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Time factor in soils of Georgia-mirror or memory of landscapes?

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Abstract

The geographic pattern of soils in mountainous region of Georgia is presented. Time is considered as one of the most important factors of soil formation in mountain areas. The age of soil cover in the areas above 1000-1200 m a.s.l. is less than 10,000-12,000 yr b.p. These soils are considered as young component of landscape. In the landscapes below this level soils do not correspond to modern ecological conditions. We can confirm that in Georgia higher than 1000-1200 m asl soils correspond to ecological conditions and they are mirror of landscapes, as one of the most important postulates of soil science. In other case, we can talk about soils memory-distorted mirror of landscapes. For diagnosing of relic features (pedogenic and lithogenic) in soils of Georgia the micromorphological method is used. The majority of landscapes in Georgia are heavily used for agriculture and suffer from high instability. These landscapes are very fragile today, characterized by high soil erosion and strong pollution with heavy metals and radionuclides.

Key words

Mirror of landscapes, Memory of landscapes, Soil age, Micropedology, Soils of Georgia

Introduction

Time is important factor of soil formation. Soil as every natural-historic body has a certain age. In soil science there is a fair chrestomatic opinion that "soil is mirror of land-scape", which reflects modern environmental parameters. But soil profiles aren't always adequate to modern conditions of soil formation and do not reflect present landscape. Sometimes they keep features of previous stages of development, and in this way reflect former landscape parameters. Such soils are not only the "mirror of land-scape", but also a "memory of landscape", which preserve relict properties and may be used for paleogeographic reconstructions (Targulyan, 2008). Evolution of soils takes place with evolution of landscapes, but those properties that formed in soil in previous conditions do not disappear completely, but are inherited and preserved for a certain period of time.

Soils are subdivided as monogenetic and polygenetic. Monogenetic soils formed in a period when the variation in environmental factors was too small, *i.e.* the direction of soil development was constant; polygenetic soil formed in two or more periods when the environmental factors were sufficiently different to produce detectably different assemblages of soil features, *i.e.* the directions of soil development were different in the periods involved (Paleopedology glossary).

Relic features in soils (buried horizons or separate relic features within soil profiles) are the base for paleogeographic reconstructions. Relict soil features may result due to changes of hydrological regime, climatic variations, *etc.* Buried soils provide an opportunity to restore past environments. Buried soils are wide spread, where changes in sedimentation took place. Such changes could be due tectonic activities, glaciations *etc.*

In the history of the Earth the changes of soil cover, burying of the old and formation of the new pedospheres on the new sediments or on the remains of old soils permanently took place. In the evaluation of modern soils it is necessary to distinguish some of the problems: age of soil cover, age of certain profile, age of soil horizon (Karpachevky, 1997).

Soils possess three categories of properties: lithogenic (inherited from parent rock), relic soil features (inherited from previous pedogenesis) and modern soil features (formed under the influence of modern environment (Targulyan and Sokolov, 1976; Makeev, 2002). If soil thickness has same age, it means that horizons are syngenetic, formed together at the same time, but if the age of layers is different soils are polygenetic. Traditionally paleosols are regarded as good records of paleoecological and paleoclimatic changes (Makeev, 2009).

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Micromorphology proved to be an informative tool in separating modern and relic features in soils. We applied it for various soils of Georgia and this paper presents our results of micromorpholigical studies.

Materials and Methods

The following soils have been studied in flat and foothill regions of the Western and Southern Georgia (Fig. 1): main soils type of humid (red, yellow and subtropical podzols) and dry subtropics (black, cinnamonic soils).

Georgia, the country in the Mountainous Caucasus, borders with Russia, Azerbaijan, Armenia and Turkey. From the west it is washed by the Black Sea. Its 69,400 km^2 soil landscape is extremely variable and includes almost all major soil types of the world. This fact inspired Dokuchaev to say that Georgia was "a museum of soils in the open air" (Urushadze, 1997).

Georgia is represented with spread spectrum of soil types, from bog soils of lowlands of humid subtropics of West Georgia to meadow-grey-cinnamonic and salt sols of dry subtropics of East Georgia, including foothills, mountain-forest, and mountain-meadow regions of country with corresponding soil types. Mixed geological structure, specific relief, contrasting climatic conditions, biodiversity and other soil forming factors determine complicated character of soil cover of Georgia and originality of geographic distribution of soils. Some climate data for all groups of described soils of Georgia are given in Table 1.

