TERPRO Focus Group PASTSOILS

INQUA

INQUA Project RAISIN

Workshop
Rates of Soil Forming Processes in Mediterranean Climate

September 24-28 in Calabria and Basilicata (South Italy)

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

Organizers:
Fabio Scarciglia (University of Calabria, Italy)
Daniela Sauer (Dresden University of Technology, Germany)

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Division 1 of International Union of Soil Sciences (IUSS)

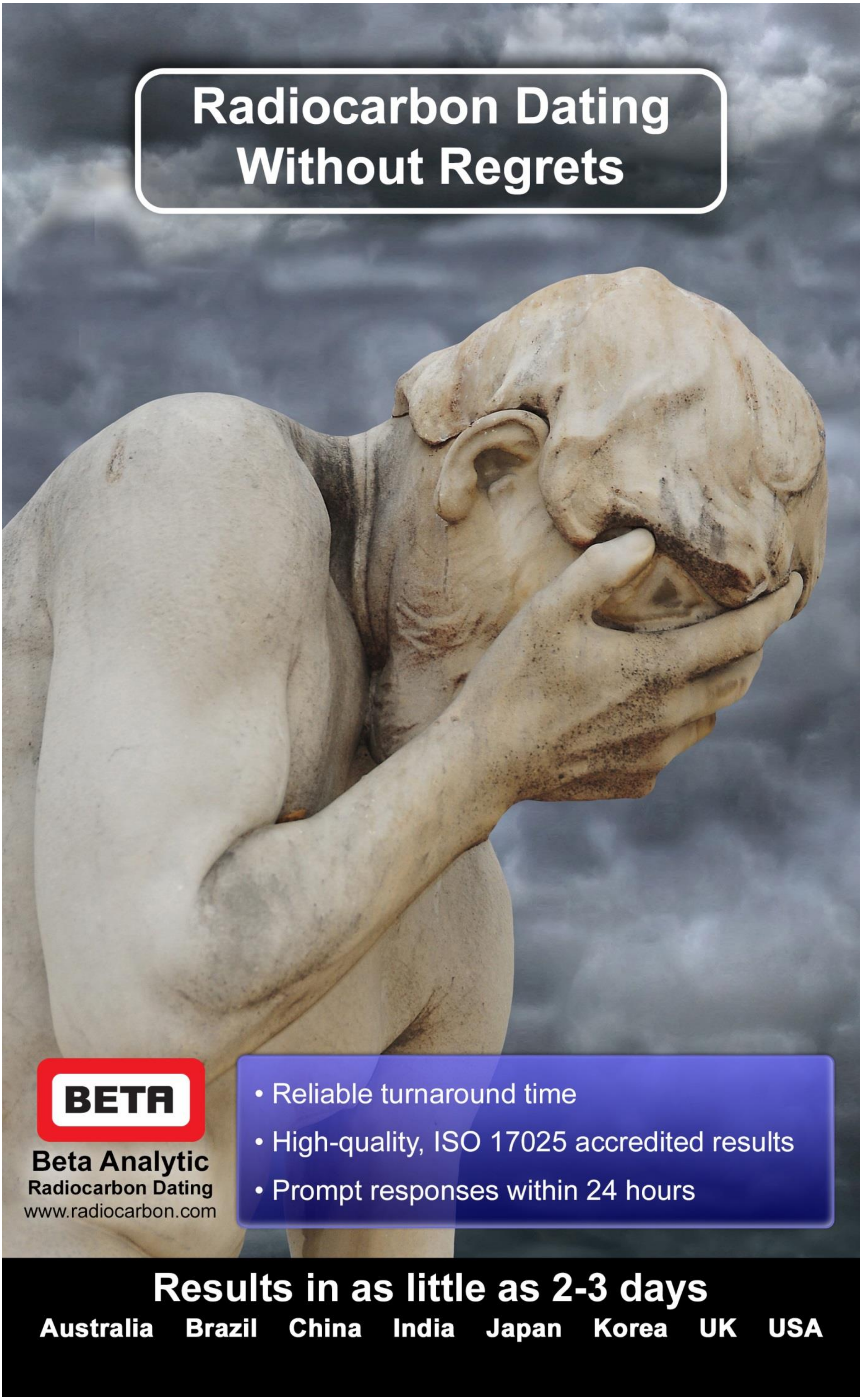
Program and Abstracts

Tuesday, September 24

8.15 am – 9.00 am registration: Please, arrive early to do all payments and paper work before 9.00 am.	
9.00 am – 10.30 am: Opening and keynote talk	
9.00-9.15	Opening of the workshop by *Fabio Scarciglia* and *Daniela Sauer*: Welcome, background and main ideas of RAISIN, main goals of the workshop
9.15-10.00 10.00-10.30	Keynote talk *Jennifer Harden:* Linking soil forming processes to carbon cycling: a study in contrasts Discussion, significance for RAISIN
10.30-11.00	*Coffee break*
11.00 am – 1.00 pm: The western Mediterranean region	
Convener:	*Fabio Scarciglia (Coordinator of RAISIN-Mediterranean)*
11.00-11.20 11.20-11.30	*Elvira Roquero:* Soil evolution indices in fluvial terrace chronosequences of the western Mediterranean: Tagus River basin (Central Spain) Discussion
11.30-11.50 11.50-12.00	*Pablo Silva:* Use of soil sequences in paleoseismology: Application to the Palomares Fault (Betic cordillera, SE Spain) Discussion
12.00-12.20 12.20-12.30	*Eric McDonald:* Soil development and regional correlations of river terraces in the Spanish Pyrenees for elucidating tectonic and climate history Discussion
12.30-1.00	General discussion on the western Mediterranean region, main outcomes for RAISIN
1.00 pm – 2.00 pm: Lunch break	
2.00 pm – 4.00 pm: The eastern Mediterranean region	
Convener:	*Peter Wigand*
2.00-2.20 2.20-2.30	*Rivka Amit:* Transition from arid to hyper-arid environment in the southern Levant deserts as recorded by early Pleistocene cummulic Aridisols Discussion
2.30-2.50 2.50-3.00	*Amir Sandler:* Evidence for estimating rates of pedogenic processes in Mediterranean soils Discussion
3.00-3.30	General discussion on eastern Mediterranean region, main outcomes for RAISIN
3.30-4.00	*Coffee break*
4.00 pm – 5.30 pm: Africa	
Convener:	*Daniela Sauer*
4.00-4.20	*Jean Pierre Nguetnkam:* Morphology of soils chronosequence on Mount Cameroon (Central Africa): evidence of soil deepen and differentiation with age
4.20-4.30	Discussion
4.30-4.50	*Peter Eze:* Late Quaternary palaeosols from South African coasts: pedogenesis and palaeoenvironmental interpretation
4.50-5.00	Discussion
5.00-5.30	General discussion on Africa, main outcomes for RAISIN
5.30-open end: Discussion of most important aspects of this day, significance for RAISIN	

