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Levan Tielidze *Editor*

Geomorphology of Georgia

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We dedicate the presented work to the 100th anniversary of the establishment of Ivane Javakhishvili Tbilisi State University (TSU). The first-ever national university in the Caucasus was opened on January 26 (new style February 8), 1918. The university laid the foundation for a European-type higher school in Georgia, based on Georgian educational traditions.

We also dedicate the presented work to the 85th anniversary of the establishment of Vakhushti Bagrationi Institute of Geography, founded in 1933 at the Tbilisi State University by the leadership of academician Alexander Javakhishvili—the founder of the Georgian geographical school.

Finally we dedicate this work to the Georgian geomorphologist-researchers of previous generation, who mainly worked in Georgia in the last century and created considerable geomorphological works; they were: Academician Alexander Javakhishvili, Professors: Levan Maruashvili, David Tsereteli, Grigol Devdariani, Shalva Kipiani, Nikoloz Astakhov, Nikoloz

Skhirtladze, Simon Nemanishvili, Demur Tabidze, Givi Maisuradze, George Changashvili, Zurab Tintiliozov (Tatashidze), Archil Tsagareli, Karlo Liponava, Ramin Gobejishvili and others. In the twentieth century, the major scientific literature was published only in Georgian and Russian languages (due to the former Soviet Union's "locked system"), and in many cases the names of the authors and their works could not reach the international scientific community, and unfortunately most of them still remain unknown.

Levan Tielidze

Preface

Georgia, located in the Caucasus region at the crossroads of Europe and Asia, is characterized by geological, geomorphological, and geographical diversities. The high snow-icy mountains, medium and high mountainous deeply fragmented landscape, narrow and deep gorges, seaside lowlands, volcanic cones, uplands and mountain ranges, the intermountain plains, hollows, and highlands give the special beauty to the landscape of Georgia.

The peculiarity of the landscape greatly affects the natural conditions. The diversity of climate, hydrographic network, vegetation cover, soils, fauna, natural and anthropogenic landscapes entirely depend on relief. For example, the Greater Caucasus Range hinders the invasion of northern arctic cold air masses in Georgia, which is why the average annual temperature here is higher than in the North Caucasus (Gobejishvili 2011). The presence of the humid and dry subtropical zones, the sharp differentiation of atmospheric precipitation between the west and east is stipulated by the morpho-hypsometry of the Likhi and Achara-Imereti ranges. The diverse spectrum of natural zones and the altitudinal zonality of geodynamic processes are associated with the hypsometry of the relief. The humid air masses blown from the Atlantic Ocean and the Black Sea leave the main amount of precipitation on the barrier-located ranges (Gagra, Bzipi, Kodori, Egrisi, Svaneti, Racha, Likhi, Achara-Imereti, and Arsiani).

The landscape of Georgia has played a major role in the formation of the Georgian nation for centuries. The ethnic zones of our country, located on the southern and northern slopes of the Greater Caucasus, intermountain lowland, and southern Georgia, look similar, but at the same time, they are very different in character, nature, dialect, behavior, and traditions that eventually form a rich and diverse common Georgian ethno-culture.

The first fundamental work of geomorphological content "The Geography of Georgia, Volume I, Geomorphology" was published by Alexander Javakhishvili in 1926. During the twentieth century, geomorphological research was carried out mainly in the Department of Geomorphology of the Institute of Geography. In 1971, as a result of their research, the most important work was created in the Russian language—"Geomorfologia Gruzii" ("Geomorphology of Georgia". Ed. Maruashvili 1971). In the 1980s, more works were published, in which Georgian geomorphologists characterized individual regions or genetic types of the relief (Astakhov 1973; Nemanishvili 1973, 1982; Tskhovrebashvili 1978; Chkheidze 2000, 2004). Since then, numerous

geomorphological facts, processes, and events have been documented by a range of authors. Research methods have also been improved, with new geomorphological research in Georgia and therefore highlighting the need for a geomorphological restudy of Georgia.

The present work is the first English language book of geomorphological content about Georgia, driven by the surveys conducted for years in the most part of Georgia by different generations of geomorphologists. We could not conduct expeditions in those regions that are currently temporarily occupied within Russia boundaries (Apkhazeti and Tskhinvali region). The relevant geomorphological materials on each region were collected from our predecessor researchers' works and processed, and they are attached to each chapter of the book in the form of used References.

We would like to express our gratitude to Ms. Nino Chikhradze and Dr. Roger Wheate for supporting us during working on the book.

Tbilisi, Georgia Levan Tielidze
2017

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Part I

Introduction to the Geomorphology of Georgia

Long-Term Geomorphic History of Georgia

1

Levan Tielidze, Ramin Gobejishvili, Bejan Tutberidze, Levan Maruashvili, Nikoloz Astakhov and Roger Wheate

Abstract

This chapter discusses the location of Georgia, its orographic units, geological and geomorphological structure, zones and zoning. The Proterozoic, Paleozoic, Mesozoic, and Cenozoic sediments; Jurassic and Cretaceous formations; Palaeogenic, Oligocene and Miocene sediments; Pliocene and Quaternary formations (Pleistocene and Holocene) are described. The three main geomorphological zones such as the Greater Caucasus, Georgia's intermountain plain, and Southern highland of Georgia are described. Within Georgia, the Neogene and Quaternary volcanisms (Late Miocene–Early Pliocene, Late Pliocene–Early Pleistocene, Middle and Late Pleistocene, and Holocene) are characterized. We do not provide the description of the Late Pleistocene glaciation of the Georgian Caucasus in this chapter, because a separate monograph directly about the glaciers of Georgia has been published.

Keywords

Geology of Georgia · Geomorphology of Georgia · Volcanism of Georgia

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1.1 Geographical Information

The territory of Georgia is mainly located in the southern slope of the Greater Caucasus: incorporating the mountainous regions of the Caucasus and southern Georgia, and including Georgia's intermountain plain. Only a small area is located on the northern slope of the Greater Caucasus. It has a distinct natural boundary in the west (the Black Sea) and north (the Greater Caucasus crest) (Fig. 1.1).

