Geography of the Physical Environment

Nana Bolashvili
Vazha Neidze *Editors*

The Physical Geography of Georgia

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Preface

Physical environment plays decisive role in formation of the people's individuality and way of life. Implementation of new territorial system must serve to well-being of people, revival of economy, and formation of powerful state.

Until recently, knowledge of Georgia was limited, as this now-independent country had been part of the Soviet Union until 1991. Georgia is well-known for its hospitality, wine, and cuisine, and also for the mountain peaks of the Caucasus which reach above 5000 m. Otherwise few people know that there are different languages and ethnic groups in Georgia, that a separate Georgian alphabet exists and that Georgia has a fascinating history of more than 2000 years.

Physical Geography of Georgia presents detailed information with text and accompanying maps for the scientists and students interested in this country.

The scientific and cartographic depictions of Georgia by Georgian scholars date back to the first half of the 18th century. Prince Vakhushti, a family member of King Vahkhtang VI Bagrationi of Kartli (the core region of Georgia), prepared a geographical description of Georgia and adjacent territories as well as geographical atlases. Vakhushti had compiled two manuscript atlases of Georgia, and the maps by Vakhushti evoked strong interest in Russia and Europe. In 2013 the "*Description of Georgian Kingdom*" and the "*Geographical Atlas*" of Vakhushti Bagrationi were registered in UNESCO's, Memory of the World documentary program.

The current book was prepared by the Institute of Geography of Tbilisi State University. The institute, named for Vakhushti Bagrationi, was founded in 1933 and has developed broad experience in carrying out research work. The staff members of the institute have a rich experience in publishing various monographs (complex, sectoral, academic, educational, popular science, etc.) on the geography of Georgia. Under its guidance number of similar publications have been prepared and published in Georgian: *Geography of Georgia* (Part 1—*Physycal Geography* (2000), Part 2—*Social-Economic Geography* (2003)), which is characterized by thoroughly aggravated natural-ecological, political, socio-economic, and demographic situation; *Geography of Georgia* (2013), which unlike the two-volume addition mentioned above, is the first complex work covered both the issues of Physical as well as Human Geography. The monograph discusses the geographical location, natural conditions, political-geographical, ecological, and socio-economic situation of the country.

The current book represents a strongly revised, updated, and completed edition of the *Geography of Georgia*, published in the Georgian language in 2013. Many scientists of Tbilisi State University (TSU) contributed with new research results. The texts, tables, and maps contain data from the following Georgian statistical sources: the National Statistics Office of Georgia, the Agency of Protected Areas, and the Georgian National Tourism Administration. The main part of the book was performed by the researchers of the institute, but some of the paragraphs were written by the invited qualified specialists from different fields.

The presented work will render significant assistance to the economic, scientific, and educational fields of the country.

Tbilisi, Georgia

Nana Bolashvili
Vazha Neidze

Acknowledgements I would like to express my gratitude to all of those with whom I have had the pleasure to work duringthis project.I am grateful to Ms. Nino Chikhradze for the translations of several chapters.

Contents

1 Location, Territory, Boundaries

Vazha Neidze

Abstract

In this chapter patterns of location, territory and boundaries are discussed. Located in the border area between Europe and Asia, Georgia occupies the central and southern parts of the Southern Caucasus. Configuration of the state's territory has a certain importance for the economic and political development of the country. Georgia has an elongated form, the length of the diagonal which is over 600 km. Except for the state border with Turkey, the number of sections of boundaries with the rest of its neighbors (Russia, Armenia, and Azerbaijan) are still controversial and create a conflict situation. Georgia is distinguished by significant advantages of the number of characteristics of geographical locations compared with the neighboring countries. The issue of Georgia's location is controversial among the experts because the Caucasus is located at the Eurasian crossroad.

1.1 Territory

Georgia is located in the border area of Europe and Asia, which is historically known as the "Caucasus neck". It occupies the central and southern parts of the Southern Caucasus. From the point of view of mathematical-geographical location, Georgia is situated between 41°07′–43°35′ N and 40°05′–46°44′ E.

Historically the area of the territory of Georgia has significantly decreased. In the second half of the seventeenth century, it was 133.1 thousand km^2, at the end of the nineteenth century (in 1886)—102.0 thousand km^2, during the first democratic republic (1918–1921)—91.1 thousand km^2, and during the Soviet period the country lost 20.4 thousand km^2. Currently, the area of the territory of Georgia is 69.7 thousand km^2. According to the size of the territory, the following European countries are far behind Georgia: Netherlands, Switzerland, Belgium, Denmark, Croatia, Bosnia and Herzegovina, Slovenia, Slovakia, Luxembourg, Montenegro, Macedonia, Albania, Moldova, Latvia, Lithuania, and Estonia.

Configuration of the state's territory has a certain importance for the economic and political development of the country. It defines the characteristics of the transport network, internal regional connections, and borderline peculiarities; it affects the border protection, relations with neighboring countries, development of military

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strategy, etc. Conditionally, Georgia has an elongated form, the length of the diagonal which is over 600 km. The parts of its extremely narrow corners are occupied by Gagra (in the northwest) and Dedoplistskaro (in the southeast) regions (municipalities). The geographical center of the country is in Imereti (Kharagauli municipality, at the place of confluence of the Rikotula and Sat-evzeghele Rivers).

The extreme points of the territory of Georgia are: in the north—Aibga Village, in the south—Eldari valley, 1400 m away from Mingachevir reservoir, in the west—Leselidze town, in the east—7 km away from the Sabatlo Village in the southeast which is mentioned as, "Mosabruni" by Vakhushti Bagrationi (Turmanidze and Tsitsagi 2017).

Mainly Georgia is a mountainous country. It is distinguished by complex orographic diversity and an abundance of attractive objects for tourism. Table 1.1 shows the distribution of the territory of Georgia according to the hypsometric levels.

1.2 Borders

The boundaries of a number of countries have been formed on the basis of natural barriers (orographic, hydrographic, and marine). The same is true about Georgia, historical territory which is an entire physical-geographical body surrounded by natural boundaries, according to the opinion of Georgian researchers (P. Ingorokva, I. Javakhishvili, A. Manvelishvili, and others); in the north, it is bordered by the Caucasian Range, in the west—by the Black Sea, in the south—by the "Armenian Upland, from which it is separated by one continuous system of snowy mountains and only with one narrow mouth—from the southeast—Georgia adjoins the Azerbaijan Plain, but even from here it is divided by Hereti desert steppes and Mtkvari—the Rhine of Georgia" (Ingorokva 1990).

Thanks to these natural barriers during the long history "Georgians managed to repel numerous and often more powerful enemies and rescued. The enemies of Georgia also understood this circumstance and therefore, it was very often that they tried to hold and remove the border corners from the territory of Georgia" (Javakhishvili 1919). But for centuries Georgia still "managed to save and protect its territory in natural boundaries" (Manvelishvili 1938).

Over time, along with the reduction of the territory of the country, the boundaries were modified too. For the last two centuries for the country, which was as a part of the Russian Empire and Soviet Union, the legal concept of

Table 1.1 Distribution of the territory of Georgia according to the hypsometric levels (Kekelia et al. 2004)

Hypsometric levels (m)	Territory	
	km^2	%
0–200	7955.4	11.4
200–400	5870.2	8.5
400–600	6512.7	9.3
600–800	6393.5	9.1
800–1000	5480.5	7.8
1000–1200	5358.0	7.7
1200–1400	4638.6	6.7
1400–1600	5073.1	7.3
1600–1800	4653.6	6.7
1800–2000	4239.1	6.1
2000–2200	3906.9	5.5
2200 and higher	9575.3	13.8
Total	69.657	100

the state border was erased. And today, as in 1918–1921, it is a determining factor of sovereign state. Unfortunately, except for the state border with Turkey, the number of sections of boundaries with the rest of its neighbors (Russia, Armenia, and Azerbaijan) are still controversial and create a conflict situation (Neidze 2013).

The westernmost border of Georgia starts at the Black Sea, at the confluence of the Psou River, goes along the river and then goes up to the Mount Agepsta (3256 m). The current territory of the country is mainly stretched from the Mount Agepsta to the Mount Tinovroso in the south of the crest of the main watershed of the Caucasus, but on the section between the mountains of Zilgakhokhi and Shaviklde, the territory of Georgia is spread in the basins of the rivers of Tergi, Asa, Arghuni, and Sulaki (Andis-Koisu) through the northern slopes of the Caucasus. The eastern border of the country begins from the Mount Tinovroso and goes down to the Alazani River, and then runs along the Alazani River almost to the confluence of the Mingachevir water reservoir.

The southern border begins on the Black Sea coast at the village of Sarpi, crosses the end of the northeastern part of the Pontic Range and the downstream gorge of the Chorokhi River, goes along the crest of the Shavsheti Range, crosses the Arsiani Range, goes up to the Erusheti highland with the Potskhovistskali River, crosses the Mtkvari River and Kartsakhi Lake, and the borderline ends near Turkey, at the Mt. Erakatar (3008 m). Then the border with Armenia crosses the river of Debeda passing through the Mt. Okuzdag (2441 m), Mt. Akhchala (3196 m), Mt. Loki, and Mglis Chishkari Pass, goes down the Kvemo Kartli plain, and ends at the Babakiari Range. Further, Georgia-Azerbaijan borderline crosses the Jandari Lake, goes round David Gareja from south, and heads to the Mingachevir water reservoir (Kekelia 2000) (Table 1.2).

1.3 Location

One of the most important notions of geography—the geographical location has a broader content. First of all, it determines the location of

Table 1.2 The main indicators of the borders of Georgia (Nikolaishvili et al. 2009)

Total length of the border, km	2114.78
The length of the land border, km	1802.07
The length of the marine border of territorial waters, km	297.89
The length of the coastal line, km	312.89
The width of territorial waters, nautical mile	12
The width of continental shelf, nautical mile	350
Border length with bordering countries (km)	
Russian Federation	897.7
Krasnodar Krai	84.25
Karachay-Cherkessia	197.14
Kabardino-Balkaria	126.46
Alania	183.94
Ingushetia	52.87
Chechnya	86.37
Dagestan	166.67
Azerbaijan	428.42
Armenia	210.57
Turkey	266.01

country, region, and so on, toward the other territories, which is contextually revealed in their relationship and interconnection. In its description, except for normal indicators (for example, distances), is essential to analyze economic, political, and ecological relations, which, in addition, requires historical understanding.

Georgia is distinguished by significant advantages of the number of characteristics of geographical locations compared with the neighboring countries. In particular, its seaside location is outstanding, which allows direct connections with the world's maritime states; and the central location in the Caucasus region determined choosing Tbilisi—the country's main city as a residence for the Caucasus government (Viceroy)—being a part of Russian Empire. The Caucasus Mountain Range in the north has also a major climate-division role for the country, which is a natural barrier (protects from the incoming cold air masses from the north), and it is a northern border of Georgia's subtropical zone. Generally, the location of Georgia in the southern latitudes (so-called mathematical-geographical location) leads to the convenience of the natural environment of Georgia in creation of optimal conditions of life for the population. These circumstances have always caused the envy of intruded enemy and their desire to conquer the territory.

The issue of Georgia's location is controversial among the experts because the Caucasus is located at the Eurasian crossroad. Several variants are considered, or the most common viewpoints (Radvani and Beruchashvili 2011):

- The border between Europe and Asia goes along the Kumo Manych depression, which in the past connected the Black and Caspian seas. According to this concept, unity of the Caucasus Range and its northern foothills is a part of Asia;
- Others draw this margin with Iran and Turkey on the political boundaries of the South Caucasus states and assigned the whole Caucasus to Europe;
- The majority of geographers draw the border over the crest of the main ridge of the Caucasus, the main climate boundary, and hydrographic watershed. In this case, the region is divided between Europe and Asia. However, political and physical boundaries do not coincide with each other. With this version, much of Georgia's territory get in Asia, and the parts of the territories of a number of historical–geographical provinces of the country (Khevi, Khevsureti, and Tusheti) are located on the northern slope of the ridge—in Europe;
- According to Herodotus, the border between Europe and Asia is created by the rivers of Rioni and Mtkvari, because of which the territories located north from them he assigned to Europe.

According to the general characteristics of spatial location, Georgia has:

1. A central location in the Caucasus region;
2. A peripheral location toward the European countries; and
3. A neighboring (border) location toward Turkey, Russian Federation, Azerbaijan, and Armenia, which directly border our country.

The emergence of geographical mega and macro locations of Georgia (previously they did not exist), formation of the country as an independent state, attempts to escape the Russia's sphere of influence or integration with the west, as well as the aims of NATO to expand the southern boundaries, conditioned the representation of small Georgia in the political map as a supposed outpost in the southeastern most part of the Europe (Fig. 1.1).

Georgia's meso location should be assessed on the common background of the Caucasus and its bordering, as well as the economic and political relations between the Black Sea region countries and the overall situation. And micro-location requires the analysis of economic-geographical, political, and military-strategic situations of the border regions of Georgia and its separate regions in relation to neighboring

Fig. 1.1 Political-geographical location of Georgia (National Atlas of Georgia, Steiner-Verlag, 2018)

countries. For example, in the north, Georgia is bordered by the Russian Federation, which is actually represented by the autonomous units with non-Russian nationalities. This almost non-contact border area of 820 km long (except the part of contact section of the Apkhazeti Psou, which is now cut off from the country), is less favorable for the economic union, because only three passes (Mamisoni, Rocki, and Jvari) crossing Transcaucasian roads' complex natural conditions and tense conflict situations are characterized as unsustainable. It has evidently improved microlocations on the border regions of Turkey. Among them, the "Sarpi Gate" (Achara), border road of Akhaltsikhe (Samtskhe)—Artaani, and "Kartsakhi Pass" (Javakheti) are notable, which promote the development of Turkey-Georgia relations in the light of the intensification of economic ties (Neidze 2003).

In addition to the physical–geographical (relief, climate, and Black Sea) and political factors, while characterization of location of Georgia, it is also necessary to consider the historical experience and mentality of Georgian people (self-sacrificing struggle for protection of Christianity and aspiration to European cultural values). It can be said that Georgia is located in the south-eastern most part of Europe.

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2 Geology

Irakli Gamkrelidze

Abstract

This chapter presents the general overview of country's geology. The territory of Georgia is a component of the Caucasian segment of the Mediterranean (Alpine-Himalayan) collisional orogenic belt. Lithological character of the sedimentary rocks and composition of submarine volcanites are quite different within the different tectonic zones of Georgia. The territory of Georgia, as a part of the Caucasus, underwent a long and complicated tectonic evolution and contains structures of various types, scales, and genesis. The chapter also discusses the main features of the geodynamic evolution of the Caucasus.

2.1 Introduction

The territory of Georgia is a component of the Caucasian segment of the Mediterranean (Alpine-Himalayan) collisional orogenic belt. Within the territory of the Caucasus, accretionary terranes are distinguished, which are characterized by a specific lithological-stratigraphic section and magmatic, metamorphic and structural features (Fig. 2.1).

At the same time, the latest geodynamic settings were created in Mesozoic and Early Cenozoic times when post accretionary formations in places overlapped the borders of older terranes. For example, formations of Mesozoic-Early Cenozoic marginal sea of the Greater Caucasus overlapped the northern margin of the Black Sea-Central Transcaucasian terrane (Gagra-Java and Chkalta-Laila subterranes or zones), were involved in rising of the Greater Caucasus and formed Southern part of the contemporary fold system of the Greater Caucasus. Besides, in Late Alpine, the west and east parts of the Dzirulasubterrane turn into intermountain molassic depression (Kura and Rioni) separated by central elevation zone (the Dzirula massif).

2.2 Stratigraphy and Rock Types of the Different Tectonic Units of Georgia

So long as the degree of metamorphism, lithological character of the sedimentary rocks, and composition of submarine volcanites are quite different within the different tectonic zones of Georgia, the stratigraphic units are considered to

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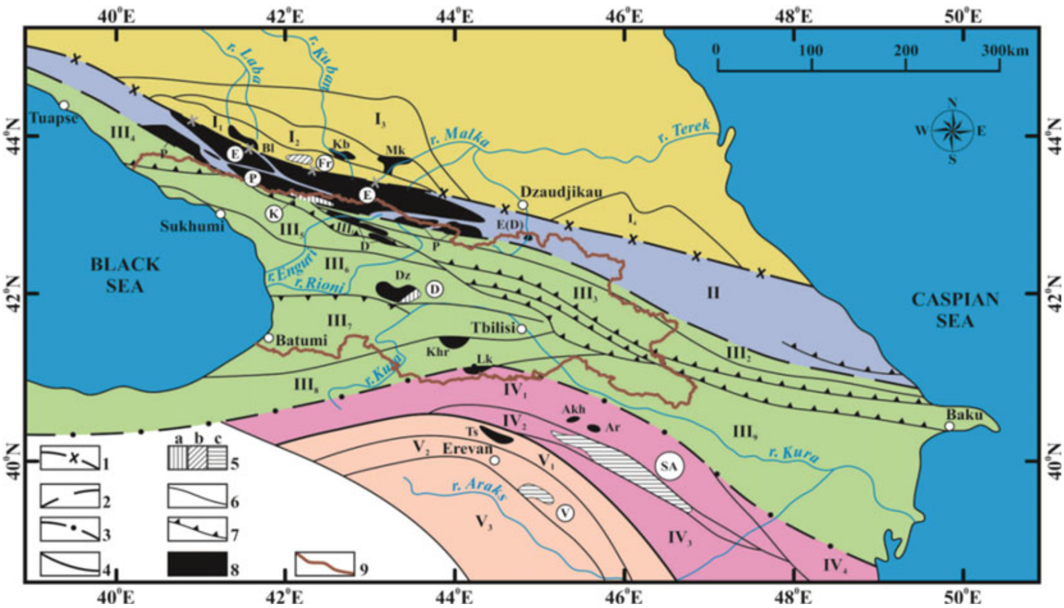

Fig. 2.1 Tectonic subdivision of the Caucasus on the basis of terrane analysis and exposures of the pre-Alpine crystalline basement (Gamkrelidze 1997a; Gamkrelidze and Shengelia 2005; Gamkrelidze 2016). Key: I = Part of Scythian platform involved in Neogene time into rising of the Greater Caucasus); I1 = Forerange zone, I2 = Laba-Malka (Bechasin) zone, I3 = zone of North Cauasian monocline, I4 = Daghestan Limestone zone. Accretionary terranes and subterranes: II = Greater Caucasian terrane; III = Black Sea-Central Transcaucasian terrane. Subterranes: III1 = Chkalta-Laila, III2 = Kazbegi-Tphan, III3 = Mestia-Dibrar, III4 = Novorosiisk-Lasarevskoe, III5 = Gagra-Java, III6 = Dzirula (Georgian Block), III7 = Adjara-Trialeti, III8 = Artvin-Bolnisi, III9 = Middle and Lower Kura; IV = Baiburt- Sevanian terrane. Subterranes: IV1 = Somkhito- Karabakh, IV2 = Sevan-Akera, IV3 = Kafan, IV4 = Talysh; V = Iran-Afghanian terrane. Subterranes: V1 = Miskhan-Zangezur, V2 = Erevan-Ordubad, V3 = Araks. 1 = borders of terranes-ophiolite sutures (here and there presumable) marking the location of small and large oceanic basins: 1 = of Early?-Middle Paleozoic age, 2 = of Neoproterozoic-Paleozoic age, 3 = of Neoproterozoic-Early Mesozoic age, 4 = of Mesozoic age; 5 = ophiolite terranes (obducted plates): 5a = of Neoproterozoic-Paleozoic age 5b = of Paleozoic age, 5c = of Mesozoic age; 6 = borders of subterranes (deep faults or regional thrusts); 7 = detached cover nappes of Alpine age; 8 = exposures of pre-Alpine crystalline basement: GC = Greater Caucasian, D = Dizi series of the southern slope of the Greater Caucasus, Dz = Dzirula, Khr = Khrami, Lk = Loki, Akh = Akhum, Ar = Asrikchai, Ts = Tsakhkunyats; 9 = boundary of the territory of Georgia

be within separate tectonic zones (Gamkrelidze 1997b, 2016; Gudjabidze 2003).

The pre-Alpine metamorphic complexes outcrop within the Greater Caucasus (Main Range and southern slope zones), in the Black Sea-Central Transcaucasian terrane (Dzirula and Khrami massifs), and within the Baiburt-Sevanian terrane (Loki massif) (Fig. 2.1).

The oldest (Precambrian and Lower-Middle Paleozoic) rocks are exposed in all the tectonic units (Fig. 3.1). They are represented by gneisses, migmatites, crystalline schists, and amphibolites within the Main Range zone of the fold system of the Greater Caucasus, the Georgian Block (in the so-called Dzirula massif), and the fold system of the Lesser Caucasus (in the so-called Khrami and Loki massifs) (Gamkrelidze and Shengelia 2005). Paleozoic rocks are exposed in the central part of the southern slope of the Greater Caucasus as well. They are represented mainly by black shales, phthanites (cherts), sandstones, turbidites, olistostromes, lenses of marbles, and calc-alkaline andesite-daciticvolcanoclastics. Their visible thickness reaches 2000 m. This is the so-called Dizi Series, in which faunally (by corals, foraminifera, and conodonts) the Devonian, Carboniferous, and Permian are established. Comparatively weakly metamorphosed Paleozoic sediments are exposed in the Dzirula massif as well. These are the allochthonous plates of the so-called “phyllitic suite”, which are in contact with Upper Paleozoic granitoids and Paleozoic and Precambrian gabbro- amphibolites and serpentinites. The latter are meta-ophiolites (Gamkrelidze et al. 1981). Precambrian and Paleozoic meta-ophiolites within the crystalline core of the Greater Caucasus and in Somkhito-Karabakh zone (in the Loki massif) are present as well.

The Upper Paleozoic rocks are also developed in all tectonic units. In the Main Range zone, crystalline rocks are overlain by weakly metamorphosed sandstones, conglomerates, and argillites, which contain Upper Carboniferous-Lower Permian marine fauna (marine molasse).

Continental and coastal calc-alkaline rhyolitic volcanic rocks and coal-bearing argillites with lenses of reef limestone are known in the Dzirula and Khrami massifs. Lower-Middle Carboniferous corals, brachiopods, foraminifers, and terrestrial flora have been found in this formation in the Khrami massif.

Mesozoic and Cenozoic formations are developed in all tectonic units of Georgia (Gamkrelidze 1997b, 2016; Gudjabidze 2003).

Triassic sediments are observed in the Dizi Series apart from the above-mentioned Upper Paleozoic deposits. To the Triassic also belong dacitic-rhyoliticvolcanics, quartz sandstones, and siltstones with variable thickness (80–500 m), which crop out in the Dzirula massif and contain flora of Triassic age.

Lower Jurassic-Aalenian sediments that everywhere rest transgressively are spread throughout all tectonic units of Georgia.

In the fold system of the Greater Caucasus, these deposits are more than 5000 m in thickness and are represented by black shales, sandstone turbidites, rhyolitic (in the lower part), and tholeiite-basaltic (in the upper part) lavas, and their pyroclastics.

In the Georgian Block, Lower Jurassic sediments (80–90 m thick) crop out only along the edges of the Dzirula massif and are represented by arkosic sandstones, gravelstones, conglomerates, clays, and red zoogenic limestones containing rich marine fauna (Ammonitico Rosso facies).

In the southern parts of the Khrami and Loki massifs, the Lower Jurassic consists mainly of terrigenous deposits (120–600 m thick).

In the central part of the fold system of the Greater Caucasus, the Bajocian stage is represented by sandstone–siltstone flysch, shales and marls, and elsewhere by a thick (3500 m) volcanogenic series, which contains marine fauna and consists mainly of calc-alkaline-basaltic, andesite-basaltic, and andesite-dacitic lavas and pyroclastics. Tephroturbidites, sandstones, and conglomerates are rather scarce.

The Bathonian Stage in the fold system of the Greater Caucasus is represented by sandstone-siltstone flysch, and by regressive coal-bearing terrigenous deposits (65–200 m) on its southern slope (in the Gagra-Java zone).

In the Central and Eastern parts of the Southern slope of the Greater Caucasus (Mestia-Tianeti zone), the Upper Jurassic sediments which follow conformably to the Middle Jurassic slates consist mainly of calciclastic flysch (1100–1500 m). On the rest of the territory, they lie transgressively and discordantly.

In the Western and Eastern parts of the Gagra-Java zone, an Upper Jurassic marine facies are present. In the lower part, it is represented by sandstones and clays (120–200 m), and in its upper part by reef limestones (400–900 m). A rich marine fauna (ammonites, corals, etc.) is found in these sediments. To the south and within the Georgian Block, gypsum-bearing lagoonal-continental terrigenous (Kimmeridgian-Tithonian) deposits and to a lesser extent alkaline basalts, trachytes, and pyroclastics are present.

Upper Jurassic shallow-water limestones and marls, alternating with calc-alkaline basalt-andesite-dacitevolcanics, are exposed at the Western edge of the Khrami massif and in the Somkito-Karabakh zone also.

There is a variety of Cretaceous deposits in Georgia. Within the Greater Caucasus fold system (in the Mestia-Tianeti flysch zone), the Lower Cretaceous is developed in the form of calciclastic and siliciclastic flysch (750–1600 m), which conformably follows the Upper Jurassic flysch. In the south and within the Georgian Block, the old formation, including crystalline rocks of the Dzirula massif, is overlain transgressively by Lower Cretaceous rocks (300–550 m). In the main, limestones are developed within this area. Only in the middle of the section appear marls and clays (Albian Stage) and glauconitic sandstones (Cenomanian Stage). Reef limestones of Urgonian facies (Barrenian Stage) and ammonitic limestones (Aptian Stage) are distinguished in the Lower Cretaceous.

In the Upper Cretaceous sediments of the Mestia-Trileti Flysch zone, siliciclastic (in the lower part) and calciclastic (in the upper part) flysch (500–900 m) prevail. Within the Gagra-Djava zone and Georgian Block, they are spread mainly as shallow-water limestones, marls, and glauconitic sandstones (250–1200 m), whereas to the west in the Dzirula massif, an alkali basalt-phonolitic series (70–300 m) occurs locally.

In the Adjara-Trialeti zone, the Upper Cretaceous is represented by a volcanogenic suite with calc-alkaline-basaltic composition, which in the lower part also contains the Albian Stage. Stratigraphically higher, upper Turonian-Senonianlimestones and marls (300–1200 m) follow.

In the Arthvin-Bolsini Block and Lock-Karabach zone, transgressive Upper Cretaceous sediments are present, which subdivide into three parts. A Cenomanian volcanogenic- carbonate series (900–1200 m) overlaps directly the Khrami and Loki massifs and Jurassic rocks. Ascending the section, there follows a basalt-andesite-dacite-rhyolite series (1100–3300 m) of Turonian-Santonian age. The uppermost part (Campanian–Maastrichtian) is represented by shallow-water limestones and marls with interlayers of acidic tuffs (300–350 m).

Paleogene deposits are found in all tectonic units. In the southern slope of the Greater Caucasus, the Paleocene-Eocene is represented by sandstone–siltstone flysch (600–850 m). In the southern part, the Upper Eocene is built up of olistostromes (10–400 m).

In the Georgian Block, the Paleocene and Eocene consist of an alternation of limestones and marls (30–400 m). In the middle part of the Lirolepis horizon, a horizon of marls is distinguished, which begins the Upper Eocene.

In the Adjara-Trialeti zone, the Danianis are built up of limestones and marls, whereas the transgressive Paleocene-Lower Eocene consists of sandstone–siltstone and clastic limestone flysch (Borjomi flysch), the thickness of which increases from west to east (1500–3000 m). These are followed by a very thick Middle Eocene volcanogenic suite, which in the western part of the zone is represented by tholeiitic and shoshonitic, mainly basaltic, submarine volcanics, and tephro-turbidites, whereas in the eastern part there are calc-alkaline and tholeiitic, mainly andesitic rocks, olistostromes, and tephro- and sandstone–siltstone turbidites. Its thickness increases from east to west (1000–5000 m). In the Artvin-Bolnisi zone and the Somkhito-Karabakh zone, a Middle Eocene volcanogenic suite is built up of calc-alkaline basalt-andesite-dacite-rhyolite volcanics (1200–2700 m) and transgressively overlaps Cretaceous and Jurassic rocks and the Loki Crystalline Massif.

In the Adjara-Trialeti zone, the Upper Eocene is distinctly transgressive and consists of marls, clays, sandstones, and gravelstones (500–1500 m), whereas in the western part of the zone, it consists of andesitic-basaltic volcanoclastics (1000 m).

Oligocene deposits (mainly the Maikop Series) are generally represented by thin-bedded gypsiferous clays, which contain fish scales and sandstones. This series continues in the lower part of the Miocene, too. It outcrops in the Gagra-Djava zone, in the Georgian and Artwin- Bolnisi blocks, and in part of the Adjara-Trialeti zone. Its thickness is rather variable (250–3000 m).

Neogene formations are present only in molasse depressions. The Lower Miocene, as was mentioned, belongs to the Maikop Series. Further up the section, the Miocene is represented in the lower part (Middle Miocene-Middle Sarmatian) by marine molasse (clays, sandstones, conglomerates, limestones, and marls), and in the upper part (upper Sarmatian-Pliocene) by marine and continental molasse (conglomerates, sandstones, sands, and clays). There are very distinct unconformities at the bases of the Miocene, Meotian Stage, and Upper Pliocene.

In the Artvin-Bolnisi zone and Somkhito-Karabakh zone, and partially in the southern part of the Adjara-Trialeti zone, the Neogene is represented by subaerial calc-alkaline andesites, andesite-dacites, and dolerites. Their upper part includes the Pleistocene and Quaternary, too. In the lower part (Upper Miocene-Lower Pliocene) subaerial volcanics contain a rich terrestrial flora, and in the Upper Pleistocene there is mammalian fauna.

Quaternary deposits are distributed very irregularly. These consist of river terraces, moraines of three glaciation periods, and a volcanic formation in the form of volcanic cones and lava flows (in the Greater Caucasus, to the south of Kazbegi, and on the Trialeti Range in the Borjomi region). There are also vast accumulation plains in intermontane areas.

2.3 Tectonic Structure

The territory of Georgia, as a part of the Caucasus, underwent a long and complicated tectonic evolution and contains structures of various types, scales, and genesis (Gamkrelidze et al. 2013; Gamkrelidze 2016).

Tectonic structures of the pre-Alpine basement are characterized by the existence of several deep-seated nappes including obducted ophiolites (Gamkrelidze and Shengelia 2005).

Alpine structures have a different character in the various tectonic zones. The northeastern tectonic unit of Georgia, the fold system of the Greater Caucasus, is characterized by a distinctly expressed asymmetry in its structure: southward verging, often isoclinal folding on the southern slope and quiet, poorly folded, or monoclinal structures on the northern slope. Large, southward-directed nappes are developed also on its southern slope (Gamkrelidze 1991, 2016). The above-mentioned structures provide evidence of the leading role of Late Alpine underthrusting of the comparatively rigid Georgian Block under the Greater Caucasus during its deformation (intraplate subduction).

The northern boundary of the Georgian Block, in its western part, is formed by a deep fault, which in the sedimentary cover manifests itself as a regional flexure. Study of the structural peculiarities of the Georgian Block has shown that its central and western parts are characterized by a mosaic-block structure of the basement and occurrence of typical above-fault folds in the sedimentary cover. In the eastern area of subsidence of the Georgian Block, its cover is detached and shifted toward the south together with the nappes of the southern slope of the Greater Caucasus (Gamkrelidze 1991, 2016).