Wednesday, September 25

8.30 am – 10.30 am: The central Mediterranean region 1	
Convener:	*Rivka Amit*
8.30-9.15	Keynote talk *Fabio Scarciglia:* A comparison of Quaternary soil chronosequences from the Ionian and Tyrrhenian coasts of Calabria, southern Italy: Rates of soil development and geomorphic dynamics
9.15-9.30	Discussion
9.30-9.50	*Guido Mariani:* Micromorphological evidence of contrasting pedogenetic processes in Holocenic soil development in the Northern Apennines
9.50-10.00	Discussion
10.00-10.20	*Peter Wigand:* Holocene Soils of Southern Italy: Human and/or Climate Interaction
10.20-10.30	Discussion
10.30-11.00	*Coffee break*
11.00 am – 1.00 pm: The central Mediterranean region 2	
Convener:	*Markus Egli*
11.00-11.45	Keynote talk *Daniela Sauer:* Interplay of soil-forming processes, aeolian and geomorphic dynamics in the Mediterranean - the 730 ka Metaponto soil sequence, Basilicata, S Italy
11.45-12.00	Discussion
12.00-12.20	*Benoit Deffontaines:* Marine terraces and seismic cycle: case example of the Southern Apennine deformation front (Basilicata, Taranto gulf)
12.20-12.30	Discussion
12.30-1.00	General discussion on the central Mediterranean region
1.00 pm – 2.00 pm: Lunch break	
2.00 pm – 3.40 pm: Temperate and cool climates 1	
Convener:	*Jennifer Harden*
2.00-2.45	Keynote talk *Markus Egli:* Soil chronosequences in Alpine areas: possibilities and limitations for deriving reaction rates
2.45-3.10	Discussion
3.10-3.30	*Emmanuel Opolot:* Modeling evolution of weathering indices with SoilGen: preliminary results and perspectives
3.30-3.40	Discussion
3.40-4.00	*Coffee break*
4.00-5.00	General discussion on temperate to cool climates, main outcomes for RAISIN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Abstracts

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Linking soil forming processes to carbon cycling: a study in contrasts

Jennifer W. Harden[1], Brittany Johnson[1], Corey Lawrence[1], Marjorie Schulz[1], and Katherine Heckman[2]

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Soil development occurs over all timescales as a result of many physical, biological, hydrological, and biogeochemical processes, all of which are inexorably linked to biology and the cycling of organic carbon. Effectively estimating reactivity and turnover of organic carbon involves targeted sampling, fractionation, and enrichment of radiocarbon in soils sampled since the 1990s. Meanwhile several soil parameters such as surface area, organic carbon, carbon density, extractable iron oxides, and clay content have significant correlations with soil radiocarbon measurements. Last, field-based indices of soil development are correlated with and can be used as proxies for soil parameters and in turn for radiocarbon and estimates of carbon turnover. In this paper, we examine two soil chronosequences from the western U.S. that formed over the past ~1MY. In central California, granitic alluvium, Mediterranean climate, and grassland or savannah vegetation resulted in Inceptisols (young) to Alfisol soil orders with subsoils rich in clay and Fe oxides and moderately rich in base cations. In western Washington, andesitic alluvium, humid moisture regime, and forest cover resulted in a mixture of Inceptisols to Ultisols with subsoils rich in Fe and Al oxides and depleted of base cations. In soils of both study areas, radiocarbon enrichment and C storage are inversely proportional to depth, indicating fast turnover of C in the surface. In the subsoil, radiocarbon enrichment is inversely proportional to surface area, indicating slow turnover in horizons rich in clay and oxides.

Soil evolution indices in fluvial terrace chronosequences of the western Mediterranean: Tagus River basin (Central Spain)

Elvira Roquero[1]*, Pablo G. Silva[2], José L. Goy[2], C. Zazo[3]

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Soil chronosequences on fluvial terraces of the Tajo and Henares rivers (Central Spain) are studied in order to find out the variation of soil properties with time. Chronology of terraces has been established on the basis of the available numerical and paleomagnetic dating for the Tagus river basins, but also cross-checked with the reported Pleistocene faunas and geomorphic correlations. Direct numerical dating come from OSL, TL and Th/U dates, but the eventual age data used in this study come from altimetry/age empirical correlations recently established for the Tagus basin (e.g. Silva et al., 2013). This relationships match with 2nd and 3rd order polynomial regressions for the entire drainage basins, but with potential ones for individual river basins.

Previous studies (Roquero et al 1997, Roquero 2010) established some soil evolution indices based on analytical properties of soils such as: Clay content (%) in argillic horizons (**CC**); Global clay content (**GCC**), obtained from the product of thickness and clay percentage in argillic horizons; Illuviation index (**ILI**), or ratio between clay content in argillic horizon and clay content in the overlying horizon; and finally the clay/silt ratio or soil ageing index (SAI), which results from the division of clay and silt percentages in argillic horizons, representing an estimation of the "Soil Ageing". These previous works established nice empirical relationships between the aforementioned soil indices and the altimetry of the preserved terrace surfaces, resulting in lineal regressions with correlation indices (R2) up to 0.70. Among these relationships studied the "Soil Ageing Index" (SAI ratio) has proved most useful to evaluate progressive soil development and showed more consistent correlations. Clay/Silt ratio is an obvious consequence of a long and pronounced pedogenesis of the materials of argillic horizons. The original silt particles are weathered to clay fraction (exception made of unweatherable minerals) and at the same time clay fraction notably increases by the illuviation process. Therefore, lower values of "ageing index" indicate less developed soils associated with younger terrace levels whilst high values are associated with older terrace surfaces where soils are strongly developed.

In this study, Age/Ageing Index relationships applied to two relevant terrace systems of the Tagus river basin, result in consistent lineal regressions with correlation values always around R2= 0.9. However it is noticed that overall relationships for an entire drainage basin (e.g. Tagus Basin) do not efficiently illustrate the age of the terraces studied from the corresponding Ageing Index, since the original clay content in the soil profile is variable depending on the source areas (granitic, metamorphic or sedimentary rocks). On the contrary, discrete relationships performed for individual terrace systems (i.e. river basin) can be used to estimate the soil age with a good confidence level. This is considering no relevant variations in the lithology of rocks exposed in the sources areas with time (river incision), and the same climatic history affecting the studied valley section. Under these assumptions, and once established the best-fit age/altimetry regression for an individual valley, the Soil Ageing Index reflects soil evolution through time. These correlations have been also preliminary applied to other river basins with comparable Mediterranean climate and climatic history in Central Spain (e.g. Duero Basin) resulting in similar linear relationships and supporting the consistency of this soil index. Relationships among the other indices (GCC, CC and ILI) offer lower correlations. Particularly ILL index show a great variability, so its use as an evolution criterion is less accurate, depending on the degree of preservation of the soil profile because modification of former overlying horizons by erosion leads to truncate the upper part of the original soil profiles. On the other hand, the misfit between the used age/altimetry relationships (polynomial or potential functions) and the obtained age/soil relationships (lineal functions) might reflect the difference between the "increasing" and "changing" fluvial incision rates and the apparently "constant" pedogenic clay formation. River terrace production is influenced by base-level changes and differential uplift, but soil evolution in fluvial sequences is mainly only climatically driven subject to alternating stages of accelerated and decelerated soil genesis in a sort of dynamic equilibrium, but the resultant rates accumulated through time are apparently constant.

Study supported by the Spanish Research Projects CGL2012-33430 (CSIC) CGL2012-37581-C02-01 (USAL).

