5 Soil Distribution and Properties

Lia Matchavariani and Besik Kalandadze

Abstract

The following soil classes of Georgia, corresponding of the WRB groups are considered: Leptosols Umbric, Cambisols Dystric, Rendzinas, Leptosols Molic, Chernozems, Vertisols, Cambisols Chromic, Kastanozems, Solonetz Humic, Nitisols Ferralic, Acrisols Haplic, Luvisols Albic, Gleysols, Fluvisols. The main indicators of soils distribution and their major characteristics are described there, particularly: location, soil-forming conditions, profile structure, macro- and micromorphological descriptions, morpho-chemical properties with some chemical data, agro-physical features, etc.

Keywords

Soil zoning • Taxonomic units • WRB • Soil classes • Soil distribution • Soil morphochemistry

5.1 Introduction

Soil formation and classification, as a rule, are a key field of research in the soil science (Hartemink and Bockheim 2013). There are many different national and international classifications of soils used in the world. Soil classification means grouping the soils based on their common features, properties, and fertility and implies the identification and formulation of the principles of classification; scientific treatment of the hierarchical system of taxonomic units (type, subtype, etc.); development of the soil nomenclature (system of appellations); and identification of the features used to diagnose and map the soils of all classification subsets. The basis to develop the modern classification systems is a genetic principle used to consider the features of the properties of soils as a result of the soil-formation process and to unite ecological, morphological, and evolutionary approaches. As a rule, the classifications thoroughly consider the morphological and micro-morphological properties of soil profiles, texture and properties of soils, ecological processes, qualitative content of organic substances, etc.

The main taxonomic unit of a national soil classification system is the genetic type of the soil. Lower taxonomic units are subtype, genus, species, variety, and phase.

The subtype is marked out from soil types. It is a group of soils, which is a transitional step between the soil types and is determined by the major soil-forming process.

Genus is marked out from subtypes. The qualitative genetic properties are determined under the influence of local conditions, such as the composition of soil-forming parent materials and chemism of ground waters. It can be also determined by the properties acquired during the phases preceding weathering and soil formation (relict horizons or features).

Species are marked out from soil genus and differ by the degree of the development of the soil-formation process (e.g., podzolization, gleization, argilization, etc.).

Variety is determined by the mechanical composition of the upper soil horizons and soil-forming parent materials.

Phase is determined by the genetic properties of soil-forming parent materials (e.g., alluvion).

Within every genetic type, central types with term typical or ordinary used to describe it and transitional subtypes possibly incorporating the features different from the subtype or associated with neighboring types can be distinguished. They also use additional terms to describe leading processes (e.g., Cinnamonic Calcareous); to identify morphological peculiarities (color) (e.g., light gray-brown); to locate the soils (e.g. black southern), etc.

The terms determining the properties typical to soils are used for the nomenclature of soil genus (e.g., solonetz, gley), indicators of relict properties (e.g., residual meadow, residual gley), etc.

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The nomenclature of the soil species contains the terms characterizing the soil properties quantitatively and soil processes. Three categories of terms are used: texture (with little, average or high content of soil organic matter); depth of individual soil horizons or of the whole profile (of little, average or great strength, etc.) and indicating the events (slightly, averagely, intensely gley, etc.).

The names of mechanical texture are used for the soil nomenclature, while the terms describing the lithology and the genesis of the soil-forming parent materials are used for the nomenclature of phases.

The full name of a soil has the following order: type, subtype, genus, species, variety, and phase. For example, cinnamonic (type), typical (subtype), meadow (genus), average humus (species), heavy loamy (variety), and sandy loamy (phase) soil.

For the diagnostics of the soils, meaning identifying a set of features used to attribute the soils to some or other classification subcategory, usually, easily identifiable morphological properties and simple analyses are used. However, these features are not sufficient for a number of soil types, and the results of more complex analyses are used instead (content of soil organic matters and absorbed cations, results of some chemical analyses), as well as hydrothermal characteristics of soils, etc.

The national classification used in Georgia is associated with the name of Sabashvili (1948). The classification plan developed in the 1960s used the materials of soil maps and the soils on it are positioned in groups and types corresponding to the principal vertical and landscape zones. In addition to types, the plan shows the soil subtypes and genera. The description of soil groups and types start with Lowlands, continue with piedmonts, mountain-and-forest zones, and end with mountain-meadow zones. The classification also includes intrazonal soils: marsh, salt, and zonal soils—alluvial. The units of classification: soil group, type, subtype, genera, variety, as well as texture, bedrock, type of development, and degree of erosion (Urushadze 2013).

The components of the classification of the soils of Georgia developed by A. Charkseliani, R. Petriashvili, and M. Kipiani at the end of the 1980s are group, type, subtype, genera, kind (depending on the thickness of an accumulative horizon layer, content of soil organic matter, degree of development), variety, and phase.

According to Sabashvili (1948, 1965), three quite different soil regions (Western, Eastern, Southern) are distinguished in Georgia with appropriate subregions, zones, and areas (Fig. 5.1).

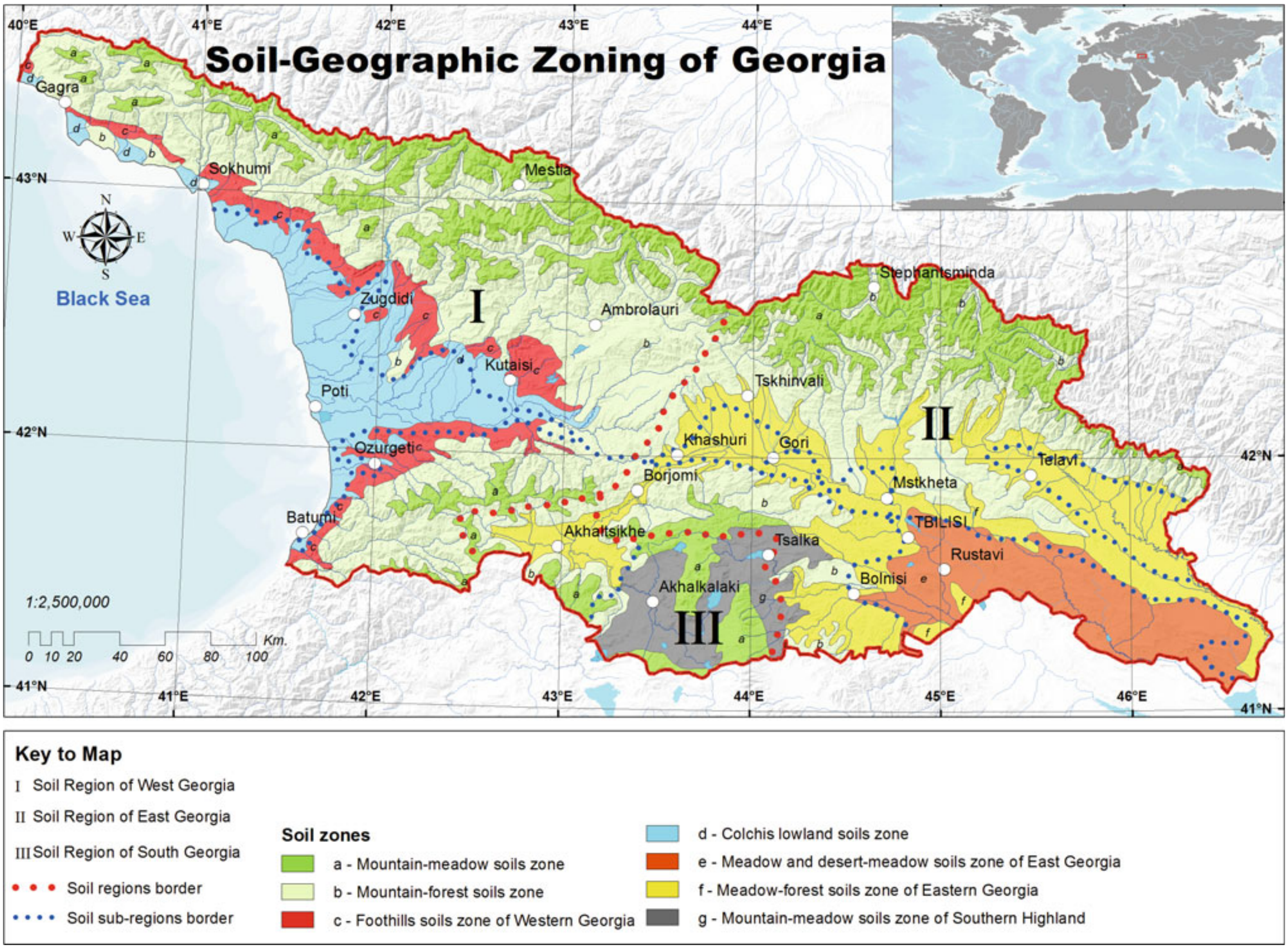

Fig. 5.1 Soil-geographic zoning. This map is created by D. Svanadze, based on data of M. Sabashvili

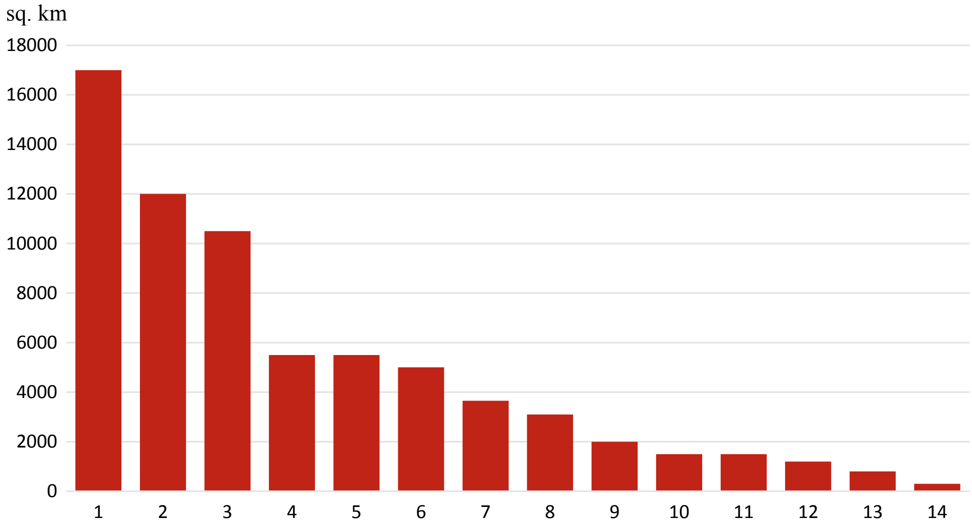

Fig. 5.2 The areas occupied by the main soil classes (according to data of T. Urushadze): 1—Cambisols Dystric; 2—Leptosols Umbric; 3—Cambisols Chromic; 4—Fluvisols; 5—Acrisols Haplic; 6—Rendzinas; 7—Luvisols Albic, Plinthosols; 8—Vertisols; 9—Chernozems; 10—Nitisols Ferralic; 11—Kastanozems; 12—Gleysols; 13—Leptosols Molic; 14—Solonetz Humic, Solonchak

In 2002, in the framework of the project "Cadastre and Land Registration" (realized with the financial support of KfW), a group of researchers, on the basis of the modern international approaches, made an inventory of Georgia's soils.[1]

Nowadays, one of the most popular classified-diagnostic systems is the World Reference Base for Soil Resources (WRB), that is, standard of soil correlation and international communication (Urushadze 2013; Urushadze and Blum 2011). This approach is based on fundamentally different principles and aims of the development of scientific relations. It is also a fundamental part of the soil resources management and rational use. WRB is not a dogmatic and legal document, and as unified common "soil language", it is developing an open system, which serves the national soil classification and correlation diagnostics (World Reference Base 2015). WRB is not intended to replace the national classifications. It is a real opportunity for individual countries—the doorway to the international scientific community and the general orientation.

Accordingly, the soil type names of the national classification are fundamentally different from the FAO and WRB soil class taxonomy. The description of soils in this chapter is given by the corresponding of the FAO-WRB groups (Fig. 5.2), combined with the national classification.

5.2 Leptosols Umbric

Leptosols Umbric, which correlate with the national classification as mountainous-meadow soils, is quite a common soil class in Georgia. It is mainly spread in the subalpine and alpine zones of Great Caucasus and southern mountains of the Lesser Caucasus, at 1800(2000)–3200(3500) m above sea level (Fig. 5.3). The hypsometric limits of its distribution vary depending on the distance from the sea, physical–geographical conditions of the mountainous massifs and economic activity of the population. The hypsometric amplitude of the distribution of the mountain-meadow soils over Great Caucasus is greater than it is in the southern mountains of the Lesser Caucasian. This type of soil adjoins to the so-called mountainous-meadow-chernozem-like soils in the subalpine and alpine zones, and "Mountain-forest-meadow" in the Subalpine zone and primitive soils in the nival zone (Fig. 5.4).

The first researcher of the "Mountainous-Meadow" soil was V. Dokuchaev, who identified the properties of this type of soil (such as turf formation, little strength of a soil profile). Detailed studies of mountain-meadow soils were accomplished by Sabashvili (1965, 1970), as well as Tarasashvili (1956), Talakhadze (1962), Talakhadze and Mindeli (1980), Iashvili (1987), Urushadze (1997), etc.

Considered soil is mainly formed on the leached hard parent materials weathering products and occupies all expositions of the upper parts of the mountains and slopes where the amount of precipitations exceeds the evaporation by 2 or 3 times what determines the washing regime of the soils.

The climatic conditions are severe, characterized by a long winter with an enduring snow cover and cool summer. During the year, the average monthly air temperature varies within a great range. The annual amount of precipitations reaches 1500 mm, with the maximum precipitations falling in May. The coefficient of humidification is high; however, in summer, despite the maximum amount of precipitations, it diminishes to one due to intense evaporation. Severe climatic conditions support the physical weathering of rocks and minerals and restrict chemical weathering. As a result, a great amount of parent material fractures has accumulated on the soil surface.

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[1] This chapter uses a part of the illustrative material from the project "Cadastre and Land Registration".

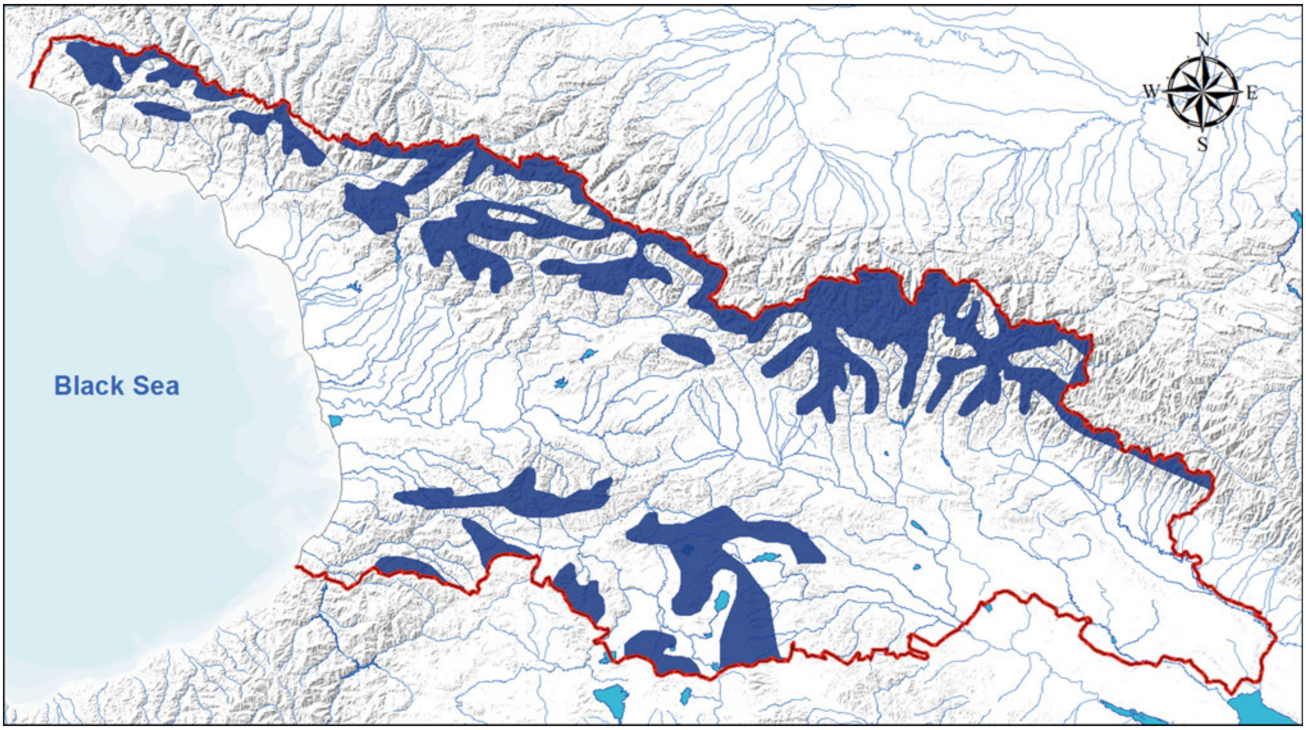

Fig. 5.3 Location of Leptosols Umbric. This map is created by D. Svanadze, based on data of L. Matchavariani

Fig. 5.4 The landscape in the area of Leptosols Umbric formation (Project "Cadastre and Land Registration", KfW)

The erosion–denudation relief dominates in the zone of the uppermost crests, where forms of the glacial origin dominate. There are also relief forms originated through the quaternary effusive volcanism. At lower altitudes, there are erosive gorges with steep slopes spread. Despite the fact that geomorphologically, the high-mountainous area is a region of a denudation and destruction type, it has smoother shapes as compared to the relief in the mountain–forest zone.

The geology of the high-mountainous area is quite complex. In West Georgia, crystal slates, quartz-mica slates, and quartz diorites are common, as well as limestones, crystal rocks, granites, and gneisses. The geology of the high-mountainous area of East Georgia is presented by shales, sandstones, and limestones. The peaks are built with effluent effusive parent materials. There are moraine sediments on the Great Caucasian, while in the mountain–meadow zone of South Georgia, there are andesites, porphyries, trachytes, and intrusive effluent rocks.

The high-mountainous vegetation is characterized by a clear zoning. The vegetation cover is mainly represented by subalpine mid-herbaceous and alpine low-herbaceous meadows, and sometimes, by bushes. The vegetation of the subalpine zone is quite diversified, including both meadow and meadow-steppe plant species and subalpine forest. There is xerophilous vegetation spread on relative dry positions.

The main diagnostic properties of the Leptosols Umbric of Georgia are a little or average strength of its profile, a non-differentiated profile and a clear accumulative horizon (Fig. 5.5). The morphological structure of the profile is Ak–A–B–BC.

The difference between the mentioned soil in the subalpine and alpine zones is negligible. Soils in the Alps are distinguished for a stronger accumulative horizon, less profile strength, and stronger profile than those in the subalpine zone.

The “Mountainous-Meadow” soils mostly have average or little strength, with turfing from surface, acid or weak acid reaction, dark-colored accumulative horizon, high (rarely average) and deep humification, fulvous or humate-fulvous type of soil organic matter, dense illuvial horizon, skeletal nature, and high content of rock fractures. They are characterized by light clay mechanical texture with unequal distribution of main fractions, with sialith weathering and high content of hydromicas and chlorites in clay minerals, with increased content of silicate of iron at great depths, low or average amount of absorbed cations, etc. The data of the gross chemical composition are presented in Table 5.1.

The data about the soil acidity (Fig. 5.6) and content of absorbed cations evidence that there is no connection between the properties of different types of soils and the soil-formation parent material what can be explained by the deluvial nature of the soil.

The Leptosols are characterized by a dark accumulative horizon turfed from the surface (Fig. 5.7). The amount of soil organic matter depends on a complex of factors—altitude, exposition, slope inclination, hydrothermal conditions, type of vertical structure of natural-territorial complexes, vegetation cover, degree of anthropogenic transformation of the area, etc. Thus, amount, reserves and distribution of SOM in the soil layers were studied in the landscapes (Nikolaishvili and Matchavariani 2010), that covers Leptosols, as well as all other main soil types of Georgia. Due to the widespread of the denudation processes, these soils characterized by a younger age of soil formation.

The Leptosols Umbric differs from the “Mountain-forest-meadow” soil (formed in the lower part of the subalpine zone) by a dark color, better and more stable structure, skeletal nature and higher content of mobile ferrum forms. The difference between the Leptosols Umbric and “Mountainous-meadow-chernozem-like” soil is that the former has a lighter color, less strong structure, more acid reaction and less absorption capacity, and higher content of fulvous-type soil organic matter.

Usually, there are hay meadows and pastures over the Leptosols Umbric soils. The necessary condition for their rational use is controlled grazing. Irregular grazing not only causes the violation of the soil cover and provokes erosive processes but also leads to the change of the vegetation.

According to our previous micropedological study (Matchavariani 2008), these soils are characterized by raw-moder and moder-raw types of SOM in the upper horizon, with dark brown color, great amount of vegetation tissues with a survived cellular structure and clear birefringence what is the evidence of humification structure, with excess excrements, spongy microstructure and inter-aggregate microstructure, nonhomogeneous microstructure, and sandy-dust-plasmic and sandy-plasmic elementary microstructure, with plasma isotropy in the surface horizons caused by masked clay particles of the SOM substance. In the lower layers, the aggregation reduces and optical orientation of a mixed-fiber structure, diversified mineralogical association and large admixtures of parent materials fragments covered with disperse calcium occur, weakened and marked; nonhomogeneous plasma and clay-dusty cutans, inleakages distributed in a micro-zonal manner.

5.3 Cambisols Dystric

Cambisols Dystric soils correlate with the national classification as Brown-Forest soil. They are widely spread in Georgia over the mountain slopes, under the forest formations, at various altitudes of mountain-and-forest zone of all soil zones (west, east, and south). As compared to the west, where these soils are spread at 800(900)–1800(2000) m above sea level, in the zone of East Georgia is common at higher altitudes, 900(1000)–1900(2100) m asl (Fig. 5.8); as for the soil zone of South Georgia, the altitude varies from 1500 to 2000 m. The area of the so-called Brown-Forest soils in Georgia is more than 18% of the total area of the country.

So-called Brown-Forest soil was first classified as an individual soil type by Raman. As for these soils of Georgia, the first scientist to study them was B. Prasolov. Basic studies of such soils belong to Tarasashvili (1956, 1965), Sabashvili (1948), Shevardnadze (1963), Urushadze (1987), etc.

Mentioned soils are mostly formed over the slopes, what, in terms of the warm and humid climate, makes for free intra-profile drainage. In the west, the Cambisols Dystric

Fig. 5.5 Profiles of Leptosols Umbric: **a**—Svaneti; **b**, **c**—Kazbegi. Photo by B. Kalandadze

Table 5.1 Gross chemical composition of Leptosols Umbric soils, % (according to data of T. Urushadze)

Horizon (cm)	Loss on ignition	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	MnO	CaO	MgO	Na_2O	K_2O	SiO_2: R_2O_3	SiO_2: Al_2O_3	SiO_2: Fe_2O_3
0–12	30.0	68.6	16.7	6.3	0.9	0.1	2.6	2.1	2.0	2.1	4.3	5.4	22.5
12–25	27.7	66.2	17.1	6.7	1.0	0.1	2.2	2.1	2.1	2.1	5.3	6.6	26.3
25–40	21.0	66.2	16.7	6.6	1.0	0.1	2.7	2.1	2.1	1.9	5.0	6.3	24.9
40–80	14.3	66.3	17.2	7.3	0.7	0.1	2.1	1.9	1.9	1.8	5.1	6.5	24.6

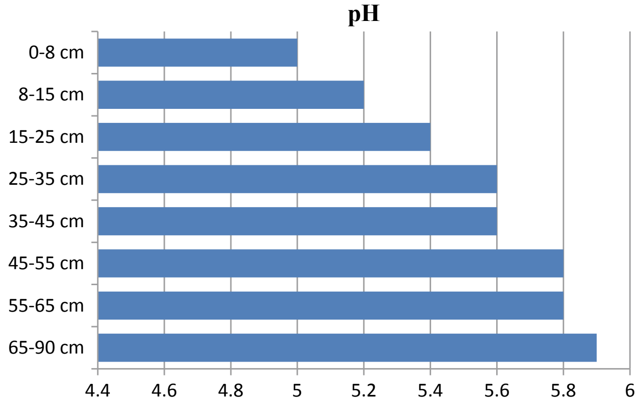

Fig. 5.6 pH distribution in profile of Leptosols Umbric (according to data of N. Iashvili)

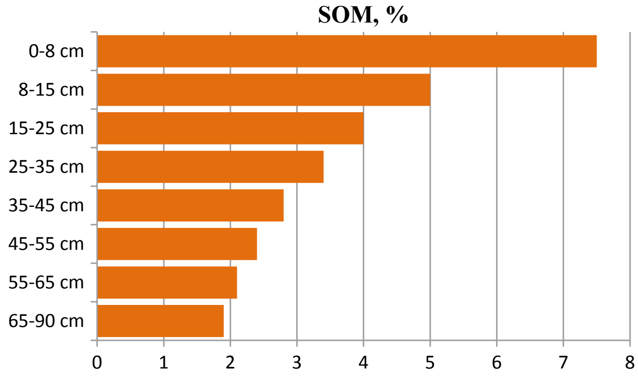

Fig. 5.7 Content of soil organic matter in Leptosols Umbric (according to data of N. Iashvili)

adjoin so-called Yellow-Brown-Forest and Mountain-Forest-Meadow soils, while in the east they adjoin “Cinnamonic” and “Mountain-Forest-Meadow” soils. Soil formation of the Cambisols Dystric soils is younger what is associated with their evolution capability in other soil types (Fig. 5.9).

Soil-forming parent materials, over which the Cambisols Dystric soils are formed, are presented as Jurassic sandy loams, shales and limestone–clay slates, while in the soil zone of South Georgia, they are presented as tertiary volcanic and sedimentary parent materials and their weathering products (porphyries, andesite-basalts, sandstones, conglomerates, etc.).

Cambisols Dystric soils are formed in a relatively warm and humid climate with an average annual temperature from +4 to +11 °C. The temperature of the warmest month of the year reaches +22 °C and that of the coldest month does not fall below +2 °C. The vegetation period lasts for up to 7 months. The atmospheric precipitation amount to 550–1700 mm a year. Humidity coefficient is more than 1 making for the wash-down water regime.

The morphological structure of the soil profile is 0–A–Bm–BC–C (Fig. 5.10). These soils are characterized by a well-established forest litter, rust color, profile skeleton (in their lower layers particularly), and acid reaction, which reduces at greater depths (Fig. 5.11). Cambisols Dystric soil is moderately or deeply containing soil organic matter (Fig. 5.12). It has a strongly pronounced organic material of a dark color. Its profile is cloddy, and partly granular in the upper profiles. With their mechanical texture, the soils are classified as loamy soils. They get heavy in the lower layers. The profile is characterized by intense weathering.

