4 Soil Processes

Lia Matchavariani

Abstract

The micromorphological diagnosis, typification, and assessment of main soil-forming processes have been conducted for soils of Georgia: humification, argillization, gleization, podzolization, lessivage, ferrugination, and carbonization. Morphotypes of soil organic matter were determined in main soils—five groups were identified: raw, raw-moder or moder-raw, moder, moder-mull or mull-moder, mull. The process of argillization is diagnosed as in situ weathering and depending on the clayzation intensity, three main grades were identified: intense, medium, and weak. Lessivage is diagnosed by the presence of the optically oriented clay cutans in transit pores and is visible as clay cutans, silty cutans, and complex cutans in the form of films on the walls of the pores and mineral grains. The diagnostic sign of gleization is the contrast in the distribution of ferrum hydroxides. It was grouped according to the degree of intensity as strong, medium, and weak. Ferrugination processes take place mostly in humid zone. Two main forms are distinguished: concretions and ferruginated plasma. The gradation of ferrugination was done by the intensity of process. Carbonization is diagnosed according to genetic-morphological groups of carbonates and the sizes of calcite crystals. It is divided into concretions and carbonized plasma; with the intensity of strong, average, and weakly calcareous.

Keywords

Argillization • Podzolization • Lessivage • Gleization • Ferrugination • Carbonization

4.1 Introduction

One of the major methodological principles of genetic soil science is the concept of the soil-forming process as a complex set of elementary soil processes, which are the result of the interaction between the transformation and the migration of organic and mineral substances.

As a rule, the soil-forming processes are defined as a set of phenomena of transformations and movement of substances within the Earth's pedosphere. The processes constituting the soil formation in general were named by Rode (1948) as common soil-forming processes, since they take place in any soils in different qualities and quantities and various combinations. A specific manifestation of general processes depending on the factors and conditions of soil formation are called private soil-forming processes. All soil-forming processes are divided into macro-processes concerning the entire soil profile, and micro-processes, the mineral and organic transformations within the local sections of the profile.

The private soil-forming macro-processes were proposed to call Elementary Soil Processes (ESP) by Gerasimov (1973). In the early works (Gerasimov and Glazovskaya 1960), these processes were called as elementary soil-forming processes. The ESP plan was later updated by Rozanov (1975).

The elementary soil processes are rather complex with their significance and nature; virtually, they determine the formation of the genetic profile and are by no means elementary in the meaning of the word *elementary* itself.

As a result, the elementary soil processes incorporate the natural and anthropogenic processes, which are specific only for soils and form specific soil horizons in the profile, and they determine the structure of the profile, composition, and ratio of the system of genetic horizons, and their various combinations take place in several types of soils. In other words, the major profile-forming processes belong to the elementary soil processes.

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According to Bockheim and Gennadiyev (2000), Soil Taxonomy (ST) and the World Reference Base (WRB) on soil resources do not adequately assess the role of soil processes in soil taxonomic systems, despite the fact that these modern systems are based on genetic principles. The authors believe that the consideration of soil processes is important for understanding the genetic basis of modern soil taxonomic systems and the development of quantitative models of pedogenic systems. Therefore, the effects of soil-formation processes on current and future soil classification systems and pedogenic models are examined (Bockheim and Gennadiyev 2000).

The most successful means to diagnose ESP in pedology is the micromorphological analysis of soil thin sections. Consequently, special importance was given to the micropedological research in the diagnosis of the processes, forming the genetic soil profiles of Georgia.

Thus, based on the existing manuals and guidelines on micropedology (Kubiena 1938, 1970; Brewer 1964; Ball 1973; Bullock et al. 1975, 1985; Dobrovolsky 1977; Jongerius 1981; FitzPatrick 1984; Gerasimova et al. 1992; Tursina 2002; Stoops 2003), the micromorphological diagnosis, typification, and assessment of the level of main soil-forming processes manifestation have been conducted for soils of Georgia, in particular: humification, argilization, gleization, podzolization, lessivage, ferrugination, and carbonization.

4.2 Diagnosing and Distribution of Profile-Forming Processes

The options of formation and accumulation of soil organic matter were described by a set of micromorphological features reflecting the transformation of organic matter; argillization (weathering in situ)—by the nature of microstructure and the optical orientation of plasma; gleization—by decolorization of the basic mass (due to the loss of ferrum) and segregation of Fe-hydroxides; podsolization—by the presence of signs of movement of weathering products of the primary minerals; lessivage (illimerization, desilting) is described by the properties of the mechanical movement of the mobile clay material, i.e., by the nature of the sinter deposits forms; ferrugination (laterization, ferrallitization, and other processes associated with the movement, accumulation, and transformation of ferrum)—by the presence of various forms of ferruginous formations, the nature of ferruginous micro-zones, or zones of impregnation of plasma with a ferrous substance; carbonization—by the presence of calcite grains in the skeleton, microforms of carbonates and impregnations, or calcite crystals of various dimensions scattered in plasma material.

4.2.1 Distribution of Soil Organic Matter Morphotypes in the Soils

For the purpose of diagnosing the morphotypes soil organic matter, a thorough registration of micromorphological indices of all organic components in the organic profiles of the soils of Georgia was done: vegetation remnants, soil fauna, their metabolic by-products, and end products of humification (Fig. 4.1). On the basis of developing the relevant criteria, the main morphotypes of soil organic matter (Kubiena 1953; Müller 1987) were determined in the studied organic profiles of soils depending on the roughness and/or dispersion of the organic matter of soils. As a result, five groups of SOM in the soils of Georgia were identified (Matchavariani 2008): I—raw, II—raw-moder or moder-raw, III—moder, IV—moder-mull or mull-moder, and V—mull (Fig. 4.2). Of the studied soils, mainly: Gleysols and Solonetz correspond to the raw soil organic matter group; Rendzinas, Luvisols Albic, Acrisols Haplic, and Fluvisols correspond to group moder (medium dispersed soil organic matter); Vertisols, Chernozems, and, in some cases, Cambisol Chromic correspond to group mull (dispersed soil organic matter); Leptosols Umbric and Luvisols Albic correspond to group raw-moder and/or moder-raw (a transitional form from the dispersed soil organic matter to the medium one); Nitisols Ferralic, Kastanozems, Cambisols Dystric, and Cambisol Chromic correspond to group moder-mull and/or mull-moder (a transitional form from the medium soil organic matter to the dispersed one).

4.2.2 Distribution of Argillization in the Soils

Depending on the conditions of soil formation, there are different kinds of a microstructure of clay plasma. The process of argillization at a microlevel is diagnosed as in situ weathering, which is manifested in the soils of Georgia less or more (Fig. 4.3). Depending on the intensity of