The Adjara-Trialeti zone of the Lesser Caucasus, which is situated to the south of the Georgian Block is, on the whole, an anticlinorium and is characterized by block-fold structures. To the west from the Dzirula massif along the northern margin of this zone, an overthrust nappe is developed.

The Artvini-Bolnisi zone consists of two different tectonic units: the Javakheti zone (in the west) and the Bolnisi zone (in the east). In the young (Neogene-Pleistocene) volcanic cover of the Javakheti zone, sublatitudinal gentle folds are observed. Two deep submeridionalseismogenic faults are established which served as conduit channels for young volcanics. The Bolnisi zone includes the horst-like Khrami salient of pre-Alpine basement and the territory covered with Cretaceous and Paleogene volcanic rocks. Brachyanticlines and steep faults of various orientations are developed to the south in a sedimentary cover, which generally forms a gentle syncline.

The northeastern wedge of the Somkhito-Karabakh zone forms part of Georgia and is characterized by echelon-like disposition of internal anticlinoria. In the core of a sub- latitudinal Loki anticlinorium, the pre-Jurassic crystalline basement is exposed. The axis of this structure plunges in both western and eastern directions and causes periclinal closure of the sedimentary cover.

The fold and fault systems of the Adjara-Trialeti, Somkhito-Karabach, and the Artvini-

Bolnisi zones were formed as a result of the manifestation of Late Alpine (Neogene) tectonic movements with the displacement of masses from south to north (Gamkrelidze 1991, 2016).

2.4 Geodynamic Evolution and Paleotectonic Reconstructions

The aforesaid data about geological structure, character of sedimentation and magmatism, geology, and the age of ophiolites, side by side with paleomagnetic data and global plate tectonic reconstructions (Stampfli and Borel 2002) allow us to consider the main features ofthegeodymanic evolution of the Caucasus and adjacent areas (Gamkrelidze 1986; Gamkrelidze and Shengelia 2005; Gamkrelidze 2016).

As a result of horizontal displacements of the ancient East European and African platforms, as well as of certain lithospheric plates within the Mediterranean belt during the Precambrian- early Mesozoic, the generation and development of oceanic basins took place. In the present structure of the Earth's crust, these basins are marked by rocks of ophiolitic association.

The most ancient of these oceans, the Proto-Paleotethys, developed in the course of time from the Precambrian up to the Middle Jurassic (Fig. 2.2). At this time, the Caucasian province was an active continental margin of Europe. The southern, Lesser Caucasus part of the Transcaucasus massif was located at the margin of the Paleotethys and belonged to the northern margin of the Iran-Afghanian plate (Gamkrelidze 1986).

Side by side with the Proto-Paleotethys Ocean during the Neoproterozoic and Paleozoic, relatively small oceanic basins of the southern slope of the Greater Caucasus and the so-called Arkhis basin (between the Main and Fore Range zones of the Greater Caucasus) are developed.

In the rear of the gradually closing Paleotethys, the joining together of Iran and Arabia and the generation of Neotethys had been taking place already since the Triassic.

The next extension occurred during the early Jurassic and beginning of the Middle Jurassic. At the northern active margin of the Paleotethys, the Transcaucasus island arc and marginal sea of the Greater Caucasus can be discerned (Fig. 2.3).

One can suppose that the Lesser Caucasus branch or bay of the Tethys was formed in the rear of the closure of the Paleotethys since the end of the Middle Jurassic.

The closure of the Neotethys Ocean, as well as of the Paleotethys relic basin, occurred as a result of movements that spread from north to south. In particular, only the northern part of the Caucasian segment of the Mediterranean belt was affected by the Bathonian (Adygean), Late Cimmerian (pre-Cretaceous), and Austrian (pre-late Cretaceous) movements. These epochs of tectonic activity are associated with the intense manifestation of andesitic volcanism and granitoidplutonism due to the processes of subduction on the continental margin of the oceanic basins (Fig. 2.3).

The movement of the Austrian phase closed the Lesser Caucasian branch of the Mesotethys. At that time, ophiolite nappes were formed in the Lesser Caucasus.

The subsidence that began in the Paleocene reached a maximum in the Eocene, especially in the Middle Eocene, and it was accompanied by calc-alkaline volcanic activity throughout the Lesser Caucasus. Northwards, this was substituted mostly by the basaltic sub-alkaline series of the Adjara-Trialeti rift (see Fig. 2.3).

The subsequent phases of Alpine tectogenesis caused the accumulation of molasse deposits, total compression, and final formation of the present-day structure of the Caucasus (Caputo et al. 2000).

The abundance of andesitic and andesite-dacitic volcanism and granitoidplutonism in the orogenic stage can be related to the continuing activity of subduction zones (intraplate subduction).

At the same time, at the location of maximum compression of the Mediterranean belt caused by an active northward sub-meridional advance of the Arabian Plate, a vast transecting transverse set of extensional fissures developed which was responsible for the penetration of orogenic volcanism far into the continent, in a zone of Transcaucasian transverse uplift.

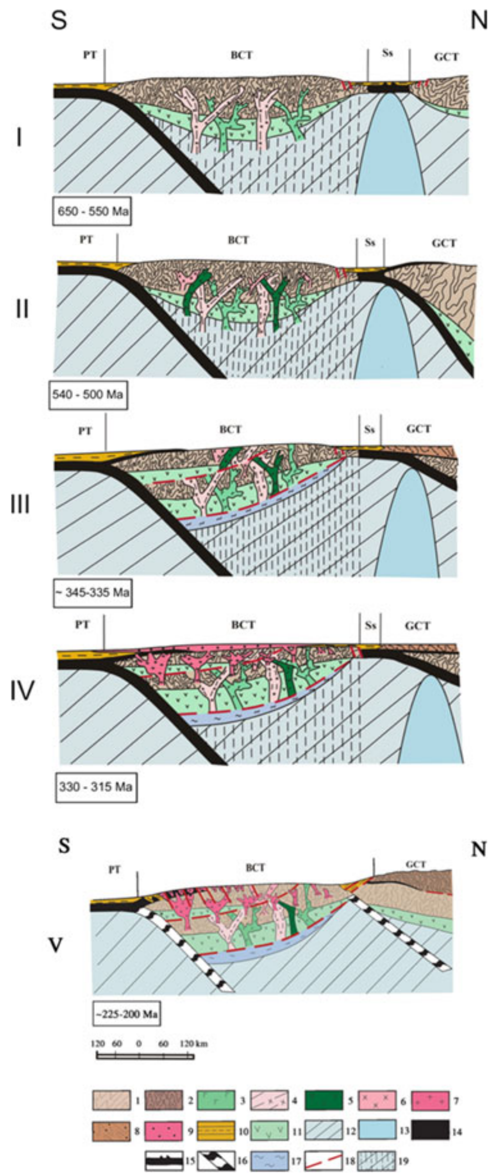

Fig. 2.2 Palinspastic profiles of the Mediterranean belt for: I—Cadomian stage, II—Late Baikalian stage, III—Bretonian (Saurian) stage, IV—Late Variscan (Sudetian) stage, V—Early Cimmerian (Indosinian) stage (Gamkrelidze and Shengelia 2005). Vertical scale is exaggerated approximately for three times. By representation of pre-Alpine extend of terranes the magnitude of Alpine shortening is not taken into account. 1—Grenville plagiogneiss-plagiomigmatite complex with concordant schistose and boudinated bodies of metabasites, 2—rocks of infrastructure within the Elbrus subzone of the Main Range zone of the Greater Caucasus, 3—Neoproterozoic gabbroids, 4—Cadomianorthogneisses, 5—Cambrian gabbros, gabbro-diabases, diabases, 6—Late Baikalian-granitoids, 7—Late Variscanpotassic granites, 8—Lower-Middle Paleozoic mainly pellitic sediments within the Greater Caucasian terrane, 9—Upper Paleozoic rhyolite tuffs, 10—sediments of the oceanic floor and continental slope, 11—basaltic layer of the Earth's crust, 12—upper mantle, 13—astenosphere, 14—oceanic crust including obducted ophiolites, 15—Middle oceanic ridge, 16—inactive subduction zones, 17—"crust astenolayer" (astenolens), 18—overthrust surfaces and other faults, 19—streams of suprasubduction heat, fluids and magmatic melts in mantle. Paleooceanic basins: PT—Proto-Paleotethys, Ss—small oceanic basin of the Southern slope of the Greater Caucasus. Continental plates: BCT—Black Sea—Central Transcaucasian terrane, GCT—Greater Caucasian terrane (island arc)

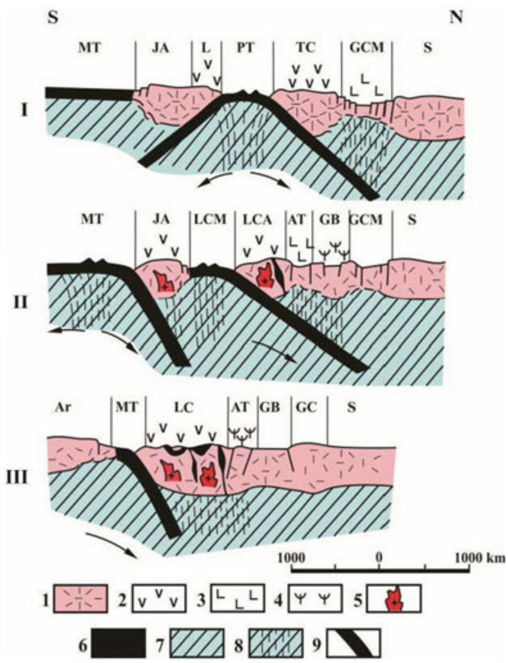

Fig. 2.3 Palinspastic reconstructions of the Caucasus segment of the Mediterranean belt along N-S profile for Alpine time (Gamkrelidze 1997b). I—Early Jurassic and beginning of the Middle Jurassic; II—Late Cretaceous; III—Eocene. Vertical exaggeration is approximately 10 times. 1—consolidated continental crust; 2–4—manifestation of volcanism: 2—calc-alkaline, 3—basaltic, 4—alkaline-basaltic; 5—granitoid magmatism; 6—newly formed oceanic crust and ophiolites; 7—upper mantle; 8—heated upper mantle; 9—subduction zones; Oceanic areas and small sedimentary basins: PT—Paleotethys, MT—Mesotethys (Neotethys), LCM—Lesser Caucasian branch (bay) of Mesotethys, GCM—Greater Caucasus marginal sea. Continental plates and microplates: TC—Transcaucasian island arc, GC—Greater Caucasus island arc, LC—Lesser Caucasus, L—Lock-Karabach Zone, S—Scythian Plate, JA—Iran-Afghanian Plate, LCA—Lesser Caucasian island arc, AT—Adjara-Trialeti intra-arc rift, GB—Georgian Block, Ar—Arabian Plate

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3 Hydrogeology and Mineral Waters

Berdo Zautashvili and Badri Mkheidze

Abstract

There are three hydrogeological districts in the territory of Georgia according to the structural-hydrogeological zoning. These zones with physical and chemical patterns of the mineral waters are described in this chapter. The hydrogeological District I of the Main Range zone is characterized by a high degree of cracking of crystalline and metamorphic rocks and contains fracture and fracture-vein groundwaters. Hydrogeological District II consists of Kolkheti and Kartli-Kakheti artesian basins and their divider Dzirula hydrogeological massif. Its building Mesozoic-Cenozoic sediments are represented by alternation of water permeable and waterproof complexes that result in the formation of typical artesian horizons. Hydrogeological District III is constructed mainly by volcanogenic-sedimentary, carbonate and terrigenous formations with the insertions of intrusives of different ages.

According to the structural-hydrogeological zoning, there are three hydrogeological districts in the territory of Georgia spatially from the north to the south: the fold system of the Caucasus (I), the intermountain depression of Georgia (II) and the fold system of the Lesser Caucasus (III). All of them include hydrogeological structures of the second category (Zautashvili and Mkheidze 2011).

The hydrogeological region of the Main Range zone included in the District I is characterized by a high degree of cracking of crystalline and metamorphic rocks and contains fracture and fracture-vein underground waters, water content of which is unimportant (debits of sources are 0.01–1.0 l/s). Only in the upper zone of the open cracks and in the loose rocks are found the high debit sources of groundwaters (10–50 l/s). These waters are mainly composed of HCO_3-Ca and ultra-fresh with 0.1–0.2 g/l mineralization. In the areas of tectonic disorders, fracture-vein and pressured waters are found in-depth, which are saturated with carbon dioxide gas. These waters are of HCO_3-Ca and HCO_3-Cl-Na composition with common mineralization of 3.0 g/l (Zautashvili et al 1997).

The second unit of the same district—the hydrogeological region of the southern slope—is mainly built of intensively folded Lower Jurassic clay-shales, Bajocian volcanogenic-sedimentary formations, Upper Jurassic—Lower Cretaceous flysch formations, and partially Lower and Middle Jurassic volcanogenic and terrigenous rocks, in which are mainly developed the stratified-fissure and fissure underground waters. In the rocks of the upper hydrodynamic zones, the water content is very low; the source debits

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do not exceed 0.1–0.5 l/s. In the carbonate rocks, the debit increases and sometimes reaches 30–70 l/s. Water abundance of the Quaternary sediments is quite increased to 1000–1500 l/s (Zautashvili et al 1997).

With chemical composition, these waters contain HCO_3-Ca, ultra-fresh with 0.02–0.1 g/l mineralization. Even in lower hydrodynamic zone, rocks are characterized by low water content. They are represented by carbon acid soda and alkaline-saline waters with mineralization reaching 35 g/l. In the east, along the sinking structures, the chemical and gas composition of the waters are changed and the carbon acid is replaced by methane chloride-sodium waters.

Hydrogeological District II consists of Kolkheti and Kartli-Kakheti artesian basins and their divider Dzirula hydrogeological massif. The Kolkheti artesian basin, composed of several lower-rank artesian basins, is a western sunken part of the intermountain depression structurally. Its building Mesozoic-Cenozoic sediments are represented by alternation of water permeable and waterproof complexes that result in the formation of typical artesian horizons. Here are two structural levels (Zautashvili and Mkheidze 2003).

The upper level combines the Quaternary, Pontian-Maeotian, Sarmatian, Middle Miocene, and Paleogene-Upper Cretaceous water-content horizons with high filtration properties (Kf = 100–300 m/day), in the opened sections, where circulate the fresh waters with HCO_3-Ca, while in the lower pressured horizon—the waters with Cl-Na.

The lower level is constructed from Neocomian carbonate, Bajocian porphyritic, and loess shaley complexes. In the opened part, the Neocomian carbonate sediments are characterized by powerful sources of karst fresh waters of HCO_3-Ca composition with the debit of 100–200 l/sec, while in the closed part it is characterized by thermal waters (t = 80–90 °C) of SO_4-Cl-Ca-Na with the mineralization up to 2 g/l. The Jurassic complex is characterized by relatively low filtration properties (debit of the sources 0.1–0.2 l/s) and mainly Cl-Na-Ca waters of 50-250 g/l mineralization; at a depth of 4–5 km mineralization reaches 340 g/l.

In the alluvial sediments of the Kartli-Kakheti artesian basin, the powerful streams of fresh waters of HCO_3-Ca composition are developed. Here, the water permeability coefficient reaches 1.500 m^2/day. In the Upper Pliocene and Lower Quaternary sandy-gravel sediments (Alazani basin), there are pressured horizons formed that contain substantial resources of low mineralization water of HCO_3-Ca composition. Eocene, Oligocene, Miocene and Pliocene clays, clay slates, and sand distributed in Gare Kakheti are characterized by a low rate of wateriness. The sources are rare here and their debit is mostly low by 1.0 l/s. Even for the zone of active water exchange, a high water mineralization and SO_4-HCO_3-Na composition are characterized. In the complicated water exchange zone, the waters of Cl-Na and Cl-Na-Ca composition and with mineralization of 20–45 g/l are revealed by drillings.

Hydrogeological District III is constructed mainly by volcanogenic-sedimentary, carbonate, and terrigenous formations with the insertions of intrusives of different ages. This district covers the hydrogeological regions of Achara-Trialeti and Artvini-Bolnisi folded zones which sharply differ from each other. The first one is the typical admassif, in the periphery of which the two small depressions are formed (Guria and Akhaltsikhe artesian basins) (Zautashvili et al. 2005a, b).

Hydrogeological nature of the region is mainly determined by the Middle Eocene volcanogenic-sedimentary and Upper Cretaceous carbonate suites, which are the main collectors of the fracture and fracture-karst waters. Upper hydrodynamic zone is characterized by an average level of wateriness. Freshwaters of HCO_3-Ca composition are common here. In the lower hydrodynamic zone, low-mineralized nitrogenous therms (up to $t = 70$ °C) are mainly developed. In the central part of the region, carbone acid thermal waters of HCO_3-Na and HCO_3-Cl-Na composition and medium mineralization are common.

The vast area of the southwestern part of the Artvini-Bolnisi folded zone is covered by thick (200 m and more) layers of Upper Pliocene–Quaternary dolerite-andesite-basalt lavas. Their intensive cracking promotes the emergence of powerful streams (1000–4000 l/s) of underground waters, many exits of which are observed in the river gorges. These waters are of HCO_3-Ca composition and are characterized by low mineralization up to 0.2 g/l. At several points in the region, carbonic acid, thermal alkaline-saline mineral waters with 7.0–12.0 g/l mineralization are found in the Upper Cretaceous—Paleocene carbonate sediments.

Hearth of Georgia is rich in mineral waters with a wide range of physical–chemical properties. About 1800 mineral waters are discovered and studied in sources, boreholes and mining productions. Their chemical and gas composition, specific micro components, mineralization, temperature and other physical–chemical indicators have been identified (Zautashvili et al. 2005a, b).

The number of mineral waters' approved operating resources in Georgia is more than 67,000 cubic m/day, which is a small part of their natural resources.

In the 80s of the last century, mineral water bottling in Georgia reached 420 million of 0.5 l bottles, which was less than 30% of the approved reserves. Only 46 mineral water origins were used partly, on the basis of which the 17 bottling factories, 18 balneo resorts, and 27 water treatment resorts were functioning.

The chemical-physical properties of mineral waters, their spatial distribution, and dynamics are significantly determined by the gas environment, where they are being formed. There are three provinces distinguished in the territory of Georgia by gas composition: (1) the province of waters with carbon dioxide, which coincides the hydrogeological district of the southern slope of the Caucasus, (2) the province of waters with methane, nitrogen, and hydrogen sulfide, corresponding to the hydrogeological district of the Caucasus intermountain depression, and (3) the province of waters with nitrogen, carbon dioxide, and methane, comprising the hydrogeological district of southern highland.

Mineral waters in carbon dioxide province belong to the carbonic acid type, except for one or two exceptions. In the heads of the rivers of the Greater Caucasus Range—Bzipi, Kodori, Enguri, and Rioni, the HCO_3-Ca carbonic acid waters of very low mineralization (0.1–0.2 g/l) are found. In this zone increase in content of mineralization and some micro components while moving from the west to east is noted. Carbon dioxide content in mineral waters reaches 2.0 g/l. On the southern slopes of the Caucasus, the outlets of carbonic acid waters are observed in the rock of all genetical-lithological types and ages from the heads of the Bzipi River up to the Aragvi River gorge. According to chemical composition they are represented by three types: (1) HCO_3-Ca-Na (or Na-Ca), (2) HCO_3-Na and (3) HCO_3-Cl-(or Cl-HCO_3)–Na (Zautashvili et al. 2005a).

The carbonic acid waters of the southern slope of the Caucasus deserve special attention due to their high healing properties and pleasant taste. This applies to both sodium and alkaline-saline mineral waters, while the waters type of Narzan are inexhaustible the source for their massive bottling of drinking water due to their gigantic resources (Zautashvili et al. 2009).

On the eastern periphery of the southern slope of the Caucasus, the carbonic acid waters are replaced by nitrogenous thermal waters with low mineralization. Among them, the famous source of Torghva bath is distinguished by its debit (800 cubic meters/day), the temperature of which is 36 °C on the surface of the ground (Zautashvili et al. 2007).

The mineral waters of the methane, nitrogen, and hydrogen sulfide province are distinguished by diverse chemical compositions. Their natural outlets are small; large resources are revealed through a wide net of boreholes in the deeply sunken water-content horizons of the Kolkheti artesian basin. In the most part of the basin the hydrochemical inversion occurs: the Upper Cretaceous horizon's high-mineralized (15–70 g/l) hydrogen sulfide-methane waters (Besleti, Chaladidi, Khorga, and Menji) are replaced in the Lower Cretaceous sub-horizon by nitrogen, nitrogen–hydrogen sulfide, methane, radon, mainly chloride and sulfate–chloride waters of the middle and lower mineralization (Fig. 3.1) (Gagra, Besleti, Kindghi, Okhurei, Tkvarcheli, Tsaishi, Zugdidi, Nokalakevi, Samtredia, and Tskhaltubo). It should be noted that the abundant resources of underground waters of the Kolkheti basin have been incompletely used so far. The following resorts are functioning based on them: Tskaltubo, Gagra, Besleti, Tsaishi, Menji, and others. They are partially used for hot water supply and greenhouse farming in largely populated areas. In addition, in western Georgia there are also revealed the mineral waters of different compositions, including the unique "Lugela"; it is actually a ready-made medicine—a 5% solution of calcium-chloride (Zautashvili 1970, 2016).

Within the eastern part of the second province—the Kartli-Kakheti artesian basin, the natural outlets are represented by mostly nitrogen–hydrogen-methane low-mineralized waters. In the western part of the basin, the deep boreholes open the low mineralization (0.4–0.6 g/l) HCO3-Cl-Na composition and relatively mineralized (2.1 g/l) Cl-SO_4-Na composition hot (39–82 °C) nitrogen-methane waters (Tsromi, Agara, and Khvedureti), and in individual sections (Kheiti and Ujarma)—relatively higher mineralization (5–21 g/l) Cl-Ca-Na and Cl-HCO_3-Na content thermal waters. In the northern periphery of the Alazani basin, low-mineralized nitrogen–hydrogen warm waters (Kvareli) are widespread, and in the deeply located water-content horizons the borehole has opened the medium mineralization methane Cl-Na-Ca hot waters (Eretiskari and Tsnori). In the southern part of the Alazani basin and Gare Kakheti, the outlets of mud volcanoes (Akhtala, Pkhoveli, Kila-Kupra, and others) are observed, wherein the zones of faults, the pressured underground waters bring out from the deep depths on the surface the healing clay porridge-like mass. The waters are methane and Cl-Na composition with the mineralization of 13.3–33.8 g/l (Zautashvili et al 1997).

The third province is distinguished by the variety of hydrogeological structures, which enables the diversity of mineral waters. Their representatives include mineral water deposits: Borjomi (Fig. 3.2) (Central, Likani, and Vashlovani-Kvibisi districts), Nabeghlavi, and partly, Sairme. The positive peculiarity of waters is considered the slight composition of sulfate (less than 10 mg/l), as well as the best medicinal properties, and important operation reserves

Fig. 3.1 Nokalakevi mineral water (photo by M. Tutberidze)

(1080 cub. m/day at all three districts of Borjomi) and developed bottling and resort infrastructure. In this region, the low mineralization (less than 5 g/l) HCO3-Ca-Na composition type Sairme mineral waters (Sairme, Tsaghveri, Mitarbi, Kokotauri, Uraveli, and Phlate) and relatively mineralized HCO_3-Cl-Na composition (Zvare, Tsinubani, Gujareti, Nedzvi, Zanavi, and Loshkneti) are common. Nitrogenous thermal waters are found in this province almost everywhere. According to the gas-chemical characteristics, the following types of waters are distinguished: (1) Tbilisi-Lisi CO_3-Cl-Na, (2) Tbilisi-Central District SO_4-HCO_3-Na and SO_4-Na, (3) Abastumani Cl-SO_4-Na, and (4) Biisi HCO_3-Na and Cl-HCO_3-Na (Zautashvili 2016).

The first type is spread mainly in the deep zones (Lisi and Saburtalo) of the eastern sinking of the Achara-Trialeti folded zone and partly, in the western and central zones (Sulori and Zekari). They are characterized by ultra-low mineralization (0.2–0.4 g/l), high temperature (up to 67 °C), and alkaline content; in some areas, with increased hydrogen sulfide content.

The second type of nitrogen thermal waters is characterized by low mineralization (0.3–0.5 g/l), temperature—up to 42 °C, and substantially increased content (22 mg/l) of hydrogen sulfide. Among them the Tbilisi sulfur baths are remarkable. The Abastumani-type nitrogen thermal waters are spread in the central (Abastumani and Udabno) and western (Bughaura and Tomasheti) parts of Achara-Trialeti. Their mineralization is 0.5–0.8 g/l and the temperature reaches 71 °C. They are distinguished by increased levels of silica (55 mg/l). The Abastumani Balneological Resort was established on their base. Biisi-type thermal waters are distinguished with high PH (8.3–9.8), relatively increased mineralization (0.5–1.5 g/l), and high content of the fluorine (10–28 mg/l). Their temperature varies within 35–48 °C (Zautashvili and Mkheidze 2011).

In the southern part of the third District (III), in the hydrogeological region of Artvini-Bolnisi, there are sources of HCO_3-Cl-Na composition mineralized (9.5–13.6 g/l) thermal (43 °C) waters (Nakalakevi) and carbonic acid mineral waters of HCO3-SO4-Mg-Na composition medium mineralization (7.1 g/l) (Bolnisi).

It should be emphasized that most of Georgia's mineral waters, along with high healing and tasteful properties, which stipulate the perspective of their extensive use in the bottling industry of mineral waters and balneology, have got other attractive sides as well; in particular, many of

Fig. 3.2 Borjomi mineral water (photo by N. Bolashvili)

them can be used to obtain geothermal energy, thanks to high temperatures and large resources, and some—to obtain rare chemical elements (Cs, Li, Rb, Br) (Zautashvili 1970).

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4 Mineral Resources

Revaz Khazaradze and Elene Salukvadze

Abstract

This chapter presents the diversity of mineral resources in Georgia. The mineral resource fund of the country comprises 950 mines and revelations of semi-precious and manufactural stones. Fuel resources in Georgia are represented by oil, natural gas, coal and peat mines. The most important of the ferrous metals is the world-famous Chiatura high-quality **Manganese** mine. From rare metals, the small mines of molybdenum, tungsten, mercury and stubium are represented. From non-metallic minerals in Georgia, there are important areas of barite, chalcedony, diatomite, bentonite clays, agate, zeolite and fireproof clay mines. **Construction and Facing Materials** are found in abundance in Georgia associated both with sediment and magmatic rocks.

Georgia is distinguished by its diversity of natural resources and is rich both in mineral and non-metallic resources, fuel resources, construction materials and facing stones as well as mineral and thermal waters. Distribution and capacity of the current mineral resources in the bosom of the land of Georgia is subordinated to geological (tectonical) regularities (Tvalchrelidze and Kvirikadze 1981).

According to A. Tvalchrelidze's survey, the mineral resource fund of the country comprises 950 mines and revelations of semi-precious and manufactural stones. Among them 62. 8% of the resource fund are large (national and international) mines, 30.9%—local mines and 6. 3%—revelations. The fund is divided according to Georgian regions as follows: Imereti—20.7%, Kvemo Kartli—12.5%, Apkhazeti—11.6%, Shida Kartli—9.3%, Samegrelo and Zemo Svaneti—8%, Kakheti—8.1%, Mtskheta-Mtianeti—6.0%, Guria—3.4%, Achara—2.3% and Tbilisi—0.6% (Tvalchrelidze et al. 2011).

Fuel resources in Georgia are represented by oil, natural gas, coal and peat mines. Among the oil ores, most of which are located in Kakheti, worth mentioning are the ores of Mirzaani, Taribani, Shiraki, Samgori-Patardzeuli, Norio-Martkopi, Satskhenisi, Teleti, Ninotsminda (Sagarejo municipality), Rustavi, Supsa and the Black Sea shelf, which belongs to the prospective regions of **Oil** and **Natural Gas** detection (Tevzadze 1998). The oil reserve amounts to 169.7 million tonnes; it contains less sulfur and is of high quality. The country's only natural gas field is located in the surrounding of the town Rustavi, with a reserve of 5.2 billion m^3.

Among coal mines, the black coal mines in Tkibuli-Shaori and Tkvarcheli and the brown coal mines in Akhaltsikhe are important. Among

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them, 402 million tonnes of black coal and 82 tonnes of brown coal are on the state balance.

Peat mines are located on the Black Sea coastline (in the surroundings of Poti, Kulevi, Pichori, Imnati, Ochamchire, etc.). The peat is used in the production of fertilizers.

The most important of the ferrous metals is the world-famous Chiatura high-quality **Manganese** mine (its exploitation started in 1879). It is also worth noting the Chkhari-Ajameti ore line, the manganese areas of Kvirila depression, Cholaburi, Rodinauli, Rikoti, Shkmeri and, etc. **Iron** mines and revelations in Georgia are known from ancient times. It is worth mentioning the so-called Poladauri Group (Bolnisi Municipality) of hematite ore mines, hematite-magnetite ores of Dzama (Kareli Municipality) and **Magnetite Sands** nests of Supsa-Natanebi.

Among non-ferrous metals, the **Copper** mines are associated with volcanogenic rocks. It is worth mentioning the ore mine in Bolnisi municipality and other ore revelations in Tamarisi, Kvemo Bolnisi, Davit Gareji, Merisi, Chkhornali (Keda municipality), Adenge, Gentsvishi (Apkhazeti), Zhabeshi, Guli, Zeskho (Svaneti), Zopkhito, Chveshura (Racha), Devdoraki (Khevi), Saketseti (Khevsureti) and others.

Among the **Lead–Zinc** ores, the lodes of porphyritic suite (Kvaisa, Dambluti and Rtskhmelauri), as well as the revelations of stratified ore bodies—Brdzishkha and Akugra (Apkhazeti), associated with the reef structures of Upper Jurassic age. **Lead and Zinc** often play a satellite role in various types of ore systems; in this respect, it is worth mentioning the mines of Amtkeli (Apkhazeti), Dambluti (Loki massif) and Merisi (Achara).

The **Arsenic** is also being extracted, the mines of which are associated with Neogene magmatic processes; among them, the following are notable: Tsana (Kvemo Svaneti), Uravi (Zemo Racha and Lukhunistskali gorge), as well as the arsenic revelations in Sakaura and Kodidziri. Surmi mines are known in Zemo Racha, Svaneti and surroundings of Kazbegi.

Strong (100 m) deposit of **Limestones with Analcime** containing aluminium is presented in the area of Gelati (Khazaradze et al. 2000).

From rare metals the small mines of molybdenum, tungsten, mercury and stubium are represented. The molybdenum mines are known in Karobi (Zemo Racha) and Gharta (Khashuri municipality), the tungsten mines –in the Ghebi village, the ore valley—in Zopkhito and the ore revelations—in Notsari, Motsantsari and Mamisoni (Zemo Racha). **Mercury** mines are associated with the Lower and Middle Jurassic clay slates, more rarely—with a narrow strip of carbonate sediments. The mercury ore layer spreads across the southern slope of the Caucasus in Apkhazeti (Akhei and Avadhara), Svaneti, Racha, Shida Kartli, etc.