Use of soil sequences in paleoseismology: Application to the Palomares Fault (Betic cordillera, SE Spain)

Pablo G. Silva[1]*, Elvira Roquero[2], Miguel A. Rodríguez-Pascua[3], Teresa Bardají[4], Pedro Huerta[1], José L. Goy[1], Cari Zazo[5]

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Natural fault exposures and fault-trench analysis are devoted to unravel the paleoseismic history of surveyed faults by means of the identification of discrete earthquake event horizons. We use offset paleosols as earthquake horizon events and soil development as a relative timing-clock tool in the natural exposures of the strike-slip Palomares Fault (PLF) located in the Murcia Region (Silva et al., 1997). In this region paleoseismic studies indicate that stronger events have long recurrence between 15 and 30 ka, and maximum estimated magnitudes of 6.4 Mw to 7.0 Mw. This is mainly due to the slow fault slip rates (<0.5 m/ka) linked to the Africa-Eurasia plate convergence rates (4 mm/year) controlling the Quaternary tectonic activity in the Betic Cordillera (e.g. Martínez-Díaz et al., 2012).

The section studied is located in the locality of La Escarihuela, on the PLF fault trace. The section record a total amount of six paleosols on alluvial-colluvial deposits vertically displaced by the fault a maximum of 33 cm. The faulted soil sequence is sealed by an undisturbed thick (0.6 m) mature calcrete horizon at top. The paleosol sequence develops on successive and overlapped sedimentary units, 50 to 20 cm thick, indicating alternating stages of soil formation and sedimentation evolving upwards to more arid conditions. This is evidenced by the increasing accumulation of carbonate on the original Bt horizons, leading the superposition of different pedogenetic cycles responsible of the recalcification of the underlying paleosols. The common horizon sequences are featured by reddish brown Bt horizons (5YR5/4d, 5YR4/4m) overlying calcic horizons ($CaCO_3$. 35%). In some cases these calcic horizons are originated by the recalcification of the existing Bt horizons giving place to a lightening (5YR 6/3d, 5/4m) associated with $CaCO_3$ content about 8-12%. Clay content are variable but soil colours are similar since they are mainly inherited from previous well developed red soils (2,5YR 4/6d, 3/6m) in the metamorphic source area. Recent dating of alluvial fan surfaces in the region, indicate that thick mature calcretes on alluvial sediments hold a minimum OSL ages of c. 330 ka BP (Ortuño et al., 2012).

Comparing soil features (e.g. soil depth/spacing, soil thickness, Bt thickness, clay and carbonate content) with the conventional Marine Oxygen Isotopic (MIS) curve is possible to establish relative paleoclimatic relationships and obtain a relative time-scale for soil development. Considering an age of c. 330 ka BP for the top calcrete horizon the complete sequence of paleosols developed between c. 612 ka BP (MIS 15) and c.337 ka BP (MIS 9), with peaks of soil formation during intervening warmer subisotopic stages of MIS 13 and 11.

Comparing the obtained soil-time data and accumulated fault offsets (33 and 12 cm) is possible to discriminate two paleoseismic events with and vertical displacement per event of 21 cm (Event 1) and 12 cm (Event 2). The Event 1 affects the three basal soils recording true surface faulting, but the second event only triggered surface flexure, both of reverse – strike-slip nature, with a recurrence period of c. 125 ka and estimated magnitudes of c. 5.9 Mw ± 0.2 and 6.4 Mw ± 0.3 respectively.

Paleosols provide a unique evidence of surface faulting in paleoseismology, since these particular geological elements can be unequivocally related to an ancient ground surface. In Mediterranean zones subject to slow convergence rates, the comparison of Middle-Late Pleistocene alluvial paleosol sequences with existing paleoclimatic time-scales can offer good approaches to establish the timing for the seismic history of a zone.

Study supported by the Spanish Research Projects CGL2012-37581-C02-01 (USAL), CGL2012-33430 (CSIC).

Soil development and regional correlations of river terraces in the Spanish Pyrenees for elucidating tectonic and climate history

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J. L. Peña-Monné[4], E. Rhodes[5]

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In the Ebro basin (Spain) and adjacent Pyrenees, we are determining records of glacial fluvial activity and regional trends in terrace deformation and stream incision to test models of post-tectonic uplift. Time-related trends in soil development serve as the primary means of regional correlation of terrace remnants and to confirm radiometric age estimates. The studied terraces are strath terraces that have ~4-8 m of fluvial gravel and sand overlying scoured bedrock and include up to ten regionally distinct terrace surfaces mapped as Qt10 (lowest) to Qt1 (highest). Terraces and glacial deposits have been dated using radiocarbon, luminescence, magnetostratigraphy, and nuclide depth profiles using cosmogenic Be^{10}. The ages obtained from glacial deposits indicate glacial periods at about 85 ka, 64 ka, and 36 ka (from glacial till) and 20 ka (from loess). The fluvial drainage system fed by glaciers, developed extensive terrace systems which have approximate average dates of 11 ka (Qt9), 45-47 ka (Qt8), 61-68 ka (Qt7), 97 ka (Qt6), 151-178 ka (Qt5), 395-430 ka (Qt3), and > 740 ka (Qt2).

The morphology of multiple soils was described on terraces along the Rio Cinca and Rio Gállego. The modern climatic regime is Mediterranean with precipitation ranging from ~125 mm/yr at the lower elevations to ~250-350 mm/yr at the higher elevations. The lithologic composition of the soil parent material (fluvial sediment) is siliceous igneous and metamorphic rocks (~75% of the deposits) and secondarily of carbonate marine rocks (~25% of the deposits). General trends in soil development in the arid part of the chronosequence show strong time-related trends in pedogenic accumulation of calcium carbonate (from 15 to 75-85% wt.), weak trends in iron oxides (0.5 to 1.8 % wt. total extractable Fe), the type and degree of carbonate cementation, total profile thickness, and soil development index values (SDI) ranging from about ~5 (Qt10) to ~90 (Qt3). By comparison, trends in soil development in the semi-arid to sub-humid part of the chronosequence have stronger overall accumulation of clay and iron oxides (0.5 to 3.8 % wt. total extractable Fe), minimal pedogenic carbonate (0 to 22% wt.), SDI values from ~ 15 (Qt9) to ~ 120 (Qt3), and greater profile depths relative to the soils in the arid localities. Maximum soil developed occurs on the Qt3 surface with weakly developed soils on the older Qt1 and Qt2 surfaces, reflecting the erosional degradation of the two oldest terrace remnants. Soil morphology, especially development of soil Bkm and Bt horizons, strongly reflects the original bar-and-channel depositional topography. Soils formed at bar positions have higher gravel content, stronger developed Bkm horizons with carbonate cemented gravel (III-IV^{+} carbonate stage morphology), relative to soils formed at channel positions. Soils formed at channel positions have low gravel content (parent material is primarily overbank and loess deposits) and Btk horizons with scattered to abundant carbonate nodules (I-II carbonate stage morphology).