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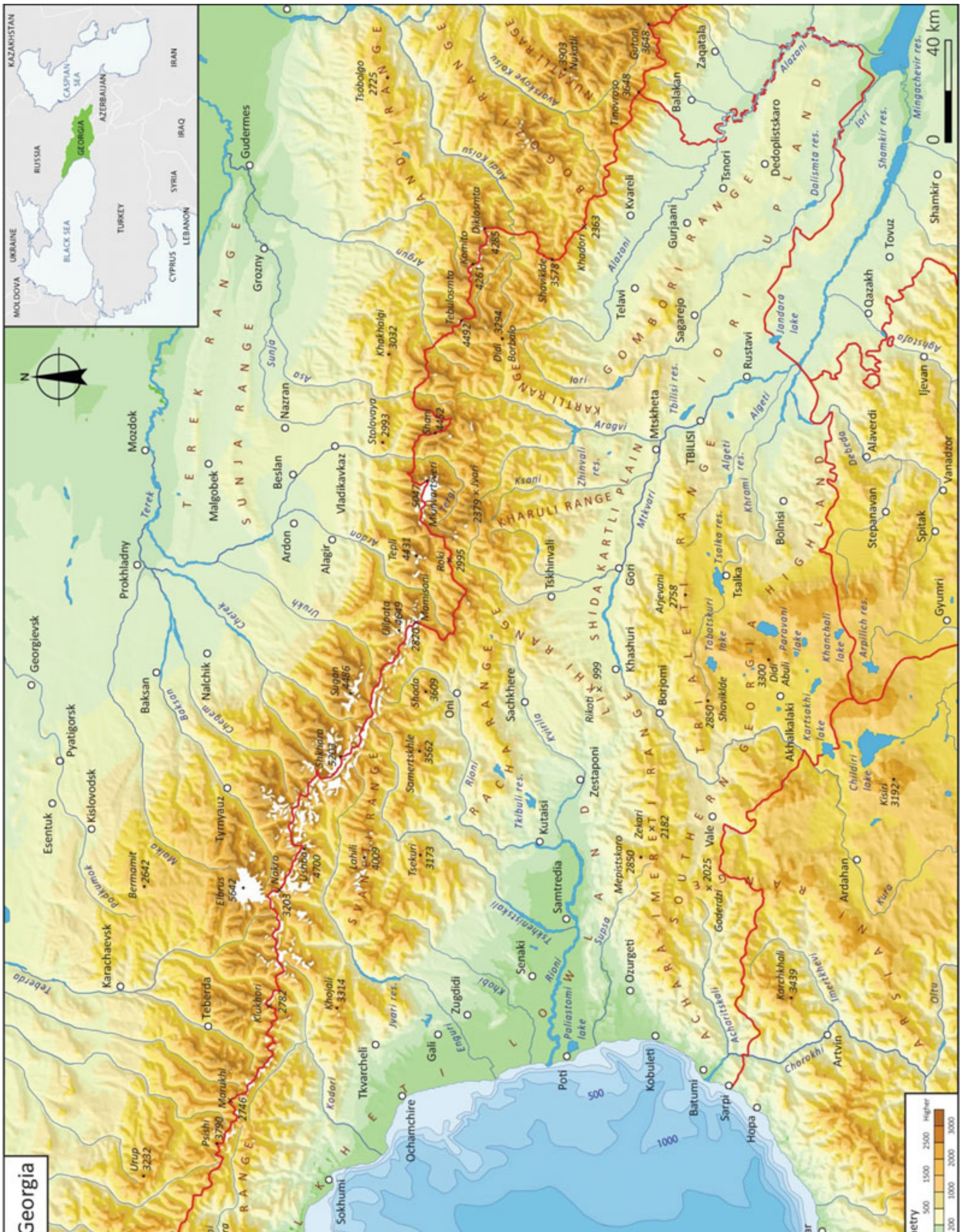

Fig. 1.1 Physical map and location of Georgia

The Caucasus Mountains occupy the entire northern belt of Georgia; the highest peak is Shkhara—5203 m above sea level (asl). The southern slope of the Greater Caucasus Range in Georgia stretches from Mt. Avadhara (2960 m) to Mt. Tinovroso (3374 m) for about 750 km (Tielidze 2016). Parallel and transverse ranges include: Gagra, Bzipi, Chkhalta (Apkhazeti), Kodori, Svaneti, Egrisi (Samegrelo), Lechkhumi, Racha, Shoda-Kedela, Germukhi, Kharuli, Lomisi, Kartli, Kakheti, and others. A short section of the northern slope of the Greater Caucasus intrudes from Mt. Vatsisparsi (3573 m) to Mt. Shaviklde (3578 m) including the Khokhi, Kuro, Shani, Kidegani, Khevsureti, Pirikita, Atsunta, and Mutso subranges. Adjacent to the medium and high mountainous tectogenic-erosive relief, there are widespread glacial, old glacial (Pleistocene and Holocene), volcanic, karst, and gravitational landscape types.

The Psou, Bzipi, Kodori, Enguri, Rioni, Liakhvi, Ksani, Aragvi, Iori, and Alazani rivers flow to the south from the Greater Caucasus, while the Tergi (Terek), Asa, Arghuni, and Tushetis Alazani (Andi Koysu) rivers flow to the north. Many notable rivers originate from the lakes of Didi Ritsa, Patara Ritsa, Amtkeli, Kvedi, Ertso, Keli, and Archvebi.

The Caucasian climate is humid within the western part of Georgia, promoting the development of rich vegetation—deciduous and dark coniferous forests, evergreen and relic species. High mountainous relief is decorated by alpine and subalpine vegetation; the glaciers are distributed over the crest of the Greater Caucasus.