Among all the components of landscapes-soil distinguished by the greatest diversity. According to the conditions of soil formation, each genetic type distinguishes a number of soil subtypes, forms, families and characterized by certain specificity.

In the post soviet region Georgia was the only republic where subtropical soil land-scapes, suitable for subtropical crops, were widespread, accounting for the heightened interest of soil scientists in its soils. Practically all leading soil scientists contributed to their studies, beginning with the Report of the Dokuchaev Transcaucasion Statistical Committee in 1899. The "law of vertical soil zonality" was based on these studies in the Caucasus mountains.

Subsequently the Red and Yellow and other subtropical soils were studied by many scientists. Zakharov (1924) first described the soil that became known as the calcareous Cinnamonic soils of the drier subtropics; several subtypes are now recognized. According to the 1: 500 000 soil map, the Brown forest soils (with an illuvial Bt horizon) are dominant soil types.

In Western Georgia, humid subtropics, Red (Nitisols Ferralic), Yellow (Acrisols Haplic), Subtropical Podzolic (Luvisols Albic), Yellow-Brown Acrisols Haplic) and Bog (Gleysols) soils are distributed. Red (Nitisols Ferralic), Yellow (Acrisols Haplic), Subtropical Podzols (Luvisols Albic) are typical soils of this region. Yellow-Brown (Acrisols Haplic) soils are very near to Yellow (Acrisols Haplic) soils and are investigated together. Bog (Gleysols) soils due to their specific character cannot be investigated as a paleo geographical object. Most interesting are Red (Nitisols Ferralic), Yellow (Acrisols Haplic), Subtropical Podzolic Soils (Luvisols Albic).

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Morphological and micromorphological studies were supported by traditional chemical analyses by conventional methods. The soils were classified according to World reference base for soil resources (WRB for Soil Resources, 2006). Conformity of soils nomenclature with WRB is given according to soil map, 1: 500 000 (Soil Map of Georgia, 1999).

Results and Discussion

Total area of Red soils (Nitisols Ferralic) makes 130,400 ha (1.9%). They have red color and deep profile: A-AB-B-BC-C. These soils are distributed in south-western part of West Georgia on the surfaces with elevations of 300-400 m above sea level.

According to World reference base for soil resources (2006), Nitisols are deep, well-drained, red, tropical soils with diffuse horizon boundaries and a subsurface horizon with more than 30% of clay and moderate to strong angular blocky structure with elements that easily fall apart into characteristic shiny, polyphedric elements. These soils are a classic example of typical tropic soils in subtropics.

Red soils (Nitisols Ferralic) are characterized by high clay content in middle and bottom part of soil profile, acid reaction, high to moderate amount of humus with the predominance of fulvic acids. Cation exchange capacity is low to moderate, with predominance of hydrogen in exchanged cations, as a rule. Texture heavy loam, clay and heavy clay. Soils are poor in silica and bases and enriched by sesquioxides. Clay minerals are presented by kaolinite, halluazite, hetite and gibbsite. Silicate iron dominates over non-silicate iron. Different forms of iron are distributed in soil profile more or less equally. Main soil formation processes of Red Nutisols Ferralic soils are ferallitization, kaolinization (clay sation) and humus accumulation (Urushadze, 1997). Deep ferralitic weathering, characteristic for Georgian red soils (Nitisols Ferralic) cannot be explained by modern ecological conditions (relief, climate data and vegetation). Properties of the Ferralic Nitisols are influenced by parent rocks (red color of ancient weathering crust).

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Table - 1: Some climate data of investigated soils area

