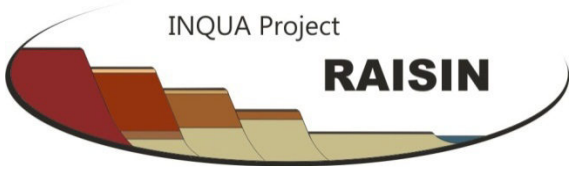


Workshop

Rates of soil forming processes – achievements, challenges, research gaps

November 5-8 2012 in Charlotte (North Carolina, USA)

Organized by INQUA project RAISIN:
Rates of soil forming processes obtained from soils and paleosols in well-defined settings

with financial support by INQUA, IUSS Division 1 and the University of Florence, Italy

Workshop report

Monday, November 5, 2012

1st session

The RAISIN project coordinator and workshop organizer Daniela Sauer (University of Technology, Dresden, Germany) welcomed the participants and presents the development of the INQUA Focus Group "PASTSOILS" and the projects "AEOMED" and "RAISIN". She gave an overview of the goals, objectives and work schedule of the project.

In the subsequent discussion the following issues were identified as particularly relevant for RAISIN work:

- long loess-paleosol sequences of Chinese Loess Plateau should be considered;
- soils in almost all parts of the world are influenced by dust input to varying extent; the effects of such dust additions (e. g. "rejuvenation" of soils) need to be considered; e. g. Chinese last interglacial paleosols show much less intensive weathering than European last interglacial paleosols on loess, on the other hand Chinese last interglacial paleosols are much thicker because of the continuous loess aggradation; Mediterranean soils and desert soils are strongly influenced by dust input as well – collaboration with the AEOMED project group should be sought;
- discussion of identification of dust additions through particle size analyses raises questions on which methods and which pre-treatments should be recommended; the group might prepare a paper discussing this issue and giving recommendations for future studies;
- one of the major aims of the project is to compile data of soils that have developed for a known time-span under well-defined climatic conditions; this means however that also past climates under which these soils have developed need to be known; two soils that are located in the same climatic region today (one in the center and one closer to a climatic boundary) may have experienced different climates in the past (the boundary of the climatic region might have shifted so that e. g. the soil closer to the boundary experienced a different climate for some time while the soil in the center of the climatic region was under similar conditions over the whole time.

2nd session

Bruce Harrison (New Mexico Tech University, Socorro, USA) gave a keynote talk "Reflections on Chronosequences and Chronofunctions".
Important issues raised in the talk and picked up in the following discussion include:

- we usually study a limited number of surfaces of different age and assume that soil development between data points proceeds at the same rate, which is not necessarily the case since certain pedogenetic thresholds may exist between the data points;
- landforms are continuously modified; e. g. terrace bodies are covered with colluvial material close to the next higher terrace and are progressively eroded close to the edge towards the next lower terrace;
- soil development on a land surface varies between north- and south-facing slope even if soils are of the same age;
- soil development does not proceed in the same way and at the same rate over time, but there are pedogenic thresholds including extrinsic thresholds (e. g. changes in precipitation or dust influx) and intrinsic thresholds (e.g. a soil-forming process such as calcification or clay illuviation may change permeability of the soil thus creating perched water);
- there is great variability of soils on landforms of same age; Bruce Harrison recommended use of non-destructive mapping tools to get an overview on variability before placing soil profiles.

Tuesday, November 6, 2012

1st session

In the morning Elizabeth Solleiro Rebolledo (UNAM, Mexico City) gave a keynote talk on "rates of soil formation of Quaternary volcanic paleosols at different chronological scales". She pointed to the fact that soils developed in volcanic material of different ages have a wide distribution over the world and contain easily weatherable minerals and are thus very useful for the RAISIN work. She showed examples of well-dated soils and paleosols from different regions of Mexico. Soil development in volcanic materials in Mexico starts with SOM accumulation and within <600 years leads to Andosols in which allophanes are the characteristic clay minerals. Usually, soil development proceeds to soils with clay illuviation (Luvisols, Acrisols) in about 10 ka. This transition takes place when the source of easily weatherable minerals is exhausted and allophanes are transformed into smectites. Clay content, amounts of crystalline clay minerals and pedogenic iron increase; contents of SOM and oxalate-extractable Fe, Al, Si, soil porosity, water holding capacity and permeability decrease. Luvisol formation in less than 10 ka could be explained by soil formation in pre-weathered material (fragments of clayey aggregates) and hydrothermal alteration.
Apparently, the soil development sequence Leptosol - Andosol – Luvisol – Acrisol is the same in a certain range of climates; the effect of (paleo-)climate on the rates of the underlying pedogenic processes needs to be constrained in more detail.