Georgia's intermountain plain is represented by the Kolkheti Lowland, the Imereti Highland, the Shida Kartli, Kvemo Kartli and Alazani plains, the Iori Upland, and some lower ranges.

The important rivers in the Kolkheti Lowland are: Kodori, Mokvi, Rioni, Enguri, Khobi, and Supsa. The Paliastomi Lake is the largest among the lakes. The climate of Kolkheti is warm and humid, frosts are rare, and annual precipitation is 1500–2500 mm. The vegetation cover is mostly modified by human influence, although in some areas it is represented by Colchis type forests—oak (*Quercus*), hornbeam (*Carpinus*), chestnut (*Castanea*), alder (*Alnus*) with abundant evergreen subforest consisting of box tree (*Buxus colchica*), rhododendron (*Rhododendron ponticum*), laurel (*Laurocerasus officinalis*), and holly (*Ilex colchica*). The main part of the Imereti Highland is built from old crystalline rocks (Dzirula massif). The climate here is cool and drier than in the Kolkheti Lowland. Natural vegetation is represented by deciduous forest and poor Colchis subforest (Gobejishvili 2011).

Shida Kartli Plain is located at a height of 500–800 m asl; the climate is moderately warm semi-continental and the annual precipitation is 500–700 mm. Vegetation is represented by forest-valley and secondary valley. The Mtkvari (Kura) River and its tributaries—Prone, Liakhvi, Lekhura, Ksani, and Aragvi flow across the plain. Kvemo Kartli Plain is located at a height of 300–500 m above sea level, but otherwise is similar to the Shida Kartli Plain.

In the Iori Upland, flat plains are mixed with structural hillocks at a height of 1000–1200 m, built of Tertiary sediments. The climate is arid, with annual precipitation 300–400 mm. Chernozems and Kastanozems underlie valley vegetation; this is reduced to a semidesert landscape in the Eldari Lowland.

The Alazani Plain is a sediment-filled continental geosyncline, at 400–700 m elevation. The climate is milder than in the other regions of the eastern Georgian plain. The vegetation is represented by forest and forest-valley; there can be found the elements of mesophilic flora. The Likhi, Kvernakebi, Saguramo-Ialno, and Gombori ranges are located in Georgia's intermountain plain.

The highland of southern Georgia consists of volcanic upland and ranges (Achara-Imereti, Trialeti, Loki, and Shavsheti) built of Tertiary sediments bordering from the north. In the western part of the Trialeti Range, at Borjomi, the young volcanic relief is developed in the form of lava flows, plateaus and cones. In the western part of the Achara-Imereti Range, the climate is humid with abundant vegetation (deciduous and coniferous forests, subalpine with

rhododendron shrubs (*Rhododendron caucasicum*) and alpine meadows). The climate in the ranges located in the east becomes dry and losses the Colchis elements. The Mtkvari River (Borjomi gorge) antecedently crosses the Achara-Trialeti Range system.

The volcanic upland of Georgia is constructed from Neogene and Quaternary effusives, covered with boulders; the highest peak is Didi Abuli—3301 m asl. The relief is represented by lava plateaus (Dmanisi, Gomareti, Chochiani, Bedeni, and Kvemo Kartli), folded hillocks and flatlands, and rows of volcanic cones (Samsari and Javakheti ranges). The Javakheti region is rich in lakes: Paravani, Tabatskuri, Kartsakhi, and Saghamo. The climate is cold and mildly humid with 600–1000 mm annual precipitation. Chernozems dominate in the lava plateaus, characterized by the absence of forest cover. There are alpine meadows with rhododendron shrubs (*Rhododendron caucasicum*) and birch (*Betula*) groves in the slopes of Javakheti and Samsari Ranges (above 2100 m).

1.2 Stratigraphy

The territory of Georgia contains geological formations, ranging from Neoproterozoic (~1000–1200 mln years) to modern era (Gamkrelidze 2012) (Fig. 1.2).

The oldest—the Proterozoic and Early-Middle Paleozoic formations, are metamorphic and are represented within the Greater Caucasus main watershed range and Dzirula and Khrami crystalline massifs. These rocks are dated based on both the geologic (interrelation of rocks) and new geo-chronological data. All of these have experienced a polycyclic regional metamorphism. The Laba metamorphic complex of the Greater Caucasus main range as well as the metamorphic slate suites of Dzirula and Loki massifs belong to the Early and Middle Paleozoic.

Upper Paleozoic formations are represented by continental rhyolites and rhyodacites and their pyrocrystals in the north of the Dzirula massif and in the north and east of the Khrami massif. The molasse sediments of sand suite in the Greater Caucasus main range belong to the upper part of the Carboniferous system.

The mainly terrigenous and weakly metamorphic rocks of the Dizi series belong to the Middle and Late Paleozoic. In some areas, the upper parts of the Dizi series also include the Triassic stage. The Dizi series is outcropped on the southern slope of the Greater Caucasus within the Svaneti region.

Mesozoic and Cenozoic sediments are fully represented in the territory of Georgia and are characterized by rich fauna fossils.

Jurassic sediments, which are transgressively located almost everywhere, contain all the stages of the Jurassic age including Tithonian, and are dated mainly by ammonite fauna (Gobejishvili et al. 2011). These sediments are found in all tectonic units of Georgia and they are quite different by character. They are mainly represented by thick clay slates and sandstones of the deep sea, flysch formations, shallow sea limestones, and lime-alkaline and tollite volcanogenic rocks. The volcanogenic suite of the Bajocian age (porphyritic series) is particularly thick, represented by the lime-alkaline basalt-andesite-rhyolite series.

Cretaceous formations, which are often transgressively distributed over the older formations, are also widespread and are represented mainly by carbonate (limestones, marls) and volcanogenic rocks. Thick flysch Cretaceous sediments are widespread in the southern slopes of the Greater Caucasus.

