Soil memory: Types of record, carriers, hierarchy and diversity

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ABSTRACT

The concept of palimpsest-wise soil memory and record is generally characterized in comparison with the book-wise memory and record of sedimentary rocks. Soil systems have a capacity for storing information about environmental factors and pedogenic processes that have been acting for a period of pedogenesis. The main mechanisms of soil memory and record formation are those sets of pedogenic processes that generate the solid phase products and features within the multiphase soil system. The main types of solid-phase carriers of soil memory and their spatial/temporal hierarchy within the soil system are briefly described. The phenomena of isomorphism and polymorphism of soil record carriers in regard to the pedogenic processes should be realized when we try to decode and understand the information stored in soil memory. Each specific type of climate could not be imprinted in only one type of pedon. When reading the record in the soil system under one type of climate, it is obligatory to account for the diversity of solid phase soil horizons and pedons induced by the diversity of parent materials (lithodiversity), topography (topodiversity), biota (biodiversity) and duration of pedogenesis (chronodiversity).

Key words: soil memory, solid phase carriers, isomorphism, polymorphism.

RESUMEN

El concepto de registro y memoria palimpséstica en suelos es generalmente caracterizado en comparación con la memoria y registro en forma de libro presente en rocas sedimentarias. Los sistemas de suelos tienen capacidad para almacenar información sobre los factores ambientales y los procesos que han estado actuando durante un periodo de pedogénesis. Los principales mecanismos de memoria del suelo y formación de registro son aquellos conjuntos de procesos pedogenéticos que generan los productos de fase sólida y los rasgos dentro del sistema de suelo multifásico. Se describen brevemente los principales tipos de portadores en fase sólida de la memoria del suelo y su jerarquía espacio-temporal. Los fenómenos de isomorfismo y polimorfismo de los portadores del registro del suelo, en relación con los procesos pedogenéticos, deben ser considerados cuando tratamos de descifrar y entender la información almacenada en la memoria del suelo. Cada tipo específico de clima podría no estar marcado o grabado en un solo tipo de pedón. Cuando se lee el registro en el sistema de suelo bajo un tipo de clima, es obligatorio tener en cuenta la diversidad de los horizontes de suelo de fase sólida y los pedones inducida por la diversidad de materiales parentales (litodiversidad), topografía (topodiversidad), biota (biodiversidad) y duración de la pedogénesis (cronodiversidad).

Palabras clave: memoria del suelo, portadores de fase sólida, isomorfismo, polimorfismo.

TYPES OF ENVIRONMENT RECORDING IN EARTH LAND SURFACE SYSTEMS

Soil memory is both: (i) a capacity of the complex multiphase soil system to record environmental phenomena through pedogenic processes acting *in situ* in each point of the land surface of the Earth, and (ii) a record itself of this environmental and process information on the resistant soil solid-phase carriers *in situ*.

There are three main fundamentally different pathways of recording of environmental and process information on the time-resistant and long-living solid carriers. The first one is a very specific way of recording in glaciers where the individual ice layers record regional and global climatic conditions, as well as chemical and dust composition of the atmosphere (Petit *et al.*, 1990). Records in glaciers have very high temporal resolution and follow exactly the seasonal and annual snow precipitation. But this way of recording is realized only in several very cold regions of the Earth (Antarctic, Arctic, and high-mountain glaciers).

The second pathway (Figure 1) is a well-known recording by the Earth sedimentary systems, both continental and marine. These systems reflect a much more complex set of environmental factors and processes: climatically, biologically and geologically controlled mobilization of solid particles and solutions from watersheds, their mechanical and geochemical transfer, and sedimentation, diagenesis and epigenesis of sediments (Strachov, 1963). Sedimentary records are very diverse: they could be biogenic (fossil plants, animal bones, phytoliths, spores and pollen, coal, humus, etc.), lithogenic (mineral grains, rock debris), or geochemical (salts, carbonates, Fe, Al, Si oxides precipitation). Sedimentary records are always formed in individual lithological layers stacked up in vertical sedimentary sequence, which reflects the temporal changes in environment and lithogenesis. Therefore, this type of record has high and exact time resolution and resembles a book-wise memory. At the same time, the sedimentary record always accumulates the environmental and process information of the specific catchment area (or an area of eolian transfer) and therefore memorizes the environment and geomorphic processes of some territory, but not of an individual site. So, sedimentary records have usually low space resolution because they are not on-site specific. They summarize the results of bioclimatic and geomorphic processes and factors, which are acting on some territory not only *in situ* but also laterally, along the land surface.