Cambisols Dystric soils are provided with nitrogen. The type of soil organic matter is fulvous. The properties of humic acids and fulvoacids are quite similar. Alumosilicates decompose easily, thus contributing to the formation of secondary clay minerals (e.g., a group of montmorillonite). One of the typical features of these soils is the accumulation of SiO_2 in upper horizons. Calcium dominates in the exchange cations. The sum of absorbed cations is average. Accumulation of Fe_2O_3 and Al_2O_3 takes place in the middle part of the soil profile. The data of the gross chemical composition are presented in Table 5.2.

There are mostly forest massifs growing over the Cambisols Dystric soils. They are usually used as arable land, hay meadows, or pastures. Due to their location over the slopes, these soils are prone to water erosion. Heavy texture and high humidity ratio protect them against erosion.

According to our previous micropedological study (Matchavariani 2008), the upper horizons of Cambisols Dystric soils are characterized by dark color, soil organic matter of a moder-mull and/or mull-moder morphological type, high micro-aggregation, masking of clay material with disperse soil organic matter, and at the depth, they are characterized by brown color, weak aggregation, fissure-like porosity, high birefringence of clay material of a scale and fiber-scale structure, argillaceous and ferrum-argillaceous

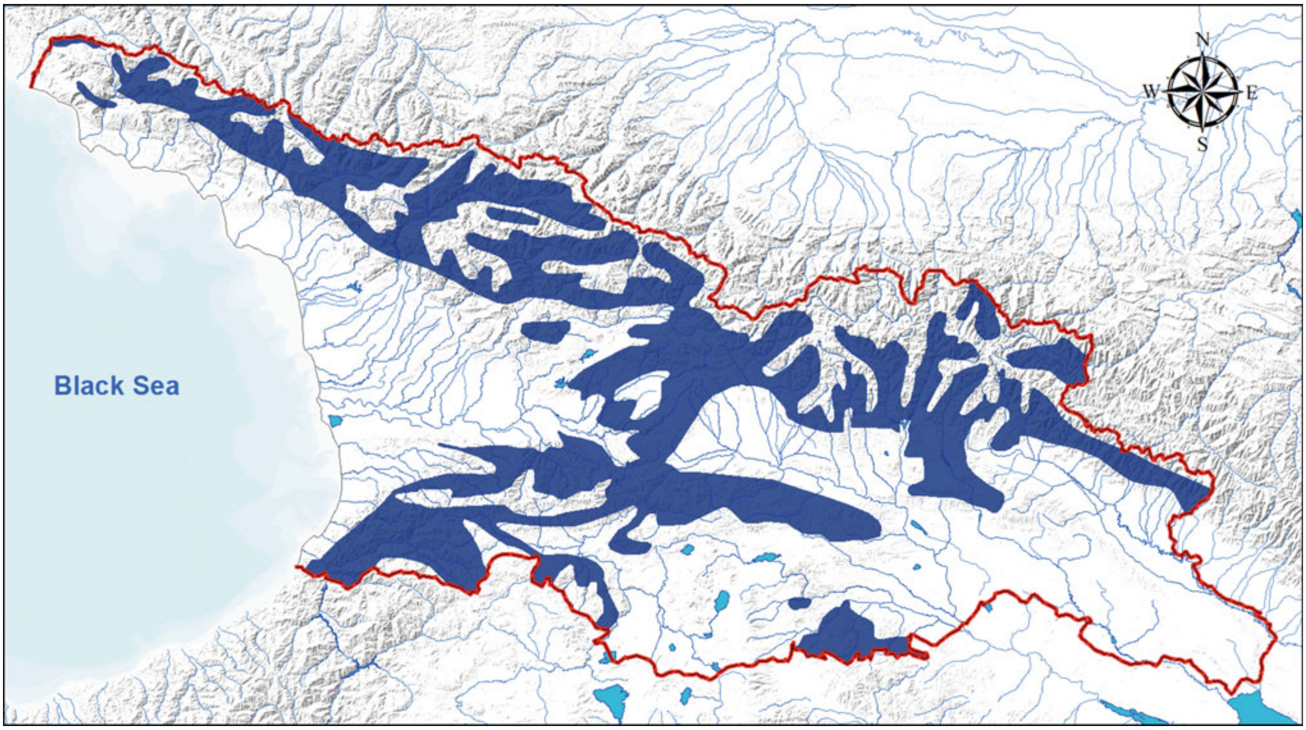

Fig. 5.8 Location of Cambisols Dystric. This map is created by D. Svanadze, based on data of L. Matchavariani

Fig. 5.9 The landscape in the area of Cambisols Dystric formation (Project "Cadastre and Land Registration", KfW)

Fig. 5.10 Profiles of Cambisols Dystric. Photo by B. Kalandadze

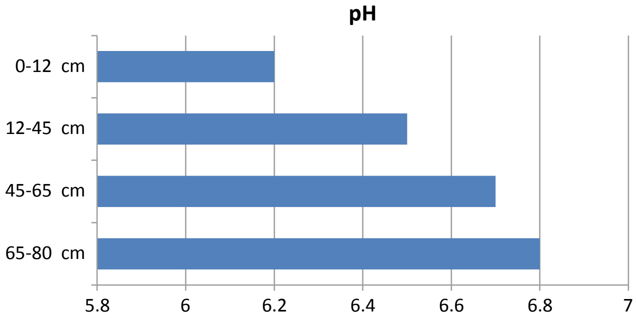

Fig. 5.11 pH distribution in profile of Cambisols Dystric (according to data of T. Urushadze)

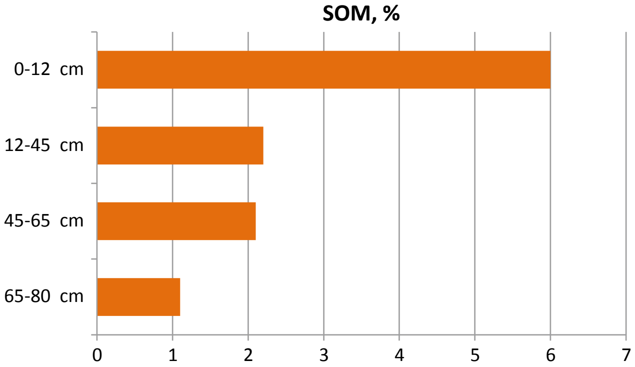

Fig. 5.12 Content of soil organic matter in Cambisols Dystric (according to data of T. Urushadze)

Table 5.2 Gross chemical composition of Cambisols Dystric, % (according to data of T. Urushadze)

Horizon (cm)	Loss on ignition	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	$SiO_2:R_2O_3$	$SiO_2:Al_2O_3$	$SiO_2:Fe_2O_3$
3–10	15.00	58.5	21.7	8.6	5.3	2.4	3.6	4.6	15.7
10–25	13.77	57.2	21.7	9.4	6.8	1.9	3.5	4.4	16.5
25–48	13.83	57.1	21.2	8.4	6.5	2.5	3.5	4.4	18.4
48–69	10.81	57.2	20.5	10.3	6.0	1.8	3.5	4.6	15.3
69–80	12.41	56.6	22.4	9.3	6.7	1.5	3.5	4.4	16.5

cutans in pores and cracks, all through the profile, particularly, in its middle part and with the micro-zonal saturation of thin-disperse substance with Fe-hydroxides.

As a transitional type between the Cambisols Dystric and Acrisols Haplic soils, in the subtropical zone of West Georgia, at 400(500)–800(1000) m asl, according to national soil classification, is spread so-called Yellow-Brown-Forest soil. They occupy 1.5% of the total area of the country. Sometimes this soil considers as a subtype of “Brown-Forest” soil.

I. Gerasimov was the first to identify the “Yellow-Brown-Forest” soil in the environs of Batumi, and thus showed its transient nature from the Brown-Forest soil of a moderately warm zone to the humid subtropical soil. A doubt about the possible presence of Yellow-Brown-Forest soil in Georgia was expressed by S. Zonn as well. T. Urushadze demonstrated the need for isolating this type of soil as an individual genetic type.

The parent materials in the areas with abovementioned soil are a porphyry stratum of the middle Jurassic period and old effluent (andesite, andesite-basalt) denudation crust and their derivatives. The type of relief is erosive-denudation. The climate is subtropical humid with warm winter and warm summer. Average annual temperature is 11 °C and the sum of active temperatures varies from 3500 to 4500 °C. The duration of the vegetation period is 6 to 7 months and the average annual amount of atmospheric precipitations is great (1000–2150 mm), with over half of it falling in the warm period of the year. The annual humidity coefficient is more than one. The vegetation is presented by chestnut forests with the fragments of Caucasian hornbeam, oak, oriental maple, and other plantations. A peculiar sign of these forests is wide areas of evergreen understory.

The genesis of “Yellow-Brown-Forest” soil is the result of the joint action of Cambisols Dystric and Acrisols Haplic soil-formation processes, and consequently this type of soil has much in common with both soils. As a result, such a combination of processes forms new properties determining the individual nature of this type. Besides the vegetation, the hydrothermal conditions also play a particular role in the formation of this kind of soil.

Morphologically, this soil is characterized by a clearly expressed illuvial horizon of yellow-brown color with a strong soil organic matter and cloddy structure. The main diagnostic properties are allitic weathering and ferrum concentration. Profile has the following structure: A–AB–B1–B2–C1–C2.

As the analytical data suggest, soil has acid reaction, particularly in its accumulative horizon. The soil acidity shows a decreasing trend (an increasing pH value) as the depth increases. The content of soil organic matter is high; however, distribution of SOM is not subject to the regularities typical to the forest soil. As the depth increases, the content of SOM in the profile reduces gradually and insignificantly reaching great depth. Nitrogen distribution across the profile shows similar regularities.

Soil organic matter is of a fulvous type. The soil is unsaturated with bases. The amount of absorbed hydrogen is quite great. The “Yellow-Brown-Forest” soil is poor in calcium and manganese. The amount of these elements in the soil depends on the eluvial processes on the one hand and on the lithological and the petrographic structure of the soil-forming parent materials on the other hand.

With its texture, the “Yellow-Brown-Forest” soil belongs to the category of heavy loams. Movement of a micron fraction across the profile is not typical to this type of soil. The mineral portion of the soil is characterized by eluvial processes. The clay minerals are presented by chlorine-montmorillonite and contain great amounts of kaolin and average amount of chlorines. The amount of mica is relatively little.

The most part of the soil is covered with forest, and small part of it is used to grow perennial crops, vine, fruit, etc. Unlike the “Brown-Forest” soil, which is formed in cooler conditions, the mentioned soil is of a yellowish and sometimes, of a reddish color and has no forest litter, is characterized by stronger ferralitic weathering, higher content of soil organic matter, less absorption capacity, more content of different forms of iron, and more acidic reaction. The accumulation of nonsilicate ferrum in the illuvial horizon can be explained by an intense wash down. Unlike the so-called Yellow and Red soils, which are formed in warmer conditions, the “Yellow-Brown-Forest” soil has light yellowish or reddish color, strong accumulative horizon, better structure, and less weathering.

According to our previous micropedological study (Matchavariani 2008), the “Yellow-Brown-Forest” soil is characterized by an intense coloration of aggregated accumulative horizon with organic mass, favorable microstructure, mull-moder type of soil organic matter, and large amounts of the vegetation remain at different stages of decomposition. Plasma is intensely saturated with Fe-hydroxides across the whole profile what is seen as spots and concretions. Due to the masking with soil organic matter and ferrum substances, the fine-disperse material is distinguished for weak optical orientation and is characterized by high content of parent materials fragments and presence of clay inleakages in the lower portion of the profile (Fig. 5.13).

5.4 Rendzinas

Rendzinas (Leptosols Rendzic), which correlate with the national classification as an intrazonal type—raw-humus-calcareous soil, are widely spread in West Georgia (Abkhazeti, Samegrelo, Racha-Lechkhumi, Zemo Imereti), as well as East Georgia (Mtiuleti, Samachablo, Kakheti, Kartli). Their area coincides with the areas with limestones and marls. In addition to the mountain–forest zone, these soils are spread in the humid and dry subtropics and high-mountainous regions (Fig. 5.14). They occupy 4.5% of the total territory of the country.

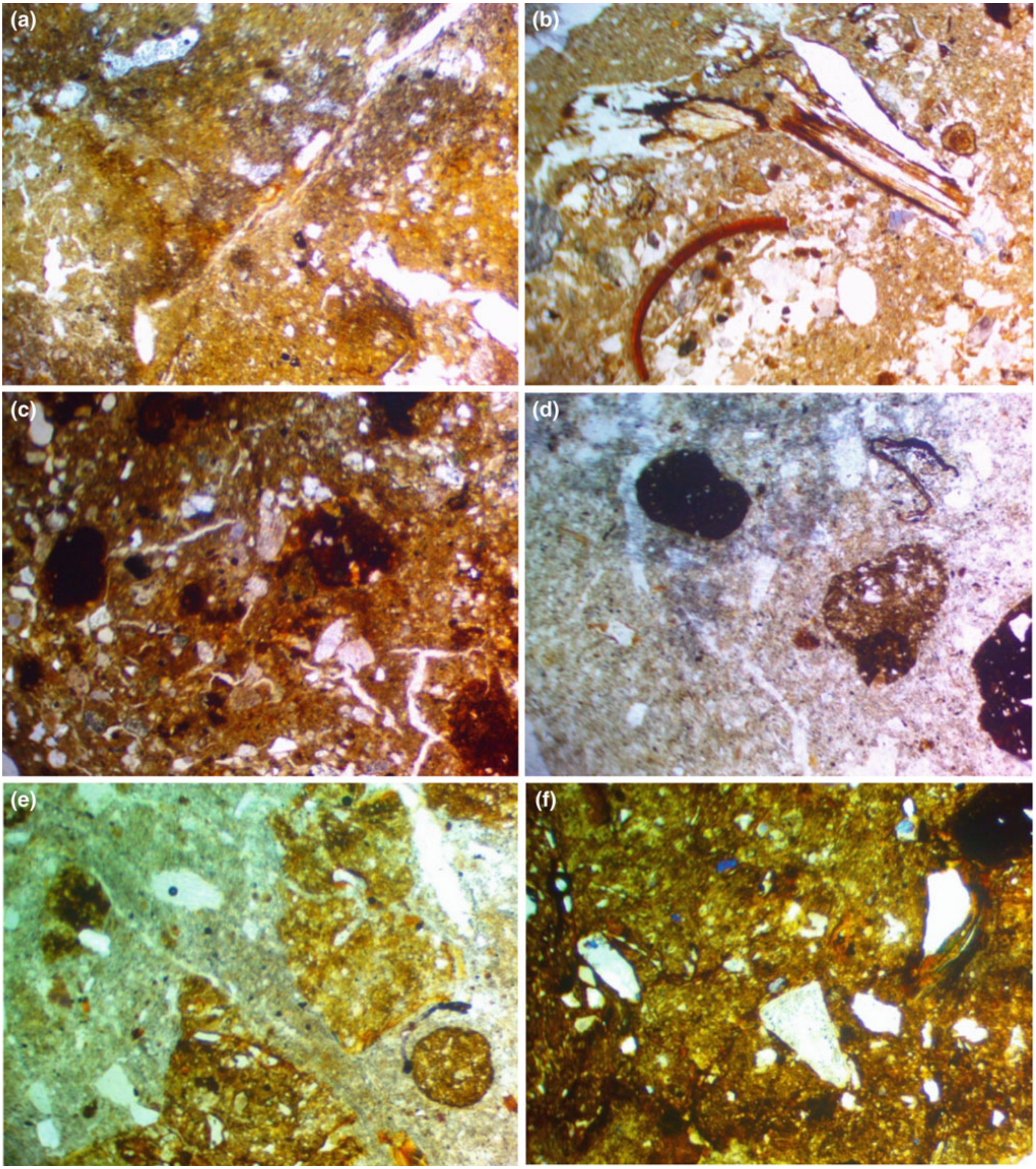

Fig. 5.13 Microstrucutre of "Yellow-brown-forest" soil, nic.II; Pit-3, horizons: **a** 0–14 cm; **b** 14–28 cm; **c** 28–55 cm; **d** 55–80 cm; **e**–**f** 80–100 cm. Photos by L. Matchavariani

The "Raw-humus-calcareous" soil of Georgia was studied by Zakharov (1924), Talakhadze (1964), Sabashvili (1965), Chkheidze (1977), etc. Sabashvili was the first to explore the chemical content of this type of soil and to develop the issues of its classification; Talakhadze, together with the ordinary "Raw-humus-calcareous" soils, identified Rendzic Terra Rossa.

Rendzinas is mainly formed in the forest zone, over the parent materials enriched with $CaCO_3$ (gypsum, marble, dolomite, marl), and is characterized by a flushing or periodically flushing regime of moisture (Fig. 5.15). There are two main types of relief in the area with carbonate rocks: glacial and karst. The glacial relief is developed with old glaciers and it runs as a continuous strip in the high-mountainous region of

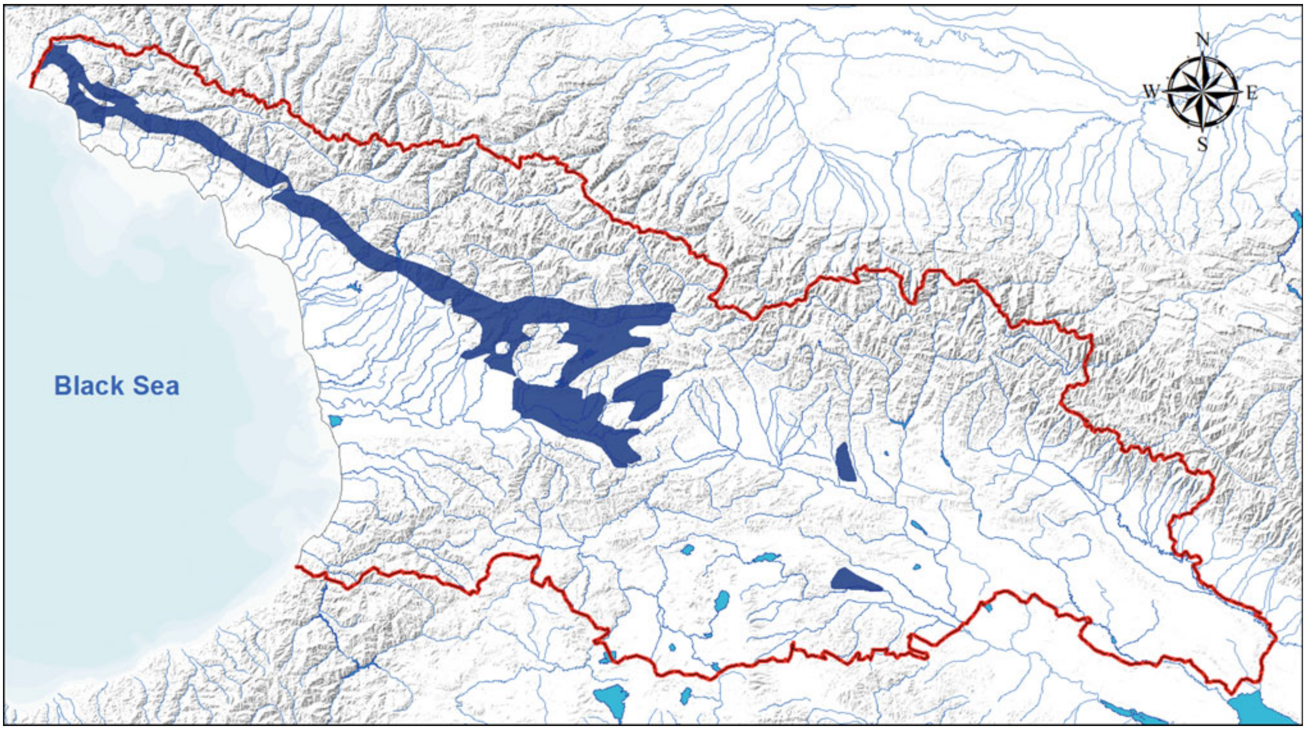

Fig. 5.14 Location of Rendzinas. This map is created by D. Svanadze, based on data of L. Matchavariani

Fig. 5.15 The landscape in the area of Rendzinas formation (Project "Cadastre and Land Registration", KfW)

West Georgia. Karst relief is widely spread in the middle zone and its development is associated with the sediments of a Cretaceous system. The relief in the area of these soils is of an erosive type and is presented as denudation, denudation-accumulation, and denudation-landslide forms.

The climate in the mountain–forest zone of Georgia, where the Leptosols Rendzic soil is widely spread, is moderately warm. The temperature of the coldest month is −1, −4 °C and that of the warmest month is +18, +20 °C. The sum of active temperatures is 2000–3500 °C.

Fig. 5.16 Profiles of Rendzinas soils. Photo by B. Kalandadze

The annual amount of atmospheric precipitations reaches 1400–1600 mm.

The vegetation in the region is presented by a hardwood forest (oak-and-hornbeam forests) with wide areas of grass. The cultivated areas are used to grow vineyard, orchards, bay trees, and other perennial plants.

The mentioned soils are characterized by a slightly differentiated profile (Fig. 5.16), which usually has the

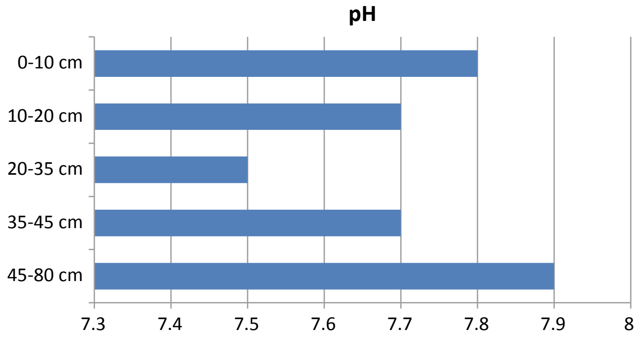

Fig. 5.17 pH distribution in profile of Rendzinas (according to data of T. Chkheidze)

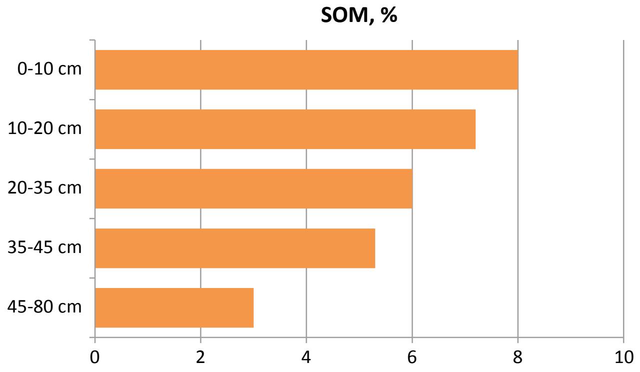

Fig. 5.18 Content of soil organic matter in Rendzinas (according to data of T. Chkheidze)

following structure: A–AB–CD or A–AB–BC or A–AC. The soil is distinguished for a clear accumulative horizon and granular or fine-cloddy-granular structure. Soils developed over the limestones are more skeletal than those developed over the marls. However, the latter type has a stronger profile than the former one.

As the analytical data suggest, Rendzinas is characterized by a neutral or weak alkaline reaction (Fig. 5.17). The soil organic matter is a humic type with an average or little content. In addition, the soil developed over the marls is distinguished for a less content of soil organic matter. As a rule, the soil is deeply humificated (Fig. 5.18). The amount of carbonates varies within great limits. The content of nitrogen is average or low and the amount of calcium constitutes 92% of the absorbing complex. The soils developed over the limestones are characterized by clay mechanical content, while those formed over the marls have a loamy texture. Rendzinas have a predominant content of silicate ferrum. The content of nonsilicate or amorphous ferrum is within the horizon transient to the maximum. The data of the gross chemical composition are presented in Table 5.3.

Rendzinas differ from the Cambisols Dystric soil by a dark color, alkaline reaction, weak argilization, and carbonate content.

The Leptosols Rendzic soil incorporates typical, leached and red (Terra Rossa) subtypes. The carbonates in the typical soils are spread on the surface or in the accumulative horizon and develop in the area of the Cambisols Dystric over such parent materials, which contain large amounts of calcium carbonates. The carbonates in the leached soil are found in the illuvial horizon and develop over relatively stronger elluvion-delluvion layer of the carbonate parent materials. Red-colored Terra Rossa develops over the dense limestones and marls and has a carbonate nature, red color, and weak acid or neutral reaction.

According to our previous micropedological study (Matchavariani 2008), the diagnostic properties of Rendzinas are black color of the upper portion of the profile, moder type of soil organic matter, carbonate nature of the whole profile, even saturation of the clay material with organic hydroxides, masking of optically oriented clay from carbonates, presence of microgranular calcite in the upper horizons, and reddish-chestnut color of the lower part of the profile as a result of the participation of R_2O_3 oxides and organic acids in the soil solutions.

5.5 Leptosols Molic

According to Georgian national soil classification, mountainous-meadow-chernozem-like soils, which correlate with WRB as Leptosols Molic, are spread in the Subalpine and Alpine zones of South Georgia (Fig. 5.19), at an altitude of over 1800(2000) m above sea level. This type of soil covers 1.6% of the total area of the country and borders primitive mountain-meadow soils of the nival, subalpine, and alpine zones and mountainous-forest-meadow soils of the subalpine zone (Fig. 5.20).

The abovementioned soil was the subject of study of I. Liverovskyi and V. Friedland. They associated the formation of this soil in the Caucasus with the rocks rich in carbonates, limestones, and carbonate slates. When studying the soils of the Caucasus, Zonn (1974, 1987) established that this soil is formed on the carbonate-free parent materials in the dry regions of high mountains. They are extracted on the erupted lava and tuffs on the South Caucasus Plateau. As the most recent studies suggest (Urushadze et al. 2010), most of these soils spread in Georgia belong to so-called Andosols, or soils formed in volcanic tephra, tuffs, pumice, and other effusive volcanic material, and partially, on other silicate sediments in terms of hilly or mountainous relief, under various thermal conditions and vegetation communities. Swift weathering of a porous substrate causes the accumulation of sustainable, organic mineral compounds, and origination of slightly crystallized minerals.