A regular talk of Serafín Sánchez Pérez (UNAM, Mexico City) on "the Teotihuacan black paleosols: chronology of pedogenic processes and their relation to environmental changes" followed. He reported that a black Calcic Vertisol was widespread in the Teotihuacan valley at the time of the pre-Hispanic settlement, during the 1st - 7th century AD. In the following discussion it is generally

agreed that the pedogenic carbonate accumulation in the paleosol must have required a significant period of land surface stability, whereas humus accumulation and Vertisol formation take only short periods of time (< 1 ka).

2nd session

Pauline Yawoa Da Costa (University of Lomé, Togo) gave a keynote talk on "the soil cover of West Africa: soil characteristics and pedogenesis". Her overview included 16 countries located in tropical West Africa, namely Senegal, Niger, Mali, Burkina Faso, Guinea-Bissau, Cape verde, Gambia, Mauritania, Chad, characterized by dry climates, and Ivory Coast, Ghana, Togo, Benin, Nigeria, Cameroon, Gabon, where humid climates prevail. Climates altogether comprise a range from desert (MAP 100 mm) to equatorial (MAP 2000 mm, < 2 dry months). Parent materials for soil development include i) sand of the Sahara; ii) sandy Quaternary formations of the «Boucle du Niger» (bend of the Niger River); iii) the «Continental terminal» and «Continental intercalaire» consisting of reworked clayey sand having undergone strong ancient ferrallitic weathering; iv) Cambrian-Ordovician sandstones of Guinea, Mali, Central and Western Burkina Faso; v) crystalline basement consisting of plutonic, metamorphic and volcanic rock. Soil groups (WRB 2006) mainly comprise Ferralsols, Plinthosols, Acrisols, Lixisols, Nitisols, Planosols and Vertisols in humid regions, and Solonetzes, Solonchaks, Leptosols, Cambisols, Regosols and Arenosols in dry regions.

Pauline Yawoa Da Costa pointed to the following peculiarities characterizing pedogenesis in West Africa:

- ferralitic and lateritic soils / soil sediments are widespread also in areas that are in dry climates today; they are explained by a humid tropical paleoclimate that prevailed in all countries south of the Sahara from the Cretaceous period on;
- many hills and plateaus, topped with a petroplinthite armor protecting them from further erosion, are remains of ancient eroded surfaces; they often exhibit characteristics of former groundwater influence that disappeared with the incision of the valleys. Thick red soil sediments, spread gravel and old concretions can be observed in the valleys;
- the Quaternary is marked by alternation of moist and dry periods causing strong erosion, including incision down to the base of the weathering profiles;
- during the dry periods of the Quaternary, extensive dune systems (ergs) developed in the northern part of West Africa.

Further, she mentioned a scientific problem that is common to all West African countries having lateritic soils: the origin of the stone line (Vincent, 1966)

- two basic kinds of hypothesis exist for the formation of the stone line: the allochthonist and autochthonist hypotheses;
- a widely accepted concept postulates an erosive phase during a dry climatic period of the Quaternary; this concept interprets the stone line as a coarse residuum of the eroded part of the soil; however, the origin of the overlying materials is still debated;
- according to another theory stone lines could be caused by long-term termite activity;
- since the stone line has not yet been dated, its Quaternary age is speculative.

The presentation showed that the majority of the soils in West Africa developed on pre-weathered material on extremely old land surfaces that have been strongly influenced by geomorphic processes over time. Establishment of soil chronosequences is extremely difficult if not impossible in this region. An appropriate way of handling the described kind of soil development within RAISIN needs to be found.

