Paleopedology Newsletter

IUSS Commission 1.6 – Paleopedology
INQUA Palaeopedology Working Group

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Issue 30, June 2021

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Cover photo: Stacked petrocalcic horizons due to incisions between backwater (flooding from the Mediterranean) events during the Pliocene-Pleistocene, Tivissa (Catalonia, Spain, photo courtesy: Rosa M. Poch). Castelltort, F. X., Balasch, J. C., Boixadera, Jaume., Rodriguez, R., Poch, R. M. 2021. Paleosol architecture in a Quaternary incised valley and surrounding areas. Poster contribution 920, Session T01-SS01, 35th IAS Meeting of Sedimentology.

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Preface

After having to skip the December 2020 issue, this episode of Paleopedology Newsletter returns with fresh tidings! The news & events part includes the annual report, list of major publications and a summary of our recent online international meeting. The herald section is followed by special honouring for Maria Dergacheva and Svetlana Sycheva. The invited contributions incorporate fruitful collection from Africa, Europe and North America. First, Peter N. Eze provides his interpretation for a pedo-stratigraphic section in northern Botswana. Next, Georges Stoops, Roger Langohr and Eric Van Ranst share the paleopedology part of their meta-analysis micromorphological study from Belgium. Finally, Curtis Monger delineates a global view on soil's potential for sequestering CO_2 as soil inorganic carbon.

If I may add a personal note, early this month, we lost Hanna Koyumdjisky (1921–2021). Hanna (as she would have preferred to be called in her first name) was an inspiring and outstanding soil scientist, probably one of the oldest ever woman pedologists. Born in Bulgaria, Hanna was a Holocaust Survivor. In her doctoral studies, Hanna was Dan Yaalon's student. *Yehi Zichra Baruch* (may her memory be blessed).

Best wishes and please stay safe,

Danny Itkin

News & Events

Annual report of the IUSS Commission 1.6, May 2021

Commission events

As many of us know, the XIVth International symposium and field workshop on paleopedology (ISFWP-XIV) paleosols, pedosediments and landscape morphology as archives of environmental changes (Russia, Altai) was initially planned for the 13-23 August 2020. Commission 1.6 has been contributing strenuous efforts since 2018 in trying to make this event. Unfortunately, we had no choice but to shift it to August 2021 and later to August 2022 (for further details, please visit http://isfwp.100igras.ru/). Instead, after a year without any active communication, Commission 1.6 and the INQUA Paleopedology working group have decided to organise a three-day online meeting on paleosols and ancient societies, which was finally held on June 10-12, 2021. Fifty contributions were submitted. Preceding the Paleopedology international event, a three-day pre-conference Ibero-American online workshop on paleopedology and geoarchaeology ('Paleolber 2021') took place on June 7-9 (2021), mainly in Spanish (see below).

Integration in professional geoscience unions

Paleosols are regarded as one of paleoenvironmental records (proxies). Foreseeable future challenges in paleoenvironmental reconstructions will result from multi-proxy approach and correlation of different types of paleoenvironmental records. Therefore, IUSS Commission 1.6 Paleopedology is aimed to promote interdisciplinary collaboration and integration in professional geoscience unions.

The International Union for Quaternary Research (INQUA) officially established a Working Group status as a long-term association addressing specific broad-scale scientific issues in 2020. This decision was stimulated mainly by activities of the paleosol community developed under the umbrella of IUSS Commission 1.6. Recognition of Working Group status allowed the paleosol community to take up a more stable permanent position in INQUA. Now, the paleosol community functions within INQUA as Paleopedology Working Group (led by the officers of IUSS Commission 1.6). We received the official Working Group status in 2020, and in 2021 got our continuation. Further information can be found at https://www.inqua.org/commissions/wgs.

European Geosciences Union (EGU) cooperation: Commission 1.6 successfully developed the cooperation with EGU in the Soil System Sciences division. Traditionally, Commission 1.6 co-organises sessions at EGU general assembly. The EGU general assembly was held in an online format in 2021. Commission 1.6 co-organised session on Soils as records of

past environmental conditions, climate change and anthropogenic impact in the program block SSS3 – Soils as Records in Time and Space, on 27 Apr, 09:00–12:30 (CEST). Convener: Oren Ackermann, co-conveners: Anna Schneider, Kunshan Bao, Maria Bronnikova, Gaël Le Roux, Tobias Sprafke, Barbara Fiałkiewicz-Kozieł, Claudio Zaccone It contained 42 short (2 minutes) presentations in zoom format. Every presenter had an opportunity to upload a file with additional materials accessible for all registered participants for 2 months. Presented contributions were concerned with peatland records, loess-paleosol records, paleofires, man-impact in soils and sediments.

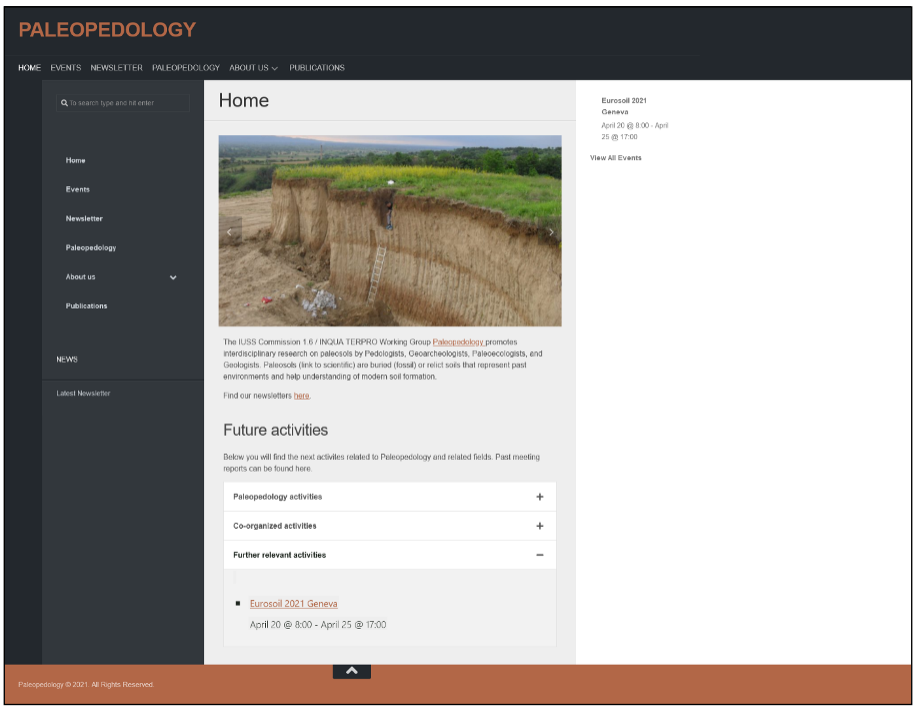
Eurosoil 2021 Connecting People and Soil was initially planned for 24-28 August 2020, Geneva (Switzerland), but cancelled due to the pandemic. It was shifted to August 2021 and is now announced in an online format. The session related to the Paleopedology Working Group activities is 6.16 – Soil archives to understand future climate changes, landscapes, and the pedosphere. Conveners: Tobias Sprafke, Daniela Sauer, Maria Bronnikova. 6 orals and 6 posters have been accepted.