No.	Meteorological station (m) above sea level	Precipitation (mm)	Relative humidity (%)	Temperature per year (°C) Average	Minimum Average	Minimum Absolute	Maximum Average	Maximum Absolute	Period without frost (days)
				Red soils – 0-100(300) m above sea level					
1	Batumi, 2	2685	79	14.3	11.0	-5	18.6	41	233
2	Kobuketi, 7	2514	81	13.4	8.9	-8	18.1	41	246
3	Lanchkhuti, 20	1980	78	13.8	9.4	-9	19.2	39	255
4	Anaseuli, 158	2115	76		9.8	-6	18.8	40	277
				Yellow soils – 0-400(600) m above sea level					
5	Gagra, 2	1340	76	14.1	9.9	-13	18.3	42	273
6	Gali, 63	1569	79	13.7	9.2	-18	19.6	40	250
7	Kutaisi, 114	1380	70	14.5	10.4	-17	19.6	42	288
				Subtropical podzols – 30-200 m above sea level					
8	Ajameti, 107	1380	71	14.1	-8	-20	19.5	42	261
9	Zugdidi, 117	1616	76	13.8	-7	-19	19.2	40	196
				Yellow-brown forest – 400(500)-800(1000) m above sea level					
10	Tzageri, 474	1235	78	11.4	6.2	-26	18.1	41	209
11	Tkibuli, 593	1890	72	12.2	7.7	-27	17.3	38	180
				Brown forest – 800(1000)-1800(2000) m above sea level					
12	Tianeti, 1099	795	78	7.5	2.4	-34	14.0	36	143
13	Abastumani, 1265	648	77	6.4	0.8	-32	13.6	37	137
14	Avadkhara, 1650	2185	81	3.5	-1.2	-30	11.5	33	124
15	Bakuriani, 1660	839	77	4.3	0.2	-31	10.3	31	118
				Mountain-meadow – 1800(2000)-3200 (3500) m above sea level					
16	Bakhmaro, 1926	1602	73	4.0	-0.2	-30	8.8	31	124
17	Gudauri, 2000	1452	74	3.3	-1.5	-33	6.6	27	120
18	Cross Pass, 2395	1503	81	-0.2	-4.1	-38	4.1	27	93

According to our previous research (Matchavariani, 2008), Red soils (Nitisols Ferralic) are characterized by compact micro fabric, dustplasma elementary micro structure, crackle pores, enrichment of iron and high clay content, optical orientation fabric of plasma with high birefringence and fibrous structure, presence of small iron segregations in surface horizons, and also parceled Fe-assemble and spotted zones of iron in thin sections. The amount of coarse particles is increasing with depth. Clay and iron cutans indicate local translocation within a certain horizon. Inclusions of rock fragments enriched with iron are common.

Total area of Yellow soils (Acrisols Haplic) makes 2,898,034 ha (4.1%). Soils have yellow color and deep profile: A-AB-B-BC-C. These soils are spread in the eastern part of East Georgia (except south-east part) at the altitude of 100-300 m asl. Yellow soils are formed on weathering crust of clay shale which is richer in earth silicon. This is the reason of difference between red and yellow soils.

Yellow soils (Acrisols Haplic) are also characterized by high clay content due to kaolinite in clay minerals assemblage acid reaction, and low to medium humus content. Cation exchange capacity complex is not saturated with bases, but the degree of saturation is considerably changing. Variations in clay content with depth are insignificant. Content of amorphous iron is low, but content of non silicate iron is relatively high. According to the total chemical analysis main oxides are not equally distributed. In clay fraction, the ratio of SiO_2:R_2O_3 changes at a high extent and indicates both ferralitic and siallitic weathering. Main soil formation processes of yellow soils are feralitization, kaolinization (claysation), humification and gleyzation (Urushadze, 1997). Yellow soils (Acrisols Haplic) as well as red soils (Nitisols Ferra-lic) are characterized by ferralitic weathering. According to the World reference base for soil resources (2006), Acrisols are soils that have higher clay content in the subsoil than in the topsoil as a result of pedogenetic processes (especially clay migration) leading to an argic subsoils horizons. Acrisols have in certain depths a low base saturation and low-active clays. The characteristic of yellow soils of Georgia suites WRB criteria for Acrisols. On the other hand, Acrisols are formed in humid tropical, humid subtropical and warm temperate regions. Present climatic parameters for Georgian yellow soils do not suite these criteria and indicate that Yellow soils are relic soils of former environment. We suggest, that properties of yellow (Acrisols Haplic) soils are influenced by parent rocks (yellow color inherited from ancient weathering crusts,