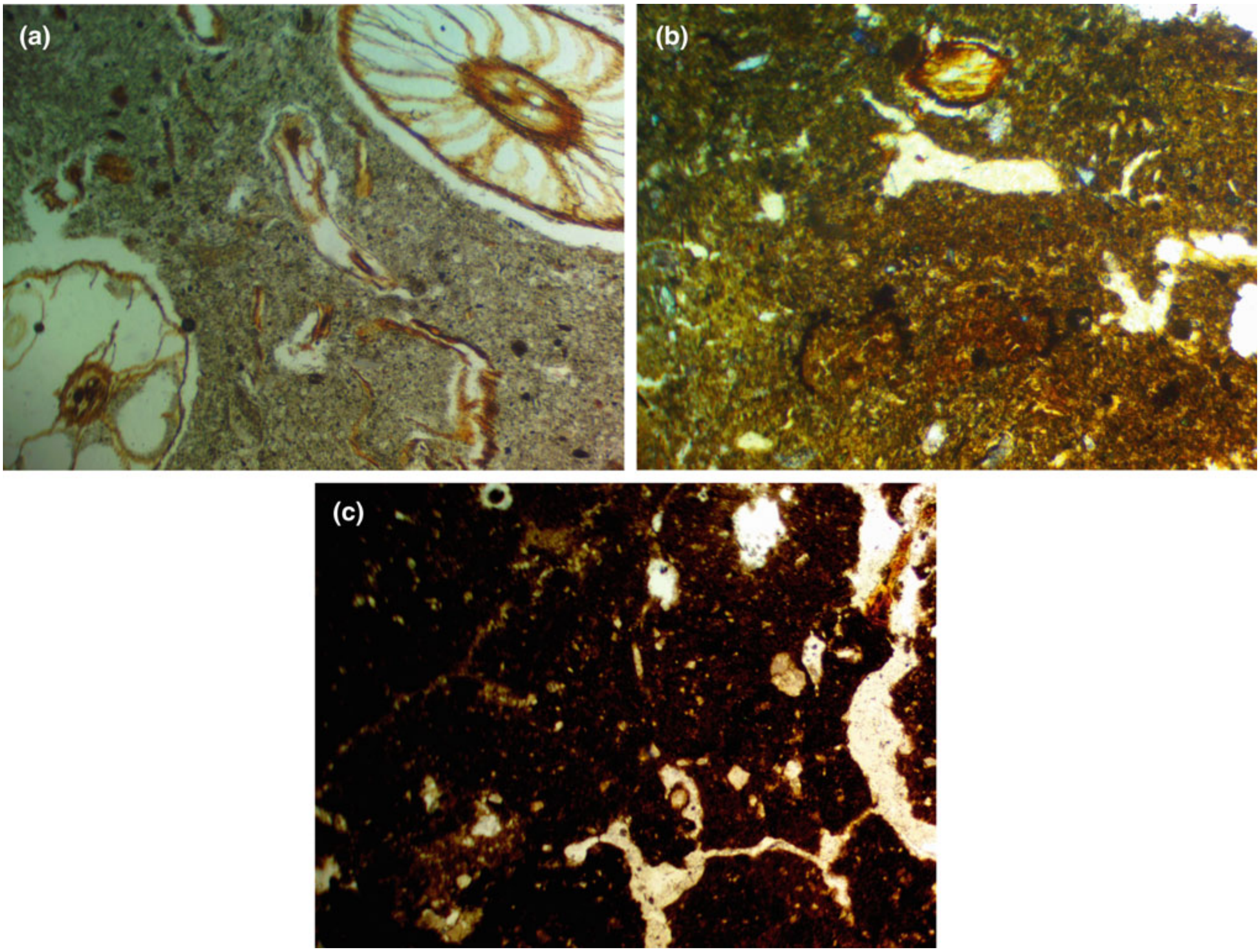

Fig. 4.1 Soil organic matter morphotypes: **a**—raw type (Luvisols Albic, nic.II); **b**—moder type (Fluvisols, nic.II); **c**—mull type (Vertisols, nic.+). Photos by L. Matchavariani

manifestation of the process of claying, three main grades were identified for the soils of Georgia (Matchavariani 2008): intense, medium, and weak (Fig. 4.4). This process is manifested most intensely in the following types of soils: Cambisols Dystric, Vertisols, Chernozems, and Cambisol Chromic. The mean values of the manifestation of the process of claying are identified in Kastanozems, Leptosols Rendzic, Leptosols Umbric, Leptosols Molic, partially Fluvisols. The process of argillization is weaker in Solonetz, Nitisols Ferralic, Acrisols Haplic, and Luvisols Albic. With Gleysols, the process of argillization as ESP is not virtually diagnosed in a micromorphological respect.

4.2.3 Distribution of Podzolization in the Soils

Usually, a diagnostic index of podzolization is the presence of the signs of destruction of primary minerals in soil surface horizons and transfer of the products of their chemical transformation down the profile. Podzolization, as the major profiling process, with the types of the soils of Georgia, including Luvisols Albic (in national classifications called as Subtropical-Podzolic/Yellow-Podzolic, and Gley-Podzolic soils), is not clearly diagnosed (Matchavariani 2008) despite the fact that this term, according to national classifications and FAO-UNESCO, even appears in the titles.

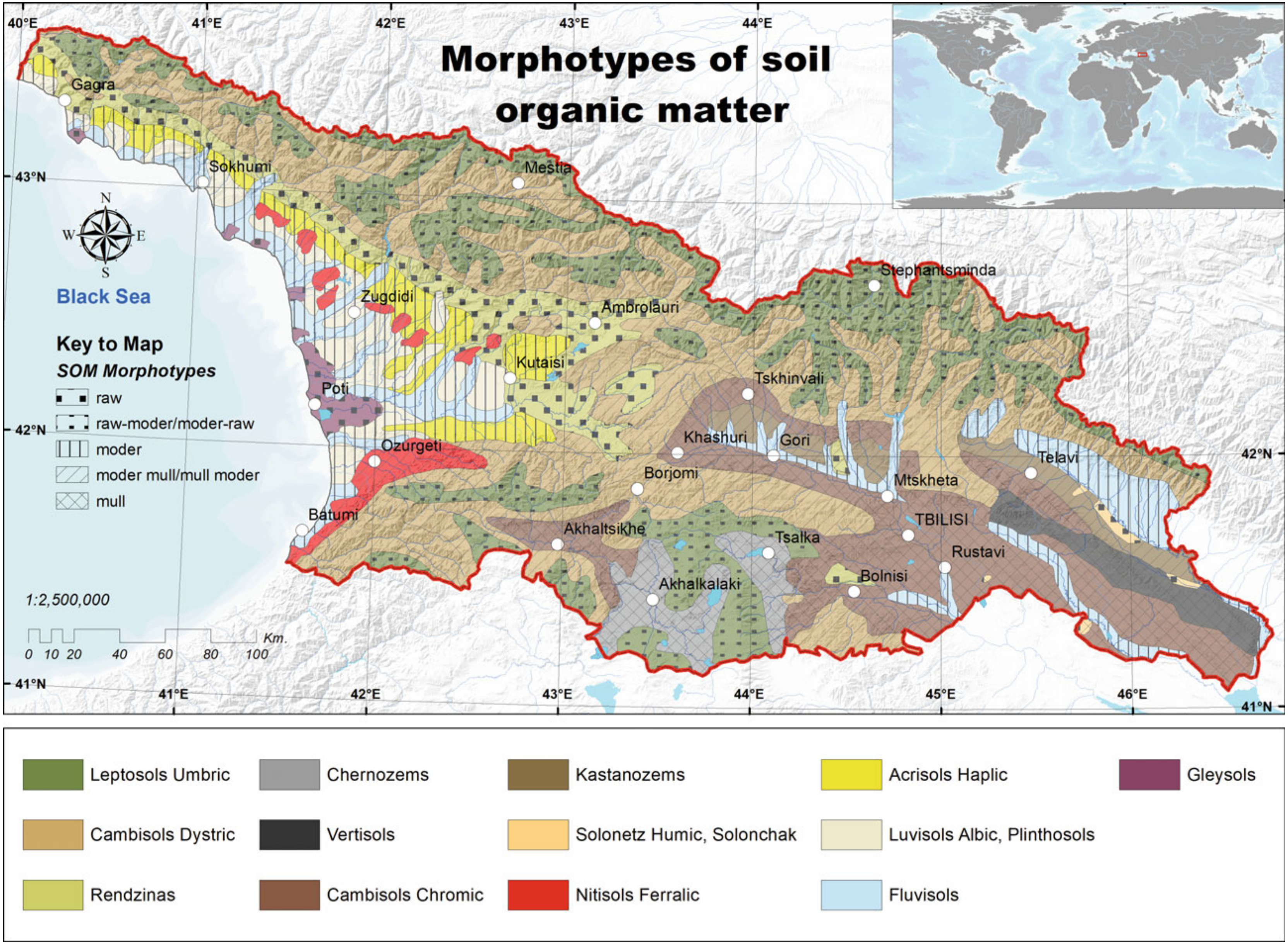

Fig. 4.2 Morphotypes of soil organic matter in soils. This map is created by D. Svanadze, based on data of L. Matchavariani