In contrast with sedimentary memory and record, soils and weathering mantles* have a quite different type of memory and record, which was proposed to be called soil memory (Targulian and Sokolov, 1978; Targulian and Goryachkin, 2001). Soil memory and soil record (Figure 1) are forming *in situ*, in each specific place of on site interactions of soil-forming factors in time. Solid carriers of soil memory can be developed from any kind of solid parent materials: igneous or sedimentary, natural or anthropogenic. Soil records are forming *in situ* within the body of parent material due to its gradual transformation by the interacting climatic, biotic, hydrological vertical and lateral fluxes and cycles (including the anthropogenic ones). Parent material changes, that resulted in new composition and/or arrangement of substances, could be perceived simultaneously as soil formation and as the soil recording of environment.

Due to *in-situ* formation of soil memory, in each 'point' of land surface it records very local, even 'point', combinations of environmental factors and pedogenic processes at the levels of small-area ecosystems, variations of microclimate, microrelief, parent rocks mosaics, etc. Therefore, soil memory has much more exact space resolution than sedimentary memory. On the other hand, soil record is forming usually in one volume and thickness of the parent materials and rocks having been penetrated *in situ* by atmo-hydro-biogenic forces, fluxes, and cycles. When these factors are changing in time, their records in soil are changing thereafter and are superimposing on the previous records in the same volume. Such superimposing can lead to different and complex combinations of older and newer records in the same soil volume and thickness: addition, juxtaposition, plexus, or obliteration of the features of each record.

Such sophistication of soil records leads, in the case of environmental evolution in time, to less exact time resolution of soil memory compared with sedimentary memory. In contrast with book-wise sedimentary memory and record, the soil memory and record could be called palimpsest-wise, which is a the term proposed for the geomorphic systems (Allaby and Allaby, 1990).

Sedimentary and soil records are the two main complementary ways of environmental records within the upper part of the land lithosphere. The first one occurrs both in terrestrial and marine environments, but only in areas of accretion; land areas without accretion do not have sedimentary memory. In such land areas, the main systems recording the interaction of climate and biota with lithosphere are the soil and weathering systems developing *in situ* (Martini and Chesworth, 1992). Moreover, soil records can be formed within the sedimentary rocks, being superimposed on the sedimentary memory as the memory of the latest existing environment events (epilithogenic pedogenesis). In several cases, the rates of slow terrestrial sedimentation are comparable to the rates of soil formation, and so called synlithogenic pedogenesis takes place. In such cases the processes of solid particle deposition are closely combined with the humification, weathering, leaching, and other pedogenic processes within the forming soil body (many alluvial soils, Fluvisols, and volcanic-ash soils, Andosols). More often in areas of terrestrial sedimentation, the stratigraphic lacunae are imprinted by soil and/or

* We consider the weathering mantle of all kinds of rocks as well as the soil to represent *in-situ* formed exogenic records on the land surface.