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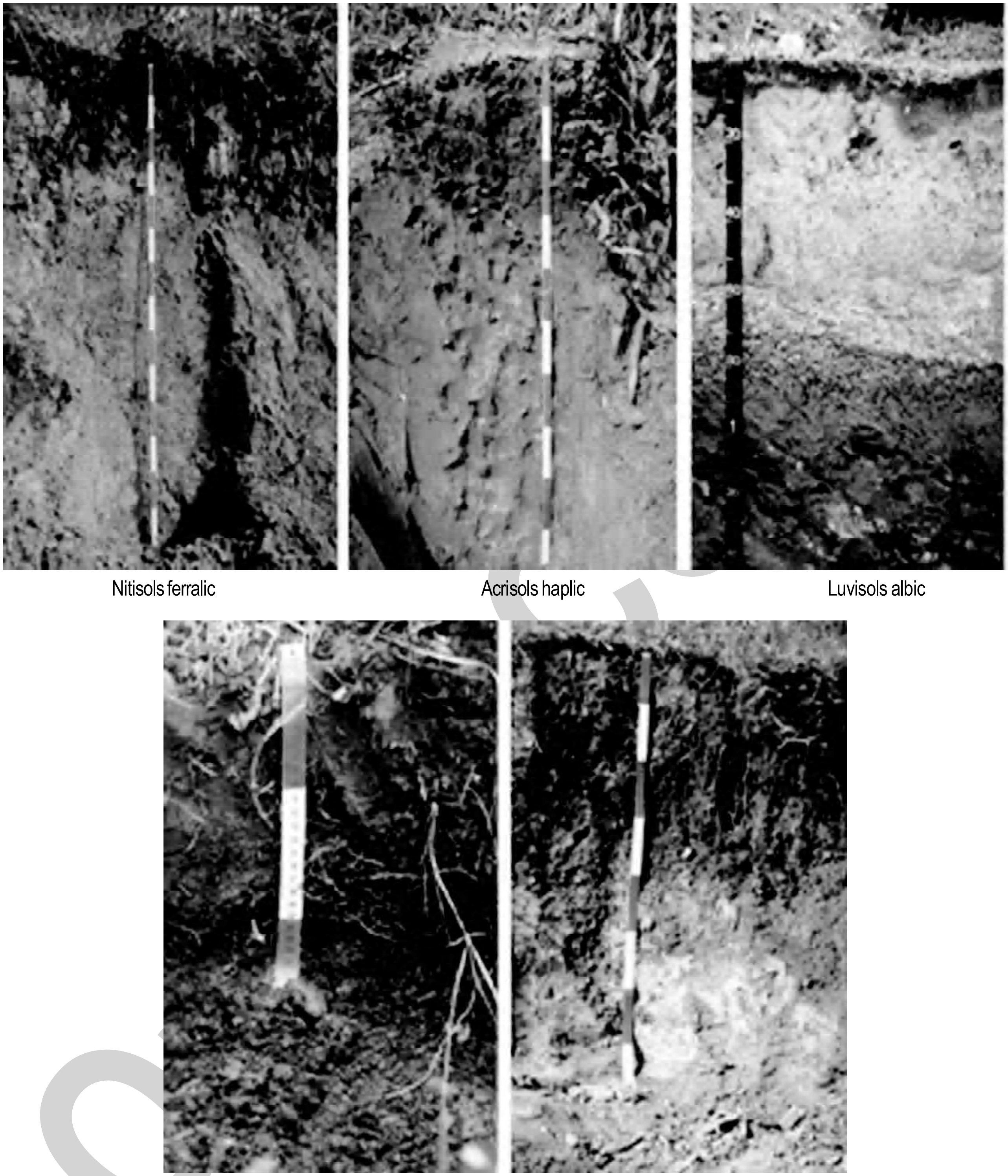

Nitisols ferralic Acrisols haplic Luvisols albic

Black soils (Vertisols) Cinnamonic (Cambisols cromic)

Fig. 1: Humid subtropical (a) and semi-arid subtropical (b) soils of Georgia

sporadically remained from Pleistocene period (Janelidze, 1980). This conclusion is also supported by the fact that yellow (Acrisols haplic) soils have sporadic distribution. This fact could not be explained by modern pedogenesis.