Palaeogenic sediments occur across all tectonic zones of Georgia and are represented by terrigenous, carbonate and sediment-volcanogenic rocks. In many areas, the Paleogene is transgressively located over the older sediments.

The Oligocene and Early Miocene (Maicopian series) are represented by the marine molasse: carbonate clays (Khadum horizon), gypsum clays, conglomerates, and sandstones.

Middle and Late Miocene and Pliocene sediments are developed in orogenic hollows (molasse depressions) and are represented by marine and continental molasses. The Chokrakian age sediments are often located transgressively and with angular discrepancy.

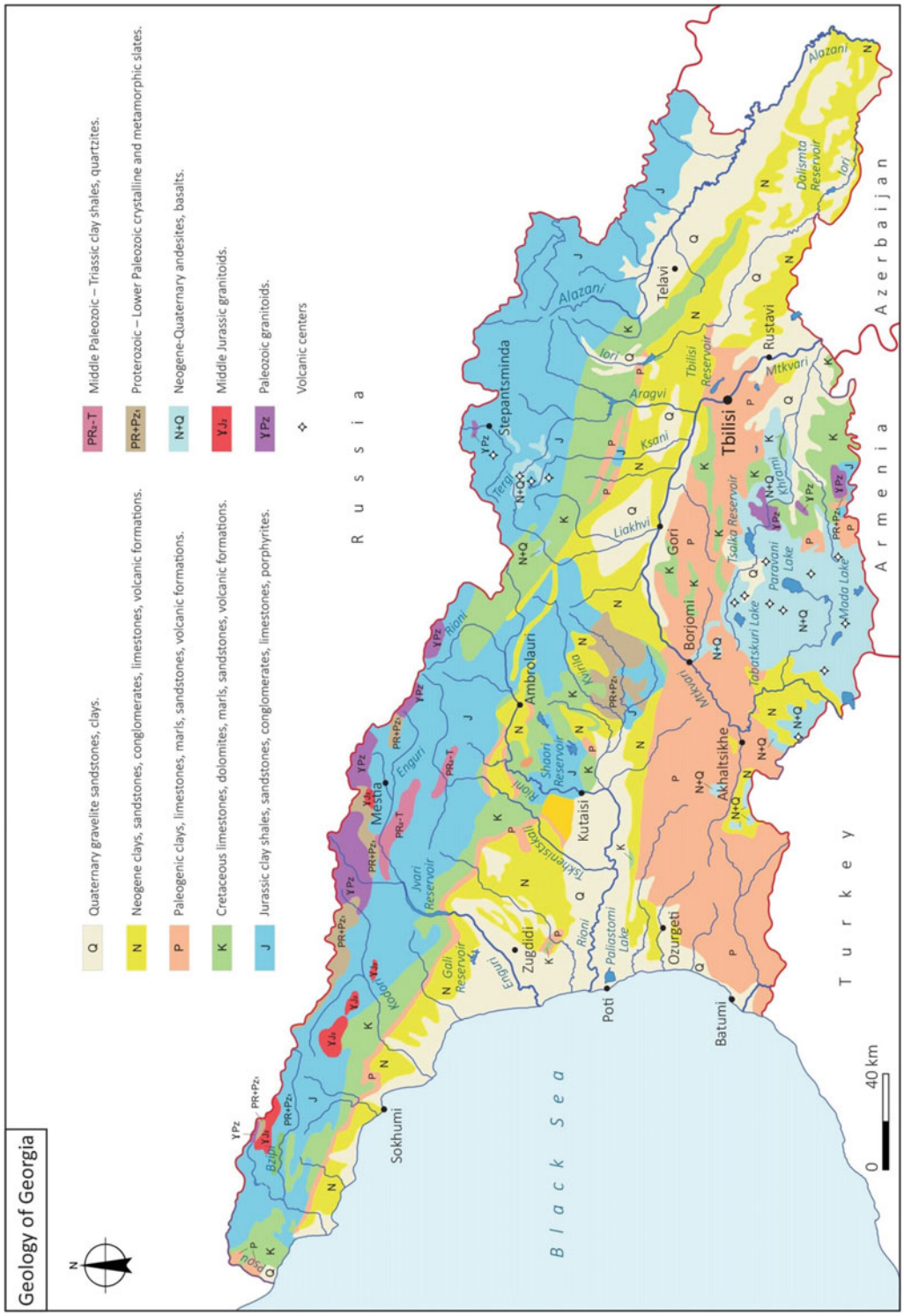

Fig. 1.2 Geological map of Georgia (Gamkrelidze 1992; Khazaradze et al. 2000)

Following the Maeotian transgression, the territory of Georgia has been divided into two sediment provinces—the Black Sea and Caspian Sea provinces (Gamkrelidze 2012).

In the Late Miocene and Early Pliocene, in the southern part of the Achara-Trialeti zone and in the western part of the Artvini-Bolnisi zone, subaerial volcanism (the Goderdzi suite) is present.

Pliocene sediments are widely developed in western Georgia and represented by marine terrigenous rocks, while the Pliocene is represented by continental and marine facies in eastern Georgia and approaching the Caspian Sea basin.

In the Late Pliocene and Early Pleistocene, in the territory of Javakheti Upland, subaerial lime-alkaline, andesite-basaltic, andesite and also doleritic, basaltic, and dacite volcanisms are evident.

Quaternary system is created by marine, alluvial, lacustrine, wetland, glacial, deluvial, proluvial, and cave sediments (Khazaradze et al. 2000; Gobejishvili and Tsereteli 2012a) (Fig. 1.3).

The marine sediments are developed in the sinking zones of western and eastern parts of Georgia (Kolkheti Lowland and Gare Kakheti), in Apkhazeti and Achara. Quaternary marine sediments are constructed with terrigenous facies: with the alternation of cobblestones, sands and clays. In Apkhazeti and Achara, the marine sediments are mostly found on the Black Sea terraces. Under the influence of tectonic movements and Black Sea eustatics, the terraced surfaces of different ages are located at different hypesometric levels. Here, the marine sediments are composed with the alternation of cobblestones, sands, and clays as well.