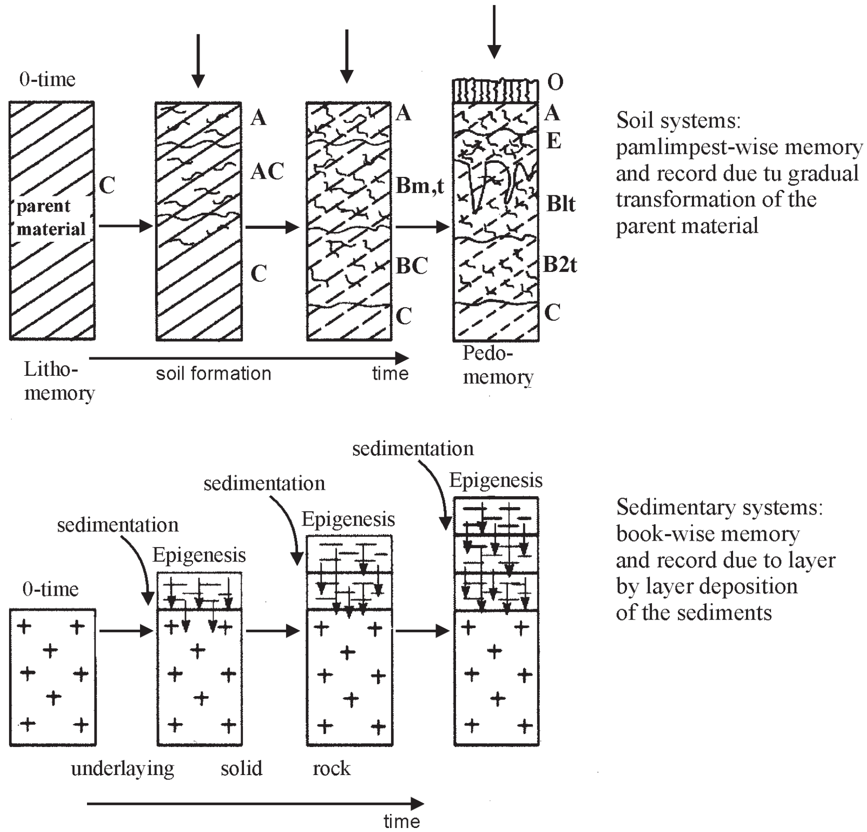

Figure 1. Formation of sedimentary (book-wise) and soil (palimsest-wise) memory.

weathering profiles that record the environment conditions during the break of sedimentation (loess-soil, tephra-soil sequences).

MECHANISMS OF SOIL MEMORY FORMATION

The essence of soil memory and record consists of the *in-situ* interaction of so called flux-factors (climate and biota) with the site factors of the land surface –parent rocks, both consolidated and unconsolidated–, in each given geomorphic position during time. Such *in-situ* exogenic atmo-hydro-bio-litho-interactions gradually transform the solid-phase substances of parent material by weathering, leaching, aggregation, etc., and create some new substances, which were absent in parent material (humus, peat, phytolites, clay minerals, etc).

The phenomenon of soil record was discovered by V.V. Dokuchaev and expressed in his bright and well-known slogan "soil is a mirror of landscape". Then the slogan was developed (Rode, 1947; Yaalon, 1970; Gerasimov, 1973; Jenny, 1994) into the main pedogenic triad formula "factors → processes → features" in which the resistant soil features could be understood as the carriers of soil memory created by pedogenic processes and reflecting the main environmental characteristics during the time of pedogenesis. Later, in the 1970s, Targulian and Sokolov, 1978 recognized that the expression "soil as a mirror of landscape" is not correct enough and a new one was proposed instead: "soil is an *in-situ* memory of landscape development in time". On the basis of the increased understanding of functioning, formation, and evolution of soil systems, the triad pedogenic formula was supplemented by one more link subdividing the term 'processes' into two parts: multiphase processes of soil functioning, and processes of formation and accumulation of solid-phase pedogenic features *in situ* (Targulian and Sokolova, 1996). This supplemented formula could be expressed as following: factors → processes of soil functioning → pedogenic processes → soil features. Factors in this formula mean atmo-hydro-bio-litho- cycles and fluxes interacting *in situ* with the parent material. Processes of soil functioning mean external and internal multiphase (gases, solutions, biota, and solids) exchange of matter and energy, *i.e.*, diurnal, seasonal and annual processes creating the solid-phase residual products within the soil body. Pedogenic processes mean formation, retention, accumulation, and differentiation of solid-phase residual products of soil functioning *in situ*, which change the parent material into an horizonated soil body and weathering mantle. Soil features mean a solid-phase horizonated soil body containing the set of resistant solid-phase macro- and microfeatures, which are recognized as the carriers of soil memory.