Soil stratigraphy is used to link dated and undated terrace remnants to develop robust regional stratigraphic framework of fluvial terraces. The longitudinal profile of the terraces clearly diverges away from the distal terminus of the rivers (confluence with the Ebro Rive) basin towards the river's headwaters in the Pyrenees. We attribute upstream divergence to erosional denudation and isostatic rebound of the Pyrenees and adjacent basin margin.

A comparison of Quaternary soil chronosequences from the Ionian and Tyrrhenian coasts of Calabria, southern Italy: Rates of soil development and geomorphic dynamics

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Three soil chronosequences developed on different terrace staircases along the Tyrrhenian (western) and Ionian (eastern) coasts of northern Calabria, southern Italy, were compared to investigate rates of soil formation during the Quaternary. Two of these soil chronosequences developed on early to late Pleistocene marine terraces in two sectors of the Praia area, whereas the third one developed on fluvial terraces in the Rossano area spanning from middle to late Pleistocene ages, respectively. In particular, we compared and integrated wide analytical datasets including both novel results and already published data related to selected morphological, physical, chemical, mineralogical and SEM analyses from the two coastal sectors. We focused on soil geochemistry (major and trace elements including REEs) to explore the effects of time, soil-forming processes, parent material and geomorphic dynamics on direction and rates of pedogenesis. The geochemical signature points out a complexity of parent materials, showing both relevant similarities and some heterogeneity between the two study areas but also across single soil profiles, as a consequence of geomorphic dynamics (soil reworking, aggradation, burial and/or erosion), in turn promoting soil ageing and/or rejuvenation. These processes, along with lithological discontinuities identified in the field and evidenced by laboratory data, can explain some data scattering from soil chronofunctions calculated for peculiar soil properties and pedogenic indexes plotted against estimated soil ages. Good positive correlations were obtained for exponential and linear functions of the $(Fe_d–Fe_o)/Fe_t$ and Fe_d/Fe_t indexes (weighted on the basis of total soil profile and single horizon thicknesses), confirming their reliability as soil development proxies. In addition, our results suggest that: (i) rates of soil development did not change significantly over about 100-800 ka, despite the cyclical alternation of Pleistocene climate changes; (ii) dominant soil-forming processes tend to minimize original differences of pedogenic substrata and local (pedo)climatic conditions through time. Moreover, on the basis of best fitting soil chronfunctions we estimated the unknown age (namely the time range of soil development before burial, which resulted of about 200 ka) of a buried soil profile in the Rossano area, not correlated to any terrace surface of known age. The identification of quartz grains affected by severe etching and secondary silica precipitation features in soils of different ages for the two study areas indicates different rates of silica dissolution in the two coasts of Calabria, very likely related to different climatic conditions, especially in terms of rainfall and consequent soil moisture availability to trigger chemical reactions.

Micromorphological evidence of contrasting pedogenetic processes in Holocenic soil development in the Northern Apennines

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Climate variations during the Holocene are a strong constraint to soil development. Long-scale shifts in temperature and precipitations can alter the environmental framework of pedogenesis and produce complex sequences, which can be problematic to understand. In this situation, a valuable help comes from soil micromorphology, since its resolution allows, on one side, to focus on single process and, on the other side, to put the identified genetic phases together in a uniform framework. The northern slope of Mt. Cusna (2121 m a.s.l.) in the Northern Apennines is characterized by the presence of a paleosurface shaped at the end of the last glacial period. Nine soil profiles related to the paleosurface were described and sampled (for bulk and micromorphological analyses) at an altitude range between 1723 and 1860 m a.s.l.
Field descriptions and bulk analyses indicated the presence of two main soil units. The upper unit showed the structure of a colluvial deposit interested by a weak pedogenesis. The lower unit can be regarded as a truncated paleosol with evidence of strong brunification (Duchaufour 1983) together with clay illuviation. Moreover, in the flatter areas, a blackish organic horizon was found at the top of the deep unit.
Through micromorphology we were able to identify three main pedogenetic stages (biostasy, Erhart 1951) separated by two moments of strong slope movements (rhexistasy, Erhart 1951). These were linked to major variations in climate and environment. In the deep unit, different generations of clay coatings suggested the development of brunification during a temperate period with contrasted seasons, followed by a gradual loss of seasonality. A later phase of instability led to the truncation of the upper part of the paleosol. The blackish horizon overlying the paleosol shared no similarity with it both in microstructure and mineral components; instead, it showed signs of frost action. These features were interpreted as the result of the slow accumulation of organic matter over the new truncated surface in a colder thermal regime. In the upper unit, groundmass was sometimes completely composed by rock fragments of colluvial origin, or soil fragments (i.e. pedorelicts, Brewer 1976) very similar to the paleosol itself. From these data, it was possible to say that the in situ development of this unit appeared to be of little significance. This unit was deposed during a second moment of slope instability. Dates from charcoal found in the lower unit provided a time frame for the two instability events: the first was linked to the climatic recrudescence at the beginning of the Late Holocene, the second to the Little Ice Age.
In conclusion, the changing environmental context acted on pedogenesis with different results, both in terms of process and strength, forming soils with a very aleatory development. The use of soil micromorphology was essential to recognize these three different pedogenetic phases and their relative action during time.

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Interplay of soil-forming processes, aeolian and geomorphic dynamics in the Mediterranean - the 730 ka Metaponto soil sequence, Basilicata, S Italy

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A staircase of marine terraces extends about 25 km inland along the Gulf of Taranto, S Italy. Brückner (1980) mapped one Holocene (T0) and eleven Pleistocene terraces (T1 – T11). The marine terraces between Lido di Metaponto (located on T0) and Pisticci (on terraces T9 and T10) are composed of a gravelly terrace body with a thickness of several meters, built up in a littoral environment during sea-level regression phases. It is usually covered by finer lagoonal or alluvial sediments of varying thickness. One new and several published U series (Brückner, 1980) and OSL (Zander et al., 2003, 2006) ages are available for the terraces T0 to T4. The identification of Senegalese fauna (especially *Strombus bubonius*) in some places, e.g. Ponte del Re, provides additional evidence for the MIS 5e age of terrace T3. A tephra layer embedded in the upper terrace body of T8 is attributed to an eruption of the Phlegraean Fields 500-600 ka BP. The Brunhes/Matuyama boundary is located between the uppermost terraces T10 and T11. Thus, a chronological framework has been established for the terrace sequence, offering an excellent opportunity to study soil development and geomorphic processes over the last ca. 730 ka.

The most conspicuous changes of soils with terrace age include increasing rubefication and increasing soil thickness. The latter can be best described by a power function. However, the use of the criterion soil thickness is complicated by severe erosion and colluviation processes. Moreover, addition of eolian sediments to soils is a widespread phenomenon. In some locations even up to several meters of loess-like sediments (derived during glacial periods from river beds in the Apennine foreland and the dry shelf) are found. Solum thickness is also a difficult criterion in cases where the terrace soils have been buried by alluvial or colluvial deposits. Depending on the thickness of the deposit, such burial may have slowed down or stopped pedogenesis in the underlying soil. On the other hand, pedogenesis also took place within the cover sediment.