Noble metals have a limited distribution, namely, **Gold** is found as companion components in copper and other ores of metallic mines. It is worth mentioning the Madneuli polymetallic deposition in Bolnisi, Khrami massif, Adigeni and Gharta ore centres; the golden sandy accumulations in the Enguri and Ktsia River basins are notable. **Mercury** is mostly found in sulfide mines—Madneuli (Bolnisi municipality), Kvaisa lead–zinc mine, David Gareja, Merisi (Achara), etc.

From non-metallic minerals in Georgia, there are important areas of barite, chalcedony, diatomite, bentonite clays, agate, zeolite and fireproof clay mines.

The **Barite** is represented mainly in the Bajocian volcanogenic rocks of Kudaro and Kvaisa (Shida Kartli), Patsihkvara (Apkhazeti), Khaishi (Mestia Municipality), Chordi (Oni Municipality), Kutaisi vicinities (Ghvedi, Khvamli-Mekveni, Tsiplnariskhevi, etc.) and Madneuli (Bolnisi Municipality) deposits. The barite is also found in the Upper Jurassic carbonate rocks in the Apshri mine (Apkhazeti). Total reserve of 33 barite mines exceeds 8 million tonnes.

Among the **Acidproof Andesite** mines, the Bakuriani and Kazbegi mines are (total reserve of 22.1 million tonnes) are notable.

The **Bentonite Clays** are located in the sediments of the Upper Cretaceous and Middle Eocene ages. Important deposits are in Gumbi (Tskaltubo municipality) and Askana (Ozurgeti municipality).

The **Chalcedony** is widespread in Terjola municipality.

The only deposit of **Diatomite** is found in Kisatibi (Akhaltsikhe municipality), which is located in the volcanogenic, so-called Goderdzi-Kisatibi suite of the Upper Neogene age.

The **Talc and Serpentine** are presented in the eastern part of Dzirula crystalline massif and in the crystalline rocks of the Paleozoic age of Shida Kartli; a group of Chorchana mines is also well known (Kvashava, Cheshuri, Tetri Mindori, Utslevi, Tsnelisi and other mines).

The **Dolomite** is being extracted in the Abano deposit (Kareli municipality), which is represented in the form of layered deposits and is associated with the Cretaceous deposits.

Zeolites are associated with the Jurassic, Cretaceous and Paleogenic volcanic suits. They are widespread in Dzegvi (Mtskheta municipality) and Tedzami River gorge, in the Zemo Khandaki village (Kaspi Municipality), as well as in Akhaltsikhe municipality. Zeolites' supply of Georgia (22 million tonnes) is of world importance.

Fireproof Clays are found in Shrosha (Zestaponi municipality), Makvaneti (Ozurgeti municipality) and Tsetskhlauri (Kobuleti municipality).

Kaolin Clays are revealed in many locations; among them the Jvarisa (Tkibuli municipality) mine is important.

The **Agate** is found in the volcanogenic rocks of the Eocene age. There are many agate deposits in Akhaltsikhe municipality (Shurdo, Pamaj-Ziareti deposits).

Native Sulfur deposit is in the Abano mine, located in the Tergi River gorge (Kazbegi municipality).

Deposits of phosphorites, apatites, asbestos, jet, graphite, pegmatites, etc. are of relatively limited distribution (Fig. 4.1).

Construction and Facing Materials are found in abundance in Georgia associated both with sediment and magmatic rocks. Their

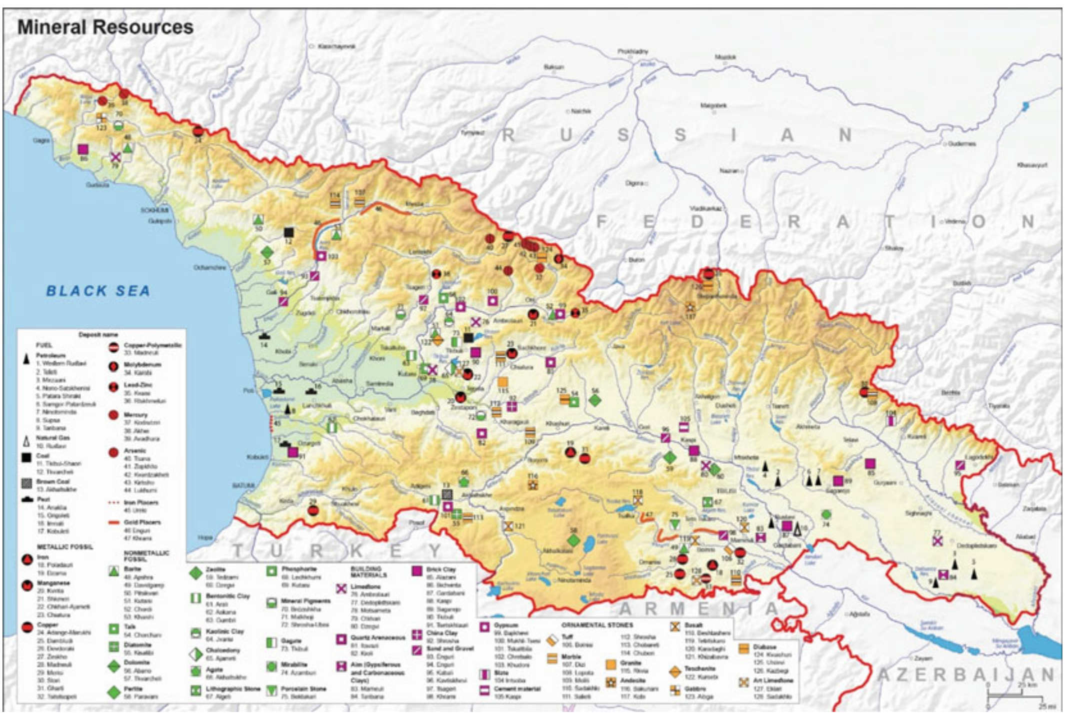

Fig. 4.1 Mineral Resources (National Atlas of Georgia, Steiner-Verlag, 2018)

exploitation has been in process for a long time. The raw materials (marls, clays and limestone) suitable for cement are found in the area of Kaspi and Bzipi. Quartz sands, which are used in construction and glass production, is spread in Sachkhere and Khashuri municipalities.

The **Sheetrock** deposits are abundant in the surroundings of Tbilisi. **Jypsum** deposits are found in western Georgia. The wall stones are obtained by the processing of limestones, sandstones and volcanic rocks. **Limestones** are widely spread. The deposits Dedoplistskaro, Senaki, Motsameta, Gantiadi and Surami are well known.

Among the facing stones the **Marble,** pattern **Tuff, Teschenite and Basalt** are known. Marble in Georgia is a high quality and is very popular. The deposits of Lopota (Kakheti), Shrosha (Dzurula River gorge), Salieti (Chiatura municipality), Dizi-Chuberi (Svaneti), Sadakhlo (Marneuli municipality) and Chobareti (Aspindza municipality) are well known. **Marbled Limestone** deposits are found in Ilto (Telavi municipality), Gumista (Abkhazia) and Moliti (Imereti). The deposits of Kursebi (Tkibuli municipality) and Eklari limestone deposits are known at Kutaisi. Basalt is used to produce stone castings, which is being extracted in Sataplia (near Kutaisi). The tuff deposit in Bolnisi is well known. In Tbilisi, there are a lot of remarkable buildings furnished using the tuff. Deposits of brick-roofing tile clays and silicate brick bases are also important.

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5 Relief

Ramin Gobejishvili and Emil Tsereteli

Abstract

In this chapter diverse and complex morphology, morphometry, and morphography of the terrain are analyzed. The interaction of endogenic and exogenic processes has led to the distinguishing three major morphostructural zones. The special role in the formation of the morphostructure of the relief of Caucasus belongs to the fault lines, which are observed in the relief in the form of stairs. The intermountain plain is a tectonic depression. The formation of the relief took a long period of time. The relief of the highland of southern Georgia is characterized by different morphostructural and morphosculptural peculiarities, with the reflection of tectonic and lithological conditions of the constructing suites.

The relief of Georgia is characterized by diverse and complex morphology, morphometry, and morphography. The complexity of the relief is derived from its geotectonic nature and the diversity of the relief—from the altitudinal zoning of the relief and peculiarities of geodynamic processes (Gobejishvili 2011). The highest point of Georgia is Mount Shkhara (5203 m), and the lowest point (−1 m) is located in the Kolkheti Lowland. The interaction of endogenic and exogenic processes has led to the distinguishing major morphostructural zones (units):

I. Medium and high mountainous relief zone of the Caucasus Range;
II. Intermountain plain zone;
III. Highland zone of southern Georgia.

5.1 Medium and High Mountain Relief Zone of the Caucasus Range

Within Georgia the Caucasus Range enters as follows: the southern slope of the Caucasus—from Mount Avadhara (2960 m) to Mount Tinovroso (3374 m), and the northern slope—from Mt. Vatsisparsi (2562 m) to Mt. Shaviklde (3578 m) Hypsometrically, the highest is the central section of the Caucasus within the Racha-Svaneti region. The peaks with the height over 5000 m above sea level are located on the Pitsrula and Shkhara massifs. The highest peak is the Mt. Eastern Shkhara (5203 m) (Fig. 5.1).

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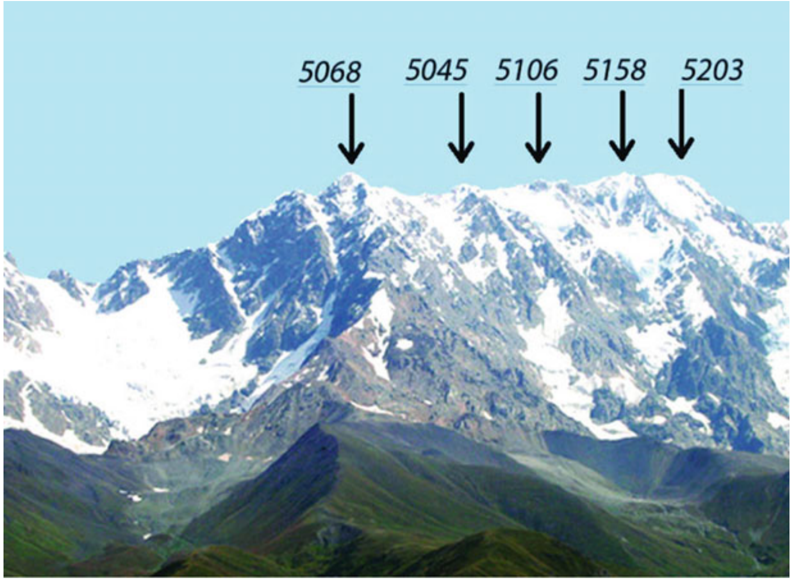

Fig. 5.1 Shkhara massif (photo by R. Gobejishvili)

The axis strip of the Caucasus, from Mt. Avadhara to the Mamisoni Pass is built by the Paleozoic and Proterozoic plagiogranites, plagiognenisses, amphibolites, crystalline slates, etc. The Dariali gorge is built with the same rocks. The Jurassic, Cretaceous, and Tertiary suites participate in the construction of the southern slope of the Caucasus folded system. The northern slope is built by Jurassic suites. The Racha-Lechkhumi syncline and its continuation in the form of a narrow strip up to Java are built by the Tertiary sedimentary rocks. The carbonate-Triassic suites build the center of the Svaneti Range and its continuation to the west and east.

The special role in the formation of the morphostructure of the relief of Caucasus belongs to the fault lines, which are observed in the relief in the form of stairs. On the slopes of the Caucasus, the lineaments are conceived on the edge of the main suites—between the crystalline suites and the Jurassic sediments, between the Bajocian and carbonate suites, and between the Tertiary and the Cretaceous sediments. The faults of the submeraldional direction are also seen in the relief (Gamkrelidze 1977). Earthquakes are frequent in the knot of the faults crossing; in this respect, the north-eastern section of Racha is particularly notable.

The relief of the Caucasus experiences the differential movement. Axial strip goes up by 10–15 mm/year (Lilienberg 1969), inverse and semi-inverse ranges constructed by carbonate flysch go up by 4–8 mm/year, and the areas located among them, represent the relative sinking zones, sinking by 1–3 mm/year. In the intensive uprising areals, the falling of the riverbeds is high and erosion processes are in progress, in the relative sinking zones the falling is up to 10–12 m/km and mainly the accumulation and side erosion are underway in the riverbed. Due to the depth erosion of rivers, while they cross-sect the ascended morphostructures, the narrow gorges and cliffs are formed, especially in the Cretaceous suites (the rivers of Bzipi, Gumista, Kelasuri, Kodori, Okumi, Ghalidzga, Enguri, Khobistskali, Tekhuri, Abashistskali, Tskhenistskali, Rioni, Tergi, etc.).

The gorges, generated in the direction of morphostructures, are wide and they are represented in the form of basin (Bzipi (Pskhu), Kodori, Enguri, Tskhenistskali, mountain Racha, Racha-Lechkhumi, Java, Truso, Tusheti, etc.). In other cases, the form of gorges is V-shaped and the inclination of the slopes is different.

Besides the tectonic and erosive processes in the genesis of relief, the role of exodynamic processes is considerable, such as nival-glacial, karst, and gravitational processes. The formation of relief in high mountainous zone is associated with the old and modern glaciations. The modern glaciers are widespread in the Central Caucasus (Svaneti-Racha section and Khokhi Range) and Western Caucasus (from Marukhi Pass up to Dalari Pass). Large size glaciers of valley type (Lekhziri, Chalaati, Tsaneri, Adishi, Khalde, Kirtisho, Boko, Devdoraki, Gergeti, etc.) are found among the morphological types of glaciers. There are many cirque glaciers of small size. For the last 200 years the glaciers of the Caucasus have been retreated: the valley-type glaciers—by 1.0–2.5 km and the corrie type glaciers—by 300–500 m; the snow line in the Caucasus has been shifted up by 200 m, which was accompanied by the shifting up of natural zones as well. Snow and snow avalanches have great impact on the formation of micro and mezzo forms of the relief in the Caucasus. During old glaciation, at the height of 2000 m, due to the impact of active nival and glacial processes, the relief experienced total denudation and now it is in progress above 300 m. In Würm (Late Pleistocene) the tongues of large glaciers came descended to the height of 600–1000 m, the indication of which are the glacier forms, moraines, and trough valleys formed by them. In the high mountainous zone the cirques, carlings, glacial horns, ledges, debris, rock streams, and other nival-glacial forms are common.

In the peripheral strip of the southern slope of the Caucasus, there powerful limestones of the Cretaceous age are common, which facilitate the formation of surface and underground karst forms. The high karst zone is well developed in Gagra, Bzipi, and Racha ranges, as well as in separate massifs (Rikhva, Okhachkue, Kvira, Migaria, Askhi, Khvamli, etc.). The surface karst forms are represented by sinkholes, poljes, wells, dolinas, and shafts. The underground caves are made up of stalagmites, stalactites, and various underground speleothems as well. The world's deepest abysses are located in the Arabika massif: the Krubera (2208 m), Sarma (1543 m), Ilyukhina (1275 m), Arabika (1110 m), and Dzou (1090 m). The limestone massifs are separated in the relief by cliffs, on the slopes of which the debris cones are formed.

The gravitational forms are intermittently represented in the Caucasus, especially it refers to rock avalanches. In the area of their distribution, modern lakes or the traces of lakes are found (Didi Ritsa, Patara Ritsa, Amtkeli, and Kvedi). The lakes (Khakhieti and Patsa), generated as a result of the 1991 earthquake, were filled up by the solid deposits of river.

The volcanic relief is represented in the areas of Mt. Mkinvartsveri and Keli Upland. The relief of volcanic cones and lavas are characterized by interesting forms. The volcanic relief is mainly of Pleistocene age. The Khorisari, Tkarsheti, Tsitelikhati, and Khodzi volcanic flows and the volcanic cones generating them, are of Holocene age.

According to morphological and morphometric features, the Caucasus Range is divided into three sections (subzones): the Western Caucasus (from Mt. Avadhara to Dalari Pass), Central Caucasus (from Dalari Pass to Jvari Pass), and the Eastern Caucasus (from the Jvari Pass to the Mt. Tinovroso).

The main morphological regions of the Caucasus Range are the mountain ranges and river gorges of sublatitudinal and latitudinal directions located on the slopes of the Western and Central Caucasus. Among the mountain ranges, the following are notable: Gagra, Bzipi, Chkhalta, Kodori, Svaneti, Egrisi, Lechkhumi, Shoda-Kedela, Racha, Germukha, and Khokhi. On the slopes of the Central and Eastern Caucasus mainly the longitudinal ranges are located: Kharuli, Lomisa, Kartli, Kakheti, Kuro, Shani, Kidegani, Khevsureti, and Atsunta. At the same time, these mountain ranges are the watersheds for the main river gorges—Psou, Bzipi, Kodori, Enguri, Rioni, Liakhvi, Ksani, Aragvi, Iori, Alazani, Tergi, Asa, Arghuni and Pirikita Alazani.

5.2 Intermountain Plain Zone

Intermountain plain of Georgia is located between the Caucasus and southern Georgia's highland. It is stretched from the Black Sea to the east—the downstream of the Alazani River (up to Azerbaijan border). Its relief is very specific, although its highest places do not exceed 2000 m above sea level (Mt. Tsivi, 1991 m), but on the background of low plains, they are orographically sharply distinguished in the relief (Gombori Range, Ialno Range, Imereti Highland, and Likhi Range). The plains with flat surfaces are surrounded by the foothill hilly relief and Iori Upland. The hilly relief is fragmented due to the active impact of erosion and denudation processes. In the plains prevail the accumulative and denudative processes and the forms related to them (Tsereteli 1966).

The intermountain plain is a tectonic depression. The formation of the relief took a long period of time. It obtained its final look in the Pliocene and Pleistocene. The surface of modern relief experiences the differential movements. The absolute sinking region is the Poti area (−6.0 mm/year); on the background of general uprising, the Kolkheti Lowland, Shida Kartli and Kvemo Kartli Plains, and the Alazani Valley of graben character experience relative sinking (1–2 mm/year); the uprising of the Gombori Range is 4–6 mm/year, and the uprising the Iori Upland is 2–3 mm/year.

The relief of the intermountain lowland, except the Dzirula massif, is constructed with young sediments. Kolkheti Lowland, Shida Kartli and Kvemo Kartli Plains, Alazani Valley, and the flatlands of Iori Upland are generated by the Pleistocene alluvial and deluvial sediments. The hilly-hillock line, the lower tier of the Iori Upland, and the Gombori Range are represented by the marine-continental molasses (sandstones, clays, conglomerates, clay sandstones, and marls in some areas) of Tertiary period. The axial line of the Gombori Range is constructed from the Cretaceous carbonate suites. In the western Georgia, the hilly-hillock strip (in the northern part) is constructed by the Cretaceous limestones.

Dzirula massif is different, which underwent the peneplanation several times. The central strip of the Dzirula massif and Likhi Range are constructed with Proterozoic gneisses, amphobolites, granitoids, quartz diorites, and Middle Jurassic granitoids. The old rocks around Dzirula massif are covered by the Middle Jurassic (Bajos), Cretaceous, and Tertiary sedimental suites that are stretched mostly horizontally on the old substrate.

Along with the geologic and tectonic processes, the relief forming exodynamic processes are in progress, such as: erosion, accumulation, mudflow, and landslide processes, horizontal washing away, etc. Erosion processes occur mainly in the hilly-hillock relief; widely expanding V-shaped gorges are generated in the Tertiary sediments. In the Chiatura neighborhoods, in the Cretaceous sediments, the Kvirila River gorge has a form of canyon. Accumulation processes are in progress in the Kolkheti Lowland, Alazani Valley, Mukhrani-Tiriponi and Marneuli-Gardabani Plains, and in the flatlands of Iori Upland.

Powerful debris cones (in Kakheti and Kartli) are created by mudflow processes. Landslide processes are active in the Kolkheti hilly-hillock strip and Gombori Range. Individual landslide areas can be found in almost entire hilly-hillock relief. The karst processes actively develop in the intermountain plain. Low mountain karst is represented by caves, sinkholes, poljes, and shafts. The subregions of Tsebelda, Odishi, and Okriba are notable. The well-equipped caves are: Tskaltubo, Sataplia, Navenakhevi, and Akhali Athoni. The caves of Apkhazeti and Imereti were the dwellings for a human of Paleolithic era.

The intermountain plain is divided into two subzones—Kolkheti (western Georgia) Plain and Iveria (eastern Georgia) Plain. These two subzones are separated from each other by the Likhi Range. The Kolkheti Plain is sloped toward the west and entirely belongs to the Black Sea basin. And the Iveria Plain is sloped toward the east and its river network belongs to the Caspian Sea basin.

These two subzones are quite different in natural conditions. In the Kolkheti Plain the humid subtropics prevail, and the Iveria Plain belongs to the dry subtopics. This peculiarity is reflected in the differences of landforms and the exodynamic processes taking place in them.

In the Kolkheti Plain the following regions are distinguished: Kolkheti Lowland, the northern Kolkheti foothill hilly-hillock relief, the southern Kolkheti foothill hilly-hillock relief, Imereti Upland, and the Likhi Range.

In the Iveria Plain subzone, the following regions are distinguished: Shida Kartli Plain, Kvemo Kartli Plain, Iori Upland, Gombori Range, and Alazani Valley.

5.3 Highland Zone of Southern Georgia

The highland of southern Georgia occupies the southern and southwestern parts of the country's territory. It borders the intermountain plain zone from the south along the entire length.

The highland of southern Georgia is far behind the Caucasus by hypsometric indices. Here, the highest peaks are: Didi Abuli (3301 m), Samsari (3285 m), Godorebi (3188 m), and Legli (3156 m). The watershed of the Black Sea and Caspian Sea basins stretches along the crests of the Achara-Imereti and Arsiani ranges, which leads to differentiation in natural conditions. The morphological units, located within the Mtkvari River basin, are characterized by relatively small amounts of precipitations, and the Achara-Imereti and Shavsheti ranges are distinguished by abundance of precipitation. It is notable that the most humid area in Georgia—the Mt. Mtirala is situated in the Achara-Imereti Range.

The relief of the highland of southern Georgia is characterized by different morphostructural and morphosculptural peculiarities, with the reflection of tectonic and lithological conditions of the constructing suites (Astakhov 1973). It consists of two subzones: 1. Achara-Trialeti-Loki mountain relief, and 2. volcanic relief of Georgia.

The folded relief of Achara-Trialeti-Loki is mainly built with Paleocene and Eocene volcanogenic suites, which are located on the Cretaceous, Jurassic crystalline rocks, and the Loki massif crystalline rocks. In the eastern part of the crests of Achara-Imereti and Trialeti ranges, the Cretaceous sediments are outcropped, such as: sandstones, marl limestones, volcanic breccias, and pink limestones. The Akhaltsikhe depression is constructed with coastal-marine sediments: sandstones, clays, conglomerates, aleurolites, marls, and the layers of lignites. The Eocene volcanic rocks—diorites and Garbo are found in the form of islands.

The southern Georgia's highland relief is constructed with Pliocene and Pleistocene (Goderdzi suite) lime-alkaline andesites, dacites, andesite-dacites, rhiolites, basalts, lacustrine conglomerates, sands, and clays. The Goderdzi suite's peripheris are constructed with continental sediments of Miocene and Pliocene age: tuffs, volcanic breccias, conglomerates, diatomites, lime-alkaline andesites, and basalts (lower breccia part of Goderdzi suite).

The Khrami-Loki surroundings are constructed with crystalline rocks of Proterozoic age: crystalline schists, amphibolites, migmatites, Paleozoic quartz diorites, plagiogranites, and gniesses.

The main role in the formation of the southern Georgia's highland belongs to erosive, tectonic, volcanic, gravitational processes and horizontal washing away. Differential tectonic movements are active in the formation of the morphostructures. The main morphostructures are the mountain ranges that are still in the process of uprising movement (Achara-Imereti, Trialeti, Loki, Shavsheti, and Arsiani ranges). Achara, Akhaltsikhe, Tori-Tadzrisi, and Tsalka synclinal depressions are in the relative sinking process. The volcanic relief covers the southern part of the zone. The main landforms are the Pliocene–Pleistocene and the Holocene age volcanic cones and the plateaus and lava flows generated by volcanic lavas. It is worth to note the Javakheti volcanic upland, the Erusheti volcanic massif, and the volcanic plateaus of Persati, Bedena, Chochiani, Dmanisi, Gomareti, and Kvemo Kartli, as well as the Gujareti, Borjomi-Bakuriani, Dabadzveli, Pampula lava flows, etc. A row of the longitudinal volcanic cones is represented in the Samsari and Javakheti Ranges.

The landforms created by the erosive processes are widely distributed. The canyons are formed by the river erosion in volcanic plateaus and are quite long and deeply cut into the relief. The longest canyons are the Mtkvari gorge from

Aspindza up to the borders of Georgia, Paravnistskali gorge below Akhalkalaki, Khrami gorge in the Kvemo Kartli volcanic plateau and the Mashavera gorge at Patara Dmanisi. The asymmetric gorges of Gujaretistskali, Borjomula, and Mashavera are formed at a contact of bedrocks and lava flow. The Achara-Imereti and Trialeti ranges are split by the erosive action of Mtkvari River and generated the antecedent gorge. It is stretched from the village of Atskuri to the village of Tashiskari. The morphology of erosive gorges formed in the Achara-Trialeti Range is related to the lithology of the constructing rocks. In the firm rocks, the slopes of the gorges are strongly sloped and the bed is cascade. The slopes of the gorges formed in the soft rocks and in the direction of structures are widely opened (Mtkvari from Aspindza to Atskuri, Gujaretistskali, Vere, Tana, Dzama, Tedzami, Kvabliani, Acharistskali, Ktsia, etc.).

A certain role belongs to the impact of Würm glaciers in the formation of the high mountain ranges of Samsari, Javakheti, Achara-Imereti, and Arsiani. Cirques and morains have remained in the relief. Rock flows are formed as a result of nival processes. Rock avalanches are found locally. However, landslides are widely spread in Akhaltsikhe, Achara, and Tori-Tadzrisi basins (the active landslides of Kodiani and Dgvara are well known). Landslides are found in separate areas in the Trialeti Achara-Imereti and other folded structures.

The smoothed surfaces are well observed in the folded structures. They are distributed stepwise on the slopes of Achara-Imereti, Trialeti, and Shavsheti ranges. Here can be distinguished six steps, the age of which is dated as Miocene-Pliocene and Pleistocene.

As mentioned above, two subzones are distinguished in the highland of southern Georgia. Each of them includes several morphological units (areas).

1. **Achara-Trialeti-Loki mountain relief—**it includes the following areas: Achara-Imereti Range, Borjomi gorge, Trialeti Range, Shavsheti Range, Achara basin (Acharistskali River gorge), Arsiani Range, Akhaltsikhe basin, Khrami-Loki medium mountainous area;
2. **The volcanic highland of Georgia,** which combines: the Erusheti highland, upper gorge of the Mtkvari River, Javakheti Upland, Nailiskuri Range, Samsari Range (Fig. 5.2), Javakheti Range, Tsalka basin and volcanic plateaus (Bedena, Kvemo Kartli, Chochiani, Gomareti, and Dmanisi).

5.4 Morphogenetic Types of Relief and Their Distribution Areas

5.4.1 Tectonic and Petrogenetic Relief

Lithology and tectonic nature of the structural rocks of the territory of Georgia are of great importance to the development of large morphological units of relief. The origin of the main

Fig. 5.2 Samsari range (photo by R. Gobejishvili)

morpho-structural units of the Caucasus folded system, intermountain plain, and the highland of southern Georgia are related to tectonic processes. Their formation was underway during the long geological period (Astakhov 1973; Lilienberg 1969; Tsereteli 1966).

The evolution of the lower range morphostructures took place by the interaction of tectonic and erosive processes. The mountain ranges located on the southern and northern slopes of the Caucasus and the basins between them belong to the united tectonic structures, but due to the river erosion, they are represented by individual ranges and basins.

The Gagra-Java geotectonic structure is represented by high elevated semi-inverse ranges in the construction of which the sediments (suites) of Bajocian porphiritic series participate. These are the eastern part of the Bzipi Range (Chedimi Range), Chkhalta, Kodori, Samegrelo, Lechkhumi, and the eastern section of the Racha Range.

In the Mestia-Tianeti structural zone, the sublateral Shoda-Kedela Range is of the horst-syncline nature, and the structural zone in eastern Georgia is partitioned by the meridional rivers; therefore, the relief and geological structures do not correspond to each other. The structure of the watershed of the Kakheti Caucasus Range in the east of the Mount Borbalo is reflected in the morphology of relief.

Short and high southern slope built from the complex of the Jurassic and Cretaceous schists is overthrust on the Pliocene–Pleistocene suites through the active fault line. From the Mount Avadhara up to Mamisoni Pass the Caucasus watershed range of horst-anticline structures built with crystalline rocks is well seen orographically.

Horst-anticline watershed range is separated from the Jurassic suites by the deep fault line and is represented in the reliefs with steps of various altitudes (in Svaneti, Racha, Chkhalta, and Bzipi gorges). Graben relief is represented by Jurassic non-carbonate flysch. Soft rocks are easily subjected to denudation and are formed as separate basins in the nature (Pskhu, Chkhalta, Mestia-Mulakhi, Lapuri, mountainous Racha, Truso, Tusheti, etc.).

The long-term vertical movements in the mountainous zones have formed a deeply fragmented diverse relief. Differential movements in the intermountain plain zone formed the plain-lowlands (Kolkheti, Kartli, and Kakheti) and individual massifs (Imereti and Khrami-Loki).

Hilly-hillock structural relief built of Tertiary sediments stretches along the edges of the plains and lowlands of the intermountain plains. As a result of slow differentiated motion, it is uplifted at 300–1000 m above sea level and is fragmented because of exogenous processes.

The sinking trend is characteristic of the Kolkheti Lowland and the Alazani Valley, where the solid sediments were accumulated in Pleistocene.

The tectonic structure of the peneplained Dzirula massif of ascended movement is a buffer between the Kolkheti and Iveria sinking zones. The tectonic structure of the Imereti highland is represented by sediments of different generations. Cretaceous and Tertiary sediments lie horizontally on the old substrate.

A well-expressed structure built with Tertiary and Cretaceous suites stretches along the southern slope of the Caucasus folded system. The first is a syncline morphostructure of Racha-Lechkhumi, and the second is a monoclonal relief built with Cretaceous rocks. The relief of Racha-Lechkhumi basin is directly related to the synclinal structure of Tsageri and Kvemo Racha basins (Fig. 5.3), while the syncline in the east of Oni is expressed as a narrow, high-rising stripe.

Massifs of predominantly monocline structures and mountain ranges built with Cretaceous limestones are stretched from Gagra to Ertso. Its morphology is characterized by deep and narrow erosive gorges-rocky passes, and the surfaces of massifs—by karst forms and cliffs.

Achara-Trialeti mountain system is a unified geotectonic structure, which is divided by the Mtkvari antecedent gorge into Trialeti and Achara-Imereti Ranges. In the south of these ridges, the synclinal Achara and Akhaltsikhe basins are located, and on the southern slope of the Trialeti Range, there is a Tori-Tadzrisi basin. The basins are separated from each other by meridional mountain ranges (Kodiani and Arsiani).

Fig. 5.3 Khidikari rock gate (photo by R. Gobejishvili)

In the eastern part of the highland of southern Georgia, the Khrami-Loki Paleozoic crystalline massifs characterized by deep and narrow gorges and peneplained gentle relief are directly reflected in relief.