The additional element introduced in the classical triad formula is the soil functioning or soil life, according to A. Rode (1947). These terms usually represent almost innumerable multiplicity of current interacting processes among all components of the soil system: gases, solutions, macro-, meso-, and microbiota, and different solid particles of parent material. Some general characteristics are common and very important for soil life processes, which were called microprocesses by A. Rode. All these microprocesses are predominantly multiphase and consist of exchange of substances and energy among all components in the whole soil system. They are predominantly short-term and fast processes: diurnal, seasonal, annual. The majority of microprocesses look like regular or periodical cycles and fluxes; many of the cycles are not completely closed, as well as many fluxes are not balanced by inputs and outputs.

Such non-closed cycles and off-balanced fluxes of soil microprocesses generate some residual solid-phase products retained within the soil system. Solid residual products (SRP) could be biogenic or abiogenic, mineral or organic, and organo-mineral. Each single cycle and flux usually generates a micro amount of neo-formed or transformed solid product, which could hardly be detected in the enclosing parent material. But being produced regularly during the long-term soil life (tens, hundreds, thousands years and more) these micro amounts of SRP are gradually accumulated within the soil body in macro amounts of SRP that can be detected both morphologically and/or analytically as pedogenic solid-phase features.

The long-term processes of gradual intrasoil accumulation and differentiation of solid residual products finally form the assemblages of features and horizonation of a soil body. Such a set of processes is usually recognized by pedologists as pedogenesis: the holistic process, which transforms the parent material into a newly arranged and horizonated soil body. The whole pedogenesis is usually subdivided into the particular (or elementary, or specific) pedogenic processes according to the diversity of process-diagnostic solid-phase features: humification, clay formation, lessivage, podzolization, gleyzation, leaching, ferralitization, segregation, aggregation, etc. (Rode, 1971; Gerasimov, 1973; Buol *et al.*, 1973)

The solid-phase diagnostic features can have positive-accumulative character –neoformation of substances or pedality within a soil body (humus, clays, cutans, peds, concretions, etc.)–, or negative-depletion character – destruction of the substances and structures of parent material (decomposition of minerals, leaching of carbonates and salts, formation of porosity as a result of dissolution). In some soils and horizons we could not detect the distinct chemical or mineralogical changes but mainly the rearrangement of the physical structure (pedality) of parent material (some Regosols, Cambisols, Cryosols). It is important that in all cases we are able to detect some morpho-analytical phenomena in soil solid-phase composition and/or arrangement, which could be interpreted as a cumulative result of a given pedogenic process.

According to the main pedogenic formula (factors → functional processes → pedogenic processes → soil features), the whole set of the stable solid-phase soil features existing in each given soil is the result of a specific local combination of the particular pedogenic processes. These processes were generated by long-term soil functioning, which is, in turn, a result of temporal interaction of soil-forming factors.

On the basis of the fundamental paradigm of pedology, this four-links chain could be perceived as the pathway of information transfer from environmental factors toward solid pedogenic features of the soil system. These features are gradually storing and recording the information of environment, functioning, and pedogenesis in each given ‘point’ of the land surface written on the special ‘language’ of soil nano- and micro-molecules and minerals, soil aggregates and concretions, soil horizons, pedons, and soil cover patterns (Fridland, 1974; Sposito and Reginato, 1992; Kozlovskiy and Goryachkin, 1996, Sparks, 2002). Thus, all combinations of stable solid features hierarchically arranged in a soil body could be perceived as the carriers of soil memory, or pedomemory (Targulian and Sokolova, 1996).

In this sense, pedogenesis is not only one of the exogenic biogeochemical and mineralogical process on the land surface but at the same time, one of the most important and specific processes of pedorecording of bio-litho-anthroposphere interactions *in situ*. In turn, each particular pedogenic process could be considered as the particular recording mechanism producing the definite set of solid-phase features of soil memory. The essence of soil formation and evolution in time could be considered accordingly not only as an exogenic process of the transformation of parent materials into soils, but also as an informative process of compiling and retention of environmental information within the soil body –formation of a pedorecord.

