particle-size reduction and neoformation. Variability largely reflects sediment stratification, including fining-upward sequences in outwash profiles. All trends support the interpretation of a single interglacial record of pedogenesis.

A pervasive period of pedogenesis in stream valleys of the Central Great Plains during MIS 3

Layzell, Anthony and Mandel, Rolfe
Kansas Geological Survey, University of Kansas

Studies of late-Quaternary landscape evolution throughout stream valleys of the Central Great Plains have identified thick packages of alluvium, preserved along the margins of valley floors, which date to Marine Isotope Stage (MIS) 3. One to two paleosols are commonly developed in these packages. Here, we report the characteristics of those paleosols and paleoenvironmental proxy records developed from them. In particular, we compare and contrast these records along the steep east-to-west bio-climatic gradient of the Central Plains.

In stream valleys of the east-central Plains, the Severance Formation comprises thick packages of late-Pleistocene alluvium and colluvium. Soils developed in the Severance Formation exhibit common morphological features, including >1 m-thick, well-expressed Bt horizons with brown, yellowish brown, and/or reddish-brown matrix colors, prismatic structure, prominent clay films, and iron and manganese oxide concentrations. Age control (^{14}C and OSL) suggests that river systems in the east-central Plains were actively aggrading during early MIS 3. Aggradation slowed after ca. 40 ka allowing soils to develop through ca. 30 ka. In some river valleys, a second pulse of alluviation occurred after ca. 30 ka followed by a period of landscape stability and soil development during early MIS 2 (ca. 25–19 ka).

In stream valleys of the west-central Plains, soils developed in late-Pleistocene alluvium are generally similar to those developed in the Severance Formation, including >1 m-thick, well-expressed Btk horizons with prismatic structure and distinct clay films. Secondary accumulations of calcium carbonate are an important distinction and are present in the form of common fine threads, patchy coats on ped faces, and fine nodules. The timing and patterns of alluviation and landscape stability in stream valleys of the west-central Plains during MIS 3 are also generally similar to those in the east. At some localities, pedogenesis appears to have been uninterpreted from ca. 45–27 ka. At other localities, a soil developed over a brief period from ca. 40–38 ka and was buried soon after that time. Alluviation slowed sometime before ca. 26 ka, resulting in pedogenesis and the formation of a soil with a Bk-Btk profile. A final brief pulse of aggradation occurred at the beginning of MIS 2 but landscape stability and soil development was underway before ca. 24 ka.

$\delta^{13}C$ values determined on soil organic matter in paleosols were used to reconstruct the C_3 vs. C_4 composition of vegetation communities across the Central Plains during MIS 3. In the east-central Plains, $\delta^{13}C$ values indicate the transition from a C_3-dominated plant community to a mixed C_3/C_4 community (up to 46% C_4 biomass) before ca. 30 ka. In the west-central Plains, $\delta^{13}C$ values indicate the presence of a C_4-dominated plant community (66%–89% C_4 biomass) from ca. 45–27 ka.

The results of this study indicate that landscape stability and soil development predominated during much of MIS 3 across the Central Plains. The paleosol $\delta^{13}C$ record is consistent with other regional paleoenvironmental records (e.g., lake level and pollen) that suggest increasing aridity throughout the Great Plains during MIS 3.

Modern and pedogenesis in loess; an insight to the paleoclimate reconstruction

Farhad Khormali[1] and Martin Kehl[2]
1 Department of Water and Soil Engineering, Gorgan University of Agricultural Sciences and Natural Resources, Iran, fkhormali@gmail.com
[2] Department of Geography, Faculty of Mathematics and Natural Sciences, University of Koblenz, Germany
mkehl@uni-koblenz.de

Loess-paleosol sequences are valuable archives of past environments. Climate, topography, parent material, organism and time as soil forming factors, determine the dominant soil forming processes and consequently the type of soils in a region. Knowledge on the pedogenesis of the modern soils along ecological gradients could provide insight on the formation of paleosols formed in the same area under climatic conditions of the past. Modern soils formed on loess along an ecological gradientin Northern Iranian were investigated and the major soil forming processes were compared.. The soils were classified and the major physico-chemical properties, micromorphology, clay mineralogy, magnetic susceptibility and C stable isotope geochemistry of the different horizons were investigated. The loess deposits in Northern Iran reach a thickness of about 70 m in the loess plateau of Golestan Province and ca. 30 m on the northern footslopes of Alborz Mountains. These loess deposits contain several paleosols showing different degrees of weathering probably related with paleo-climatic conditions and duration of soil development. A pronounced precipitation gradient of about 800 mm year^{-1} over 70 km from north to south and corresponding vegetation from dry steppe over steppe grassland to forest vegetation provides condition for the formation of a variety of modern soils on loess and will have governed soil formation during the past as well. In this study we discuss the major properties of modern and fossil soils and suggest pedostratigraphic correlation of loess-paleosol sequences developed along assumed precipitation gradients of the past. Unlike precipitation, there is, however, no significant temperature variation along the studied ecological gradient. Thus precipitation and edaphic moisture are the main driving forces of pedogenesis. The main soil forming processes are variable in the regions studied suggesting the important role of climate elements in the distribution of soils. The pedogenic knowledge gained by studying the modern soils of a region could be applied to the underlying paleosols in order to deduce their potential environment of formation. It is concluded that the pedogenic proxies all reveal the role of precipitation on the soil distribution along the transect. This correlation is also seen in the underlying paleosols and it appears very likely that pedogenesis of interglacial paleosols was governed by similar climate-controlled trends to those reflected in the modern soils. This study was supported by of INSF (Iran National Science Foundation Project № 99006758).

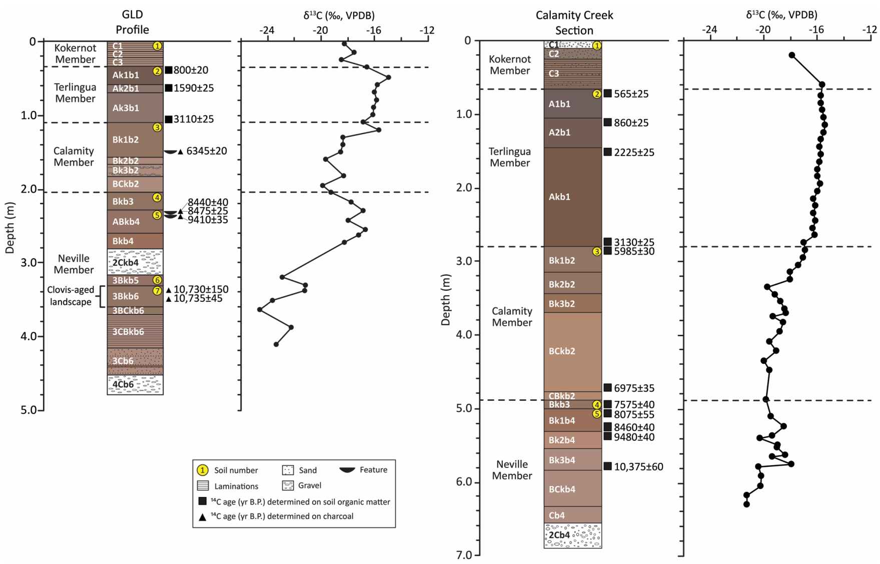
In the Footprints of Kirk Bryan and Claude C. Albritton, Jr.: A Reinvestigation of Soils as Evidence of Late-Quaternary Climate Change in the Northern Chihuahuan Desert of the Big Bend Region, Southwest Texas.

Mandel, Rolfe D.
Kansas Geological Survey, University of Kansas

During the 1930–40s, Kirk Bryan and Claude Albritton defined the stratigraphy of late-Quaternary alluvial fills in the northern Chihuahuan Desert of the Big Bend region, southwest Texas, resulting in a benchmark paper, “Soil Phenomena as evidence of climatic changes,” that demonstrated the value of paleosols as indicators of climatic change and set the stage for the use of soil science in Quaternary studies focused on climate change. Here, I present the results of soil-stratigraphic investigations at localities studied by Bryan and Albritton, plus several new sites, including the type section (GLD Profile) of a newly established lithostratigraphic unit, the Lykes Formation. The morphology and physical and chemical properties of surface and buried soils were analyzed. Also, δ^{13}C analysis of soil organic matter (SOM) was used to reconstruct late-Quaternary bioclimatic change that drove landscape evolution.

The Lykes Formation consists of four lithologically distinct late-Quaternary alluvial fills: the Neville, Calamity, Terlingua, and Kokernot members. Aggradation of the Neville Member between ca. 10,700 and 8400 ^{14}C yr BP and was punctuated by episodes of pedogenesis. Paleosols in the Neville have truncated, well-developed Bk horizons with rubified matrix colors, stage II carbonate morphology, and 6–15% $CaCO_3$ equivalent (CCE). Aggradation of the Calamity Member was underway by ca. 7000 ^{14}C yr BP and continued until soon before ca. 6000 ^{14}C yr BP. Buried soils sometimes occur within the Calamity Member but are weakly developed and not widely traceable. A soil with a truncated, moderately expressed Bk-BCk profile, brown matrix colors, stage I carbonate morphology, and CCE values of 5–8% is developed at the top of the Calamity. The Terlingua Member slowly aggraded between ca. 3100 and 500 ^{14}C yr BP and has a cumulic A horizon that spans almost the entire thickness of the unit; there is stage 0-I carbonate morphology and CCE values are <6%. The Kokernot aggraded after ca. 500 ^{14}C yr BP and has surface soils with thin A horizons above stratified alluvium (C horizons).

The δ^{13}C values of SOM indicate a C_3-dominated plant community at the onset of the Younger Dryas (ca. 11,000 ^{14}C yr BP), but a shift towards a C_4-dominated community occurred by ca. 10,700 ^{14}C yr BP and continued with warming and increased aridity through the middle Holocene. The soils and δ^{13}C values indicate that the northern Chihuahuan Desert was a C_4 grassland from ca. 3100–500 ^{14}C yr BP with greater effective annual precipitation compared to ca. 7000–6300 ^{14}C yr BP. By around 400–300 years ago, overgrazing by livestock transformed the grassland into a shrubby desert.



Session 2 Organic and inorganic carbon as a part of soil memory

Paleo-fires evidence on soils from karstic environments in Quintana Roo, Mexico.

Moreno-Roso, Sol[1], Solleiro-Rebolledo, Elizabeth[2], Sedov Sergey[2]
[1]Posgrado en Ciencias de la Tierra, Universidad Nacional Autónoma de México, Mexico City, Mexico.
[2]Instituto de Geología, Departamento de Ciencias Ambientales y del Suelo, Universidad Nacional Autónoma de México, Mexico City, Mexico.