5.4.2 Volcanic Relief

Volcanic relief is represented in all geotectonic zones in the territory of Georgia. Their distribution is more localized in the highland of southern Georgia and Keli-Kazbegi neighborhood. The volcanic relief is sharply distinguished from other morphogenetic forms of relief. The volcanoes generated not only the mountain ranges and peaks, but the lavas erupted from them filled the folded structures and formed plateaus and uplands.

In Georgia, the Pliocene–Pleistocene age volcanic plateaus of Akhalkalaki, Kvemo Kartli, Dmanisi, Gomareti, Chochiani, Bedena, and Parsati are remarkable in Georgia. The Keli volcanic uplands are represented by volcanic cones and plateaus of various sizes.

The height of the plateau-shaped surface of Javakheti is between 1500–2000 m and the heights of the Keli Upland—between 2600–3300 m. Samsari and Javakheti Ranges of meridian direction are erected at the height of 500–1300 m from the plateau surface. Samsari Range is the highest volcanic range. The volcanic cones of the meridian direction are located in two rows. The high peaks are Abuli (3301 m), Samsari (3285 m), and Godorebi (3188 m), which are complex volcanic structures.

There are craterless and monogene lava cones widely spread in the Samsari Range. There are frequent the cone-shaped and dome-shaped extrusive formations with independent centers, sometimes with lateral cones. These volcanoes are: Shavimta, Samsari, Tsitelmta, eastern and western Shaori, Abikhi, Amiranismta and others. Shield-shaped craterless volcanoes are found in the Javakheti Range; their base is wide and characterized by a small relative height. The cones are constructed with massive lavas of andesite-basalts and basalts.

The polygenic volcanoes with craters in the Caucasus are large in size. Apparatus of these volcanoes are built with andesite-dacite and andesite lavas and slags. The polygenic volcanoes with craters are: Mkinvartsveri (with four times eruptions), Narvani, Khorisari, and Sakokhe with slagy cones.

Quite long lava flows are associated with this type of volcanoes. The monogenic craterless volcanoe with lava flows is Tsitelikhati in the heads of the Ksani River, and Knogho—in the heads of the Patara Liakhvi River; Khodzi lava plateau was formed by the lava erupted from the Shadilkhorkhi cone in the Kelli Upland, and the Akhubati lava plateau (in the head of the Didi Liakhvi River)—by the lavas erupted from the Pidarkhorkhi and. The lava erupted from the Mepiskalo volcano cone was spread even in the Jvari Pass.

The lava flows are interesting landforms, which are built with basalts, andesite-basalts, and andesites. Length, width, and volume of lavas are different. In the relief, the lava flows are of different forms—strongly angled, sometimes from the stepped forms to the weakly sloped vast plateaus. The stepped lava flows are Khorisari (Tergi gorge) and Bakuriani.

Generation of deep, asymmetric erosion ravines on the edges of the lava flows is frequent. For example, the Bakuriani lava flow (Borjomula and Gujaretistskali), Pkhelshe lava flow (the narrow gorges of Kesia and the Pkhelshe), and the Kvemo Kartli lava plateau (Mashavera and Algeti gorges).

Sometimes the rivers cut the lava surfaces and generate quite deep canyons: the river of Khrami in the Kvemo Kartli Plateau, and the Mashavera River at Patara Dmanisi. Canyons of Mtkvari upper gorge, Paravnistskali, and Tkarsheti formed in the Akhalkalaki Plateau are interesting.

Lava flows that come in the main gorge are characterized by a very interesting morphology. The end part of the lava is boot-shaped (Pkhelshe, Khorisari, and Borjomi-Bakuriani).

In the gorges of impounded rivers, the lacustrine deposits are being developed (the Tergi River at Tkarsheti), and the morphology of the gorges takes the form of lava flows (the Mtkvari River at Borjomi, Tergi—at Kasriskeli, and Tergi—at Pkhelshe). The morphology of the gorges developed on the edges of the lava flow distributed in the gorges is asymmetric. The cliffy slope is on the side of the lava, and the edges of the lava flows (the heads of the Didi Liakhvi River) of Karsikheli, Akhubati, and Khodzi—on the side of steeply sloped main rocks; the Mtiuleti Aragvi and Khadistskali gorges—at Mleta and etc.

The volcanic formations of different ages are found in Apkhazeti (Gorapi massif of Jurassic age). The volcanic formations of the Miocene-Pliocene period are widespread in the northern section of the Arsiani Range, in Akhaltsikhe depression, Javakheti Range, and Erusheti upland, in Borjomi (Dabadzveli Plateau), in Imereti (Perevisa and Goradziri), in Racha (Namanevi and Vanati) and others. The Upper Pliocene–Pleistocene effusves are common in the vulcanic areas. Khorisari, Tkarsheti, Tsitelikhati, Khodzi flow, Tsitelmta (Samsari), and others are of Holocene age.

5.4.3 Erosive Relief

The erosion processes together with the tectonic movement determine the appearance of the relief of Georgia. The hypsometric distribution of the relief and the lithology of its structural rocks are the preconditions for the depth fragmentation of the relief. The high mountainous relief of the Caucasus is most deeply fragmented, followed by medium and low mountainous relief. In nature, erosion relief is mainly expressed in river gorges, the morphology of which is closely related to the lithology of rocks, young tectonic movement, and direction of geological structures, and water content of rivers.

Along with rivers, the mudflows, landslides, snow avalanches, rockslides, volcanic lavas, and of course the modern and old glaciers actively participate in the formation of gorges. The depth of the ravines in the high mountains of the Caucasus is 2000–3000 m, in the highland of southern Georgia and in the middle mountainous relief of the Caucasus the depth of the gorges is 1000–1500 m, ad in the intermountain plain and the volcanic upland—300–800 m.

Among the erosive formations, the V-shaped gorges are most widely distributed, the angle of slopes of which is different that is related to the lithology of the rocks.

Box-shaped gorges are found in Lower and Upper Jurassic soft suites and carbonate flysch rocks. At the same time, the box-shaped gorges are related to relative sinking zones or basins: Kodori, Enguri (Mestia and Mulakhi), Lashkheti, Lechkhumi, Racha (Fig. 5.4), mountainous Racha, Java, Truso, Tusheti, Achara, Akhaltsikhe, Tsalka and Ertso-Tianeti. Along with the erosion of the gorge, the accumulation processes and lateral planation are active on the bottom of the gorge.

During crossing the morphostructures, rivers generate the antecedent gorges. A great contribution to the creation of their morphology is the lithology of structural rocks. The gorges in the relief built by Jurassic and carbonate flysches are narrow and V-shaped with the depths of 1500–2000 m. The Rioni River gorge (Saglolo-Utsera section) is antecedent as well as several sections (the rivers of Aragvi, Iori, Alazani sources, Asa and Arghuni) of the submaridian gorges of the Eastern Caucasus. The Mtkvari River gorge is also antecedent from Atskuri to Akhaldaba (Borjomi gorge), etc.

Rivers develop quite deep (500–1000 m), short and narrow gorges while crossing the morphostructures diagonally in the areals of distribution of Cretaceous limestones and crystalline rocks. The river flows through the bottom of the gorge with steep slopes.

Such narrow gorges have the following rivers: Blip (below the Blue Lake), Gega, Iupshara, Kodori, Enguri (Khaishi and Jvari); narrow rocky passes are found on the rivers of Khobistskali, Tekhuri, Abashistskali, Tskhenistskali (Muri and Zubi rocky passes), Rioni (Khidikari and Tvishi rocky passes), Lajanuri, Kheori (Kvagakhetkila), Tergi (Dariali and Tkarsheti), Asa and others.

Fig. 5.4 Racha Basin (photo by R. Gobejishvili)

The river gorges are quite narrow and deep and with steep slopes in the relief built with Bajocian porphiritic series. On the plateaus constructed by volcanic lavas and in the Imereti karst plateau (Chiatura), the rivers form the canyons of Mtkvari (over Aspindza), Paravnistskali (below Akhalkalaki), Khrami (in the Kvemo Kartli Plateau) and Kvirila (in the surroundings of Chiatura). Small-depth canyons are developed in the rivers flowing on the volcanic plateaus.

A certain role in the formation of river gorges belongs to volcanic lavas. The erosive gorges formed on the edges of lavas are of asymmetric forms. The slope of the gorge is steep on the side of volcanic lava, and the slope developed in the main rocks on the other side is strongly angled. Two gorges were formed on the edges of lavas at the place of one paleo gorge. On the edges of the Mleta flow, the Mtiuleti Aragvi and Khada gorges were formed, on the edges of Borjomi and Borjomi-Bakuriani lava flow—the Borjomula and Gujaretistskali gorges and on the edges of Pkhelshe lava stream—the Kesia and Pkhleshe gorges.

The asymmetrical gorges were formed in the Mashavera River gorge over Patara Dmanisi, in the Mna gorge before joining with the Tergi River. The volcanic lavas that were descended to the bottom of the gorge blocked it and due to the erosion actions of rivers, narrow asymmetric gorges were formed. In this section, the morphology (configurations) of the gorges are defined by the configuration of lava streams. Mtkvari gorge at Borjomi, Khorisari lava stream, Tergi gorge in the Kasriskeli section and at the village of Sno.

In the box-shaped gorges, rivers form the terraces on the both slopes of the gorge: Zemo Racha and Kvemo Racha basins, Tsageri basin, Akhaltsikhe basin, Tbilisi basin, etc.

The depth of river erosion cut is 300–500 m in the foothill zone. The over floodplain 1st and 2nd terraces are well developed in the gorges.

5.4.4 Accumulative Relief

The accumulative activity of rivers is associated with extensive plains both in coastal areas (Kolkheti Lowland) and in the uplifted relief as a result of differential neo-tectonic activity; in particular, Alazani Valley, Shida Kartli and Kvemo Kartli plains, Kvemo Racha, Zemo Racha, and mountainous Racha basins, Lechkhumi basin, Tergi gorge bottom over Stepantsminda, Akhaltsikhe basin and other small areas.

The mentioned plains represent a temporary erosive basis for the main rivers and their tributaries. The relief of alluvial plains is more horizontal, sometimes less wavy, surfaces are sloped toward the riverbed—Alazine Valley. In the Kolkheti Lowland some rivers flow above the surface of the plain—Rioni and Khobistskali. These river beds are bounded with artificial dams, and as a result of accumulation of solid material, their beds are elevated; sometimes the dams are destructed that cause damage to the population; the Rioni River—1987, Kheobistskali—2010. In the accumulative zones, rivers develop terraces very poorly. Some rivers have well-observed meanders and "narionalebi" (waterless riverbeds): Alazani, Ktsia, and Rioni.

Among the forms of accumulative relief, the debris cones and the coastal deltas are notable. The rivers of Kodori, Bzipi, Rioni, Chorokhi, and Enguri have clearly visible deltas. Debris cones of different sizes are distinguished in the morphology of the bottoms of the river gorges in the mountainous relief. Powerful debris cones are characteristic of the areas near mudflow rivers and gorges.

Climatic and geological-geomorphological factors determine the formation of mudflows. Powerful mudflows and extensive forms generate from them are common in the area of the Caucasus built from carbonate flysch, and at the soft rocks of Tertiary period (at Kolkheti and Kartli hilly-hillock relief, Akhaltsikhe and Racha-Lechkhumi basins, etc.).

Individually should be noted the mudflows and large debris cones of the Kakheti Caucasus and Gombori Ranges. The mudflows block the main rivers in different areas of the Caucasus built with carbonate flysch and cause the powerful floodings—mountainous Racha, Kvemo Svaneti, Pshavi-Mtiuleti, and others.

5.4.5 Gravitational Relief

Relief of gravitational genesis in Georgia extends to both extensive areas and is localized in separate areas. Landslides, rockslides, and debris belong to the gravitational relief.

Landslides are very widely distributed. They are directly related to the lithology of relief building rocks, morphological nature of relief and climatic conditions. Active landslide processes are associated with Tertiary (Maikop series) marine molasses: clays, sandstones, conglomerates, and gypsum clays. These rocks construct the Racha-Lechkhumi syncline, the hilly-hillock strip of intermountain plain, the Achara-Akhaltsikhe-Tori-Tadzrisi basins, and the Gombori Range. Active (creeping, flowing) landslides are widespread in vast areas, in the middle and lower sections of the slopes of gorges.

The landslide bodies are morphologically expressed in area, glacier-like, cirque-shaped, and tongue-shaped forms. In some areas, landslides were in action for entire Pleistocene in Racha, Lechkhumi, Gombori Range, etc. Often the activation of stable landslides and generation of new ones are associated with human activities –construction of roads, deforestation, improper use of soil, construction of houses and etc.

The landslide bodies of Somitso, Kldisubani, Lailashi, Orbeli, and Dgvari (40–60 million m^3) are particularly powerful. Individual powerful landslides are developed in the Jurassic soft rocks and their weathering crust—Lavladashi (Zemo Svaneti), Khakhabo (Khevsureti), Duruji (Kakheti), and Tsviriana (Lentekhi). Many landslides were occurred by erosive action of rivers. Landslide relief in Georgia exceeds 1.5 million hectares.

Rockslides are less developed in Georgia than landslides. They are represented as separate centers. The rockslide formation is associated with strong earthquakes, active seismo-tectonic structures, and fault lines. Morphologically rockslides are best associated with the spread of limestones and massive rocks. Rockslides occur as a result of strong earthquakes block the gorges and generate the lakes—Didi Ritsa and Patara Ritsa (in the Iupshara gorge), Amtkeli (in the Amtkeli gorge) and Kvedi (in the Kvedrula gorge). These rockslides were formed as a result of the 1891 earthquake.

In 1991, as a result of the Racha-Imereti earthquake, the rockslides of Khakhieti and Patsa occurred that generated the lakes, which are filled up with solid material brought by rivers. The rockslides are formed on the cliffs of the limestone massifs; such rockslides brought the Jonoula boulder (Lechkhumi) and Khaishi Bajocian porphritic boulders.

In the limestone cliffs and high mountainous nival-glacial zone, the debris cones are well developed on the steep slopes.

5.4.6 Nival-Glacial Relief

In Georgia, the high mountainous region belongs to the relief created as a result of nival-glacial processes: relief of Georgia above 3000 m and in old ice age—above 2000 m. Above these elevations, the relief was under the total denudation and the different forms of relief were formed. Glacial and nival reliefs are well represented in the Caucasus Range; and in the mountain ranges of the highland of southern Georgia (Adjara-Imereti, Samsari, Javakheti, Trialeti, Nailakuri) the traces of old glaciers are spread as individual areas.

The combination of nival-glacial processes in the high mountainous zone leads to the formation of bare, rocky, sharp, strongly sloped, serrated, and carling relief. From the pointed peaks, the following are notable: Ushba, Shkhelda, Dalari, Chaukhebi, and others. The high, rocky, and pyramidal peaks are as follows: Shdavleri, Tetnuldi, Shkhara, Jangha, Tikhtengeni, Chanchakhi, Jimara, Khalatsa, Burchula, Zeskho, Tebulo, and others. Among carlings the following are notable: Lakchkhildari, Dalakora, lekhziri, Tskhvandiri, Dalari, Baki, Kareta, Dombura, Klichi, Samsari, and others. In case of different lithological conditions, the stepwise relief is developed, which is the area of action of nivel processes, and the rocky glaciers, debris cones, rocks, stone fills, and stone flows are formed at the base of the step.

The geological structure of the Caucasus contributes to the formation of different meso and microforms of the relief. On the Apkhazeti, Racha-Svaneti, and Khevi sections of the Caucasian the following relief forms are morphologically well-expressed: steep-walled slopes, carlings, large-fractured debris cones, corrie forms, ledgers, and horns, which are related to the spread of crystalline rocks. Relatively gentle forms are related to the distribution of Mesozoic sedimentary rocks; these forms are: inclined slopes covered with fine-fractured deluvial trails, deformed glacier cirques, and smoothed crests.

Glaciers are widespread in the Caucasus watershed range. Modern glaciers are formed in the nival-glacial zone (up to 3000 m) and their tongues are ended in the alpine zone. 786 glaciers with the area of 555.90 km^2 are located in the Caucasus Mountain Range. Out of them, 224 glaciers with the area of 298.0 km^2 are located in the Svaneti section and in the Racha section—64 glaciers with the5 area of 58.0 km^2. Snow line (glacial zone) is located above 4200 m and is continuous only in the Racha-Svaneti section. The firn line rises from west to east and is spread at the height of 3000–3500 m.

Among the morphological type of glaciers, the valley and corrie glaciers are notable. Smaller corrie glaciers exceed by number, and the valley glaciers dominate by areas.

In nineteenth-twentieth centuries the firn line shifted up by 150–200 m. The air temperature increased by 1.0–1.5^{0}C, followed by the altitudinal shifting of boundaries of natural zones. Valley-type glaciers are spread only over the Central Caucasus section. Over the past 200 years, the glaciers of Georgia retreat due to the global warming of climate. The area of glaciers decreased by 20–25%, while the length of tongues decreased by 18–20%.

The old glaciation was important in the formation of the relief forms of the Caucasus and lateral mountain ranges. For half a million years, especially in the Upper Pleistocene, the morphology of the relief of the watershed range was formed by the influence of glaciers. The glacial forms—cirques, corries, ledges, troughs, and moraines are well represented in the relief. Lithology of rocks determines the formation and maintenance of glacial forms (Fig. 5.5).

Old glacial forms are especially well preserved in the Racha-Svaneti section built with granites and crystalline rocks. Due to the active action of erosive and denudative processes on the watershed range of the Caucasus, constructed with relatively soft rocks, the old glacial forms are poorly preserved.

Almost in all gorges are the traces of influence of Upper Pleistocene glaciers: the trough gorges with wide bottoms are well preserved in Nenskra, Dolra, Mulkhura, Mestiachala, Adishura, Khaldeschala, the head of Enguri, Zopkhitura, Chveshura, Chanchakhi, Gharula, Juta, Roshki and other gorges. The lateral moraines of Würm glaciations are preserved on the slopes of these gorges.

The Nenskra and the Dolra gorges are especially notable. Mulkhura and Lekhziri glaciers occupied the area of the village of Latali with joint tongue, the indicators of which are the lateral and bottom moraines represented there. During the Würm, the glacier of Mulkhuri was overflowed the Zagari Range and flowed down the Enguri gorge. This is indicated by the Ipari erratic boulder (a tower is built on the boulder) and the moraine hillocks in the vicinity of Ughviri and Zagari.

The large size (1000 cubic meters) erratic boulders brought from the watershed of the Caucasus prove the distribution of old glaciers; among them, the following are notable: the boulders of Sakeni, Mestiachala, Latali, Ipari, Ghebi, Goni, Glola, Saglolo and Oni (Fig. 5.6).

The lakes have been developed in the bottoms of the old corrie forms generated by the exaration actions of glaciers in the high mountainous zone.

5.4.7 Karst Relief

The main center of spreading karst relief in Georgia is a powerful limestone strip on the southern slope of the Caucasus from the Psou River to the Ertso Lake. This strip is divided into the individual massifs by the erosive effect of rivers. Among them, particularly interesting are

Fig. 5.5 Patsa Lake formed after earthquake, 1991 (photo by R.Gobejishvili)

the following limestone massifs—Arabika (542 km^2), Bzipi (556 km^2), Racha (594 km^2), Askhhi (459 km^2), and others.

The area of karstified rocks is 4475 km^2 or 6.4% of the whole territory of Georgia. High and low karts are hypesometrically distinguished within the karst relief; the boundary between them is conditional and stretches along the 800 m horizontal. High karst areas are as follows: the Arabika massif, Bzipi Range, Askhi, Khvamli, Migaria (Fig. 5.7), Okhachkue, and Kvira massifs, the Racha Range, and the others.

Low karst is developed in the foothill area in Apkhazeti, Samegrelo, and Imereti. In the hills of Imereti, karst is formed in the horizontal layers of the Upper Cretaceous limestones. Surface karst forms are represented by corries and corrie valleys, sinkholes, poljes, cavities, abysses, dolinas, wells, and shafts. The underground caves are adorned by stalagmites, stalactites, and various underground speleothems.

High karst is distinguished by the deep vertical circulation of karst waters, to which the freshwater outlets in the Black Sea shelf strip are related. In the relief of high karst, old glacial forms are preserved. In some caves, snow and ice are formed, such as Skhvava, Boga, Snezhnaa, etc.

The narrow, deep gorges are generated by rivers in the areas crossing the limestone strips, such as the gorges of Bzipi, Iupshara, Abashistskali, Tskhenistskali (Muri and Zubi), and Rioni (Khidiskari and Alpana). On the edges of the limestone massifs the steep cliffs are formed with debris cones and rockslides (Bzipi, Okhachkue, Askhi, Khvamli, and Racha Range). The karst relief is characterized by the vaucluses and waterfalls. There is a Jonoula boulder rolled down from the Askhi massif canyon the donate is a drop of Jonolus.

5.4.8 Anthropogenic Relief

Relief and human relations are bilateral; on the one hand, the relief defines the formation of noosphere and action, and on the other hand, human is constantly in contact with relief, which

Fig. 5.6 Oni Boulder (photo by R. Gobejishvili)

forces him to study it. Human contact with relief begins by selecting his place of residence. And later, the development of agriculture, arrangement of infrastructure, tourism development, construction of factories, construction of roads and pipelines, construction of large towns, and many others, is directly related to the transformation of relief and the occurrence of new forms. When people do not take into account the relief forms and processes in them, people are always injured and often they get tragic outcomes (Gobejishvili 2011).

The nature of Georgia created favorable conditions for human life. From the sixth millennium, the human contact with the relief through the agriculture, and during the Bronze Age—through mining activities, particularly, construction of tunnels (Racha, Kartli, Javakheti, and Kolkheti). Then the construction of the caves and related irrigation channels (Uplistsikhe, Vardzia, Vaniskvab, Gareji, Shio Cave) have been widely developed. There were many caves in Kartli, Kakheti, and Meskheti. The caves were constructed in Pleistocene dolerite lavas, Neogene

Fig. 5.7 Migaria massif karst relief (photo by K. Tsikarishvili)

conglomerates, and sandstones, and Eocene and Neogene volcanogenic sediments (tuffs and tuffobreccias). Artificial residential hills were created in the Kolkheti wetlands and Javakheti lakes, kurgans—in Kakheti and Kartli.

Anthropogenic impact on the relief in recent times (twentieth and twenty-first centuries) is very intense. The construction of large cities modifies the meso and microforms of the relief, sometimes completely destroying it (coast protection works on slopes, construction of roads and residential buildings, underground communications, etc.).

There are mainly distinguished strong, average, and weak anthropogenically transformed reliefs. According to distribution, there are distinguished spatial, linear, and point reliefs. The relief is heavily transformed in the urban territories and mining areas.

The area of the Tbilisi basin has been modified very much: insertion of the Mtkvari riverbed into artificial frames, abolishment of some gorges, construction of water reservoirs, and most importantly, building of new settlement massifs. Tbilisi basin is under the intensive technogenic pressure provoking earthquakes (the technogenic earthquake).

Construction of transport communications modifies the relief linewise: slope profile violation (development of landslides and rock slides), changing riverbeds with debris materials, construction of tunnels, leveling of wavy and hilly-hillocky relief, etc.; construction of tunnels during the mining activities, creation of waste bank relief, generation of sinkholes and landslides, etc. (Chiatura, Tkibuli, Tkvarcheli, Kvisa, and Madneuli).

Construction of pipelines, hydro-stations, and water reservoirs (Jvari, Lajanuri, and Zhinvali) as well as the irrigation channels (Kakheti, Kartli) belongs to average transformation. Agricultural works, such as plowing, sowing, and cattle breeding, as well as the construction of small settlements on plains, belong to the weak transformation.

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Karst of Georgia

6

Kukuri Tsikarishvili, Zaza Lezhava, and Lasha Asanidze

Abstract

This chapter reports a very diverse underworld of Georgia. The caves and cavities of Georgia have been attracted of human's attention from time immemorial. Very interesting scientific findings occurred in the process of studying the caves of Kudaro, Tsona, Jruchula, Dzudzuana, Tsutskhvati, Tskaltubo ("Tetra"), Satsurblia, and other caves. Even more impressive is the fact that out of ten karst abysses with the depth over 1000 m, registered in the area of the former USSR, nine are located in Georgia (Abkhazeti).

Georgia is one of the unique regions of the earth according to the distribution of the karst rocks. In Georgia all stages and sub-stages of the Upper Jurassic, as well as the Cretaceous system and the Lower Paleogene are being karsted, which is stipulated by the geological and geotectonic structure of the territory of Georgia and the history of its geological development. The underworld of Georgia is very diverse—karst caves and abysses, with which people are connected from time immemorial. The karstified (relatively easily soluble in water) rocks, in which the cave abysses are formed, occupy more than 10% of the territory of Georgia (Asanidze et al. 2019, 2021). It is noteworthy that Georgia is one of the most outstanding countries in the world with the abundance of these wonderful phenomena (Lezhava et al. 2020, 2021).

The caves and cavities of Georgia have been attracted of human's attention from time immemorial. They are often referred to in ancient Georgian chronicles and literary monuments (Juansheri, Rustaveli, Sulkhan-Saba Orbeliani, Vakhushti Bagrationi, etc.), in foreign researchers and travelers' writings (Strabo, Archangelo Lambert, Dubois de Montpereux, Eduard Alfred Martell, etc.).

Karst relief of Georgia required a planned and systematic study and their economic development. For this purpose in 1958, the establishment of the Laboratory of Karstology and Speleology (Head—Dr. Shalva Kipiani) in the Vakhushti Bagrationi Institute of Geography of the Academy of Sciences of Georgia and the Speleological Commission (Chair—Acad. Niko Ketskhoveli) at the Georgian Academy of Sciences Presidium, created the foundation for systematic research of geographic regularities of karst in Georgia.

The total length of surveyed and cadastered karst caves in Georgia is about 280 km, and the depth—90 km. Most of them (> 950) are located

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in Abkhazeti, in the limestone massifs of Bzipi, Arabika, Gumishkha-Psirtskha, Gumista-Panavi, and Tsebelda. At present, among the 500 sub-horizontal caves, 341 (68.2%) caves are of about 100 m long, 127 (25,4%) caves—within 100–500 m, 25 (5%) caves—501–2000 m and 7 (1,4%) caves—more than 2000 m long (Tsikarishvili and Bolashvili 2013) (Table 6.1).

Among them is the Europe-wide known Akhali Athoni Cave System, which was discovered in 1961 by Georgian researchers (Zurab Tatashidze, Shalva Kipiani, Arsen Okrojanashvili, Boris Gergedava, and Givi Smir), the initiator of complex survey and improvement project was the Institute of Geography. For this merit, a group of research scientists (Zurab Tatashidze, Shalva Kipiani, and Arsen Okrojanashvili) was awarded with the state prize of the USSR in 1977.

A large part of more than 500 registered horizontal caves is spread in the vicinity of the densely populated settlements of western Georgia. Such caves have always been of interest to a person. Initially, it was conditioned by practical necessities: our distant ancestors used them for living, shelter, and later for the cult purposes. This is proven by the discovery of the early epoch stone age and the late feudal centuries human dwellings by Georgian researchers.

Very interesting scientific findings occurred in the process of studying the caves of Kudaro, Tsona, Jruchula, Dzudzuana, Tsutskhvati, Tskaltubo ("Tetra"), Satsurblia, and other caves. These caves turned out to be the archaeological sites of world importance (Fig. 6.1).

In the Jruchula Cave, the rich archaeological material of Paleolithic time has been found, such as animal bones, knives, etc. In the front part of the Dzudzuana Cave, a dwelling of the Paleolithic human has been found. Later, in the cultural layers of the cave, the existence of 35–32,000 years old wild linen fibers was proven.

The remains of the Acheulean age found in the Kudaro and Tsona Caves were previously found only in the conditions of open-air,

Table 6.1 Georgia's longest (> 1000 m) first ten karst caves

Name of the cave	Limestone massif	The height of the entrance, m a.s.l	Total length (m)	Total depth (m)	Bottom area (m^2)	Volume, (m^3)
Mchishta vaucluse cavity	Bzipi-Khipsta watershed	30	> 20,000	83	–	–
Tskaltubo ("Prometheus") cave system	Sataplia-Tskaltubo massif	147	> 15,500	–	91,520	684,850
Sakishore	Racha massif	1200	4500	20		
Akhali Athoni Cave System	Khipsta-eastern Gumista watershed	60	3285	189	50,000	> 1.5 million
Abrskili	Kelasuri-Kodori watershed	265	2500	10	19,100	95,500
Gega	Arabika	250	2250	155	9600	86,000
Usholta	Racha	1700	2150	–	10,700	43,000
Potoltsvena	Migaria	1100	1800	280		
Tkibula-Dzevrula	Rioni-Dzusa watershed	490–510	1635	220	5500	35,000
Kelasuri	Tsebelda	190	1400	25	2300	14,000
The Okrojanashvili Cave	Askhi	750	1300	15	6000	50,000
Koko Cave	Migaria	280	1000	5	2500	6500

Dzudzuana Cave entrance

Archaeological section in the Dzudzuana Cave

Fig. 6.1 Underground archaeological monuments of world importance (Photos by K. Tsikarishvili)

displaced by the wind and petrified. Such kind of a discovery and cave dwellings, in addition, at such a hypsometric altitude (1500–1700 m), are very few in the world. Tsona Cave (Fig. 6.2) is one of the caves located at highest altitudes above sea level (2100 m) in Europe that was the shelter for primitive hunters. As it turns out, the territory of Georgia was one of the most favorable regions of settlement for primitive humans.

During many enemy invasions, the Georgian people used caves on high rocks and inaccessible cliffs to save the important state documents, precious manuscripts, or nation's treasury. Vakhushti Bagrationi notes: "To the west of Rioni, at the foot of the mountain, is a Khomli's rock, very high. there is a cave carved in this rock, the inaccessible for enemy, the storage for the treasures of the kings" (Bagrationi 1997).

The Khvamli limestone massif, which is erected between the rivers of Tskhenistskali and Rioni (up to 2000 m), is distinguished by slightly inclined slopes toward the north and very high and effective cliff looking toward the south. This is the cliff, where the hanging streams have generated there several small karst cavities, including the legendary Khvamli Cave, which historically has been visited by a number of groups of robberies interested in grabbing the treasure (Janashvili 1904).

Scientists of the Vakhushti Bagrationi Institute of Geography (Zurab Tatashidze, Levan Maruashvili, Shalva Kipiani, Tamaz Kiknadze, Jumber Jishkariani, Boris Gergedava, Kiazo Rakviashvili, Kukuri Tsikarishvili, Zaza Lezhava, and others) have contributed greatly to the study of the underground world of the Caucasus. They conducted important works to study the Akhali Athoni, Sataplia, Tskaltubo (Prometheus), and other cave systems that later became the basis for equipping these wonderful speleo-objects of nature for tourist purposes.

The discovery of the Akhali Athoni Cave (1961), its complex studies (1961–1988), and the ending of well-equipment works at the level of international standards (1975) resulted in a wide range of scientific and public resonance.

The Akhali Athoni Cave was opened for tourists in 1975 and became a popular monument in a short time (Fig. 6.3). With the number of visitors for 4 years, it has left behind the well-known caves of Europe and Asia (1976—804,447 visitors, 1977—821,041 visitors, 1978—786,500 visitors, and 1979—707,600 visitors) (Tintilozov (Tatashidze) 1983).