The principal diagnostic morphological features of the Leptosols Molic are clearly seen intense accumulative

Table 5.3 Gross chemical composition of Rendzinas, % (according to data of T. Chkheidze)

Horizon (cm)	Loss on ignition	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	SiO_2:R_2O_3	SiO_2:Al_2O_3	SiO_2:Fe_2O_3
0–10	26.90	56.4	11.8	7.4	0.60	19.7	1.76	5.85	8.18	20.63
20–40	26.62	60.7	12.7	6.7	0.62	15.0	1.39	5.99	8.09	24.10
60–80	25.84	42.6	4.6	4.0	0.36	45.1	1.08	10.13	15.75	28.36
110–150	32.36	44.4	8.2	4.9	0.44	37.6	1.68	7.39	9.23	24.63

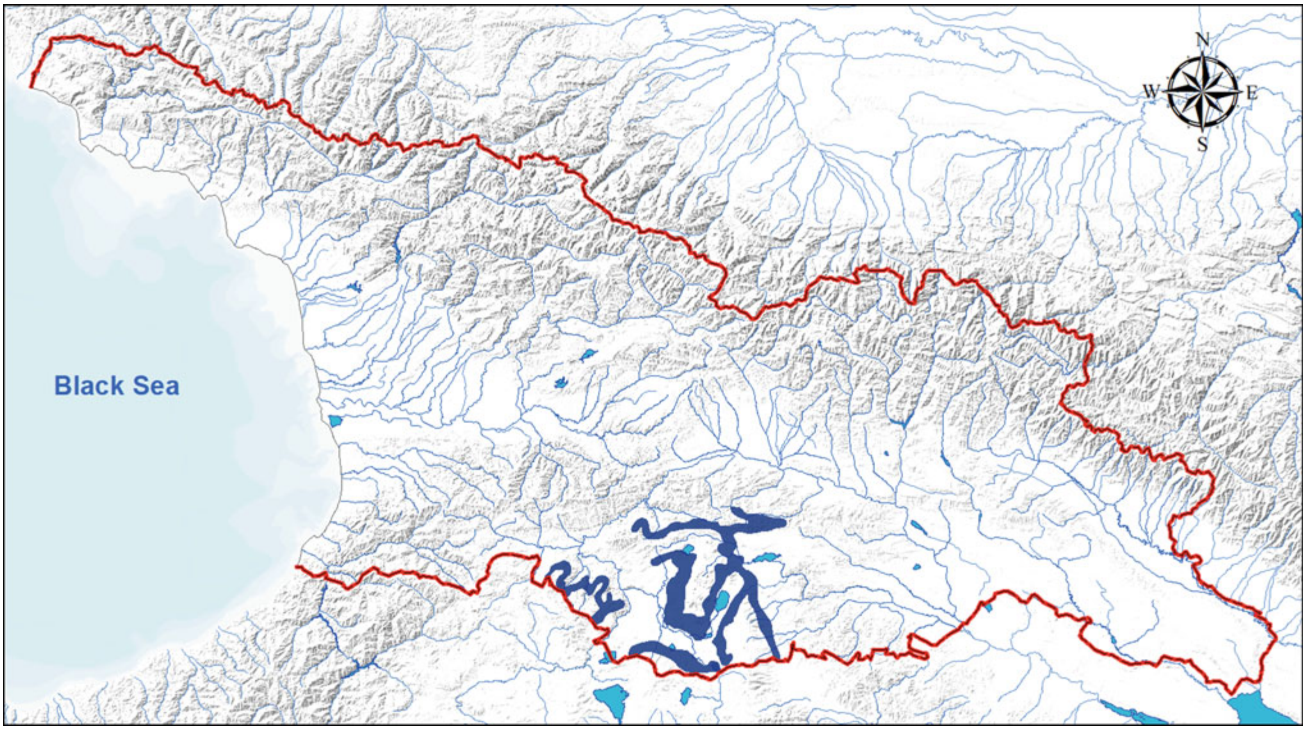

Fig. 5.19 Location of Leptosols Molic. This map is created by D. Svanadze, based on data of L. Matchavariani

Fig. 5.20 The landscape in the area of Leptosols Molic formation (Project "Cadastre and Land Registration", KfW)

Fig. 5.21 Profiles of Leptosols Molic soils. Photo by B. Kalandadze

horizon, little or average strength, and non-differentiated profile (Fig. 5.21) with the following structure: A_1'–A_1''–BC or A_1'–A_1''–B–BC.

The Leptosols Molic develops under alpine and subalpine stepped meadows and meadow steppes in high-mountainous regions and is used as pasture and hayfields consequently. The relief is a volcanic plateau, with its central part occupied by two meridian ridges of volcanic cones. The bedrocks are mainly presented by base volcanic rocks, andesite-basalts, and basalts.

The climate is cold with cool short summer and long severe winter. The temperature of the coldest month (January) is −7.8 °C and that of the warmest month (August) is +13.6 °C. Average annual temperature is +3.2 °C. The duration of the vegetation period is up to 4 months. The duration of the period without frosts is up to 2 months. Annual amount of precipitations is 600 mm. Maximum precipitations fall from April to June. Average annual relative air humidity is 78%; humidity coefficient is 1–3. The water regime of the soils is washing down and is periodically washing down in the moderately humid regions with a drough period.

As the analytical data suggest, the mentioned soil is characterized by weak acid reaction (Fig. 5.22), high content of humate type of soil organic matter (Fig. 5.23), deep humification, high absorption capacity, weak unsaturation, clay or loamy texture, higher content of sludge fraction and

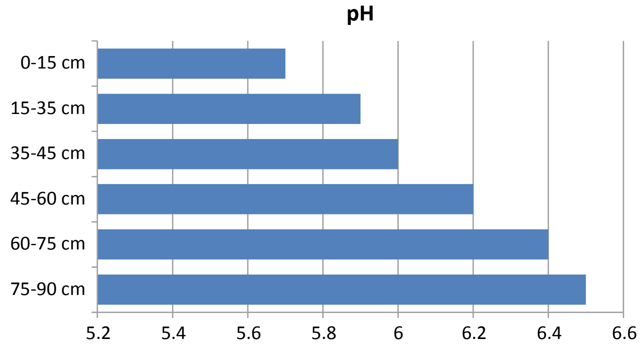

Fig. 5.22 pH distribution in profile of Leptosols Molic soil (according to data of T. Urushadze)

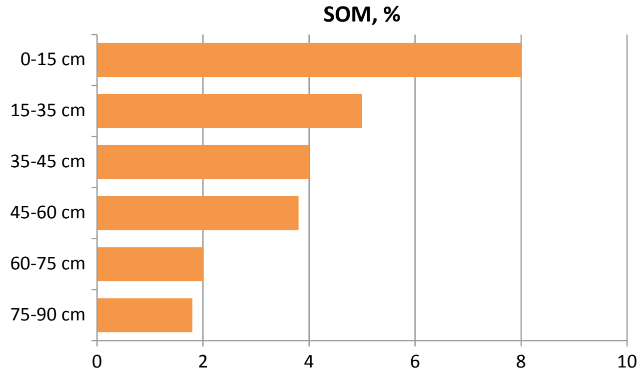

Fig. 5.23 Content of soil organic matter in Leptosols Molic soil (according to data of T. Urushadze)

physical clay at greater depths or in the middle of the profile, and bulk of hydromica in clay minerals. The data of the gross chemical composition are presented in Table 5.4.

Leptosols Molic differs from the neighboring Leptosols Umbric by a dark color, solid structure, weaker acid reaction, high absorption capacity, high content of soil organic matter, deep humification, and presence of humate type of soil organic matter, and it differs from the Chernozem by the absence of carbonates, more intense porosity, and less clear differentiation.

5.6 Chernozems

Chernozems of Georgia occupied 1.4% of the total territory of the country nature and are spread at 1200–1300 m asl (Fig. 5.24). In a national soil classification, they called as mountain Chernozems unlike the Vertisols (black soils) of plains. The mountain Chernozems are common over the volcanic plateau of the southern mountainous area of Georgia having a mountain plain (Fig. 5.25). These soils belong to the group of mountain-meadow steppe soils located between the mountain-forest and mountain-meadow soils of the subboreal zone.

The first researcher of the mountain Chernozems of Georgia was V. Dokuchaev. These soils were also studied by Zakharov (1924), Talakhadze (1962, 1964), etc.

The volcanic, mountainous region is built with andesite, andesite-basalt, and basalt rocks. They are covered with lacustrine sediments in the depressions. The presence of moraine sediments in the region evidences that the southern mountains were subject to the influence of the Glacial Age.

The origination of the Chernozems is associated with secondary meadow formation—the processes of retreat of the subalpine forests and evolution of the lakes. Typical and leached soils can be identified as subtypes of mountain Chernozems.

The area of mountain Chernozems spreads in the cold climate zone with an average annual temperature of +6 °C. The temperature of the warmest month is up to 17 °C and that of the coldest month is −7.5 °C. The vegetation period lasts up to 5 months. The annual amount of atmospheric precipitations is up to 800 mm, much of which falls as snow.

Following the climatic conditions, the processes of weathering and soil forming take an intense course, and consequently the soil is of a heavy texture, it is rich in clay minerals (montmori-llonite, illites, kaolin), and the thickness of its profile does not exceed 1 meter.

In a morphological respect, Chernozems are characterized by quite a strong black accumulative horizon, with a cloddy-nutty or prismatic structure and profile argilization (Fig. 5.26). The structure of the soil profile is A_1'–A_1''–AB–BC.

As the analytical data suggest, the mountain Chernozems are characterized by clay or heavy loamy texture. The silt fraction is usually equally distributed in the upper horizons and decreases gradually at greater depths. The soil has a weak acid, neutral or weak alkaline reaction (Fig. 5.27). It is enriched with bases and Fe-oxides; calcium is found in the greatest amounts in the exchange cations. The content of soil organic matter is high and soil organic matter penetrates deep in the profile (Fig. 5.28). The data of the gross chemical composition are presented in Table 5.5.

Table 5.4 Gross chemical composition of Leptosols Molic, % (according to data of T. Urushadze)

Horizon (cm)	Loss on ignition	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	MnO	CaO	MgO	Na_2O	K_2O	SiO_2: R_2O_3	SiO_2: Al_2O_3	SiO_2: Fe_2O_3
0–10	24.0	65.8	18.4	6.9	0.7	0.1	2.2	1.9	7.1	1.9	4 9	6.1	25.5
10–30	17.8	67.6	57.0	5.7	0.8	0.1	2.4	1.8	2.4	2.0	5.6	6.8	31.3
30–60	17.9	67.5	17.0	5.6	0.6	0.1	2.4	2.0	2.4	2.1	5.6	6.8	32.1

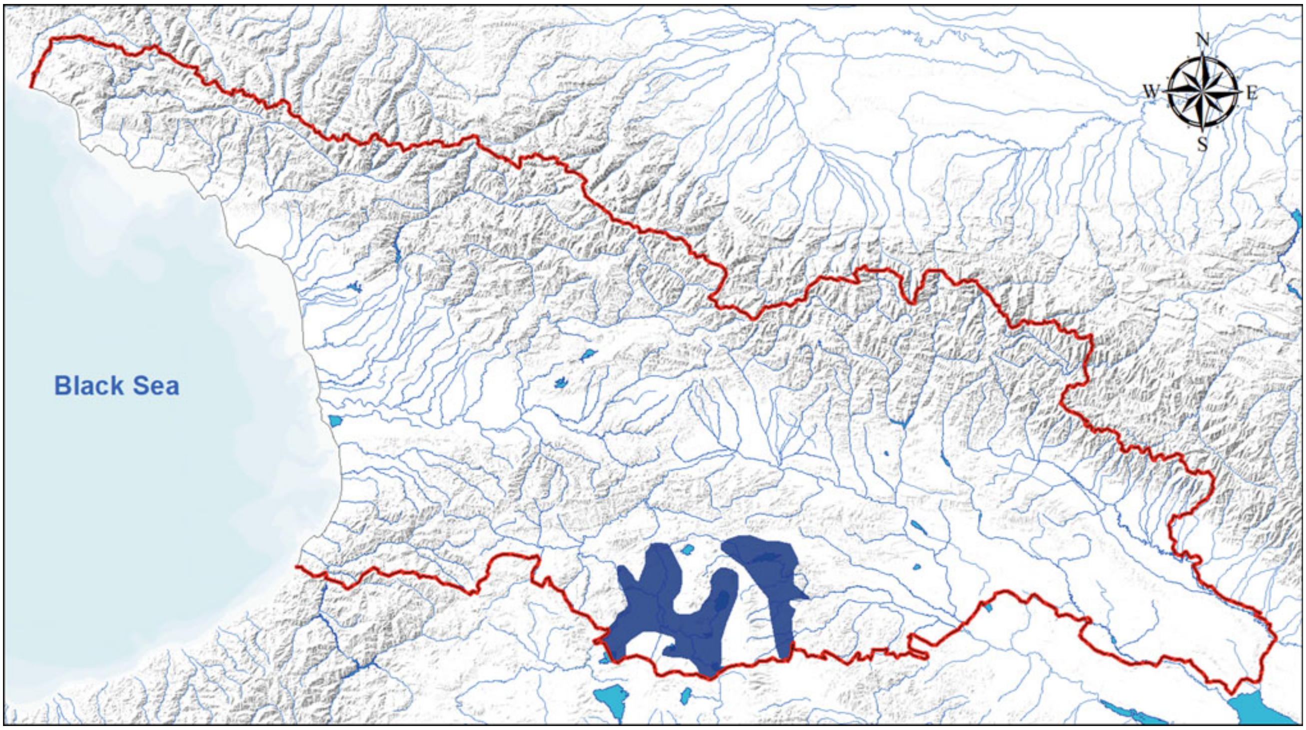

Fig. 5.24 Location of Chernozems. This map is created by D. Svanadze, based on data of L. Matchavariani

Fig. 5.25 The landscape in the area of Chernozems formation (Project "Cadastre and Land Registration", KfW)

Despite the fact that the Chernozems are considered a high-productive soil, their use is limited in agriculture due to the severe climatic conditions.

According to our previous micropedological study (Matchavariani 2008), the principal properties of the Chernozems' microstructure were identified: loose and sponge-like microstructure, plasma with an organic-clay content, mull-type organic matter strongly bound with clay, bulk of vegetation remains and excrements in the decomposition phase, presence of coprolite macro- and

Fig. 5.26 Profiles of Chernozems. Photo by B. Kalandadze

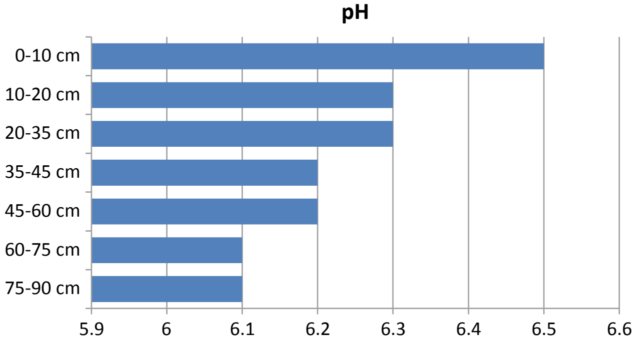

Fig. 5.27 pH distribution in profile of Chernozems (according to data of T. Urushadze)

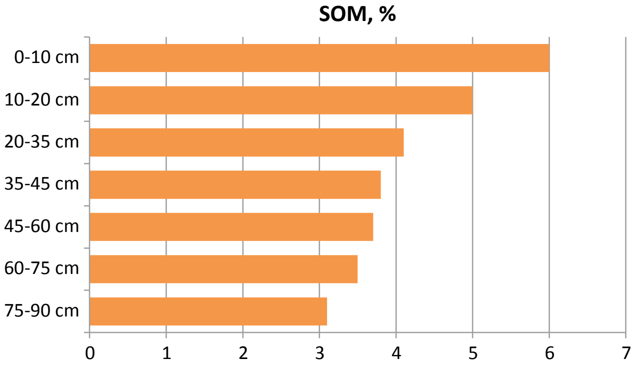

Fig. 5.28 Content of soil organic matter in Chernozems (according to data of T. Urushadze)

micro-aggregates, signs of intense pedogenic treatment from mesofauna, sandy-dusty-plasmatic elementary microstructure, light color at greater depths, carbonate-clay plasma, presence of ferrum and organic-Fe micro-concretions, presence of new carbonate formations as dispersed calcite grains, and presence of needle-like calcite in the pores.

Table 5.5 Gross chemical composition of Chernozems, % (according to data of T. Urushadze)

Horizon (cm)	Loss on ignition	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	$SiO_2:R_2O_3$	$SiO_2:Al_2O_3$	$SiO_2:Fe_2O_3$
0–15	15.0	60.4	18.9	8.7	0.4	3.7	3.1	5.3	4.2	18.5
15–35	14.7	60.4	18.9	8.9	0.4	3.3	3.2	5.3	3.7	18.3
35–65	14.0	61.2	19.3	8.9	0.4	3.2	3.1	5.4	4.1	18.4
65–90	14.0	58.9	20.9	8.8	0.3	3.2	3.2	4.9	3.8	17.8

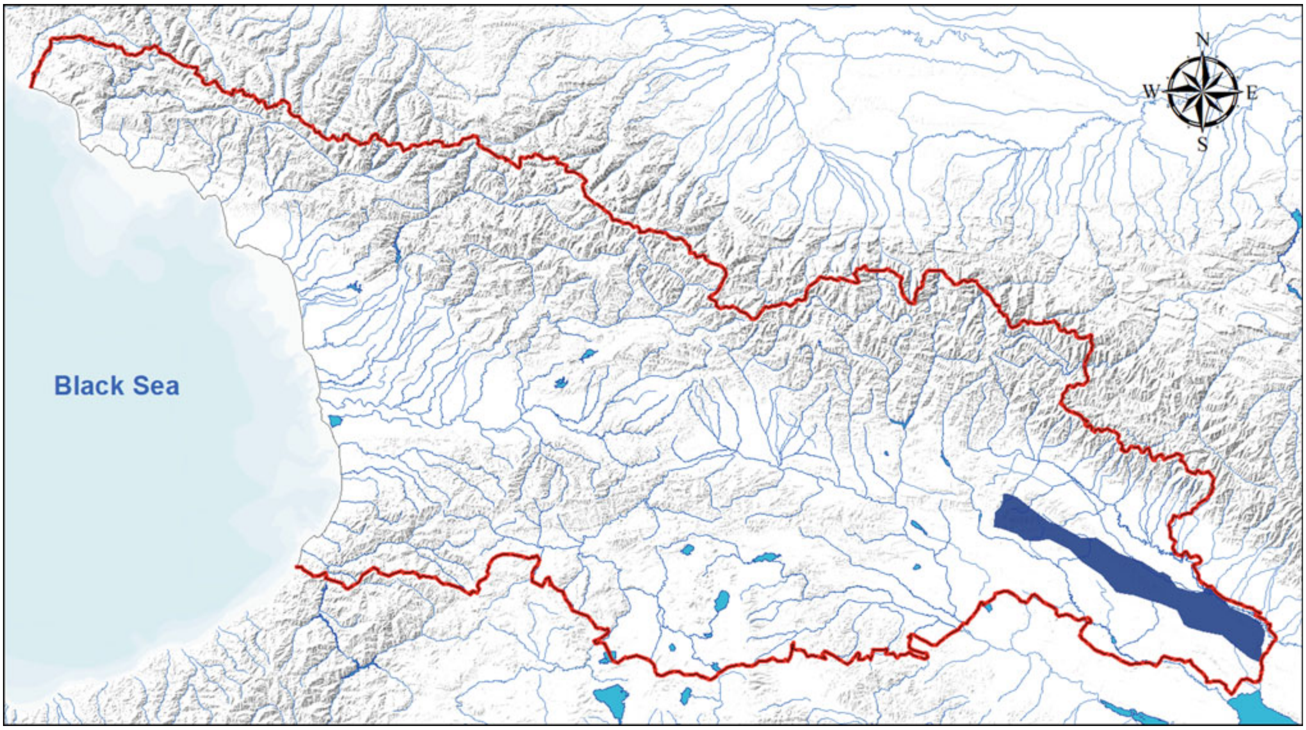

Fig. 5.29 Location of Vertisols. This map is created by D. Svanadze, based on data of L. Matchavariani

5.7 Vertisols

Vertisols, which are called in national soil classification as plain Chernosems, or Black soils, are spread in the intermontane zone of East Georgia (Kakheti, Shida Kartli, and Kvemo Kartli), in the dry subtropical steppes and occupy the area of 3.9% of the total territory of the country (Fig. 5.29).

The so-called Black soil of Georgia was studied by Zakharov (1924), Sabashvili (1948, 1965), Talakhadze (1962, 1964), Mardaleishvili (1973), Mardaleishvili and Pipia (1988), Mardaleishvili et al. (2005), Pipia (2008), etc.

As per Sabashvili (1948), the high content of gypsum in the loess-like sediments evidences that they are of a lacustrine origin. In opinion of Talakhadze (1962), the formation of one part of this soil is associated with the evolution of the alluvial plains, while the formation of another part is associated with the evolution of the lakes and relief forms of a depression type. It was him to develop the classification of this type of soil.

The zone of the Vertisols is formed by denudation-accumulation and accumulation-genetic geomorphological types. The relief forms of the intermontane lowland zone in East Georgia are relatively younger and belong to the Upper Tertiary and Quaternary Ages (Fig. 5.30). The deluvial–proluvial sediments are widely spread on this territory. The zone where this is spread contains also a sloping terrace-like plain, with its hypsometric levels varying between 650 and 750 m above sea level. The accumulation relief types are widely spread in the area where the Black soil is spread.

The Vertisols develop in terms of dry subtropical climate, with winter with almost no snow and hot, dry summer, where the average annual temperature is +10, +12 °C; the temperature of the warmest month (June) is +23 °C and that of the coldest month (January) is −0.3, −4 °C. The sum of

Fig. 5.30 The landscape in the area of Vertisols formation (Project "Cadastre and Land Registration", KfW)

Fig. 5.31 Profiles of Vertisols. Photo by B. Kalandadze

active temperatures reaches 4000 °C; the duration of the vegetation period is 6 to 7 months. The atmospheric precipitations usually fall as rain, with the average annual amount of 400–600 mm. The precipitation minimum is fixed in winter months, and the maximum is fixed in the May or June. During the year, the evaporation exceeds the amount of the atmospheric precipitations (consequently, the humidity coefficient is 0.3–0.9). Average annual relative air humidity is 64–70%. During the year, the soil temperature does not fall below 0 °C, and as a result, the soil biogenicity

Table 5.6 Gross chemical composition of Vertisols, % (according to data of A. Nanaa)

Horizon (cm)	Loss on ignition	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	SO_3	$SiO_2:R_2O_3$	$SiO_2:Fe_2O_3$
0–20	18.8	63.8	15.9	5.9	4.2	3.3	1.4	3.7	1.0	5.5	29.1
20–40	17.0	63.3	16.0	6.7	3.3	3.2	1.5	4.0	1.1	5.3	25.1
40–60	16.1	60.4	16.0	6.8	4.9	2.9	1.6	3.4	3.5	5.0	23.6
60–100	17.1	62.2	15.3	7.3	5.0	2.8	1.6	3.2	1.9	5.3	22.7
100–125	17.1	61.4	15.5	7.4	3.7	3.4	1.7	3.1	2.6	5.2	22.1
125–150	16.8	60.4	15.4	7.8	3.7	3.7	2.4	3.2	2.1	5.1	20.7

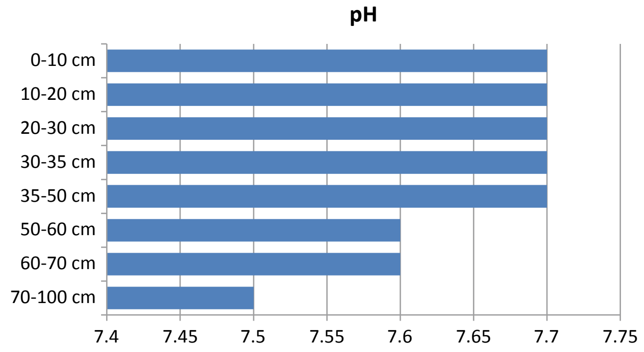

Fig. 5.32 pH distribution in profile of Vertisols (according to data of A. Nanaa)

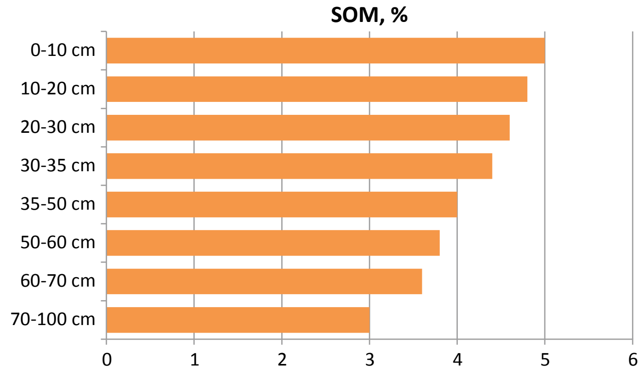

Fig. 5.33 Content of soil organic matter in Vertisols (according to data of A. Nanaa)

is quite high during the year and the soil-forming processes take place all year long with different intensities.

The Vertisols are spread in dry subtropical steppes, and as Ketskhoveli (1935) states, it is classified as two groups: of the primary and of the secondary origin. The steppe vegetation is made up of thornbush, beard grass, feather grass, and grasslands.

In a morphological respect, the Vertisols of Georgia divide into a typical, carbonate, leached, and meadow-gleied subtypes. The morphological structure of the profile is A_1'–A_1''–AB–B–BC–C. The principal diagnostic indicators of these soils are the black color of the upper layers, argilization, and carbonization (Fig. 5.31). Vertisols are distinguished by a strong accumulative horizon and increasing density at greater depths, characterized by a clear accumulative horizon, cloddy-granular and nutty-prismatic structure at greater depths, heavy texture, signs of compactness, carbonate-illuvial horizon, and white spots of carbonates.

The data of the gross chemical composition of Vertisols are presented in Table 5.6. As the analytical data suggest, the Vertisols are characterized by the weak alkaline reaction, with the calcium carbonates spread right from the surface with a gradually increasing content at greater depths (Fig. 5.32). As for the soil organic matter, its content shows an opposite trend and decreases as the depth increases. The SOM is of a humatic type, with little content of mobile humic acids evidencing the high stability of soil organic matter (Fig. 5.33). The silt fraction contains great amounts of R_2O_3; besides, the content of SiO reduces at greater depths, while that of Fe_2O_3 increases gradually. A dominant Fe-form is a silicate one fixed in the middle part of the profile, while amorphous forms are accumulated in the upper horizons.

The texture of Vertisols is classified as light and average clays. The content of physical clay reaches 60–80%. They are characterized by a high content of sludge fraction.

With its mineralogical content, the light fraction is presented by quartz, feldspars, and fractures with clay and earth silicon; the coarse fraction is presented by magnetite-ilmenite, augite, zircon, biotite, and anhydride. Clay minerals are presented by smectites and illites, while chlorite, kaolin, feldspars, and quartz are spread as admixtures. This type of soil is characterized by a greater content of a silicate ferrum as compared to that of a nonsilicate ferrum. Amorphous ferrum is fixed in little amounts and is accumulated in the upper part.