Googlegroup communication

In 2021 we realised that communication via the google groups forum does not work properly anymore. We extracted the email list from the googlegroup webpage, which contains > 300 email addresses. Our request to all of these to provide feedback resulted in approximately one hundred positive answers, few negative ones and thirty failure notes, where email did not work. While we wait for further response, we identified about twenty colleagues who are not on this list. Based on this update, we can safely assume that 120-150 paleopedologists will be in our updated network. If you wish to receive information letters from our Google group, please contact one of the commission officers (https://www.iuss.org/organisation-people/people/).

Website

The currently existing webpage of the IUSS Commission 1.6 Paleopedology (https://sites.google.com/site/palaeopedology/) was created more than ten years ago and contained numerous meeting announcements, reports, commission history and a link to a google groups forum where paleopedologists have registered since 2007. During a Commission officers meeting at the EGU 2019, we agreed that our webpage was technically outdated, visually repelling and too much loaded with weakly structured information. Since then, we stored the existing content and developed a new structure for a current web page. As we are not professional web designers, this process has required many learning hours. Using WordPress and nimble webpage builder, we now arrived at a first visually attractive version of the Paleopedology webpage, waiting for a host and being filled with content. Tobias Sprafke is responsible for the site renovation:



Major Publications

Catena special issue: Contemporary soil and paleosol landscapes as records of past environmental conditions, was processed in collaboration with EGU SSS3 – Soils as Records in Time and Space. Invited editors: Anna Schneider, Maria Bronnikova, Elizabeth Solleiro-Rebolledo (published in December 2021). This special issue contains eleven studies examining the factors and processes of pedogenesis and applying related knowledge in studies of paleosols and anthropogenically affected soils. The studies use a range of different approaches to account for or use the soil record's spatial heterogeneity and show up challenges and potential pitfalls in environmental reconstruction from paleosols and (anthropogenically affected) contemporary soils connected with the soil landscape palimpsest. The special issue includes the following titles:

Agatova, A.R., Nepop, R.K., Bronnikova, M.A., Zhdanova, A.N., Moska, P., Zazovskaya, E.P., Khazina, I.V., 2020. Problems of 14C dating in fossil soils within tectonically active highlands of Russian Altai in the chronological context of the late Pleistocene megafloods. CATENA 195, 104764. doi:10.1016/j.catena.2020.104764.

Calitri, F., Sommer, M., van der Meij, Marijn W., Egli, M., 2020. Soil erosion along a transect in a forested catchment: Recent or ancient processes? CATENA 194, 104683. doi:10.1016/j.catena.2020.104683.

Donovan, S., Ignatiadis, M., Ouimet, W., Dethier, D., Hren, M., 2021. Gradients of geochemical change in relic charcoal hearth soils, Northwestern Connecticut, USA. CATENA 197, 104991. doi:10.1016/j.catena.2020.104991.

Drohan, P.J., Raab, T., Hirsch, F., 2020. Distribution of silty mantles in soils of the Northcentral Appalachians, USA. CATENA 194, 104701. doi:10.1016/j.catena.2020.104701.

Golubtsov, V., Bronnikova, M., Khokhlova, O., Cherkashina, A., Turchinskaia, S., 2021. Morphological and isotopic study of pedogenic carbonate coatings from steppe and forest-steppe areas of Baikal region, South-Eastern Siberia. CATENA 196, 104817. doi:10.1016/j.catena.2020.104817.

Hirsch, F., Raab, T., Błaszkiewicz, M., 2021. Evidence for an alternative concept of the Finow soil formation. CATENA 198, 105064. doi:10.1016/j.catena.2020.105064.

Nguetnkam, J.P., Solleiro-Rebolledo, E., Díaz-Ortega, J., Témátio, P., 2020. Evaluating weathering of palaeosols in Cameroon (Central Africa) as a tool for paleoenvironmental reconstruction. CATENA 194, 104688. doi:10.1016/j.catena.2020.104688.

Romanis, T., Sedov, S., Lev, S., Lebedeva, M., Kondratev, K., Yudina, A., Abrosimov, K., Golyeva, A., Volkov, D., 2021. Landscape change and occupation history in the Central Russian Upland from Upper Palaeolithic to medieval: Paleopedological record from Zaraysk Kremlin. CATENA 196, 104873. doi:10.1016/j.catena.2020.104873.

Sycheva, S., Frechen, M., Terhorst, B., Sedov, S., Khokhlova, O., 2020. Pedostratigraphy and chronology of the Late Pleistocene for the extra glacial area in the Central Russian Upland (reference section Aleksandrov quarry). CATENA 194, 104689. doi:10.1016/j.catena.2020.104689.

Valera-Fernández, D., Cabadas-Báez, H., Solleiro-Rebolledo, E., Landa-Arreguín, F.J., Sedov, S., 2020. Pedogenic carbonate crusts (calcretes) in karstic landscapes as archives for paleoenvironmental reconstructions – A case study from Yucatan Peninsula, Mexico. CATENA 194, 104635. doi:10.1016/j.catena.2020.104635.

Zwanzig, L., Zwanzig, M., Sauer, D., 2021. Outcomes of a quantitative analysis of 48 soil chronosequence studies in humid mid and high latitudes: Importance of vegetation in driving podzolization. CATENA 196, 104821. doi:10.1016/j.catena.2020.104821.