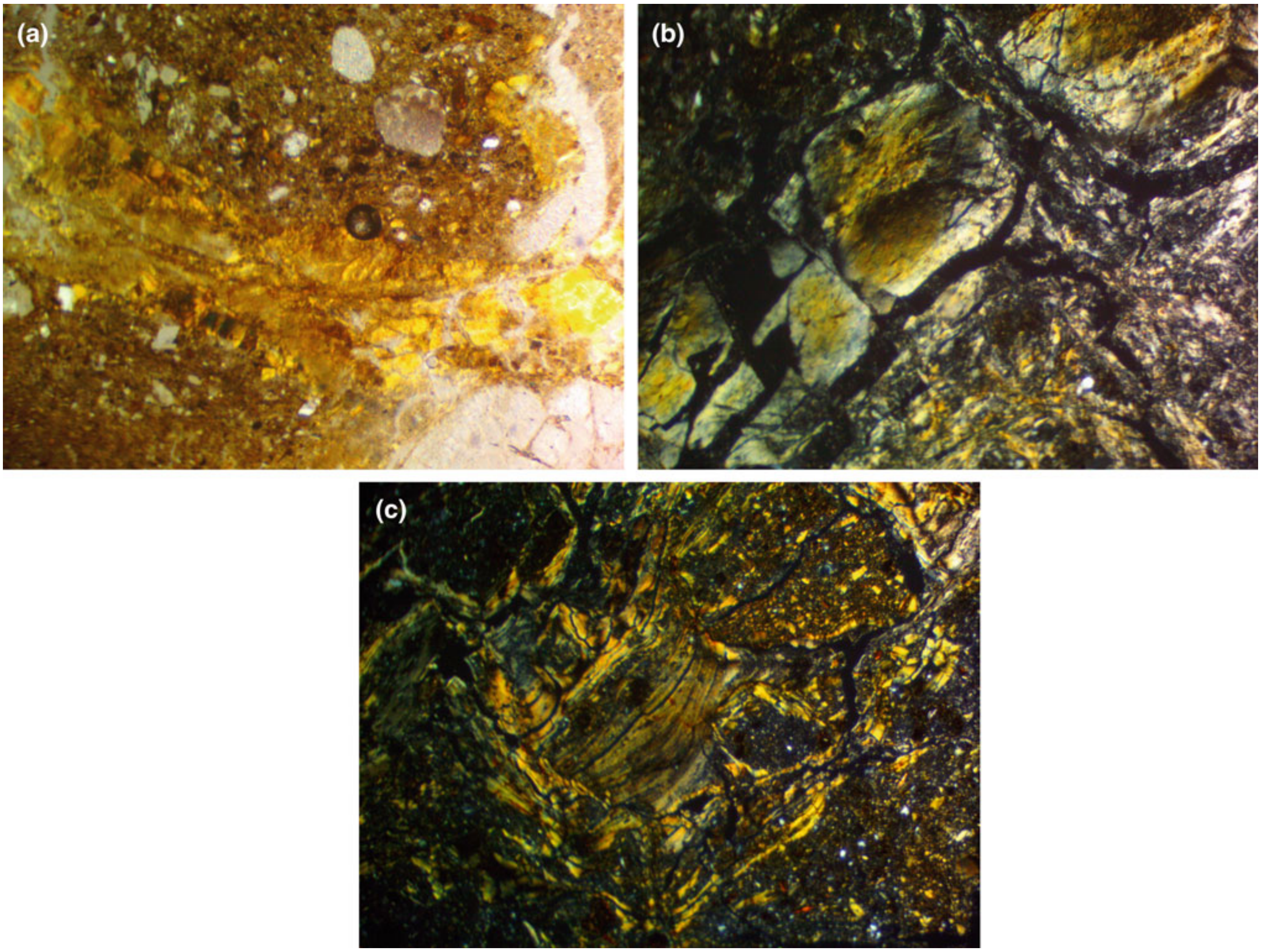

Fig. 4.3 Appearance of argillization process in soils on a microlevel; **a**, **b** and **c**—nic.II. Photos by L. Matchavariani

In theory, humid subtropical climate should promote intense degradation and movement of substances through a vertical profile. However, based on micromorphological studies, some signs of the presence of the products of chemically modified substances in the transit pores are fixed only locally. Therefore, the process of podzolization in these soils sometimes has only an intra-horizon, not an intra-profile value.

4.2.4 Distribution of Lessivage in the Soils

Micromorphologically, lessivage is diagnosed by the presence of the optically oriented clay cutans (sinter deposits, clay flows) in vertical, transit pores (Fig. 4.5). In the soils of Georgia (Matchavariani 2008), this process is manifested as following three forms (Fig. 4.6): clay cutans, as a sign of the actual lessivage and typical to the soils in humid regions—Nitisols Ferralic, Acrisols Haplic, and Luvisols Albic; silty cutans (sometimes clayey silty or sandy silty), typical to the soils of mountain regions—Cambisols Dystric, Acrisols Haplic, Rendzinas, and Leptosols Umbric; and complex cutans in the form of films on the walls of the pores and mineral grains (clay particles move short distances in different directions), typical to the soils of East Georgia—Cambisol Chromic, Kastanozems, and partially Vertisols.

4.2.5 Distribution of Gleization in the Soils

The diagnostic sign of the process of gleization at a microlevel is the contrast in the distribution of ferrum hydroxides (Fig. 4.7). This process, as a profile-forming one, in Georgia is manifested primarily in humid subtropical soils (Matchavariani 2008). In addition, as local signs, gleization occurs in low, depressed areas of different regions, partly in