Unlike the mountain Chernozems, the texture of the Vertisols is heavier, with more intense argilization and compactness; the content of Fe-forms is high and the soil is sometimes characterized by the accumulation of easily soluble salts. They distinguish between the typical, carbonate, leached, and meadow-gleized soil subtypes.

According to our previous micropedological study (Matchavariani 2008), the Vertisols of Georgia are

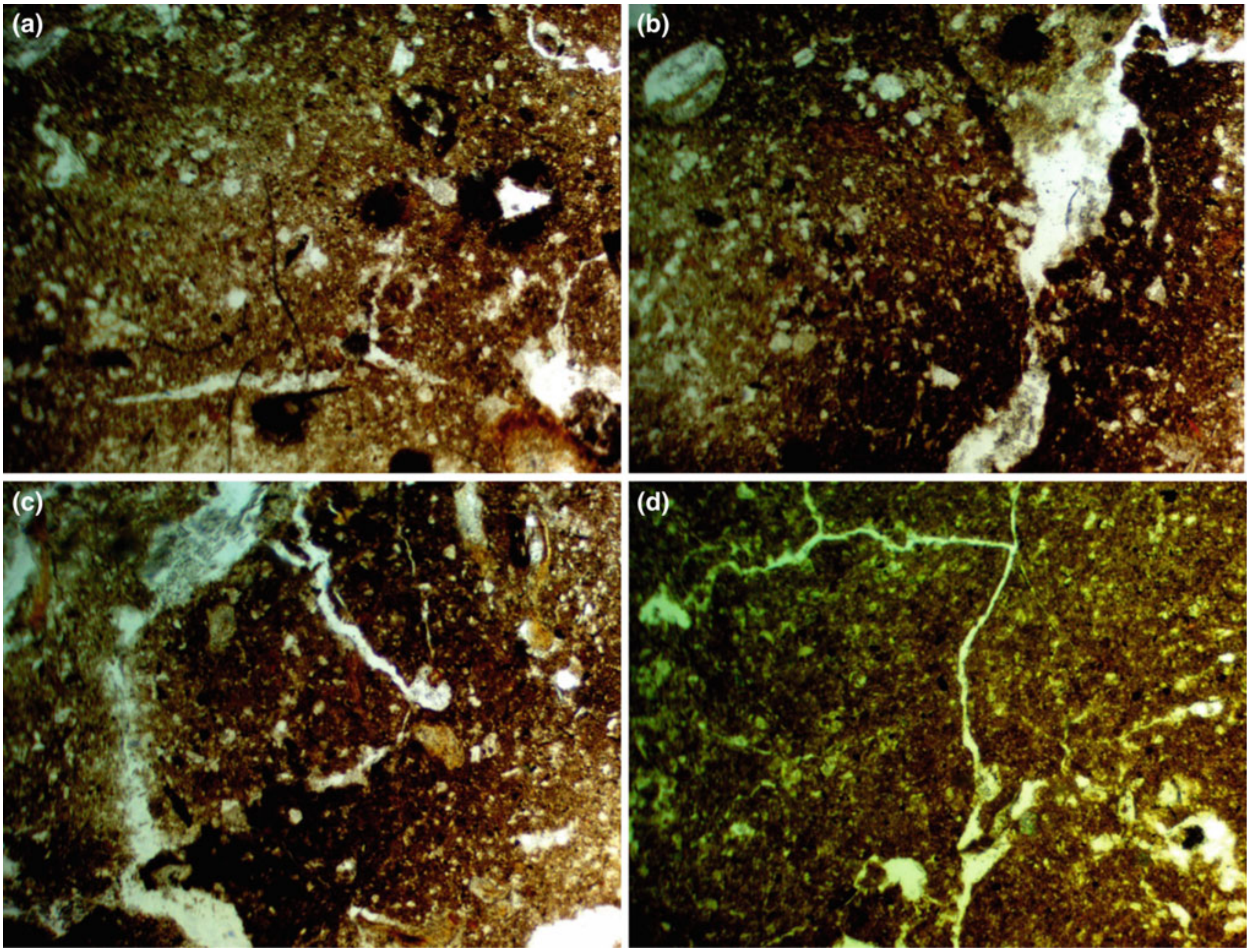

Fig. 5.34 Microstructure of Vertisols, nic.II; Pit-66, horizons: **a**–**b** 0–6 cm; **c** 15–20 cm; **d** 20–25 cm. Photos by L. Matchavariani

characterized by loose, fragmental, and compact microstructure, with a dark, chestnut-brownish mass, channel-like pores of irregular shapes, fine biogenic aggregation, organic-clay or carbonate-organic-clay plasma structure, mull-type of organic matter, remains of coprolites, fine microzones of organic matter and intensely decayed vegetation remains, carbonate nature of the main mass seen as fine-grain calcites, with the weak optical orientation, dusty-plasmatic elementary microstructure, significant densification, and intensified carbonate content at greater depths (Fig. 5.34).

5.8 Cambisols Chromic

Cambisols Chromic, called as Cinnamonic soils, are spread in the subtropical forest-steppe zone of East Georgia, at the altitude of 500(700)–900(1300) m above sea level (Fig. 5.35). Its lower border adjoins Kastanozems and Vertisols and its upper limit adjoins the Cambisols Dystric soils. They cover 4.8% of the total territory of the country.

The first who reflected the “Cinnamonic” soil on the Trans-Caucasus soil map were S. Zakharov (1924) and M. Sabashvili (1939, 1948). They made a valuable contribution to the study of this type of soil. I. Gerasimov theoretically confirmed the necessity to classify this soil as a type of its own genesis. The properties and peculiarities of abovementioned soils were studied by Anjaparidze (1979), Nakaidze (1977), Urushadze (1987, 1997), and others.

Cambisols Chromic are formed in a dry subtropical climate with warm winter, almost without snow and hot, dry summer with an average annual temperature of +9 to 12.5 °C. The duration of the vegetation period is up to 7 months. The sum of active temperatures is 2800–3800 °C. The amount of average annual precipitations is 300–800 mm, with two maximums at the end of spring and at the beginning of autumn. The humidity coefficient is 0.5–0.8, i.e., evaporation exceeds the amount of fallen precipitations.

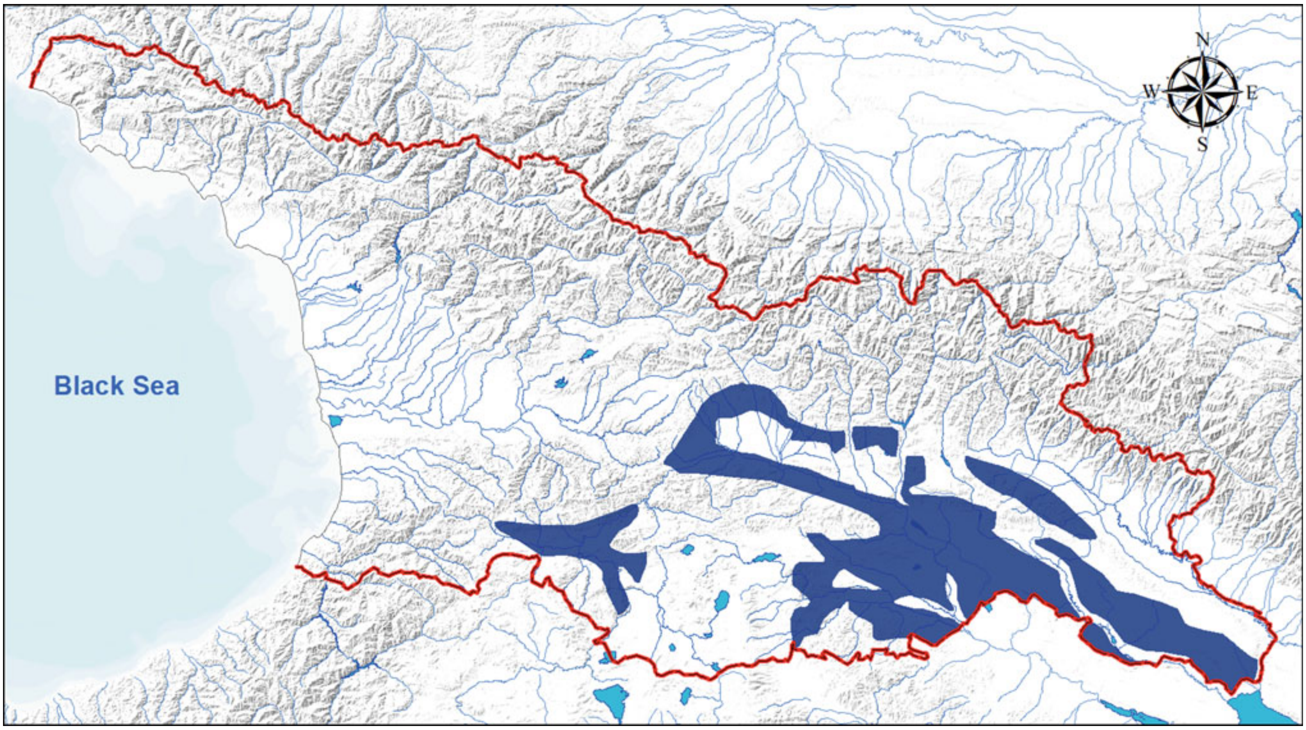

Fig. 5.35 Location of Cambisols Chromic. This map is created by D. Svanadze, based on data of L. Matchavariani

The geology of the northwestern and northeastern areas of the region is mainly presented by sandy clay and volcanogenic formations of the Paleogene Age and conglomerates, sandstones, and limestones of the Neogene Age. Inclined slopes and trains are presented by alluvion. The geology of the southern and southwestern areas of the region is presented by volcanogenic rocks of the Neogene Age: porphyry tuffs, lava flows, Upper-Cretaceous limestones, etc. The climate, which is peculiar as it is rich in parent material cations, promotes the formation of the weathering crust rich in carbonates.

The formation of the largest areas of the relief is mostly associated with erosive processes. At some locations, the relief is presented as landslide forms. The slopes are crossed by a number of wide gullies at many places. In the lower zone of some slopes, there are whole formations of flattened platforms observed.

The vegetation is presented by sparse arid and oak forests (Fig. 5.36). Sparse arid or light forests belong to the savannas of the subtropical climate. The grass cover is mainly presented by yellow bluestem. All plant species in the area are light demanding and drought resistant with a strong root system.

The age of soil formation in Cambisols Chromic is great. It is divided into light, carbonate, typical, alkaline, and Rendzic-Brown subtypes. Most of the areas of Cambisols Chromic are cultivated and the existing landscapes are almost totally anthropogenic.

Morphologically, the profile of the so-called Cinnamonic soil has a clear differentiation with the following common structure: $A–B_{Ca}–BC(BC_{Ca})–C_{Ca}$. The main diagnostic properties are clearly observed accumulative horizon, dark grayish-brown color, cloddy structure, heavy texture (clay and heavy loam), metamorphous horizon, and profile carbonization (Fig. 5.37). As for the gross chemical composition, the data are presented in Table 5.7.

As the analytical data suggest, the Cambisols Chromic soil is characterized by a light alkaline or neutral reaction (Fig. 5.38). Alkalinity increases at greater depths. The content of soil organic matter is average, but the soil is deeply humificated. Carbonate subtype contains carbonates right from the surface, while typical soils contain them from horizon AB and alkaline soils contain them from horizon C. Calcium carbonates form carbonate-illuvial horizon at some depth. The content of silicate iron exceeds that of nonsilicate iron. Besides, free (amorphous and crystallized) iron is accumulated in the upper part of the profile. The hydrothermal regime of Cambisols Chromic soil supports deep weathering of the primary minerals. Among sludge fraction minerals, montmorillonite and hydromica are found in the largest amounts. The hydro-physical properties of the mentioned soil are quite favorable. These soils have their

Fig. 5.36 The landscape in the area of Cambisols Chromic formation (Project “Cadastre and Land Registration”, KfW)

Fig. 5.37 Profiles of Cambisols Chromic. Photo by B. Kalandadze

Table 5.7 Gross chemical composition of Cambisols Chromic, % (according to data of A. Nanaa)

Horizon (cm)	Loss on ignition	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	SiO_2: R_2O_3	SiO_2: Al_2O_3	SiO_2: Fe_2O_3
0–14	14.6	61.1	20.3	8.4	2.7	1.7	2.81	1.87	4.1	5.1	19.5
14–28	14.4	61.7	20.1	8.9	2.4	1.5	2.33	1.87	4.1	5.2	18.6
28–43	13.2	61.4	20.0	8.0	2.7	2.2	2.53	1.96	4.2	5.2	20.4
43–75	11.6	61.3	19.6	8.7	2.8	1.8	2.72	1.92	4.1	5.3	18.8
75–100	12.9	60.6	19.5	8.8	3.2	1.9	2.78	1.94	4 1	5.3	18.4

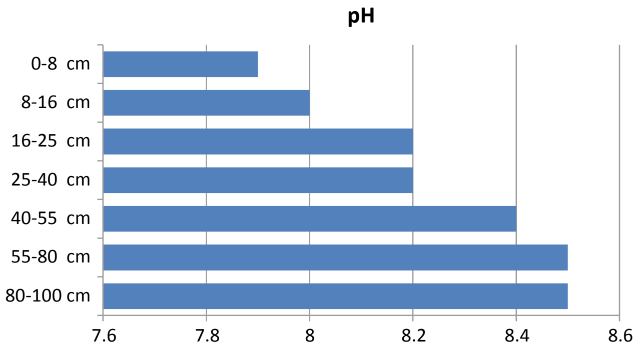

Fig. 5.38 pH distribution in profile of Cambisols Chromic (according to data of A. Nanaa)

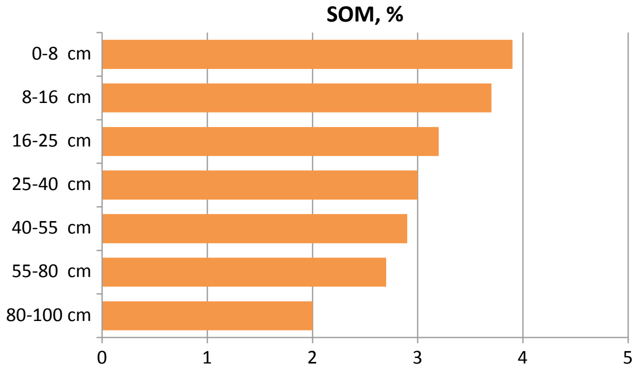

Fig. 5.39 Content of soil organic matter in Cambisols Chromic (according to data of A. Nanaa)

greatest density in Horizon B. General porosity is 40–52% and the least moisture content is 30–45%.

Unlike the “Meadow-cinnamonic” subtype, Cambisols Chromic is characterized by a clearer argilization and great amount of new carbonate formations. Unlike the Kastanozems (which has less moisture and is formed in terms of higher thermal provision), they have a lighter color, higher content of soil organic matter (Fig. 5.39), strong accumulative horizon, presence of carbonates at different depths in some subtypes, and less content of different forms of iron. Unlike the Vertisols, formed in similar terms of humidification, the Cambisols Chromic has a horizon with less soil organic matter, brown color, grain and prismatic structure, compacted and metamorphous horizon, with a less sharp transition from the accumulative horizon to the lower layers, less porosity, and water conductivity.

Unlike the Cambisols Dystric, formed under colder and more humid conditions, the Cambisols Chromic has a brown color, illuvial-carbonate horizon and intense argilization of the central part of the soil profile, less content of soil organic matter in the upper horizon, alkaline and neutral reaction, etc.

The Cambisols Dystric has quite high productivity and together with Vertisols and Chernozems is the most productive soil on the territory of the country. With its agricultural properties, it is one of the most favorable soils to grow high-productive vine and fruit. This soil is also used to grow cereals, vegetable, and other crops.

According to our previous micropedological study (Matchavariani 2008), the diagnostic properties of Cambisols Chromic are dark chestnut homogeneous structural anisotropic plasma; loose and sometimes spongy microstructure with the participation of complex aggregates of an irregular form; dusty-plasmatic elementary microstructure; presence of mull-type soil organic matter evidenced by the saturation of plasma with dark disperse organic substance and presence of numerous fine spots; organic-clay content of the main mass and weak optical orientation; presence of dispersed fine-grain calcites in plasma, bulk plasma on skeleton, almost total carbonization of plasma at great depths (carbonate content of the carbonate subtypes from the surface), etc. (Fig. 5.40).

In the area of the Cambisols Dystric, soils in the lower parts of relief are formed so-called meadow-cinnamonic soils. They are common in Kvemo Kartli and Zemo Kartli, Kakheti (on the right bank of the Alazani River) and Meskheti; present in the subtropical forest-and-steppe zone of Georgia, with a higher ground and surface humidity and occupied 2% of the total territory of the country. Sometimes this soil considers as subtype of “Cinnamonic” soils.

Fridland was the first to classify these soils in Georgia as Meadow-Cinnamonic soils as a soil type of the plains and foothills in East Georgia. Sabashvili (1948, 1965) referred to them as an “old alluvial meadow”. Later (in 1965), he called them as Meadow-Cinnamonic soils. M. Sabashvili identified

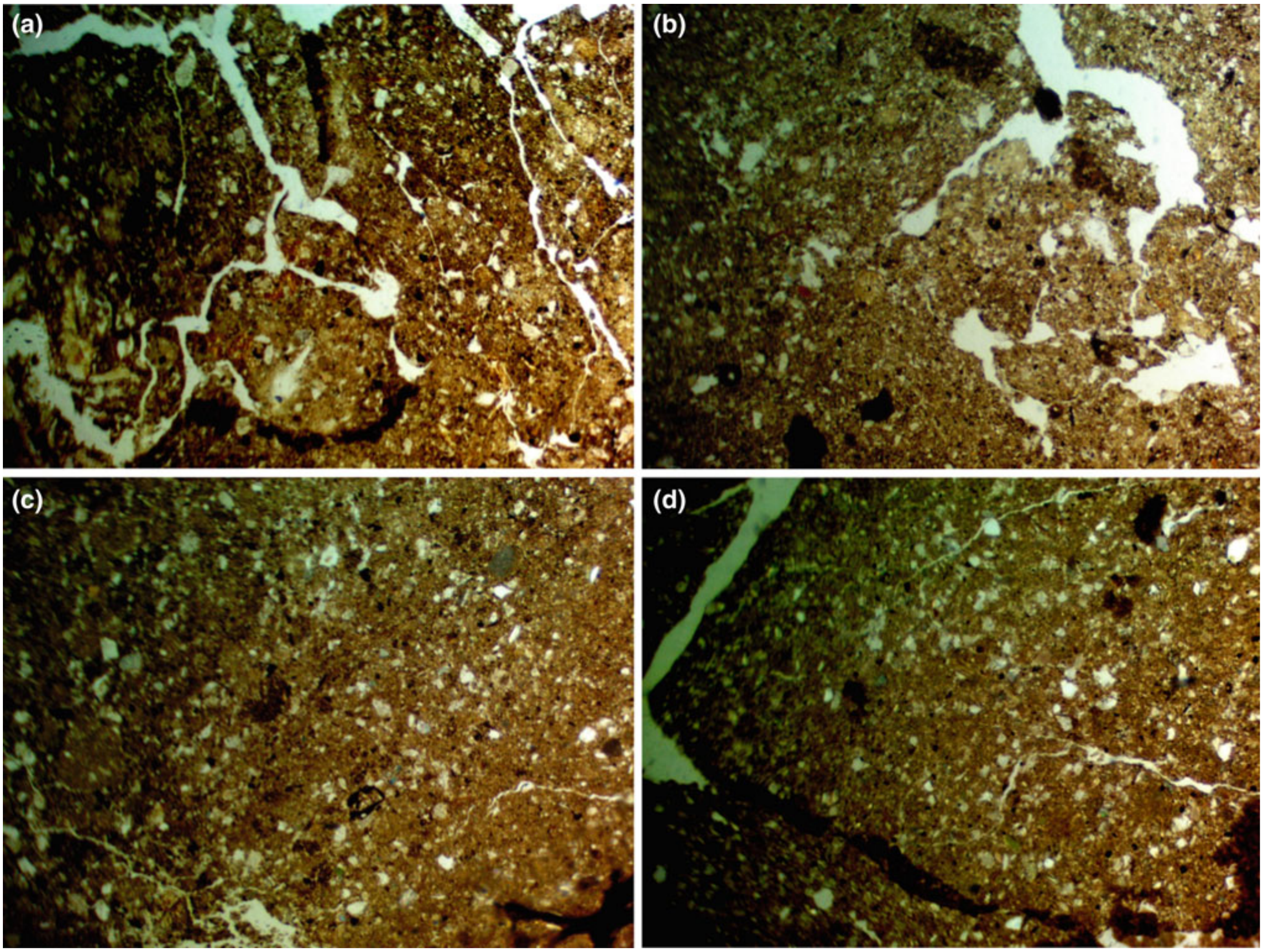

Fig. 5.40 Microstructure of Cambisols Chromic soils, nic.II; Pit-17, horizons: **a** 0–10 cm; **b** 22–27 cm; **c** 57–68 cm; **d** 80–128 cm. Photos by L. Matchavariani

two stages in the genesis of these soils: (1) the stages of the development of alluvial floodplain and meadow soils toward the “Cinnamonic” soils are clearly seen and (2) under the climate and human impact, the forest vegetation tends to change by the steppe vegetation. Talakhadze (1964) considered this type of soil as the step following the “Cinnamonic” soil evolution, as a partial elevation of the groundwater level supported the process of meadow formation and directed the development of the “Cinnamonic” soil towards the “Meadow-cinnamonic”. These soils were also studied by Nakaidze (1977), R. Kirvalidze, K. Mindeli, E. Lataria, etc.

The soil-forming parent materials spread in the area of so-called meadow-cinnamonic soils are presented by strong alluvial and deluvial–proluvial deposits of a heavy texture and stone admixtures. The climate is moderately warm. Average annual temperature is 10–11 °C; the sum of active temperatures is 2800–3800 °C; the duration of the vegetation period is 6 to 7 months; the amount of precipitations varies between 460 and 520 mm; and the humidity coefficient is 0.5–0.9. The natural vegetation is presented by floodplain forest (oak forests). The major part of the area is used as arable lands, orchards, or vineyards and is mostly irrigated (Fig. 5.41).

The difference between the “Cinnamonic” and “Meadow-cinnamonic” soils is that the latter has a darker color, the signs of gleyzation expressed as bluish or rusty-colored spots, by less argilization and presence of new carbonate formations.

Morphologically, the mentioned soils have a dark brown color and slightly differentiated and relatively stronger profile than the brown soils; signs of gleyzation almost through the whole profile, heavy texture, carbonization of the whole profile, and slightly expressed carbonate-illuvial horizon (Fig. 5.42). The morphological structure of the profile is A–AII–AB–$B_{Ca(g)}$–$BC_{Ca(g)}$.

Based on the profile analysis of “Meadow-Cinnamonic” soils, they are characterized by alkaline or weak alkaline reaction, with little sum of absorbed bases and little content of soil organic matter in the arable horizon, but by deep

Fig. 5.41 The landscape in the area of “Meadow-cinnamonic” soil formation (Project “Cadastre and Land Registration”, KfW)

Fig. 5.42 Profiles of “Meadow-cinnamonic” soil. Photo by B. Kalandadze

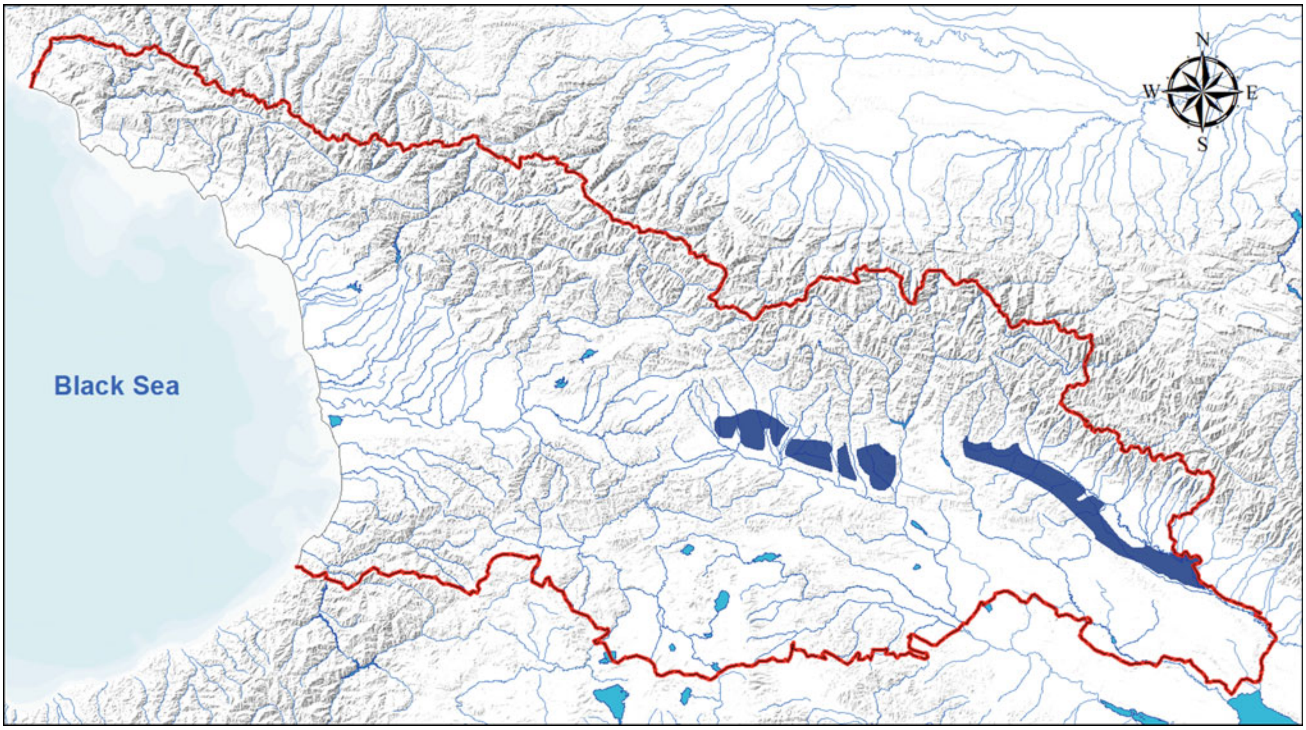

Fig. 5.43 Location of Kastanozems. This map is created by D. Svanadze, based on the data of L. Matchavariani

humification. Carbonates are observed right from the surface, with their amount significantly increasing in the bedrock. With their texture, soils belong to the category of light and average clay. A dominant part in the mineralogical content of silt is hydromicas. Argilization is clearly observed in the middle portion of the profile. Silicate exceeds non-silicate one with its maximum in the mid-profile.