Twitter profile

Our Twitter profile https://twitter.com/6Commission was established in 2019 and further maintained by Danny Itkin.

Online activities during the Covid pandemic

Paleolber 2021: Iberoamerican course on Paleopedology and Geoarchaeology (7-9 June 2021)

The Ibero-American Workshop on Paleopedology and Geoarchaeology (Spanish: Curso Iberoamericano de Paleopedología y Geoarqueología) is a training activity that looks for sharing the recognition of soils in time and space and their relationship with ancient cultures. The Paleolber 2021 was organised in the framework of the International Paleopedology Meeting by the Mexican Paleosols Group (Institute of Geology – National Autonomous University of Mexico). The group has developed paleopedological and geoarchaeological teaching and research for more than 20 years. The opening ceremony was conducted by Maria Bronnikova, Chair of the Commission 1.6 – Paleopedology.

The program included the following topics:

- Soil memory: pedofeatures in paleosols – Elizabeth Solleiro-Rebolledo (Institute of Geology, UNAM).
- Morphology and micromorphology of paleosols – Juan Carlos Loaiza (National University of Colombia).
- Dating of paleosols – Ana María Soler-Arechalde (Institute of Geophysics, UNAM).
- Workshop on micromorphometry applied to the paleopedology and geoarchaeology – Jaime Díaz-Ortega, (Institute of Geology, UNAM).
- Prequaternary paleosols – Alexander Makeev (State Moscow University).
- Pleistocene paleosols – Sergey Sedov (Institute of Geology, UNAM).
- The soil as raw material: earth architecture and ceramics – Héctor Cabadas-Báez (School of Geography, UAEM).
- Paleopedology and geoarchaeology at northeast Mexico – Georgina Ibarra-Arzave, (Institute of Ecosystems and Sustainability Research, UNAM).
- Paleopedology and geoarchaeology in Central Mexico – Yazmín Rivera-Uria (Institute of Geology, UNAM; Serafín Sánchez-Pérez (School of Anthropology and History)
- Paleopedology and geoarchaeology at southeast Mexico – Berenice Solís-Castillo (Center of Environmental Geography Research, UNAM).

For supporting the visibility of Paleolber 2021 on social media, it was promoted by a series of infographics related to Paleopedology and Geoarchaeology. These infographics are part of the Edafografías project (a previous project developed by the group, see below).

Participants

The Paleolber 2021 had 157 official-registered participants, streamed on Zoom and Facebook (@psuelox). In Mexico, 22 of the 32 States attended the Paleolber. In the

international scope, the Paleolber impacted 17 countries: Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Ecuador, El Salvador, Spain, France, Guatemala, Honduras, Mexico, Paraguay, Serbia, Uruguay y Venezuela. The main participants were bachelor's students (58%), between 19 to 25 years old (31%) and 26 to 31 years old (33%). Furthermore, the principal interest of the participants was geoarchaeology.

Organizing committee

Both the Edafografías and Paleolber 2021 were organised by the Institute of Geology of the National Autonomous University of Mexico with support of the IUSS Commission 1.6 – Paleopedology, INQUA, Researchers of the Quaternary and Anthropocene (INCUA), National School of Anthropology and History (ENAH), and Russian Academy of Sciences (RAS).

Co-organisers: Elizabeth Solleiro Rebolledo (UNAM), Sergey Sedov (UNAM), Axel Cerón González (UNAM), Daniela F. Vargas Rodríguez (UNAM), Pamela A. García Ramírez (UNAM), Thania A. García Zeferino (UNAM), Sol de J. Moreno Roso (UNAM), Karla Guillén Domínguez (UNAM), Yazmín Rivera Uria (UNAM), Serafín Sánchez Pérez (ENAH). Technological Support: Alejandro Silva Esquivel (UNAM). Marketing Campaign: Jesús Aceves Romero (UNAM).

International paleopedology meeting: Paleosols and ancient societies – from early humans to the industrial revolution (June 10-12, 2021)

After a whole year without any active face to face interaction, we finally had a three-day (online) meeting. Organised and hosted by the Paleopedology Group of UNAM, this event was co-organised by the IUSS Commission 1.6 – Paleopedology, INQUA, Paleopedology

Working Group Researchers of the Quaternary and the Anthropocene (INCUA), Institute of Geography of the Russian Academy of Sciences (IGRAS), and UNAM.

Twenty-five people attended the Paleopedology business meeting (June 11). The main topic concerned with linking paleosols to the history of the interactions between humans and the environment. This issue is particularly relevant today when human activities strongly affect the planet.

Fifty-four abstracts were received and divided to 5 scientific sessions:

- Paleopedological indicators of early human ecology along the migration routes out of Africa and beyond.
- Soil mantle under the impact of ancient agriculture: transformation, degradation and resilience. Paleopedological indicators of ancient land use. Man-made soils and soil horizons: artificial terraces, raised fields and plaggen.
- Features, processes and evolution of urban pedogenesis: settlement soils from the Paleolithic to the Industrial era. Stratigraphy, microstratigraphy and micromorphology of the archaeological soil-sedimentary sequences and living floors that serve as a record/ memory/archive of site formation processes and on-site life cycles.
- Soil as a raw material for ancient technologies (earth-architecture, pottery, etc.): provenance, chaîne opératoire and environmental effects.
- Soil chronosequences on artificial land surfaces as a tool for evaluating timescales, rates and characteristic times of pedogenetic processes.

From these contributions, 49 presentations (15 min each) were given by colleagues from Argentina (1), Belgium (1), Colombia (4), France (4), Germany (3), India (1), Israel (1), Italy (1), Poland (1), Mexico (15), Russia (16), United States (1).

The meeting was attended by 40 to 60 people from the speaker's countries, but also from additional countries, e.g., Brazil, Peru, and Switzerland. Discussions were very intense at the final of each session block. Following which, a special issue is planned for the Boletín de la Sociedad Geológica Mexicana (open access).