A major process of chemical weathering of silicates is hydrolysis, *i. e.* exchange of Na^+, K^+, Ca^{2+} and Mg^{2+} in silicates for protons. Hydrolysis of feldspars and volcanic glass leads to release of Na^+, K^+, and Ca^{2+}, whereas Mg^{2+} is derived from mica and mafic minerals. The released cations are prone to leaching in humid environments. Progressive chemical weathering and cation leaching change the ratios of these mobile cations and less mobile elements in soils. In this study a base leaching index (BLI), using the molar element ratio, is applied: BLI = (Ca+Mg+K+Na)/Al.

Silicate weathering and related base leaching with time in the Metaponto area can best be described by a power function: BLI = 0.9724 * terrace age$^{-0.184}$.

Increasing Fe_d/Fe_t ratios with terrace age can best be described by a power function:
Fe_d/Fe_t ratio = 0.2348 * terrace age$^{0.1325}$.

Holocene Soils of Southern Italy: Human and/or Climate Interaction.

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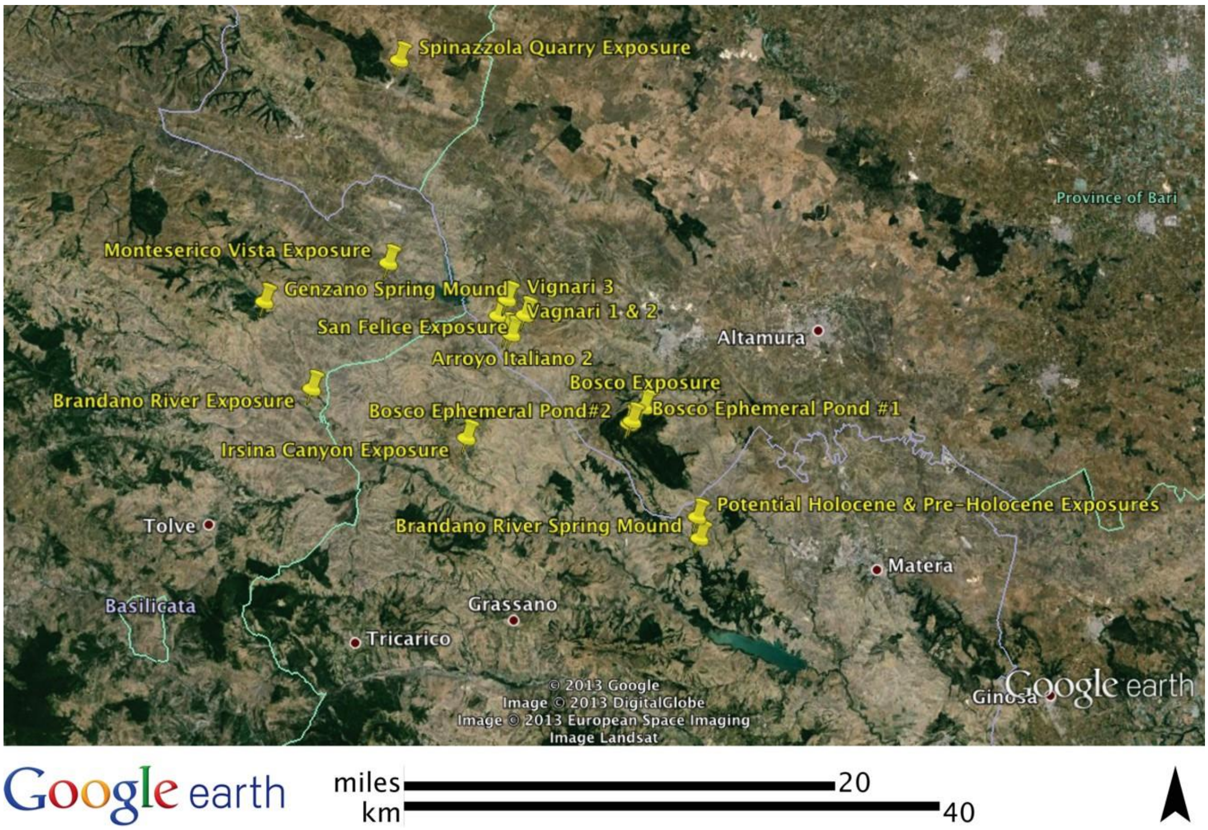
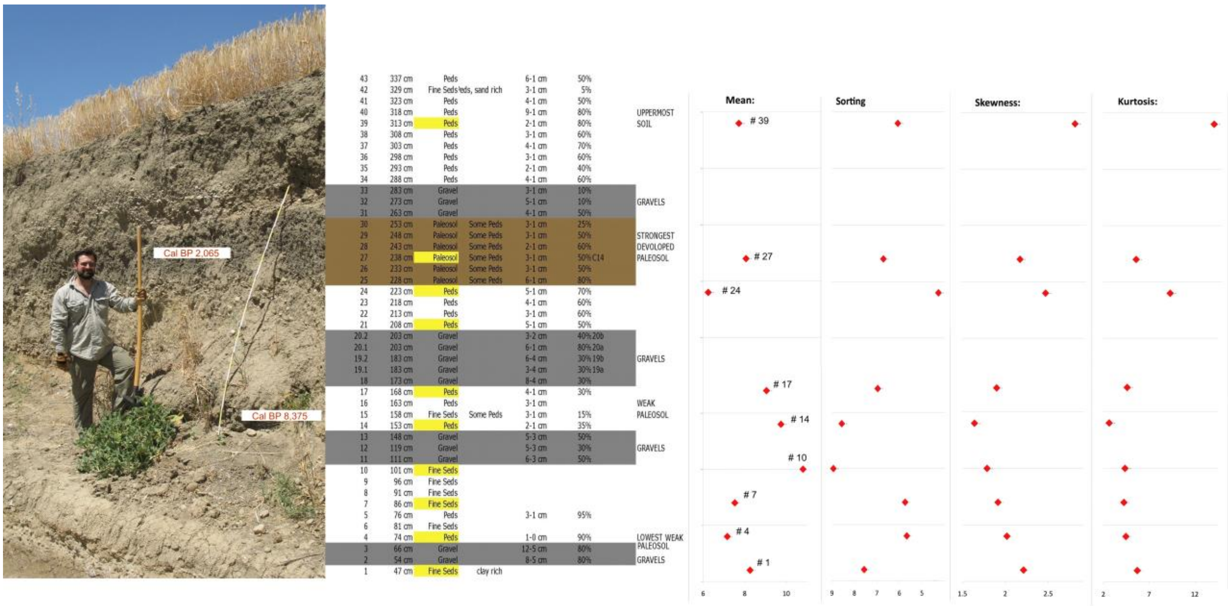
In the course of research being conducted to reconstruct the environmental context of a Roman age villa in the area west and south of Gravina in Puglia, southern Italy, a Holocene record of soils is being developed. Examination of a series of alluvial exposures and spring mounds are providing data for the reconstruction of a history of erosion, deposition, and soil formation.



These data are being coupled with dating of episodes of increased spring discharge to determine the potential relationships between climate, human activity, and geomorphic processes during the Holocene. Thus far, several exposures have been sampled, and initial analysis and dating provide a rough chronosequence of surficial processes spanning the last 9,400 years.