The keynote talk on West-African soils and related discussion was followed by a regular presentation of Jean Pierre Nguetnkam (University of Ngaoundere, Cameroon) on "Mineralogy and geochemical behavior during weathering of greenstone belt under tropical dry conditions of the extreme north Cameroon (Central Africa)". He presented a soil profile on hydrothermally altered and metamorphized Tertiary volcanic rock in a dry savannah environment (MAT = 28°C, MAP = 800mm). The lower part of the profile is characterized by monomineralic formation of nontronite (iron-rich smectite), whereas two horizons in the upper part also contain kaolinite. Mass balance calculations, using Th as immobile element, indicate that Al and Fe are relatively enriched at the bottom and strongly depleted in the upper part of the profile. Alkaline and alkaline earth elements are strongly leached throughout the profile, except for Ca. In the following discussion it was hypothesized that the presence of Ca and decreased contents in Fe and Al may be the result of dust addition to the upper part of the soil.

3rd session

In the afternoon Jennifer Harden (U.S. Geological Survey, Menlo Park, CA, USA) gave a keynote talk on soil chronosequences and soil carbon stocks. She emphasized the importance of understanding the processes behind the data that are obtained from soil analysis. She pointed to the fact that many important questions related to critical zone processes and carbon cycling also require knowledge on the processes taking place in soils. Soil organic carbon accumulates during early stages of soil development; in older soils it may be partly lost. However, it can be stabilized by clay or amorphous poorly crystalline iron oxides. Another aspect raised by Jennifer Harden is that different types of soil chronosequences can be distinguished. The type of chronosequences dealt with in RAISIN are primary chronosequences; i. e. sequences of soils developing on a fresh parent material, e. g. after deglaciation or formation of fluvial or marine terraces. In addition she presented a chronosequence of soil catenas, and moreover mentioned other types of chronosequences such as those forming after fire, land use change, etc.

4th session

The next step of the RAISIN work will be to compile existing data on soil chronosequences and soils of known age developed in well-defined climates. Prior to the workshop, Daniela Sauer had asked by e-mail for suggestions for database solutions. Jennifer Harden had suggested using the existing web-based Soil Carbon Database (http://www.fluxdata.org/nscn) after modifying it according to the needs of RAISIN. Jenifer Harden introduces the Soil Carbon Database to the group. Since i) the use of the Soil Carbon Database offers a number of advantages, ii) the Soil Carbon Database group has agreed to collaborate, and iii) no money is available to create a new database, RAISIN will go this way. Advantages are that it will save a lot of work and time because the database already exists. In addition, the RAISIN data will be made available for regional and global soil carbon budget estimates as well; colleagues who have already entered their data in the Soil Carbon Database will just need to add the data required for RAISIN work but won't need to enter their complete data sets a second time. Moreover, the Soil Carbon Database is already established and well-known in the soils community; hence dissemination of RAISIN data by entering them into the Soil Carbon Database will be more efficient than by creating a small new database.

Wednesday, November 7, 2012

1st session

The first session included four talks from Central and South Africa, Europe and the USA.

Jean Pierre Nguetnkam (University of Ngaoundere, Cameroon) gave a presentation on "buried paleosols in Cameroon (Central Africa): examples from the Adamoua region and implications on landscape evolution". In the discussion it was noticed that the duration of development of the buried paleosol, which formed on Precambrian granite, is not known. The paleosol has been buried by an Eocene lava flow; hence the age of the surface soil on that lava flow is known, and that soil would be suitable for the RAISIN database. Moreover, Jean Pierre Nguetnkam reported that there are also lava flows of different ages (Pleistocene and Holocene) in the South of Cameroon. Soils on these lava flows would also be valuable for the RAISIN project.

Peter N. Eze (University of Cape Town, South Africa) presented a part of his PhD work dealing with "application of geochemical climofunctions to palaeosols from West Coast Fossil Park, South Africa". In the following discussion it was observed that great care is required when using geochemical weathering indices for obtaining paleoclimatic information from paleosols because these weathering indices are not only sensitive to climate but also to soil age. Moreover, the degree of weathering decreases with soil depth; in an eroded paleosol the most strongly weathered upper part may have been removed so that only the weathering index of the lower part is available. Hence, both soil age and erosion need to be considered in order to obtain reasonable paleo-climatic information.