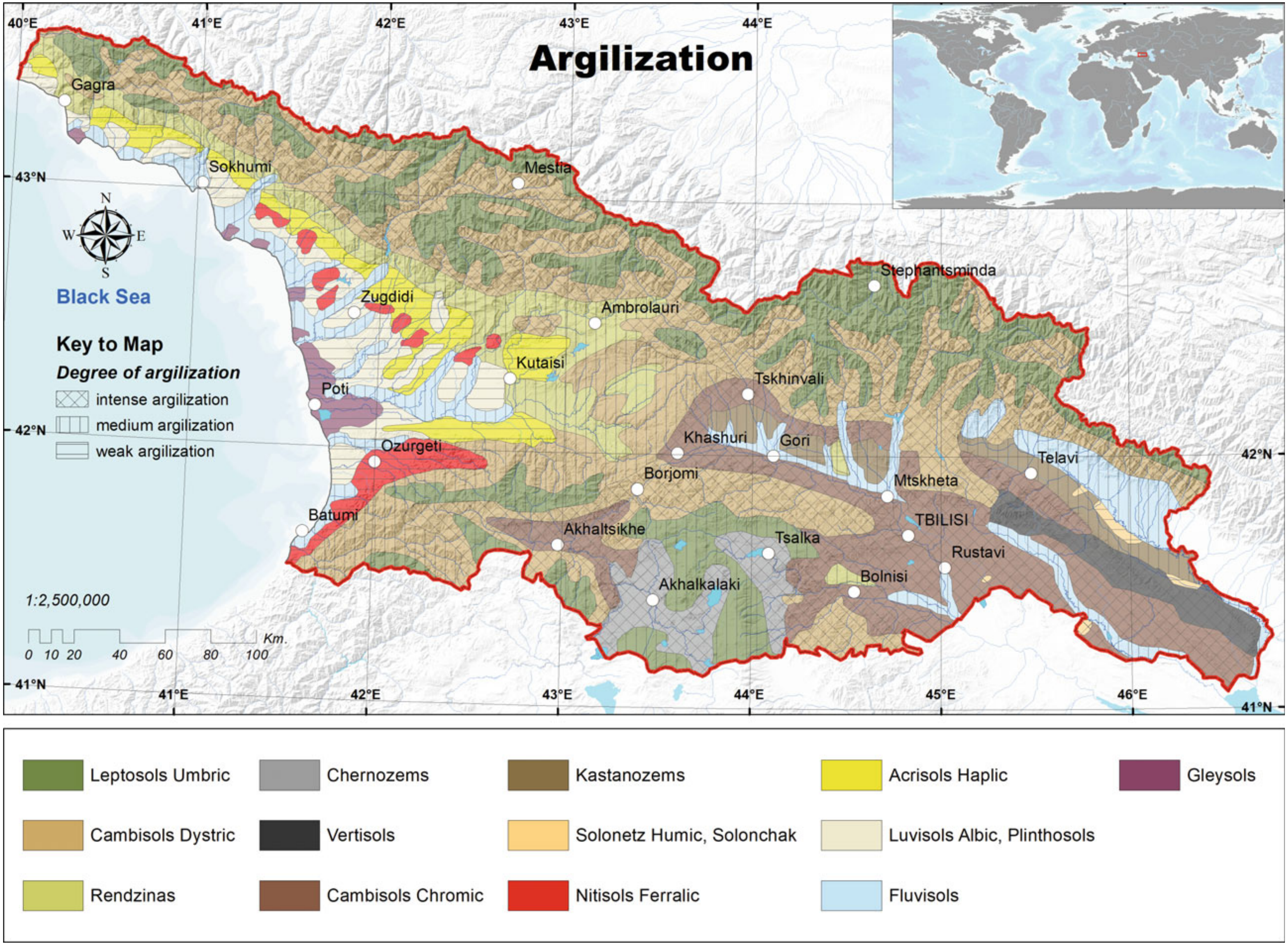

Fig. 4.4 Intensity of argillization in soils. This map is created by D. Svanadze, based on data of L. Matchavariani

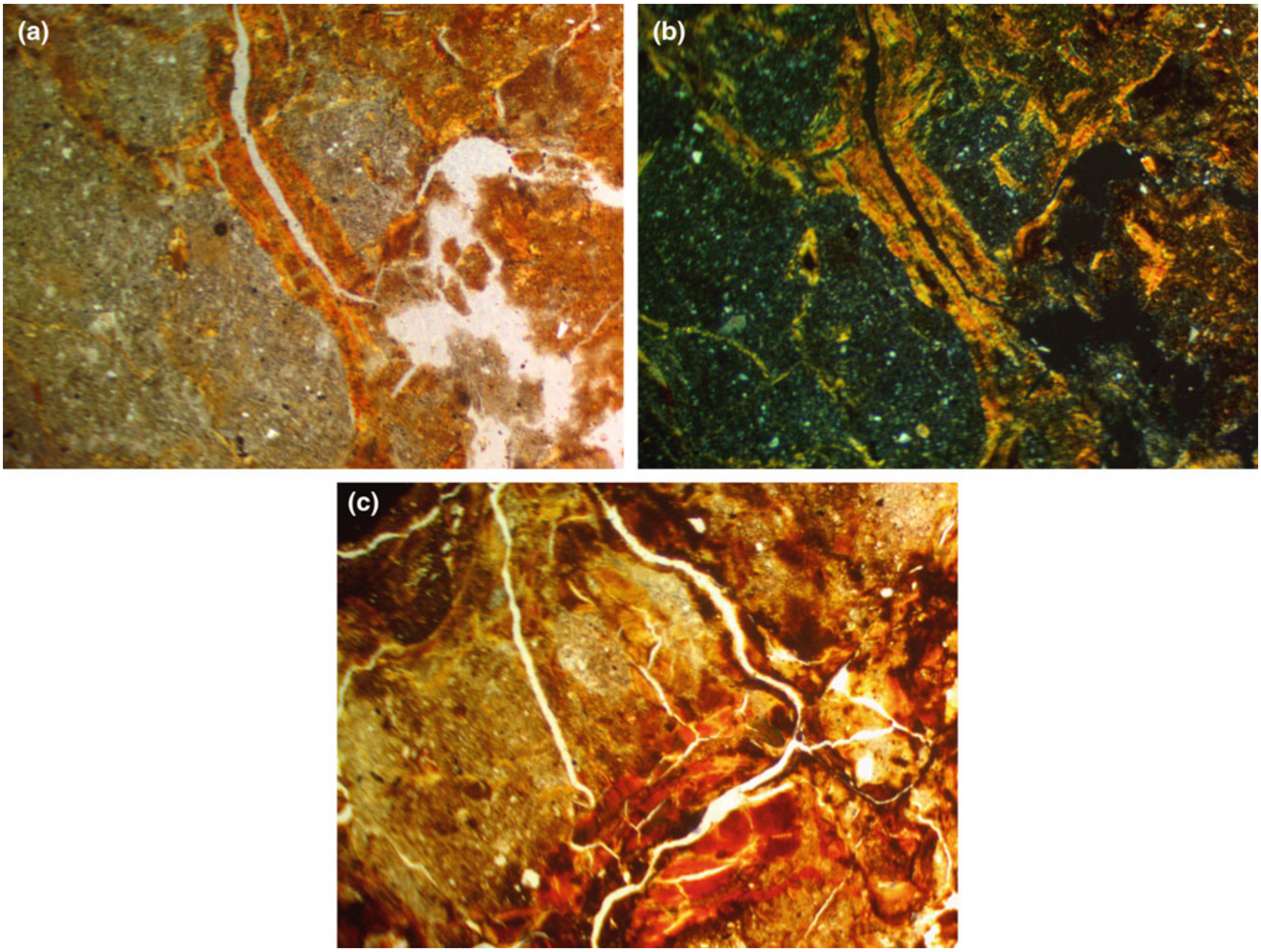

Fig. 4.5 The manifestation of the lessivage process at a microlevel—the sinters of optically oriented clay; **a** and **c**—nic.II; **b**—nic.+. Photos by L. Matchavariani

the mountain-meadow zone. Therefore, this process in the soils of Georgia is grouped according to the degree of intensity of the signs of gleization, as strong, medium, and weak (Fig. 4.8). The most intense process of surface gleization, like ESP, is manifested in the following types of soils: Acrisols Haplic, Luvisols Albic, Gleysols, and Fluvisols; the gleization of a medium intensity occurs in Nitisols Ferralic, Leptosols Umbric, and Solonetz Humic; weaker signs of gleization are also diagnosed in Cambisol Chromic, Kastanozems, and Chernozems.

4.2.6 Distribution of Ferrugination in the Soils

The processes associated with sedimentation, movement, and transformation of ferrum take place in many different kinds of soils of Georgia (Matchavariani 2005, 2008), and in humid subtropics first of all: Nitisols Ferralic, Acrisols Haplic, Luvisols Albic, Gleysols, and Fluvisols; the signs of ferrugination as small micro-zones of segregation and impregnation of plasma are manifested in Cambisols Dystric. Partially ferruginous secretions are also noted in arid regions. In Solonetz Humic, ferrum secretions are sometimes observed as large concretions with complex structure, being the result of the past stages of soil formation. Depending on the kind of manifestation of ferrugination in soils, two forms can be easily distinguished: concretion and plasma ferrugination, although with many humid subtropical soils, ferrugination takes place in fact, in both forms, both in the form of concretion formations and in the form of ferruginous zones impregnated in the basic mass (Fig. 4.9). As a result, the gradation of ferrugination was done by considering the intensity of the process manifestation (Fig. 4.10).