Elizabeth Solleiro-Rebolledo, Maria Bronnikova and Tobias Sprafke

Laudations

On the 80th Anniversary of Prof. Maria Dergacheva (March 16th, 2021)

Maria Dergacheva is a prominent paleopedologist from Novosibirsk, Russia, the founder of the original Russian school for the study of humic compounds in soils. Dergacheva has collected and analysed a unique collection of humic acids. She is a great teacher and supervised a large number of PhD and doctoral dissertations. For many years, she and her students have successfully applied the composition of humic substances to the study of recent soils and paleosols of different ages. Since 2010, Dergacheva initiated and conducted ten international field schools on paleosols for young scholars in the Altai region: "Paleosols as a source of information about the environment of the past." Dozens of prominent scientists - experts in the study of paleosols and related disciplines, and hundreds of students and postgraduates were involved in the school's activities. For many of the young scientists, participation in the school determined their scientific careers. Dergacheva is an amazingly whole-hearted and enthusiastic person, involving everyone who came into contact with her into her orbit. On behalf of the Russian and International Palaeopedology Commissions, we sincerely congratulate Maria on her Anniversary, wish her good health and her inherent enthusiasm for many years to come!

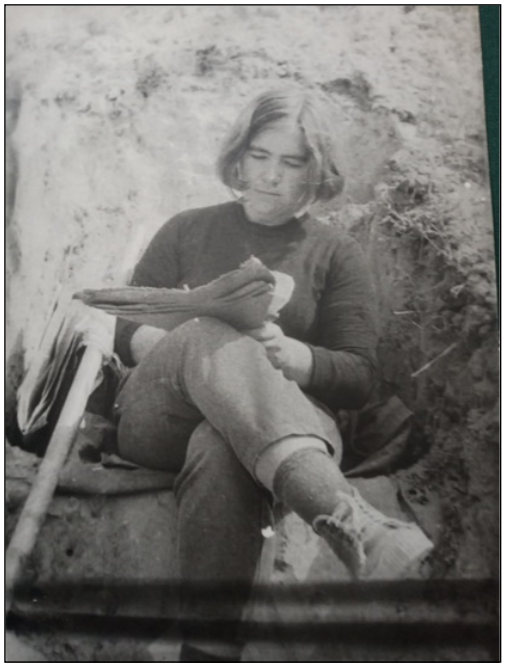
Alexander Makeev, Lomonosov Moscow State University, Russia
Maria Bronnikova, Institute of Geography, Russian Academy of Sciences

Prof. Dergacheva lecturing at the International Paleopedology summer school (left). School participants in the famous Denisova cave, the foothills of Altai mountains (right; photos courtesy: Maria Bronnikova).

On the 9th of May we celebrated the 70th birthday of Dr Svetlana Sycheva

On the 9th of May, we celebrated the 70th birthday of Svetlana Sycheva – a renowned Russian paleopedologist, an expert in Quaternary paleoecology and geoarchaeology. For decades Sycheva has studied paleosol-sedimentary sequences of European Russia, first in the paleogeographical team of A. Velichko and then in the group of soil geography. Each summer, Sycheva travelled through the Russian Plain accompanied by her devoted assistant – husband Nikolay, searching for exposures that provide the most detailed records for different chronointervals. Sycheva has paid special attention to the slope and depression profiles (largely neglected earlier) and, with scrupulous studies of their stratigraphy and detailed correlation schemes, proved their significance as a paleoenvironmental proxy. During the last two decades, Sycheva has extended her research towards the Central Mexican Highlands. Application of her paleosol-geomorphological approach to the tephra-paleosol sequences gave a new impulse to their study and interpretation. Sycheva is an enthusiast of documentation and popularisation of the role of women in scientific research. Her books “Women - soil scientists” and “Women in Russian science: role and social status” are a unique collection of biographical information about many women who made an essential contribution to the development of soil science throughout its history, and lively discussion of up-to-date gender issues in soil science and Russian science in general. International Commission on Paleopedology wishes to Svetlana health and energy to carry out her scientific plans – which we know she is developing with enthusiasm and dedication.

Sergey Sedov, Universidad Nacional Autónoma de México
Maria Bronnikova, Institute of Geography, Russian Academy of Sciences



Svetlana Sycheva studying loess sections near Oka river, Russia (1972, left).

During an excursion in the mountainous tropical forest of Oaxaca, Mexico (2009, right; photos courtesy: Maria Bronnikova).

Invited Contributions

A Pedostratigraphic section in the Chobe Enclave, northern Botswana

Peter N. Eze

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(ezep@biust.ac.bw)

The alluvial plains of Chobe Enclave, northeast of the famous Okavango Delta, Botswana, presents an intriguing landscape feature – carbonate island platforms (Fig. 1). Dotted all over the plains, the carbonate rocks are assumed to be products of late Quaternary hydrological dynamics. A deep (~8 m) Quarry excavation (Fig. 2) shows a rather interesting soil stratigraphy. A palaeopedological examination of the section shows compound palaeosol profiles: an older weakly developed palaeosol profile (PL1) overlying by younger palaeosol profile which has developed on late Quaternary carbonate-rich fluvial sediments (PL2). OSL dating of carbonate islands from Chobe Enclave (Diaz et al., 2019) reported that carbonate island formation in the Chobe Enclave spanned from MIS6 to MIS1 and possibly occurred in two phases, marked by ~40 kya of depositional paucity or erosion.