Daniela Sauer (University of Technology, Dresden, Germany) presented a talk on "soil formation on land surfaces of known age in S Norway". She introduced a soil chronosequence on loamy marine sediments developing into Albeluvisols. Several parameters such as proportion of voids covered by clay films, Fe_d/Fe_t ratio and molar ratio of (Ca+Mg+K+Na)/Al are closely related to soil age. However, other parameters such as pH and degree of base leaching change considerably in the first few thousand years but show no strict relation to soil age afterwards. This behavior is partly explained by strong preferential flow which is obvious in these soils. It is hypothesized that base leaching and acidification only occurs along the white albeluvic tongues surrounding dense large prisms in the Btg horizons, whereas inside the dense prisms hardly any leaching takes place.

Eric McDonald (Desert Research Institute, Reno, NV, USA) introduced major processes characterizing the formation of desert soils. He emphasized that desert soils are not stable but are continuously altered by interplay of pedogenesis and geomorphic processes. One of the key processes in deserts is dust accumulation. Dust is trapped between rock fragments and is washed down; rock fragments move up and bury the dust. This process results in an upward growth of the profile occurring in co-evolution with the formation of a desert pavement. On one hand the fresh dust leads to dilution of weathered soils and thus rejuvenation. On the other hand, the dust provides easily weatherable silt-sized material; it is hence the main source of clay, as well as of carbonates and salts in these soils. With time, a desert pavement and vesicular horizon form, leading to decreasing infiltration rates. The accumulated dust contributes to further horizon differentiation so that over time-spans of about 100 ka well-developed soils of several meters thickness can be observed. Eric McDonald raised the question of how these soils with well-differentiated horizon sequence can develop and persist despite considerable geomorphic processes and bioturbation.

2nd session

Peter Finke (Ghent University, Belgium) gave a keynote talk on "modeling soil genesis at pedon and landscape scales: achievements and problems". After providing a brief overview of the state of the art he explained in more detail the model SoilGen that he developed. "SoilGen is essentially a solute transport model that simulates unsaturated water flow, chemical equilibriums of various species with calcite, gypsum and gibbsite as precipitated phases, an exchange phase of Na, K, Ca, Mg, H and Al on clay and organic matter and a solution phase comprising various cations and anions. Additionally, a number of pedogenetic processes are simulated: C-cycling, chemical weathering of primary minerals, physical weathering of soil particles, bioturbation and clay migration" (Finke, 2012). The model was applied to a climosequence (Finke and Hutson, 2008), a chronosequence (Sauer et al., 2012), a toposequence (Finke, 2012) and as part of a spatio-temporal soilscape reconstruction (Zwertvaegher et al., in review). Furthermore, the clay migration component has been calibrated and tested (Finke, 2012) and so has the organic matter decomposition component (Yu et al., in review). Quantitative comparisons between simulations and measurements resulted in the identification of possible improvements in the model and associated inputs and problems to be solved" (cited from the abstract).
Finally, Peter Finke stated that, in addition to the pedon scale, also the soilscape scale should be addressed in the further development of pedogenetic models. Most of the models that have been proposed for this scale so far, emphasize rather soil production and redistribution but do not include pedogenic processes. Peter Finke gave an overview of such models and pointed to options of combining pedon-scale and soilscape-scale models.

3rd session

In order to compile available soil chronosequence data in the Soil Carbon Database, the RAISIN group needs to define the kind of data that shall be entered so that the respective data fields can be added to the database. For this purpose, Daniela Sauer had created an Excel spreadsheet containing a suggested data set that was circulated and improved by comments of RAISIN members prior to the workshop. The group worked on this Excel spreadsheet on Tuesday afternoon and finalized it on Wednesday afternoon. The final version of the workshop will be circulated a last time among all group members for final improvements.

4th session

Sergey Sedov (UNAM, Mexico City), one of the RAISIN coordinators, had sent the following proposal (shortened version) together with Elizabeth Solleiro Rebolledo (UNAM, Mexico City), to be discussed at the workshop:
Glacial periods are characterized by enhanced geomorphic processes and suppressed pedogenesis in periglacial regions. However, short milder phases (interstadials) existed within these periods, providing better conditions for soil formation. Interstadial soils are used as stratigraphic markers in loess research but their pedogenesis has not been studied in detail so far. Even during stadials some synsedimentary pedogenesis took place, especially in loess-like sediments. However pedogenic processes of these periods are often neglected, as sedimentological and geomorphological processes are more evident.