While analyzing the problem of soil memory we need to take into account that the initial parent materials, including both consolidated rocks and unconsolidated sediments, are not the *tabula rasa* for pedogenesis. In each 0-time of soil formation, each parent material has its own lithomemory expressed in morphology, mineralogy, structure and texture that recorded the processes and milieu of its formation (Kuznetsov, 1993). Lithomemory of parent materials could be endogenic (effusive and intrusive rocks), or exogenic (sediments, weathering mantles), or even tectogenic. The features of lithomemory are completely inherited by the soil system at 0-time and then are gradually obliterated, transformed and/or substituted by the features of pedomemory during the pedogenesis (Figure 2a). Most existing soils have different combinations of inherited lithomemory and pedogenically newly formed memory (pedomemory). The ratio between litho- and pedomemory

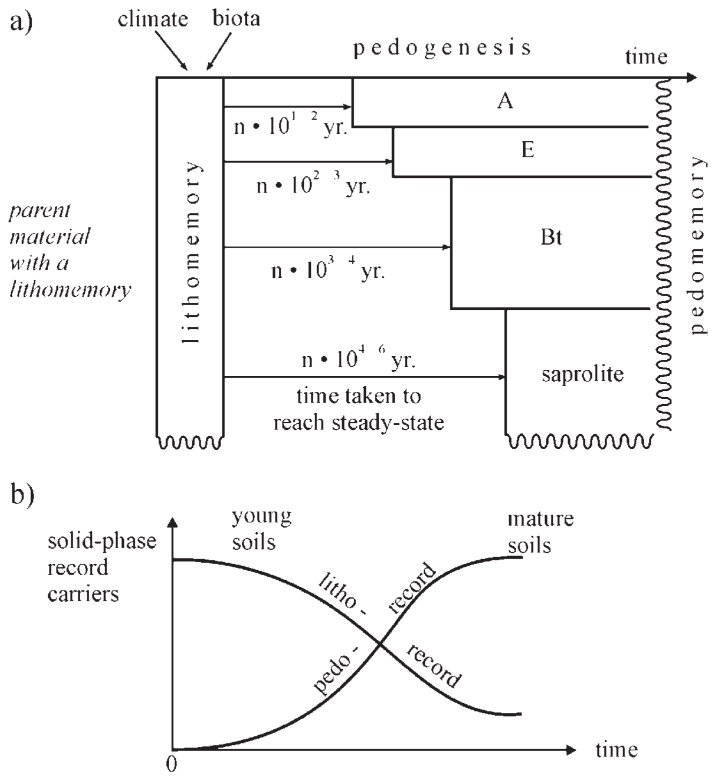

Figure 2. Interrelation between lithomemory and pedomemory. a) Generalized concept of characteristic times of pedogenesis; b) Change of lithomemory and pedomemory in time.

in soils generally depends on intensity and duration of soil formation and weathering, which is controlled by the pedogenic potential of climate and biota, transformation ability and recording capacity of parent materials, absolute age of soil, and duration of pedogenesis.

During pedogenesis, the proportion of lithomemory and pedomemory is gradually changing with the increase of pedomemory and decrease of lithomemory features (Figure 2b). The common rule is that lithorecords are essentially predominant in all young soils in any climate and vegetation conditions, in soils of cold and arid climates, and in soils developed on strongly resistant parent materials like quartz sands, kaolinite clays, pegmatites, etc. In the mature soils of humid, semi humid and semiarid temperate and boreal climates, the pedorecords are expressed perfectly well but some part of lithorecords are usually present. Only in the oldest, most mature soils and weathering mantles of humid tropics, pedorecords substantially predominate over lithorecords (*e.g.*, the quartz veins in kaolinitic saprolites derived from granites).

CARRIERS OF SOIL MEMORY: TYPES AND HIERARCHY

The carriers of pedomemory are very diverse and have not been tracked down and understood completely. Generally speaking, we assume that any pedogenic transformations and/or neoformations in solid-phase composition and organization of parent material constitute the records of pedogenic processes and of the environmental factors generating these processes. The carriers of pedomemory could be subdivided on the basis of different criteria. They could be mineral, organo-mineral and organic, biogenic or abiogenic, natural or anthropogenic. It is possible to distinguish the morphological, mineralogical, geochemical, textural and structural carriers of soil memory from the whole set of soil features.

Given the well-known complexity of soil as a three-dimensional system, the carriers of soil memory should be perceived in their spatial hierarchy. In this hierarchy, all levels of solid-phase substance organization in soil systems are included, from the molecular level through the crystal, ped, horizon and pedon levels up to soil cover levels (Voronin, 1986, Sposito and Reginato, 1992).