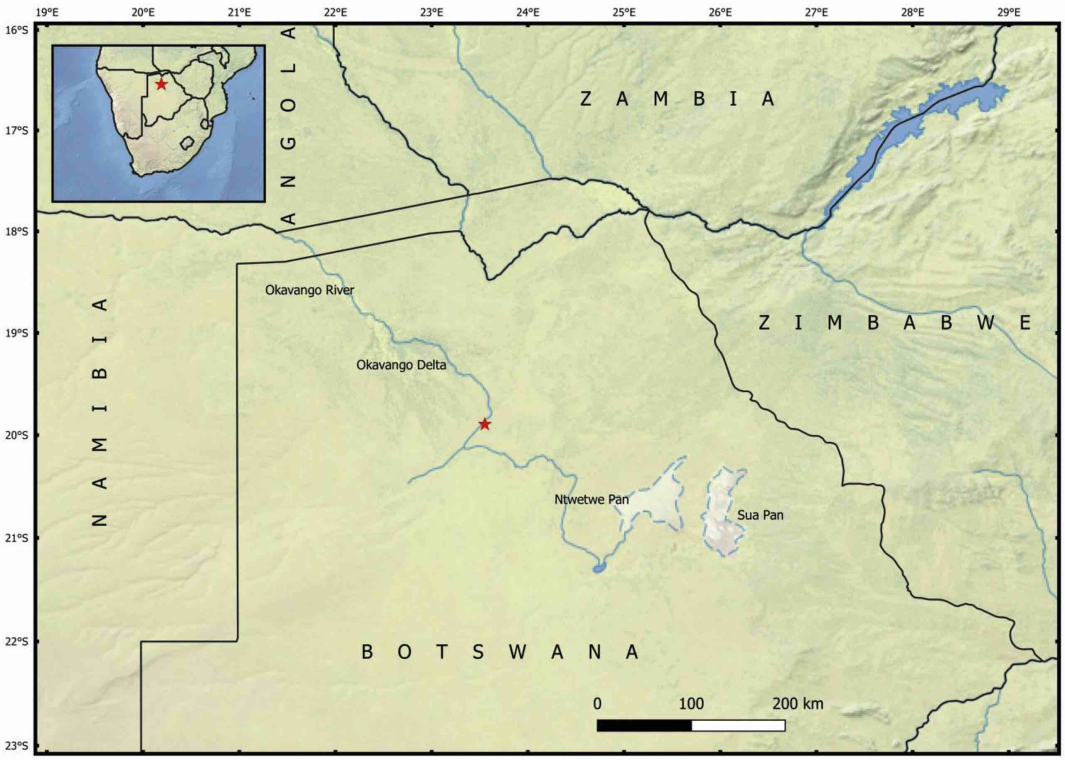

Figure 1. Location map of the study area (indicated by red star, from Eze et al., 2021).

Macromorphological features of PL2 suggest simultaneous accumulation and pedogenic alteration (i.e. formation of genetic horizons) of the carbonate-rich sediments. Using modern soil classification, PL1 would qualify as Fluvisols and PL2 as Calsisols which commonly form in the area from protracted period of post burial dissolution, downward translocation and recrystallization of the palustrine carbonates (Eze et al., 2021). Original depositional beddings in the pedostratigraphic section have been completely masked by pedogenic processes. An abrupt horizon boundary between PL1 and PL2 clearly points on differences in their evolutionary pathways. In a region where records of Late Quaternary climate change are poorly preserved, this pedostratigraphic section in the Chobe Enclave, Middle Kalahari, is invaluable for paleoenvironmental studies.

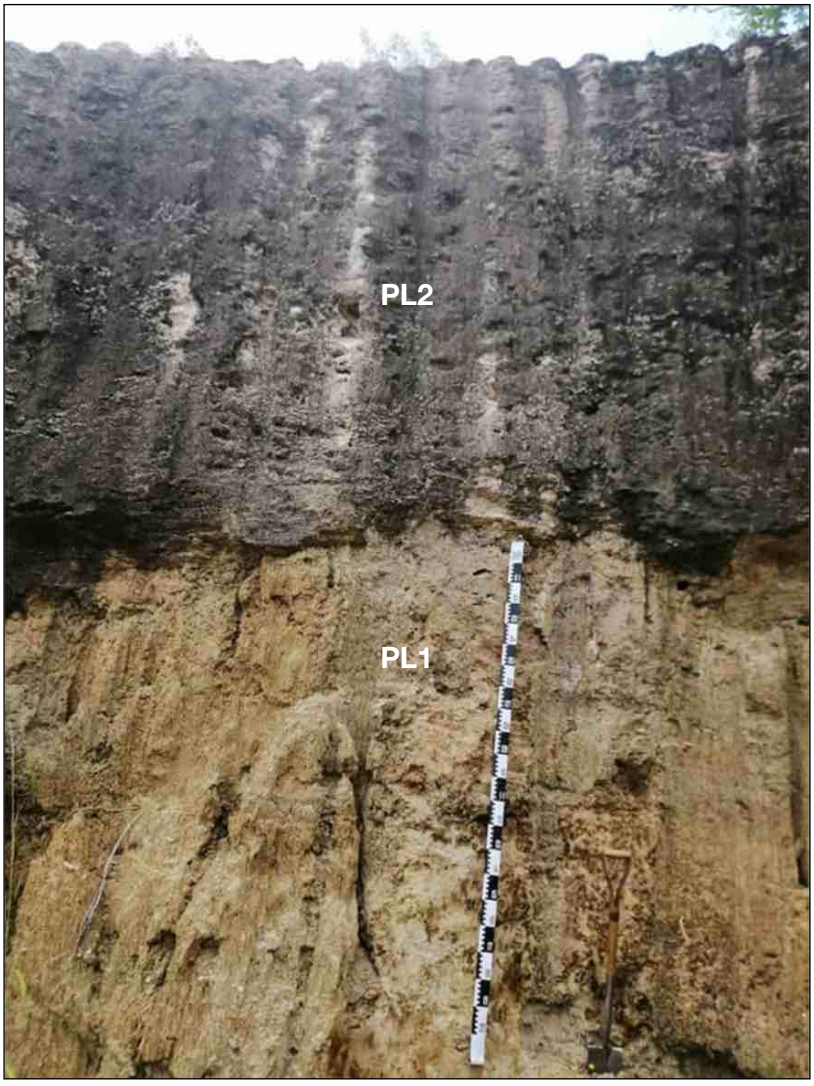

Figure 2. Pedostratigraphic section in the Chobe Enclave, northern Botswana (photo courtesy: Peter Eze)

References

Diaz, N., Armitage, S.J., Verrecchia, E.P. and Herman, F., 2019. OSL dating of a carbonate island in the Chobe Enclave, NW Botswana. Quaternary Geochronology, 49, 172-176.

Eze, P.N., Molwalefhe, L.N. and Kebonye, N.M., 2021. Geochemistry of soils of a deep pedon in the Okavango Delta, NW Botswana: Implications for pedogenesis in semi-arid regions. Geoderma Regional, 24, p.e00352.

Micromorphology of soils and palaeosoils in Belgium. An inventory and meta-analysis

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(georges.stoops@ugent.be)

Catena 194, https://doi.org/10.1016/j.catena.2020.104718.
Abstract of the part dealing with buried palaeosoils:

The oldest palaeosoil discussed in the paper is a 40 m thick tropical weathering profile truncated by the Cretaceous sea and overlain by a thin basic conglomerate (Fig. 1). In the Upper Palaeocene, pedogene silicifications affected bleached parts of fluvial sands. Early Eocene podzols in the Neerrepen sands contain gypsum and jarosite, probably related to an overprint of an oxidised coastal march formation before the deposition of the overlying Hennis clay, as confirmed by the study of several profiles. A giant humic palaeopodzol of Oligocene age is observed in Tongerian sediments. In Middle Belgium truncated reddish palaeosoils (Ultisols or Alfisols), covered by loess are described in several localities. In several pedosequences in Pleistocene loess deposits micromorphological features related to clay illuviation, redox processes, calcite migration, fossil permafrost and colluvionation are detected. In the coastal area, Holocene podzols buried by marine clays occur. In addition, palaeofeatures in polygenic soils are discussed in the paper.