According to our previous studies (Matchavariani, 2008) yellow soils are characterized by compact dissimilar clay fabric with fragmentary microcomposing, interaggregate porosity. The pores are mostly round in shape, with rare figural pores. Surface horizons

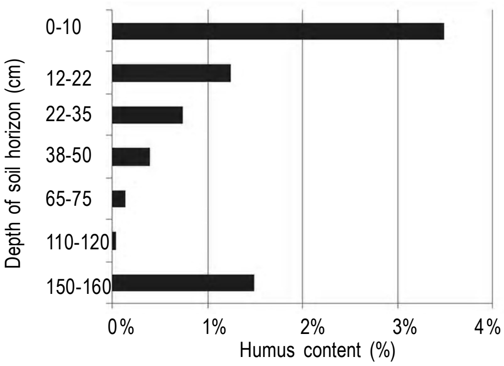

Fig. 2: Humus content in subtropical podzolic soils with buried humus horizons,Georgia with some data of chemical analysis

are bright in color in plain light and enriched in humus substances and has silt-plasma elementary micro fabric. Subsurface horizons are enriched in iron and abundance of clay in plasma. Iron nodules are unequally distributed, sometimes saturated with humus substances. Coarse particles are characterized by rich association of minerals. Birefringence is increasing with depth.

So, micromorphological studies of red and yellow soils of Georgia (Nitisols ferralic and Acrisols haplic) confirm that modern climatic parameters do not correspond to the properties of soils which are distributed below 1000 m. We suggest that deep weathering and red and yellow colors are inherited from ancient weathering crusts of Pleistocene age for yellow soils and Eocene age for red soils (Janelidze, 1980).

Total area of subtropical Podzols (Luvisols albic) in Georgia is 5,733,897 ha (8.2%). They are typical for Kolkheti lowland area and characterized by well differentiated profile: A-A1A2-A2(g)-B1-B2-BC-C. The main diagnostic properties of these soils are: well expressed eluvial horizon, which is poor in clay and sesquioxides (Fe_2O_3 and Al_2O_3) and yellow-brown illuvial horizon. Luvisols albic are characterized by acid, neutral and alkaline reaction, moderate content of humus and deep humus horizon, with predominance of fulvic acids. Cation exchange complexes could be both saturated or not satu-ra-ted by bases. Reaction of soils corresponds to the chemistry of ground waters. Soils have loam and clay texture. Humus and eluvial horizons are poor in clay. According to the total chemical analysis, basic oxides are characterized with eluvial-iluvial distribution. As a rule content of silicate iron predominates over non silicate iron. In many soils plinthic horizon is present (Urushadze, 1997; Matchavariani, 2008).

As it is known (World reference base for soil resources 2006) plintic horizon is a subsurface horizon that consists of Fe-rich (in some cases also Mn-rich), humus-poor mixture of kaolinite clay (and other products of strong weathering, such as gibbsite) with quartz and other constituents, and which changes irreversibly to a layer with hard nodules, a hardpan or irregular aggregates on exposure to repeated wetting and drying with free access of oxygen. It was also stated that micro morphological studies may reveal the extent of impregnation of the soil mass by Fe. The plintic horizon with nodules has developed under redoximorphic conditions caused by temporally stagnating water and shows a stagnic color pattern. The plintic horizon with mottles in platy, polygonal or reticulate patterns has developed under oximorphic conditions in the capillary fringe of ground water. In this case, the plintic horizon shows a gleyic color pattern with oximorphic colors and is in many cases underlain by a whitish horizon. In many plintic horizons, there are no prolonged reducing conditions.

According to our previous studies (Matchavariani, 2008), subtropical podzolic soils are characterized by weak structure, sand silty-fabric, short canal pores, low content of humus with light disperse humus particles, sepic plasma, high content of Fe-concentrations. Plintic horizons have compact fabric, thin crack porosity, asepic plasma, and high content of iron in the form of big nodules. Plintic horizons are heterogeneous in fabric, have crack porosity, asepic plasma with high birefringence. Clay plasma in some places has mosaic and streamed structure and with iron and silt micro zones. Heterogeneity of parent material is evidenced by the following features of microstructure: there are no signs of movement of thin dispersal substances within soil profile. Clay plasma with high birefringence supports the idea of the absence of genetic contacts between horizons and indicates polygenetic nature of soils. Existing climatic data indicate that there are no ecological conditions which can form plintic horizon in the area of subtropical podzols (Luvisols albic) in Georgia at present.

General micromorphology indicators for soils of humid subtropical zones of Georgia are dissimilar composition and microstructure of soil matrix, layer of profile with correlation and distribution of plasma and skeleton materials, compact micro fabric, weak color of humus, asepic type of plasma and contrast distribution of iron hydro oxides and micro zones without iron silt plasma.