Sergey Sedov and Elizabeth Solleiro Rebolledo suggest:

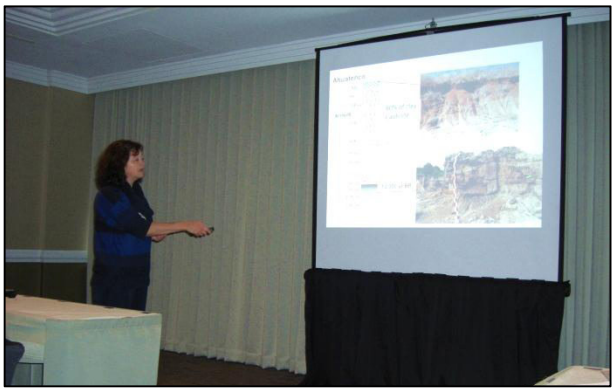
- *studying and interpreting weak interstadial paleosols and synsedimentary pedogenetic features as important complimentary records of glacial periods, also in the context of paleolithic archeological sites*
- *identifying which pedogenetic processes take place in cool climate and limited time of interstadial phases, leading to paleopedological characteristics that can be observed in paleosol-sediment sequences*
- *developing conceptual models of interaction between pedogenesis and erosion / sedimentation during glacial periods and describing how this interaction is documented in paleosol-sediment records*
- *evaluating the role of soils in the carbon cycle during glacial periods, especially with respect to their carbon storage capacity*

This research shall first focus on paleosols of the last glacial period and then be extended to earlier ice ages.

The proposal was discussed, especially with regard to whether the proposed work could be done by a sub-group of RAISIN chaired by Sergey Sedov, or if the tasks of the proposal require another INQUA project proposal under the umbrella of the PASTSOILS Focus Group.
Result: The RAISIN group encouraged Sergey Sedov to contact the community working on paleosols in loess (including the Chinese Loess Plateau) and ask this group to contribute existing data of paleosols in loess / loess-like sediments that developed within a known period of time under known climatic conditions to the database.
This might be the first step in i) analyzing the state of the art, ii) identifying and defining more precisely existing research gaps in the field of pedogenesis during glacial periods, iii) establishing a group willing to work on this topic, and iv) preparing a proposal for an INQUA project chaired by Sergey Sedov and Elizabeth Solleiro Rebolledo, focusing on identified research gaps with respect to the interplay between pedogenesis and sedimentation during glacial periods.
Comment added later by Daniela Sauer: Such INQUA project would preferably submitted under the umbrella of the two Focus Groups "PASTSOILS" (chaired by Daniela Sauer, Rivka Amit and Sergey Sedov) and "Loess & Pedostratigraphy" (chaired by Slobodan Markovich). It could thus be the beginning of collaboration between the Focus Groups, which would be very reasonable and desirable.

Invitation to the next RAISIN Workshop

Daniela Sauer invited the group to the Second RAISIN Workshop on September 24-28, 2012, organized by Fabio Scarciglia and Daniela Sauer at the University of Calabria (Arcavacata di Rende) with field trip to soil chronosequences on marine terraces along the Ionian coast of Calabria and Basilicata, South Italy. The field trip will address both i) soil properties that are closely related to soil age and may be used to obtain chronofunctions, and ii) geomorphic processes interfering with progressive soil development that need to be considered in the interpretation of Pleistocene soil chronosequences.
The workshop has also been announced on the RAISIN website:
https://ppsg2011.uni-hohenheim.de
This website provides more detailed information and will be updated regularly in the next months.



Elizabeth Solleiro Rebolledo (Mexico) highlighting the value of soils in volcanic materials of different age.

Serafín Sánchez (Mexico) introducing black paleosols from Central Mexico.

Pauline Da Costa (Togo, West-Africa) giving an overview on the soil cover of West-Africa.

Jennifer Harden (California, USA) relating soil age, position (mountain front - basin) and carbon storage.

Peter Finke (Ghent, Belgium) introducing the model SoilGen that he developed to model soil development.

Continuing discussion during break, from left to right: Bruce Harrison (New Mexico, USA), Peter Eze (Nigeria), Peter Finke (Belgium), Eric McDonald (Nevada, USA).

Jean Pierre Nguetnkam (Cameroon), Marith Reheis (Colorado, USA), Pauline Da Costa (Togo).

Field trip guided by Missy Eppes (NC, USA): discussing soils and geomorphic processes in a small catchment.

List of workshop participants

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