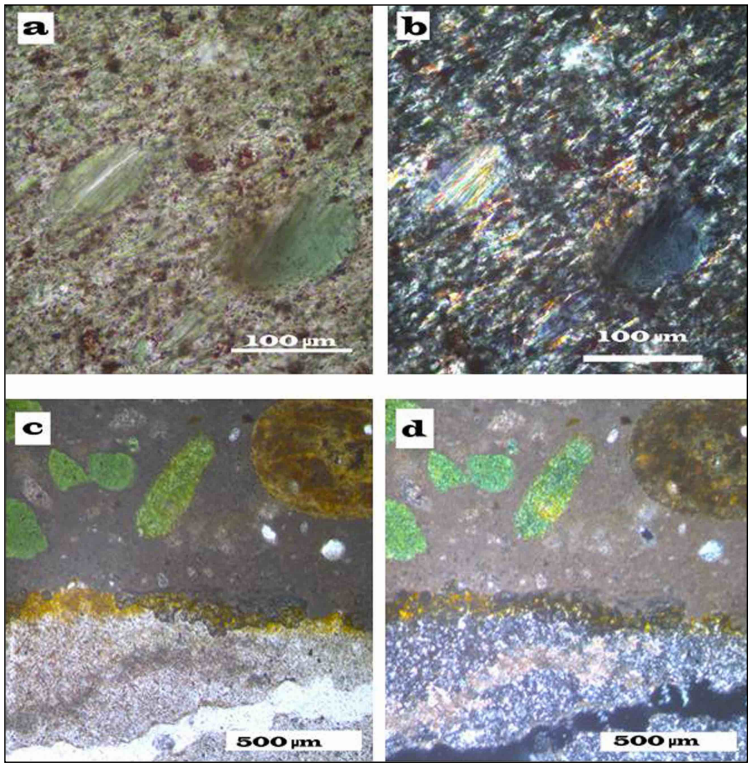

Figure. 1 (Fig. 7 in the original article). Pre-Cretaceous palaeosoil. (a) stacks of chlorite; left partly altered, right unaltered: note schistosity (PPL); (b) idem, notice higher interference colours of the altered stack (XPL) (drilling of Nevele, 270 m below present surface, 38 m below contact with Cretaceous deposits); (c) contact between the micrite impregnated top of truncated saprolite and the micritic Cretaceous glauconite containing microconglomerate; notice that many of the glauconite particles are transformed saprolite fragments (PPL); (d) idem (XPL) (drilling of Nevele, 232 m below present surface).

A global map depicting soil's potential for sequestering CO_2 as soil inorganic carbon

Curtis Monger

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Can soil inorganic carbon (SIC) be managed to sequester atmospheric CO_2? If so, which soils provide the greatest potential? With regard to paleopedology, was more carbon sequestered as SIC in the geological past than now? These questions have been discussed for decades but need to be discussed again in light of the current focus on climate change.

SIC refers to the carbon in the carbonic acid system that includes soil carbonate, mainly calcite ($CaCO_3$), as well as gaseous carbon dioxide (CO_2), bicarbonate (HCO_3^-), and the carbonate ion (CO_3^{2-}). This article focuses on $CaCO_3$ in soil and HCO_3^- in groundwater. The carbonic acid system is the mechanism that enables CO_2 to be pulled from the atmosphere and stored in soil as $CaCO_3$, as bicarbonate in groundwater, or as limestones in oceans. In fact, Reaction 1, the Ebleman-Urey reaction, has been the biogeochemical process that has controlled CO_2 in the Earth's atmosphere, thus preventing CO_2 from being the major gas in the atmosphere, which is the case for Venus and Mars.

$$CO_2 + CaSiO_3 \rightarrow CaCO_3 + SiO_2 \qquad (1)$$

If Reaction 1 can be accelerated, then $CaCO_3$ might be a "negative emissions" method that could be used in combination with other methods to mitigate climate change—perhaps. However, there are many questions surrounding the use of SIC as a short-term sequestration method with each question requiring further research.

1. How quickly does Reaction 1 occur in nature? In dryland climates, radiocarbon dating reveals that pedogenic $CaCO_3$ is typically thousands to tens-of-thousands of years old. But observational evidence, such as carbonate on buried plastic, indicates that it can form much faster under certain circumstances. In humid regions, "enhanced weathering" as a method to sequester CO_2 is becoming progressively well-known. It consists of adding finely-ground basalt to agricultural soils. Sequestration using this method occurs as HCO_3^- in groundwater rather than pedogenic $CaCO_3$ following the Ebleman-Urey reaction (Fig. 1). More data, however, are needed to make confident conclusions how quickly this reaction occurs.