Lacustrine sediments are widely spread in Javakheti Upland. Their genesis is related to negative forms created by lava flows. The lacustrine sediments are also found in the surroundings of Tbilisi that are composed with the alternation of sandstones and clays.

Wetland sediments are widespread in Kolkheti Lowland; their absolute age is about 6000 years and is associated with the "New Black Sea transgression phase" of the Black Sea. The maximum height of these sediments is about 9 m (Khazaradze et al. 2000). The wetland sediments are formed by peat and sapropel.

Glacial formations of Quaternary age are mainly represented in the high mountainous zone of the Greater Caucasus Range. Here, in the terrain, the traces of glaciation are mainly preserved in the form of cirques and trough valleys. Alongside the southern slope of the Greater Caucasus Range, the lateral and stadial moraines create glacial deposits in the heads of the gorges of all large rivers (Bzipi, Kodori, Enguri, Rioni, Liakhvi, Ksani, and Aragvi). In some gorges, the number of stadial moraines is about 8, which indicates a short-term suspension of movement of the old glaciers. In some areas, the large size erratic boulders brought by glaciers are observed.

Deluvial and proluvial sediments are widespread and are the rock weathering product. Their thick accumulations are observed in the mountainous part of western Georgia. Relatively high temperature, humidity, and high indicators of atmospheric precipitation contribute to the intensity of weathering processes and creation of significant thickness of deluvial and proluvial sediments.

In the second half of Quaternary period, the primitive human often used karst caves for temporal or permanent habitation. Cultural deposits are preserved in many of them that contain the ancient tools of hunting and economic activities of Stone Age humans as well as the remnants of their cuisine wastes (osteological material).

In Georgia, cave dwellings of primitive human are found in many areas—on the southern slope of the Greater Caucasus Range (Kudaro and Tsona), in Dzirula massif (Ortvala Klde, Dzudzuana, Samgle Klde, and Chruchula), in the Okriba-Argveti hill (Tsutskhvati cavern and Sagvarjile cave), in Apkhazeti (Apiancha) and etc. Their age is Middle and Late Pleistocene. The cave sediments are composed primarily with the alternation of limestones, detritus, and loams.

Among the Quaternary sediments of Georgia, the open dwellings of Homo sapiens are found rich in paleontological and anthropological materials (Dmanisi), the absolute age of which is 1.8–2.04 million years (Vekua et al. 2002).

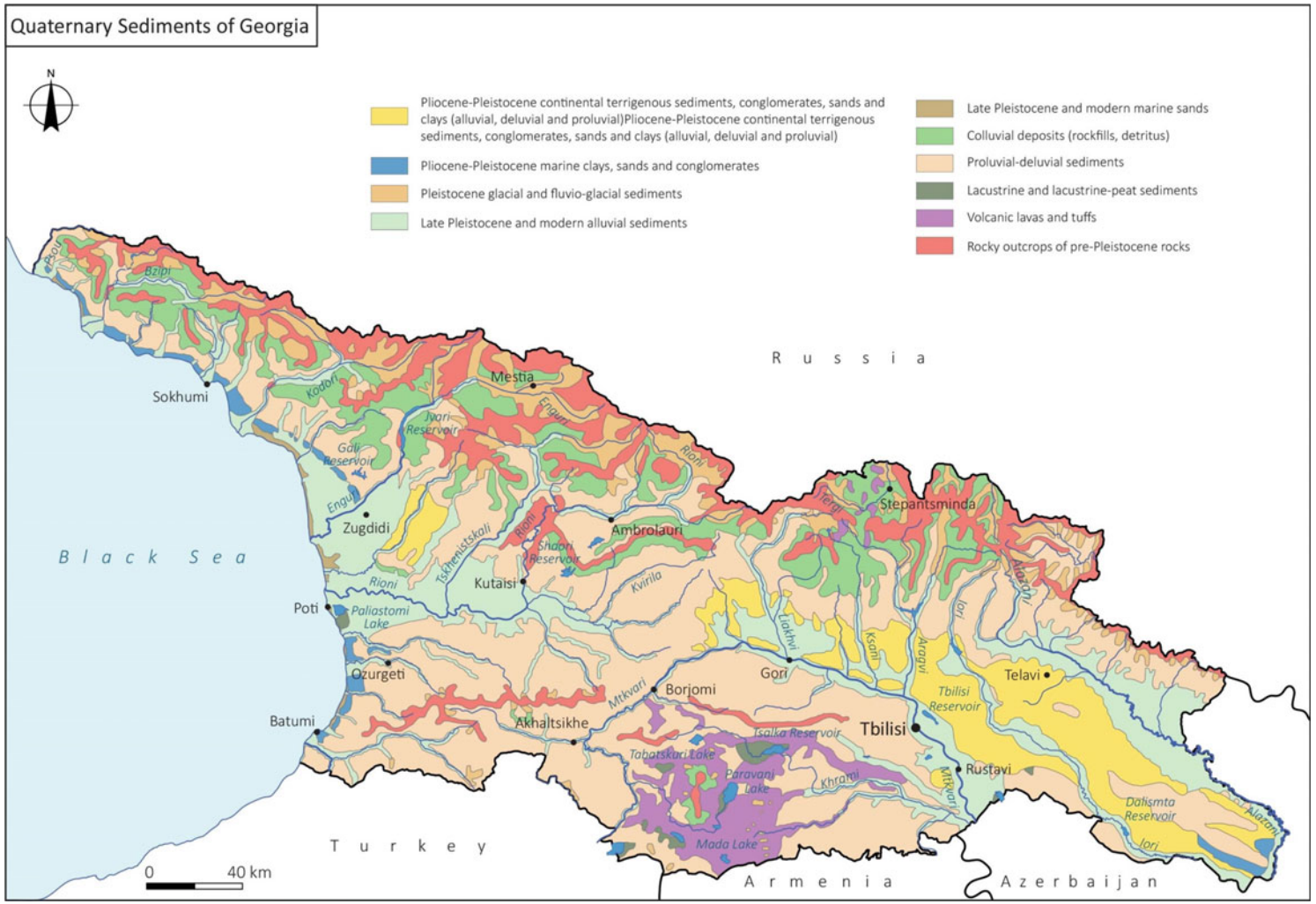

Fig. 1.3 Quaternary sediments of Georgia (Tsereteli 1964; Gobejishvili and Tsereteli 2012a)

Cultural sediments are of polygenetic genesis and are mainly composed of loams and sands, as well as volcanic ash and carbonate sediments.