According to our previous micropedological study (Matchavariani 2008), "Meadow-Cinnamonic" soil characterized by: slight aggregation of upper horizons, dark chestnut homogeneous structural mass; loose and sometimes spongy microstructure with the participation of complex aggregates of an irregular form; fragmental porosity, with the participation of dusty-plasmatic elementary microstructure; presence of inter-aggregate porosity; saturation of plasma with dark disperse soil organic matter substance and presence of numerous fine organic spots; organic-clay content of the main mass and weak optical orientation; presence of individual organic-iron spots; slight optical orientation of fine-disperse substance; high content of calcite microcrystal; presence of dispersed fine-grain calcites in plasma, bulk plasma on skeleton, almost total carbonization of plasma at great depths (carbonate content of the carbonate subtypes from the surface); dense illuvial horizon, etc.

5.9 Kastanozems

Kastanozems, which correlate with the national classification as Gray-Cinnamonic soils, are common in the dry steppes of the subtropical zone of southeast Georgia (Fig. 5.43). They border Vertisols, Cinnamonic, Meadow-Cinnamonic soils. The area occupied by the Kastanozems in Georgia is 9.1% of the total territory of the country.

First, this type of soil was studied by Zakharov (1924) under the name of Kastanozems. D. Gedevanishvili was the first soil scientist to use term Gray Cinnamonic with the modern meaning. The initiative to classify the Gray-Cinnamonic soils as an individual zonal type of soil belongs to A. Rozanov. These soils were thoroughly studied by Sabashvili (1948), Nakaidze (1977), etc.

Kastanozems of Georgia have an old age. They are formed in terms of moderately dry subtropical climate with the average annual temperature of 12–13 °C. The sum of active temperatures is 4000–4500 °C; the duration of the vegetation period is more than 7 months; the average annual amount of precipitations is 300–500 mm with its maximum in spring and autumn; the humidification coefficient is 0.4–0.6; the relief is presented as plains, piedmonts, and low

Fig. 5.44 The landscape in the area of Kastanozems formation (Project "Cadastre and Land Registration", KfW)

mountains; the soil-forming parent materials are presented by proluvial, alluvial, and eluvial–deluvial deposits of different granular, mineralogical, and chemical contents (sometimes, saline); the vegetation is a dry-steppe one. Most of the territory is used as arable or sowing lands to grow agricultural crops (wheat, barley, maize, and sunflower). A relatively small area is occupied by perennial plants (orchards and vineyards). A large area is used as winter pastures (Fig. 5.44).

The properties of Kastanozems soil are associated with modern bioclimatic conditions. The process of soil formation mainly takes place in terms of severe moisture deficit. Consequently, the vegetation remains, and newly formed soil organic matter are subject to intense mineralization. The peculiarities of the dry subtropical climate (high temperature combined with short humidification periods) result in intersoil weathering by accumulation of clays, Fe-hydroxides and carbonates. In humid conditions, the soil solutions (with dominant calcium and manganese hydrocarbon content) have a descending dislocation, while in dry periods, they have an ascending dislocation. One of the main properties of the Kastanozems is the spaciousness of a carbonate-illuvial horizon.

Morphologically, Kastanozems soil has a brown or grayish color; it is slightly differentiated, mudded, with carbonate and little accumulative horizons, presence of soil organic matter and carbonate horizons, well-expressed argilization in the middle part of the profile and presence of carbonates right from the surface (Fig. 5.45). The morphological profile of the soil usually has the following structure: A_{Ca}–Bm_{Ca}–BC_{Ca}, or A1′–A1″–AB–$B1_{Ca}$–C1–C2.

As the analytical data suggest, Kastanozems have weak alkaline or alkaline reaction and little content of soil organic matter—type of soil organic matter: fulvous humate (Figs. 5.46 and 5.47). The upper and middle parts of the profile have heavy clay texture, which is lighter in the lower part. The argilization of the middle part of the profile is one of the diagnostic properties of this soil. The main oxides are distributed evenly in the profile. The content of carbonates varies from 4 to 23%. Generally, the carbonates are fixed from the surface, and in this way, these soils differ from the soils found in dry subboreal steppe zone. The absorption complex is saturated with bases. Calcium dominates in the exchange cations. The content of calcium decreases at the expense of the increased content of exchange manganese at greater depths. Exchange sodium is a part of the absorption complex of Kastanozems. Montmorillonite and hydromicas dominate in the silt fraction, while the content of kaolin, quartz, and other minerals is low. The content of silicate iron is more than that of a nonsilicate Fe in the Kastanozems. The maximum content of ferrum is observed in the upper part of the soil profile. The data of the gross chemical composition are presented in Table 5.8.

Unlike the Cambisols Chromic, which are formed in terms of higher humidification and less thermal provision, the Kastanozems are characterized by a darker color, less content of soil organic matter, the carbonate nature of the whole profile, and higher alkalinity. They differ from the Vertisols by a less strength of an accumulative horizon, lighter texture, and presence of an illuvial-carbonate horizon.

According to our previous micropedological study (Matchavariani 2008), Kastanozems is characterized by a

Fig. 5.45 Profiles of Kastanozems. Photo by B. Kalandadze

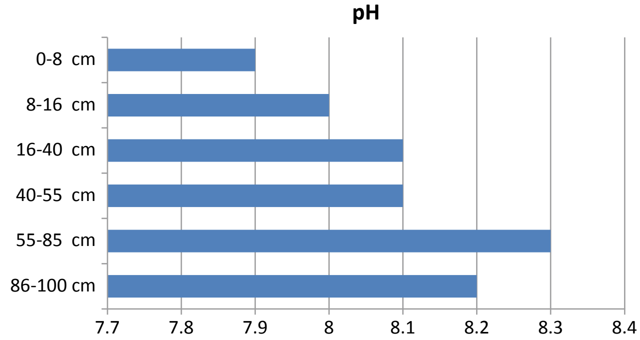

Fig. 5.46 pH distribution in profile of Kastanozems (according to data of A. Nanaa)

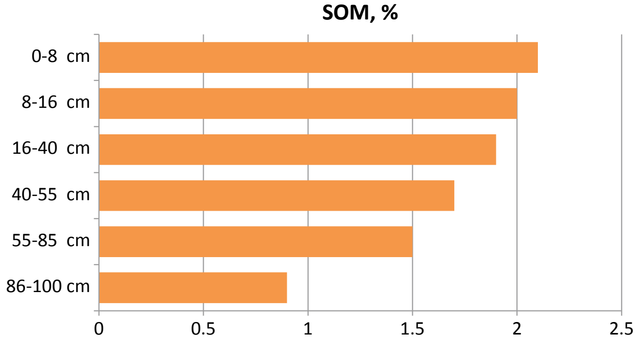

Fig. 5.47 Content of soil organic matter in Kastanozems (according to data of A. Nanaa)

cloudy structure, inter-aggregate, and fracture porosity at some locations, moder-mull or mull-moder morphological type of SOM, elementary sandy-plasmatic microstructure, soil organic matter coloration, mineralization of most organic remains, organic-carbonate-clay content of plasma, point structure of optical orientation and presence of dispersed grains of fine-crystal calcite in the arable horizon; by compact microstructure and increased clay content, carbonate-clay plasma, presence of numerous nodules of fine-grain calcite, point and mixed-fiber structure in the carbonate horizon; and by less argilization of fine-disperse mass and lower optical orientation of carbonate-clay plasma and dusty-plasmatic elementary microstructure in the lower horizons.

In the area of Kastanozems, in the lower parts of relief, in terms of higher humidification, there are spread so-called Meadow-Gray-Cinnamonic soils. They are common in the

Table 5.8 Gross chemical composition of Kastanozems, % (according to data of A. Nanaa)

Horizon (cm)	Loss on ignition	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	SiO_2: R_2O_3	SiO_2: Al_2O_3	SiO_2: Fe_2O_3
0–20	14.4	62.0	17.0	8.2	2.8	3.6	2.7	2.9	4.7	6.2	20.1
20–40	13.9	61.1	17.2	8.1	3.4	3.3	3.1	3.1	4.7	6.0	20.3
40–55	14.7	60.5	16.8	7.9	4.0	3.7	3.4	2.8	4.7	6.1	20.5
55–90	13.9	58.5	16.9	7.7	6.9	3.6	3.5	2.2	4.6	5.9	20.2
90–110	15.3	60.4	16.5	8.0	4.4	3.8	3.1	2.9	4.8	6.2	20.2
110–140	11.4	61.1	17.4	7.9	3.5	3.1	4.1	2.1	4.6	6.0	20.7

southeast part of the country (on the right bank of the Alazani River), in Kvemo Kartli and as fragments in Shida Kartli. This soil is formed in terms of dry subtropical climate, over the plain relief with dominant negative forms. The soil formation is affected by an anthropogenic factor (irrigation). The morphological structure of the profile is A_{Ca}–$B1_{Ca}$–$B2_{Ca}$,t,g–BC_{Ca},g–Cg (Fig. 5.48).

5.10 Solonetz Humic

The area occupied by Solonetz Humic soil group is making 1.6% of the total territory of the country. This soil is spread as saline soil, salt soil, and solonetz in eastern Georgia on the accumulation plains, sloping plains, and slopes of the erosive watershed plateau of deserts Kakheti, as well as plains fragments in Shida Kartli (Fig. 5.49). Salt soils have easily soluble salts right from their surface, while saline soils have such salts at various depths and Solonetz contains absorbed sodium in their illuvial horizon. The group of soils was studied by Sabashvili (1948, 1965), Chkhikvishvili (1970), Akhvlediani (1973), etc.

Solonetz Humic soils are formed in dry subtropical climate, with hot summer and warm and almost non-snowy winter with average air temperature of +12, +13 °C; humidification coefficient of 0.3–0.5, sum of active temperatures of 4000–4500 °C, vegetation period lasting up to 7 months, and annual amount of atmospheric precipitations of 350–500 mm with its maximum in May and June.

The soil-forming parent materials where Solonetz Humic are spread are mainly presented by alluvial, proluvial–deluvial, and saline sediments with saline clays. The type of soil-forming parent materials results in high salinity of ground waters to a certain extent.

The relief is presented by intermontane depressions, alluvial plains, and elements of former lakes. Solonetz soil mostly develops on young depression relief, while salt soil develops on the elements of an old, elevated relief. Salination is more intense on a flat plain relief than on the inclined slopes where ground waters are located deep and the process of periodic salination takes place (Fig. 5.50).

Saline and salt soils are characterized by heavy texture (mostly, clay). Ca dominates in the absorbed cations; however, Na and Mg are also found in great amount. The content of soil organic matter is low and it sharply decreases as the depth increases. These soils contain different amounts of easily soluble salts with their amount increasing at greater depths. Clay minerals are presented by montmorillonite and hydromicas. The main oxides are distributed evenly in the profile. Saline soils are characterized by low productivity; however, owing to proper melioration measures, their productivity is possible to improve significantly.

The profile of typical salt soils is slightly differentiated and is characterized by a high salt content (Fig. 5.51). The morphological structure of the profile is A–BC–C. Salt soil is characterized by strong alkaline reaction and air–water regime of a poor structure. These soils have unfavorable physical (water–air) properties. Among saline soils, one can identify automorphous (with maximum salt content on the surface and deeper) and hydromorphous soils formed near the ground waters under the periodic wash-down regime. With the hydrological conditions, Solonetz soils are classified as hydromorphous formed in case of near location of the mineralized groundwaters (1.5–3 m) and automorphous soils, which are spread where the mineralized ground waters are located deep (up to 10 m).

The profile of the Solonetz soil has a specific structure with a differentiated eluvial–illuvial structure, heavy texture, alkaline reaction (Fig. 5.52), column and prismatic structure, dense Solonetz horizon Bt^{Na+} (what is its diagnostic index), increased amount of absorbed sodium, and poor water conductivity in the lower horizons. Clay minerals are also presented by montmorillonite and hydromicas. Content of soil organic matter varies between great limits and it is higher in weak Solonetz soils than in intense or average Solonetz soils (Fig. 5.53). The content of easily soluble salts also varies. Saltiness, as a main genetic feature, is determined by the content of absorbed Na and reaches 30% in the intense and average Solonetz soils. Content of absorbed magnesium is another feature. Solonetz has very poor water conductivity. The data of the gross chemical composition are presented in Table 5.9.

Fig. 5.48 Profiles of "Meadow-gray-cinnamonic" soil. Photo by B. Kalandadze

According to our previous micropedological study (Matchavariani 2008), Solonetz characterized by a non-aggregated mass and high content of easily soluble salts and dispersed crystals, clay-carbonate or clay-salty anisotropic plasma (with the participation of carbonate micro-concretions in the lower horizons), relict forms of a raw-type soil organic matter of a dark color, which are the remains of the meadow-forming stages, with the signs of disperse soil organic matter displacement, accumulation of sinter forms, densification at greater depths, signs of gleyzation, optical orientation of a current-like and scale structure, presence of snowflake Fe-spots at the level of microzones, etc.

5.11 Nitisols Ferralic

Nitisols Ferralic soils, which correlate with the national classification as Red soils, are spread in the southwest part (Adjara, Guria) and partly in the western (Samegrelo) and northwestern part (Abkhazeti) of Georgia (Fig. 5.54). The total area on the territory of Georgia occupied by these soils is about 2% of the total territory of the country. Nitisols Ferralic soils are spread at 100–300 m above sea level, in a humid subtropical zone, on hilly reliefs. They border Yellow-Black, Yellow, Subtropical Podzolic, and Gley Podzols.

The first researchers to study the "Red" soils were A. Krasnov and V. Dokuchaev, who equalized it with laterites. In K. Glinka's view, it is a relict soil with a gley-formation process taking place in it at present. It was him to classify the so-called Red soils, Laterites and Zheltozems (Yellow soils) into different groups in the first world map of soils. The fundamental studies of "Red" soils were accomplished under the leadership of B. Polinov making it clear that in the humid subtropics of West Georgia, the acid forms of soil formation develop on the red-color weathering crust and modern soil is younger than the weathering crust. These soils were also studied by Sabashvili (1948, 1965). The works by the latter consider the regularities of the geographical distribution of these soils. Daraselia (1939, 1949, 1974) studied the physical properties, hydrological regime, and humidity of them.

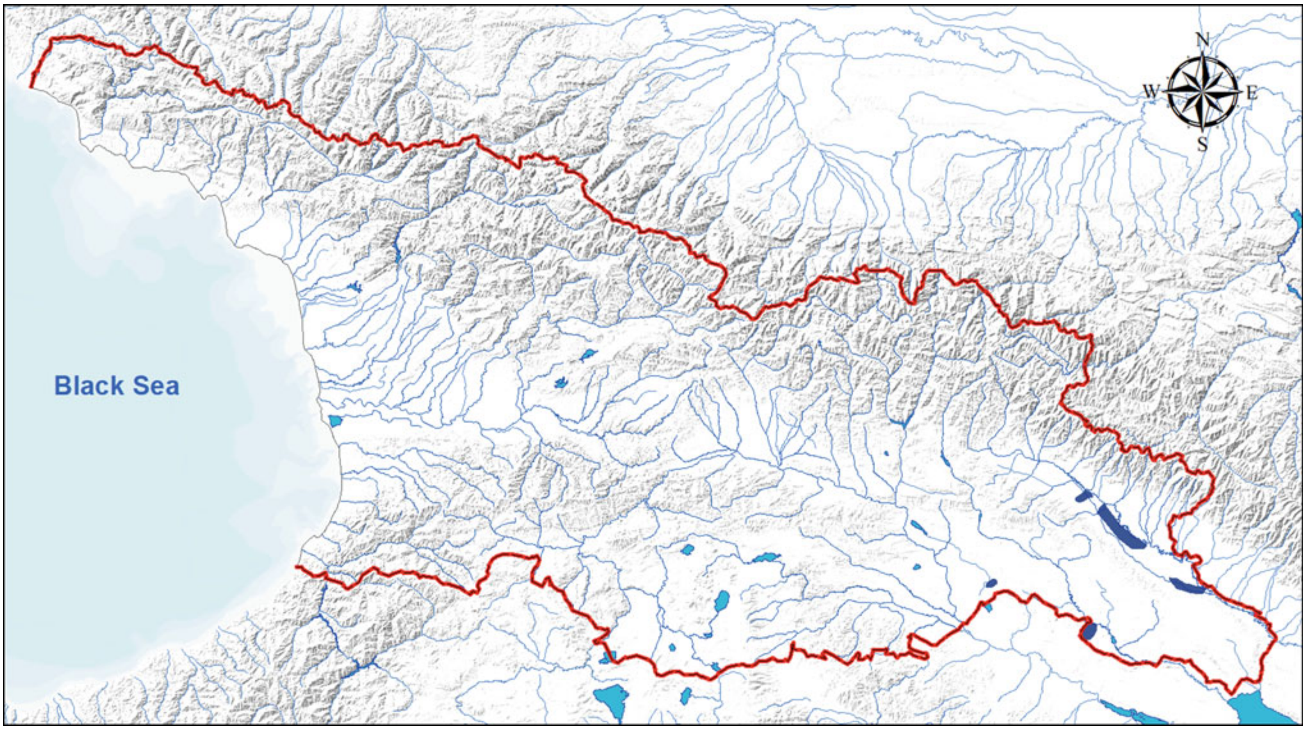

Fig. 5.49 Location of Solonetz. This map is created by D. Svanadze, based on the data of L. Matchavariani

Fig. 5.50 The landscape in the area of Solonetz formation (Project "Cadastre and Land Registration", KfW)

Monographs about the "Red" soils of Georgia belong to Romashkevitch (1966, 1974a, b) and Palavandishvili (1987).

The Nitisols Ferralic soils are formed on the base-effluent parent materials (andesites mainly) and red-colored weathering products. The color of the parent materials results from the presence of the closely associated Fe-hydroxides on the surface of clay particles. The soils formed on them well maintain the red color and all properties of weathering products, and the name of this type of soil comes from its color.

The climate in the zone with Nitisols Ferralic is humid subtropical; the average annual temperature is quite high (+14, +15 °C); the vegetation period lasts for 8 months and the annual amount of atmospheric precipitations is 1200–2500 mm, with the minimum falling in spring. The natural vegetation is presented by the mixed fragments of subtropical forest and evergreen undergrowth (Fig. 5.55).

The morphological structure of Nitisols Ferralic is A–AB–B–BC–C. They are characterized by a strong profile of a red coloration (Fig. 5.56). Soil reaction is acid (pH = 4–4.5)

Fig. 5.51 Profiles of Solonetz and Solonchak (Project "Cadastre and Land Registration", KfW)

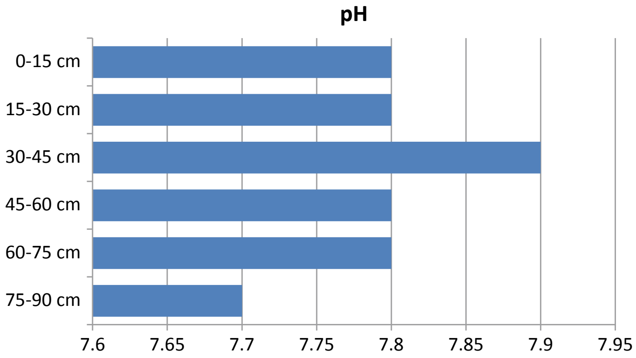

Fig. 5.52 pH distribution in profile of Solonetz (according to data of T. Urushadze)

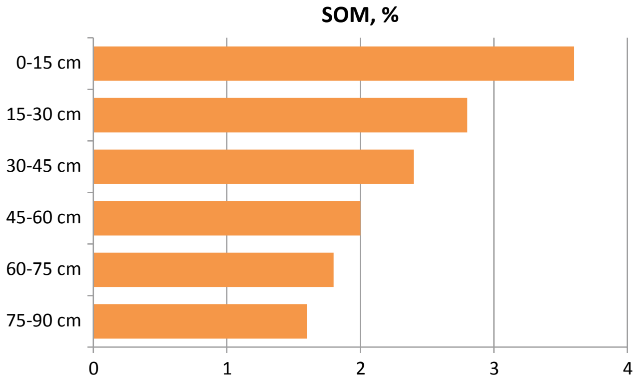

Fig. 5.53 Content of soil organic matter in Solonetz (according to data of T. Urushadze)

Table 5.9 Gross chemical composition of Solonetz, % (according to data of T. Urushadze)

Horizon (cm)	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	Na_2O	K_2O	SiO_2:R_2O_3	SiO_2:Al_2O_3	SiO_2:Fe_2O_3
0–6	70.9	12.7	6.1	0.6	2.2	1.4	3.7	1.4	7.3	9.5	31.1
6–12	68.6	15.2	6.3	0.5	2.2	1.4	2.9	1.8	6.1	7.7	19.3
12–28	64.6	16.7	7.7	0.5	1.7	1.0	3.6	1.9	5.1	6.6	22.4
28–40	66.3	16.1	7.3	0.4	2.3	2.0	2.7	2.0	5.4	7.0	24.6
58–70	66.7	17.2	7.8	0.6	1.4	2.23	1.2	1.2	5.1	6.6	22.7
110–115	67.2	17.1	7.8	0.4	0.6	2.21	1.8	1.3	5.2	6.7	22.9
180–192	67.0	16.4	7.9	0.5	0.7	1.53	2.4	1.6	5.3	5.9	22.8

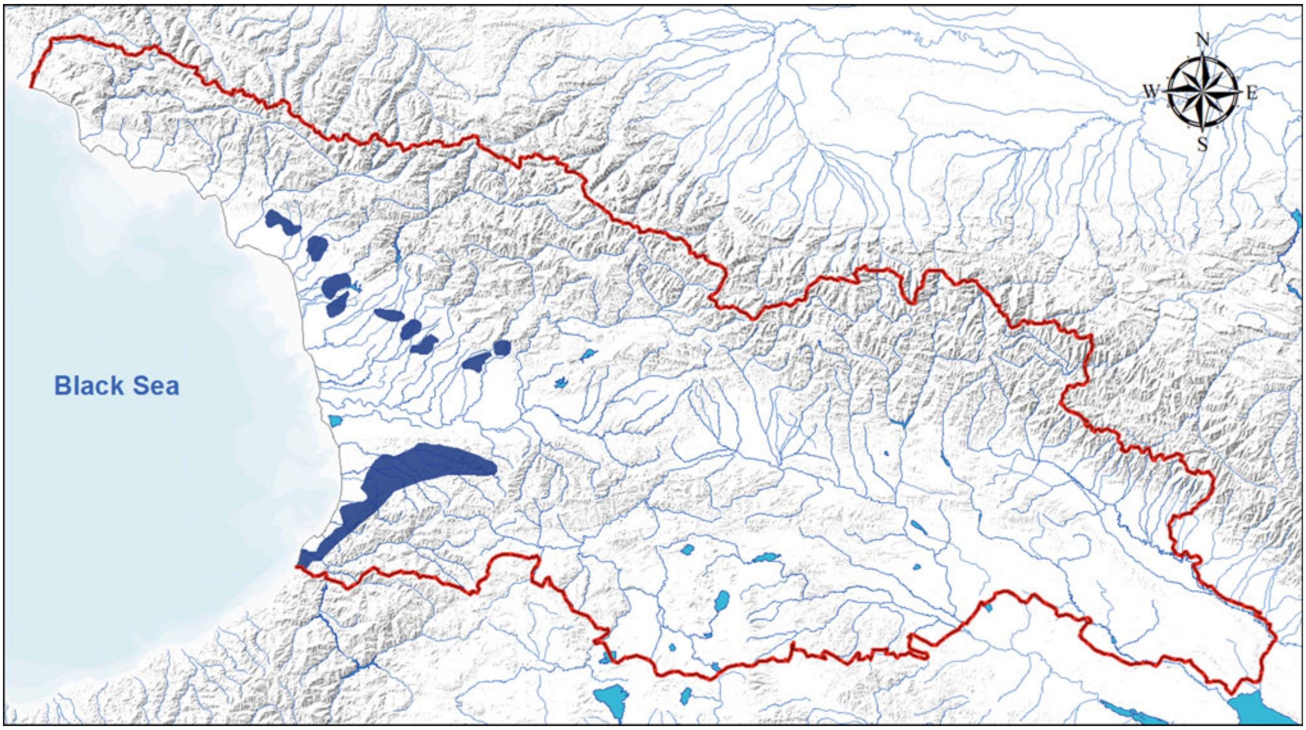

Fig. 5.54 Location of Nitisols Ferralic. This map is created by D. Svanadze, based on the data of L. Matchavariani

and changes insignificantly through the profile (Fig. 5.57). The soil organic matter is of a fulvous type; its content is from average to high (6%, decreasing gradually as the depth grows) (Fig. 5.58). In the upper horizons, the structure is cloddy, nutty, and granular. The mechanical composition (texture) of the profile is heavy—a loamy soil, average or heavy clay, with a typical process of argilization. The soil is poor in earth silicon and bases. The absorption capacity of Nitisols Ferralic is low to average and they are rich in R_2O_3. The mineral portion of these soils is characterized by ferralitic weathering. Clay minerals are presented by kaolin, halloysite, goethite, and gibbsite. In the Nitisols Ferralic, silicate ferrum dominates over the nonsilicate ferrum. Individual forms of ferrum are distributed more or less evenly with their profile. The data of the gross chemical composition are presented in Table 5.10.

Unlike the Acrisols Haplic, which develop in the same bioclimatic conditions, on the parent materials rich in earth silicon, the Nitisols Ferralic are distinguished for a red coloration, less coarse structure, and greater weathering. They are used to grow subtropical crops and tea plantations.

According to our previous micropedological study (Matchavariani 2008), Nitisols Ferralic are characterized by a compact microstructure and crumbling porosity and dustplasmic elementary microstructure (Fig. 5.59). Their upper horizons are reddish-brown clay mass, with a moder-mull and mull-moder morphotype of soil organic matter, with the presence of Fe-segregation, plasma with intense optical

Fig. 5.55 The landscape in the area of Nitisols Ferralic formation (Project "Cadastre and Land Registration", KfW)

orientation with a fine-scale and fiber structure (Fig. 5.60). The transient horizon has a dusty-loamy structure of a yellow color. Plasma has an Fe-loamy structure with a weak optical orientation. Illuvial horizon is yellowish, disperse, dense, dusty-plasmic, and intensely ferruginated. The Fe-concretions in the profile are dissected and are often presented as spot microzones saturated by Fe-hydroxides. The skeletal nature is intensified as the depth increases, with the large rock fragments present. The local clay movement is evidenced by clay and ferrous-clay cutans. The horizon transient to parent material is of a light gray color with yellowish strips, sandy-dusty-plasmic microstructure, and slight optical orientation. Intensely ferruginated strong clay cutans are fixed.