4.2.7 Distribution of Carbonization in the Soils

The carbonization, at the microlevel, is diagnosed according to a number of characteristics, taking into account the genetic-morphological groups of carbonates and the sizes of

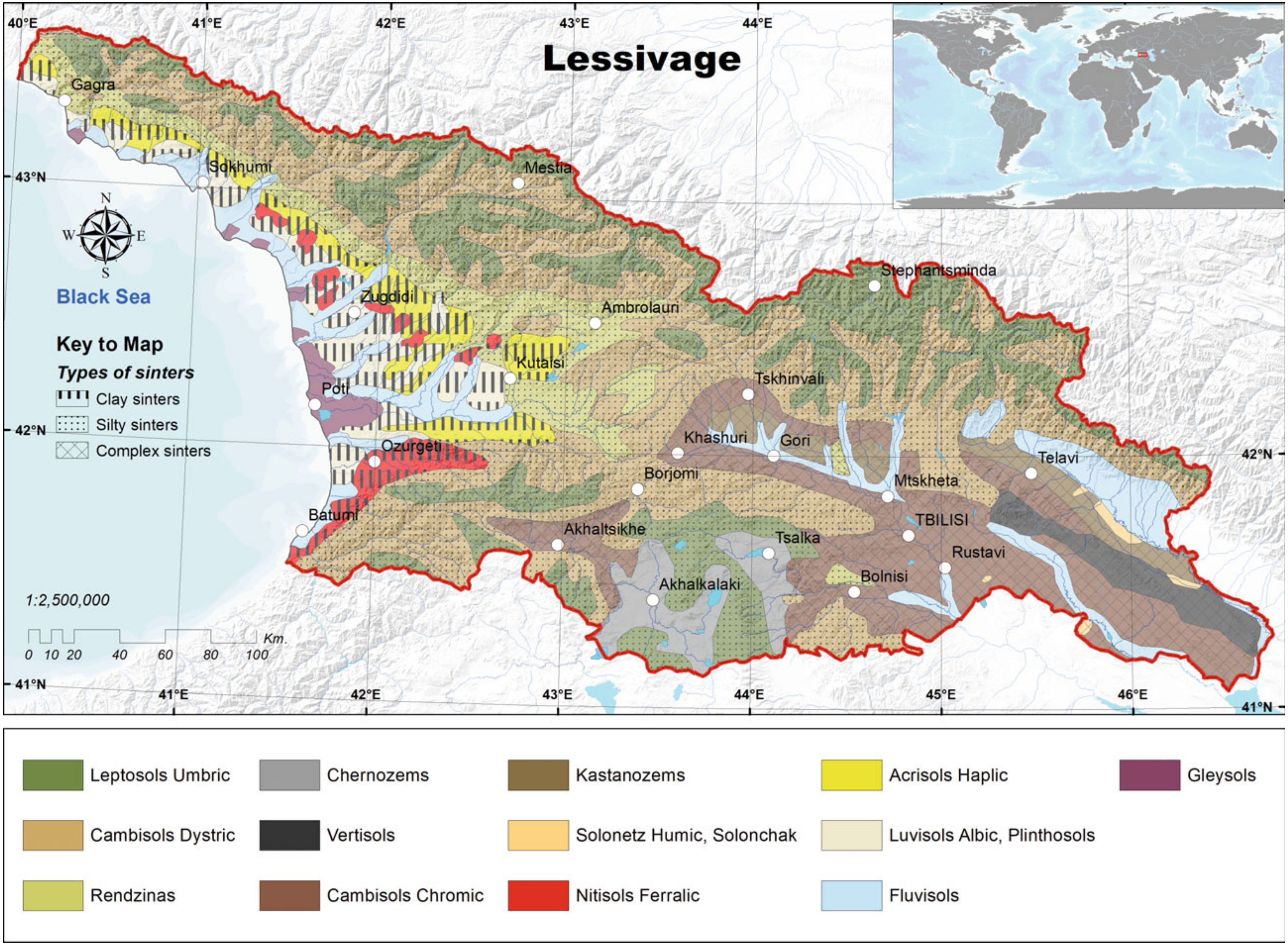

Fig. 4.6 The types of sinter deposits in soils. This map is created by D. Svanadze, based on data of L. Matchavariani

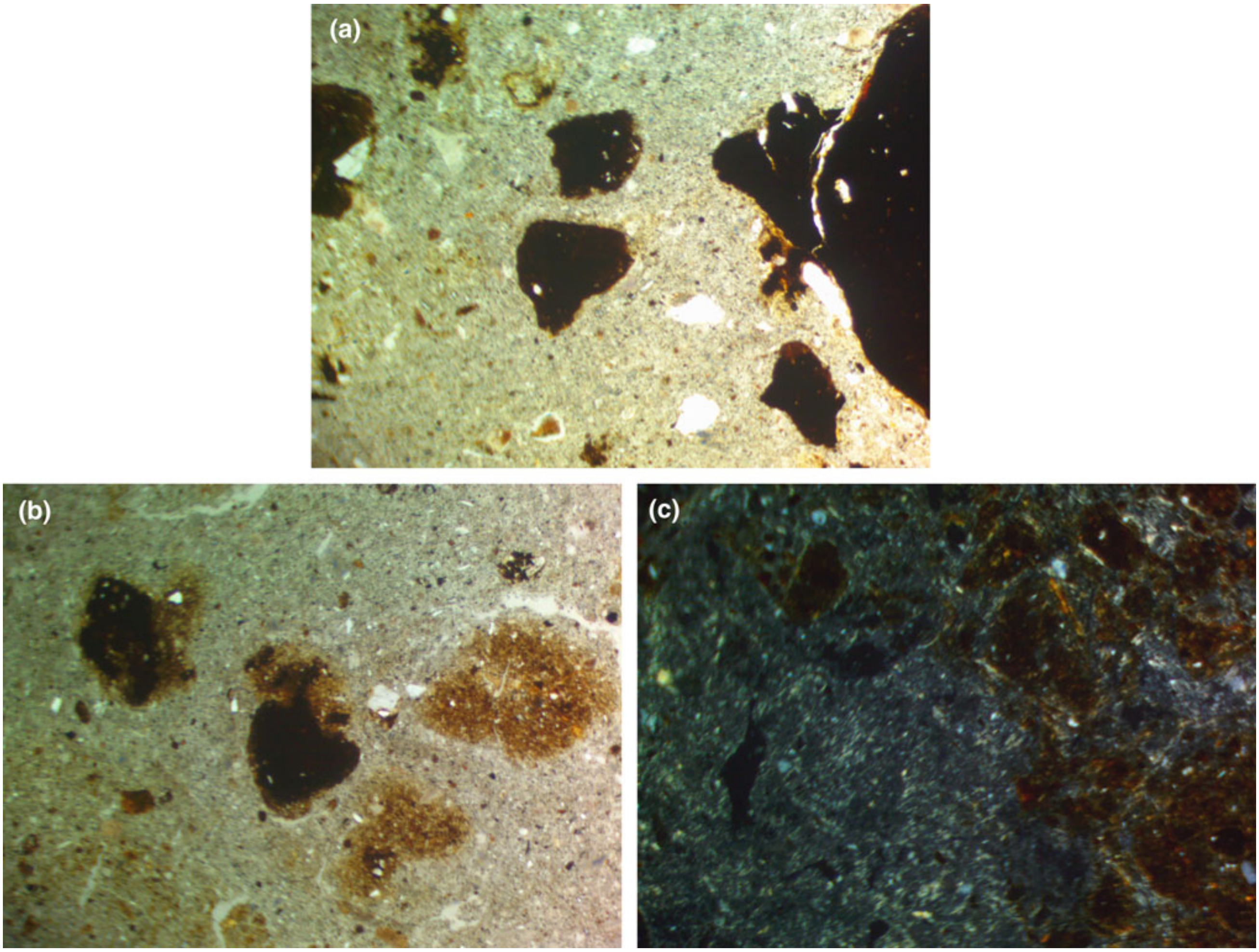

Fig. 4.7 The manifestation of the gleization process in soils at a microlevel; **a** and **c**—nic.II; **b**—nic.+. Photos by L. Matchavariani

calcite crystals (Fig. 4.11). This process, as a major profile-forming one, is manifested in the following soils of Georgia (Matchavariani 2008): Rendzinas, Vertisols, Cambisol Chromic, Kastanozems, partly in Leptosols Molic, Solonetz Humic and Solonchak, and depending on the region of formation, in the Fluvisols. With its form of expression, the carbonization is divided into two main types: concretion and plasma; with the intensity of manifestation, it is divided into strong, average, and weakly calcareous. In soils where this process is the most intense and leading, practically both groups of carbonizations are fixed (Fig. 4.12).