The lowest level is represented by individual amorphous compounds (organic molecules, chelates, allophanes, etc.) and individual crystal particles (silicates, oxides, carbonates, salts, etc,) from nano- up to macroscales. On this level, the chemical composition of organic molecules and chelates reflects the conditions of production and decomposition of biogenic substances and the reactions among organic and mineral compounds. The etching surfaces of mineral grains record the aggressiveness of intrasoil media; ultra-thin coatings on individual crystals record some micro-scale illuvial and/or transformation phenomena; the interaction of soil solutions with the phyllosilicates generate the diversity of pedogenic clay minerals.

The next level is the various intrapedal associations of clay plasma, individual clay and skeleton mineral particles, as well as organic and organo-mineral intrapedal neoformations. They record many transformations, eluvial and illuvial pedogenic processes conditioned by the climatic and biotic forces of the environment.

The next level is the soil pedality, which is very complex and can include a few orders of soil pedal organization by size and shape and their intrinsic combinations. At this level we usually find very important carriers of soil memory –the pedal cutans (coatings)– and clearly encounter the problem of possible strong differences between soil records within the internal masses of solid soil materials and on their interfaces (Kozlovsky and Goryachkin, 1996). The interfaces of any solid particle and ped (without reference to their size and shape) are permanently exposed to soil micro- or macro-porosity and therefore they are open for direct impact of gases, solutions, plant roots, microbiota, *i.e.*, the main driving forces of soil functioning and development. The internal masses of soil solid fragments (grains, peds, etc.) are partially defended from such direct influences, and accept them through and after interface interactions. Therefore the interface memory is more sensitive, more labile, more fast-forming, and less resistant than the memory of internal masses. These intrapedal masses are more inert to environmental factors; they reflect and record the pedogenic information much slower than interfaces but retain it much longer in the course of soil formation and evolution.

The next level of soil memory is the horizon level. In cases where soil horizons are very heterogeneous, like EBt horizons in Albeluvisols, soil memory can be subdivided into morphons – the homogeneous sectors of horizons. The horizon level of soil memory is very complex and, on one hand, it consists of the memory of all previous levels, but on the other hand, it has its own holistic informative sense. The existence of a definite diagnostic horizon (mollic, cambic, argic, cryic, ferralic, etc.) reflects a whole set of pedogenic processes forming this horizon and, accordingly, records a definite set of environmental conditions (soil forming factors) and sometimes also approximate duration of pedogenesis.

The level of pedon soil memory has several informative aspects. The presence of the developed *in-situ* soil body, as such, records that this parent material and this geomorphic surface have been exposed on a diurnal surface during some time without strong denudation and strong accretion. Moreover, the presence of a well horizonated, mature, thick soil body indicates a relatively long period (10^3 – 10^4 years or more) of denudation or accretion decline and stability of land surface under a mature plant cover. This aspect of pedon soil memory is very important while studying the present-day geomorphic and geological processes, and particularly when we study the stratigraphic sequence of sedimentation processes and meet the fossil soils, which indicate the halts and intermissions in sedimentation. Another aspect of pedon soil memory is the well-known regular combination of pedogenic diagnostic horizons compiling the classic major soil groups of the existing pedosphere: Chernozems, Podzols, Gleysols, Luvisols, Ferralsols, Solonchaks, Cambisols, etc. (Deckers *et al.*, 1998). The presence of such very typical soil pedons, either on the present-day surface or as a fossil paleosoil, definitely indicates some general climatic and biotic characteristics of environment: arid or humid, boreal or tropical climates, forests or grasslands.

The highest levels of soil memory are the levels of soil cover patterns in different scales: soil microcomplexes, soil catenas, mosaics, local and regional soil covers (Fridland, 1974). These levels of soil memory reflect and record spatial heterogeneity and diversity of soil forming factors (topography, parent materials, biota, macro- and microclimate) on the chosen territory at different scales.

Another complementary approach to understanding and decoding of soil records is the substantive approach based on different substantial composition of soil memory carriers: mineral, organic, metallo-organic (chelates). These carriers in turn could be subdivided in accordance with their genesis: lithogenic and pedogenic, abiogenic and biogenic (spores, pollen, seeds, phytoliths, etc.) (Golyeva, 2001).