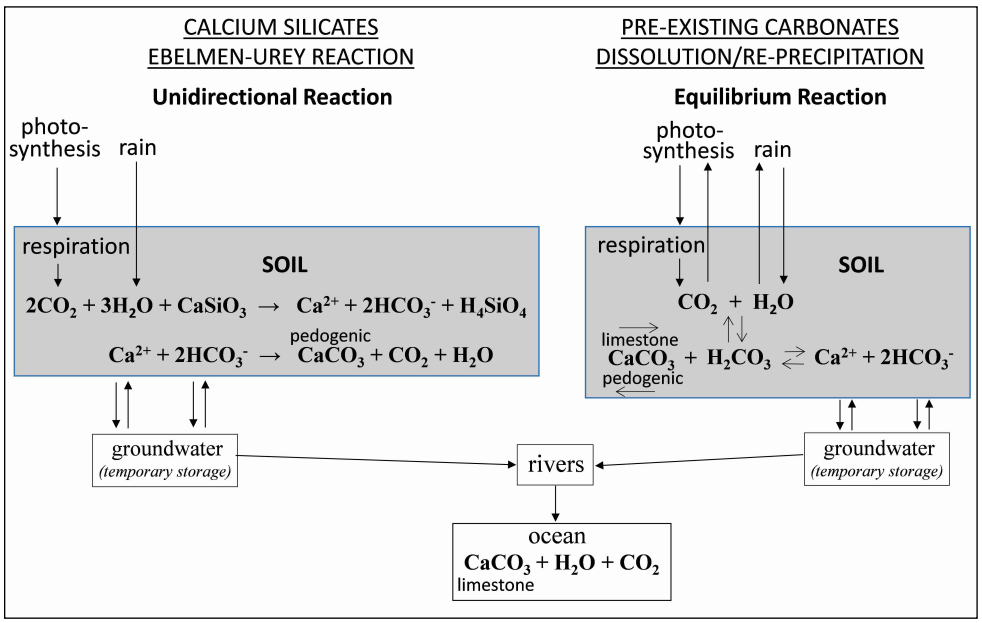

Figure 1. Soil inorganic carbon pathways when calcium originates from silicates versus pre-existing carbonates. Modified from Monger et al. 2015. Geology 43:375-378.

2. Do both types of SIC (pedogenic and lithogenic) sequester CO_2? Pedogenic $CaCO_3$ precipitates in the soil profile in various forms, such as filaments, coatings, nodules, calcic and petrocalcic horizons that parallel the land surface. Lithogenic is $CaCO_3$ detritus inherited from bedrock. Some calcareous soils are primarily pedogenic others lithogenic. For instance, one map below shows the amount of soil $CaCO_3$ in the United States (Fig. 2a). The second map shows the distribution of calcic or petrocalcic horizons (Fig. 2b). The first map is based only on lab measurements of $CaCO_3$. The second map is based on lab measurements plus field evidence of in situ precipitation. Soils of the upper Midwest have enough $CaCO_3$ to qualify as calcic horizons, but $CaCO_3$ is detrital, not pedogenic. But knowing whether the carbonate pedogenic or lithogenic doesn't answer the question about sequestration. That depends on the source of Ca as described below.

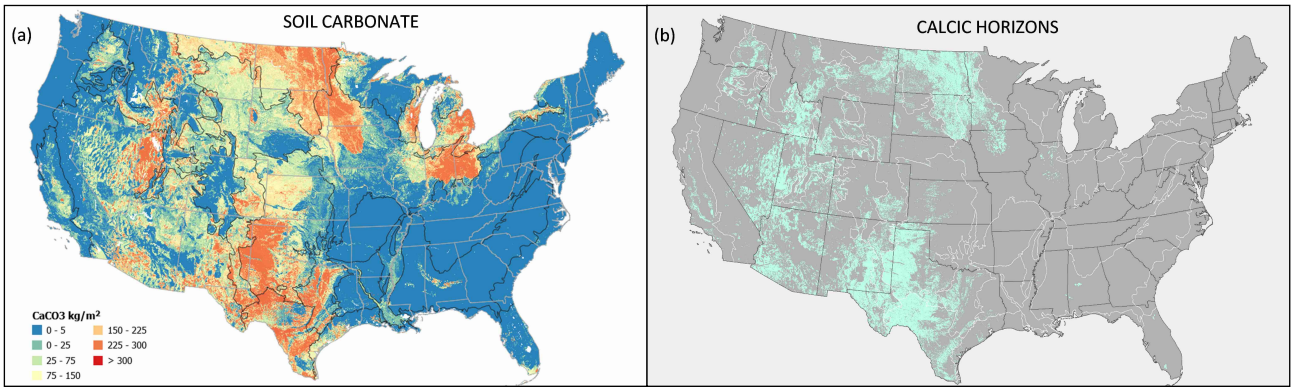

Fig. 2. (a) Distribution of soil carbonate expressed as mass (kg) per area (m2). (b) Soils containing a calcic or petrocalcic horizon (illustrations courtesy: Curtis Monger).

3. What is the source of Ca in $CaCO_3$? Knowing this is the essence of knowing if SIC sequesters CO_2. Based on stoichiometry, as shown in Reaction 1, if Ca is from Ca-silicates the $CaCO_3$ sequesters one mole of carbon. If Ca is from pre-existing $CaCO_3$ then no net sequestration has occurred, it is only a transfer. The dissolution/re-precipitation reaction can be viewed as an equilibrium reaction in contrast to the Ebleman-Urey reaction which is a unidirectional reaction (Fig. 1). To ascertain whether SIC sequesters CO_2 it is necessary to know the Ca source, as shown in the classification scheme (Fig. 3).

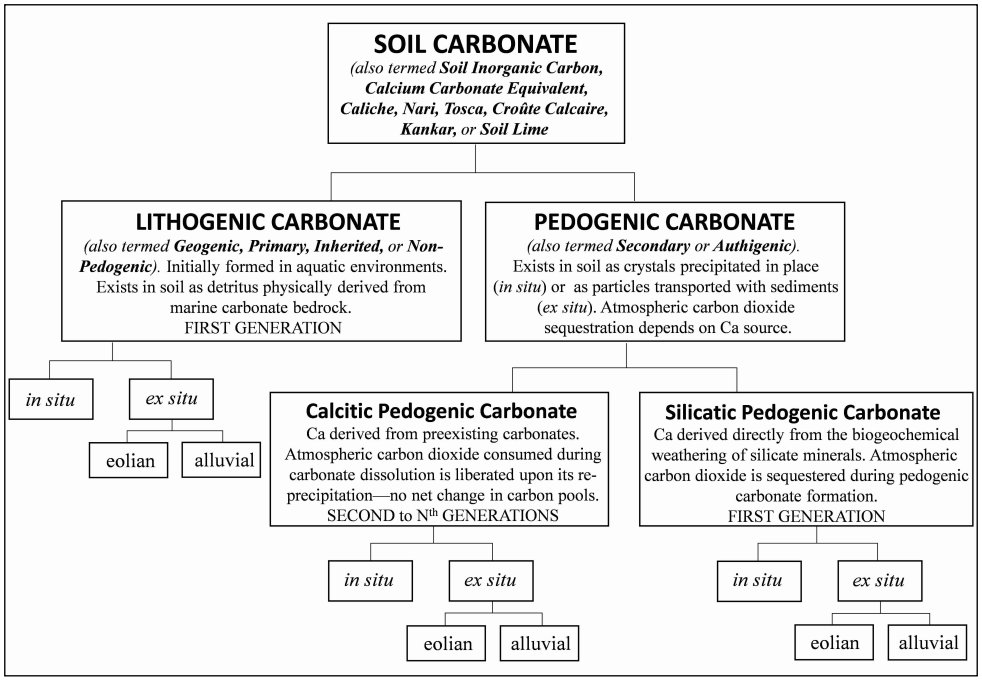

Figure 3. Classification of soil carbonate into sequestration categories based on calcium source, the concept of generations, in situ versus ex situ, and mode of transport (illustration courtesy: Curtis Monger).