4.2.8 Conclusion

Based on the micromorphological diagnosis of the above-mentioned ESP, the groups of processes most typical to the specific soil types were identified. A map showing the distribution of the main profile-forming processes in the soils of Georgia (Matchavariani 2008) is compiled (Fig. 4.13). In order to establish the geographic features of soils, an attempt has been made to correlate this material with the landscape map of the Caucasus (Beruchashvili 1979), where at a type level, depending on the degree of humidification, humid, semi-humid, semiarid, and arid regions are distinguished on

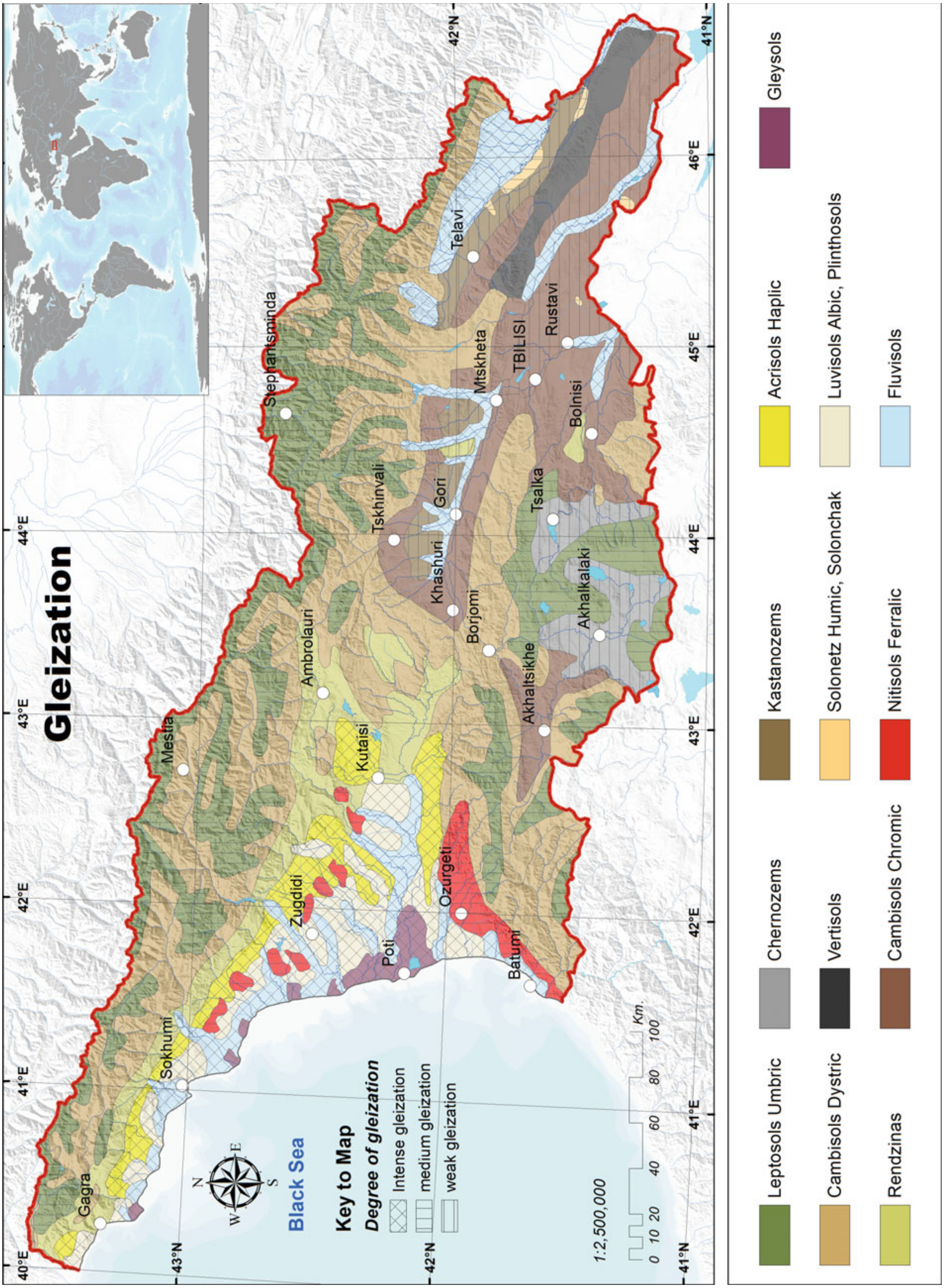

Fig. 4.8 Degrees of gleization in soils. This map is created by D. Svanadze, based on data of L. Matchavariani

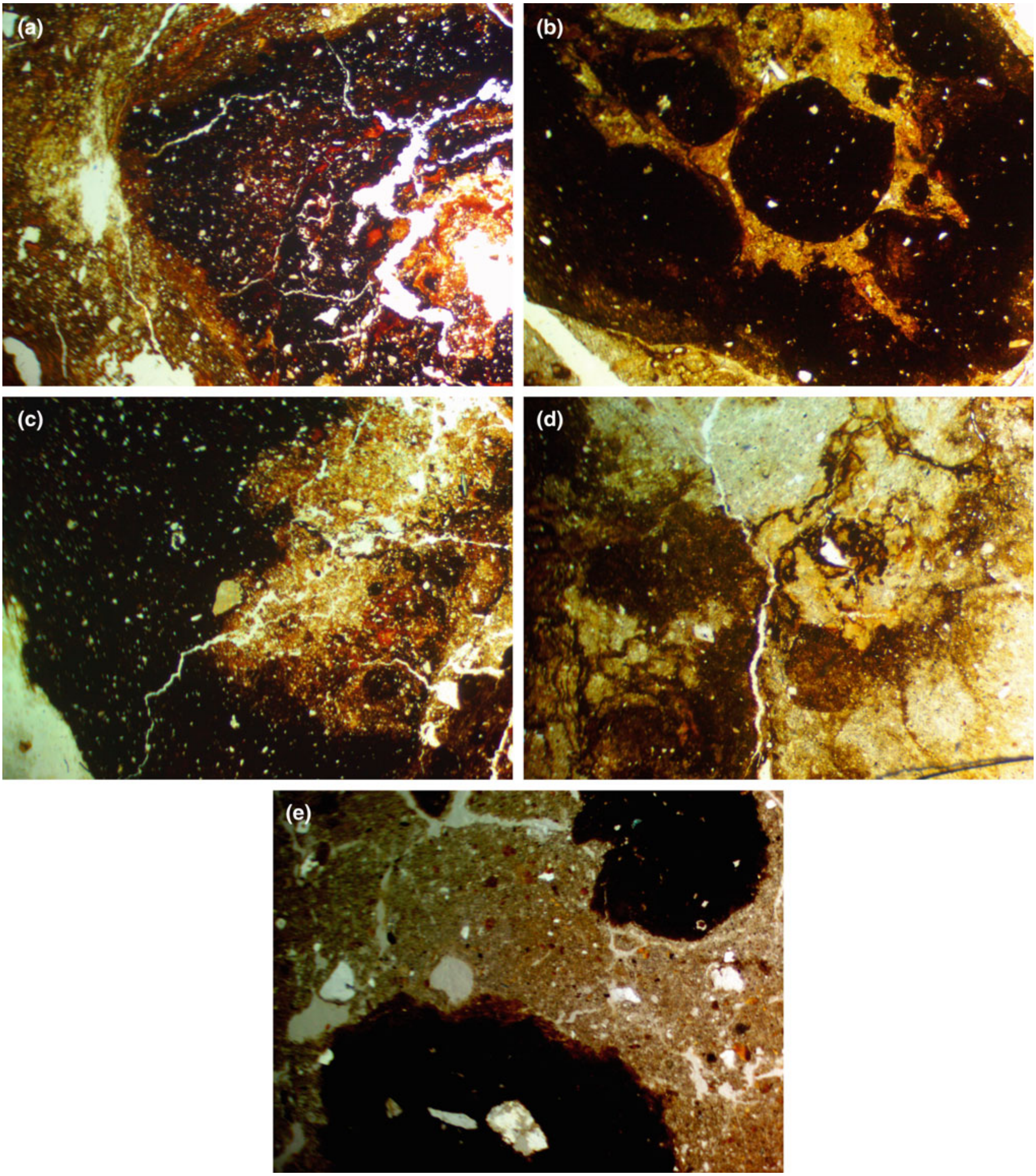

Fig. 4.9 Forms of the ferrugination process manifestation in soils at a microlevel; nic.II. Photos by L. Matchavariani