Speleoturism is originated in Georgia from the Famous Sataplia Cave, which was detected in the territory of the Sataplia Strict Nature Reserve, in the vicinity of Kutaisi in 1925 by Petre Tchabukiani, a tireless researcher of history and nature monuments. After discovering more than 200 footprints of dinosaurs in the vicinity of the cave, interest toward the Sataplia Cave has

Fig. 6.2 Paleolithic dwelling in the Tsona Cave (Photo by D. Tushabramishvili)

increased. By doing so he has made a great contribution to the promotion and development of speleology in Georgia. Today “Sataplia” is one of the most interesting and popular speleo-tourist monuments in Georgia (Tsikarishvili et al. 2015) (Fig. 6.4).

In summer of 1984, the speleo-team of Vakhushti Bagrationi Institute of Geography detected a previously unknown underground monument in the Kumistavi Village densely populated district of the Tskaltubo limestone massif, which turned out to be an interesting speleological object. The main entrance of the cave (known as “Tskvarami”) has been known from the earliest times, which has long attracted the attention of the specialists, but everything was ended by looking around a 60-m tunnel, beyond which only the bats were able to reach the exit. In the next summer of 1984 (July 15), at the end of the hall, at the height of 2.7 m from the bottom of the hall, after widening and overcoming the 40 cm diameter oval hole in the clay stopper, the researchers got in the underground halls decorated with beautiful speleothems. Researchers were step-by-step patiently expanding the narrow passages filled out of clay and water stopper. Overcoming each barrier was ended up with the discovery of new and different size halls distinguished from each other by abundance of different shape speleothems.

What has been mysterious for millennia, has become available for visitors due to the great enthusiasm and devotion to Georgian researchers. The modern standards well-equipment works

Fig. 6.3 Line of tourists at the Akhali Athoni Cave entrance (1975) (photo by K. Tsikarishvili)

of Tskaltubo Cave has been completed in 2012. The speleo-objects located adjacent to the cave system (Solcotta, Satsurblia, Orpiri, etc.) are of speleo-tourist and speleo-therapeutic importance, (Tatashidze et al. 2009a, b).

In the Akhali Athoni Cave, the most beautiful columns of long stalagmites, cypress-like stalagmites, calcite peculiar surfaces—"stony waterfalls", stalactites of eccentric form, helictites of strange form (like a spring, question mark, circle, screw, etc.), luxurious „chandeliers" decorated with the carvings of speleothems, "Dry Spas", decorated with the calcite crystals, the "underground workshops" of cave pearls and many others.

There are large stalagmites in the main and lateral corridors of Tskaltubo ("Prometheus") Cave with the rows of finely sculptured stalactites grown from the ceiling. Along with the snow-white and dark honey stalactites the black speleothems also attract attention. The calcite "castle-towers" are fantastic. The powerful columns of stalagmites made up of figures of various forms add really triumphal look to the halls. There is one more wonder of nature in the last part of the cave—the stalagmite of "Bermukha" (Fig. 6.5).

An interesting speleological discovery was made on the northern slope of the Nakerela Range, in the areas of so-called "Bangvalamdelo". The entrance of the Muradi Cave opens on the slopes of the south-eastern exposition of one of the hills of the northern slope of the Nakerala Range, at an altitude of 1495 m above sea level, and has an arc shape. The width of the entrance is 4 m, and the height is 1 m. The 2nd floor of the

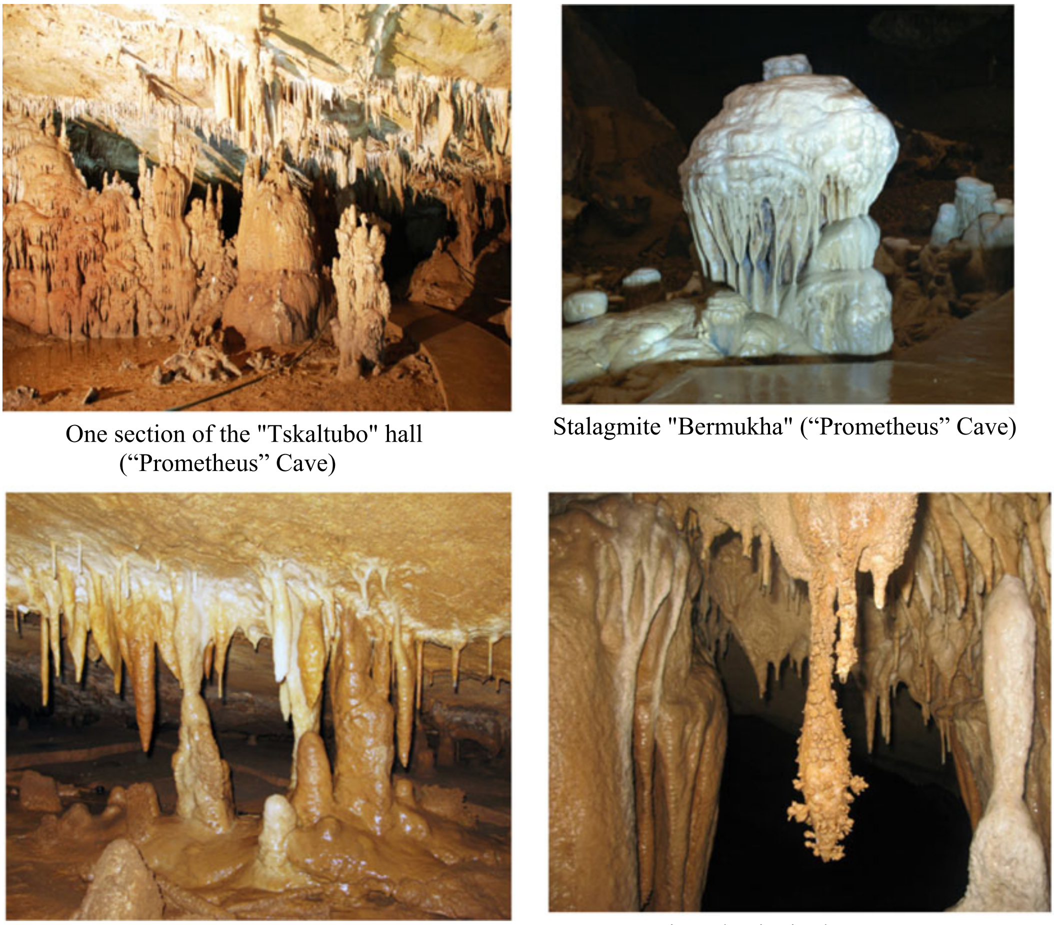
Fig. 6.4 "Giant stalagmite" in the Sataplia Cave (Photo by K. Tsikarishvili)

cave is rich in speleothems. The existing microclimate conditions (dry and humid sections, districts with cozy and air-sensitive mobility) and high-chemical soluble water jets and drops, which are mainly formed by infiltration and condensation, create favorable conditions for the intensive development of speleothems. This section contains almost all types and sub-types of water-chemogenic deposits, which are presented in the caves of Georgia (Fig. 6.6).

Here are presented stalactites, stalagmites, stalagnates, helictites, travertins of different sizes, forms, and colors, as well as calcite stony curtains and waterfalls, stony calcite "forests" and "flowers", underground lagoons and gours—with the water pools of miniature or important areas; also crystallized from water solutions—oolites, pizolites and cave pearls (Fig. 6.7).

Specific mineral aggregates are—limestone dough, lunar milk or stone milk, calcite stony plates, calcite layered sediments, calcite bark, and others. The calcite formations are found in the dry sections in dried or weathered form (Lezhava et al. 2016).

In some places, the scattered old fragmented boulders are covered by a thick layer of calcite and stalagmites, calcite miniature forests, flowers, and other forms are developed. One of the



One section of the "Tskaltubo" hall (“Prometheus” Cave)

Stalagmite "Bermukha" (“Prometheus” Cave)

The fragment of the “Solkotta” Cave

Eccentric stalactite in the "Bear" Cave

Fig. 6.5 Some cave formations (Photos by K. Tsikarishvili)

most interesting formations in the Muradi Cave is the peculiar mineral aggregates, so-called “limestone dough” and “lunar milk” or “stone milk”. These forms are not often found in the caves of Georgia. In the Muradi Cave, as well as in the other caves, the noted mineral aggregates are mainly represented in humid corridors and tunnels and occupy miniature water pools and deep pits. Their origin is actively underway under the aggressive influence of condensation waters. Muradi Cave is unique and beautiful due to the eccentric round formations (“Rafaelo balls”) formed from calcite aggregates—pizolites and oolites that do not have analogy in the Caucasus (Asanidze et al. 2017a,b,c) (Fig. 6.8).

In the future, it is important to consider their advanced laboratory study with the help of the relevant field specialists to determine the complete and convincing picture of the origin and growth of these unique, eccentric calcite round formations.

In Georgia, other similar and possibly even better monuments are expected to be revealed. One of the most promising underground phenomena of the planet is to be noted on the 3rd km from Sokhumi-Sochi central highway. The Mchishta powerful underground stream (Fig. 6.9), which erupts from the crack of the southern slope of the Bzipi Range, reliably protects its mysterious underworld so far.

Fig. 6.6 Underground Laguna in the “Muradi” Cave (Photo by L. Asanidze)

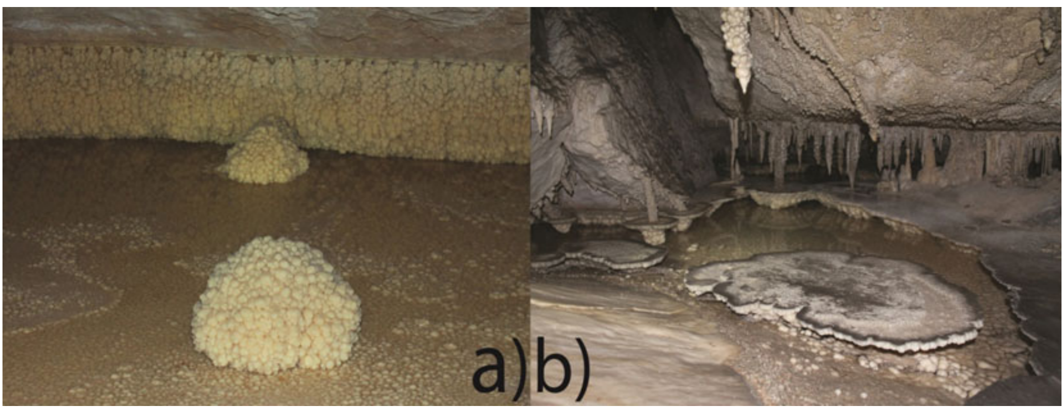


Fig. 6.7 **a** Pool calcite speleothems related to water table fluctuations; **b** Shelfstone type of speleothems formed around the edges of the small pool surface (photos by L. Asanidze)

The Mchishta powerful underground river (average annual discharge is 9.5 m^3/sec, maximum discharge—197 m^3/sec) collects water from the vast high mountainous area of Bzipi limestone massif. Almost all of the underground waters of entire Bzipi massif are gathered in the Mchishta basin. Therefore, Mchishta and “Snezhnaya-Mezhennogo” abyss are the constituents of the same hydrogeological system. This system starts with the entrance shaft of “Snezhnaya” (at 1960 m above sea level) and ends with the Mchishta powerful vaucluse exits (at 70 m above sea level). So, the relative difference between the surface water absorption and exit centers reaches 1890 m (Tatashidze et al. 1987, 1988).

According to the estimations of the Georgian researchers (Zurab Tatashidze, Levan Maruashvili, Givi Gigineishvili, Davit Tsitsishvili, etc.), the Mchishta underworld contains several

Fig. 6.8 Spherical stalactites in the Muradi cave (Photo by L. Asanidze)

Fig. 6.9 The Mchishta River powerful vaucluse stream

tens of kilometers long underground cavities filled by water and air (Tatashidze et al. 1989).

We have full bases to look at the future of speleological surveys very optimistically and realistically, moreover, out of the world's top ten of the deepest karsts abysses five are in Georgia—the 1st and the 2nd places are shared by the "Veryovkina" (2212 m) and "Krubera" (2197 m) abysses, detected in the high mountain limestone massifs of Georgia.

Even more impressive is the fact that out of ten karst abysses with the depth over 1000 m, registered in the area of the former USSR, nine are located in Georgia (Abkhazeti) (Table 6.2).

The "Napra-Mchishta" (Bzipi massif) water content system studied in the Mchishta basin turned to be the deepest on the earth (2345 m). Similar karst hydro-systems are detected only in Mexico (2553 m) and China (> 2500 m) (Kiselev 1995).

At present there are single cave abysses in Georgia that are distinguished by grandiosity and magnitude. the following comparison gives us the vivid illustration of this fact: the total volume of more than 800 karst caves found in the well-studied speleo-region of mountainous Krimea is 1.5 million m^3. The same volume has only the Akhali Athoni Cave in Abkhazeti. One more, the volume of 1500 caves (more than 5 million m^3) revealed in the Middle Asia region at present, is almost as much as the volumes of Akhali Athoni and Snezhnaya Caves together (Tatashidze et al. 2002).

There are indeed excellent prospects of speleological research in Georgia. We have full bases to look at the future of speleology very optimistically and realistically, moreover, this fact in itself shows us the increased authority of Georgian speleology internationally.

The medium and high mountainous limestone massifs of Georgia's karst strip are also rich in snow-icy caves. Especially should be noted the upper part of the "Illusion-Snezhnaya-Mezhennogo" Cave System, namely the "Snezhnaya", the bottom of which (so-called "Large hall") at 200 m deep is entirely occupied by the many centuries firn-ice cone of 60 thousand m^3 volume. It is the only abyss on the earth, where the snow, firn, and underground glacier extend to such a great depth.

The following freezers are also notable in the "Vakhushti Bagrationi" (firn and ice—1300m^3), "Giants" (800 m^3), and "Marteli" (600 m^3) abysses in the Arabika massif; "Boga" (Khvamli massive), "Skhvava", "Khreiti" and "Nikortsminda" freezers in the Racha massif, and the hanging meadow and freezer 's snowy wells in the Askhi plateau. A wide distribution of icy wells in the high limestone massifs of Gagra and Bzipi is also notable.

The icy caves are also found in the highland of southern Georgia, in the volcanic, lava, and dolerite rocks (Khorkhebi and Khizabavra Freezers), as well as on the southern slopes of the Caucasus, in the volcanic boulders (Sabatsminda and near Tskhinvali), and in Achara—in the so-called "Samkinvaroebi" (freezers) generated in limestones, etc. It is notable that ice and ice crystals in the natural freezes appear only on hot summer days.

In this regard, worth of interest is the "Khorkhebi Freezer" (Fig. 6.10) occurred in the large

Table 6.2 1000-m karsts abysses of Georgia (Abkhazeti)

No.	Name of the cave	Limestone massif	Height of the entrance a.s.l. (m)	Total depth (m)	Total length (m)
1	Veryovkina	Arabika	2309	2212	12,700
2	Krubera (Voronja)	Arabika	2320	2197	16,058
3	Sarma	Arabika	2200	1830	6370
4	Illusion-Snezhnaya-Mezhennogo	Bzipi	1960–2000-2390	1753	24080
5	Pantyukhinskaya	Bzipi	1786	1508	7560
6	Ilyukhin	Arabika	2369	1275	5890
7	Moskovskaya	Arabika	2300	1250	1800
8	Arabika (Kuybyshevskaya)	Arabika	2240	1110	3250
9	Dzou	Arabika	2240	1090	6000

lava rocks (30–40 m^3 volume) in Tetritskaro region, in the areas of the village of Kldeisi, on the Bedena Plateau, as a result of the Upper Pliocene dolerite lavas, tectonic or gravitational processes.

The information about it comes from the first half of the eighteenth century.

According to Vakhushti: "… Khorkhebi is a cavity of the rock, which is warm in winter, as in the bath, and in the summer the springs flow from the rock; … And the ice is pure and abundant, in summer they carry it for the King". Apparently, ice has occurred in great amounts in the past and has been widely used for medicinal and economic purposes (Tsikarishvili et al. 2010).

According to Vakhushti that local people also confirm, the ice is only occurs here on hot summer days.

Of the same origin is the Sabatsminda Freezer (Tskhinvali region), where the small ice crystals and thin ice plates emerge in the 2–3 m deep stone embankments on the background of accumulated snow-ice and low air temperatures in winter.

In Trialeti, in particular, in Tsalka region, in the Kizilkilisa River gorge (the right tributary of the Ktsia River), there are the freezers of similar origin, which are mentioned in Vakhushti's work too: "The Avladis-khevi (now known as Kizilkilisa River) conflows Ktsia from below from the south, flows out from the gorge-deep ravine, it is cold or icy". And in the Ateni gorge, "there is a fortress on the high rock, built a bigger one, and in the south of the fortress, there is a freezer like a glacier, where the wine is seasoned". The cold air stream generates ice in the depth of the rocky material near the Ateni fortress during the summer. Historically, the Ateni Freezer was used as a wine storage.

The pit-freezers can be also found in Aspindza region (1.5 km away from the former village of Khiza), on the right bank of the Mtkvari River, in the 1.5–3.0 m deep debris of volcanic rocks, where the ice crystals are formed in summer like in other freezers.

The real wonders of nature are the Kurtskhana Freezers in the Adigeni region (16 km away from the place where the Kurtskhana River conflows the Abastumnistskali). In summer, in the boulders and small-sized cavities, the thick layers of ice appear on the bottom and along the walls and the icicles and various forms of formations appear in the fissures. The ice also melts there in winter.

In Achara, the natural freezers are known as the "samkinvaroebi" and are mostly represented in sandstones. Even here, the ice is formed in the summer and is melted in winter. Chanchkhalo Freezer is worth of interest in the Shuakhevi region, which has been used as storage for food products for a long time by the local population.

Fig. 6.10 "Khorkhebi Freezer" formed in the dolerite rocks (Photos by K. Tsikarishvili)

As it is assumed, the conditions of the origin of ice in the natural freezers depend on the peculiarities of the relief of the site and the climate of the surrounding area. In case of violation of one of the components, the favorable factors for the emergence of ice are also violated, due to which this remarkable creature of nature loses its importance, its natural rhythm is violated and the monument faces destruction.

These are the unique underground karst monuments—caves and cavities of Racha, Imereti, Samegrelo, and Abkhazeti. It is easy to imagine what an indelible impression it will be on the visitor. The beautiful underground "palaces" of Georgia should not be left without control. All this requires nationwide protection and care.

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Natural Disasters (Mudflow, Landslide, Etc.)

7

Emil Tsereteli, George Gaprindashvili, and Merab Gaprindashvili

Abstract

This chapter presents the general overview of natural hazards, hazardous risks, and preventions in Georgia. In Georgia, landslide-gravitational hazards take main place, causing damage to widespread territory, and economic loss. Georgia is one of the most vulnerable sides of mountainous countries, with the rate of debris/mudflow activation, their development scale, return period, and catastrophic results. Several major seismic zones can be defined in Georgia, first of all, the main ridge of the Greater Caucasus and Javakheti volcanic plateau, the Adjara-Trialeti ridge fault system is also characterized by a history of destructive earthquakes.

Negative effects by the natural disasters have reached a colossal scale across our planet, including Georgia. Economic loss to the economy reaches tens of billions US dollars annually. There is a big number of victims.

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Protection of the population against geological calamities in most mountainous countries of the world, safe operation of infrastructure objects, and survival of the lands from destruction have become one of the most significant social-economic, demographic and ecological problems. This was why at the World Conference on Disaster Reduction held in 2005 (Hyogo, Japan) and in 2015 (Sendai, Japan) the identification, assessment, and monitoring of disaster risks and development of early warning mechanisms, drafting of risks maps, and development the indicators to reduce disaster risks, insecurity and adaptation were named as the major trend of 2005–2030. The normative base adopted in Georgia, which is a mountainous country, fully responds to the Framework for Action adopted at the Conferences and is realized by considering the financial and technical resources of the country (Tsereteli et al. 2015).

Georgia is one of the most complicated regions of the world's mountainous areas, with the development of disaster geological processes, with their return period, negative results inflicted on the population, agricultural lands, and infrastructural facilities (National Report about Environment Condition 2014).

Natural hazards followed by two different events and results:

1. Negative meteorological phenomena (tropical cyclones, hurricanes, storms, and atmospheric precipitation and air temperature positive and negative sharp deviations from multi-year

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average norms) in the lower layers of the atmosphere;
2. Hazardous geological processes on the surface of the earth and its crust (landslides, debris/mudflows, sea coast, riverbank erosion, rock avalanches, rockfalls, volcanoes, earthquakes, etc.).

Thousands of settlements, land plots, roads, oil and gas pipelines, high voltage power transmission towers, mining-tourist complexes, etc. are periodically affected by the strong impact of geological disasters (often catastrophic results). Almost all landscapes and geographical zones are located in the natural hazard risk zone—from the Black Sea to the mountain area. Socio-economic results caused by landslides, rockfall/rock avalanches, debris/mudflows, sea coast and riverbank erosion, floods, and flashflood cover all areas of human activity (Figs. 7.1 and 7.2).

Difficult situation occurs in mountain zones of Georgia, where the activation of the disaster is very high, causes resettlement of households. In 2011–2017 1290 households were resettled to geologically stable areas (eco-migrants) from 6984 families assessed by the department of Geology of the National Environmental Agency. In 1995–2017, 141 people were killed as a result of geological disaster.

In the last period activation and development of natural disasters, in the background of

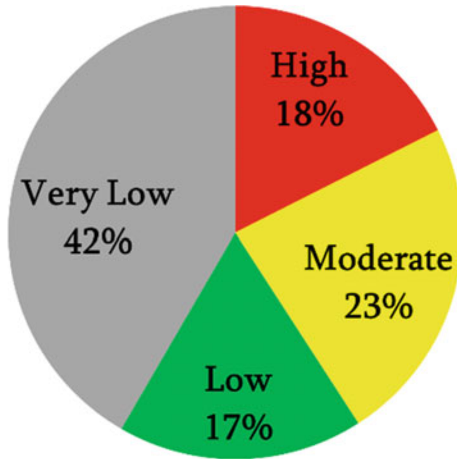


Fig. 7.2 Percentage of settlement under geological hazard risk (Informational Geological bulletin 2018)

extremely sensitive geological environment caused by:
1. The intensification of high-intensity earthquakes in the Caucasus (1988—Spitak, 1991—Racha-Imereti, 1992—Pasanauri-Barisakho, 2002—Tbilisi, 2009—Oni, 2010—Vani).
2. On the background of global climate change increase in the frequency of negative meteorological events (primarily atmospheric precipitation, temperature, and humidity) and the quantitative increase in favor of the average long-term indicators;

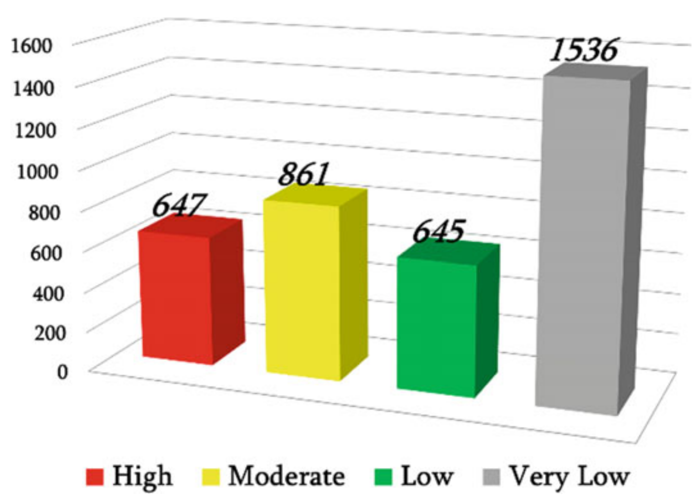


Fig. 7.1 Total number of settlements under geological hazard risk (Informational Geological bulletin 2018)

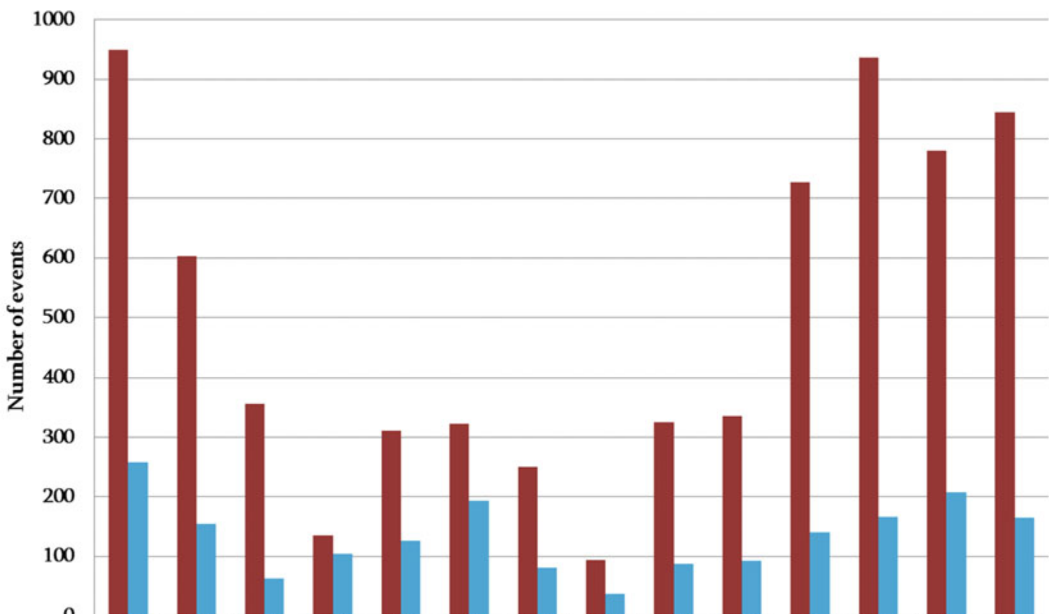
3. Human's large-scale impacts on the environment and its balance sheets, such as population construction and reconstruction of new infrastructure objects in geodynamically complicated areas, cutting the slope, deforestation, etc. Studies have confirmed that the population settles in temporary stabilized landslide bodies, debris/mudflow alluvial fans, and flood plains without proper geological assessment.
4. The risk of geological disaster increases by the low level of readiness, inadequate awareness of the expected geological disasters, their activation trends, and results (Gaprindashvili et al 2016; Tsereteli et al 2012).

According to the Department of Geology of the National Environmental Agency, in the years 2004–2017, the scale of activation of landslide and debris/mudflow processes in the territory of Georgia increased significantly (Fig. 7.3). According to the data of 2017, 18% of Georgia's settlements (647 points) are under high risk of geological processes (Informational Geological Bulletin 2018).

In recent years several natural geological catastrophic events have been observed in Georgia that accompanied loss of human beings and large ecological damage. Among them are:

In Tbilisi during 13–14 June 2015 heavy rainfall in the riv. Vere basin area and its tributaries caused a drastic increase in the water level and triggered/activated large-scale landslide and debris-flow events. This put the Tskneti-Samadlo and Tsnketi-Akhaldaba motorways out of order. Residential buildings and miscellaneous infrastructural facilities, buildings, and Tbilisi Zoo are located at the low elevations in the riv. Vere Gorge was significantly damaged or/and totally destroyed. 23 persons died during the disaster (National Environmental Agency 2015; Gaprindashvili 2016) (Fig. 7.4).

On May 17 and August 20, 2014, catastrophic debris/mudflow process occurred in the area of junction of rivers Tergi and Devdoraki-Amali,



	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Landslide	949	603	356	136	311	323	250	94	325	336	727	936	780	845
Debrisflow	258	155	63	104	126	193	81	37	88	93	141	167	208	165

Fig. 7.3 Recorded landslide and Debris/Mudflow event in Georgia (2004–2017)

Fig. 7.4 Akhaldaba "big" Landslide (Tbilisi), June 2015 (Photo by G. Gaprindashvili)

which completely paralyzed functioning of infrastructure objects having strategic meaning for the country. Debris flow have damaged Georgian military road, "North–South" connecting 700 and 1200 mm gas pipelines, knocked down transmission line, means of transportation, isolated base of border guards, customs point, residence of Georgian Patriarchate, also caused 10 victims (including foreign citizens)—(Gaprindashvili and Gaprindashvili 2015).

On June 18, 2011, catastrophic landslide/debris-flow process occurred in the area of Rikoti pass (Central Georgia), which destroyed infrastructure objects and causes eight victims (Fig. 7.5).

7.1 Landslide-Gravitational Hazards

In Georgia, landslide-gravitational hazards take main place, causing damage to widespread territory and economic loss. The morphological and climatic areas of their development are indefinite—from lowland seaside to high mountainous alpine-nival zones. In Georgia, it is recorded around 53 000 Landslide-gravitational phenomena, damages more than 1.5 million hectares of land. Under the landslide hazard risk are around 55% of settlements, 25% of the roads, oil and gas pipelines. In Georgia over 80% of the total damage to the population and infrastructural facilities was inflicted by the geological disaster (Figs. 7.6 and 7.7).

The damage inflicted by landslide to Georgia's economy will be determined by several tens of millions of dollars in terms of background development, hundreds of millions in extreme activation, and sometimes even billions.

In recent times such broad scaled development/reactivation of landslide-gravitational events are conditioned by:

- Positive deviation of landslide triggering negative hydro-meteorological phenomena (precipitation, humidity) from average multi-annual norm on the overall background of geological and climatic changes;
- High technogenic pressing on the geological environment without considering an assessment of its resistance. In this regard, there is a very difficult situation on the area of Tbilisi territory, where if in 2000 year 60 landslides

Fig. 7.5 Debris flow in Rikoti Pass (Khashuri Municipality), June 2011 (Photo by G. Gaprindashvili)

Fig. 7.6 Landslide in Sheshelidze str. (Tbilisi), April 2016 (Photo by G. Gaprindashvili)

were recorded (according to the Geological Monitoring Information Newsletter), by the 2017 year this number exceeds three hundred;

- Intensification of earthquakes in Caucasus Region;

All kinds and types of landslide-gravitational events known in geodynamics find their development place on the territory of Georgia: starting from the simplest, deformations of which do not beyond the aeration zone, to the deepest (tens of meters). Also, certain landslide areas (from units to hundreds of hectares) and volumes (from several thousands to the tens and hundreds of cubic meters) are changed in large diapason.

Today, the number of general-theoretical, regional, and targeted (special) classifications of landslide-gravitational phenomena in Earth Science has exceeded hundreds. All of them are different with fullness and authenticity of the

Fig. 7.7 Landslide in Khulo municipality, April 2013 (Photo by G. Gaprindashvili)

process (geology, structure, structure, mechanism, kinematics, morphology and et al.) and to some extent deserve attention.

The regional classification of landslide events in Georgia is based on the principle of the main mark of the process of bas-deferential factor, which witnesses the mechanism of bringing out the landslide equilibrium conditions. Accordingly, we have the following group of landslides:

1. ***Coastal (Basic) Landslides***—originated on the Black Sea coast, along the banks of large rivers and reservoirs, as a result of erosive and abrasive cutting.
2. ***Climatogenic Landslides*** dominate all other types of landslides and are primarily formed into the slope of the sedimentary deposits, triggered by meteorological events;
3. ***Tecto-Seismogenic Landslide-Gravitational Phenomena*** that differ substantially from all other genetic types according to the formation conditions and motion emissions, characterize the development and localization of active tectonic faults in different ranges;
4. ***Karst-Sufic Landslides***.
5. ***Cryogenic Landslides***—characterized by zonal development and are characteristic of any alpine-area zone;
6. ***Technogenic (Anthropogenic)*** landslides are formed by wrong activities of people (cutting the slope et al.), which leads to a violation of relief-based homoseastism.