This record includes a sequence of at least three to four Holocene soils. A particularly strongly developed one coincides with the late Hellenistic through early Roman periods, and two earlier Holocene soils one centered about 8,400 cal B.P. The depositional record in which these soils are developed reflect a sequence of sediment erosion and deposition that overlies gleyed silty clays. At least three major cycles of erosion and deposition are represented. Alluvial cuts in the middle portions of drainages in the area are comprised of cycles that begin with cutting then infilling with gravels, followed by fining of the sediments upward. Soils are usually formed in the fine sediments at the top of each of these cycle. This research is ongoing, and will include the integration of pollen analysis as well. This provide additional information regarding the impact of both climate, and coupled with the archaeological record of the area, of human activity on the landscape as well.



Marine terraces and seismic cycle: case example of the Southern Apennine deformation front (Basilicate, Taranto gulf)

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Detailed tectonic analyses and geological mapping in muddy fold-belt front is a hard target. Using both fieldwork and GIS software associated to new soil datings of the different marine terrassic levels of the Taranto Gulf (Southern Italy), we were able to re-locate, characterize, quantify from an active tectonic point of view the deformation front of southern Apennines due to its obliquity to the numerous marine terraces.

By combining AGIP offshore seismic lines, and these structural, geological and datings with the known eustatic curve of the Mediterranean sea along the southern Italian shore, we were able to better understand the landscape evolution of that deformation front. Furthermore, we propose to differenciate the signal of both active tectonic uplift due to the differential shortening of the first overthrusting unit and "classical" eustatic processes and their related geomorphic features on the Taranto Gulf marine terrasses. Therefore the observed seismic cycle of the Southern Apenine deformation front is revealed and appear to be coherent with both a regular interseismic linear creep period (time = 251 ka/uplift=71m) and a rapid coseismic uplift (time :10Ka/uplift = 42m). This gives us new major inputs to better understand the neotectonic activity of the deformation front of Southern Apennine (Southern Italy).

Transition from arid to hyper-arid environment in the southern Levant deserts as recorded by early Pleistocene cummulic Aridisols

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The time at which deserts established their current arid or hyper-arid conditions remains a fundamental question regarding the history of Earth. Cosmogenic isotope exposure ages of desert pavement and welded, calcice-gypsice-salic Reg soils that developed on relatively flat alluvial surfaces ∼2 Ma ago in the Negev Desert indicate long geomorphic stability under extremely dry conditions. Over a short interval during their initial stage of development between 1-2 Ma, these cumulative soils are characterized by calcic soils reaching maximum stage III of carbonate morphology. This interval is the only period when calcic soil horizons formed on stable abandoned alluvial surfaces in the southern Negev Desert. Since ∼1 Ma pedogenesis changed toward more arid soil environment and the formation of gypsice-salic soil horizons that were later followed by dust accumulation. The dichotomy of only moderately-developed calcic soil (stages II-III) during a relatively long time interval (10^5-10^6 years) indicates an arid environment that does not support continuous development but only occasional calcic soil formation. The very low $\delta^{18}O$ and relatively high $\delta^{13}C$ values of these early pedogenic carbonates support soil formation under arid climatic conditions. Such an environment was probably characterized by rare and relatively longer duration rainstorms which occasionally allowed deeper infiltration of rainwater and longer retention of soil moisture. This, in turn enabled the growth of sparse vegetation that enhanced deposition of pedogenic carbonate. At ∼1 Ma these rare events of slightly wetter conditions ceased and less atmospheric moisture reached the southern Negev Desert leading to deposition of soluble salts and dust deposited in the soils. The combination of long-term hyperaridity, scarcity of vegetation and lack of bioturbation, salts cementation, dust accumulation and tight desert pavement cover, has protected the surfaces from erosion forming one of the most remarkably stable landscapes on Earth, a landscape that essentially has not eroded, but accumulated salt and dust for more than 10^6 yr.

Evidence for estimating rates of pedogenic processes in Mediterranean soils

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Dust was intensively accumulated on the land surface of the Levant during the last glacial maximum (LGM, 23-19 ka), leaving massive loess deposits on the desert edge and supplying much of the fine parent material to Mediterranean soils further north. Much or most of the LGM mountainous soils' material has been eroded and deposited in local depressions or at base-level basins. This is evidenced by the Fazael Fm. that was sedimented upon the late Pleistocene lacustrine Lisan Fm. north of the Dead Sea (Stein et al., 2010). Its unique red color is due to reworked terra rossa soils that were eroded during the Holocene (probably the Holocene climate optimum) from the mountain ranges on both sides of the Dead Sea Rift. Remains of brown soils (oldest OSL age 15 ka), preserved only at the bottom of archeological terraces of late Roman times and younger, were found on a bare slope of a Judean hill, indicating complete erosion of this Pleistocene brown soil (Davidovich et al., 2012). Therefore, the age of active mountainous soils could not be more than about 5 ka. As dust has been continuously added to soils, though to a lesser extent since then, it is surprising that horizonation in terra rossa, a typical Mediterranean soil, is hardly recognized, neither in grain size, nor in chemical and mineralogical composition. Yet, the CaO content in various leached Mediterranean soils is 3 to 8 fold lower than in dust and clay assemblages, which reflect variable local environments, markedly differ from dust (Sandler, 2013). All this evidence suggests pedogenic modifications in parent material to be rather rapid. How rapid are they? As numerical dating of such soils is apparently absent the answer to this question is yet unresolved. However, changes observed in clay minerals due to modern cultivation of similar soils and of short known duration might shed light on this issue. In a sandy vertic soil in central Israel increased fertilization regime induced a slight decrease in illitization parameters after 30 years of crop rotation. It seemed that increased fertilization caused enhanced plant growth that led to potassium consumption beyond supply. An opposite trend was observed in a banana-planted stony colluvial soil (50 years) where potassium has been heavily added. Though clayey soils are less liable than sandy soils to mineralogical modifications, verstisols in northern Israel displayed obvious changes from one season to the other: smectite formed during the rainy season at one site, whereas at another site illitization accompanied palygorskite formation. Significant changes in clay mineralogy were recognized in a tomato-planted sandy soil (>85% quartz) in the central coastal plain of Israel, attributed to high permeability and to low soil reactivity. Both kaolinite and illitic phases increased, at the expense of IS phases, within 50 years of cultivation. Consequently, if the rates of changes in clay mineralogy in natural (fallow) soils are 1 order or 2 orders slower, then anticipated rates of pedogenic clay modifications might be hundreds to a few thousands of years. Associated processes as carbonate dissolution and leaching and iron-oxyhydroxides formation should have comparable rates.