Fires affect soil directly because temperature increases modify their biological, physical, and chemical properties. Fires leave organic and inorganic evidence that can be preserved for a long time in soil memory. This fire evidence helps in the reconstruction of past events in the landscape. On the other hand, fires can negatively alter the soil, increasing surface erosion. This study focused on the paleo-fires evidence from different soils, paleosols, and pedo-sediments from the karstic environment of Quintana Roo coast in Mexico. Field descriptions, micromorphology, and physical-chemical analyses were used for studying the soil profiles and samples. Different fire evidence was found on the studied materials, such as burned limestones, charcoal, burned shells, structure loss, and rounded and reddened aggregates. Besides, the radiocarbon dating results were associated with the Maya occupation of Yucatán Peninsula. Therefore, the fire evidence found can be linked to the burn-and-slash agriculture that has been a common practice in the area since ancient times. These agricultural practices have a significant environmental impact increasing soil erosion and the following soil accumulation in karstic depressions. Karstic sinkholes, like karstic pockets, are an excellent location for preserving paleo-fire evidence in the landscape. Radiocarbon ages of different materials found in the pockets and caves are around 3,800 cal BP, what document the impact of agriculture in the region during that time.

Effect of Biochar on Soil Properties and Nutrient Uptake of Maize (Zea mays) in Agbani, Enugu State, Southern Eastern Nigera

Prof. Oliver E. Ngwu
Department of Agronomy and Ecological Management and Faculty of Agriculture and Natural Resources Managements Enugu State University of Science and Technology, Enugu Nigeria.
Email: ngwueoe@yahoo.com; Phone No: +2345036764402.

The study evaluated the effect of biochar on soil properties and nutrient uptake of maize plant in 2020 and 2021 planting seasons in Agbani, Enugu State Eastern Nigeria. The study employed a randomized complete block design in which four (4) biochar rate (0.0, .05, 0.1 and 0.15t/ha) served as the treatments that were replicated six times, plant and soil samples collected from each plot after plant harvest were analyzed using standard laboratory procedures. Data were further subjected to Analysis of Variance (ANOVA), correction and multiple regressions using Genstat Statistical package version 18, Biochar generally had better impact on soil and plant properties in 2020 that 2021 planting season, apart from Soil C/N ratio. Result showed that particle size distribution was not significantly impacted by biochar irrespective of rates and planting season. However, with increasing rates, biochar significantly ($P<0.05$) and increasingly improved moisture content (from 5.6 to 9.98% and from 5.03 to 7.3%). Bulk density (from 1.58 to 1.29g/cm3 and from 1.6 to 1.37gcm3),1.259 to 2.075% to 2.075%), total nitrogen from 0.086-0.0163% and from 0.065-0.103%). ECEC (from 4.719-5.633Cmol "kg-1) and 4.0065.053CMol-1kg-1(. .% BS (61.57-83.41% and 53.29-78.16%) and basic cations (Ca, Mg and), in control and 0.15 tons ha-1 biochar rate in 2020 and 2021 planting season respectively. Maize nutrient uptake by both stover and grain followed decreasing trend of N>P>K>Ca>Mg but was taken up more by grains than stover. Subsequently all the plant parameters (plant height, number of leaf, leaf area index and leaf

length) were significantly ($P<0.05$) and persistently increased with increasing biochar rates of application. Moreover, organic matter (from 1.620 to 3.124% and 1.259 to 2.075%). pH from 5.43 to 6.11 and 5.04 to 5.85), bulk density (from 1.58 to 1.29 gcm-3 and from 1.6 to 1.37 gcm-3) average phosphorus (from 11.07 to 24.19 mgkg-1 and from 9.73 to 22.03mgkg-1), TEA (from 1.8 to 0.927C molkg-1 and from 1.85 to 1.10Cmolkg-1), and percent base saturation (61.57-83.41% and 53.29-78.16%) had strong association with plant nutrient uptake. Since there was better performance of mazie as a result of biochar application in 2020 than in 2021 planting season, farmers are advised to augment soil nutrient after previous year plant harvest.

Previous year plant harvest, hence BIOCHAR is very good in remediation of Soil Fertility.

Keywords: Biochar, Zea mays, Soil properties, Nutrient uptake, Agbani.

Supraglacial organo-mineral systems as a source of organic carbon for recent and paleosols (as based on 14C-data analysis)

Zazovskaya E.[1] , Mergelov N.[2], Dolgikh A.[2], Dobryanskiy A.[2], Turchinskaya S.[2], Cherkinskiy A.[1] Goryachkin S.[2]

[1]Center for Applied Isotope Studies University of Georgia, Athens, US

[2]Institute of Geography RAS, Moscow, Russia

For a long time, glacial material was considered by researchers to be practically an abiotic substrate. Currently, glaciers are being viewed as a distinct biome, the study of which is particularly important in today's world with glaciers rapidly retreating. As glaciers retreat, supraglacial organo-mineral formations become part of soil formation processes in the periglacial zone. The organic matter that accumulates and transforms in supraglacial soils and soil-like bodies significantly influences the periglacial zone. The places where this material accumulates are "hotspots" for soil formation in the periglacial zone. Glaciers contain approximately 6 petagrams (1 petagram is 10^{15} grams) of organic carbon (C), with the majority in a water-soluble form and approximately a quarter in solid-phase particles (Hood et al., 2015).

We conducted research on the radiocarbon age of organo-mineral formations on glaciers in the Svalbard, the Caucasus, and the Altai. Organic matter on the glacier surface, as well as in soils, consists of several pools with different radiocarbon ages. However, despite the presence of a large number of primary producers in the supraglacial zone, and all these formations being on the surface, the radiocarbon age determined based on the total carbon for all these objects almost always differs from the modern age. The age of cryoconites on Svalbard glaciers varies within the range of 8200 to 3700 ^{14}C yr BP (Before Present), on the Caucasus glaciers from 850 to 7500 radiocarbon years BP, and on the Altai glaciers from 350 to 560 ^{14}C yr BP. The radiocarbon (^{14}C) age varies among different fractions of supraglacial material. Separating organic matter (OM) in cryoconite by density fractions (Zazovskaya et al., 2022) allowed for a more precise characterization. It was found that the fresher OM (<100 years) from the Aldagonde Glacier on Svalbard was primarily found in the lightest fraction of free OM (FPOM), while the older OM (11120 ± 40 BP and 8850 ± 30 BP) was associated with the heavier fractions (HF1 and HF2), which are linked to organo-mineral complexes and adsorption on the mineral matrix.

Climate changes during the Holocene have influenced the extent of glaciations and glacier dynamics. In the process of glaciers melting, organic matter accumulated on the surface and in the glacier body was involved in the process of soil formation, including ancient organic carbon. When dating paleosols in the periglacial zone, such material can significantly skew the age of the studied soils, making them appear much older than they actually are.

This study is supported by the RSF, Project No. 20-17-00212

Formation of pedogenic carbonates in the Teotihuacan Valley, México_ paleoenvironmental implications

Daisy Valera Fernández[a],Elizabeth Solleiro Rebolledo[a],Sergey Sedov[a],Konstantin Pustovoitov [b, c]
[a]Universidad Nacional Autonoma de Mexico, Instituto de Geologia, Ciudad Universitaria Campus, Ciudad de Mexico, Mexico
[b]University of Tübingen, Institute for Archaeological Sciencesand Senckenberg Center for Human Evolution and Palaeoenvironment, Tübingen, Germany
[c]Institute of Oil and Gas, Yugra State University, Chekhova str. 16, 628012, Khanty-Mansiysk, Russian Federation

The formation of pedogenic calcium carbonates is a result of the interrelation of the terrestrial cycles of calcium (Ca) and carbon (C). Over time, secondary carbonate accumulation results in the development of calcic and petrocalcic horizons in soil profiles. These horizons can be considered important indicators of past climatic changes. Micromorphological, mineralogical, and geochemical characteristics of secondary carbonates from three paleosol profiles (Cerro Gordo 1, Cerro Gordo 2, and Maseca 1) were analyzed in this study. Pedogenic carbonates were characterized by irregular and variable carbonate crystal sizes, inclusions of soil particles, and dark or light micrite and microsparite laminations. Micromorphology and scanning electron microscopy revealed weathered plagioclase minerals as a potential source of calcium for carbonate precipitation. The $\delta^{13}C$ isotopic composition evidenced a mixture of C3 and C4 plants during the Pleistocene and a transition to a higher proportion of C4 vegetal cover during the Holocene. This agreed with an increase in modeled paleo-temperature from 10.9 °C to 13.7 °C based on ^{18}O-temperature equations. Our results support those determined for the regional paleoenvironment during the Pleistocene, the Pleistocene-Holocene transition, and Mid-Late Holocene

Keywords
Pedogenic carbonates, Paleosols, Ca^{2+} sources, Stable isotopes, Micromorphology

A comparative study of carbon isotope signature in pedogenic carbonates of cold (South Siberia) and hot (Chihuahuan Desert) semiarid environments

Bronnikova Maria[1,2], Monger Curtis[1], Zazovskaya Elya[3]
[1] New Mexico State University, [2] Institute of Geography RAS,
[3] Center for Applied Isotope Studies University of Georgia

Pedogenic carbonates are very specific and still underestimated compartment of paleoenvironmental memory/record of semiarid and arid soils. These pedofeatures are especially attractive because ones can be potentially ^{14}C dated. There were relatively numerous publications dealing with radiocarbon dating and isotopic signatures of pedogenic carbonates though the interpreting of these data is still contradictory as the formation of isotopic record of soil carbonates are not completely understood.

A comparative study was conducted on the radiocarbon age and isotopic record of soil carbonates in two different semiarid environments: one with a cold climate (MAT -3.8°C) in South Siberia and the other with a hot climate (MAT +17°C) in the Chihuahuan Desert. Carbonate coatings on rock clasts and carbonates of fine earth of the surrounding matrix were conducted for pre-dated (Late Holocene) anthropogenically deposited/affected substrates. Climatic characteristics of the studied sites differ mostly in part of temperatures while the sum of annual precipitation is about the same 200-300 mm. Cold semiarid site has pure C3 vegetation never intervened by C4 plants even in a long-term perspective. Hot semiarid site now is also dominated by C3 plants (creosote bush) but was dominated by C4 grasses 150 years ago. In both cases soils do not contain detrital calcite but contain old (Pleistocene) pedogenic carbonates. In both sites, coatings on rock clasts within anthropogenically accumulated parent material have been radiocarbon dated to a later period compared to deposition of the material itself. Carbonate coatings penetrate up to the base of the human-constructed 3 m embankment in the cold semiarid site. Carbonates of the matrix in the loamy layers of the embankments and carbonates of fragmented ex-situ coatings imbedded into the matrix pre-date the embankment construction. Both are inherited from soil material used for the construction. Fine earth matrix carbonates of the horizons above and below the hearth (hot semiarid conditions) have compatible ^{14}C ages with the carbonates of coatings in these horizons; at the same time matrix carbonates of the surface crust are surprisingly older than the hearth. This fact implies that carbonates above the hearth are multigenerational and along with newly formed pedogenic carbonates may contain older ex-situ pedogenic calcite. In both sites presence of old (Late Pleistocene) pedogenic carbonates in the system (within the zone of contemporary soil processes acting) didn't have a significant influence on pedogenic carbonates of the younger generations. δ13C of pedogenic carbonates in soils from both hot (Chihuahuan Desert) and cold (S. Siberia) sites have similar values varying in a range between -0.9 and -6.7‰. At the same time intra-profile variability of δ13C in soil of the cold site reveals clear trend in enrichment of δ13C related to Late Pleistocene colder environment. We suppose that relatively high δ13C values of soils carbonates in Chihuahua Desert and S. Siberia are governed by different key factors. The participation of C4 plants plays a crucial role in the formation of the isotopic signature in the desert. In the case of the cold site, δ13C enrichment results from prevailing abiotic processes at low temperatures, particularly cryogenic carbonate formation. δ18O values show significant depletion in carbonates formed in cold environments (S. Siberia) compared to those formed in hot climates. The δ18O values of 'warmer' Holocene carbonates are higher compared to the 'colder' Late Pleistocene carbonates at the cold South Siberian site. All the data clearly demonstrate the complexity and multigenerational character and morphological variety of the pool of pedogenic carbonates in both profiles. All that stresses that interpreting of stable isotopic and ^{14}C data for soil carbonates demands great awareness and cautious.