On the basis of the different types and hierarchy levels of soil memory carriers, it is possible to distinguish mineralogical memory, organic or humus memory, ped and porosity memory, horizons and pedons memory, biotic (biomorphic) and abiotic memory, pedo- and litho-memory.

ISOMORPHISM AND POLYMORPHISM OF SOIL RECORD

When considering the problem of soil memory carriers and their record accuracy, we have to take into account the complicated phenomena of soil features polymorphism and isomorphism in regard to pedogenic processes and factors. This phenomenon appears in all hierarchical levels of soil memory, but the most crucially at the levels of mineral-ped-horizon-pedon.

The essence of isomorphism is that one specific feature of record carrier could be generated by more than one types of pedogenic processes and by more than one type of soil forming environment. One of the best examples of pedogenic isomorphism is the phenomena of bleaching of soil mineral materials, starting from bleached eluvial and/or gleyic soil horizons (E, G) down to the individual bleached and etched mineral particles. These phenomena could be generated by quite different processes and environments: acid hydrolysis and chelatization in boreal humid forest ecosystems, stagnic reduction of iron oxides in hydromorphic soils of quite varied environments (from humid to arid ones and from cold to hot ones), alkali hydrolysis and/or ferrolysis in arid and semiarid hydromorphic environments.

The essence of polymorphism is that one environment and one soil forming process can with time generate the successive range of different soil features that reflect and record different stages of pedogenesis under the common and stable environment. A good example of pedogenic polymorphism is the development of true podzolization in boreal mountain podzols derived from granites. In the first stages, this process generates the brown colored illuvial Al-Fe-humus (spodic) horizons (Bhs) within the surface mineral horizon just under the litter. Accordingly, all the skeleton particles in such horizons are covered by amorphous Al-Fe-humus cutans. But during soil development, the continuous eluvial chelatization bleaches the surface mineral horizons and forms a strongly bleached and weathered eluvial horizon E without cutans on the skeleton, whereas the Bhs horizons sink deeper into the pedon (Targulian, 1971).

Taking into account the possible poly- or-isomorphism of the soil records we need to be very cautious when we attempt to decode the pedomemory and to reconstruct the pedogenic and environmental processes and events. As in many other 'reconstructive sciences', like geology, paleontology, and paleogeography, it is much better to avoid the use of only single or selected memory carriers to make such reconstructions; it is more effective to use the whole available set of carriers on all hierarchical levels of soil memory (Kozlovskiy and Goryachkin, 1996). The resulting working hypothesis of environment reconstruction should explain the complete combinations of soil record in macro-meso- and microscales.

DIVERSITY OF SOIL MEMORY AND RECORD IN REGARD TO CLIMATE

For a long time, the cherished idea of pedologists and paleopedologists was that each specific type of climate was imprinted in one type of pedon. From the 1920s through the 1950s, this idea was reflected in the concept of so-called 'zonal soil type'. The concept was developed for the soils of great plains of Eastern Europe and North America that are rather homogeneous with regard to parent materials, topography, and age. But when the world soil mapping was expanded into tropical, mountain, and volcanic regions with strong differences in geology, relief, and duration of pedogenesis, it became clear that the zonal soil type concept could not describe adequately the real diversity of the soils derived under one type of climate.

Taking into account the existing world experience in soil genesis and geography it is possible to conclude that each individual type of climate is reflected in the whole spectrum of soil pedons according to the following rules (Figure 3):

Soil lithodiversity. Different soil pedons are formed within contrasting parent rocks and materials: granites and basalts, clays and sands. In boreal humid forest landscapes, the Podzols form on granites and sands, the Cambisols on basalts, the Albeluvisols on silt loams, and the Gleysols on heavy clays.

Soil topodiversity. Different soil pedons are developed at different topographic positions: well-known soil catenas from uplands to the depressions –xeromorphic, mesomorphic, and hydromorphic conditions of pedogenesis.