5.12 Acrisols Haplic

Acrisols Haplic soils, which correlate with the national classification as Yellow soils, are widely spread on old-marine terraces, dissected and adjoining foothills in the humid subtropical zone of Georgia, at 300–600 m asl (Fig. 5.61). The total area of these soils in Georgia is making 4.5% of the territory of the country. In Guria, Imereti, and Abkhazeti, these soils are spread adjacent to the Nitisols Ferralic, adjacent to the Luvisols Albic and Gleysols in Samegrelo and Cambisols Dystric in Abkhazeti, Imereti, and Guria.

Some data about the so-called Yellow soils (Zheltozems) are found in the works by P. Kosovitch, I. Vitin, and S. Zakharov. The name "zheltozem" was introduced following the similarity with the lower horizons of the "Red" soils developed on a yellow-colored weathering crust in West Georgia. Sabashvili (1965) explored these soils thoroughly. He was the first to fix the dependence of this kind of soils on the nature of the soil-forming parent materials. Earlier studies identified the "Yellow" soils as a subtype of "Red" soils. However, at present, they are considered as a separate genetic type.

Soil-formation parent materials, over which these soils are formed, are presented on the acid and averagely acid (mainly slates) weathering products. This kind of soil usually develops on loose clay parent materials. The soil-forming parent materials belong to sialith clays; however, sometimes there are ferrallitized ones, too. The area of Acrisols Haplic, like that of Nitisols Ferralic, is determined by the scales of spreading of parent materials.

Acrisols Haplic soils are formed in a humid subtropical climate, with an average annual temperature of +13, +15 °C; the temperature of the coldest month (January) is +3, +7 °C; the temperature of the warmest period of the year (July and August) is +19, +25 °C. The vegetation period lasts for 8 months. The annual amount of precipitations is 1100–2500 mm, but the precipitations are distributed unevenly in different months, with the maximum in April, May, and June.

The natural vegetation is presented by a mixed subtropical forest (oak, elm zelkova, chestnut, wing nut, beech, maple) (Fig. 5.62). At present, the vegetation cover on the

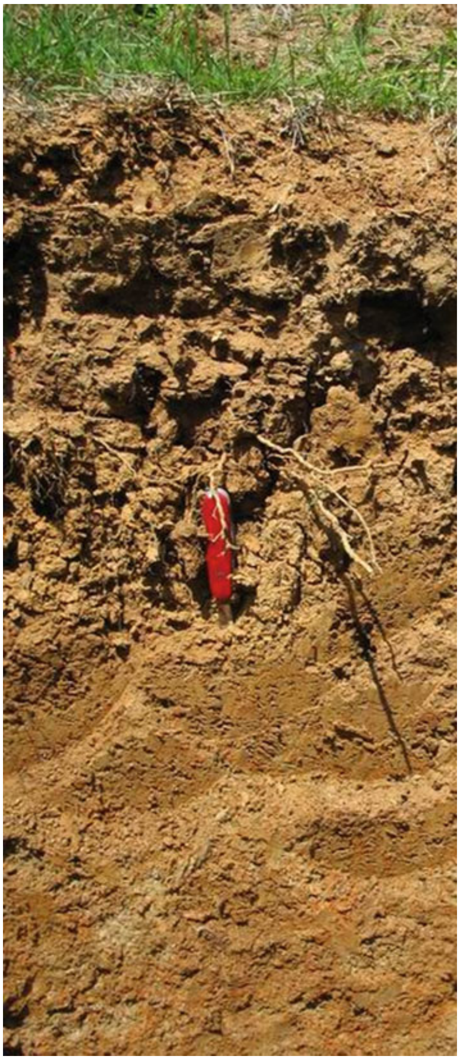

Fig. 5.56 Profile of Nitisols Ferralic. Photo by B. Kalandadze

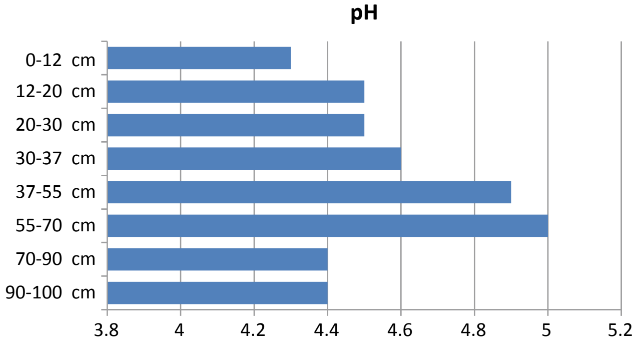

Fig. 5.57 pH distribution in profile of Nitisols Ferralic (according to data of T. Ramishvili)

most of the territory is destroyed and agricultural fields and plantations are cultivated instead.

The morphological structure of Acrisols Haplic is A0–A–AB–B–BC. These soils are characterized by a yellow color, argilization, and strong profile (Fig. 5.63). The soil reaction is averagely acidic (pH = 5–6) and changes slightly through the profile (Fig. 5.64). The content of soil organic matter is 4–5% and decreases drastically as the depth increases (Fig. 5.65). The soil organic matter has fulvous composition. The absorbed complex is not saturated with bases, but the degree of unsaturation varies within the great limits (4–7 to 60–70%). The mechanic composition (texture) of the Acrisols Haplic is heavy and slightly changes at greater depths; the content of physical clays (<0.001 mm) is 40–45%. The amount of amorphous iron is little and that of nonsilicate ferrum is quite high. The main oxides are distributed unevenly. SiO_2:R_2O_3 ratio in the sludge/silt fraction evidences both, ferralitic and sialithic weathering. The data of the gross chemical composition are presented in Table 5.11.

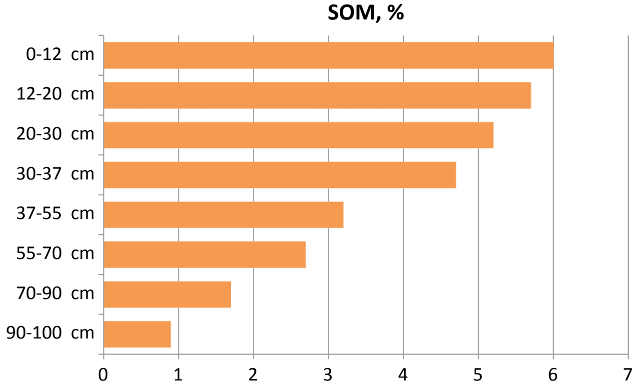

Fig. 5.58 Content of soil organic matter in profile of Nitisols Ferralic (according to data of T. Ramishvili)

Unlike the Nitisols Ferralic soil, the Acrisols Haplic, which develop in the same bioclimatic conditions, but on the parent materials poor in earth silicon, have a yellow color, weaker weathering, and less solid and coarser structure.

The distribution scales and properties of Acrisols Haplic depend on the nature of parent materials. In the soil-forming process, ferrum moves and intense hydration of its compounds result in the yellow color of the profile. Intense hydration of the mentioned soils has resulted from the retention of a great amount of water by clays and shales.

Acrisols Haplic soils are poor in nutrition elements and rapidly lose their productivity when exploited. Their physical properties are not favorable, either. They have poor water conductivity, aeration, and weak structure. Therefore, they can be most efficiently used under permanent plantations (tea, citruses, tung tree). Rich harvest can be gained only by applying large amounts of organic and mineral fertilizers.

According to our previous micropedological study (Matchavariani 2008), the Acrisols Haplic soils are characterized by nonhomogeneous dense clay mass, inter-aggregate porosity, pores with roundish or figurative shapes (Fig. 5.66), moder type of soil organic matter in the upper horizon and

Table 5.10 Gross chemical composition of Nitisols Ferralic, % (according to data of T. Ramishvili)

Horizon (cm)	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	SiO_2:R_2O_3
0–20	52.70	25.33	16.76	1.63	1.28	1.44	2.48
58–86	51.87	25.84	16.66	1.61	0.84	1.52	2.46
86–136	57.24	25.54	16.79	1.52	0.92	0.85	2.97
136–180	44.92	29.97	19.15	1.57	2.04	2.69	1.83

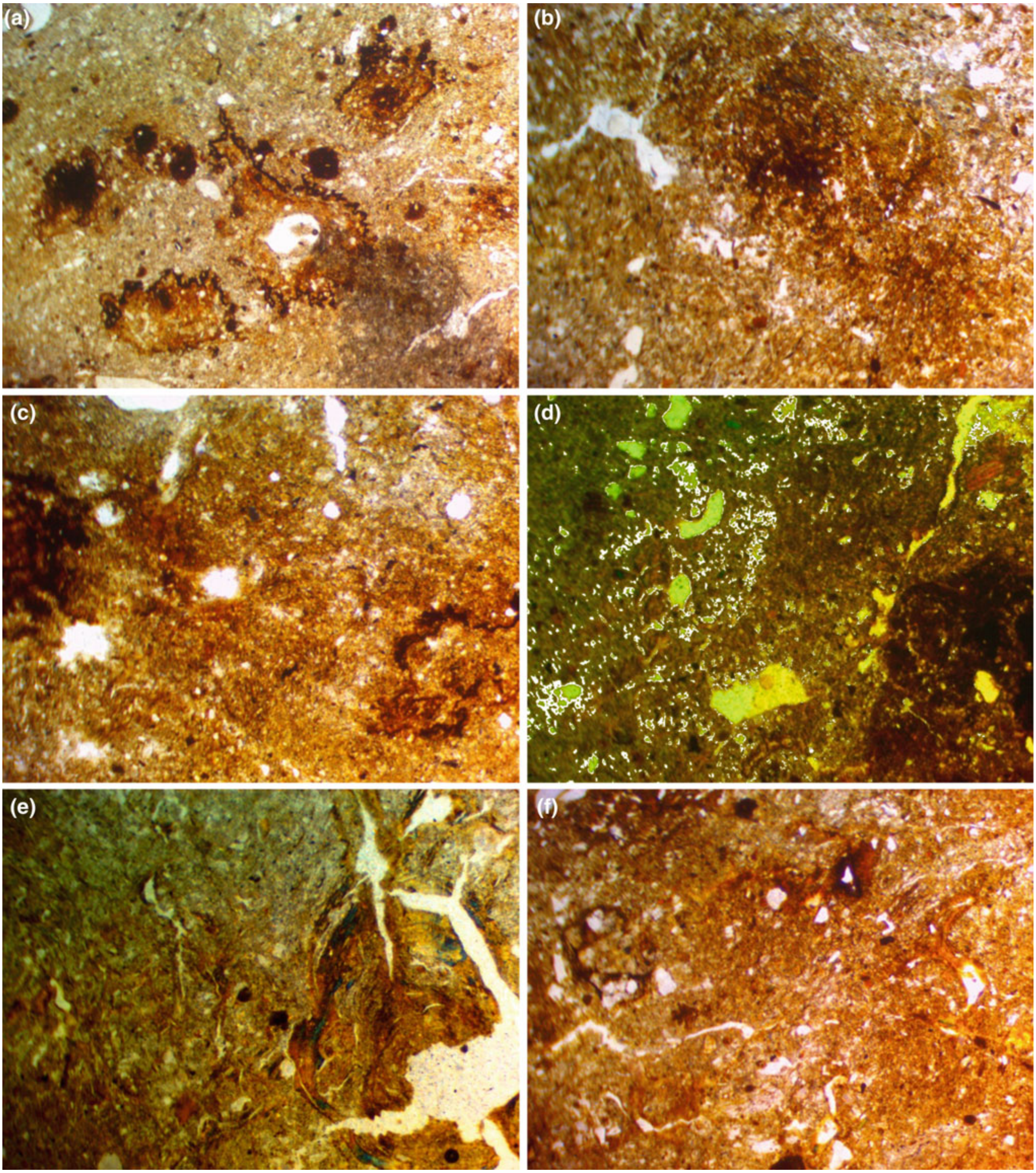

Fig. 5.59 Microstructure of Nitisols Ferralic, nic.II; Horizons: **a** 0–20 cm; **b** 20–58 cm; **c** 58–86 cm; **d** 86–130 cm; **e–f** 136–180 cm. Photos by L. Matchavariani

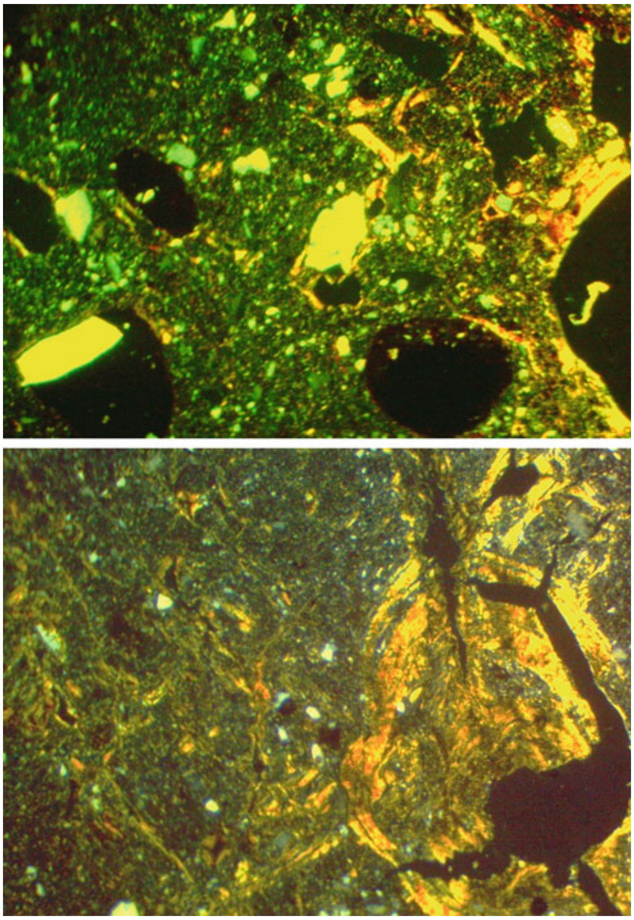

Fig. 5.60 Microzones with optical orientation plasma in Nitisols Ferralic, 136–180 cm, nic.+. Photos by L. Matchavariani

plasmic saturation from disperse soil organic matter (Fig. 5.67), dusty-plasmic structure at great depths, with Fe-clay and clay plasma at some locations, intense ferrugination, uneven distribution of Fe-formations, rich mineralogy of skeleton (Fig. 5.68), and intense optical orientation of clay in lower structures.

5.13 Luvisols Albic

Luvisols Albic soils, which correlate with the national classification as Subtropical Podzolic or Yellow Podzolic soils, are widely spread in the humid subtropical zone of West Georgia, at 30–200 m above sea level, in the northern and eastern peripheries of Kolkheti Plain, but are less widely spread in the western part of the plain, over the marine terraces (Abkhazeti); they are spread as fragments in the southwestern part of Kolkheti Plain (Fig. 5.69). Large massifs of this type of soils are spread on the old terraces of the Kodori, Enguri, Khobi, Rioni, Kvirila, and other rivers. This type of soil covers 2% of the whole territory of the country and borders both, Acrisols Haplic (Yellow soils) and Leptosols Rendzic (Raw-Humus-Calcareous soils) and Gleysols.

Luvisols Albic is quite a peculiar soil and is quite argumentative in a genetic respect. Due to the morphology of its profile (with a clearly seen upper light, whitish horizon), the first researchers, starting from V. Dokuchaev, attributed it to the Podzol soils. D. Gedevanishvili was the first to call this type of soil Subtropical Podzolic, later the term used by scientists: I. Vitin, S. Zakharov, V. Kovda, B. Polinov, M. Sabashvili, M. Daraselia, and many others. M. Sabashvili extended the area of the process of podzolization to “Red” and “Yellow” soils. However, B. Polinov noted: “Even if admitting the genetic connection of these soils to the Podzols, attributing them to podzolized soils is as much inadmissible as e.g. attributing Grey soils to Chernozems”. V. Kovda named several features evidencing the soil podzolization in the study region. K. Bogatiriov was the first to try to isolate this type of soil from the group of podzolized soils and pointed to another way of formation of the light horizon. He linked the lighting of the upper horizon to the elluviation resulted by excess surface humidity and ferrum segregation what was considered a sign of podzolization earlier. In his article “What are Subtropical Podzols of Abkhazia?”, Gerasimov (1966), criticized and strongly doubted about the podzolized nature of these soils. He called the possibility of founding Podzols in the Black Sea coastal area of the Caucasus an absurd geographical paradox. He proposed title “Subtropical Pseudo-Podzol”, i.e., strongly lessivaged, superficially gleized, illuvial-ferruginated soil, formed under the influence of seasonal surface excess moisture. Zonn (1974, 1987), Zonn and Shonia (1971), Romashkevitch (1974a, b, 1979), and others evaluate this type of soil in the same respect.

Later, aiming at explaining the complex genesis and contradictory opinions, Matchavariani (1987, 2002, 2005, 2008) thoroughly studied so-called Subtropical Podzol soil and concretion formations. As a result of the study it was established that the mechanism of formation of a texturally differentiated profile is associated with an originally nonhomogeneous lithological background—the heterochronic nature of the sediments building the profile, which take part in modern pedogenesis. As for the process of lessivage, it takes place on such a nonhomogeneous lithological background having no profile-forming function. Despite the fact that humid subtropical climate must make for the intense movement of plasma across the profile, the process of lessivage takes place locally and has an intra-horizon (not an intra-profile) nature, as the presence of an underlying heavy clay horizon and complicated mode of filtration hampers the migration of fine-disperse substance across the concretion nodules and local lessivage. As for the process of podzolization seen in the name of this type of soil, virtually, it is not diagnosed because as the results of the thorough studies

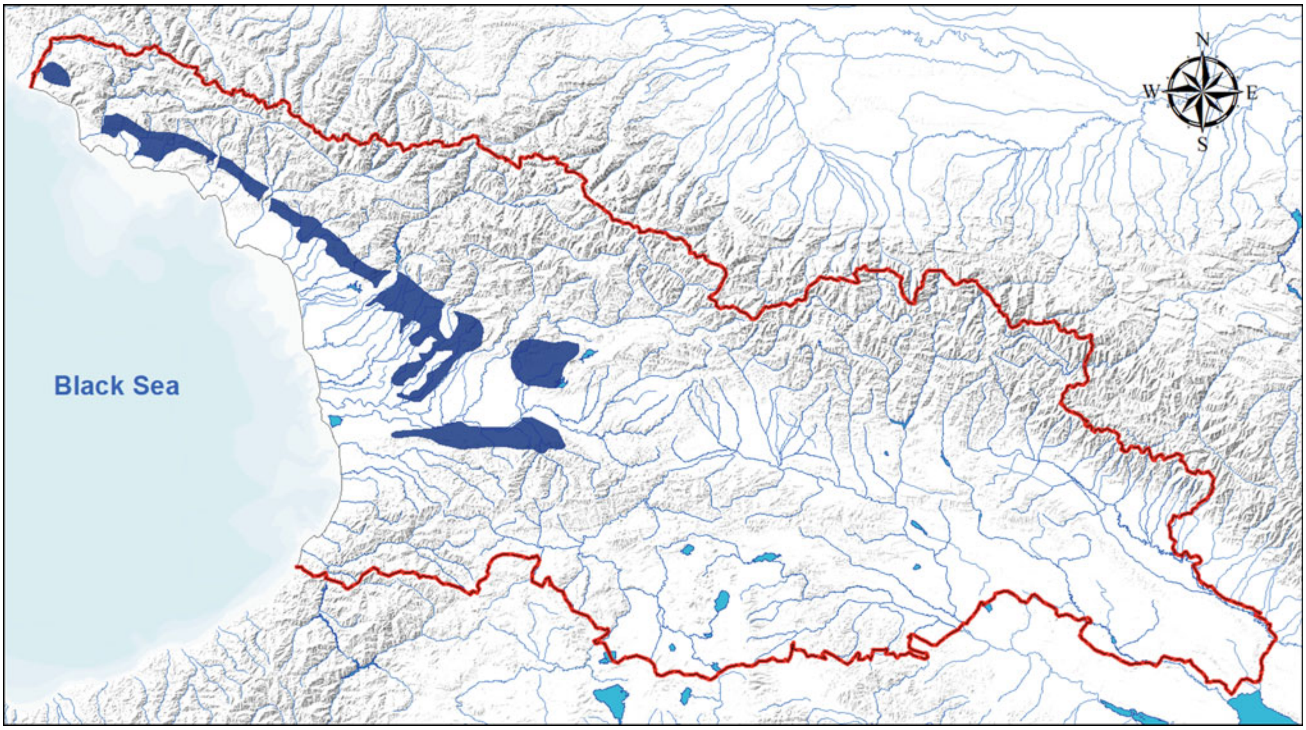

Fig. 5.61 Location of Acrisols Haplic. This map is created by D. Svanadze, based on the data of L. Matchavariani

Fig. 5.62 The landscape in the area of Acrisols Haplic formation (Project "Cadastre and Land Registration", KfW)

accomplished by L. Matchavariani suggest, no process of decomposition of primary minerals in the upper horizon is fixed at macro-, meso-, micro- or submicro-levels and no signs of movement of chemically modified talus material across the vertical profile are seen.

The Luvisols Albic soil is formed on old-marine and river terraces. The general inclination of the terraces is from the peripheral part of the Colchic Lowland toward the Black Sea (Fig. 5.70). A high hypsometric zone of the terraces is relatively dissected and drained, while the lower part is less

Fig. 5.63 Profile of Acrisols Haplic. Photo by B. Kalandadze

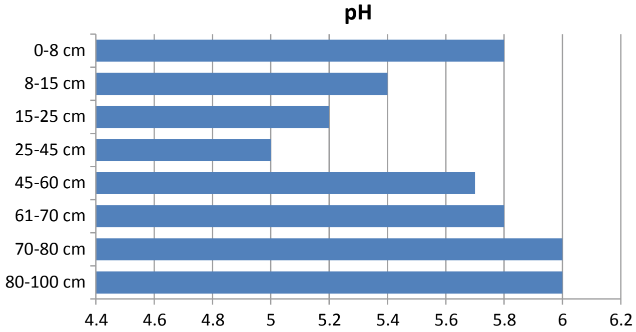

Fig. 5.64 pH distribution in profile of Acrisols Haplic (according to data of T. Ramishvili)

water permeable. Soil-forming parent materials are loose and are, usually, heterogenous. The low terraces in the northwestern part of Colchic Lowland are presented by loamy sediments, which cover shingle and clay sediments at some locations. The central and northwestern piedmonts of Colchic Lowland are presented as high terraces. There are tertiary parti-colored clays, zebra-like clays, and shingle spread here. Heavy clays are common on old river terraces, which are substituted by lighter sediments at a certain depth.

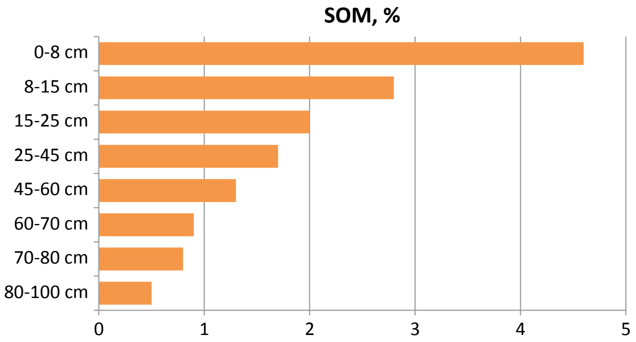

Fig. 5.65 Content of soil organic matter in Acrisols Haplic (according to data of T. Ramishvili)

The Luvisols Albic soils are formed in terms of a humid subtropical climate with abundant atmospheric precipitations (1500 mm), warm winter and hot summer (with an average annual temperature of +14, +19 °C); the sum of active temperatures is 4000–4500 °C; the duration of the vegetation period is 8 months and the duration of frost-free period is 250–290 days. The periods with abundant precipitations are often changed by droughty periods. The relative humidity in summer and autumn reaches 90% and it is minimal (67–79%) in spring and autumn.

The Polydominant Colchic forest grew in this zone, but at present, the natural vegetation is disturbed due to the felling of trees. The areas of former forest massifs are now used to grow agricultural crops: tea, citruses, tobacco, and maize. Colchic forest has survived as fragments.