Acknowledgements: This study was supported by Fulbright Program IIE ID: PS00332966; isotopic data and 14C dates were funded by Jornada Experimental Range

Precipitation variability in the Transbaikal region (Southeastern Siberia) during the Late Glacial and Holocene based on $\delta^{13}C$ values of paleosols organic matter

Golubtsov V.[1], Ryzhov Yu.[1,2], Cherkashina A.[1]

[1]V.B. Sochava Institute of Geography SB RAS, 664033 Irkutsk, Russia

[2]Institute of Earth's Crust SB RAS, 664033, Lermontova str., 128

Global climate change has caused major shifts in global and regional precipitation regimes. Precipitation and subsequent plant water availability controls the magnitude of soil carbon sinks at the regional to global scale. Therefore, effective predictions of future changes in precipitation based on relevant information about climate in the geological past is needed.

Over recent decades stable carbon isotopes in paleosols and sediments have been widely used to reconstruct paleoenvironments and have provided important insights into patterns of past climate and environmental changes.

At present, practically no such studies have been carried out for the vast inland territory of Siberia. Previously revealed a close relationship between the stable carbon isotope composition of organic matter in regional soils and the amount of precipitation (Golubtsov et al., 2021) makes it possible to quantify the level of atmospheric moisture for various time spans.

The main object of study was the well-dated soil-sedimentary sequences of the Selenga middle mountains.

In general, the largest amount of precipitation during the vegetation season in the study area is characterized by the early Holocene, as well as intervals corresponding to short-term warming within the Late Glacial. The minimum amount of precipitation is typical for the interval of 10-4.2 kyr BP with a minimum at the end of this time period. Up to 2 kyr BP an increase in moisture was observed, which was replaced by a relatively short-term stage of aridization of about 1 kyr BP and a further increase in precipitation.

The described pattern of changes in humidity is comparable well with earlier regional reconstructions based on biostratigraphic data, especially in terms of Middle Holocene aridization, which coincided with a pronounced increase in temperatures at that time. The trends of the reconstructed changes are also well comparable with the qualitative assessment of the intensity of pedogenesis, which we performed earlier for the territory of the Selenga middle mountains (Golubtsov et al., 2017). The minimum intensity was typical for the Middle Holocene and the maximum for time intervals chronologically corresponding to the time frames corresponding with Preboreal and Subboreal periods of the Holocene.

The study was funded by State assignment AAAA-A21-121012190055-7 (FWEM-2021-0002).

Golubtsov V.A., Vanteeva Yu.V., Voropay N.N. Effect of Humidity on the Stable Carbon Isotopic Composition of Soil Organic Matter in the Baikal Region // Eurasian Soil Science. 2021. Vol. 54. №. 10. p. 1463–1474. DOI: 10.1134/S1064229321100069.

Golubtsov V.A., Ryzhov Yu.V., Kobylkin D.V. (2017) Pedogenesis and sedimentation in the Selenga Middle Mountains in the Late Glacial and Holocene. Irkutsk: Publishing House of the Institute of Geography SB RAS. 139 p. (in Russ.).

October 8, 2023

Session 3 Surface soils and time-factor: clues of contemporary and paleoenvironments, analogues of paleosols

The record of paleolake shoreline sediments in polygenetic soils of arid steppe, Kyzyl Kums, Uzbekistan

Kabala C.[1], Gadek B.[2], Metrak M.[3], Szymczak K.[4], Suska-Malawska M.[3]

[1]Wroclaw University of Environmental and Life Sciences, Wroclaw, Poland; [2] University of Silesia, Sosnowiec; [3] University of Warsaw, Faculty of Biology; [4] University of Warsaw, Faculty of Archaeology

Although the Neolithic Kelteminar culture of hunters, fisherman, and, subsequently, stockbreeders has developed along the shorelines of the (paleo-)lakes and (paleo-)channels of the former Zerafshan delta, many settlement sites of this cultures were identified along the contour line of 200 m ASL, without clear relation to known water bodies. Some archeologists postulate the presence of a great lake in a mid-Holocene period; however, the existence of such a lake has not been confirmed in the context of evolution of adjoining marine, lake, and river systems. One of the best known Kelteminar settlements (6000 – 5400 cal BC and 4000 – 3000 cal BC) is located 65 m above and 2 km east of the present-day shoreline of a small (artificial?) Ayakagytma lake in the Kyzyl-Kum desert. The aim of the pilot geomorphological, pedogenic and paleobiological study, exploring the sequence of 5 soil profiles, located between the highland and lake shoreline, across the archaeological site, was to verify the working hypotheses on: (a) location of the Kelteminarian settlement on specific sediments of water (fluvial or lacustrine) origin, and (b) presence of soils typical for shoreline environments, which differ from the soils of terrestrial environments of dry steppe (MAAT 14.9 ^{o}C, MAP 135 mm). Calcaric Skeletic Gypsisol, located on a highland above the archeological site, is developed from eolized sands resting on high-energy fluvial sediments, rich in rounded gravels and pebbles. B horizon is well developed and overlies a gypsic horizon containing large gypsum and calcite crystals (‘brushes’).

Gypsic Sodic Solonchacs, located in the archeological site, are clearly stratified with prevailing heavy loamy and clayey textures. Soils do not contain any skeletal grains to the depth of at least 100, even if overly the hard rock. Both profiles contain buried humus layers of variable thickness, resting on strongly mottled horizons (with paleo-gleyic properties). One of profiles has a 50-cm thick dark, heavy loamy humus horizon in the topsoil, with cracks 30 cm deep, presently filled with eolian sand. Calcaric Gypsiric Fluvisol, located on a fluvial pan in a basin below the archeo-site, is a relatively young soil, finely stratified throughout the profile. MRT of organic matter below the single stony layer at 110-112 cm was approximated at 7500-7200 cal BC. Calcaric Gleysol, located on a shoreline of Ayakagytma lake, is a shallow, clay-textured, poorly developed soil, calcareous, gypsiferous, and saline, but its pedogenic features do not meet the diagnostic criteria for salic, gypsic or calcic horizons. Moreover, the expected organic or mineral-organic lacustrine sediments are not present (MRT of organic matter in Gleysol was at ca 12,000 cal BC, while the MRT in the present-day lake sediments was at 1300-1400 cal AD).

It was confirmed, that the soils in the archeological site at ca 200 m ASL were developed from water sediments of the Holocene age, most probably of lacustrine origin, and totally differ from highland soils, developed from older, Pleistocene (?) fluvial sediments. Also, the buried A horizons confirmed subsequent flooding of the settlement site, but the takyr-like humus-rich topsoil suggests the alluvial origin of the younger sediments and soil development on a local flooding plain. Whereas, young and poorly developed soils located in the basin, below the archeological site, do not confirm the presence of a large water-body. It seems, the Neolithic settlement developed on a shoreline of a small water-body, closed by natural orographic barrier and fed by seasonal tributaries. Destruction of the barrier, probably due to periodic increase of climate humidity, led to disappearance of the local lake, changes in hydrological status of soils, and finally resulted in a desertification of the area of former settlement.

Geomorphic patterns in Rangeland soil landscapes

Harrison J B J
New Mexico Tech

With ongoing attempts to model climate change impacts on the water resources particularly in arid areas, there is increasing need to determine the scale and variability of soils in rangeland areas. All rangeland areas have been mapped mostly at a scale of 1:24,000 or greater. The broadly defined taxonomic units and compound soil mapping units common at this scale mean these maps provide only a very general picture of the soil landscape. However, the utility of climate and landscape modeling is dependent on the accuracy of the soil data used. This is particularly true of hillslope soil landscapes.

Improving the accuracy of rangeland soil maps will rely on remote sensing, and digital soil mapping techniques, with the prospect of machine learning of the existing soil data as well. Challenges to improving rangeland soil mapping include identifying the scale of soil variability and characterizing subsoil properties remotely. Identifying the major drivers of soil variability and their proxies will aid in the prediction of soil landscape patterns.

We do have some conceptual models which can aid in identifying in particularly the scale and patterns of soil variability on hillslopes such as weathering limited /transport limited hillslopes, soil catenary relations and the concept of spatial and temporally controlled soil landscapes.

Spatially controlled soil landscapes are those where the soils are sufficiently stable that slope orientation slope position, and lithology exert a control on the pattern of soil variability. Temporally controlled soil landscapes are those where the main driver for soil variability is the age of the soil, common in areas with high erosion and deposition rates.

Examples of two types of soil landscapes are discussed, a geomorphically active drainage in the Southern Alps of NZ, Camp Creek, and two drainages in the foothills of the Ladrone Mts in the Rio Grande Rift.

Some Analogs of Late Paleozoic and Mesozoic Soils in Recent Soil Landscapes

Goryachkin Sergey, Spiridonova Inga
Institute of Geography, Russian Academy of Sciences, Moscow, Russia

Late Paleozoic and Mesozoic are periods when the active formation of limestones and gypses took place. These substrates were involved in the relevant pedogenesis. So, the study of recent soils on the calcareous and gypsum matrix in different climates may give us a clue for the kind of soil formation in those ancient epochs.

Soils on hard gypses, lacustrine lime and marbles were studied in Central Europe, northern European Russia and Baikal area in Siberia. In boreal climate conditions the Holocene calcite-free regolith with a depth n*10cm-1m is forming on hard gypsum rock. Peculiarities of soils and ecosystems formed on this regolith in taiga zone are the mineralogical purity, very specific geochemical cycle, and unique oligotrophic phytocenoses different from usual taiga vegetation.