Morphology of soils chronosequence on Mount Cameroon (Central Africa): evidence of soil deepen and differentiation with age

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Mount Cameroon is located in the Gulf of Guinea at the South West Region of Cameroon, between latitudes 3°57' to 4°27'N and longitudes 8°58' to 9 °24'E, with the main peak at 4°7'N and 9°10'E. It belongs to the Cameroon Volcanic Line, a chain which has been active for at least 65 Ma. Mount Cameroon is considered to be one of the most active volcanoes in Africa; its volcanic activity started 11 Ma ago in the Upper Miocene and continues today. Within the past 100 years it has erupted eight times (1909, 1922, 1925, 1954, 1959, 1982, 1999 and 2000). The climate of the area is a humid tropical type characterized by extreme rainfall and elevated temperatures all year long. However, climatic conditions are not uniform on the volcano: The highest rainfall is recorded on the southwest flank of Mount Cameroon where precipitation can reach 12 m/year. Lower rainfalls occur on the opposite flank because this region is partially sheltered from the oceanic influence (1800 mm/year). The combination of high relief (4095 m) and proximity of the sea leads to strong local climatic contrasts. Mean annual temperatures decrease from 26 to 29 °C at sea level to 0 °C at the top of the mountain. Thus, Mount Cameroon is an ideal target to study soils chronosequence because it is made up of lavas of different age which have a rather uniform chemical composition (basaltic composition). Field descriptions were carried out on 20th century and Holocene lava flows in view to investigate morphology of soils chronosequence. Soil horizon characteristics described include depth, color, texture, structure, consistence, horizon boundaries, and special features such as mottling. Soils developed on the 20th century and Holocene lava flow volcanic formations exhibit a diversity of characteristics.

The 2000 lava flow was observed high on the flank of Mount Cameroon. It is unweathered and its scoriaceous upper part is covered by moss. So, no soil horizon is observed. The soil developed on 1959 lava flow was observed near Ekona on the northeast flank of the volcano at an altitude of 485 m. Here, the vegetation consists mainly of shrubs, ferns, orchids, mosses and lichens. Two horizons have been identified: (1) A surface horizon (A horizon) with 25 cm tick, dark grey, made up of very abundant millimeter-size roots forming rootsheet, associated to numerous millimeter to centimeter-size fragments of volcanic rocks; (2) a 25 cm thick subsurface horizon, grey brownish, sandy, with millimeter-sized lapilli and ash.

The 1922 lava flow is located on the western flank of the volcano at sea level near Bibundi, the site with the highest rainfall. Here soils are cover by shrubs and herbaceous vegetation. The soil profile is weakly differentiated and made up of two horizons: (1) a 5-10 cm thick organomineral (Ah), dark grey to dark brown, clayey silty to clayey, with relative abundant millimeter-size roots, associated to some centimeter-size fragments of volcanic rocks; (2) a 20 cm subsurface horizon (Bw), brown, clayey, with polyedric structure and few fragments of volcanic rocks. The soil developed on 1909 was observed high on the flank of Mount Cameroon, near the 2000 lava flow. The soil profile is made up of three horizons: (1) a 5 cm dark grey horizon silt clayey with millimeter-size roots, associated to some few fragments of rocks; (2) a 10 cm brown horizon, silt clayey, with millimeter-size roots and some few fragments of rocks; (3) a dark reddish brown, silt clayey, with millimeter-size roots and some few fragments of rocks.

The soil developed on the Holocene lava was observed in two localities: at Ekona, near the 1959 lava flow, and near Bibundi around the 1922 lava flow. At Ekona, the soil is well developed with a dark brown horizon (15 – 20 cm thick) and a thick (> 120 cm), yellow, clayey Bw horizon. Near Bibundi, the soil profile displays a thick dark brown organomineral horizon (25- 30 cm) and a thick (> 100 cm), brown yellow to yellow, clayey Bw, horizon, with some relics of volcanic rocks.

It appears that time, which is an important factor of soil formation, make it possible to distinguish, between soils formed from volcanic materials of different age on Mount Cameroon. Soils developed on the 20th century lava flow are less differentiated, and are characterized by their shallowness and the presence of stone, while that formed from Holocene lava flow are well differentiated and deep.

Ongoing study will allow characterizing in detail the Mt Cameroon soils chronosequence in view to understand their genesis and physicochemical properties along with involved mechanisms.

Late Quaternary palaeosols from South African coasts: pedogenesis and palaeoenvironmental interpretation

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We studied selected late Quaternary (<75 kya) palaeosols exposed at sea cliff and coastal barrier at Koeberg and Goukamma coasts of South Africa to improve our understanding of their pedogenesis and palaeoclimate dynamics. Palaeosol-based proxies explored include: elemental geochemistry by X-ray fluorescence spectrophotometry, $\delta^{13}C$ and $\delta^{18}O$ isotopes, micromorphology and clay mineralogy by x-ray diffraction. Selected physico-chemical soil properties were analyzed by routine laboratory procedures. The palaeosols were dominantly loamy sand to sandy clay loam in texture, had a high pH (>6.5), and very low electrical conductivity (<0.89 mS cm^{-1}). Silica and CaO are the most abundant of all the elements in the cambic and calcic horizons respectively. Low levels of Al in the parent materials invalidated the applicability of chemical weathering indices (CIA) to assess weathering intensity. In the case of chemical index of weathering (CIW), the age and sedimentary settings of the palaeosols overruled the possibility for K metasomatism and illitization by metamorphism. WI-1 and W1-2 of Darmody et al. (2005) seems more consistent with results. The palaeo MAT computed from palaeosol carbonate oxygen isotope is 22 and 18^{o}C for Koeberg and Goukamma respectively, while the MAP gotten from the cambic horizon of Goukamma coastal barrier is 230 mm yr^{-1}. The layering seen in the thin section of the calcic layer at Goukamma indicates deposition of possibly by sedimentary differentiation across a palaeo slope. Calcite and muscovite mica are the clay minerals in these palaeosols indicating a semi (arid) palaeoenvironments and impeded chemical weathering. The palaeosols qualify as aridisols; with pedogenesis being greatly constrained by active coastal erosion and low precipitation. We conclude that along the southern South Africa coasts, palaeosol based approach to palaeoenvironmental and palaeoclimate reconstruction in combination with other proxies such as pollens and marine based isotopes would continue to provide a high spatio-temporal insight into the environmental oscillations.

Key words: geochemistry, palaeosols, palaeoenvironments, Quaternary, weathering

Soil chronosequences in Alpine areas: possibilities and limitations for deriving reaction rates

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High-mountain soils develop in particularly sensitive environments. Consequently, deciphering and predicting what drives the rates of soil formation and the development of life in such environments is a major challenge. Natural chemical weathering can usually not be reproduced by experimental studies due to the time over which the weathering occurs. Chronosequences have greatly advanced our understanding of short- to long-term soil and landscape processes. They are useful for estimating field weathering rates (element depletion rates), mineral formation or transformation rates, disposition rates of nutrients, sequestration rates of carbon and nitrogen and soil biological processes. Alpine areas are particularly useful for studying these processes, because they usually have low human impact and formerly glaciated areas offer well-defined time sequences and make ideal natural field laboratories. Soil formation rates in high-mountain areas (alpine climate) range from very low to extremely high values and show a clear decreasing tendency with time. Very young soils have development rates 3 – 4 orders of magnitude higher than old soils (10^5 to 10^6 years). Time seems to be a very dominant soil-forming factor.

Despite these apparent advantages, criticisms have accompanied the chronosequence approach from the beginning, including that, i.e., soils may be of polygenetic or ‘nonfunctional’ nature. Alpine soils exhibit, furthermore, properties (e.g. rock fragments) that complicate their investigation. Additionally, chronosequences are often incomplete in Alpine areas and only little data is available to derive trends (e.g., for the period 2 – 8 ky BP when studying Holocene sequences). Environmental settings may easily have changed (depending on the duration of the observations): some soils may show progressive and regressive development stages (due to varying climatic conditions or hillslope processes) and the question remains how time-split rates can be determined. The usage of unstable isotopes with differing decay rates could be a valuable alternative or additional method to chronosequences.