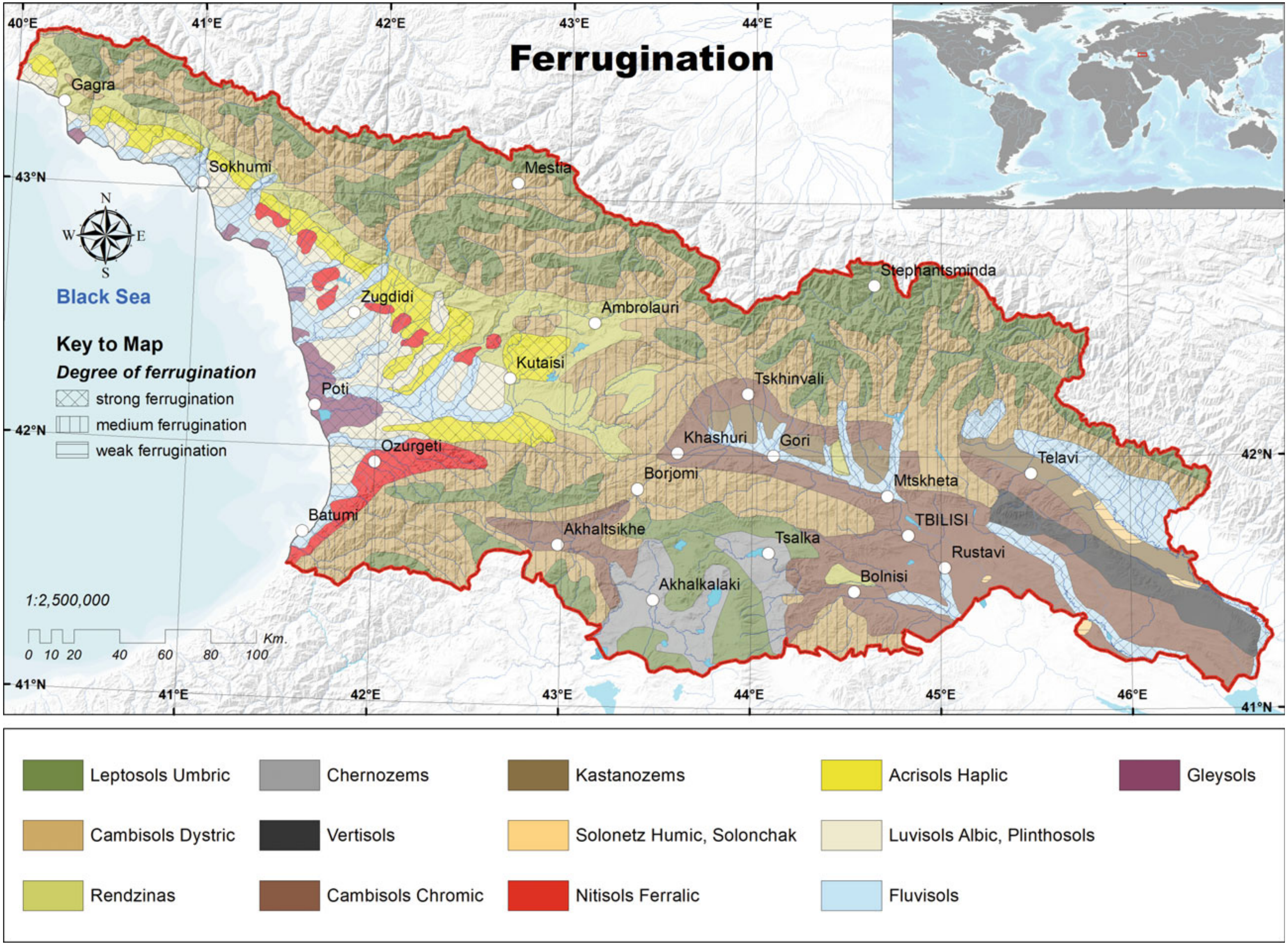

Fig. 4.10 Degrees of ferrugination in soils. This map is created by D. Svanadze, based on data of L. Matchavariani

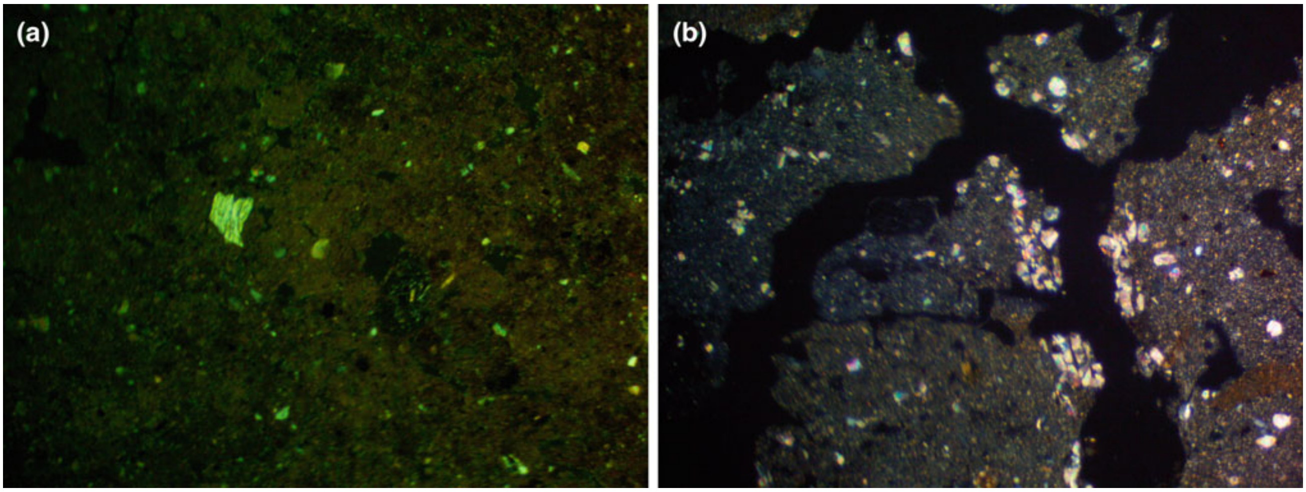

Fig. 4.11 The manifestation of the carbonization process in soils at a microlevel; nic.+ **a**—crypto-grained calcite (calcareous plasma); **b**—granular calcite crystals. Photos by L. Matchavariani

the territory of the country. The humid landscapes, which occupy the largest territory of the country and cover a large group of qualitatively different soils—Luvisols Albic, Plinthosols, Acrisols Haplic, Nitisols Ferralic, and Cambisols Dystric—combine the following ESPs: lessivage, gleization, ferrugination, and partly argilization. Arid landscapes occupying a small area of the southeastern part of the country include a small part of only Cambisol Chromic and, in fact, have their typical features. Semi-humid landscapes mainly constitute Fluvisols of East Georgia, which belong to the azonal types and are less subject to climatic factors. The same is true with intrazonal Rendzinas, in the formation of which the leading role is played by a carbonate substrate.

A more distinct is the relationship between the semiarid landscapes, incorporating Cambisols Chromic, Kastanozems, Vertisols, and Chernozems, with the following leading processes: humification, carbonization, and argillization (Fig. 4.13). Bog and floodplain soils (along river valleys), which are a part of the group of hydromorphic landscapes, have no general landscape-geographical regularities.

Thus, the ratio of the maps reflecting the spread of the major profile-forming processes in the soils of Georgia with the types of landscapes (humid, arid, semi-humid, and semiarid) has shown a very peculiar picture. A clear correlation is observed only with semiarid landscapes, where the leading ESPs are humification, carbonization, and argillization. Soil is a special component of the landscape, not always complying with certain regularities. In the process of forming of certain soils, often some factor may play a decisive role and a commonly known soil-formation process, based on the complex action of factors, may fall out of general geographic patterns. Therefore, it is not accidental that in the names of landscapes the soil appears to the least extent.