Mineralogical purity of gypsum accounts for the absence of stable residual products of weathering, since the ultimate result of this process is a total dissolution. The loose soil layer exists in conditions if the rate of gypsum disintegration is higher than the rate of dissolution, which is the case in humid boreal climate. The initial stage of this type of hard rock weathering is related to cryogenic cracking, hydration of relics of anhydrite resulting in gypsum forming, and intrusion of roots. The leading role belongs to cryogenic mechanisms – wedging action of ice freezing in large pores and cracks and cryohydration – oscillation of wedging pressure of thin moisture films absorbed in micropores. Synergistic action of processes of disintegration, dissolution and total removal of dissolved gypsum results in crushing of hard rock to the size of gypseous powder (< 1 mm) and decrease of the bulk density.

It was found out that the deeper litter leads to shallower horizon of disintegrated gypsum rock. It is because of the deep litter smoothed the fluctuation of temperatures during the process of freezing and thawing.

Soils on marbles are similar to ones on hard gypsum, but the disintegration is pronounced only in areas with continental climates with strong seasonal cryogenesis. Both on gypsum and marble disintegration is substituted by total dissolution in warm humid climates and by recrystallization in arid climates.

The geochemical cycle in ecosystems on hard gypsum is specific because of a sharp deficiency in most macro- and microelements except Ca, S, and Sr in soils. Nutrient deficiency causes the appearance of oligotrophic open woodlands on gypsum, which differ from usual boreal forests ecosystems on silicate rocks by a low phytomass (53 t/ha), low canopy density, the predominance of suppressed larches and pines, and the presence of arctic-alpine and rare species.

Except the bulk composition, most other physical and chemical properties of gypsum regolith (texture, drainage, soil temperature, water capacity, pH) are favorable for plants. These "positive" properties become effective in cases if the nutrient deficiency is compensated at the expense of adjacent silicate soils, which results in a higher stand quality class and an increased biodiversity in comparison with zonal ecosystems. Vegetation influences soils in boreal ecosystems on hard gypsum as follows: (1) the income of nutrients with falloff from adjacent phytocenoses of silicate soils, (2) control over the depth of gypsum weathering and fine earth formation, because of regulation of heat and moisture regime, and (3) erosion hindrance.

Late Paleozoic is characterized by alteration of cold and warm biospheres when the disintegration may have prevailed however Mesozoic is characterized by warm conditions and the dissolution of Ca-matrix may have been predominant.

Recent and Paleofeatures in Soils of Mountainous Cryo-Steppe Landscapes, Southeastern Altai

[1]Konoplianikova Yu.V., [1]Bronnikova M.A., [2]Lebedeva M.P, [2,3]Gerasimova M.I.
[1]Institute of Geography RAS
[2]Dokuchaev Soil Science Institute
[3]Lomonosov Moscow State University

Surface soil profiles are generally interpreted and classified as containing features consistent with the actual environment. However, detailed hierarchical morphogenetic analysis gives us opportunity to identify paleofeatures in recent surface soils due to soil capability to record environmental conditions and pedogenic processes in stable elements of the soil body. We studied profiles of cryoxerophyte steppe soils on the Southeastern Altai based on the hierarchical morphogenetic analysis, with a special focus on soil micromorphology.

Three studied soils compose a landscape-altitudinal sequence: Skeletic Kastanozems (Cambic) under a cryoxerophyte steppe with alpine elements (2400 m), Skeletic Cambisols (Protocalcic) under a cryoxerophytic steppe (2200 m) and Skeletic Cambic Calcisols (Yermic) under a desertic cryoxerophyte steppe (1900 m). All those soils are united within a cryoaridic soil type in the Russian soil classification. They occur under extremely cold, ultra-continental aridic conditions (MAT below zero, MAP 100-200 mm, annual temperature amplitude up to 55°C). Soils are formed on skeletal sandy loams and have AK-BPL-BCAic (Ae-Bw-Bk) horizons. The upper part of the soil profile (0–40 cm) comprises two horizons: dark brown A and dull yellowish brown B. Both have granular microstructure, abound in weakly decomposed plant residues with silty-clay-organic coatings on them and on mineral grains. Dry, weakly decomposed "root felt" is accumulated in the upper Bk, the Bk horizons are very stony. Abundance of low-decomposed fine (0.1-0.5 mm) plant residues, clay-silty-sandy cappings on the upper surfaces of stones, ooidal and lens-like microstructure, postshlieren texture, frost-shattered aggregates are typical features of these soils and interpreted as recent cryogenic processes.

The most humid object has the thickest humus horizon with well-developed structure and microfeatures related to mesofauna; the most distinct and developed cryogenic ooid aggregates in B horizons. The most arid object has yermic properties: elements of desert pavement, and vesicular and fine platy crust over the humus horizon, it contains carbonates all over the profile. Impregnation of plant residues by iron compounds and carbonates are expressed here, and the lower Bk horizons has carbonate cementation. The following pedogenic processes well agree with current arid-semi-arid and ultracontinental cold conditions: 1) accumulation of specific organic matter in A horizon; 2) biogenic micro-structuring; 3) cryogenic processes: frost shattering, frost sorting, formation of silt cappings; 4) recrystallization of calcite in pendants followed by possible short-distant eluvial-illuvial redistribution of carbonates; 5) impregnation of plant residues.

Para-extreme lithological conditions (coarse fragments content is 30-80% by volume) determine localization of pedofeatures on the surface of rock fragments, so Bk horizons soils have various multi-layered calcite and humus pendants on gravels and stones. The morphology of layers in pendants made it possible to reconstruct the main evolutionary phases of cryoaridic soils. These are: 1) formation of microsparite–micritic dense silica-containing coatings due to short-term fluctuations of the shallow alkaline bicarbonate groundwater level in the semiarid–arid climate; 2) formation of sparitic dense coatings under the slow accumulation of carbonates from low-mineralized bicarbonate water in less arid conditions; 3) the eluvial-illuvial formation of micritic loose coatings under stable automorphic semiarid conditions; 4) formation of Fe-humus coatings in cool humid climate: Al-Fe-humus phase of pedogenesis; 5) the recommencement of the eluvial-illuvial formation of micritic loose coatings under aridization of the last thousand years of the Holocene.

Cryoaridic soils in Altai mountains are polygenetic. Their Bk horizons contain relic features — evidences of former carbonates (7-8 cal ky BP) and humus (3.8 cal ky BP) migration

in the soil, whereas the upper horizons (Ae, Bw) have features, basically related to recent environment with cryogenic and biogenic pedogenic processes.
This study were performed within the framework of state assignment of the Institute of Geography RAS, theme no. AAAA-A19-119022190169-5 (FMGE-2019-0006)

Palaeopedogenesis of Red Palaeosols in Southwestern China and Their Paleoenvironmental and Landscape Evolution Implications

Lu Shenggao, Wang Siyuan, Chen Yuyin
College of Environmental and Resource Science, Zhejiang University, Hangzhou 310058. China

Red palaeosols are widely distributed in the plateau regions of southwestern China. The palaeopedogenesis recorded in the red palaeosols greatly increase our understanding on the palaeoenvironmental changes, landscape evolution and tectonic uplift pattern in the plateau. Pedogenic features, geochemistry, mineralogy and rock magnetism of red palaeosols collected at 2200 to 2400 m elevations from the Yunnan Plateau were investigated to interpret the pedogenical weathering processes and palaeoclimatic conditions recorded in the palaeosols. Pedologically, the red palaeosols were characterized by the dark red color (a hue of 5YR or redder), strong acidity, and high free iron oxide (>50 g/kg) and clay (>50%) contents. Chemical weathering indices, such as CIA (CIA=[Al2O3/(Al2O3+CaO+Na2O+K2O)]×100), Sa (Sa=SiO2/Al2O3), Saf (Saf=SiO2/Al2O3+Fe2O3), and A-CN-K diagram (Al2O3-CaO+Na2O-K2O) revealed that the red palaeosols had experienced strong chemical weathering processes. Quartz grains of the red palaeosols were characterized by a number of deep dissolution pits and cracks on their surfaces. The clay minerals of the red palaeosols were composed of kaolinite, gibbsite, hematite, and vermiculite in the order of abundance. Pedological, geochemical and mineralogical studies indicated that the red palaeosols possess palaeopedogenic features of the laterization processes associated with the tropical and subtropical pedogenic conditions. Red palesols are characterized by highly magnetic signals and contain significant amount of fine-grained superparamagnetic (SP) grains, which is attributed to the higher concentration of pedogenic SP maghemite. Magnetic evidence suggests that the red paleosols experience a strongly pedogenic processes. Pedogenic processes result in the neoformation of hematite and maghemite, and causes a substantial increase in the magnetic susceptibility and other magnetic signals. It concluded that these highly magnetic red paleosols could not be formed under the present climate of plateau. It is deduced that the red paleosols had been uplifted by the neotectonics since its original formation. The tectonic movement of Plateau forced the soils uplifting to the plateau planation surface with an elevation of 2000–2400 m, which led to the contrast vertical distribution pattern of soils in Plateau. This explains why the highly weathered red palaeosols are widely distributed in the plateau. The presence of highly weathered soils at an altitude of 2200-2400 m indicated the influence of of tectonic uplift on the soil vertical distribution. Palaeopedogenesis of red palaeosols provides new insight into the palaeoclimatic and palaeoenvironmental reconstruct and tectonic movement of plateau. Therefore, the palaeoclimatic reconstruction based on palaeopedological analyses may be a powerful proxy for reconstructing palaeopedogenical environments in plateau. The neotectonics revealed by the red palaeosols are important not only for understanding the amplitude and the age of plateau uplift but also for reconstructing the paleoclimates.

Possible analogues of ancient proto-soils in modern extreme environments

Mergelov Nikita
Institute of Geography RAS

Knowledge of the first ecosystems on land that existed outside aquatic environments has expanded significantly over the past decade (Stüeken et al., 2012; Beraldi-Campesi, 2013; Wellman and Strother, 2015; Lenton and Daines, 2017; Homann et al., 2018, 2019). Rapid increase in geochemical, paleontological, and paleogenetic data on terrestrial ecosystems of the Archean and Proterozoic opens up new possibilities for compiling still very crude models of soil diversity in the Precambrian. It can be assumed that ancient initial soils or proto-soils arose already at the very first stages of interaction between microorganisms and rocks. However, thick profiles of the Early Precambrian paleosols do not always allow to distinguish the first phases of soil formation. Soils formed under modern extreme conditions (Goryachkin et al., 2019) are the best available real-time models to approximate proto-soils that existed in various geological periods (Mitchell et al., 2021, 2023). Here we consider possible candidates for analogues of ancient proto-soils:

• *cryptic proto-soils with subsurface organic horizons.* Soils with endolithic and hypolithic organic horizons of microbial origin (Mergelov et al., 2018, 2020) could be the first soils that developed in the absence of an ozone screen and under other extreme factors. The pore space inside the rocks or under their fragments created an ultraviolet shadow, retained moisture more efficiently and provided nutrients. Light still penetrated through translucent minerals like quartz or feldspars to a depth of ~1 cm allowing colonization by microbial autotrophs and formation of soil microprofiles in the pore space of weathered rocks. Over time, cryptic proto-soils could evolve into epilithic varieties, while eluvial-illuvial differentiation arose in cryptic proto-soils at later stages, when fungi and lichens appeared (~1.4-0.4 Ga). Now endolithic and hypolithic proto-soils are widely represented in polar regions, hot deserts and high mountains.