In the Pleistocene and Holocene, the Volcanites are mainly represented by rocks of moderately acidic (andesites) and acidic (dacites) composition. Within the Achara-Trialeti zone, in the territory of Borjomi-Bakuriani, Early (Middle) Pleistocene andesite and andesite-dacite subaerial volcanism are presented.

1.3 Geomorphological Evolution

The modern appearance of Georgia's landscape is the result of simultaneous interaction of endogenous and exogenous processes and is divided into the three main zones and 12 subzones with multispectral morphological and morphometric conditions (Astakhov et al. 1964; Gobejishvili and Tsereteli 2012b) (Fig. 1.4).

1. The southern slope and crest of the Greater Caucasus is the Horst-anticlinal uprise of the ancient crystalline heart, which helped create the watersheds of the highest part of the system with nival-glacial and erosive-glacial ranges. On their peripheral parts, these ranges are built by the complex of Middle Jurassic volcanogenic rocks and Early Jurassic slates. In the western part of the southern slopes of the Greater Caucasus, there is a continuous belt of limestone ranges and massifs, containing karst landscape. The ranges composed of Jurassic and Cretaceous sediments (carbonate and non-carbonated flysch zone), oriented longitudinally and sublatitudinally in the medium and high mountainous relief, are evident within the central and eastern sections of the main watershed.

   The formation of large volcanic massifs and wide lava plateaus in the central part of the Greater Caucasus crest belt began from the Pliocene, and are mostly present in the Keli Upland and Mt. Mkinvartsveri (Kazbegi).
2. Formation of the relief of Georgia's intermountain plain is closely linked to the surrounding mountain system's formation. The Imereti Highland began forming in the Pliocene, with a denudation of uprising relief and the outcropped old granite ground under the Tertiary sea sediments. An extensive area was freed from the sea forming the foothills of the eastern Georgia, as well as the early sinking areas, where the marine-continental molasse sediments were accumulated. The Kolkheti Lowland experienced intense sinking and powerful Pliocene sea sediments were accumulated. In the background of the general uprising, there was relative sinking in the Quaternary and the erosion-denudation relief of the foothill hillocks began. At the end of the Pleistocene, the relief took a modern appearance. The denudation surface of Imereti Highland experienced erosion fragmentation. The sinking of the Kolkheti Lowland and the Alazani Plain and their filling with alluvial sediments continue today.
3. The Southern Highland of Georgia morphologically is divided into two parts: the high uplands and volcanic mountains of the Javakheti volcanic highland in the south, and the peripheral latitudinal ranges in the north.

The Javakheti Highland is built of Pliocene and Pleistocene volcanic formations that cover relatively older folded strata. On the volcanogenic pedestal along the meridian depth faults, there is a line of volcanic cones of the Samsari Range and the volcanic domes of the Javakheti Range, where there are deep river canyons. Old erosion-glacial forms are preserved in the crests of volcanic ranges with heights exceeding 2500 m.

The peripheral ranges of the southern highland of Georgia are mainly built on volcanogenic formations of Paleocene and Eocene that are resistant to erosion; the peculiarity of the relief is the flattened surfaces. As opposed to the Greater Caucasus, the nival-glacial relief is represented only on the uprisen crest. In the east, among the Khrami-Loki massifs, there is erosion-denudation relief of medium height built of carbonate flysch.

Fig. 1.4 Geomorphological map of Georgia

1.4 Volcanism

In the formation of the modern relief of the territory of Georgia, which started in the Cenozoic Era, the leading role of endogenous relief-originating factors belongs to tectonics and volcanism. In this regard, the role of Neogenic-Anthropogenic volcanism is significant, which is expressed in all major structural-formation units of the first rate of the Georgian territory on a different scale. There are five main stages of Neogene-Anthropogenic volcanic activity in the territory of Georgia: (1) the Late Miocene—Early Pliocene, (2) the Late Pliocene–Early Pleistocene, (3) the Middle Pleistocene, (4) the Late Pleistocene, and (5) the Holocene (Tutberidze 2012).

The Late Miocene–Early Pliocene. The powerful volcanic activity began at the end of the Miocene and ended in the Early Pliocene. The initial phase of volcanic activity involved explosive eruptions and ended with lava eruptions. The volcanites of this period are widely represented in the highlands of southern Georgia in the Erusheti highlands, Arsiani, Javakheti, and Samsari ranges. In geological literature sources, the volcanic formations of this period are known as the "Goderdzi suite". Some isolated outlets of small volcanites of the same period are observed at the northern periphery of Georgia's block and together form the Vanati-Tskhinvali-Kvasatali volcanoes' group.