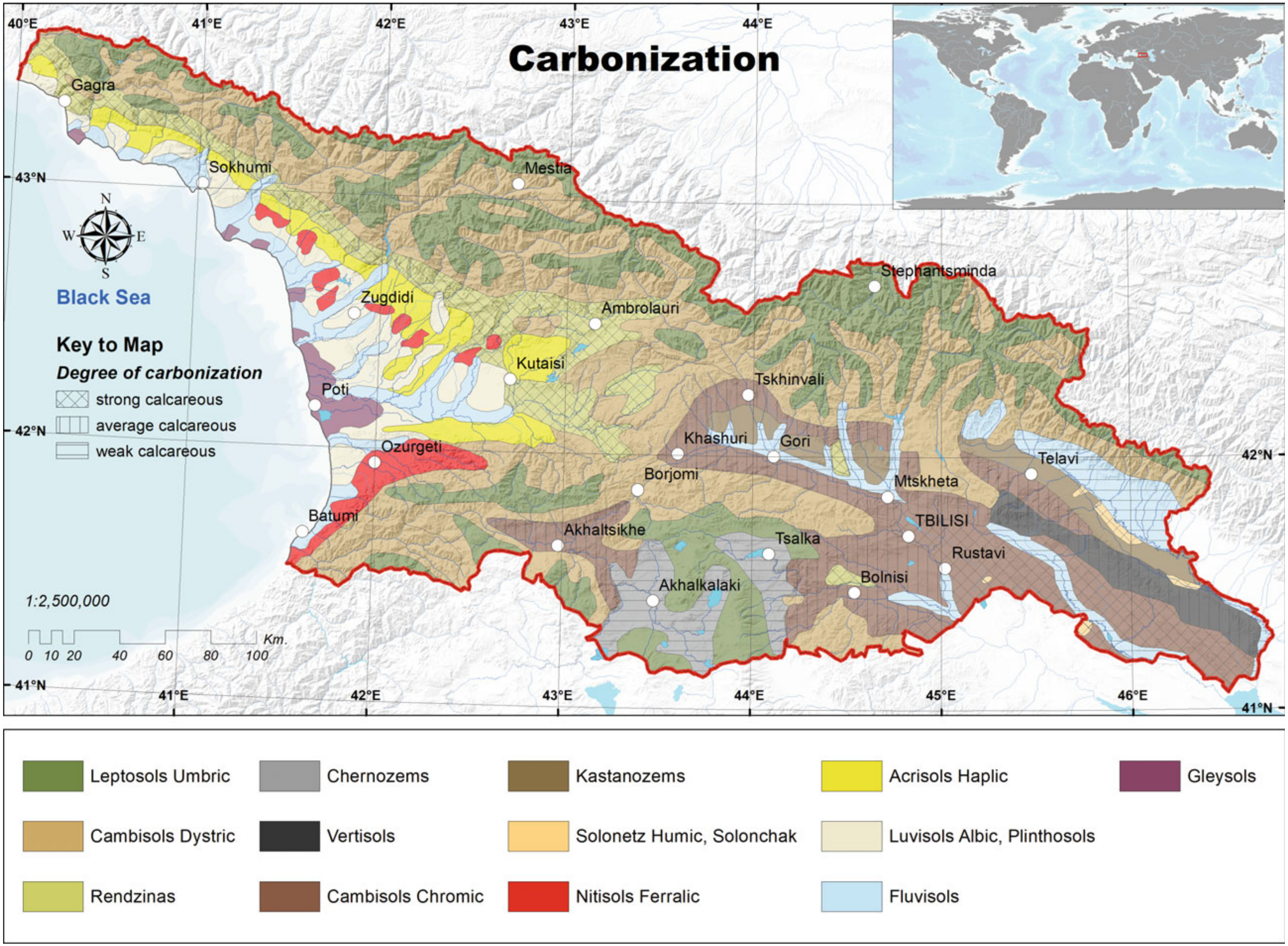

Fig. 4.12 Degrees of carbonization in soils. This map is created by D. Svanadze, based on data of L. Matchavariani

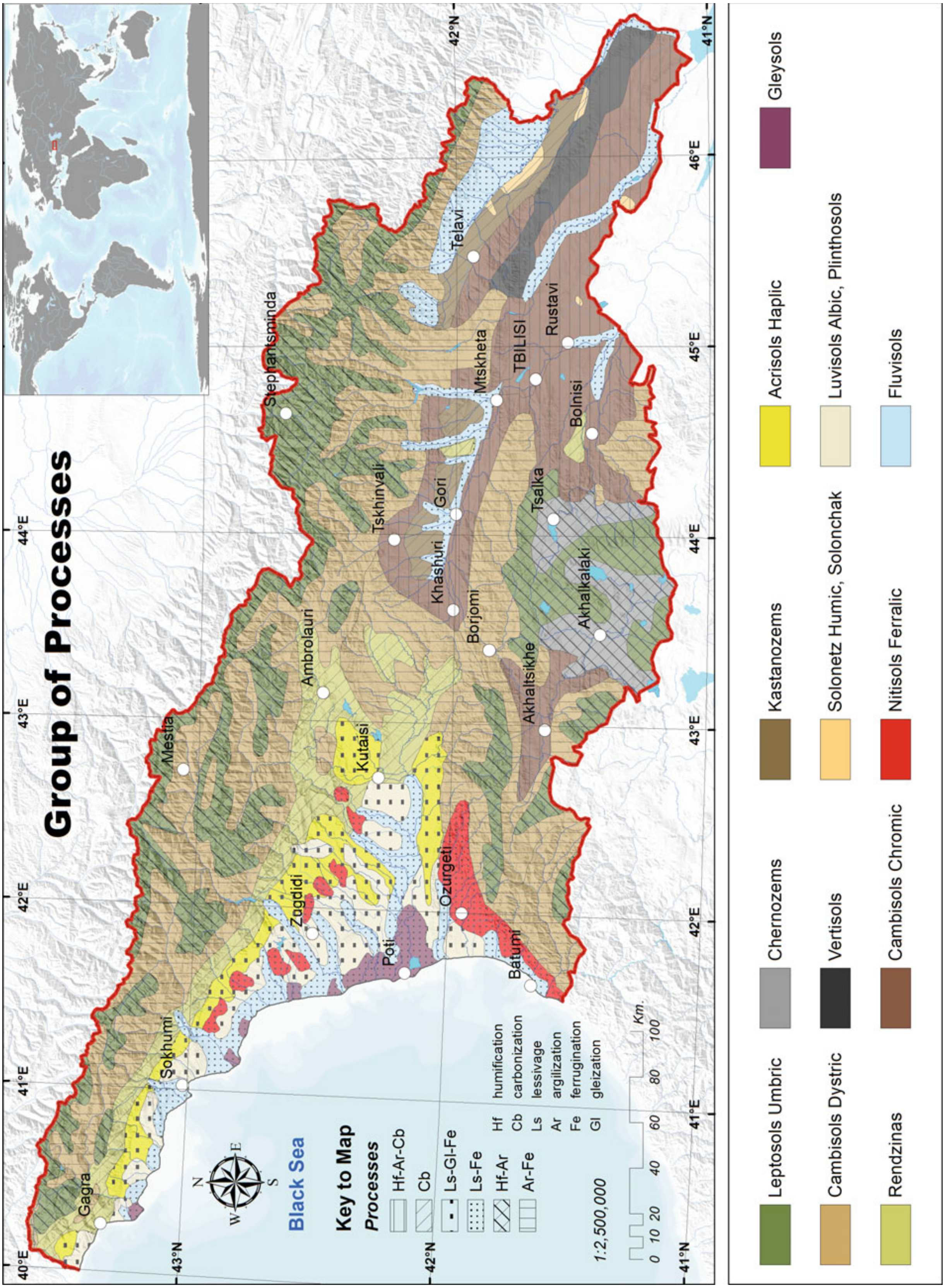

Fig. 4.13 The features of distribution of the soil processes group in soils. This map is created by D. Svanadze, based on data of L. Matchavariani

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