• *amphibious proto-soils* of coastal shallow waters with alternating subaquatic/subaerial conditions are relatively well represented in geological record of the Precambrian due to the abundance of marginal continental landscapes at that time and rapid conservation by sedimentation. Amphibious proto-soils are usually represented by polyrhythmic sequences of microprofiles under microbial mats and are possibly associated with some of microbially induced sedimentary structures (MISS - Noffke, 2010). Amphibious proto-soils played an important role in sinking organic carbon in the Precambrian landscapes (now this C is partly preserved as kerogen). We discuss examples of fossil amphibious proto-soils in the volcanogenic-sedimentary sequences of the Kaapvaal, Pilbara and Karelian cratons. Their analogues are presented in modern coastal settings with microbial mats.

• *supraglacial proto-soils.* Assemblages of mineral and organic components could have already been present on ice when subaerial surfaces massively turned into supraglacial during major cooling events in the Proterozoic. Paleoclimatic models show that even under conditions close to Snowball Earth, there was never a shortage of ice-free areas on the continents (Hoffman, 2016), and volcanic and continental dust accumulated on the ice. During periods of large-scale glaciations, supraglacial proto-soils were probably the most common soil-like bodies on the planet and served as refugiums for biota. On modern glaciers, supraglacial proto-soils develop on (a) cryoconite, (b) flat ice/snow surfaces, where algal and cyanobacterial biomass is partially transformed by heterotrophic communities into humic-like substances, and also under (c) metastable moss colonies ("glacier mice") that grow on supraglacial sediments.

• *hydrothermal proto-soils* were potentially widespread in the Early Precambrian due to the specifics of geological processes. The discovery of traces of microbial activity in geyserites aged 3.48 Ga (Djokic et al., 2017) stimulates the search for analogs of ancient hydrothermal proto-soils among the most extreme (microbial) variants of modern thermozems (Goldfarb, 2005) in regions of volcanic activity.

Paleoenvironmental and geoarchaeological significance of Desert Varnish in the Sonoran Desert, Mexico

Martínez-Pabello Pável U.[1], Sedov Sergey[1], Villalobos Cesar[2] and Menéndez Iglesias Beatriz[3]
1. Institute of Geology, Universidad Nacional Autónoma de México, 04510, CDMX, Mexico
2. Institute of Anthropological Research, Universidad Nacional Autónoma de Mexico, 04510, CDMX, Mexico
3. Gerda Henkel Foundation. Patrimonies Funding Initiative, 40211, Düsseldorf, Germany.

Desert Varnish (DV), a micrometric thin layer that coats diverse lithologies, predominantly in arid and desert environments, constitutes a natural phenomenon of great scientific interest. Comprised of approximately 70% clay minerals and 30% iron and manganese oxides, DV exhibits a black to reddish coloration and an exceedingly slow growth rate, ranging from 1 to 40 micrometers per thousand years and reaching thicknesses greater than 200 micrometers. Owing to its gradual formation, numerous studies suggest that DV represents a surface structure predominantly fashioned by past environmental conditions, qualifying it as a paleo-pedological feature.

Beyond its scientific significance, DV holds cultural and artistic value, as ancient civilizations across the globe utilized it as a raw material for petroglyphs. In the northern region of Mexico, specifically within the Sonoran Desert, samples collected from the La Proveedora and El Arroyo archaeological sites were subjected to various analytical techniques to gain insights into the nature of DV. Microscopic observations revealed the stability of DV as it extends into the bedrock like a root structure, enabling its preservation over time despite the harsh environmental conditions. Moreover, the presence of biological structures associated with proteobacteria and actinobacteria groups was identified within the varnish. Additionally, the concentration of iron and manganese oxides exhibited an alternating pattern with increasing depth within the varnish until reaching the bedrock.

We conclude that DV from La Proveedora and El Arroyo in Sonora state, formed in wetter environments in the Late Pleistocene in different lithologies. Studies carried out in thin sections reflect environmental changes in the past. Finally, we can indicate that the DV was completely developed in the past and became available to be used as canvases (in the elaboration of petroglyphs) for the inhabitants of the area who lived in the middle Holocene.

Acknowledgement
To the Project PAPIIT-UNAM code: IN218323.

Session 4 Soils, paleosols, and soil materials of past human habitats

The soils of the Rumyantsev Garden as a record of Saint Petersburg city (Russia) history

Bakhmatova K.A.[1], Sheshukova A.A.[1], Sorokin P.E.[2], Egorova S.A.[1]
[1] St Petersburg State University, [2] Institute of the History of Material Culture Russian Academy of Sciences

Urban soils have been intensively studied in the light of environmental problems and as a substrate for urban greenery. Meanwhile, urban soils are valuable information storage not only about natural conditions of city formation, but also about the city history. Stages of land use at the certain location during the centuries of urban development not always had been properly documented. However, soils accumulate material evidencies of urban landscape transformations. Besides, different types of land use that replaced each other in time at a particular area determine the modern edaphic conditions for vegetation and affect the chemical composition of groundwater and other significant indicators of the urban environment.

The soils of Rumyantsev Garden situated on Vasilyevsky Island in Saint Petersburg were studied. The total area of the garden is 1.35 ha. A total of 220 trees (oak, linden, ash, maple and larch) grow in the garden now. Vasilyevsky Island (elevation up to 3.5 m) is a part of Littorina terrace of Prinevskaya lowland. The natural soil forming materials are alluvial-marine sans and loamy sands. At the beginning of the 18th century the site was occupied by Menshikovsky market. Later, during the construction of the nearby Academy of Arts, building materials were stored here. The parade ground of the Cadet Corps was situated at this place at the end of the 19th century. In 1818, the obelisk "Rumyantsev's Victories" from the Field of Mars was moved here and in 1867 a public garden was created. In 1927, the layout of the garden was slightly changed.

Two soil profiles were chosen in archeological excavation in the trenches crossing the garden from the center to the eastern border. One profile (p.1) was situated in the central part and the other one (p.2) – in the eastern part of the garden. The soils were named as urbostratozems according Russian soil classification and Urbic Technosoil, according WRB (2022). The archeologists found that cultural layers in the garden have thickness about 2 m with rising from the central part to the periphery. This indicates the structure of the initial relief of the site, where the central rise was surrounded by a swampy depression. Redoximorphic features were observed in the anthropogenic layers of p.2 from 120 cm and deeper. The buried humus-gley soil (Umbric Gleysol) was found there from 160 cm. According to archeological findings, culture layer formation in the garden proceeded in three stages: 1) before the mid-18th century – the layer of household waste, including bones; 2) the end of 18th-the beginning of 19th century- the layer of construction waste, used for levelling of the territory; 3) the third stage took place during the garden making in the second part of 19th century, when the surface level was brought to the modern values.

The heterogeneity of anthropogenic layers of different ages was confirmed by the differences in the content of coarse particles and organic matter. Both soils were alkaline and had high concentration of phosphorus (mobile forms). Higher levels of Pb (up to 600 mg/kg) and Zn (up to 272 mg/kg) were found in the surface and in the lower parts of cultural layer. The artefacts (anthropogenic inclusions) with size of 0.25-10 mm were studied using a Leica V205C stereo microscope and a Hitachi Desktop Scanning Electron Microscope TM3000 (at the Research park of St. Petersburg State University «Center for Microscopy and Microanalysis»). Material compositions of artefacts were connected with genesis of certain layers. Artefacts were represented by fragments of animal bones, bricks and ceramics, lime mortar, glass of various ages and origins, charcoal and slag. The degree of weathering of the artefacts varied depending on their age and composition. Natural inclusions in the studied soils were grains of feldspar and quartz. Ca, Mg, P and other elements from artefacts were dissolving during soil formation and downward flow of soil solution influenced the buried paleosoils properties.

Geoarchaeological analysis of paleosols and material of earthen kurgan constructions of the Big Boldyrevo Kurgan of the Bronze Age, Southern Pre-Ural, Russia

[1]Sverchkova A.E., [2]Khokhlova O.S.
[1] Institute of Geography, Russian Academy of Sciences, Moscow, 119017 Russia
[2]Institute of Physical, Chemical and Biological Problems of Soil Science, Russian Academy of Sciences, Pushchino, 142290 Russia

Geoarchaeological studies of burial mounds (kurgans) are of interest for geology, geomorphology, archeology and geography. Soils buried beneath those kurgans make it possible to reconstruct the history of their formation and cultural chronology, changes in environmental conditions. For a long time, only buried soils were the main object of paleopedological studies of kurgan whereas the kurgan earthen constructions often did not receive due attention. However, knowledge about the construction and material composition of the earthen kurgans themselves is a valuable additional source of information about historical, archaeological, natural and environmental changes.

In our work, a geoarchaeological analysis included interdisciplinary research aimed at studying archaeological objects using the methods of various natural sciences, i.e., geology, geography, physics, chemistry, biology and soil science. All paleosols and materials of earthen mound constructions were studied at the macro- and micromorphological level, particle size distribution and chemical composition, as well as magnetic susceptibility were determined in the laboratory.

The chronosequence of paleosols buried under constructions of different ages within kurgan 1 at the Boldyrevo IV kurgan cemetery in the Orenburg region, Russia has been studied Kurgan 1 (4.2 m height, 60 m diameter) was created in two stages by population of the Yamnaya culture (second quarter to the middle of the 4^{th} millennium BC) of the Early Bronze Age. Kurgan 1 is a unique object for paleoclimatic reconstructions, studying the architecture of an earthen structure and obtaining data on the technology used by ancient people for its construction. According to archaeological data, the kurgan was built over several decades whereas radiocarbon dating determined an interval of 300 years.

The kurgan included four earthen constructions. The difference in time between I-III and IV constructions was several decades. Initially, infants were buried under constructions I and II, and between them the main burial was made, which, together with constructions I and II, was covered by construction III. The second stage included the building of construction IV, supposedly for the repair of the kurgan that had stood for several decades. Based on micromorphological analysis and study of physicochemical properties of the materials of kurgan constructions, the main technological approach of building used by ancient builders were revealed. The main technology of the kurgan building was a rough kneading and tamping of raw sandy loam material in its raw form with the addition of river silt, rare coals and bones. The analysis of the earthen constructions of the kurgan and the soils buried under them showed that the material for its building was mainly local soils, so changes in soil properties affected the properties of the constructions' material. During the building of the kurgan, both in the buried soils and in the materials of the kurgan constructions, there was a decrease in the content of organic carbon, an increase in the content of carbonates and LOI, pH_{H2O}, gypsum, exchangeable sodium and magnetic susceptibility. These changes indicate that the time span under consideration, like the entire early (Repino) stage of the Yamnaya culture, was characterized by a more arid climate than the modern one.