The Late Pliocene–Early Pleistocene. After a break in the Middle Pliocene, volcanism was revived in the Late Pliocene and continued in the Early Pleistocene. Volcanism is widely seen in the Javakheti Upland. At the initial stage of the evolution of volcanism, there were strong areal eruptions (dolerite-basalts) that were subsequently replaced by central types of eruptions (andesite basalts, andesites, unimportant amounts of dacites). These rocks have built the Javakheti and Nialiskuri ranges (dolerites, andesite-basalts, and andesites), Akhalkalaki, Dmanisi, Tsalka, Gomareti, Kvemo Kartli plateaus (dolarist-basalt), and part of the Abul-Samsari Range (andesites, dacites, rhyolites, rhyolite dacites, and obsidians). The dolerites prevail among the erupted products. In the territory of Javakheti Upland, the volcanic and volcanic-sedimentary formations of this period are known as the "Akhalkalaki suite", which represents the alternation of dolerites, andesite-basalts, andesites, and located among them the lacustrine sediments. The volcanism of this period is revealed in the Borjom-Bakuriani region of the Lesser Caucasus folded system. This includes the basaltic lavas (with limited distribution), andesite-basalts, and andesite composition and their pyroclastolites, the eruption centers of which are maintained in the relief in the form of small size hillocks (Mukhera and Saghravi; Andesite). Volcanites include the basalt bodies of Perevisa, Didi Goradziri and Patara Goradziri in the Chiatura-Sachkhere region.

The Middle Pleistocene volcanism is mainly revealed in the Keli volcanic upland. This includes the Patara Nepiskalo volcanoes' group (Tskhradzma), represented by andesite-basalt, andesite (mainly) and dacite lavas and their pyroclastolites. To this stage of volcanism, evolution belongs the Mt. Pidarkhokhi (dacites and pyroclastolites).

The Late Pleistocene volcanism is weakly revealed in the volcanic upland of southern Georgia. Volcanic activity is expressed in effusive and explosive eruptions. To this age group belong the Mtkvari stream (dolerites), volcanic formations (andesites, dacites and their pyroclastolites) of Tavkvetili, Godorebi, and Shavnabada in the Abul-Samsari Range. The volcanic formations of this period are widespread in the Kazbegi volcanic region of the Greater Caucasus folded system. These include the lavas of andesite-basalts (with less distribution), andesite (mainly) and dacite composition and their pyroclastolites developed in the Gveleti, Tsdo, Chkheri, Arsha and Suatisi gorges. The lava streams and their pyroclastolites are related to the Kabarjina, Tsiteldziri, Miliona, Narvani, Sakokhe, Sadzele, and other volcanic centers. In the Keli volcanic upland and its surroundings, the northern Narvan-Khokhi, Pidarkhokhi, Char-Khokhi, southern Shadilkhokhi, Sirkhokhi (mostly the andesites and their pyroclastolites),

and Gudauri-Mleta (andesite-basalt) stream are built of the Late Pleistocene formations.

The Holocene. The volcanic eruptions of the Holocene period in the Kazbegi volcanic region created the andesite and dacite lava flows of Shevardeni, Kichuttsveri, Tkarsheti, Khorisari, Goristsikhe and their pyroclastolites, and in the Keli volcanic upland—the Levinson-Lesing (andesites, dacites, radiodacites), Didi Nepiskalo (dacites, radiodacites, and liparites), Khodzi stream (andesites), Tsiteli Khati (andesite-basalt, andesite), and the Tsitelimta volcanic cone on Samsari (andesite, dacites).

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Climate, Hydrography, and Soils of Georgia

2

Levan Tielidze, Vazha Trapaidze, Lia Matchavariani and Roger Wheate

Abstract

This chapter details the climate of Georgia; it describes the climate regions and areas such as the western and eastern Greater Caucasus, Kolkheti Lowland, Imereti Highland, Shida Kartli and Kvemo Kartli plains, Saguramo-Gombori middle highland, Iori Upland and Alazani Valley, mountainous Achara-Guria, Trialeti, Meskheti, and Javakheti Upland. Subchapters describe the air temperature and atmospheric precipitation. The fresh water resources of Georgia are also characterized: rivers, lakes, glaciers, marshes, water reservoirs, and underground waters. The last section is dedicated to the soils of Georgia.

Keywords

Climate of Georgia · Rivers of Georgia Lakes of Georgia · Glaciers of Georgia Marshes of Georgia · Water reservoirs of Georgia · Underground waters of Georgia Soils of Georgia

2.1 Climate

Most global climate zones are represented in the relatively small territory of Georgia, ranging from the humid subtropical to eternal snow and glacier zones (Javakhishvili 1981). The diversity of the climate of Georgia is identified both by its location on the northern border of the subtropical zone among the Black and Caspian seas, and by the specific complexity of its landscape: the mountain ranges of different orientation and elevation play a role in creating the local climate. The Greater Caucasus mountains protect Georgia from the direct intrusion of cold air masses from the north, while the Black Sea moderates temperature fluctuations and contributes to variations in precipitation, especially in western Georgia.

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Due to its relatively lower latitude location and moderate cloudiness, Georgia receives considerable direct solar radiation heat, with annual sunlight of 1350–2520 h. Total radiation is 115–153 kcal/cm^2 per year while the radiation balance is variable, from the maximum (52–53 kcal/cm^2) in the humid subtropical lowlands and the minimum (25 kcal/cm^2) in the high mountainous zone of the Greater Caucasus (Mumladze and Lomidze 2012a).

Atmospheric processes, from temperate and subtropical zones, participate in the generation of the climate. Zonal circulation is disturbed by the meridian circulation, during which cold air masses intrude from the northern latitudes, and warm air masses from the south. In such cases, the Greater Caucasus and the southern highland of Georgia are of particular importance. Air masses in Georgia mainly intrude from the west and east, but the weather often changes due to warm air masses intruded from the south. In the formation of climate the air masses of moderate latitudes, as well as both the marine and continental arctic and tropical air masses are all of great importance. Subtropical processes, through which air masses intrude into Transcaucasia and, in particular, in the territory of Georgia, are grouped into the following types: (1) western, (2) eastern, (3) bilateral, (4) anticyclonic condition, and (5) wave disturbance, developed in the southern regions of the Transcaucasia (Kordzakhia 1961).