From last decades of the twentieth century, this regularity had been disrupted and their activation regime takes place almost every year above accepted background in most regions and is characterized by frequent explosions, huge economic losses, and casualties. The clear confirmation of this is incomplete data (1995–2017 years) gained from analyses of regional monitoring studies by Department of Geology of National Environmental Agency, which was mostly conducted in settlements. In this period 10,001 activated and just created landslides were recorded, their direct loss exceeded 380.72 million US dollars, and 47 people were killed (Table 7.1).

During 2003–2005, 2008–2011 and 2014–2015 many landslide events occurred over almost the entire territory of Georgia with various degrees of intensity. Critical situations occurred in Rach-Lechkhumi, Svaneti, Racha-Lechkhumi, Achara, Mtskheta-Mtianeti, Guria, and Kakheti mountainous regions, as well as in Tbilisi, Samtskhe-Javakheti, Samegrelo, and the Imereti foothills. Individual territories of Shida and Kvemo Kartli also fell under the average risk hazard zone.

Table 7.1 Recorded landslides, economic and human loss (1995–2017)

Year	Recorded events	Economic Loss (mln. GEL)—1 GEL—0.4 USD	Human Loss		Year	Recorded events	Economic Loss (mln. GEL)—1 GEL—0.4 USD	Human Loss
1	2	3	4		1	2	3	4
1995	670	132.00	6		2007	136	20.50	0
1996	610	80.30	3		2008	311	48.00	8
1997	871	102.00	2		2009	323	63.50	1
1998	543	67.00	5		2010	250	21.70	3
1999	56	12.00	1		2011	94	Unk	3
2000	65	13.00	1		2012	325	Unk	1
2001	75	15.00	0		2013	336	Unk	0
2002	69	13.80	1		2014	727	Unk	0
2003	71	14.50	3		2015	936	35.0	4
2004	949	147.00	4		2016	780	Unk	0
2005	603	96.00	0		2017	845	Unk	0
2006	356	70.50	1		Total	10,001	951.8	47

Source Department of Geology, NEA

The territory of Georgia is divided into seven conditional areas by damage caused by landslide-gravitational events and hazards risk:

1. The area with ***very high*** coefficient of damage (0.7–0.9) caused by landslide phenomena and with very high dynamic potential of development, includes: the Black Sea coast of Abkhazia, tertiary zone of Racha-Lechkhumi Syncline depression, Upper Imereti raised horst, foothills of Adjara-Imereti, mountainous Adjara;
2. The area with ***high*** coefficient of damage (0.5–0.7) caused by landslide phenomena and with notable risk of development, includes: left bank of river Psou of Sochi-Adler depression, small tuberiferous zone of Okriba, foothills of Guria region, Dusheti municipality;
3. The area with ***significant*** coefficient of damage (0.3–0.5) caused by landslide phenomena and with notable risk of development, includes: Foothills of Adjara, mountainous Guria region, northern slope of Trialeti range with Akhaltsikhe depression, hilly zone of northern Kolkheti side, the territory of Tbilisi and Asureti;
4. The area with ***moderate*** coefficient of damage (0.2–0.3) caused by landslide phenomena and with probability of significant development, includes: Trtialeti range, the erosive relief of middle and high mountainous gorges in the Jurassic clay shale, chalk, and Paleocene Flysch distribution zones, peripheral area of Shida Kartli depression, foothills of Tsiv-Gombori range;
5. The area with ***low*** coefficient of damage (0.01–0.1) caused by landslide phenomena and with significant risk of gravitational phenomena, includes: Mesozoic period's zones of the southern slope of Caucasus constructed with volcanogenic and carbonate formation, river Iori plateau, the left side of river Iori characterized with hilly terrain, the adjacent territories of to Khrami and Loki massifs.
6. The area with ***very low*** coefficient of damage (≥ 0.01) caused by landslide phenomena, with limitation of their possible development, and notable risk of gravitational phenomena includes: Javakheti volcanogenic highland, axial zone constructed with crystal rocks of Caucasus, massifs of Khrami. Loki and

Kelasuri, terraces of the rivers Mtkvari and Khrami in the Marneuli—Gardabani plain area;
7. The area is practically ***no danger*** by landslide events and with their local development on small territories, on the banks of large rivers, and on sides of irrigation channels includes Kolkheti lowland, Inner Kartli, Gardabani, Alazani, and Iori areas presented by low plain-terraces.

7.2 Debris/Mudflows

The Caucasus Region and especially Georgia are one of the most vulnerable sides of mountainous countries, with the rate of debris/mudflow activation, their development scale, return period, and catastrophic results. In Georgia we meet all genetic type debris/mudflows. Almost 30% of territory is under this type of hazard risk. All the settlements, which are located in the flood plains and adjacent territory are under hazard risk (Figs. 7.8, 7.9). Debris/Mudflows periodically damage high-ways and other infrastructure objects, and agricultural lands. In Georgia, debris/mudflows are recorded in up to 3000 rivers/gorges (Fig. 7.10). In 1995–2017, 94 people died and economic losses reached 738 million GEL (Table 7.2).

Since 2011, there have been several natural disasters in Georgia, which unfortunately accompanied loss of human beings. Among them are:

- The catastrophic debris flow developed on the territory of Rikoti Pass on June 18, 2011, which killed eight people.
- On 17 May and 20 August 2014, the Amali-Devdoraki debris-flow disaster in Dariali Gorge, Kazbegi municipality (victim—10 people);
- On 13–14 June 2015, In Tbilisi Natural catastrophic processes developed in riv. Vere Gorge (victim—23 people);

Geomonitoring studies have confirmed activation of debris/mudflow hazards from the last decade of the twentieth century. This is proven by the statistical information (Source: Department of Geology, NEA) in 1995–2017 (Table 7.2).

The territory of Georgia is divided into nine conditional areas by damage caused by debris/mudflow processes, and according to the hazard risk which is based on syncretic synergism of the elements, which are part of geological environment system, characterized by

Fig. 7.8 Debris/mudflow in Amali-Devdoraki gorge (riv. Tergi, Kazbegi) (photo by G. Gaprindashvili)

Fig. 7.9 Debris/mudflow in Tbilisi (photo by G. Gaprindashvili)

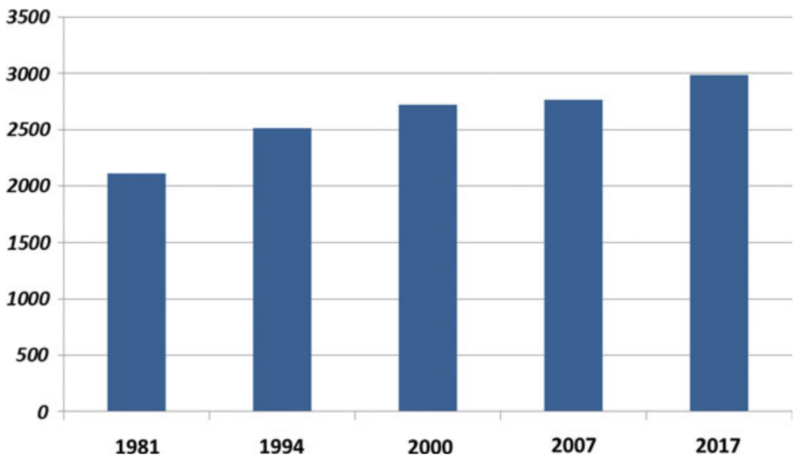


Fig. 7.10 Recorded Debris/mudflow events in Georgia by year

extremely complex multifactorial features and debris-flow processes stimulating factors:

1. The area with ***very high*** damage probability and with high risk of recurrence (Ks-0.8–0.9), includes: Low and middles-sized mountains constructed with Molasse sediments of Intermountain Belt of Eastern Georgia, Upper parts of riv. Rioni, Tskhenistkali, Tergi, Aragvi basins. Transformation of debris/mudflows takes place almost every year (daily rainfall 30–50 mm and more). Often it is repeated several times in a year.
2. The area with ***high*** damage probability and hazard risk (Ks-0.6–0.8), includes: Area constructed with flusch rows and Mesozoic shale of north and south slopes of central and eastern segments of the Caucasus, highland of Adjara of Lesser Caucasus, also right bank of riv. Mtkvari (Tbilisi city). Debris flows recurrence period once in 2–3 years. Wide range of released materials volume—0.1–0.2 mln.m^3.
3. The area with ***significant*** probability of damage by debris-flow transforming rivers and hazard risk (Ks-0.5–0.6) includes Trialeti and Meskheti ranges, middle and upper part of the river Kodori (western Caucasus), and river Bzipi basins. Debris flows recurrence period once in 3–5 years. The volume of material released by debris flows from thousands of cubic meters to amounts 0.5–1.0 mln. m^3.

Table 7.2 Recorded debris/mudflows, economic and human loss (1995–2017)

Year	Recorded Debris/Mudflow events	Economic loss (mln. GEL)—1 GEL—0.4 USD	Human loss	Year	Recorded Debris/Mudflow events	Economic loss (mln. GEL)—1 GEL—0.4 USD	Human loss
1	2	3	4	1	2	3	4
1995	250	96.0	12	2007	104	11.5	1
1996	165	27.0	5	2008	126	15.0	8
1997	335	44.0	7	2009	193	16.5	3
1998	173	20.0	6	2010	81	5.5	2
1999	27	4.5	0	2011	37	9.8	8
2000	23	3.0	0	2012	88	54.3	5
2001	26	4.0	0	2013	93	Unknown	0
2002	23	2.5	2	2014	141	165.0	10
2003	28	4.0	0	2015	167	210.0	19
2004	258	28.0	2	2016	208	Unknown	0
2005	155	9.0	4	2017	165	Unknown	0
2006	63	9.0	0	Total	2929	738.6	94

Source Department of Geology, NEA

4. The area with ***moderate*** risk of debris-flow hazards (Ks-0.3–0.5), includes middle part of the rivers Rioni, Tskhenistskali, Enguri, and Kodori basins, headwaters of river Kvirila basin, low and middles-sized mountain zone of Aphazeti Caucasus, the basin of river Algeti, Trialeti range on the territory of Tbilisi city, lowlands of Adjara. Debris flows recurrence period once in 3–10 years.
5. The area with ***limited*** debris flow hazard risk (ks-0.1–0.3), includes: lowland zone of raised horst of the Dzirula, Khrami, and Loqi, Foothills of Guria and Imereti, debris flows in the basins of rivers Psou, Sandripshi, and Zhoekvara take place once in 3–7 years, the volume of released material amounts 5-10,000 m^3.
6. The area with ***low*** probability of damage caused by debris-flow processes and hazard risk (Ks- 0.01–0.1), includes areas constructed by carbonate rocks of low and middle-sized mountains of Racha, Askhi, Khvamli, Arabika, and rivers Bzipi and Kodori, foothills of Guria and Adjara.
7. The area with ***very low*** probability of damage caused by debris-flow processes and hazard risk (Ks- < 0.01), includes: Iori Plateau and part of the downstream river Mtkvari;
8. The area ***weak*** probability of damage caused by debris-flow processes and hazard risk includes Akhalkalaki plateau and volcanogenic highland of Javakheti.
9. The area, where is ***no danger*** by debris-flow hazard risk, includes Kolkheti lowland and Black Sea coast, plains of Eastern Georgia, Kartli, and Alazani.

7.3 Earthquake

Georgia is situated in a seismically active region within the Caucasus, which is one of the most seismically active regions in the Alpine-Himalayan collision belt (Westen Van et al. 2012, Westen Van et. al 2018).

The instrumental period of seismic observation began in the Caucasus at the very beginning of the twentieth century. Since then, several earthquakes have occurred, which caused human loss and damage to infrastructure objects. In 1920 in Gori (Shida Kartli region) occurred earthquake with magnitude of 6.2, caused death of 150 people. Strong destructive earthquake occurred in 1988 in Spytak (Armenia) with magnitudes up to 7, intensity 9 (MSK scale), during this earthquake 25,000 people were killed, and 50,000 were injured. In 1991, the Racha earthquake (M = 7.2), more than 200 people were killed and approximately 60,000 were left homeless. The damage covered thousands of square kilometers. Also, capital of Georgia, Tbilisi, is subjected to high seismic risk, which was proven by the 25 April 2002 (Westen Van et al. 2012, Westen Van et al. 2018).

With the launch of antisemic construction in the future, it will be possible to avoid devastating consequences of earthquakes. But there is no second danger—the activation of landslide and mudflow events triggered by earthquakes, which often arise in areas with significant geotectonic areas. With the earthquakes of 1991–1992, about 20 thousand new landslides and rockfall events were activated, lot of debris material was accumulated in the river gorges, and plenty of cracks was created on the ground. In the negative impact zone of these events, up to 1500 hectares of land were found, with 100 victims; village Khakhieti was buried under 70 million cubic meter volume landslide, riv. Kvirila gorge (near village Perevi) was blocked by 50 mln m^3 material. In Village Chordi (Oni municipality) immediate impact of the earthquake two houses were damaged, but giant landslides triggered by earthquake destroyed 70 communal villages. Also, Beloti and Satskhenisi villages (Tskhinvali zone) were totally destroyed. Large-scale landslides developed in Zhashkhva and Bajikhevi villages (Oni municipality) areas. The landslide blocked the riv. Patsa gorge (riv. Didi Liakhvi tributary) after partially break of dam debris flow and flashfloods flooded riv. Didi Liakhvi banks and inundated villages situated on the low terraces (Tatashidze et al 2000).

The activation of landslide-gravitational phenomena triggered by earthquakes was noted outside the epicenter almost throughout Georgia. Tens of millions of cubic meters of landslides developed in Adjara, Lechkhumi, Svaneti, Mtskheta-Mtianeti regions and et al. (Tatashidze et al 2000).

7.4 Flood-Flashflood

The territory of Georgia is characterized by floods and flash floods. Floods take place less rapidly, due to runoff from sustained precipitation or rapid snowmelt exceeding the capacity of a river's channel. Flash floods result from heavy precipitation or sudden releases from an upstream impoundment created behind a dam, landslide, or glacier (Westen Van et al. 2012, Westen Van et al. 2018).

Rivers that are mainly fed by snowmelt or glacial meltwater from the Caucasus. After intense precipitation it causes flood. Rivers that originate on the southern slopes of the Caucasus, where seasonal snow exists, are characterized by spring and summer floods and autumn flash floods. Rivers that originate from the western part of Central Georgia's mountains are characterized by spring floods and summer-autumn flash floods. Rain-fed flash floods occur in the Kolkheti lowlands, the Caucasus Mountains nearby Kolkheti lowland, and in the Meskheti Range. Many rivers in Eastern Georgia and Ajara show flash flood behavior (Westen Van et al. 2012, Westen Van et al. 2018).

Many floods and flashfloods occurred in Georgia, which caused human loss and damage to infrastructure objects. For example: riv, Rioni floods in 1895 and 1922 that caused death of people and huge economic damage. Riv. Mtkvari flod in Tbilisi in 1968 on April 18–19 with a peak discharge of 2,450 m^3/s (Westen Van et al. 2012, Westen Van et al. 2018).

The 1987 flood of the Lower Rioni River. On January 21, 1987, the Rioni River breached the northern embankment at the village of Sagvichao. Many settlement areas were flooded, leading to some casualties, and huge damage to the local agricultural sector (Westen Van et al. 2012, Westen Van et al. 2018).

Data analysis shows that floods and flash floods are characteristic of almost all the rivers of Georgia. Among them are very high risks:

Imereti, Samegrelo, Guria, Mtskheta-Mtianeti region, also riv. Mtkvari and Alazani left bank. The average return period of floods until 1995 was 3–5, from 1995 to 2–20, and in 2007–2013 between 7–23. Since 1995, 64 people have died (Table 7.3).

Snow Avalanches are characteristic of the medium and high mountainous zones of Georgia and put large material losses in Svaneti, mountainous Adjara, Racha, Tusheti, Mtskheta-Mtianeti population, and infrastructural objects. Causing significant destruction, and human loss. Over 1986–1988, 330 snow avalanche events in Svaneti, caused more than 100 victims. Most active zones are western and central sections of the Caucasus and mountainous Adjara. The formation and dissemination of snow avalanches (including catastrophe) mainly cause the surface of the terrain, with high inclination, peculiarities of vegetation, and meteorological elements. However, the arrival of snow avalanches occurs in the forestry areas. This is confirmed by the destroyed forest (240–300 ha) in the riv. riv. Nenskra, Nakra, Laskadura basins in 1987. Snow avalanches are also triggered by artificial cutting of the forest, which often ends with tragic results. The classic example of this is the 1972 year disaster in village Ghurta (Khulo municipality), in 1987 tragedy of Mulakhi (Mestia municipality), where the hazards destroyed both villages and killed 77 people.

The peculiar activity of snow avalanches in the mountainous regions of Georgia has been observed since 1970. Their massive arrival is recorded in 1972, 1975, 76, 1986–88, 1992, 2996–98, and 2014–2017 (Table 7.4). The massive atmospheric precipitation of the massive arrival of catastrophic snowflakes is significantly higher than the many norms and mainly coincides with periods of intrusion into the Atlantic cyclones. According to the Road Service in 1996, snow avalanche in Adjara mountainous area arrived at 40 places, 105 in Svaneti and 149 times in Kobi-Gudauri section of military road, which resulted in road blocking for 42 days. In Gudauri-Kobi section, in 1997, snow avalanche collapsed 120 times and killed five people, while the road was blocked for 40 days. In 1998, the avalanche activated 54 times, and auto-traffic movement was stopped for 22 days.

Erosive Processes In terms of the protection and rational use of land in Georgia, the most important place is to fight against erosion, as in the country's low level, there is no longer a possibility for new land acquisition and arable land without increasing large capital investment.

Table 7.3 Recorded flood and flash Table flood events between 1995–2017 (NEA 2015; Van Westen et al 2012)

Year	Recorded flood-flashflood events	Economic loss (mln. GEL)—1 GEL—0.4 USD	Human loss		Year	Recorded flood-flashflood events	Economic loss (mln. GEL)—1 GEL—0.4 USD	Human loss
1995	4	3.2	1		2007	7	40.3	1
1996	11	28.5	1		2008	16	38	3
1997	12	38	0		2009	20	30	5
1998	2	2	1		2010	18	20.7	3
1999	8	30.5	1		2011	23	35.1	9
2000	2	2	0		2012	15	32	5
2001	4	4.1	0		2013	8	20	0
2002	16	78.7	0		2014	13	10	3
2003	6	4.2	2		2015	11	112	22
2004	10	20.5	1		2016	18	10	1
2005	20	80	4		2017	27	15	0
2006	8	15	1		Total	279	669.8	64

Table 7.4 Recorded Snow Avalanches (1995–2017)

Year	Recorded events	Economic loss (mln. GEL)—1 GEL—0.4 USD	Human loss		Year	Recorded events	Economic loss (mln. GEL)—1 GEL—0.4 USD	Human loss
1995	8	3.2	2		2007	10	3	1
1996	6	3.8	3		2008	4	1.9	0
1997	10	4.2	0		2009	6	2.8	2
1998	9	3.9	2		2010	8	2.4	1
1999	12	3.7	1		2011	6	1.9	1
2000	7	2.1	1		2012	15	3.6	1
2001	6	3.5	1		2013	8	1.2	0
2002	8	1.5	0		2014	23	8	4
2003	8	2.1	2		2015	18	4	1
2004	10	4.8	1		2016	25	6	3
2005	14	4.5	3		2017	28	4	5
2006	12	2.5	0		Total	261	78.6	35

Source National Environmental Agency

Nearly all morpho-climatic zones have a risk of adverse impact on water erosion processes. Ranging from high mountain ranges to plain.

Two types of erosion are distinguished by the nature and manifestation of water erosion formation:

1. Linear or riverbed erosion—they are characterized by concentrated flows; It can be distinguished by the river erosion, which is characterized by constant action and dilapidated erosion—is distinguished by periodic interval, spatial and time bounding; At certain stages of development, it decides its action;
2. The slope erosion, which does not have a fixed bed and the surface runoff, produce flatness (area), so-called "fluid denudation", which is called "soil erosion" by soil scientists.

Among them, the slope (area) erosion and expansion of the landfall in the mountainous zone with high energy potential of relief (large inclination of the surface > 25–45°) and high division coefficient (> 2.0–5.0 km/km^2). In addition, the slope of almost all the first three-row rivers (semi-classification) is 10–25° and more, which is directly defined by the bedrock erosion. According to the General Scheme of Georgia Against Erosion Measures drawn up for 1981–2000, erosion of arable lands was 30%, nowadays this indicator has increased almost twice. The direct reason for this is to increase in "accelerated anthropogenic" erosion processes and negative meteorological phenomena. If we rely on the criteria of erosion classification, then it turns out that erosion intensity indicator of the lands of the mountainous terrain in Georgia will be entirely in the borders of high and catastrophic classes. This is due to the large gradient areas located on land and soil cover almost completely washed out, soil production rocks directly exposed on the surface, and their biogenic restoration, in spite of optimal landscape and climatic conditions, need many years.

According to M. Daraselia In the western part of Georgia, soil erosion annually covers 1000 hectares and according to M. Kharaishvili, 100–140 tons of soil are washed in 1 ha territory, and in 150–200 tons in Western Georgia. During the heavy rains, soil wash processes increase up to 300–500 tone. It is established that river Rioni every year in the sea produces 10 million tons of highly fertile soil. Four Black Sea River basins (Bzipi, Kodori, Enguri, and Chorokhi) Annual solid waste is 17760 thousand tons, while the total number of solid sediments of the Kolkheti rivers exceeds 100 million m^3 (Geography of Georgia 2000).

The "accelerated" slope erosion on the surfaces of large slopes occurs at highly cutted forest areas, especially in subalpine zones, which in most cases lead to the overall degradation of this zone and lowering the upper boundary of the forest by 300–800 m. Studies have shown that in the same landscape-geologic conditions, cutting edge of the forest slopes deep erosion coefficient equal 3–5 km on km^2, while this coefficient does not exceed 0.2–0.5 km on km^2 in the slopes of the foothills formed by molasses sediments.

The existence of vegetation is directly dependent on the quantitative and qualitative indicators of liquid and solid runoff rivers.

Fig. 7.11 River Bank erosion in Khobi Municipality, 2009 (photo by G. Gaprindashvili)

Fig. 7.12 River Bank erosion in Tbilisi city, 2015 (photo by G. Gaprindashvili)

Studies have shown that if in the case of Georgia's rivers 34% of forests, the coefficient of solid run was 0.94%, in 52% it decreased to 0.65 and in 80%—0.15.

There is a greater risk of highly fertile lands in the wake of the intense ***river bank erosion*** of almost all river basins in the Georgian plain and lowland area not only during the critical horizons of erosive washing during the floods but during the normal regime of the river flow (Figs. 7.11, 7.12). As a result, dozens and hundreds of lands are damaged every year and this rate increases during the floods. Intensive riverbank erosion is along the riv. Rioni, Alazani, Aragvi, Tskhenistskali, Mtkvari and Kodori gorges.

The riverbank erosion is almost always accompanied by small coastal landslides. Hundreds of hectares of land are lost, infrastructure objects (roads, railways, oil and gas pipelines et al.), which are situated along the river banks are damaged, and also population is under risk. It is estimated that the damage inflicted to the country's economy directly by riverbank erosion processes varies from 40–100 million dollars per year.

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Climate

8

Dali Mumladze, Givi Gagua, and Nino Lomidze

Abstract

In this chapter great diversity of climate in Georgia is analyzed. Almost all kinds of climate (except for equatorial and tropical climates) of the earth is distributed in our country's relatively small area, from the humid subtropics of the Black Sea coast of western Georgia and dry subtropics of eastern Georgia to the permanent snow and glacial climate of the Caucasus. Climate-creating factors and climatic elements of Georgia, circulation of the atmosphere, air temperature, hazardous meteorological phenomena, climate types, and climate change are the main body of this chapter.

The great Georgian lexicographer—Sulkhan-Saba Orbeliani had not mentioned "climate" in his dictionary "Sitkvis Kona" (in Eng.: The Bunch of Words), because this term was only introduced along with the Russian language from the beginning of the nineteenth century into the Georgian dictionary. It is noteworthy that at present, the "climate" and "hava" as synonyms are equally actively used in modern Georgian climatography.

Georgia's climate is characterized by a great diversity. Almost all kinds of climate (except for equatorial and tropical climates) of the earth is distributed in our country's relatively small area, from the humid subtropics of the Black Sea coast of western Georgia and dry subtropics of eastern Georgia to the permanent snow and glacial climate of the Caucasus. As the Academician T. Davitaia noted, the mentioned peculiarity of the climate is the national wealth of Georgia, like which has no country in the world. The diversity of Georgia's climate is explained on the one hand, by the location of the country on the northern border of the subtropical zone, where the circular processes take place, characteristic of subtropical and temperate and sometimes for high latitudes, and on the other hand, by its complex physical-geographical conditions (Gagua et al. 2000).

Written information about the climate of individual regions of our country can be found still in the works of ancient Greek historians, geographers, and other scholars. It is noteworthy that Georgia was one of the most important centers of Mediterranean civilizations due to its location on the Black Sea coast, and therefore, it was at the center of attention of the old world thinkers.

Hippocrates (about 460–370 BC), while describing the climate of Colchis, underlines the characteristic of this region excessive

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atmospheric precipitations and the slightest fluctuations in the air temperature from season to season, as well as the foehn warm and dry wind “Kenkhron”, which is called “zenakari” in Guria (Kaukhchishvili 1965). Later (after about 3–4 centuries) Strabo (63 BC–24 AD) noted high humidity and abundant precipitations in the downstream of the Phasisi (Rioni) River, and the dry climate of Iberia, adorning it with epithets—blessed and pleasant to live.

Almost all foreign historians or geographers who describe eastern Georgia, characterize its climate as dry and good for health, though by Iakob Tsurtaveli, the author of “ Torture of Shushanik”—the literature monument of the fifth century (the source of the source is not localized, but our assumption This is the south-east part of Kvemo Kartli A), the climate is like a “hot sun burning as fire in the summertime, dry winds and dangerous waters”.

By Procopius of Caesarea (6th c.), in Javakheti and Artaani (part of the current Turkish territory) winter is strict and cold, the summer is long and relatively warm. In our opinion, the duration of summer is doubtful, but the winter is perfectly characterized by this historian. This territory is even now the coldest region of Georgia and it can be called “Siberia”.

Grigol Khandzteli (18–19th c.) notes that nature and climate in Meskheti and Shavsheti-Klarjeti (this is also a part of Turkey now) are beautiful. According to his description, the climate of this region is “kindly dressed from the sun and the air”.

By Giorgi Merchule (10th c.), in Apkhazeti (the Kolkheti lowland), in winter, because of warm and healthy climate, a man could “wintering” and have a good rest. However, according to him, “the country is hot”. It is surprising that he does not say anything about the excessive humidity of this region, which has always been noted by the majority of the historians.

According to the historian of David Aghmashenebeli (11–12th c.), the Iori River floodplain and the territory from Tbilisi to Barda (a city in Azerbaijan) are beautiful wintering areas, as winter is very warm there, but summer is hot and unhealthy.

As historical sources reveal, western Georgia was economically destroyed in the seventeenth century. Along with the termination of trade, the cutting of trees was stopped too. It may have caused to cover almost the entire area with impassable forests, resulting in the weakening of the eastern winds and increasing the humidity.

The Italian missioner—Don Arcangelo Lambert (his purpose was the propagation of Catholicism in the East) while description of Kolkheti special attention was paid to the great humidity of this region, where the waters flowed from rivers (Rioni, Tskhenistskali, Abasha, Enguri, Kodori, etc.) after the abundant atmospheric precipitation, widely covered the coastal area so, that the communication between villages was by means of boats. He also characterizes a thermal regime, comparing it to one of the Mediterranean regions (in particular, the Apennine Peninsula), and notes that winter in western Georgia, for example in Samegrelo, is colder than in Rome and warmer than in Naples. At the same time, he does not say anything about the eastern foehn winds, though he lived in Samegrelo for more than 15 years (1633–1650) (Don Arcangelo Lambert 1991).

From Georgian sources, the works of Georgian writers included in the “Kartli’s life” are very important, where there are scattered and fragmentary presented the materials of climate mainly of the medieval Georgia. Despite such scarcity of data, anyway, they are of great importance in research of historic climate of Georgia, because they contain very noteworthy information about the climate and it can be said of landscapes of individual regions of Georgia; and still a special role plays the “Description of Kingdom of Georgia” by Vakhushti Bagrationi.

According to the description of Vakhushti, there was a great “colorfulness” of climate in Georgia. There is nothing surprising because the complex relief (mountain ranges, uplands, plains, etc. of different directions and altitudes alternate each other here) has led to the formation of quite a lot of different climatic regions in the relatively small area of Georgia and their partial individuality by the main signs of the environment. Mainly by this is precisely explained the clearly visible individuality of live rules and habits of the population of these regions, which led to the development of separate regions of Georgia.

No one has characterized the climate of Georgia, namely, the climate of Kartli, Kakheti, and Imereti in such accuracy and detail, as it did Vakhushti Batonishvili by its own observations of the natural processes and their generalization. It can be said that he was the first, before the famous travel of Al. Humboldt (1769–1859) in the northern Andes, who used the vertical zoning law based on natural conditions, the basis of which is the reduction of the air temperature and vegetation period according to the altitude of the area.

According to Vakhushti Batonishvili (1696–1758), in the eighteenth century, the climate of Kolkheti was still excessively humid like in the past centuries. He does not tell us anything about the existence of the eastern wind too. He writes about Odishi (Samegrelo): "winter is warm, but summer is wet and dewy and humid, but unharmed, windless and frost-free". He describes Imereti as "a quiet place, where you can look from the high mountain, see entire Imereti as a forest and with no building anywhere" (Bagrationi 1997). By our supposition, he, by all means, assumes a huge and impassable forest of Ajameti, which was intensively cut along the formation of capitalism in the nineteenth century, which led to the increase of the frequency and speed of the eastern winds. However, despite such dry and strong eastern winds, a Russian military officer A. Tsimermann (1853) again noted the excessive humidity.

It is noteworthy that the peculiarities of the Georgian climate described by the Ancient and Medieval centuries' historians did not change substantially; only with the changes in the economic and cultural situation of the country, did some of the local climate indicators were changing.

Scientific study (based on the materials obtained from instrumental observations) of the climate of Georgia has been started from the second half of the nineteenth century and continues even today.

8.1 Climate-Creating Factors and Climatic Elements of Georgia Solar Radiation

Because of the location on the north border of subtropical belt, Georgia receives a significant amount of solar radiation. Unfortunately, the data of eight actinometric stations, which characterize the radiation regime of Georgia, is not sufficient (Reference book of the climate of the USSR 1968).

According to the data obtained at the actinometric stations the average annual solar intensity in the territory of Georgia, in the case of cloudless sky, at 12:30 pm on 1 m^2 area, ranges from 852 to 1116.8 watts/m^2 (Table 8.1b). It varies according to the site elevation above sea level and concentration of aerosols in the atmosphere. It is quite logical that its low indicator was observed in Tbilisi and high—in high mountainous Kazbegi, the height of which is 3653 m above sea level, and where the atmosphere is much cleaner than in the capital of our country with almost a million and a half people.