Black soils (vertisols) have total area of 2,507,539 ha (3.6%). Black soils are characterized by weakly differentiated profile, black color of humus horizon, high density of subsurface horizons, clay texture, and a following horizon sequence: AII-AIII-AB-B-BC-C. Vertisols are characterized by the presence of carbonates from the surface, with maximum carbonate accumulations at a depth of 60-120 cm. According to the total chemical composition of soil and clay main oxides are uniformly distributed within soil profile. Predominant clay minerals are smektite, hydromica and chlorite. Maximum of non silicate and crystallized iron is in the middle part of profile, but the maximum of amorphous iron content in the surface horizons; content of humus is moderate, with predominance of humic acids. Soils are slightly alkaline, in some cases there is an accumulation of la-bile soluble salts and gypsum. According to the World reference base for soil resources (2006), the vertic horizon is the main diagnostic horizon of vertisols . It is a clayey subsurface horizon that, as a result of shrinking and swelling, has slickensides and wedge-shaped structural aggregates. So we see that black soils of Georgia suites the definition of vertisols in all parameters. But existing climatic data make it evident that shrinking and swelling processes are not possible in present environmental conditions.

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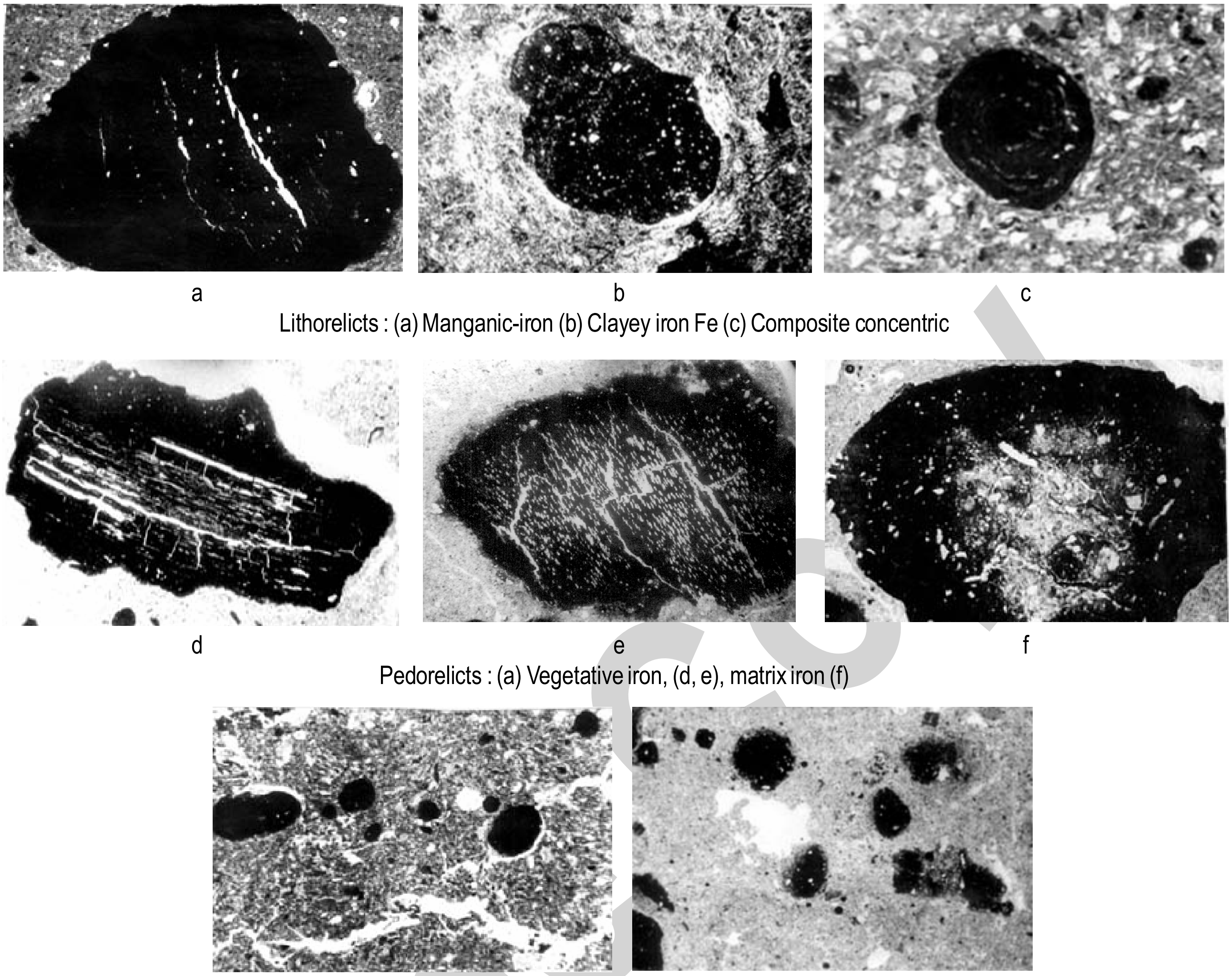