2.2 Climate Zones and Regions

Georgia is in the subtropical belt according to the solar radiation regimes. By the nature of atmospheric circulation and related weather conditions related, the territory of Georgia is divided into the two circulation air regions and one sub-region; these are: (1) subtropical marine humid climate region, (2) transitional from subtropical continental climate to marine climate region; the latter includes the sub-region transitional from dry subtropical climate to moderate humid climate of the Asia Minor highland (Javakhishvili 1981; Mumladze and Lomidze 2012b) (Fig. 2.1).

The first zone covers the area of western Georgia and is characterized by the distinctive features of the humid subtropical maritime climate. The lower part is distinguished by mild winters and relatively cool summers, with moderate temperature amplitudes, abundant precipitation, and high humidity.

The second zone covers the territory of eastern Georgia and is characterized by moderately humid subtropical climate. Here, the winter is colder than in the first zone and precipitation is relatively small low. A subzone covers the central steppe part of the southern highland of Georgia. Here, the climate is more continental, the summer is hot, the winter is cold and the amount of atmospheric precipitation is less than in the other areas located at the same elevation in Georgia.

Significant fragmentation of the landscape transforms the general atmospheric circulation and causes great differences in numerical values of meteorological elements creating climatic regions in the territory of Georgia.

2.2.1 Western Greater Caucasus

The western Greater Caucasus is located in the marine subtropical humid climate region. Due to lower latitude and higher solar altitude, it receives a large amount of solar energy throughout the year. It is under the influence of humid winds blown from the west and Black Sea. The main feature of the climate is the altitudinal zonality. The average annual temperature (5–12 °C) in the lower parts becomes negative at a height of 2500 m asl. The average January air temperature, which is 1–2 °C at a height of 700–800 m, drops to −15 °C in the highland zone, decreasing to absolute minimum temperature of −25 to −40 °C. The temperature in July–August averages 6–22 °C in the western Greater Caucasus, and absolute maximum of 20–42 °C. Annual precipitation varies within 1800–3500 mm, except for landlocked lower areas

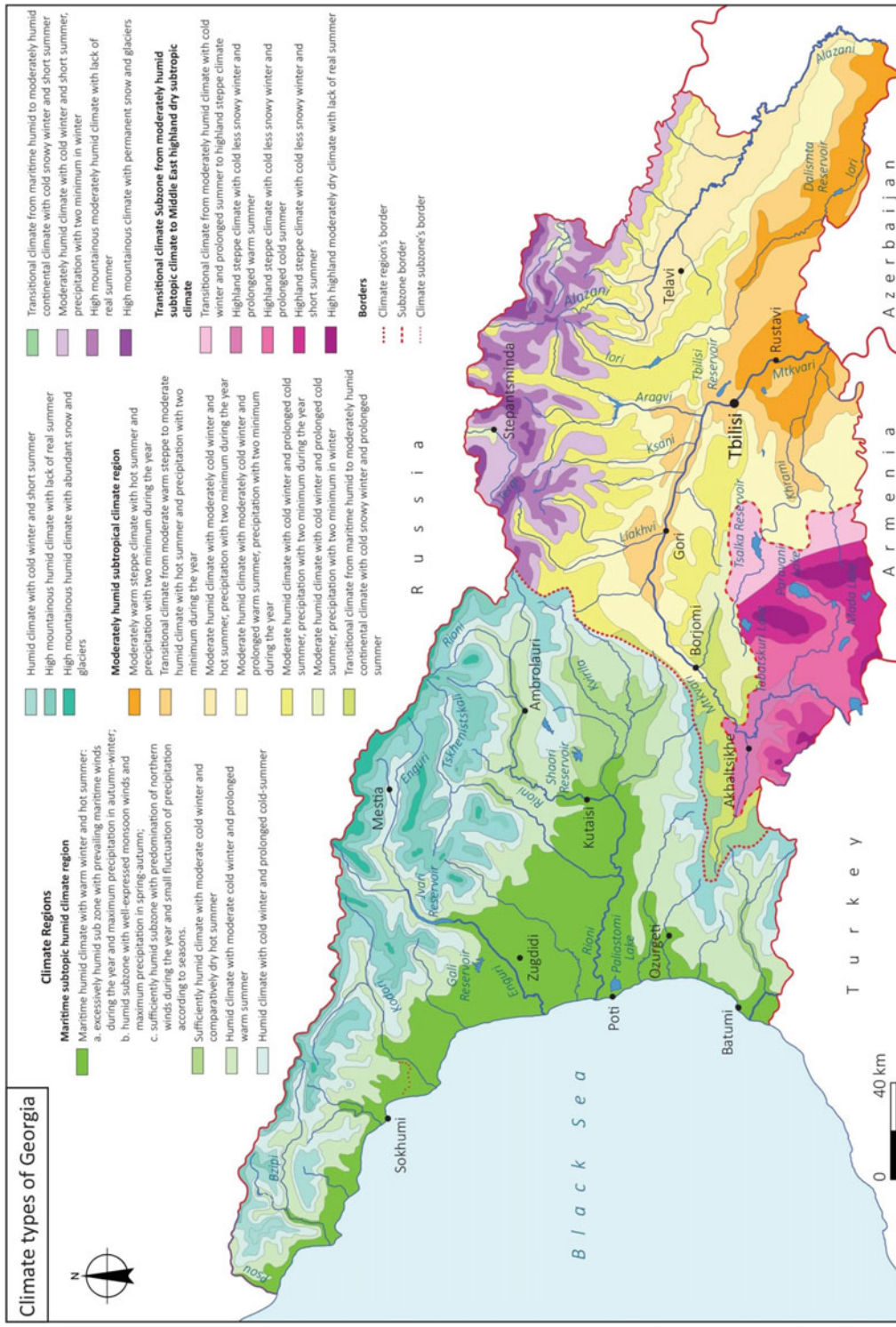

Fig. 2.1 Climate types of Georgia (Kordzakhia 1964; Mumladze and Lomidze 2012b)