Morphologically Luvisols Albic of Georgia is characterized by a clearly differentiated profile with a following morphological structure: A1A2n–BSf–Btg–BGt or A1A2n–BSf–Btg–BGt–[B/Cgh]. The main diagnostic properties of this type of soil are clearly expressed light eluvial horizon, which is depleted with a sludge fraction and oxides (Fig. 5.71). Texture differentiation, bulk of Fe-concretions in the upper horizons and ferruginated Ortshtein horizon in the middle part of the profile often as cemented layer “petroplinthic” or “plinthic” are peculiar common features for this type of soils. The Ortshtein layer is usually fixed at the spots of lithological transitions between the upper horizon with the light texture and the lower, heavy clay layer. The intensified hydromorphism in the profile is followed by less concretion nodules and reduced density of an Ortshtein layer. When the process of soil formation occurs in nonhomogeneous sediments, which have a heavy water-proof underlying layer, an Ortshtein horizon of different strengths and structures is fixed in the profile. The Luvisols Albic is characterized by poor natural productivity and unfavorable physical properties. The presence of an Ortshtein horizon is the principal

Table 5.11 Gross chemical composition of Acrisols Haplic, % (according to data of T. Ramishvili)

Horizon (cm)	SiO_2	Fe_2O_3	Al_2O_3	CaO	MgO	SiO_2:R_2O_3
0–11	74.2	5.2	17.1	0.65	0.78	6.52
12–22	75.6	4.4	15.9	0.64	0.64	6.63
26–36	72.9	5.2	19.1	0.73	0.73	5.76
43–49	66.2	6.8	23.2	0.85	0.85	4.23
64–70	65.8	6.5	25.1	0.96	0.96	3.88

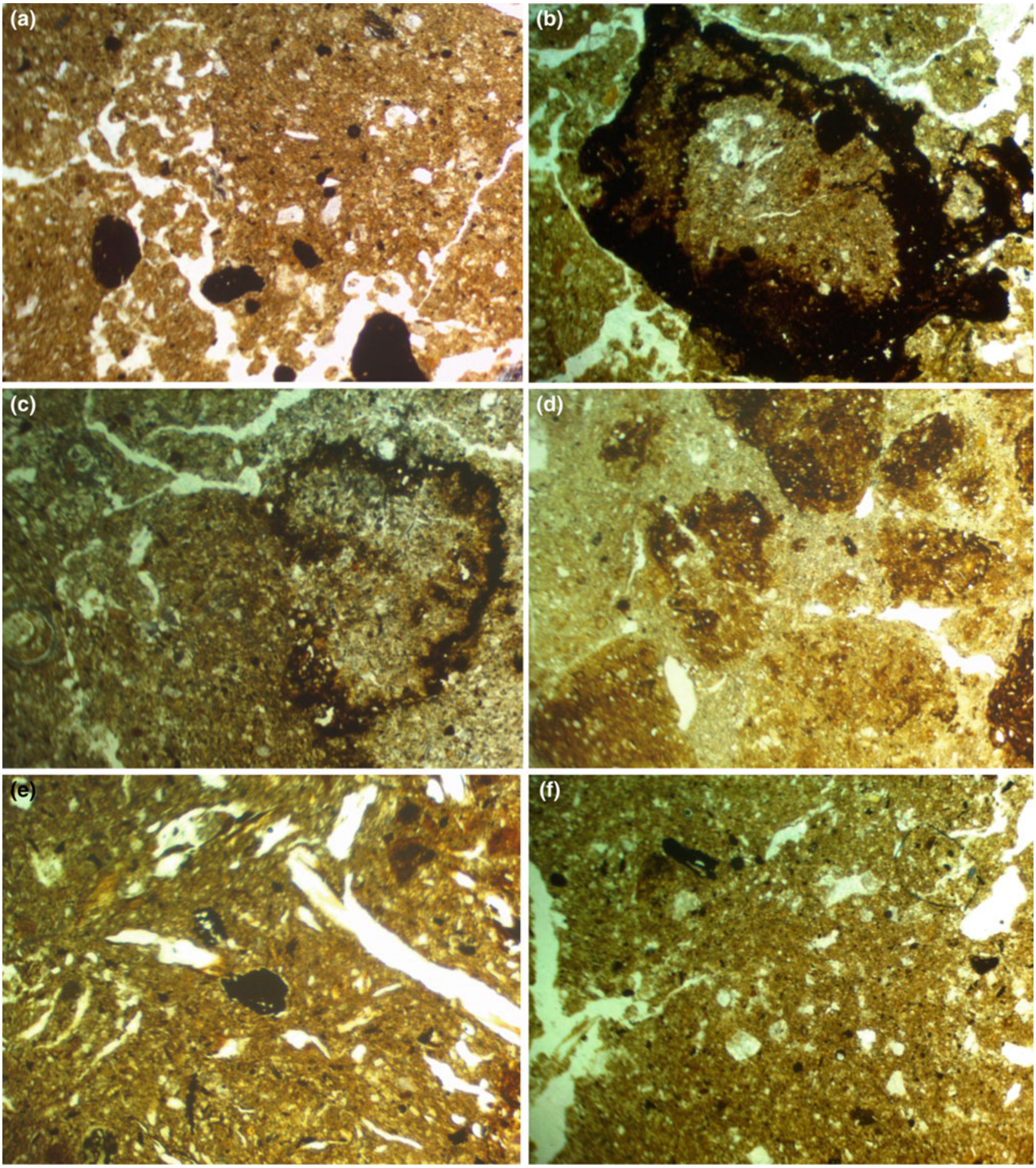

Fig. 5.66 Microstructure of Acrisols Haplic, nic.II; Horizons: **a–b** 0–18 cm; **c** 18–33 cm; **d** 33–48 cm; **e** 48–75 cm; **f** 75–100 cm. Photos by L. Matchavariani

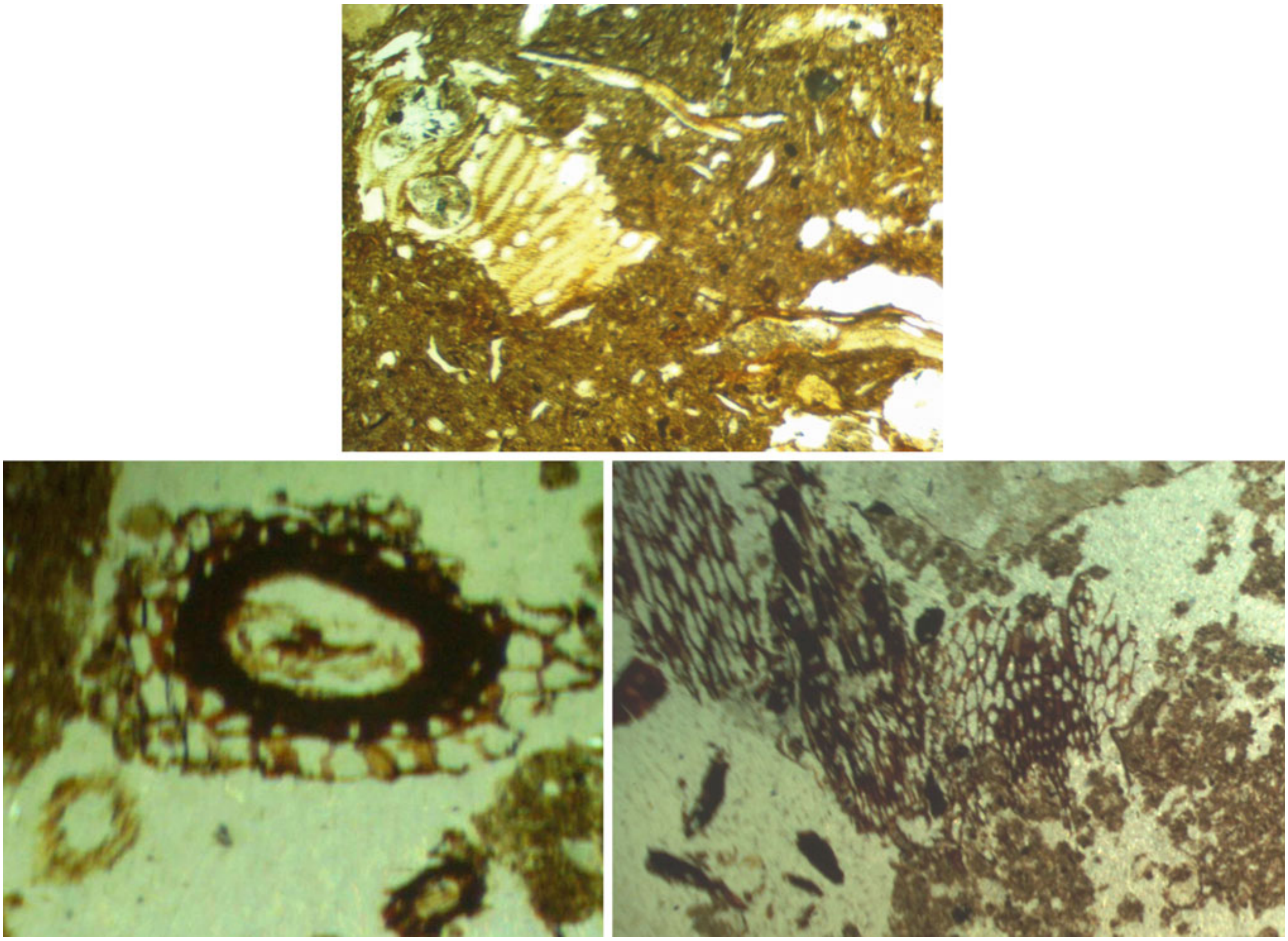

Fig. 5.67 Plant residues in the profile of Acrisols Haplic, nic.II. Photos by L. Matchavariani

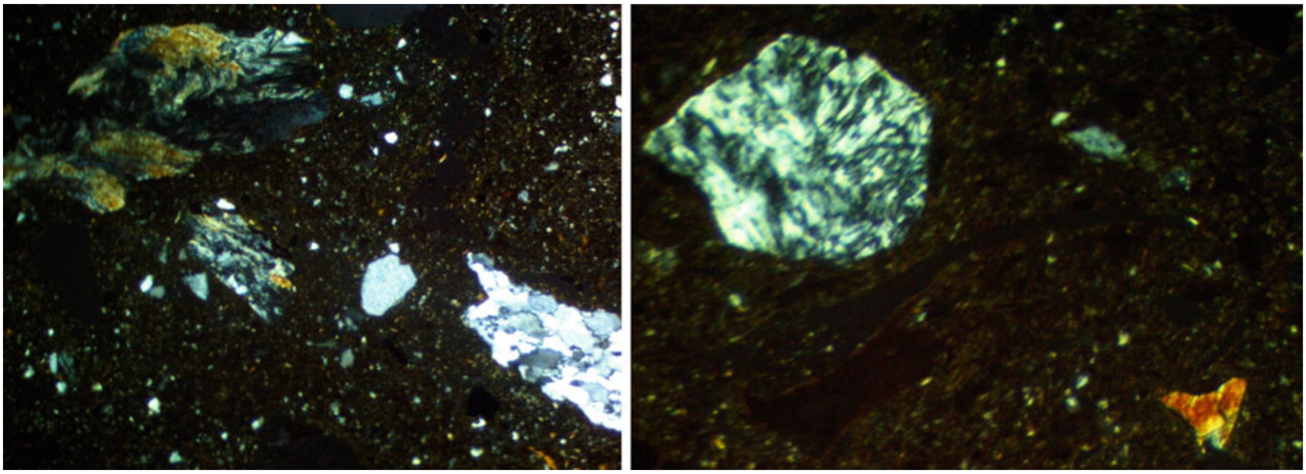

Fig. 5.68 Fragments of the parent rocks in the soil profiles of Acrisols Haplic, nic.+. Photos by L. Matchavariani

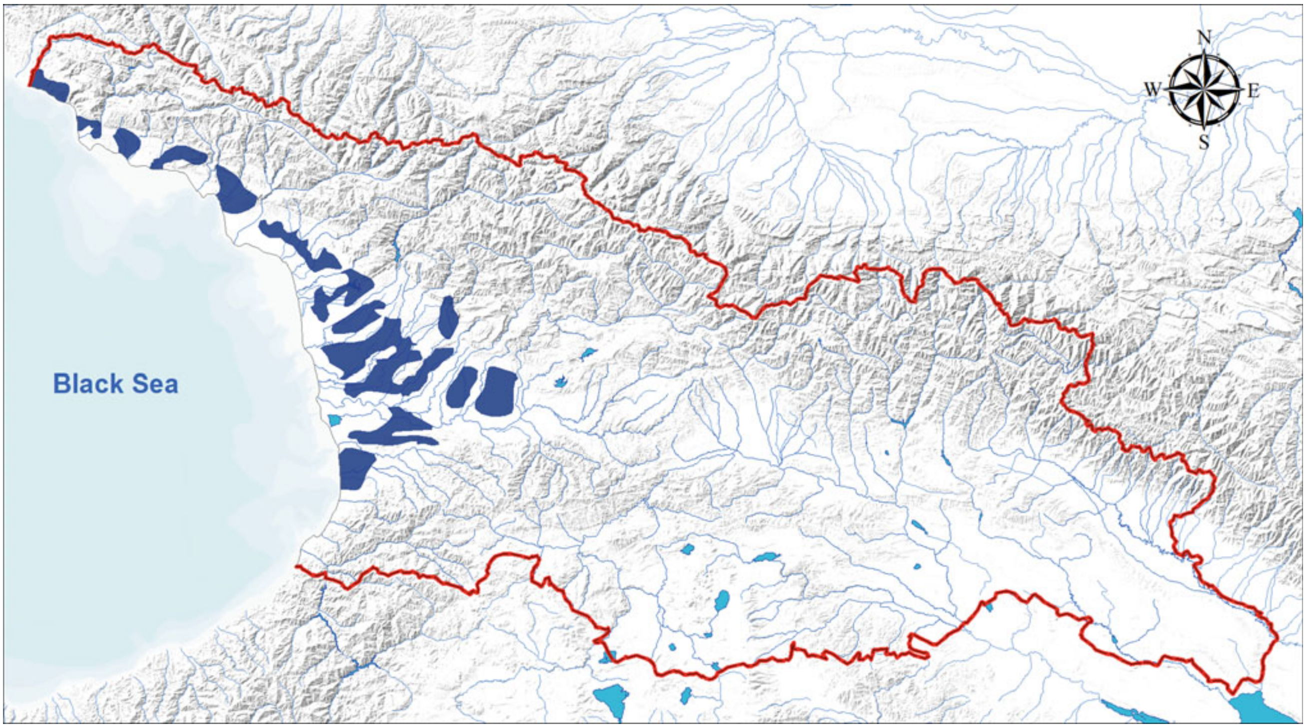

Fig. 5.69 Location of Luvisols Albic. This map is created by D. Svanadze, based on the data of L. Matchavariani

Fig. 5.70 The landscape in the area of Luvisols Albic formation (Project "Cadastre and Land Registration", KfW)

negative feature of this type of soil hampering the normal development of the root system and due to its water resistance, supports soil bogging.

As the analytical data suggest, the Luvisols Albic soils have an acid reaction (pH = 4.5–6.0), with the maximum acidity fixed in the eluvial horizon, which drastically

Fig. 5.71 Profiles of Luvisols Albic. Photo by B. Kalandadze

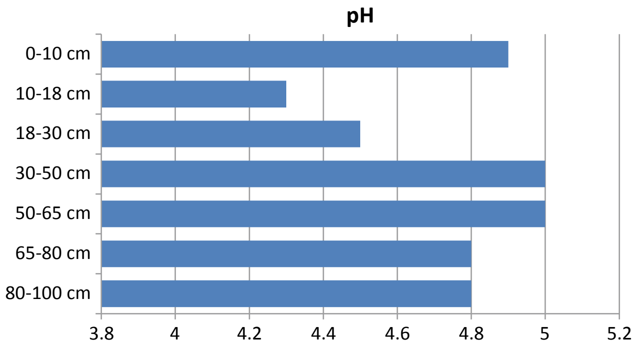

Fig. 5.72 pH distribution in profile of Luvisols Albic soil (according to data of L. Matchavariani)

decreases at greater depth (Fig. 5.72) profiles. The data of the gross chemical composition are presented in Table 5.12.

The main soil-forming processes of the Luvisols Albic soils are gleyzation. The content of soil organic matter is low or average 2.5–3% in the accumulation horizon (Fig. 5.73); the type of soil organic matter is fulvous. The texture of this type of soil is loamy or clay. Usually, the underlying horizon is particularly enriched with fine-disperse fraction. The main oxides are distributed unevenly. Eluvial horizon shows the accumulation of silica and reduced oxides. At greater depths, the amount of earth silicon increases and that of oxides decreases in the illuvial horizon. Their ratio evidences allitic weathering. The mineralogical content of silt shows dominant kaolin, chlorine, halloysite, and fine-disperse quartz. There are two maximums fixed in the distribution of individual forms of ferrum—in the upper and lower layers.

The difference between the Luvisols Albic with the Nitisols Ferralic and Acrisols Haplic soils is that the former

Table 5.12 Gross chemical composition of Luvisols Albic soil, % (according to data of L. Matchavariani)

Horizon (cm)	SiO_2	Al_2O_3	Fe_2O_3	MnO	SiO_2:Al_2O_3	SiO_2:Fe_2O_3
0–10	65.9	7.1	6.6	0.28	9.2	10.0
20–30	74.4	10.1	6.6	0.19	7.4	11.2
35–50	83.1	10.1	13.6	0.19	8.2	8.2
85–95	47.7	22.0	12.3	0.34	2.2	2.2
115–125	54.1	19.4	10.2	0.40	2.8	2.8

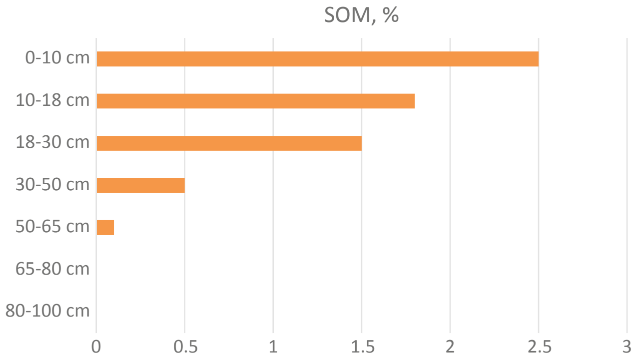

Fig. 5.73 Content of soil organic matter in Luvisols Albic soil (according to data of L. Matchavariani)

is characterized by a clearly differentiated profile, high content of Fe-concretions, and often the presence of an Ortshtein horizon, while unlike Gley-podzolic, they are characterized by slight gleyzation and less content of concretions.

According to our previous micropedological study (Matchavariani 2008), the Luvisols Albic is characterized by the following specific features of microstructure (Fig. 5.74): weak structure and porosity of the sandy-dusty mass, light color and humification, moder type of soil organic matter, isotropic plasma and bulk of ferrum concretions in the upper layers; compacted structure and fissure porosity, optical plasma orientation and high content of ferrum in the Ortshtein horizon evidenced by a joint system of microzones of large concretions and saturated with iron mass; heterogeneous structure and content, optical orientation of mosaic, sometimes current-like structure of clay and Fe-clay plasma in the lower layers. On the whole, according to many characteristics of microstructure, on the background of profile heterogeneity and strongly oriented plasma, due to the absence of intense clay migration, there is no genetic link between the profile layers to compare what is the evidence of its complex polygenetic nature.

In the relatively depressed locations of Luvisols Albic soils of humid subtropical zone, West Georgia (Fig. 5.75), are spread so-called Podzoic-gley or Yellow-podzolic-gley soils. They occupy 0.7% of the total area of the country. This soil adjoins Acrisols Haplic, Leptosols Rendzic, Luvisols Albic, and Gleysols.

Quite often, “Podzoic-gley” soils are considered as a subtype of “Subtropical Podzolic” soils. Therefore, the history of studying these soils is almost the same. “Podzolic-Gley” soils were studied by Motserelia (1954), Motserelia and Kostava (1975), Motserelia (1989), etc. As per Motserelia (1954), these soils on Colchic lowland are divided into the soils developed on the modern river terraces and on old terraces. These soils developed on modern terraces have a clear accumulative horizon with the signs of gleyzation; the degree of gleyzation increases as the depth increases and there are concretions across the whole profile. The profile of the soil formed on old terraces is clearly differentiated as genetic horizons; the accumulative horizon is of a little strength, with the gleyzation seen right from the surface, increasing as the depth increases; the concretions are observed across the whole profile and the Ortshtein layer is clearly seen.

Morphologically, the abovementioned soils are characterized by a clearly differentiated profile: A–A1A2–B1–B2–BC–CDg–G or A1A2–A2–A2B–BCg (Fig. 5.76). By its terms of development, it is quite close to the Luvisols Albic soils, but differs from them by a more intense humidification with ground and surface waters.

As the analytical data suggest, “Podzoic-Gley” soils are characterized by an acid, sometimes neutral or weak alkaline reaction what is associated with chemism of groundwaters and a moderate content of fulvous soil organic matter and deep humification. With its texture, this type of soil belongs to loams and clays. Its accumulative and eluvial horizons are depleted with a fine fraction. The main oxides are characterized by alluvial–illuvial differentiation. The content of silicate Fe usually exceeds that of a nonsilicate iron.

The mentioned soils are formed by simultaneous processes of bogging and gleyzation. As a result of bogging, gley horizon is formed and as a result of podzolization, podzolized and Ortshtein horizons are formed. A typical hydrological regime of this type of soil is noteworthy: during the period with abundant precipitations, the level of

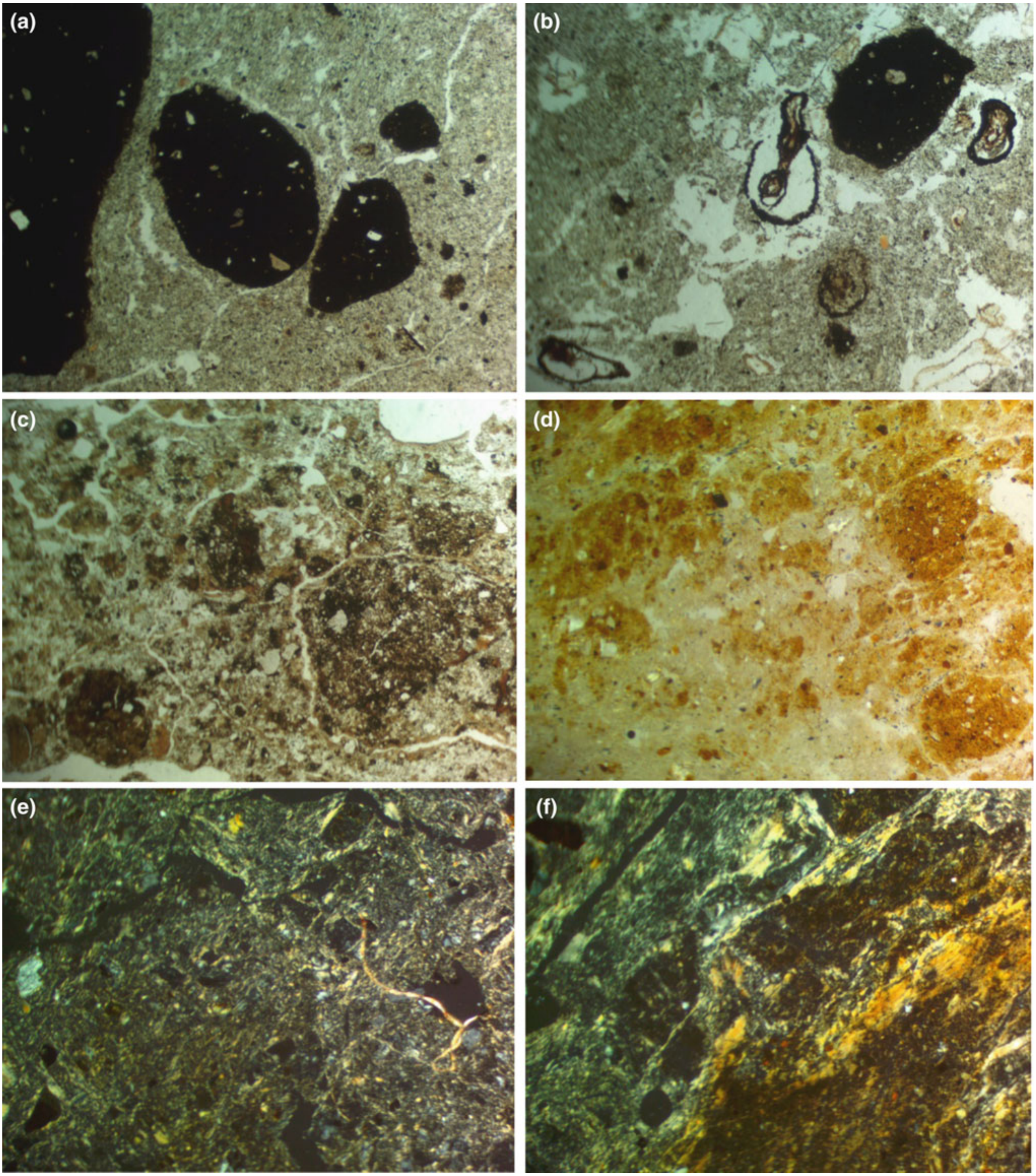

Fig. 5.74 Microstructure of Luvisols Albic soil, nic.II (**a**, **b**, **c**, **d**), nic.+ (**e**, **f**); Horizons: **a**–**b** 0–18 cm; **c** 18–33 cm; **d** 33–48 cm; **e** 48–75 cm; **f** 75–100 cm. Photos by L. Matchavariani

Fig. 5.75 The landscape in the area of "Podzoic-gley" soil formation (Project "Cadastre and Land Registration", KfW)

groundwater rises and the soil pores are filled with water, while during the droughts, the groundwater level decreases. As a result of alternating aerobic and anaerobic conditions, the oxidation–reduction processes take place and oxide is transformed into peroxide causing gleyzation and Fe-segregation.

Due to the abundant moisture, soil cultivation is associated with a number of difficulties. Therefore, its use to grow perennial crops without preliminary drainage melioration is often impossible. This type of soil is mostly used to sow corn and other annual crops.

According to our previous micropedological study (Matchavariani 2008), the "Podzoic-gley" soils are characterized by a compact microstructure of its clay mass, dusty-plasma and sandy-dusty-plasma elementary microstructure, bulk of plasma on skeleton, raw-moder or moder-raw light-colored soil organic matter and intense plasma saturation with ferrum-hydroxides, presence of the vegetation remains and carbonized particles, with the participation of fine Fe-concretions, uneven distribution of skeleton and fine-scale structure and optical orientation of plasma (Fig. 5.77).

5.14 Gleysols

Gleysols (called in national classifications as bog/boggy, swampy, marshy soils) are mainly spread in West Georgia, on Colchic Lowland (which is a kind of triangle with its shape, with its top stretching from the Black Sea coast toward east); fragments of swampy soil are also spread in the East and South Georgia (Fig. 5.78).

The area occupied by marsh and swampy soils in Georgia is 2200 km^2 making about 3% of the total territory of the country. Bog-silted (1304 km^2) and bog-peat (706 km^2) soils can be distinguished in the Gleysols.

One of the first researchers of the Bog soils on Colchic Lowland was D. Gedevanishvili. Later, these soils were studied by Zakharov (1924), Motserelia (1954), Motserelia and Kostava (1975), Kostava (1976), etc.

The climate in Colchic Lowland is warm, humid, and mild, with an average annual temperature of +14 °C and the average amount of precipitations of 1500 mm (with the minimum in summer and maximum in autumn and winter). Average annual relative humidity is as high as 71–82%.

Fig. 5.76 Profile of "Podzoic-gley" soils (Project "Cadastre and Land Registration", KfW)

Colchic Lowland is a delta-accumulative horizon plain and is filled with alluvial material, containing the decomposition products of the constituent rocks of the Great Caucasus and Transcaucasian southern mountains. The sediments are mostly carbonated with a high content of clay in their upper layers. The dominant type of vegetation is plain forests mixed with marsh vegetation (Fig. 5.79).

The Gleysols have the following morphological structure: A–B–BC (Fig. 5.80). They have a strong profile, cloddy and block structure, heavy mechanical content, and signs of gleyzation. The bog-silted soils are characterized by weak alkaline or neutral reaction (Fig. 5.81), with a high content of soil organic matter (Fig. 5.82), heavy texture through the profile, intense dispersion, bulk exchange calcium in the absorbed cations, high content of different forms of iron (with amorphous Fe accumulated in the upper profile and crystal ferrum accumulated at greater depths), and with an uneven distribution of main oxides evidencing the alluvial nature of this type of soil. The data of the gross chemical composition are presented in Table 5.13.

Gleysols contain a wide spectrum of clay minerals: montmorillonite, kaolin, halloysite, illites, etc., with uneven distribution of different forms of. In addition, the content of silicon Fe much exceeds that of a non-silicon ferrum.

There are different views about swamping of Colchis Lowland. On the one hand, swamping is thought to be associated with the atmospheric precipitations and action of the surface waters flowing from the riverbeds; on the other hand, the process of swamping is associated with the ground and soil-and-groundwater actions.

The fund of Gleysols is the reserve, which, if dried, will give many thousands of hectares of land for agriculture in the subtropical zone.