a b c

Lithorelicts : (a) Manganic-iron (b) Clayey iron Fe (c) Composite concentric

d e f

Pedorelicts : (a) Vegetative iron, (d, e), matrix iron (f)

g h

Recent pedogenic : Iron (g), humus iron (h)

Fig. 3: Types of concretions in the profiles of subtropical podzolic soil

According to our previous studies (Matchavariani, 2008) black soils (vertisols) are characterized by dark brown, sometimes light brown color. They have friable, crumple and fragmentary micro fabric. Winding, canal and irregular pores and thin biogenic aggregates are present. Plasma is enriched with humus-clay and carbonate-humus-clay substances, with coprolites, thin clots and strongly decomposed plant residues. The presence of carbonates is indicated by calcite concretions, the amount of carbonates increases with depth. Thin dispersed subs-tances have weak grain structure. Soil horizons have silt-plasma fabric and high density.

Cinnamonic (Cambisols cromic) soils make 6,218,847 ha, *i.e.* 8.9% of the total territory. These soils border meadow-cinnamonic (Cambisols chromic), Grey-cinnamonic (Cambisols chromic), Black (vertisols) and Brown forest (Cambisols chromic) soils. Cinnamonic (Cambisols cromic) soils are characterized by intense color differentiation of soil horizons, soil profile has the following constitution: A-B(Ca)-BC-BC(Ca)-C(Ca). Subsurface horizons have high clay content. Cinnamonic (Cambisols cromic) soils are formed in forest-steppe zone of East Georgia, mainly at the altitude of 500 (700) - 900 (1300) m.

Cinnamonic (Cambisols cromic) soils are characterized by dark-brown and brown color of humus horizons, small lump and grain structure, weakly alkaline to neutral reaction, moderate accumulation of humus with predominance of hymic acids, and deep humus horizons, presence of carbonates, high cation exchange capacity, even distribution of total chemical composition both in total mass and clay, predominance of silicate iron on non silicate, predominance of kaolinite, montmorillonite and hydro mica in clay minerals. According to World Reference Base for Soil Resources (2006), cambic horizon is the main diagnostic horizon of cambisols. It is a surface horizon showing evidence of alteration relative to the underlying horizons. Cambisols combine soils with at least an incipient subsurface soil formation. Transformation of parent material is evident from structure formation and mostly brownish discoloration, increasing clay content, and/or carbonates removal. In cinnamonic soils, the content of clay in the middle part of profile shows that its accumulation took place in the previous epoch.

According to our previous study (Matchavariani, 2008), cinnamonic soils (Cambisols cromic) are characterized by dark-brown, monochrome, well structured material with friable, crumple, in some places spongy micro fabric, complex aggregates of irregular forms, with brown dispersal humus with lots of thin dark humons, high content of weakly decomposed plant residues, humus-clay composition of plasma with grain structure, presence of scattered micro grains in plasma, predominant plasma over skeletal particles, considerable increase of carbonates in plasma with depth (in carbonate subtypes content of carbonates is high).

General micromorphological indicators for soils of dry subtropics of Georgia are isotropic plasma as a result of high content of humus, high aggregations of soil masses, carbonate character of profile, close links between humus materials and clay.

Relic features in the microstructure of soils of Georgia include both buried horizons and separate features, which do not correspond with modern environment. Relict soils usually are a surface (non-buried) soil containing features formed in an environment different from the present. Its development began in a preexisting landscape and continues today because it was never buried, or soil aggregates transported from their original site of formation (Paleopedology glossary). Paleosols are either buried or surface (non-buried or exhumed). Stability of relict features in soils on occasion can be explained by the fact that at present they determine modern soils regimes (Makeev, 2005).