This work was supported by the Russian Scientific Foundation, project N 23-68-10006.

Soils of a kurgan cemetery indicating the paleoenvironment in the forest-steppe area of the Central Russian Upland at the turn of millennia

Mikhaylova D.[1], Khokhlova O.[2], Makeev A.[1]

1 - Soil Science Faculty, M.V. Lomonosov Moscow State University, Moscow, Russia

2 - Institute of Physicochemical and Biological Problems of Soil Science, Russian Academy of Sciences, Pushchino, Russia

The Central Russian Upland was influenced by a variability of relatively arid and humid climatic stages during the second half of the Holocene [1, 2]. High sensitivity to moisture availability of the forest vegetation resulted in repeated shifts of plant communities in the forest-steppe ecotone [3]. The data on small-scaled landscape shifts due to short dry and wet phases within the Early Iron Age are still incomplete and controversial [2, 4] and need further studies. Our research aims to reconstruct the paleoenvironment of the forest-steppe based on soil and microbiomorphs data received in an Early Iron Age kurgan cemetery.

The Late Sarmatian culture kurgan cemetery Rublevka I built at the turn of millennia is located in the forest-steppe zone of the Central Russian Upland (Lipetsk region, Russia). It occupies the upper part of the gentle upland slope adjacent to the interfluve of Snova and its tributary Nerezhka Rivers (Don River basin) covered by a broadleaf forest. Soils develop in glacial till of the Don glaciation (MIS 16) with sand lenses.

We studied two buried soils (buried under a circular kurgan, and under a ring-shaped rampart) and five surface soils to make sure that the revealed differences from the paleosols reflect environmental changes but not natural variability of soil properties. Paleosols were buried in the 3rd century AD. The topsoil horizons in both paleosols were cut while constructing the earthen mounds which limited the study.

Soils of the chronosequence were described as *Greyzemic Luvic Phaeozem (Loamic, cutanic)*. Comparing to their modern analogs paleosols have more alkaline pH_{H2O} and pH_{KCl} profile; contain more TOC; show higher accumulation of crystalline forms of iron and higher amount of uncoated grains than in the surface soils. Nevertheless, the revealed differences are small and did not result in classification distinctions.

The palynological and phytolith data show that forest vegetation of the study site in the 3rd c. AD was less mature and diverse. Ancient forest included higher portion of thin-leaved arboreal species and had less developed understory than nowadays. The grass cover was less diverse, with smaller number of meadow species.

Pedogenic and biological evidences listed above allow us assume the general congeniality of the natural environment in the modern days and 1720±50cal BP with slightly more arid than modern climatic conditions.

This study was supported by the Russian Science Foundation (Project No. 16-17-10280).

References

1. Kurbanova, F., Makeev, A., Aseyeva, E., Kust, P., Khokhlova, O., Puzanova, T., Sverchkova, A., Kozmirchuk, I., 2023. Pedogenic response to Holocene landscape evolution in the forest-steppe zone of the Russian Plain. Catena 220, 1-22.

2. Chendev, Yu.G., Aleksandrovskiy, A.L., Khokhlova, O.S., Dergacheva, M.I., Petin, A.N., Golotvin, A.N., Sarapulkin, V.A., Zemtsov, G.L., Uvarkin, S.V., 2017. Evolution of forest pedogenesis in the South of the forest-steppe of the central Russian upland in the late Holocene. Eurasian Soil Sci. 50 (1), 1–13.

3. Spiridonova, E.A., 1991. Evolution of the Vegetation of the Don Basin in the Upper Pleistocene-Holocene. Publishing House Nauka, Moscow, p. 221. (in Russian)

4. Rusakov, A., Makeev, A., Khokhlova, O., Kust, P., Lebedeva, M., Chernov, T., Golyeva, A., Popov, A., Kurbanova, F., Puzanova, T., 2019. Paleoenvironmental reconstruction based on soils buried under Scythian fortification in the southern forest-steppe area of the East European Plain. Quaternary international 502, 197-217.

Dark Earth soils at Iron Age hillforts in the Upper Volga region (NW Russia): chronology, charcoals and chemical properties

M. Bobrovsky[1], A. Smirnov[2], D. Kupriyanov[2], L. Khanina[3], M. Dobrovolskaya[2]

[1]Institute of Physico-Chemical and Biological Problems of Soil Science of RAS, Pushchino Scientific Center for Biological Research, Russian Academy of Sciences, Pushchino, Russia

[2]Institute of Archaeology, Russian Academy of Sciences, Moscow, Russia

[3]Institute of Mathematical Problems of Biology of RAS, Branch of the M.V. Keldysh Institute of Applied Mathematics, Russian Academy of Sciences, Pushchino, Russia

The thickness and stratigraphy of cultural layers of 13 hillforts found in the Upper Volga River basin (Penovsky District, Tver Region) are described based on the analysis of cores and exploratory archaeological pits. The hillforts are located on local elevations, most of them being promontories of moraine hills. Background soils are Albic and Entic Podzols.

Coloration of cultural layers is brown, gray-brown, and dark gray (up to black). Dark coloration is determined by high content of dispersed charcoal. The upper strata of the majority of hillforts are rather homogeneous in structure and color; inhomogeneities and traces of possible pedoturbations were sometimes recorded in the lower part of the cultural layers. The thickness of the dark cultural layer varies considerably both between and within hillforts. Most often the thickness is 40-70 cm, but 110-155 cm have also been encountered. The parameters of the cultural layer of the hillforts allow us to attribute them to anthrosols, paleourbanozems, and more precisely to archaeological Dark Earth (ADE). At the same time they are surface paleosoils.

We collected and analyzed data on concentration and stratigraphy of charcoal in the cultural layers of hillforts. The average concentration of charcoal coarser than 2 mm in the ADE of most hillforts was 0.3-0.6 g kg^{-1} (dry soil); layers with concentrations above 1 g kg^{-1} were found in four hillforts; in the other four hillforts the concentrations did not exceed 0.1 g kg^{-1}.

The analysis of 26 radiocarbon dates (AMS) for charcoal samples from ADE of the hillforts and 3 dates for charcoals from sediments suggests the time of anthropogenic activity on the hillforts and the age of paleosoils. The oldest dates of the 3rd century BC were found for four hillforts. The main period of activity at the hillforts was from the 2nd-1st centuries BC to the 2nd c. AD.

Analysis of the taxonomic composition of 1037 charcoals from 216 samples collected at the hillforts showed the presence of 17 genera of woody plants. The highest tree species richness was recorded in the Early Iron Age. The greatest diversity of broad-leaved trees is noted for this period, with abundant presence of *Ulmus* and *Acer*, as well as *Quercus* surviving to the present day.

The results of the analysis of the granulometric composition show that the sand fraction absolutely predominates in the paleosoils of all hillforts. The sandy texture of the paleosoils provides high water-conducting capacity and significant aeration of strata, while creating unfavorable conditions for long-term preservation of organic matter.

Very high concentrations of some chemical elements were found in the cultural layers of hillforts. Carbon concentration reaches 6-8% which is three to four times higher than in background soils. Nitrogen concentration exceed background concentrations up to 2-7 times. X-ray fluorescence analysis allowed us to estimate the concentration of 18 elements in samples from paleosoils and background soils. Six elements (Co, Ni, As, Mg, Y, and Mo) were found only in paleosoils of the hillforts. Concentrations of another six elements (Fe, P, Mn, S, Zr, and Zn) were higher in paleosoils than in background soils, especially noticeable for P, Mn, and Zn.

This research was supported by Russian Science Foundation, grant number 22-28-01761.

Indicators of anthropization and natural events in the landfills of Templo Mayor, Mexico.

García Zeferino, Thania Alejandra[1], Díaz Ortega, Jaime[2], Rivera Uria, Yazmín[2], Pedraza Rubio, Gerardo[3], Hernández Alcántara, Daniel[3], Solleiro Rebolledo, Elizabeth[3], Sedov, Sergey[2], López Luján, Leonardo[3]

[1]Posgrado en Ciencias de la Tierra, UNAM, [2]Instituto de Geología, UNAM, [3]Proyecto Templo Mayor, Instituto Nacional de Antropología e Historia.

Different studies have demonstrated that anthropic events modified and altered the natural pedogenetic trends and these modifications are recorded in the archaeological materials. This study presents the results of the micromorphological and micromorphometric analysis done in a soil sequence recorded in operation 44 (three floors, three firm and 17 fills) which is in the Archaeological Zone of the Templo Mayor (Late Postclassic, 1200 -1521 AD) in Mexico City, to identify changes in the use of constructive materials because of natural events (as floodings). The micromorphological observations identified the presence of volcanic materials (fragments of tezontle, basalt and andesite), different types of carbonates: stucco fragments (from floors or flattened), primary and secondary carbonates, and oolites, which represented the shorelines of the lake. Additionally, a variety of diatoms were recognized, useful as environmental indicators. With the morphometric analysis, the components were classified and quantified in each level: lacustrine, anthropic, and volcanic materials. In this way, the used materials (intentional selection) were differentiated from the natural ones produced by events such as floods. Furthermore, for the selection of construction materials such as *tlatels*, architectural elements of addition of materials for leveling that allow us to compare the different types of environments. soil formation thanks to the intentional arrangement of different materials. The results of this paleopedological study of the pedosedimentary records allowed to characterize the natural changes and the anthropogenic

alterations that totally or partially modified the environment of ancient societies, before, during and after the affectation. As well as the selection and modification of materials used as construction materials.
Keywords: Tenochtitlan, raw material, flood phases

Paleoenvironments and human impact at Savannah de Bogota, Colombia, during the terminal Pleistocene and Holocene

Solleiro-Rebolledo Elizabeth [1], Triana-Vega Angélica[2], Sedov Sergey[1]
[1]Instituto de Geología, Universidad Nacional Autónoma de México. Ciudad Universitaria, 04510, Mexico City.
[2]Posdoc Research, Instituto de Geología, Universidad Nacional Autónoma de México. Ciudad Universitaria, 04510, Mexico City.

Archaeology of early human settlement in Colombia shows a long-term occupation during the Holocene which causes complex interactions with the landscape. Particularly, in Aguazuque (a pre-ceramic site), the studies have documented occupation between 8,000 and 2,500 BP. The site is in the Savannah de Bogota, a high plateau area (2600 masl), surrounded by sandstone Cretaceous ridges. Previous research in the area was concentrated in the on-site approach (directly in the archaeological site), finding a high abundance of burials, lithics, burned stones and charcoals. In this work we focused on an out-site perspective to analyze the soil cover around the site and the contribution of erosional and sedimentary processes to the landscape history. The soils and pedosediments found in the excavation showed dark brown colors, spongy consistence, silty textures, properties which are similar to Andosols. However, the soils around the site had no andic properties. They were dark brown but compact with an angular blocky structure, properties associated to vertic processes. The radiocarbon age of the humus horizon was around 6,000 cal BP. These soils were buried by a 50 cm-whitish sediment constituted by fine volcanic ash. Consequently, we suggest the soils in the archaeological site were transported by humans and mixed with materials of anthropogenic origin. In other locations, there were several layers of compact volcanic deposits (probably related to lahar deposits) that even buried human bones, dated to 12,000 cal BP. The bones were deposited on a soil with vertic features with a similar age. We consider that Aguazuque has a great potential to support ideas of initial peopling of Colombia in association to the landscape history.