4. How biological is pedogenic $CaCO_3$ and does this affect Reaction 1? At the ecosystem scale, biology is very important because it is the source of CO_2 in both the Ebleman-Urey reaction and the dissolution/re-precipitation reaction (Fig. 1). To decrease root and microbial respiration, as in the driest deserts, is to decrease $CaCO_3$ formation. To increase soil-respired CO_2 to high levels, as in deciduous forests, is to prevent pedogenic $CaCO_3$ formation. At the micromorphology scale, microbial precipitation of carbonate may be important based on scanning electron microscope of soils that reveal calcified microorganisms and root hairs (e.g., Fig. 4). Do microorganisms play a direct role in biomineralization by having specialized tissue that combines cations and anions or do they induce biomineralization by creating aqueous micro-environment in dryland soils? In either case, could microorganisms be managed to enhance carbonate formation and thereby sequester atmospheric CO_2?

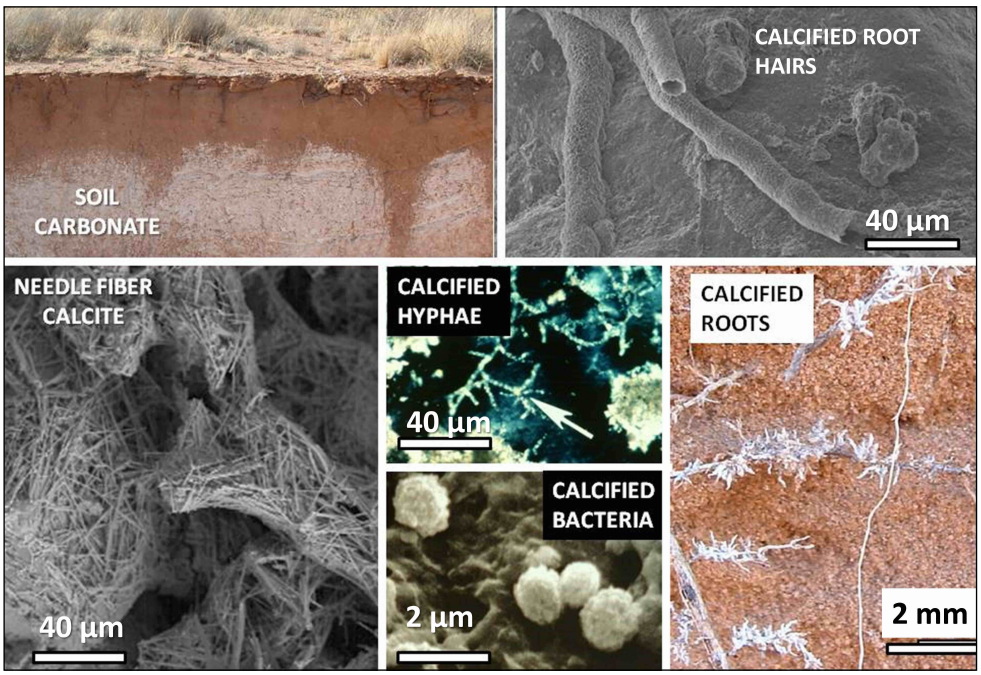

Figure 4. Micromorphology examples of calcified microorganisms and roots in southern New Mexico soils (illustration courtesy: Curtis Monger).

5. What do paleosols tell us about the rate of pedogenic carbonate in the past versus in the present (Fig. 5a)? The answer to this question, like other questions dealing with paleo-studies, provides context for understanding current conditions. It brings in the subject of soil memory. For example, carbonates found in regions where carbonates do not form today indicates drier conditions at that location in the past. In other locations, carbonate "remembers" wetter climates, as shown by dissolution pipes in the petrocalcic horizon (Fig. 5). What paleosols tell us about pedogenic carbonate in the past is a fundamental and broadscale scientific topic.

Figure 5. (a) If ages can be determined for each paleosol, the rate of carbonate formation through time can be determined. (b) Not only the carbonate formation, but also carbonate dissolution features can provide evidence of paleoclimates. Photos from southern New Mexico. Modified from Monger and Rachal. 2013. Society of Sedimentary Geology Special Publication 104. p. 63-70.

A map of SIC sequestration potential

Given the current attention on climate change and negative emissions technologies, a useful IUSS product would be a map of SIC sequestration potential. The map would be a guide to the likelihood of using SIC to sequester carbon. The map would also serve to synthesize the questions posed above. It would be color-coded green for high potential, red for low potential, and yellow for intermediate potential. The map would guide hypotheses to be tested. One hypothesis, for example, is that the highest sequestration occurs in humid agricultural soils amended with crushed basalt. The form of sequestered carbon is HCO_3^-. The soils occur in high rainfall and high temperature climates with low pH and low base saturation (i.e., Ultisols or Oxisols). Another hypothesis is the highest sequestration as pedogenic $CaCO_3$ occurs in dryland agricultural soils irrigated with water containing Ca from silicates. Another hypothesis for soils under natural conditions is more carbonate is precipitated in regions between the driest deserts, which have too little rainfall for generating significant amounts fo $CaCO_3$, and forests, which have too much rain for $CaCO_3$. A proposal is being generated to make such a map. If you're interested in participating, please contact curtis.monger@usda.gov.

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The last ‘Last Page’

A PALEO-EXCUSE

We are extremely sorry to announce that due to a shortage of creative ideas, this is (probably) the last ‘Last Page’ of Paleopedology Newsletter. This is despite our ‘never say never’ approach.

Dosvidanya (Last Page’s swansong)

Last page amigo
Ma chérie
I’ll miss you much
Last page dear
It’s not you, it’s me
But well, I lost my touch…