Soil chronodiversity. Different soil pedons and weathering mantles (deeper than 2 m control sections) are developed on the geomorphic surfaces and within the parent

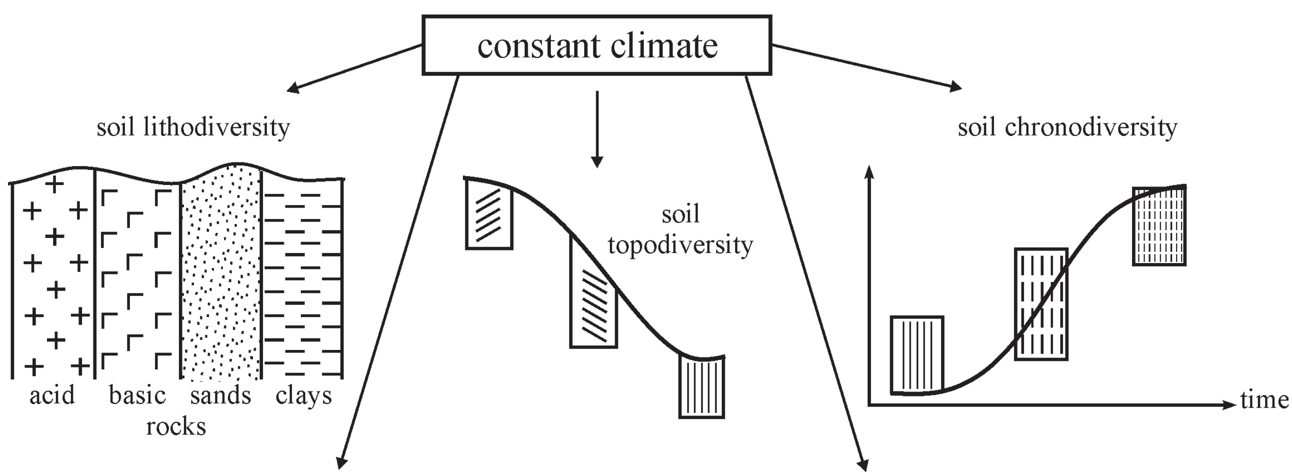

Figure 3. Inevitable diversity of soil formation and soil records in one type of climate.

materials of different absolute age: weakly differentiated soils (Regosols, Leptisols, Cambisols) with ages in the range of about n x 10^1 – 10^3 years; clearly differentiated soils (Podzols, Albeluvisols, Chernozems) with ages of about n x 10^3 – 10^4 years; deep and strongly weathered soils mainly in tropics (Ferralsols, Acrisols, Nitosols) with ages of about n x 10^4 – 10^6 years.

Soil biodiversity. Different soil pedons are formed within a similar abiotic environment (climate, parent material, topography, age) but under different plant cover: Phaozems and Chernozems under grasslands, and Luvisols and Albeluvisols under forests in the forest–steppe zone of the Russian plain.

All these types of soil diversity in regard to the climate should be obligatory taken into account in many cases of climate reconstruction, which are very actual in the study of current climate and/or paleoclimates evolution.

CONCLUSIONS

1) Soil memory is both: (i) a capacity of a soil system to record the environmental phenomena and pedogenic processes acting *in situ* on the land surface, and (ii) the record itself of this environmental and process information on the resistant soil solid-phase carriers.

2) Soil memory is a palimpsest-like pathway of environmental recording, which is complementary to the book-like sedimentary memory; soil records have more exact space resolution, but less exact time resolution than sedimentary ones.

3) Pedogenesis can be regarded not only as the biogeochemical and mineralogical process on the land surface, but also as the process of recording of environmental information *in situ* within the soil solid-phase body.

4) Soils contain different hierarchical levels (molecule, ped, horizon, pedon, soil cover, etc.) and different types (mineral, organic, biomorphic) of carriers of soil memory, thus various methods should be used to extract the information they store.

5) Isomorphism and polymorphism are crucial points in deciphering the record in soil systems. The essence of isomorphism is that one specific record feature could be generated by more than one type of soil forming environment. The essence of polymorphism is that one environment can result in the successive set of different soil features that record different stages of pedogenesis under common and stable environments.

6) The diversity of soils under the same climatic conditions induced by rocks, topography, biota and age should be taken into account while 'reading' the record in soil systems.

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