To show micromorphological diagnosing of paleosols, which could be buried or a surface (or relic), the example of subtropical soils podzolic-luvisols albic is given and buried features in soil microstructure are described there. In micro depressions profiles with the deep second humus horizons of 1-1.5 m are present. Micromorphological data of burial horizons show the following specific character of it micro structure. In general, the microstructure of buried horizon is similar with surface humus-accumulative horizons. There are various very mixed materials with a considerable quantity of humus micro zones and separate clots. This indicates that there were more favorable conditions of humus formation when second humus layer was on surface. Soil matrix of second humus horizon is characterized by thin humus layers of brown color, distributed in strongly dissimilar matrix. It is also characterized by high amount of skeletal grains, much higher than in surface humus layer. Strongly broken clay, fine silt, clay-silt and clayiron microzones of different structures and colors are present in second humus horizons. They are also characterized by microzones enriched with iron in the form of spotted flaky accumulations.

Another typical feature for second humus horizons is the abundance of weakly decomposed, sometimes charred plant residues with preserved cell structure, which are absent in lower horizons and in surface humus horizons. The abundance of phytoliths in second humus horizons of different forms and sizes (even on depth 150-170 cm) is of particular significance and together with other features described above certainly evidence that second humus horizon is a former surface layer, buried in the course of sedimentation. The buried nature is confirmed by humus content that displays the second maximum in the second humus horizon (Fig. 2).

Thus, presence in supposed burial layers of numerous humus accumulations and also included phytolits and conserved vegetation tissues in aggregated strongly mixed materials, with some data of chemical analysis, permit to diagnose polygenetic nature, heterogenic character of investigated profiles (taking into account heterogenic character and different quality of concretions, included in the form of litho and pedo-relicts). Mechanism of formation of texture differential profiles of subtropical podzols soils of Georgia, first of all are in relation with lithological dissimilarity of parent rock materials.

Finally we may conclude that presence of buried humus horizon, enriched in phytoliths and well preserved plant remains in well aggregated strongly mixed matrix, indicate polygenetic nature of subtropical podzolic soils of Georgia. This conclusion is also supported by heterogenic character of Fe-Mn nodules that occur in the form of litho and pedo-relicts. The major principle of distinguishing relict formations in soils is the disagreement between the composition and structure of the part of the concretions and the enclosing material. Chemical analyses also support such conclusion. So, clay distribution in profiles of subtropical podzols of Georgia with noticeable increase in the lower horizons (more then 80 cm), (the quantity of silt with depth increases with depth (from 10 to 70 cm) is the result of lithological discontinuity of parent rock of It is the result of lithological discontinuity of parent rock of Holocene age and only partially from Quaternary period (Janelidze, 1980).

Relic features of subtropical podzolic soils are visible also in Fe nodules (Matchavariani, 2005). Nodules can be grouped in a following way: pedogenic (modern and relict) and lithogenic. The criteria for distinguishing relict features in soils are the disagreement between the composition and structure of nodules and the enclosing matrix.

Lithorelicts are characterized by a clear separation from the matrix, compact fabric, irregular-round forms, heterogeneity of the iron impregnation a large size (up to 10 mm in thin sections) and admixtures of different materials: clay, Mn *etc.* (Fig. 3). Concentric layers pellets are also referred to as lithorelicts.

The presence of an iron cemented (plintic or petroplintic) horizon in the profiles of subtropical podzolic soils does not correspond to modern environmental conditions. Despite the humid climate favoring the intensive vertical migration of substances, the iron content in the upper horizons is insufficient to explain the origin of the iron-cemented layer through iron leaching from the upper horizons and its accumulation in the iron-cemented layer could not be the result of exclusively vertical migration of substances.

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Some other examples of relict features in the soils of Georgia were revealed by micromorphological investigations. In the subtropical gley podzols-gleysols soils on the depth 120-150 cm (horizon CDg) we sometimes observe carbonate impregnation of plasma and/or crypto-grain calcite. Presence of carbonates in acid environment does not correspond to modern climate. Iron accumulations in the lower horizons of black soils (vertisols) formed under dry subtropical climate with high seasonal contrasts indicate wetter climate in the past.

In mountain regions the age is an important factor of soil formation. We may confirm that in Georgia higher than 1000-1200 m asl, soils more correspond to ecological conditions than on plain regions and they can consider as mirror of landscapes (as one of the most important postulates of soil). In other cases we can talk about distorted mirror of landscapes science.

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