If we consider the intensity of solar radiation in the clear sky 917 watts on average on the area of 1 m^2 and compare it to the solar constant (J_0 = 1.37 kg w/m^2), which decreases by 20% on average while passing the cloudless atmosphere, under our conditions, the solar constant decreases by 6% again, which should be explained by the low index of transparency of Georgia's atmosphere and humidity.

Georgia is characterized by significant duration of sunshine which exceeds 2000 h annually almost everywhere except the territory of Achara-Guria (Table 8.1c). A number of cloudy days are 162–167 days a year (Table 8.1d), due to which the annual indicator of sunlight varies between 1828 and 1958 h. This figure is the lowest (1352 h) in Sairme due to its location in very narrow gorge. That is why, due to the closure of the horizon, the available duration of sunlight is reduced by 47%. Georgian steppe regions are distinguished by largest duration of sunshine, such as Gardabani, where the number

Table 8.1 Some of the characteristics of solar radiation

Weather station	a	b	c	d	e	f	g	h
	The elevation of the site (m)	Average annual intensity of sunlight during the cloudless sky at 12:30 h (w/m^2)	Duration of sunlight during the year (h)	The number of cloudy days during the year (day)	Q—Solar total radiation (m.j./m^2)[a]	S′—Direct solar radiation (m.j./m^2)	D—Scattered solar radiation (m.j./m^2)	B—Radiation balance (m.j./m^2)
Martvili	40	866	2004	135	4944	2660	2284	–
Anaseuli	158	900	1828	167	4827	2598	2229	2363
Sokhumi	26	878	2120	146	5107	2941	2166	2485
Skra	607	886	2350	105	5698	3448	2250	2648
Telavi	568	900	2316	116	5434	3163	2271	2506
Tbilisi observ	404	852	2112	122	5057	3017	2040	2212
Tsalka	1457	935	1984	110	5045	2803	2242	-
Kazbegi h/m	3653	1117	2232	94	6410	3322	3088	-
Batumi	2	–	1958	162	–	–	–	–
Sairme	910	–	1352	135	–	–	–	–
Gardabani	300	–	2520	106	–	–	–	–
Martvili	40	866	2004	135	4944	2660	2284	–
Anaseuli	158	900	1828	167	4827	2598	2229	2363
Sokhumi	26	878	2120	146	5107	2941	2166	2485
Skra	607	886	2350	105	5698	3448	2250	2648
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Tsalka	1457	935	1984	110	5045	2803	2242	–
Kazbegi h/m	3653	1117	2232	94	6410	3322	3088	–
Batumi	2	–	1958	162	–	–	–	–
Sairme	910	–	1352	135	–	–	–	–
Gardabani	300	–	2520	106	–	–	–	–

[a]m.j.—megajoule

of cloudy days is only 106 days a year and the duration of sunshine is 2520 h (Table 8.1c).

Because of the lack of a difference between the territory of Georgia and its geographical latitudes (41° 07′ and 43° 35′), it can be said that no climatic indicator, including the duration of sunlight, varies completely according to the latitude. It mainly depends on the cloudiness and horizon openness (Fig. 8.1).

The intra-annual distribution of sunlight is characterized by one maximum (mainly in July) and at one minimum in winter period (mainly in December or January in some areas). For example in Tbilisi, the minimum (93 h) of this indicator is in December, and maximum (272 h)—is in July.

In the conditions of real transparency of cloudiness and average transparency of

Fig. 8.1 Autumn in Svaneti (photo by R. Tolordava)

atmosphere, the annual income of total (direct and scattered) radiation in the territory of Georgia is equal to 65–75% of possible (in the case of a cloudless sky) total radiation and varies, respectively between 4827 and 5696 m.j./m^2 for low and foothill zones, and in the high mountainous zone, it reaches even 6410 m.j./m^2 (Table 8.1e).

It should be noted that the total solar radiation (roughly approximated) is 5315 m.j./m^2 on average during a year at the latitude of Georgia (Drozdov 1989). The scattered radiation share is 44% of the total income (or annual total radiation).

During the year, both the total solar radiation and direct solar radiation reach their maximums (678–411 megajoule, respectively) mainly in June in the horizontal surfaces with the area of 1 m^2 in the lower zones, for example, in the Kolkheti lowland (namely, in Senaki), in June, and their minimums (172–75 m.j.)—in December. In the high mountainous zone, for example in Kazbegi, the maximum total radiation is in May and makes 842 m.j./m^2, and minimum −264 m.j./m^2 in December–January.

Radiation Balance, which is the main climate-creating factor, is an essential component of heat balance. It determines the thermal regime of the study area, as well as evaporation and snow melting processes. The annual sum of radiation balance in low and foothill zones with the area of 1 m^2 is 43–49% of their total radiation. For example in Tbilisi, this indicator is 2212 m.j./m^2 and in Telavi—2506 m.j./m^2, and it is 46% of total radiation (Table 8.1h).

In the cold period of the year, along with the decrease in the radiation, there is a decrease in the share of radiation balance too. In November and February it is 20–30% of total radiation, and in December and January—only 10–20%, and it varies between 8.4 and 29.3 m.j./m^2 in low mountainous and foothill areas, where the average temperature for all months of winter is more than zero. The exception is a weather station Skra, where the radiation balance is 29.3 m.j./m^2 in January, and the average air temperature is −1.7 °C. This can be explained for Shida Kartli plain, where Skra is located with its characteristic thermal inversions, as M. Kordzakhia notes

(Kordzakhia 1961). In his opinion, this region is characterized by more cold, snowy, and windy winters than the slopes of the mountains of same height around it.

While analyzing the materials of the actinometric stations to describe the radiation climate of Georgia the following should be foreseen: (1) the exceptional lack of the used stations for the country with complex relief, such as Georgia, where the 12.8% of the area is located up to 200 m above sea level, 34.4%—is occupied by the area up to 200–1000 m and 53.8% area—above 1000; (2) the shortness and oldness of actinometric observation rows (observation years 1953–1964). Considering the above factors, the conclusions obtained are only approximations.

The circulation of the atmosphere is one of the main factors of climate formation. Air masses, which are periodically intruded in Georgia, are formed in the Arctic, moderate latitudes, or tropics.

The mountainous systems of our country—the Greater Caucasus Range and the highland of southern Georgia change the direction of movement of air masses. With its geographical location and different morphometric characteristics, the Caucasus significantly affects the atmospheric and radiation processes. It modifies the intensity and direction of the general circular forms of the atmosphere (western, eastern, and meridional), and ultimately affects the weather and climate of neighboring territories with low hypsometry.

Synoptic processes that stipulate the intrusion of air masses in the territory of Georgia are grouped into the following types: western, eastern, bilateral intrusion, anticyclone condition, and wave turbulence developed in southern highland of Transcaucasia.

These processes differ from each other by nature of the weather. Their recurrence and intensity, speed, and direction are changed by the influence of complex orographical units and morphometric indicators.

From above-mentioned processes, the role of the western process is important in establishing weather in Georgia. During this process, a significant decrease in air temperature in western Georgia, cloudiness, and precipitations are observed, and in eastern Georgia, its influence is reduced, however, the western winds are intensified, especially in the Mtkvari River gorge.

Cold air masses coming from the north during the intrusion from the east cannot reach Georgia due to influence of the Caucasus; they flow around the range from the east and starts moving toward the west. Activation of this process in eastern Georgia is accompanied by rain, in winter—by snow, and in western Georgia, wind blows and weather is clean.

The bilateral intrusion is mainly developed under the influence of the Caucasus. Cold air masses coming from the north intrude simultaneously in the Transcaucasia from the west and east. During this process, the air temperature decreases considerably throughout Georgia and it is accompanied with abundant atmospheric precipitation.

The anticyclone condition can be strengthened after the completion of cold air masses intrusion. Orographic conditions facilitate the strengthening and duration of local anticyclones.

The wave turbulences of airflow, developed in the south of the Caucasus, develop mostly after completion of bilateral or western intrusions of air masses. Intrusion of tropical air masses in Georgia is connected with this process that rises very high the air temperature in the summer, even up to 40–41 °C.

Air temperature. Study of temperature field of surface for Georgia, the 3/5 of territory of which is covered by medium and high mountains, is very complex that is related with the lack of appropriate quantity and quality weather stations.

The mountainous system of the Caucasus, in certain parts of which a large part of the territory of Georgian is located, is one of the main reasons stipulating its climatic peculiarity, which means the changes in climatic elements such as air temperatures, atmospheric precipitation, etc. not by geographical latitude but hypsometrical zonality from west to east.

In Georgia, like everywhere on the earth's surface, the air temperature falls down by 0.5 °C on average per 100 m. In our country's complex orographic conditions the vertical thermal gradient varies greatly according to the shape of the relief, the slope angle, the slope exposition, distance from the sea, and the seasons of the year. For visualization we give the numerical data of some thermal indicators of the air—the average temperatures of January, the absolute minimums and maximums of the air temperatures, and the sums of active temperatures for western Georgia' as well as for eastern Georgia's different vertical zones and their areas (Tables 8.2, and 8.3), (Climate Scientific-Applied Reference Book of Georgia 2004; Vladimirov et al. 1962, Reference book of the climate of the USSR 1967).

Replacement of subtropical humid climate by subtropical continental one from west to east (except distance from the Black Sea) is a result of the meridional Likhi Range outgoing from the Greater Caucasus Range that divides Georgia into two parts both territorially and climatically —into eastern Georgia and western Georgia. The location of the latter at the Black Sea determines the high-temperature regime in the cold period of the year. For example, on the Kolkheti lowland (0–200 m) the average air temperature in January varies between 4–7 °C (Table 8.2). It is noteworthy that this indicator is high in the coastal line not only in entire Georgia but also on the Black Sea western coast too. For example, the Black Sea coastal zone of Bulgaria, located on the same latitude, is colder by 4.5–5 °C (Table 8.4) than the eastern coast of Georgia which can be explained by the immediate neighboring of the latitudinal Caucasus Range and by the peculiarities of marine water circulation processes (Mumladze 1988).

The average annual air temperature is the highest, both in the Black Sea coast and along the Rioni River gorge up to 500 m above sea level, and varies from 13 to 15 °C. In the upper zone of Achara-Imereti Range (Bakhmaro, 1926 m), it reaches 4–5 °C. It is noteworthy that the average annual air temperature of 0 °C starts just from 2395 m on Jvari Pass, for example, on the Mamisoni Pass (2854 m) it is −2.4 °C, and in high mountainous Kazbegi (3653 m) it is −6.1 ° C. In eastern Georgia, Kvemo Kartli and Kakheti (12–13 °C) are distinguished with the highest average annual air temperature (Fig. 8.2).

Temperature of July is the highest (>25 °C) in Kvemo Kartli plain, on the Iori upland, and in the southern part of Alazani Valley; on the Black Sea coastline it is within 23 °C. With the increase in the height of the area, it is falling to 3 °C (Table 8.5) by the data of high mountainous Kazbegi weather station.

Absolute minimum air temperature in the coastal line is −8, −14 °C; with the distancing from the sea and increasing in altitude, the air temperature considerably falls to −28 °C (village Korbouli); the mentioned indicator in the plain

Table 8.2 Distribution of thermal indicators and areas by altitudes in western Georgia

Vertical zones (m)	Area (km^2)	January average (t °C)		Active temperature sums ($\sum$t ° > 10°)		Absol. minim. (t °C)		Absol. maxim. (t °C)	
		From	To	From	To	From	To	From	To
0–200	7673.2	4.0	7.0	3700	4600	−19	−8	40	42
200–400	2464.5	2.5	6.0	3750	4440	−22	−13	39	43
400–600	2104.6	−0.5	3.5	2900	4050	−25	−16	38	41
600–1000	4209.8	−2.5	3.0	2300	3550	−28	−19	36	39
1000–1400	4144.7	−4.0	−1.0	1950	2500	−31	−22	35	37
1400–1800	4028.6	−6.0	−3.0	1200	2050	−33	−26	34	35
1800–2200	3594.3	−8.0	−5.0	1100	–	−35	−29	32	33
2200–2600	2434.3	−10.0	−6.5	–	–	–	–	–	–
2600–3000	1303.4	−12.0	−8.5	–	–	−35	–	−25	–

Table 8.3 Distribution of thermal indicators and areas according to the altitudes in eastern Georgia

Vertical zones (m)	Area (km^2)	January average (t °C)		Active temperature sums (∑t° > 10°)		Absol. minim. (t °C)		Absol. maxim. (t °C)	
		From	To	From	To	From	To	From	To
200–400	3405.7	0.5	2.0	4100	4255	−25	−23	40	41
400–600	4245.1	−1.5	0.5	3340	3975	−32	−22	38	41
600–1000	7671.3	−3.5	−1.0	2885	3575	−32	−24	36	41
1000–1400	5851.7	−5.0	−2.5	1960	3000	−34	−26	33	39
1400–1800	5708.1	−7.5	−4.0	1300	2070	−38	−34	31	37
1800–2200	4651.7	−9.0	−5.5	845	1665	−41	−33	27	33
2200–2600	2933.8	−12.0	−7.0	510	890	–	–	–	–
2600–3000	1737.7	−13.0	−8.5	–	–	–	–	–	–
3000–3500	601.8	−14.5	−10.5	–	–	–	–	–	–
3500–4000	178.4	−16.5	−12.0	–	–	−42	–	16	–

Table 8.4 Monthly average air temperature (t °C) in the winter period

Weather station	Latitude	Latitude	January	February
Varna	43° 20′	3.8	1.2	2.4
Gagra	43° 20′	8.2	6.2	6.5
Sokhumi	43° 01′	8.1	5.8	6.7

Table 8.5 Air temperature indicators (t °C)

Weather station	Height above sea level (m)	The coldest month (I or II)	The warmest month (VII or VIII)	Average annual	Absolute minimum	Absolute maximum
Poti	3	5.2	23.2	14.1	−13	41
Batumi	5	7.1	23.2	14.5	−8	41
Sokhumi	116	5.8	23.8	14.7	−14	41
Gardabani	300	0.3	25.3	12.9	−25	41
Tbilisi observ	403	0.9	24.4	12.7	−23	40
Gori	588	−1.2	22.3	10.9	−28	40
Telavi	568	0.5	23.0	11.8	−23	38
Mestia	1441	−6.0	16.4	5.7	−35	35
Akhalkalaki	1716	−7.2	16.4	5.3	−34	34
Kazbegi h/m	3653	−15.3	3.0	−6.1	−42	16

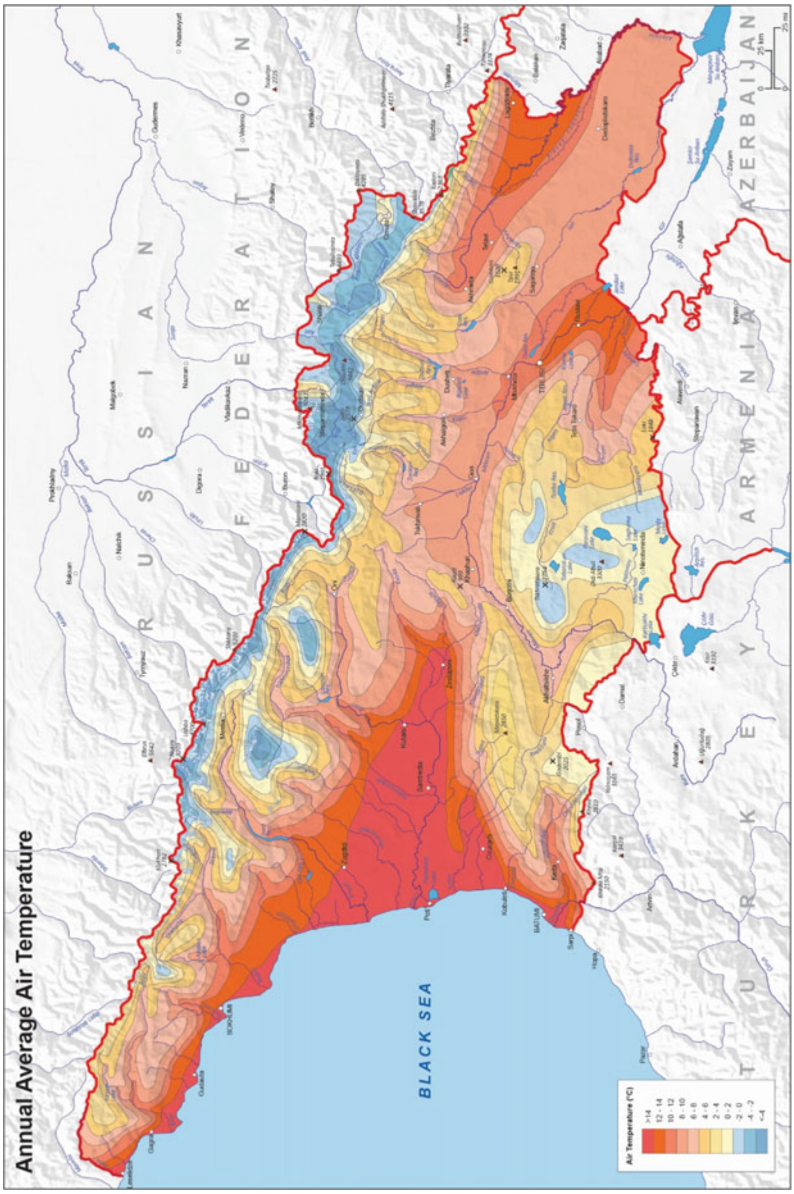

Fig. 8.2 Annual average air temperature (National Atlas of Georgia, Steiner-Verlag, 2018)

zone of eastern Georgia changes between 20 and −28 °C; in high mountainous areas it is—35, −40 °C and even lower. The shape of relief and the underneath surface character, vegetation cover and, etc., are of great importance in the territorial distribution of absolute minimum temperatures. For example, in Shaori basin (1130 m), where the cold air masses are accumulated, the observed absolute minimum is −40 °C, while in high mountainous Kazbegi is −42 °C. At the same time, on the southern slope of the Caucasus, which is covered by dense forest, the absolute minimum air temperature is higher than in the Javakheti upland.

The absolute maximum temperature of the air is quite high in the lowland area, where it is 40, 42 °C; The highest temperature of 43 °C is observed in Apkhazeti (village Lata) which decreases according to the height and is the lowest (16 °C) in high mountainous Kazbegi.

The annual amplitude of air temperature varies between 17 and 25 °C. The lowest amplitude is in the coastal zone and high mountainous part (17–18 °C). High amplitude is in Kvemo Kartli and Javakheti upland (23–25 °C).

In the Black Sea coastline, the number of cold days (temperatures below 0 °C.) in winter does not exceed 5. With the increase in distance from the sea and the height of the place, this indicator increases, and at about 600 m height it makes 1 month. In eastern Georgia, it reaches 25–30 days at the height of 500 m.

Number of hot days (with the temperature over 25 °C) in the plain zone of eastern Georgia is more than 30 days. Hot days (20–25 days) are frequent in the lower part of the Rioni River gorge and in Apkhazeti (Gagra).

Frosts in the western Georgia's lowland zone begin in December-January and are expected to be up to mid-March; in the lowland part of eastern Georgia, frosts begin in November and end in the end of March. Thus, the duration of the frost-free period is 250–300 days in the western Georgia's lowland zone and in the eastern Georgia plain—180–250 days (Gagua et al. 2000; Reference book of the climate of the USSR 1967).

The territorial distribution of **air humidity** is considerably dependent on the physical-geographical conditions of the area, season of the year, peculiarities of atmospheric circulation, soil surface conditions, and, etc.

The partial pressure (water vapor resilience) of the water vapor contained in the air and the relative humidity well characterize the atmospheric air humidity.

The annual course of the partial pressure of the water vapor in the atmospheric air is synchronized to the annual course of the air temperature both in the plain areas of Georgia and in mountains. Minimum is in winter (January–February), and maximum—in summer (July–August).

In winter, the highest value of water vapor is observed in Kolkheti lowland, especially in the coastal zone of Achara and Apkhazeti (6.5–7.5 millibars). In high mountains, for example, in Mamisoni it reaches about 2.0 millibars. In the summer, namely in July, with the increase in air temperature, this indicator significantly increases and reaches even 24 millibars in the coastal zone of Apkhazeti, while the Mamisoni it is 8.6 millibars.

The average annual relative humidity in western Georgia is high in general. The coastal zone from Batumi to Anaklia is especially distinguished with high humidity (80–82%). In the distance from the sea, to the east, the relative humidity is decreasing in Kvemo Imereti, Racha-Lechkhumi, and the Acharistskali River gorge, which is mainly caused by the activity of foehn winds. On the slopes of the mountain ranges, with the increase in altitude, the relative humidity increases again.

In eastern Georgia, the steppe zone of its easternmost part (66–70%) and a significant part of the southern highland (64–70%) is characterized by the lowest relative humidity. Similarly to precipitation, the relative humidity increases along with the rising in altitude, at the height of 2500–3000 m, and afterward it decreases.

In the coastal lowland zone, the minimum relative humidity is in the winter (64–75%) and the maximum is in August–September (75–85%); in the distant areas from the sea, the minimum is in April (64–72%) and maximum—in July–August (76–84%). The main maximum in eastern Georgia is at the end of the autumn and beginning of winter (70–80%), and the minimum—is in summer, mainly in August (55–65%).

In the coastal line, the number of dry days (less than 30% relative humidity) varies between 2 and 10. Iori upland and a significant part of highland of southern Georgia are distinguished with dry days.

The number of humid days (relative humidity is more than 13 h or equal to 80%) is considerable (70–211 days) in the coastal zone; such days are few in Akhalkalaki plateau and Iori upland (Climate Scientific-Applied Reference Book of Georgia 2004; Reference book of the climate of the USSR 1970).

Atmospheric precipitations are one of the main climatic elements that define the water balance of the area. Complex orographic conditions, meridional direction of the Caucasus and highland of southern Georgia as well as the neighboring seas modify the circulation of the prevailing atmosphere in such a way that the dry steppes are found in relatively small territory (with the annual sum of precipitations less than 400 mm) as well as the regions with excess humidity (with more than 4000 mm of precipitations).

According to Sh. Javakhishvili (1981, 1977), in Georgia, the highest amount of precipitation falls on the seaward slopes of the Meskheti Range—annual average of 4500 mm (Mt Mtirala); the lowest amount of precipitation ($\leq$ 400 mm) is in the south-easternmost of eastern Georgia. In Kolkheti, in the coastal zone (Samegrelo, Guria), the amount of precipitations is 1600–1900 mm; it is noteworthy that it decreases to the north and makes 1550 mm in Anaklia. In the eastern part of the Kolkheti plain, it reduces to 1100–1200 mm and again increases up to 1500 mm on the slopes of the Likhi Range. In eastern Georgia, the amount of precipitations is small and fluctuates territorially from 400 to 1800 mm.

Table 8.6 provides data of some meteorological stations on the average annual amount of atmospheric precipitations and indexes of their variation (variation coefficient). It is known that the lower is the sum of precipitations; the higher is the continentality and the variation coefficient. The variation coefficient of annual sums in western Georgia varies from 0.12 to 0.21, and in eastern Georgia—from 0.15 to 0.28. For comparison, we provided the data of some meteorological stations of Europe located in the latitude of Georgia.

Autumn and winter in the coastal zone of western Georgia are notable with precipitations, and spring is dry. Summer is rainy in high mountainous areas. The driest months in eastern Georgia are January and August, May and June are notable with abundant precipitation, and the secondary maximum is in September–October.

The following types of annual course of precipitations are distinguished in the territory of Georgia: (**a**) marine (maximum precipitation—in autumn, minimum—in spring), (**b**) Mediterranean (maximum—in winter, minimum—in summer), (**c**) continental (maximum—in spring or summer, minimum—in winter), (**d**) transition (maximum—in winter or summer, minimum—in spring), and (**e**) mixed (maximum—in autumn, minimum—in summer or winter).

Two main types are distinguished in the diurnal course of precipitations: marine and continental. The marine type prevails in the most parts of western Georgia—precipitations mostly

Table 8.6 Average multi-annual sums of atmospheric precipitations and their variability

Weather station	Height above sea level (m)	Average multi-annual sum of precipitation (mm)	Variation coefficient (Cv)
Poti	3	1661	0.18
Batumi	5	2531	0.17
Sokhumi	116	1478	0.16
Kutaisi	114	1380	0.19
Gardabani	300	378	0.19
Tbilisi, observ	403	505	0.23
Gori	588	498	0.21
Akhalkalaki	1716	533	0.21
Kazbegi h/m	3653	1404	0.30
Rome	20	803	0.21
Tirana	89	1189	0.24
Belgrad	132	653	0.20
Sofia	540	622	0.25

fall in the morning hours; the continental type prevails in eastern Georgia—precipitations mostly fall in the evening.

The highest diurnal record maximum (350 mm) falls in Lanchkhuti. The heavy rain intensity is higher in eastern Georgia (7.3 mm/min in the village Tsemi).

The number of precipitation days (more than 0.1 mm precipitation in a day) in western Georgia varies from 203 (Bakhmaro) to 135 days (Gagra), and in eastern Georgia—from 183 (Gudauri) to 89 days (Gardabani). In the mountainous countries, particularly important is such number of precipitation days, when the precipitation diurnal sum exceeds 30 mm. The number of such days is from 1 to 28 days in western Georgia, and in eastern Georgia, it varies within 0.4–11 days.

The precipitation fallen in the cold period in the territory of Georgia is almost everywhere less compared to the warm period. The north-western part of Apkhazeti is an exception. The frequency of cyclonic activity causes the abundance of precipitations in winter. Similar situation is in the inner mountainous Adjara and in the central part of Meskheti Range.

In most parts of the territory of Georgia, 50–70% of precipitation fall in warm spells. The amount of precipitations fallen in warm period in western Georgia varies by territory within 300–800 mm and in eastern Georgia—within 160–600 mm.

Snow cover. Due to the diversity of mountainous terrain and climate, both the number of snowy days and snow height considerably vary in the territory of our country. The duration of snow cover along with the increasing of altitude, increases rapidly, though in the eastern part of the highland of southern Georgia it does not obey this regularity and the number of snowy days is particularly small there. On the southern slope of the Caucasus, over 2500 m above sea level, the duration of snow cover is over 200 days. The permanent snow and glacier zone starts from about 3000–3200 m on average, which is located lower (2700–3200 m) in the western part of the southern slope of the Caucasus, compared to the eastern part (3200–3400 m).

Places in western Georgia located over 1000 m and in eastern Georgia—over 1200 m, are covered by snow throughout the winter.

Snow cover in the coastal line appears in the first decade of January and in the lower part of eastern Georgia—in the third decade of December. In the lowland, the average height of snow cover varies between 2 and 20 cm. According to the altitude of the site, its thickness significantly increases and exceeds 150 cm in the high-mountain zone of the Caucasus.

The wind. The origination of winds is closely related to the uneven heating and pressure distribution of the territory. The formation of wind regimes in our country greatly depends on the seasonal distribution of pressure on the Eurasian continent, the Black Sea and Caspian Sea basins, and complex orographic conditions.

In western Georgia, the eastern (terrestrial) winds are dominated in winter, and in summer, vice versa—the western (marine) winds are dominated. In west Georgia, the frequency of western winds is intensified by local winds—breezes, while in the eastern winds—by foehns. Except for the mentioned winds, in Georgia quite often emerge local, mountain-gorge winds.

Territorially the average annual wind speed in Georgia varies from 0.6 (Abastumani) to 9.2 m/s (Mount Sabueti). The number of strong wind (15 m/s) days is quite frequent; in this regard, Kutaisi (63 days a year) is distinguished in western Georgia, Khashuri (52 days)—in eastern Georgia, and in Likhi Range, in the Mount Sabueti, where the use of wind energy is foreseen, 162 days are windy. According to the wind regime along with other meteorological elements, it is obvious that the Likhi Range is a climate shed between western and eastern parts of Georgia.

In our country, warm and dry winds—foehns are distinguished by their frequency, direction of which is related to the locality; for example, in the Rioni River gorge the eastern winds are of foehn character and in the Mtkvari River gorge—the western winds are. Foehns are frequent and very strong in Imereti (Ajameti, Kutaisi, Sakara, and others). During the strong foehn, the wind speed may exceed 40 m/s, while the air temperature rises by 10–15 °C and the relative humidity falls down even to 10%.

8.2 Hazardous Meteorological Phenomena

In Georgia, especially in its eastern part, the number of hail days can make up to 16–20 days a year. However, this number is only approximate, because the observer cannot notice the hail fallen far from the meteorological station. According to genesis the two types of hail are notable: frontal and intramassive. 80% of hail is a frontal character.

Hail is a rare phenomenon in western Georgia, and in eastern Georgia, the three main regions are distinguished according to hail days: central part of the upland of southern Georgia, south-eastern slope of the Caucasus Range, and Alazani Valley, or Shiga Kakheti (Fig. 8.3). In the first two regions, the loss caused by hail is not great, because hail falls on the pastures and cheap farm crops. As for Kakheti, almost every year, in June, especially in May, hail falls on expensive farm crops like a vine, and therefore the country suffers great material losses.

Hail falls unsynchronized, which can be explained by the peculiarities of the orographic conditions, and what is most important, by the complex physical processes, which takes place in the hail clouds, especially in their motion. Hail falls in fragments in individual segments, and there are frequent cases in Kakheti, when hail falls in one village and does not fall in its neighboring one. Though, the harvest loss is still high. For example, in 1990–1992, because of hail fallen on 20 thousand hectares, the loss reached 25–30 mln GEL.

Among the hazardous phenomena strong winds (≥ 15 m/s) occupy a special place. In Georgia, they are mainly observed in February and May, damaging high voltage power lines, hindering traffic work, etc., thus obviously cause a great material damage to the country. There may be distinguished several regions with strong winds on the territory of Georgia:

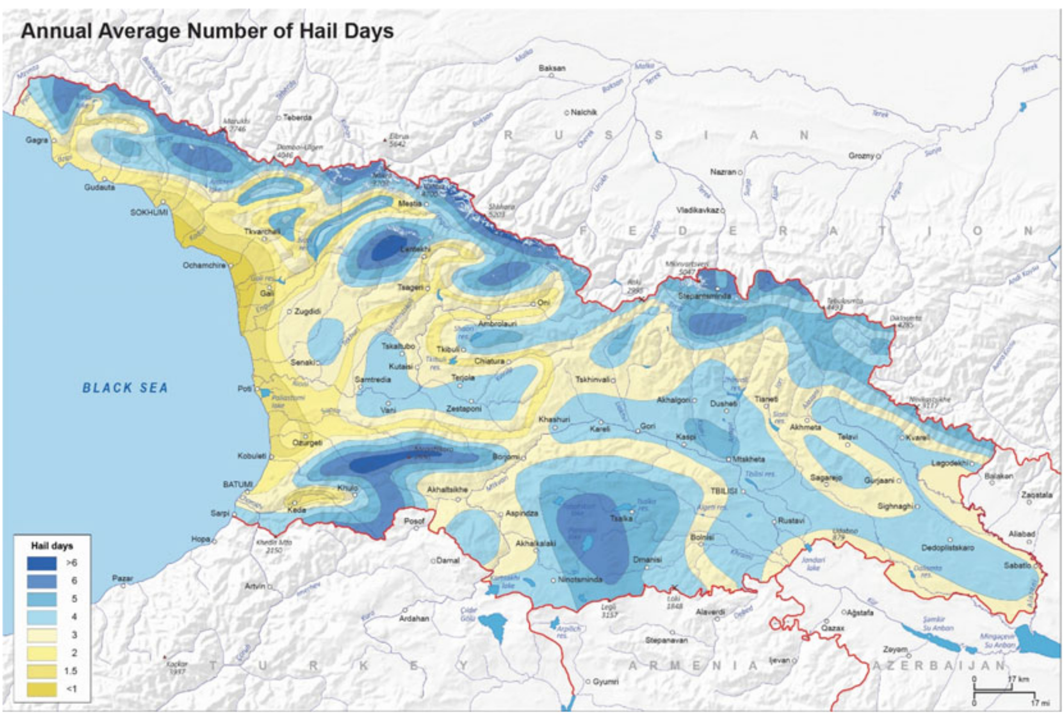

Fig. 8.3 Annual average number of hail days (National Atlas of Georgia, Steiner-Verlag, 2018)

1. The river Rioni gorge (Kutaisi);
2. The river Mtkvari gorge (Tbilisi-Samgori);
3. The western slope of the Likhi Range (Mount Sabueti).