According to our previous micropedological study (Matchavariani 2008), the Gleysols are characterized by a compact, dense, nonhomogenous, and fine-disperse mass, with partly fragmental microstructure and are saturated with ferrum, with raw and partly moder-raw type of soil organic matter, dusty-plasmic microstructure, with bulk of plasma on the skeleton, clay and clay-Fe content of isotropic plasma, with micro-sites with intense optical micro-zonal orientation, uneven saturation of the main mass with ferrum material and with the presence of organogenic remains, carbonized particles and neogenic Fe-formations and fine clay films on the pore walls. In general, marsh soils have a nonhomogeneous profile, weak skeleton, with an increasing content of primary minerals at greater depths, high ferrum content, and stratification of the profile depending on the plasma content and microstructure (Fig. 5.83).

5.15 Fluvisols

Fluvisols, which correlate with the national classification as Alluvial soil—an azonal type, are spread along the rivers in different natural zones. Consequently, alluvial soil is spread all over the territory of Georgia and covers 5% of the total area of the country (Fig. 5.84). The alluvial soils in different regions of Georgia are explored by Zakharov (1924), Sabashvili (1948, 1965), Motserelia (1954), and others.

Fluvisols are characterized by a regular flooding and sedimentation of new alluvion layers on the surface. Their properties mainly result from the nature of the basin where they develop, and consequently their regimes, structure, and properties are much diversified.

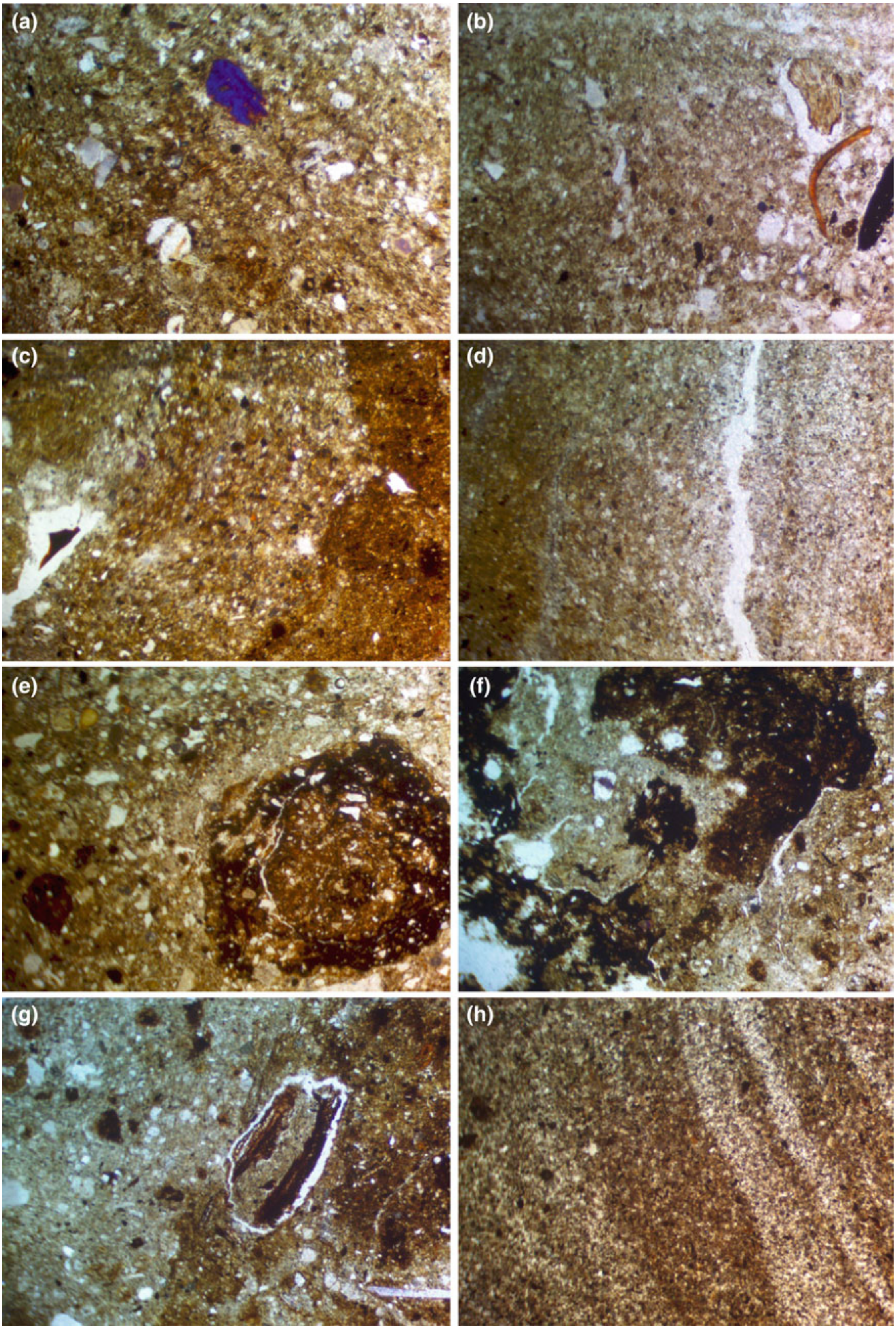

Fig. 5.77 Microstructure of “Podzoic-gley” soils, nic.II; Horizons: **a**–**b** 0–15 cm; **c**–**d** 33–60 cm; **e** 60–95 cm; **f** 95–120 cm; **g** 120–150 cm; **h** 150–180 cm. Photos by L. Matchavariani

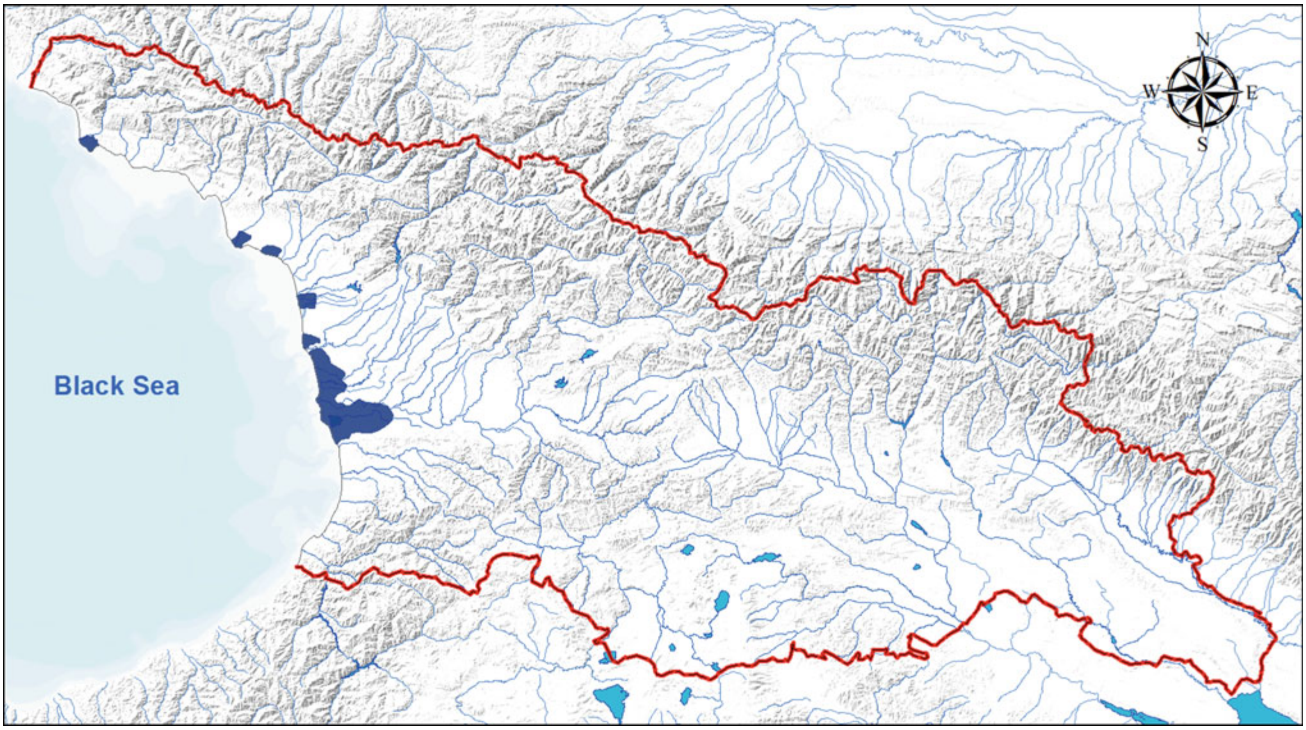

Fig. 5.78 Location of Gleysols. This map is created by D. Svanadze, based on the data of L. Matchavariani

Fig. 5.79 The landscape in the area of Gleysols formation (Project "Cadastre and Land Registration", KfW)

As the Fluvisols develop over the alluvial sediments in different natural zones, they are influenced by the climatic conditions of the zone where they were formed. The material of the alluvion over which they are formed is also much diversified. The natural biological cover is presented by floodplain vegetation (Fig. 5.85). Large areas of these territories are used to grow different agricultural crops.

The profile of the Fluvisols has the following structure: A–BC–C–CD. Morphologically, one of the most typical diagnostic properties is profile stratification (with its

Fig. 5.80 Profile of Gleysols. Photo by B. Kalandadze

mechanical structure first of all), weak structural properties and skeletal nature (Fig. 5.86). This type of soil is distinguished by a strong profile, clearly seen accumulative horizon and intense humification.

As the analytical data suggest, the reaction in Fluvisols is acid, neutral, or alkaline depending on the type of basin the concrete profile was formed in (Fig. 5.87). The content of soil organic matter is average or less; the profile is deeply humified (Fig. 5.88); the nitrogen content is high or average; and the absorption capacity is low or average. The distribution of the main oxides is more or less even both, in the soil and silt fraction. As for the gross chemical composition, the data are presented in Table 5.14.

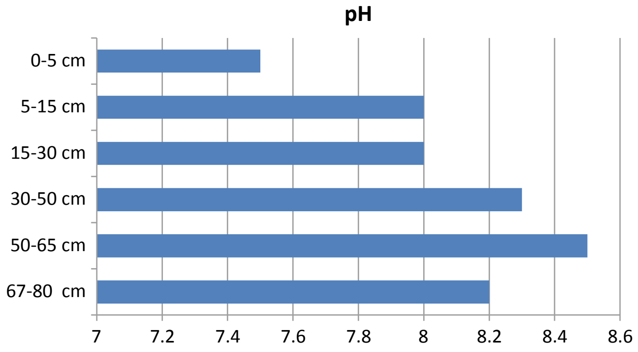

Fig. 5.81 pH distribution in profile of Gleysols (according to data of T. Ramishvili)

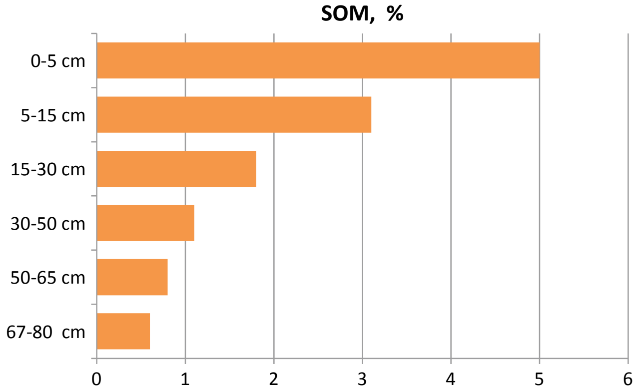

Fig. 5.82 Content of soil organic matter in Gleysols (according to data of T. Ramishvili)

Fluvisols differ from the zonal types of soil with a weaklier developed profile, stratified structure, and gleyzation. This soil incorporates two types: turf acid and turf saturated. Mostly alluvial turf-acid soil is formed under the herb vegetation in the high-mountainous and forest zones distinguished for the youngest age. They are usually low productive and are used as arable land or hay meadows. Turf-saturated soil is mainly spread in the steppe zone of East Georgia and is often of a carbonate content.

According to our previous micropedological study (Matchavariani 2008), Fluvisols are characterized by a dusty mass with a compact microstructure, which is large channel-like and chamber-like, branched and with figurative porosity at greater depths, vegetation remains decomposed to

Table 5.13 Gross chemical composition of Gleysols, % (according to data of T. Ramishvili)

Horizon (cm)	Loss on ignition	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	$SiO_2:R_2O_3$	$SiO_2:Al_2O_3$	$SiO_2:Fe_2O_3$
0–16	11.0	60.6	16.1	7.3	1.09	3.1	2.0	5.65	6.9	27.8
28–45	9.6	65.8	17.6	8.6	1.11	1.8	2.0	5.0	6.4	21.8
45–70	11.3	69.6	16.0	6.6	1.09	1.8	2.0	5.8	7.3	29.1
70–100	11.0	78.8	7.9	3.3	1.40	1.3	0.9	13.1	16.4	65.5

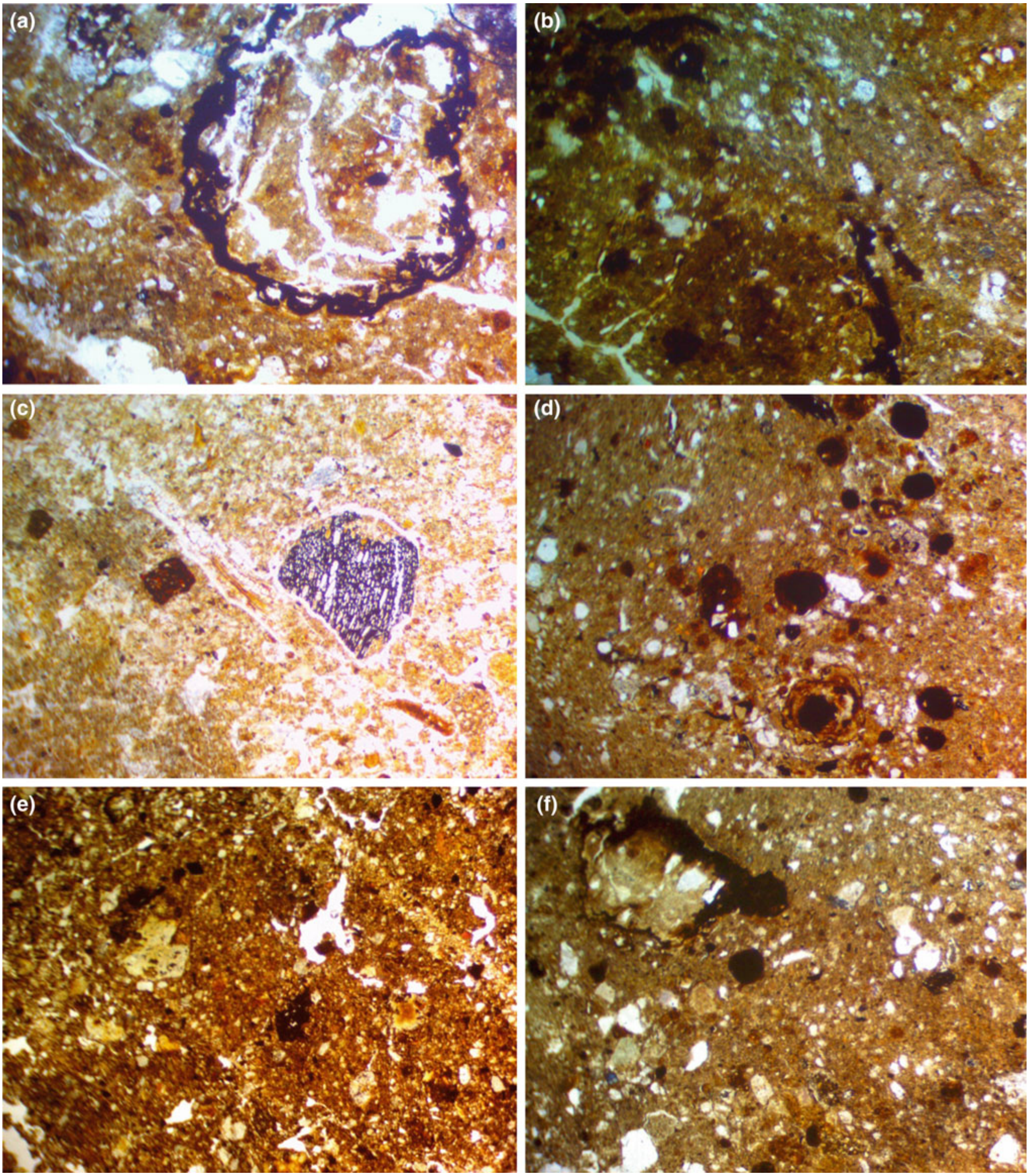

Fig. 5.83 Microstructure of Gleysols, nic.II; Horizons: **a** 0–16 cm; **b** 16–28 cm; **c** 28–45 cm; **d** 45–70 cm; **e–f** 100–140 cm. Photos by L. Matchavariani

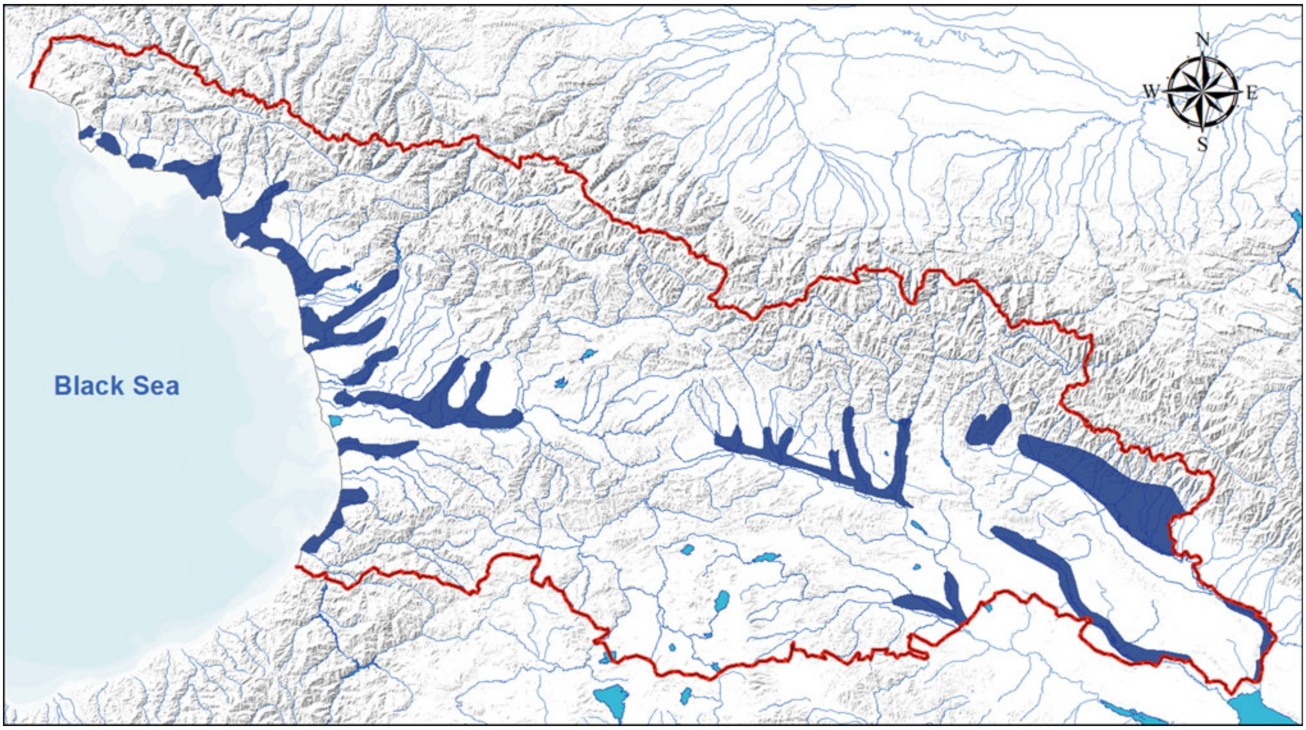

Fig. 5.84 Location of Fluvisols. This map is created by D. Svanadze, based on the data of L. Matchavariani

Fig. 5.85 The landscape in the area of Fluvisols formation (Project "Cadastre and Land Registration", KfW)

Fig. 5.86 Profiles of Fluvisols. Photo by B. Kalandadze

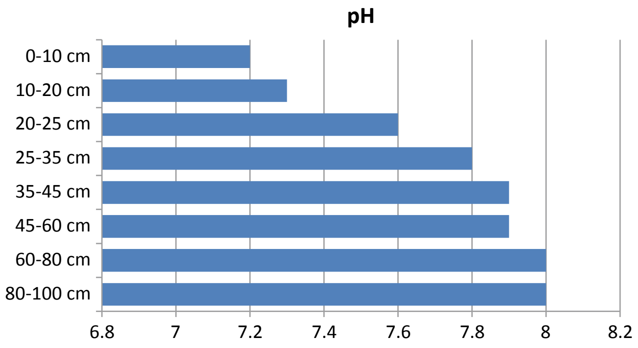

Fig. 5.87 pH distribution in profile of Fluvisols (according to data of T. Ramishvili)

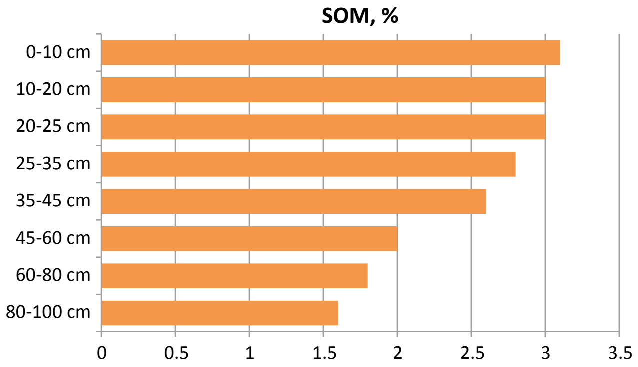

Fig. 5.88 Content of soil organic matter in Fluvisols (according to data of T. Ramishvili)

different degrees in the voids, light soil organic matter color, increased ferrum content in upper horizons, average and coarse-dusty content of skeleton, with plasma content more than skeleton content, weak optical orientation and organic-Fe-clay content. In general, Fluvisols are distinguished for a moder type of soil organic matter, with the maximum content of vegetation remains in the lower horizons, increased porosity and elementary sandy-dusty-plasmic microstructure (Fig. 5.89).

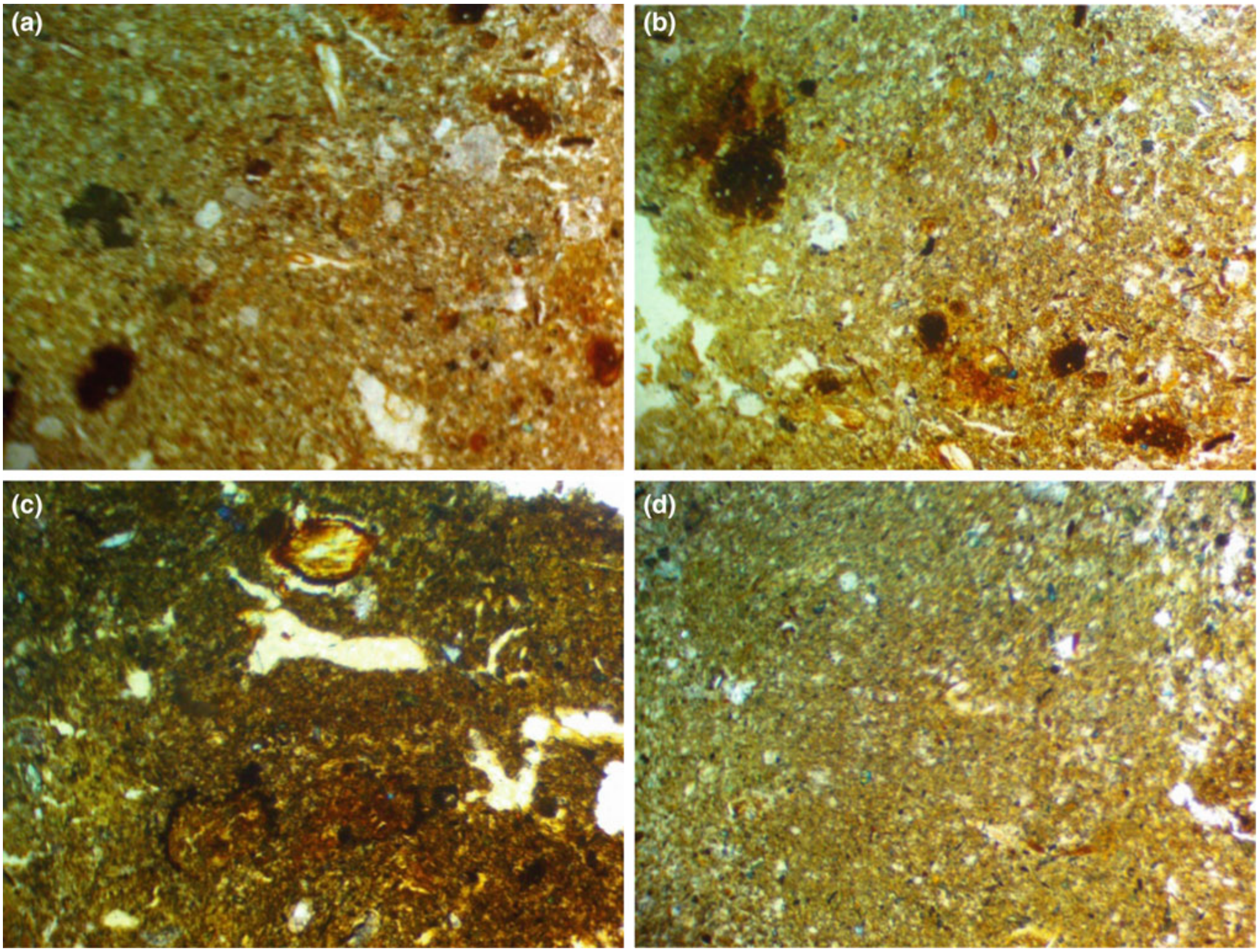

Fig. 5.89 Microstructure of Fluvisols, nic.II; Horizons: **a–b** 0–37 cm; **c** 37–72 cm; **d** 72–120 cm. Photos by L. Matchavariani

Table 5.14 Gross chemical composition of Fluvisols, % (according to data of T. Ramishvili)

Horizon (cm)	Loss on ignition	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	K_2O	Na_2O	SiO_2: R_2O_3	SiO_2: Al_2O_3	SiO_2: Fe_2O_3
0–14	8.9	65.2	15.6	7.4	0.6	3.5	2.7	2.2	2.2	5.5	7.1	23.6
14–52	5.9	65.9	15.4	7.7	0.4	3.4	2.6	2.1	2.1	5.5	7.3	22.9
52–105	5.3	65.2	15.6	7.6	0.6	3.2	3.0	2.3	2.3	5.4	7.1	23.1
105–125	5.4	64.7	15.8	7.7	0.7	3.3	2.5	2.3	2.3	5.3	7.0	22.5

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