Stages of Pedogenesis in the Central Part of the East European Plain within Isotope Stages 2 and 3 (Khotylevo I Archaeological Site)

Korkka, Maria[1]; Hein, Michael[2]; Romanis, Tatiana[3]; Otcherednoy, Alexander[4]; Savelieva, Larisa[5]; Petrov, Alexey[5]; Stepanova, Ksenia[4]
[1]Independent researcher, San Diego, CA, USA; [2]Max Planck Institute for Evolutionary Anthropology, Leipzig, Germany; [3]V.V. Dokuchaev Soil Science Institute, Moscow, Russia; [4]Institute for the History of Material Culture RAS, Saint Petersburg, Russia; [5]Saint Petersburg State University, Saint Petersburg, Russia

The study of the paleosols of the last glacial epoch (Wisconsin-Weichselian-Würm-Valday) is one of the instruments for reconstructing the paleoecological environment at each stage of the cryochron. MIS3 is a long and complex period of relative warming within a glaciation, but a fortunate one for soil research.

The object of this study is a large Middle Paleolithic archaeological site – Khotylevo I – located in the central part of the East European Plain, in the upper course of the Desna River. The high right bank is composed of Upper Cretaceous bedrock overlain by Late Pleistocene (MIS5a-c–MIS1) deposits more than 20 m thick. Middle Paleolithic cultural horizons are linked to the MIS5a-c soil-sedimentary thickness (in the bottom part of the section) and are overlain by fluvial-glacial MIS4 deposits. Above, they are overlain by the MIS2–MIS3 soil-sedimentary sequence studied in this work.

This unit is composed of four independent paleosol levels interbedded with redeposited sandy loamy or loess-like sediments. The two upper paleosols (S1 and S2) are thin and poorly developed. On the macro and micro level, cryogenic deformations and signs of gleization due to water saturation above permafrost are seen. Radiocarbon dating of the lower paleosols (S3 and S4) corresponds to the middle of the glaciation (27.8 and 34.1 kyr, respectively). At the same time, OSL dates from these levels showed significantly older ages for these soils (45.9 and 58.4 kyr, respectively). The reason for the discrepancy in the dates may be incomplete reset of the luminescence signal due to insufficient exposure during colluvial redeposition. Surface instability is also confirmed in paleosol 3, which shows signs of synsedimentary pedogenesis at the macro and micro levels. The fourth, lowest paleosol has a well-formed profile and a full set of genetic horizons (AO-E-Bw-Bk-BCk) (WRB) minimally disturbed by cryogenesis on the macrolevel. Analogous paleosols are described in Germany and Austria, and Cambic Cryosols, which form in Yakutia, can be considered the closest modern equivalent. Pedogenesis of these soils takes place in extracontinental, semi-arid climate conditions on the territory of the middle taiga zone.

Comprehensive research of the Khotylevo I section allows for the tracing of the change in climate in the long MIS3 interval from Cambic Cryosols to Gleysols at the transitional stages to MIS2. Owing to high deposition rates and the development of colluvial processes, a detailed paleosol record reflecting short-term climatic fluctuations was preserved in these soils' profiles**.**

The urban developmente of the Maya city of Palenque, Mexico

Solleiro-Rebolledo Elizabeth[1], Guerrero-Rojas, Víctor[2], Ibarra-Arzave, Georgina[3], Valera-Fernández, D.[1], Liendo-Stuardo, Rodrigo[4]

[1]Instituto de Geología, Universidad Nacional Autónoma de México. Ciudad Universitaria, 04510, Mexico City.

[2]Instituto de Investigación en Ecosistemas y Sustentabilidad (IIES), UNAM, University Campus, Morelia, Morelia-Michoacán, México.

[3]Deaprtamento de Arqueología, Instituto de Investigaciones Antropológicas, UNAM, CDMX, Mexico.

Palenque is a Maya city developed during the Classic period of the Mesoamerican chronology (250 to 900 AC). The construction of the site occurred on the karstic landscape of Sierra de Chiapas, south Mexico what implied the landscape transformation through the deviation of rivers, leveling of the territory, extraction of construction materials among other activities. To understand environmental impact caused during the construction of the site, we conducted a geoarchaeological study, using the on-site and out-site approach. First, we used LANDSAT and LIDAR images with different visualization techniques, to develop a geomorphological map. During the out-site survey, we collected samples from different soil units around the site. For the on-site research, we selected a building inside Group IV of the ceremonial-civic core of Palenque. Results show the great transformation of the landscape performed during the construction. The main soils found in the site are derived from Cretaceous sandstones. Although there are also rendzic Leptosols, under the buildings, we only found the rest of sandy soils, which represent the main soil cover over which the city was developed. The construction materials contained ceramic fragments, charcoal, mollusks, limestone fragments, travertine, soils, Fe oxides and bones, used in different amounts in each constructive period. With this information we proposed a model of landscape transformation and availability of construction materials that can be related to the political and economic conditions of the Palenque society

Geomorphic pedodiversity and ancient Maya agrosystems in the mountainous karst landscape

García Ramírez, Pamela[1], Morell-Hart, Shanti [2], Sanchez Perez, Serafin[3], Golden, Charles[4], Scherer, Andrew[2], Horseman, Grace[5].
[1] Posgrado Ciencias de la Tierra, UNAM; [2] Department of Anthropology, Brown University
[3] Escuela Nacional de Antropologia e Historia, ENAH; [4] Department of Anthropology, Brandeis University
5 Faculty of Social Sciences, McMaster University

The southern Mexico tropical karstic geosystems (both platform and mountainous) of the Maya area hosted major ancient cities and extensive settlements. The soil mantle of the geoform was a key resource for ancient Maya agriculture; in turn, the development of the geoform has been highly influenced by anthropic activity for millennia.

Previous research in collaboration with the Proyecto Arqueológico Chocoljá-Busiljá (PABC) in the areas of Busiljá and Canan, in the state of Chiapas, has shown a close relationship between the geoform and the distribution of types of soils, as well as ancient settlement patterns and land use.

The upper parts of the terrain, i.e., summits and backslopes of the calcareous hills, show a high density of settlement features (platforms, structures, and terraces), as well as shallow and highly eroded soils. The foot slopes show pedosediments with poor in situ archaeological evidence, and the valley and depressions show soils with redoximorphic properties and in some cases probable ancient canals, identified through satellite imagery (Google Earth) and airborne LiDAR.

Based on this previous research we propose two main areas with different types of agricultural activity for the Maya communities inhabiting the region of the Middle Usumacinta River. First, homegardens in habitational terraces with production primarily for family consumption, and second, valley catchment areas for more extensive and intensive production, perhaps to grow trade commodities or fulfill tithe obligations to larger city centers such as Piedras Negras.

During the 2023 field season, two areas of probable channels, Busiljá and Canan, were excavated to pursue evidence of agricultural use. Both areas are wetlands where draining would be necessary if intended for agricultural purposes. However, the area of Busiljá is close to an archaeological site and a river, while the area of Canan is not related to a specific archaeological site nor to a specific river.

Although excavations unfolded in similar areas of canals and wetlands, the studied soils in each area are quite different. The soils around Busiljá are dominated by redoximorphic properties and accumulation of secondary gypsum, while soils in the Canan area are marked by the presence of biogenic precipitated carbonates.

In the present work we present the soil characterization of the studied features and some general characteristics of each area to better define their use as agricultural fields.

Surface soils and underground pedosediments in the karstic landscapes of Yucatán: footprints of erosion and landscape degradation due to ancient Maya landuse.

Sedov Sergey[1], Solleiro Elizabeth[1], Cabadas Héctor[2]
[1]Instituto de Geología, Universidad Nacional Autónoma de México. Ciudad Universitaria, 04510, Mexico City.
[2]Facultad de Geografía, UAEM, Toluca, México

A major part of the Maya region in the tropical southern Mexico is characterized by karstic landscapes, in particular an expansive area of platform karst covers the entire Yucatán Peninsula. Pedogenesis occurring on karstified calcareous parent materials is different from the "central image" of soil development in the humid tropics. Shallow Rendzic Leptosols (Rendzinas) dominate in the low calcareous uplands in Yucatán. Usually, these soils are considered to be poorly developed products of incipient pedogenesis; however, in various profiles we observed characteristics which disagree with this viewpoint. Despite small thickness and proximity of calcareous bedrock soil matrix of Rendzinas was free of carbonates and contained about 80% of silicate clay and up to 5% of dithionite-extractable Fe. Clay minerals are presented by caolinite and vermiculite that indicate rather high weathering status. Micromorphological observations reveal microfragments of red clayey soil incorporated in the dark matrix rich in organic pigment. Among Rendzinas areas occupied by deep red clayey soils are found, classifier as Chromic Cambisols and Luvisols (Terra Rossa). Mineralogical and geochemical composition of Terra Rossa mineral mass has striking similarities with that of Rendzina. These observations led us to the alternative hypothesis of Rendzina genesis: they were formed from the residual materials left after advanced erosion of the pre-existing much more developed Terra Rossa. High accumulation of dark humus and its stability comprise an intrinsic property of Rendzinas. We suppose that interaction of inherited clay and iron oxides with organic material in presence of dissolved carbonates from shallow calcareous parent material produce abundant and stable organomineral complexes.

However the question arises: how could large-scale soil erosion develop in the Platform of Yucatan? This territory has even low-contrast relief with few pronounced slopes and besides lateral surface water flow does not develop because of vertical drainage through karstic cavities. Extensive but shallow swampy lowlands are occupied by specific hydromorphic Calcisols and do not have pedosediments derived from the upland soils – this confirms that there is no lateral soil erosion along the slope gradient. Our research demonstrated however, that vertical karstic erosion (“soil piping”) could be responsible for the degradation of soil mantle. This process consists in the transport of soil material from the surface through the karstic sinkholes to the underground reservoirs: pockets, galleries and caves. We observed red and black pedosediments in the karst pockets and cave floors, which have properties similar to that of the surface soils. These observations confirmed the “soil piping” hypothesis and revealed the final destination of soil materials derived from surface profiles and redeposited by hidden vertical karstic erosion.

Radiocarbon datings of charcoal, humus and terrestrial mollusk shells from these pedosediments produced ages corresponding to Preclassic and Classic periods (4000 – 1000 yr BP). During this period spread of agriculture, population growth the human impact upon tropical landscapes of Maya region, reached its maximum. We conclude that these anthropogenic factors accelerated vertical soil erosion and caused major changes in the soil cover, which became thin and discontinuous. We further speculate that this soil cover change could play an important role among the possible ecological reasons for the cultural collapse at the end of the Classic period. The hypothesis of climatic forsing - “the Mayan drought” was supported by various lacustrine, marine and speleological records. The lack of soil thickness could have dramatic consequences for agriculture during the droughts because of decreased water storage in the soil.