Rates of humus rejuvenation and real age of soils: the problem and its particular solution using ^{14}C data set for soils and sediments in an intermountain basin, South Siberia

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Soil chronosequence studies aimed at estimation and comparison of rates of the processes in defined conditions course a lot of methodological and interpretative problems. In the proposal of RAISIN project paleosols are mentioned as "chronometers", that implies the bodies capable to measure time. The questions of the key importance for studies of rates of soil processes: how to estimate the time spans? It seems we know the ways, but it often appears we do not know it in enough detatails. ^{14}C analysis is the most important method used to date paleosols. At the same time estimations of possible age of soil formation (rates of soil-forming processes) based on ^{14}C dates of soil humus is a complicated problem. Any soil while exposed (so to say "alive") is an open system where organic material accumulates and is renewed continuously during its lifetime. The information on specific ^{14}C activity in humus allows usually to infer that a certain soil is not younger than the obtained date. Actually the calibrated ^{14}C age obtained from a bulk sample of buried horizon is made up of an "own age" of soil humus depending on rates of humus rejuvenation before its burial and the time passed after the burial. Furthermore rates of humus rejuvenation are depth- and environmentally-dependant (depend on a type of soil formation dictated by the environmental conditions). Age of soil humus in contemporary surface soils according to limited estimations available now may vary between first hundreds and 5-8 thousands of years (Chichagova, 1985; Alexandrovskiy, Chichagova, 1998). The problem of rejuvenation rates is not that significant for Pleistocene paleopedology and totally negligible for Prequarternary paleosols, but it is of a great importance for Holocene paleopedology and evolutionary pedology dealing with more or less short-term climate fluctuations and evolutionary trends.

We try to contribute the problem of ^{14}C dating and rejuvenation of soil humus reporting our experience in analyzing a set of radiocarbon dates obtained for surface and buried soils and sediments in a small intermountain Terekhol'skaya basin, Tyva republic, South of Siberia (51ºN., 97ºE., about 1300 m a.s.l.). Our database includes in total about 160 ^{14}C dates, 60 of them were obtained from surface and buried soil humus horizons. Following palaeo-archives which cover about 13000 yrs. were studied there: lake sediments in bottom cores and on palsa-islands, soils of palsa-islands, palesol-sedimentary sequences including on delta-alluvial fan of a small river, surface and buried soils of a lake terraces.

We were lucky to discover Late Holocene surface soils with a known date of exposure (the beginning of soil formation) in one of palsa-islands of the Terekhol' Lake. There were soils developed on lacustrine sediments exposed by a quarry on the area of early medieval archaeological site. The quarry is related to the time of the archaeological site functioning. Basing both on historical and archaeological context and wiggle-match ^{14}C dating archaeological wood we know that the sediments in the quarry were exposed between 1160 – 1180 cal yrs. BP. Two radiocarbon dates were obtained from the subface of humus horizons of these soils. Basing on this set of data a rejuvenation coefficient was calculated for the soils of the locality. Then the age of surface soils on islands was estimated from their radiocarbon dates and calculated rejuvenation coefficient. The calculated age of these soils (and islands themselves) appeared to be in a good correspondence with their age based on a biostratigraphical correlation between a well dated underwater column of sediments and columns of lacustrine sediments on the islands.

Bulk samples, samples from the subface of humus horizons, samples of the top 2 cm of the A and Ab hor. and cryogenic humus wedges were dated in surface and buried soils. The radiocarbon dates from the top of Ab hor. allow approaching the date of their burial. The dates from bulk samples appeared to be acceptable only if the horizon is thin and supposedly existed for a short time. Dating of wedges allowed to get some conclusions on cryogenic phases of soil development. A correction for lifetime rejuvenation of soils buried in mid Holocene was done. As a result the age of these soils was estimated as a whole Holocene.

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Modeling evolution of weathering indices with SoilGen: preliminary results and perspectives

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Weathering indices are a useful tool to quantify the degree of soil evolution and, when applied onto chronosequences, to estimate changes in rates of weathering through time. So far, most weathering indices are calculated using soil analytical data. We think that calculating them using the simulated elemental composition of soils over time will help to answer questions like (i) are the weathering-related processes in the model defined adequately; (ii) are past and present fluxes at the model boundary sufficiently known; (iii) how will future environmental change affect weathering. Additionally, modeling weathering indices opens a store of literature for comparison of model results to data.

The SoilGen-model was extended with functionality to calculate a number of weathering indices compatible to the currently represented chemical system. SoilGen simulates the release of Ca, Mg, K, Na and Al from a simple system of primary minerals (Anorthite, Chlorite, Microcline and Albite respectively) by a first order process, where the rate constant is modified by a function of soil pH and Al is assumed to be released in an amount according to the stoichiometric composition of these minerals and the release rate of the 4 cations. Released elements enter the soil solution, where they can be transported, adsorbed to clay and organic matter, taken up by plants and precipitate to either calcite, gypsum or gibbsite. When taken up by plants, they will follow the C-cycle and become part of the organic pools identified by SoilGen. Given this simple biochemical system, the following weathering indices can be simulated: Chemical Index of Alteration (CIA, Nesbitt and Young, 1982), Chemical Index of Weathering (CIW, Harnois, 1988), Plagioclase Index of Alteration (PIA, Fedo et al., 1995), Chemical Proxy of Alteration (CPA, Buggle et al., 2011), Index B (Kronberg and Nesbitt, 1981) and Weathering Index (WI, Price et al., 1991).

We tested the evolution of simulated weathering indices for a toposequence in Belgian loess soils: a plateau position pedon and pedons on a North and South facing slope. These soils were characterized mineralogically and chemically as well. Time-depth diagrams of the weathering indices over 15000 years show a plausible development over time and depth, and also show a relation to the topographic position that was consistent to amount of percolation: The more intensive weathering occurred at the South facing slope, receiving more rain and solar radiation and the least intensive weathering at the North facing slope. The weathering indices indicated that the loess is highly depleted with mobile elements. As an example, simulated CIA-values are at such high level (94%) that the presence of kaolinite is indicated, which is in fact not the case. Thus, the simulated weathering is probably too strong or the initial pool size was underestimated. Confrontation of simulated weathering indices to those based on analytical data showed differences that were however not very large. Analytically derived CIA-values are slightly above 70%. We discuss the weathering as concluded from analytical data and XRD-analyses and compare to simulated and measured weathering indices. The results may indicate that: (i) the model needs to be calibrated in terms of the weathering parameters, (ii) boundary input fluxes of elements need to be better estimated along the timeline (e.g. aeolian dust additions or other forms of atmospheric deposition); (iii) the weathering and chemical system needs to be extended.

So far we have focused on extending the weathering and chemical system, so that it can deal with a more heterogeneous composition of primary minerals and includes more elements such as Fe and Si. We propose and discuss an extended description of weathering in the model that is based on more primary minerals, the role of the specific area of these minerals, and the effect of physical weathering on these specific areas over time.