October 9, 2023

KEYNOTE LECTURES FOR THE ROUND TABLES

PALEOSOLS AND PALEOLANDSCAPES AS CULTURAL HERITAGE

Costantini, Edoardo A.C.
President of the International Union of Soil Sciences; CNR-IBE, Sesto Fiorentino, 50019, Italy;
E-mail: eac.costantini@gmail.com

Soils are considered healthy when they can consistently provide a range of ecosystem services, including cultural benefits for humans and the preservation of geological, geomorphological, and archaeological heritage. However, strategies and policies aimed at conserving and enhancing the cultural and natural heritage of soils are infrequent and incomplete.

Among the eight primary criteria that can be employed to encompass a soil site, whether it's a profile or a soilscape, in an inventory of cultural and natural heritage, some are particularly relevant to paleosols. These criteria include scientific evidence of past environments, didactic value, inspirational qualities, scenic and aesthetic appeal, and serving as an archive of geological, geomorphological, paleontological, and archaeological heritage.

Cultural and natural values associated with soil can play a crucial role in increasing soil literacy. Incorporating descriptions of the presence of pedosites in natural preservation programs could be an immediate action, amplifying both the cultural and naturalistic significance of these areas. This inclusion would also foster collaboration between soil scientists and professionals from other disciplines, thereby promoting a transdisciplinary approach to understanding soil health and its societal interconnectedness.

Globally, the soil science community shares the common goal of raising soil awareness. The International Union of Soil Sciences advocates for the annual celebration of World Soil Day and the Soil Decade. Another shared objective could be the proposal of soil sites to be designated as part of natural and cultural heritage recognized by regional, national, and international authorities.

Below you will find key questions which are supposed to be discussed during the round table:

1. In which countries are there paleosols that are recognized and valued as natural and cultural heritage?
2. How are these paleosols valued? What specific aspects are prioritized?
3. Are these paleosols typically integrated within natural and cultural preserves, such as Geoparks or Biosphere reserves, or do they exist as independent exhibitions?
4. The IUSS provides Stimulus funds to support various activities, including projects. Should these funds be also used to promote the official recognition of soil sites as components of natural and cultural heritage?

UNDERSTANDING SOILS IN TIME AND SPACE: CONCEPTS AND CHALLENGES

Curtis Monger
New Mexico State University

Soils are the uppermost unconsolidated surface material of land. Paleosols are a subgroup of soils that formed in (and consequently record) environments of the past. They are fossil soils. Paleosols have formed throughout geologic time in many environments and across all continents at multiple scales. *Relict paleosols* are those at the land surface that "remember" one or several environments pedogenically. *Buried paleosols* remember past environments during periods of landscape stability before being buried by alluvial, eolian, volcanic, or various other sediments. Their memory is both pedogenic and stratigraphic. For both types of paleosols, the sequence *soil-forming factors → pedogenic processes → soil properties* provides the conceptual framework for understanding paleosols and modern soils as well. This framework is predictive—which is one of the main attributes of science in general. It not only enables us to understand present properties and how those properties developed, it provides a way of making predictions about how the soil will adapt to changing environmental factors.

Challenges for understanding both modern soils and paleosols, but particularly paleosols, are both technical and societal. Technical challenges include demonstrating that chemical, mineralogical, and isotopic properties have remained unaltered enough to provide a meaningful record, especially for lithified paleosols, and discovering new indicators based on new observations and experimentation. Societal challenges include conveying the paleosol concept to other scientists, policymakers, and the public, and deriving information from paleosols that is widely recognized as pertinent and significant.

UNDERSTANDING SOILS IN TIME AND SPACE: POTENTIAL GROWTH POINTS OF SOIL GEOGRAPHY AND ITS SYNTHESIS WITH PALEOPEDOLOGY

Sergey Goryachkin
Institute of Geography, Russian Academy of Science, Moscow, Russia

The basis for the soil geography was formed in XX century in principally different technological conditions than those we have now. However, the challenges that soil geography has in the XXI century convince us to rethink old approaches on the new level of technology.

One of these growth points could be the development of the concept of soil landscapes involving the digital soil mapping paradigm. Neo-Fridland theory of soil cover patterns should be based not only on spatial combinations of pedons but also on soil properties.

Global soil pattern is still predominantly elucidated by recent climatic conditions in spite of a lot of new data on geological and geomorphological features and their change in time.

Another growth point of soil geography is the development of the Human soil geography. Now there is no comprehensive theory including spatial pattern of human activity as an acting factor for soil geography. We are still very far from predicting of human-induced features in soil covers.

One more growth point is the concept of soils formation in extreme conditions – freeze, aridity, and infertile substrates. Some results of biomineral interactions widespread in these conditions (endolithic and supraglacial soils and soil-like bodies) are ignored by pedologists and they are studied in biogeochemistry. The lateral processes usually are predominant in these conditions and the perception of the soil is possible only on the landscape level.

Finally, there is the possibility to model pedosphere of different ancient epochs as now we have a new information on the climates and exogenic processes of the past, however, for that purpose we need to change priorities of looking for and studying very specific recent soil covers.

The synthesis of paleopedology and soil geography has good prospects to develop a new polygenetic theory of time-spatial organization of the pedospheres of past and recent epochs.

CONTEMPORARY METHODS OF PALEOSOL STUDIES: PROFITS OF GENETIC APPROACH, ATTRACTION AND DANGER OF GEOCHEMICAL COEFFICIENTS

Sedov Sergey[1], Bronnikova Maria[2,3]
[1]Instituto de Geología, Universidad Nacional Autónoma de México. Ciudad Universitaria, 04510, Mexico City.
[2]Institute of Geography, Russian Academy of Sciences, Moscow, Russia
[3]New Mexico State University, Las Cruces, NM, USA

Geochemical indexes based on the relations of bulk concentrations of selected major and minor elements became recently one of the most popular instruments for paleoenvironmental interpretation of paleosols and especially paleosol-sedimentary sequences due to the relative affordability of the method, allowing for obtaining a quantitative estimation of paleoclimatic parameters. The conclusion that these indexes could be successfully used as a paleoclimate "proxy" relies on the assumption that the behaviour of these elements in the soil systems depends upon some processes which are in turn controlled by the climatic conditions (temperature and precipitation). After acceptance of this assumption, researchers established and quantified empirical relationships between bulk geochemistry of modern soils and climatic data such as mean annual precipitation and mean annual temperature for a limited number of North American soils. These relationships were directly projected to the past. In the majority of cases, each coefficient is related to a single pedogenetic process and regarded as a "climafunctions" for paleosols. Most popular are coefficients indicative of weathering, among them are CIA, CIA-K, PWI. These indices called the "chemical index of alteration" were originally elaborated and applied to geological materials: sediments and regolith of crystalline rocks (Nesbitt, Young, 1982). They are based on the knowledge about differences in the element mobility after their release in the course of primary mineral alteration and usually are ratios between selected immobile and mobile element values.

We decided to verify whether these coefficients are really closely related to the weathering status of rock and soil materials and coincide with the other evidences of mineral alteration. We tested these coefficients on the bulk chemical composition of two types of objects: 1) weathering rinds of crystalline rocks and 2) genetic horizons of the profiles of Retisol and Podzol – "central images" of the temperate humid forest pedogenesis on loamy and sandy sediments respectively. Weathering rinds have shown higher values of the coefficients in comparison with the unaltered rock from the core – this confirms that in this case they correctly indicate the weathering status. However, in the soil profiles situation was quite different. The most weathered horizons in the Retisols and Podzols according to mineralogical and micromorphological data are eluvial E horizons. However, these horizons had relatively low values of the geochemical coefficients whereas their maxima were determined in the Bt and Bs horizons – where other weathering features are less pronounced. This means that in the mature profiles of humid temperate soils, the geochemical coefficients supposed to reflect the weathering status fail to meet the expectations.

We speculate that the coefficients work well in the weathering rinds because they represent a simplified model where only the weathering process is transforming the mineral mass and controls bulk chemical composition. Soil is a much more complex system where other processes are also affecting mineral mass leaving their imprint in the contents of different elements. In the particular cases of the studied soils these processes are: clay illuviation in the Retisols and illuviation of Al- and Fe- organic complexes in Podzols. These processes have their own bioclimatic requirements and rates of development which do not coincide with that of weathering. Thus, we cast doubt on the simplistic model of application of geochemical coefficients to paleoenvironmental reconstruction: coefficient value – weathering status – parameters of paleoclimate.

Further limitations to the use of geochemical coefficients are imposed by the variations in the composition of sediments within the paleosol-sedimentary sequences. These variations caused by changes in the source area or by the fluctuating characteristics of a deposition agent (e.g. wind or water flow velocities) could cause major changes in granulometric, mineralogical and thus – in the bulk chemical composition. In turn, those changes could have a major influence on the coefficient values overshadowing the weathering signal. Furthermore, frequently the sedimentary layers include redeposited soil materials. In this case, their geochemical composition could be indicative of earlier weathering and pedogenesis in the original source soil – but not of the layer to which they were incorporated. An illustrative example of this phenomenon was encountered in the Pleistocene paleosol-colluvium sequence near Kursk, Russia. In this sequence, early glacial pedosediment overlying interglacial paleosol showed similar values of weathering coefficients to the paleosol Bt horizon – despite being deposited under completely different paleoclimatic conditions. The reason for this similarity is that this sediment incorporates a large amount of redeposited Bt material – that was confirmed micromorphologically.

We conclude that the geochemical weathering indexes could be successfully utilized in the paleoecological interpretation of paleosols only as part of a toolkit of methods, after thorough detection of all pedogenetic and sedimentary processes which could influence this signal.

Below you will find key questions which are supposed to be discussed during the round table:

- How are most common geochemical coefficients (CIA, CIA-K, PWI, CALMAG etc.) influenced by a range of widely spread soil forming processes (base leaching, clay eluvial/illuvial redistribution, silicate weathering, loss and redistribution of its products (Al and Fe illuviation), carbonate accumulation etc.? How would the coefficients work in polygenetic soils with overprinting of the multistage processes within a single profile?

- What are the restrictions for applying different geochemical coefficients?

- The relationships between geochemical coefficients and climatic parameters were empirically detected for a limited number of soil profiles in North America. Are these relationships satisfactory and applicable to other environments and soils?

- Do indexes of alteration applicable to soils containing non-silicate Na, K, Ca, Mg accumulated in carbonates and/or easily soluble salts, waterlogged environments and soils developed within lithologically discontinuous parent material?

- Why were B horizons originally used as standards for establishing relationships between geochemical coefficients and climatic parameters? Is this approach correct?

- What difference in calculated climatic parameters can be considered significant? This question concerns not only quantitative paleoclimatic reconstructions based on geochemical data but also any quantitative paleoenvironmental reconstructions.

Table of Contents