It should be noted that in the latter region a number of days with strong winds (≥ 15 m / s) is 141 days a year.

Georgia's complex relief of high hypsometry and the circular processes developed there, lead to the frequency of **thunderstorm** days throughout the country's territory, especially in its mountainous regions. For example, in Akhalkalaki and Bakuriani, it is 60 days a year, sometimes even 80–85 days. In Tbilisi, it reaches 35; mainly in May and June.

It is noteworthy that thunderstorm is often a cause of hindering aviation transport and electrical communication. It can also cause the forest fire.

Distribution of number of **foggy** days in the territory of Georgia is mainly of fragmentary or uneven character, which is stipulated by the complex orography of the study area (Fig. 8.4). Annually the number of foggy days fluctuates within wide range, from 6 (Black Sea coast, Gagra) to 260 days (Mount Sabueti). Along with the increase in height, it increases both in western Georgia and eastern Georgia. For example, the number of foggy days in Gagra range is 189, on the Mount Mtrala—211, and on Tskhratskaro (2466 m)—241 days. The foggy days in Tbilisi are up to 35, mainly in the cold period of the year—in December and January, which significantly hinders transport movement (Reference book 1970).

In Georgia, as well as in the whole Caucasus, **droughty** years are quite frequent that the majority of researchers associated with the global warming climate. In the last decades, the droughty years can be considered 1976, 1992, 1996, 1998–2000, 2006, and 2010.

The drought of the summer of 2000 was distinguished with special strength, which led to an ecological catastrophe in the plain of eastern Georgia. According to the Tbilisi Airport data, a strong wind blew during 19 days, which contributed to the strong drying of soil arable layer. Loss reached several hundred million GEL. It is

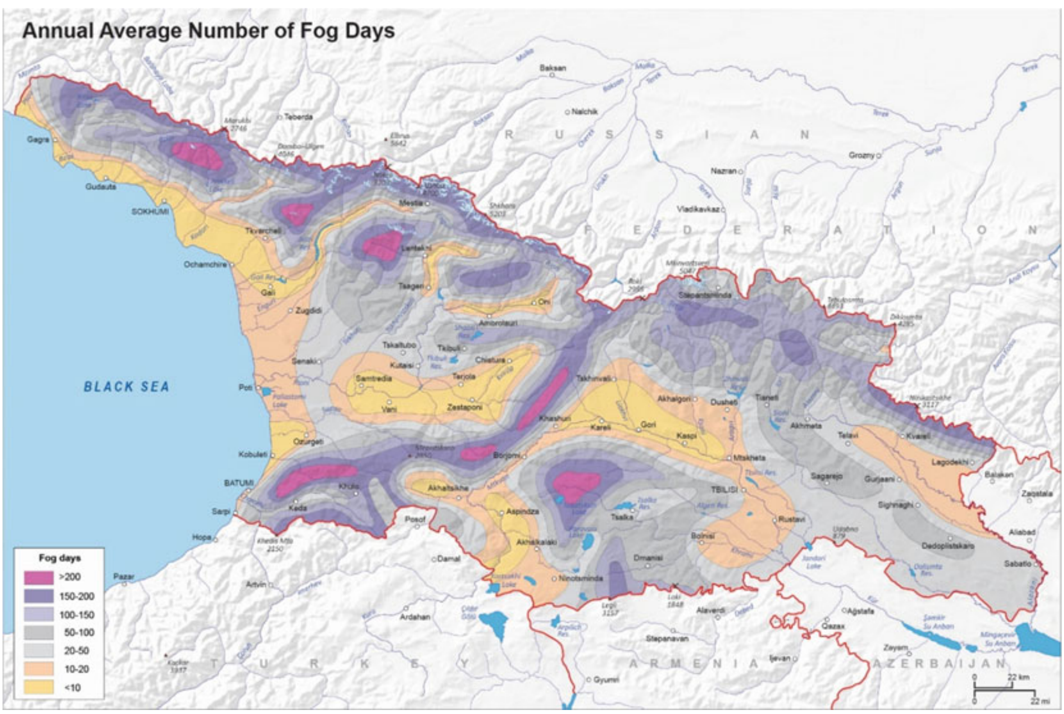

Fig. 8.4 Annual average number of fog days (National Atlas of Georgia, Steiner-Verlag, 2018)

worth to note the summer drought of 2010 when the air temperature exceeded many years norm by several degrees (5–6 °C). This period was especially difficult for one-year crops and vineyards.

8.3 Climate Types

The famous climatologist M. Kordzakhia having relied on the solar radiation regime, atmospheric circulation feature, and the weather conditions associated with them, divides the territory of Georgian into two circulation-climatic districts and one subdistrict (see a map—Climate Types), which, in turn, are divided into climatic zones, regions, and subregions. The author himself thinks that the climatic division of Georgia is schematic, even though, it is based on the most perfect and widespread classification of V. Kiopen (Kordzakhia 1961). We can say that we do not have a better and more precise division of climate of Georgian in Georgian climatology yet.

The marine subtropical humid zone

1. The marine humid climate with warm winter and hot summer:
   (a) Excessively humid subzone with the prevailing throughout the year marine winds and maximum amount of precipitations in autumn and winter;
   (b) Humid subzone with well-expressed musson winds and maximum amount of precipitations in summer and autumn;
   (c) Sufficiently humid subzone with the abundance of northern winds throughout the year and a low fluctuation of number of precipitations by seasons.
2. Sufficiently humid climate with moderately cold winter and a relatively dry hot summer;
3. The humid climate with moderately cold winter and a lasting warm summer;
4. The humid climate with cold winter and lasting cool summer;
5. The humid climate with cold winter and short summer;
6. The high-mountain humid climate with the lack of true summer;
7. The high-mountain humid climate with abundant of permanent snow and glaciers.

Moderate humid subtropical climate zone

8. Climate of moderately warm steppes with hot summer and two precipitation minimums per year;
9. Transition from moderate warm step climate to moderate humid climate with hot summer and two precipitation minimums a year;
10. Moderate humid climate with moderate cold winter and hot summer and two precipitation minimums a year;
11. Moderate humid climate with moderate cold winter and lasting warm summer and two precipitation minimums a year;
12. Moderate humid climate with cold winter and lasting summer and two precipitation minimums a year;
13. Moderate humid climate with cold winter and lasting cool summer and precipitation minimum in winter;
14. Transition from marine humid climate to moderate humid continental climate with snowy cold winter and lasting summer;
15. Transition from marine humid climate to moderate humid continental climate with snowy cold winter and short summer;
16. Moderate humid climate with cold winter and short summer and precipitation minimum in winter;
17. High-mountain moderate humid climate with the lack of summer;
18. High-mountain climate with permanent snow and glaciers.

Climate subzone transition from moderate humid subtropical climate to dry subtropical climate of Western Asian highland

19. Transition from moderate humid climate to mountain steppes climate with cold winter and lasting summer;

20. Highland steppes climate with light snowy cold winter and lasting warm summer;
21. Highland steppes climate with light snowy cold winter and lasting cool summer;
22. Highland steppes climate with short summer and light snowy cold winter;
23. High-mountain moderate dry climate with the lack of true summer.

8.4 Climate Change

The climate has undergone sharp changes in geologic epochs. According to A. Borisov (1965), a humid tropical climate was in the Paleoanalogue territory of Georgia in the Proterozoic Eera (2 billion years ago). The same climate was in Paleozoic (500 million years ago) too, and in the Mesozoic Era (155 million years ago) the subtropical climate was prevalent. The Cenozoic Era is interesting in terms of climate, as the certain radiation and circular factors of the atmosphere are developed in this period, and creation of modern natural conditions is associated with them. In the Tertiary period, the climate of Georgia was warmer compared to modern one. It was tropical. In the nearest geologic past—in Pleistocene, which is the largest section of the Quaternary period, the climate of Georgia, like the climate of other countries, has undergone significant changes. This is the time when the glacial and interglacial periods alternated with each other. If we take into account the increase in amplitude of climate change in Northern Hemisphere by latitudes and the function of the climate "wall" of the Caucasus, which has been weakening the southern distribution of cooling mechanism (in the form of sheet glaciers) directed from the north; these are the arguments that confirm the opinion of great geographer—L. Maruashvili (1956) on the fact that unlike the Alps, where Penny and e. Brühner confirm the four times glaciation (Günz, Mindel, Riss, Würm), there were only three glaciations with less power in the Caucasus, in particular in Georgia. That is why, during the glaciation, the air temperature was 2–3 °C lower, and in the interglacial epochs higher by 2–4 °C compared to modern period.

As it was already noted, the recordings of travelers and historians about past climates that have reached us, do not allow us to think that during the last 2.5–3 thousand years the climate has been thoroughly changed, especially in Georgia.

Modern climate change is determined by many factors, the most important of which are solar activity, atmospheric circulation, volcanic eruptions, and anthropogenic influence.

Anthropogenic factors of climate change are considered: intensive growth of energy generated by humans, an important increase in carbon dioxide in the atmosphere, accompanied by "greenhouse effect", change in concentration of atmospheric aerosols, and predatory exploitation of sub-surface.

All types of resources (oil, coal, natural gas, atomic, etc.) used by humans will eventually turn into heat, which is 41.9–62.8 m.joule/m^2 for developed industrial areas. It is calculated that an annual increase of production energy by 6% of will stipulate the increase in air temperature by 30% after one century.

Significant increase in carbon dioxide (CO_2) is important in the study of anthropogenic influence on the climate. Yet in 1909, the famous Swedish scientist Svante Augustus Arenius (1859–1927) first noted the role of carbon dioxide as regulator of land surface air temperature. The feature of this gas is to let the solar rays pass to the surface of the earth and at the same time, to perform the role of the screen, which significantly restricts the scattering of heat from the earth into the atmosphere, as well as creates a "greenhouse effect" mechanism that contributes to the global increase in air temperature. Based on a number of studies, it is assumed that the content of the CO_2 in the atmosphere will be doubled by 2025in comparison to 1850, which will increase air temperature by 2°–3°. However, not everybody shares such an opinion.

An important factor of climate change is the increase in the concentration of anthropogenic aerosols. A large-scale change in the biosphere with uncontrolled economic activity of humans can lead to climate cataclysms that have occurred over historical epochs. For example, it is enough to name the thinning of ozone layer, in some cases even its perforation, the water, and air pollution, decrease in quantity and species of flora and fauna, etc. The problem is a global character and it is the subject of great interest in scientists.

In parallel with the modern climate change, in particular, the global warming, stipulated by anthropogenic factors, there is another idea, according to which the human race has already "entered the Little Ice Age" and that the future climatic background will be similar to the climatic conditions typical to the period between the sixteenth-seventeenth centuries when the global air temperature was less by 0.5–1.0 °C than many years norm.

From the end of the nineteenth century, the modern climate change, which was marked by considerable increase in air temperature, namely by 0.75 °C, covered almost all of the earth (Mumladze 1991). It is obvious that Georgia is no exception. The calculation proves that during the last 150 years, the average annual air temperature has increased by 0.6 °C in Georgia, mainly due to increase in winter temperature. In the last decades, the average air temperature of winter (mainly in January) has increased by about 1.3 °C mostly in eastern Georgia.

A complex study of climate main elements shows that for the last 4–5 decades, there has been an unfavorable regime of climate in Georgia. More frequent are droughts, strong winds, and at the same time, the abundant atmospheric precipitations that are accompanied by floods and landslides.

This mentioned change in climate along with aggravating ecological problems will create more difficulties for our country's economy, especially in the plain area, where the exploitation of natural resources has exceeded the permitted limits a long time ago.

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9 Black Sea

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Abstract

Key issues of physical geographical properties of the Black Sea with ecological and economic problems are described in this chapter. The protection of the Black Sea coast of Georgia and the management of the processes on this coast should be in the hands of the state. There should be appropriate legislation that prohibits the acquisition of materials from the river confluences and riverbeds for construction purposes, construction in the wave influence zone, etc. Any protective measure should be considered in relation to the whole dynamic system.

The Black Sea, as part of the Mediterranean Sea, played an important role in geographical research from the Antique period. Its systematic-methodological study started in the nineteenth century.

The Black Sea is a typical inland sea. In the west, its shape is formed by the eastern edge of the Balkan Peninsula, in the east—by the Caucasus Mountains and the Kolkheti Lowland, in the north-east—by the eastern European plain, and in the south—by the mountains of Asia Minor.

The length of the sea coastline according to various authors is 4020–4100 km.

The Black Sea is a continental sea of the Atlantic Ocean. The Bosporus Strait connects it to the Marmara Sea, and the latter is connected to the Mediterranean Sea by the Dardanelles strait. In the northern part of the sea, the Kerch Strait connects it to the Azov Sea. The Azov Sea can also be considered a shallow bay of the Black Sea. The sea area is 420,325 km^2 (462,000 km^2 including the Azov Sea). The northernmost part of the sea is the Berezan Liman near the Ochakov (46° 33′ N), the eastern—a shore between Batumi and Poti (41° 42′ E), the southern—Giresun, to the west of Trabzon (40° 56′ N) and the western edge—the Burgas Bay (27° 27′ E). The maximum length of the sea is 1175 km, the average depth is 1271 m and the volume of water in the sea is 537,000 km^3.

In general, the Black Sea shores are less fragmented. The north-western and the northern shores are more fragmented. There are located two large bays—Odessa and Karkinit. The Novorossiysk Bay is the largest bay on the Caucasus coast; Sinop, Samsun, and Vona Bays are largest along the Turkish coast. On the coast

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of Bulgaria, there are located two bays of Burgas and Varna. There are several peninsulas on the Black Sea coast, including Crimea, the largest one (Kos'yan 1993).

In the Georgian Soviet Encyclopedia the following explanation is given on the Black Sea bottom: "The shelf, continental slope, and deep-sea basin are distinguished in the relief of the bottom. 110–160 m depth shelf reaches the north-western part (Fig. 9.1). In other areas the shelf depth is less than 110 m, the width is from 10–15 to 2.5 km (at the Turkish coast). The continental slope is strongly fragmented with underwater gorges and canyons. The average inclination of the slope is 5°–8°. The system of submarine ranges is extended along the shore between Sinop and Samsun with the length up to 150 km. The bottom of the basin is a flat accumulated plain, to the center of which the depth of the sea increases up to 2000 m and more (max depth is 2210 m)" (Black Sea … 1986).

In geological terms, the bottom consists of sections of different types of different materials. A large part of the Black Sea depression is located in the Alpine folded zone. The earth crust under the depression consists of sediment (thickness of 10–16 km) and "basalt" layers ("granite" layers are on the peripheries). The Black Sea's north-western part includes the southern edge of the east European platform and Epi-Paleozoic platform. Some researchers link the formation of the Black Sea depression to the "oceanization" processes of the earth's continental crust. Some believe that the depression is a remnant of the ancient Tethys Ocean basin. The contour of modern depression was conceived in Oligocene, when due to the tectonic ascensions in Asia Minor the Black and Caspian Seas were

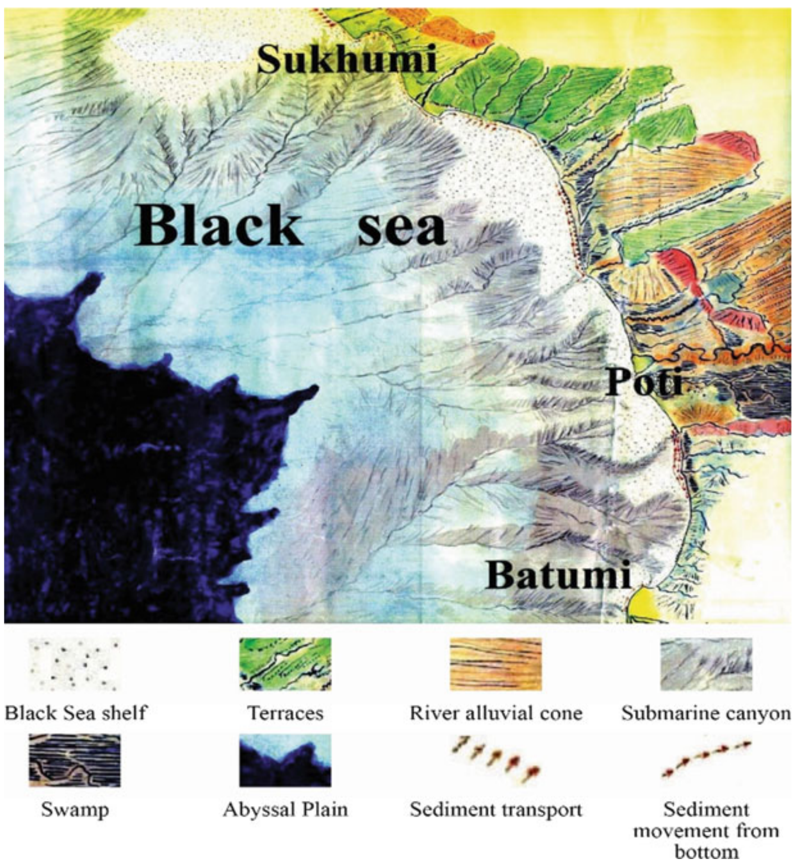

Fig. 9.1 Geomorphological map of east part of Black Sea from riv.Gumista to riv. Chorokhi, By D. Tabidze and G. Lominadze

gradually separated from the ocean. In the Late Miocene it was a part of the fresh sea-lakes (Sarmatian basin) of the Black Sea. After a short-term connection with the Mediterranean Sea, in the Meotian times, the fresh Pontian Lake was formed. At the end of the Pontian Stage, the connection between the Black Sea and the Caspian Sea was cut off.

It is likely that during the Middle and Late Pliocene it was a freshwater lake. In the Middle Pliocene the Black Sea was connected with the Mediterranean Sea two times and its water was more saline. During the last glaciating, a very freshwater New-Euxine lake-sea was formed, which connected to the Mediterranean Sea with straits 6–7 thousand years ago. This gave an origin to the modern Black Sea. Tectonic activity is manifested in earthquakes, the epicenters of which are located on the peripheries of the depression. In the coastal zone dominate the rough-fragment sediments: gravel, pebbles, and sands. At a distance from the shore, they are replaced by fine-grained sands and aleurites.

The Black Sea has been experiencing the continental polar, marine polar, and tropical air masses' influence throughout the year. Continental polar air prevails. Its intrusion in winter is accompanied by strong northern and north-eastern winds, temperature decrease, and precipitations. These winds are particularly strong in Novorossiysk region (see bora). The marine polar air intrusion from the Atlantic Ocean causes active cyclone action. The southwestern winds bring marine tropical air from the Mediterranean Sea to the Black Sea. Winter is warm and summer is hot and dry in the most parts of the Black Sea. In the central part of the sea, the average temperature in January is about 8 °C, at the eastern shores—6 °C, at the north-western shores—3 °C, and at southern and south-eastern shores—6–9 °C. Minimum temperature in the northern part is 30 °C. During the summer times, the Azor anticyclone branch extends over the Black Sea, which stipulates sustainable, clean, and warm weather. The average temperature in July is 22–24 °C, maximum—30–35 °C. Precipitation in the western and north-western parts is 300–500 mm per year, in the southern part—750–800 mm, and in the eastern part—1800–2000 mm. The compound part of the Black Sea water balance is the atmospheric sediments (230 km^3/y), continental runoff (310 km^3/y) and the water incoming from the Azov Sea (30 km^3/y), evaporation from the sea surface (360 km^3/y), and the water incoming from the Bosphorus strait into the Mediterranean Sea (210 km^3/y).

The cyclone circulation of the atmosphere and continental runoff determine the water cyclone circulation (clockwise direction). The speed of the water flow on the surface of the Black Sea is up to 1 km/h, which can reach 5–6 km/h in separate areas during strong winds. The excess of the inflowing in the Black Sea freshwater constantly flows through the Bosporus Strait in the Marmara Sea by its upper stream (up to 40 m deep); by the lower stream, the Mediterranean saline waters flow into the Black Sea, which fills the deep layers of the sea. Due to this, vertical water circulation is blocked in the Black Sea (GSE 1986).

The western rhumb winds and waves are dominated over the marine waters of Georgia just like over the entire Black Sea. In winter times, along with the western winds, the action of north-western winds is observed as well. During the whole year, the waves of 1–3 points of strength prevail over the marine waters of Georgia. Strong surfs are characteristic of the coastal zone of the central part of the Kolkheti Lowland (recurrence of about 20%). The maximum height of the waves varies within 3.5–6.5 m; it reaches 8 m at c. Poti and 9 m—at Batumi (Kiknadze et al. 2000).

In the last millenniums, the average level of the Black Sea is rising, which is caused by global warming. Annual pace of sea-level rise is 1.5–2.0 mm.

As a result of the water tides, the levels fluctuate within 40–60 cm on the Crimea coast, in the north-western part—up to 1.5 m. During tides, change in levels does not exceed 10 cm, during seiches—60 cm, and during the low tide, surface temperature of the water at the shore sometimes decreases from 25 to 10 °C and lowers just in several hours due to flowing out of deep waters. In winter the temperature of the upper layer of water (up to 60 m) decreases to 6–7 °C, in the north-western part—to 0.5 °C, and in the south-eastern part—to 9–11 °C. In summer the water surface is heated up to 24–26 °C, and at the coast—up to 29 °C. During the year-round the water temperature is around 7 °C at the depth of 60–80 m and deeper. The salinity of surface water in the open sea is 17–18‰, at the river confluences—less than 9–3‰; the salinity reaches 19–20‰ at the depth of 60–80 m, and at the bottom—22–22.5‰. In the winter the water density at the surface is 1.013–1.015 g/cm^3, and in summer—1.0085–1.0120 g/m^3. Diluted oxygen is only in the upper layer of water (8–9 ml/l). More than 150–200 m deep water is "poisoned" with sulfur-hydrogen, concentration of which reaches 11–14 ml/l. The color of the water in the central and eastern parts of the sea is greenish-blue, and in the north-western part—bluish-green. Water transparency is 16–22 m on average; it is 6–8 m at the shores, and in some areas, it decreases to 2–8 m.

There is no life at the depth of 150–200 m in the Black Sea (except for the anaerobic bacteria). Among the vegetation, about 350 species of phytoplankton algae are distributed there.

The Black Sea fauna is about three times poorer than the Mediterranean one. The bottom species (up to 1700 species) are dominant; about 2000 species of animals are found there (GSE 1986).The character of the terrain of the coastal zone is stipulated by the joint action of various factors, such as the sea wave mode, the volume of clastic material brought into the coastal zone, its granulometry and distribution along the coast, the geological structure (rocks sustainability to abrasion) of the coastal zone, the latest tectonic movements and character, etc. The intensity of these factors, both in time and space, is different in different areas of the coast and, therefore, their morphodinamical modes are different as well (Dzaoshvili and Papashvili 1993; Dzaoshvili 2003).

The formation and development of the coastal zone are mainly in progress at the expense of solid river runoff and fractions relevant to marine coastal sediments. Their movement along the coastline is caused by the wavings of the prevailing western rhumbs (Figs. 9.2 and 9.3).

The coastal zone, its water surface zone (beach), and the underwater coastal slope are in dynamic equilibrium until the energy generated by wave deformation and disintegration is discharged only on the transportation of the sea-coastal sediments. When there is a deficiency in the sediment budget of the coastal zone, the residual wave energy is used to deepen the underwater coastal slope and the wash-off and degradation of the shore. Otherwise, there is an accumulation of "excess" sediments and terrestrial growth at the expense of the sea. Exactly of such an origin are the capes of Bichvinta, Sokhumi, and Anaklia, located in the south of the confluence of the rivers of Bzipi, Gumista, Kodori, and Enguri (i.e., in the direction of deposits motion). The confluence of the Chorokhi River and the coastal location of Batumi (Burun-tabie) Cape is due to the opposite direction of the alongshore motion of the sedimentary stream (Fig. 9.4).

The clastic sediments transported by the alongshore submarine streams will be shifted to the coastline by the influence of the breaking waves, resulting in the origination and development of the beach line continuously. The full-profile beachline is such a natural formation that ultimately destroys the energy of the surf and protects the shore from erosion (Fig. 9.2).

It is also noteworthy that the full-profile beach is not only an essential element for seaside resorts and cities, but it is also a natural self-regulation means of sea and terrestrial interaction. Its sustainability is of particular importance for the accumulative type of shores that react sharply to every unreasonable and incorrect technogenic impact. That is why, the conditions of the coastal zone of Georgia, intensively growing at the expense of the sea as a result of sediment accumulation processes in the past, has been deteriorating over the last 100–120 years. This is mainly related to the anthropogenic factors, namely to the port groins breaking the alongshore movement of the sediments, the regulation of riverbeds falling into the sea, the construction of "shore protection" constructions,

Fig. 9.2 The emergency section on the southern periphery of the Batumi city coast 2005 (photo by G. Lominadze)

the improper placement of number of settlements, resorts, transport and communication networks, etc., as well as to the taking away tens of millions of m^3 gravels and sands from coastal areas and riverbeds, etc.

In the second half of the twentieth century, the Poti and Batumi ports were built on the Black Sea coast of Georgia. As a result, the Batumi Port facilities blocked the flow of beach-generating materials directed from Chorokhi confluence to Kobuleti and the wash-off process began in the north of the port from Bartskhana to Kobuleti. Their width was sharply reduced and the shore obtained such parameters that the small rivers of this section—Chakvistskali and Korolistskali have provided its feeding (Lominadze et al. 2015). The Kobuleti beaches had previously been fed by the average fine-fraction material transported from the north and large-scale fraction material transported from the south. A small number of materials transported from the north from the confluence of the rivers of Supsa and Natanebi, cannot provide the sustainability of the beaches and as a result, the seashore is intensely washed away (Fig. 9.5).

The Poti port construction completely changed the natural functioning of the Kolkheti Lowland beaches built with the sand of the Rioni River. Since the location of the main riverbed of the Rioni River threatened the sustainability of the port building at the southern entrance (due to the activity of existing underwater canyon), the main bed was artificially moved to the north of the port, to the Nabada area.

To the south of the port, passing through the area of the city, a low capability channel cannot provide (during floods) the passing through of the required amount of sand, and as a result, the Grigoleti coast is being washed away. In the north of port, in the territory of Nabada, the area adjacent to the new main riverbed of the Rioni River was intensely increasing. The new delta split into two flows more and more intruding deeply into the sea. Materials transported by waves to the south and north of the delta, simultaneously threaten two ports—Poti port and

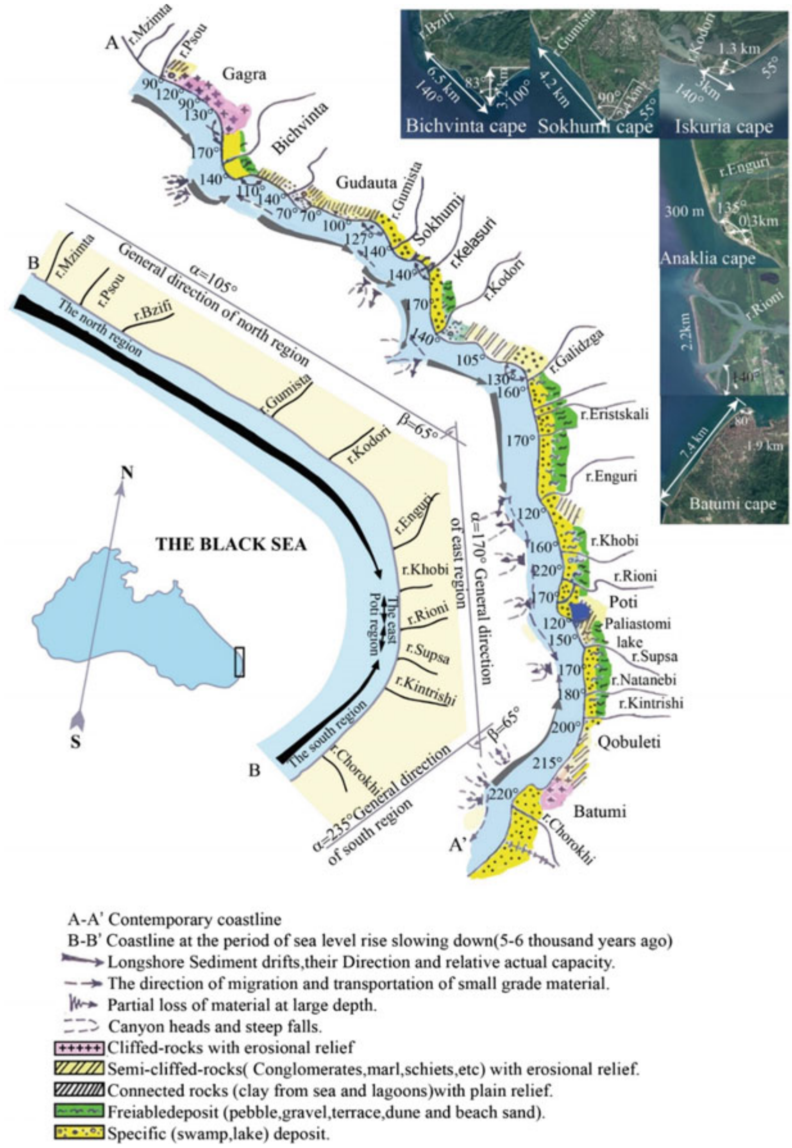

Fig. 9.3 Lithodonamic scheme of the Black Sea coast of Georgia according to A. Kiknadze (Kiknadze et al. 2000)

newly built Kulevi port (Papashvili et al. 2015) (Fig. 9.6).

From the 50s to the twentieth century, an intensive resort construction started on the eastern coast of the Black Sea. Ballast of millions of cubic meters removed from riverbeds and from the beaches directly was used as building material. In order to protect the resort areas from flooding, almost all the rivers have been placed in the frames, which has been fundamentally changed the established for thousand years distribution regime of materials brought out from the sea by river during flooding (Fig. 9.7).

This caused intensive washings of all the beaches on the eastern coast of the Black Sea. In danger appeared urban areas, farmlands, and especially railway lines near the coast. The problem of protection of the coast has been raised on the agenda. The shore protection was independently maintained by the Union Railway and separate Ministries of that time. The coastal protection measures carried out by them brought

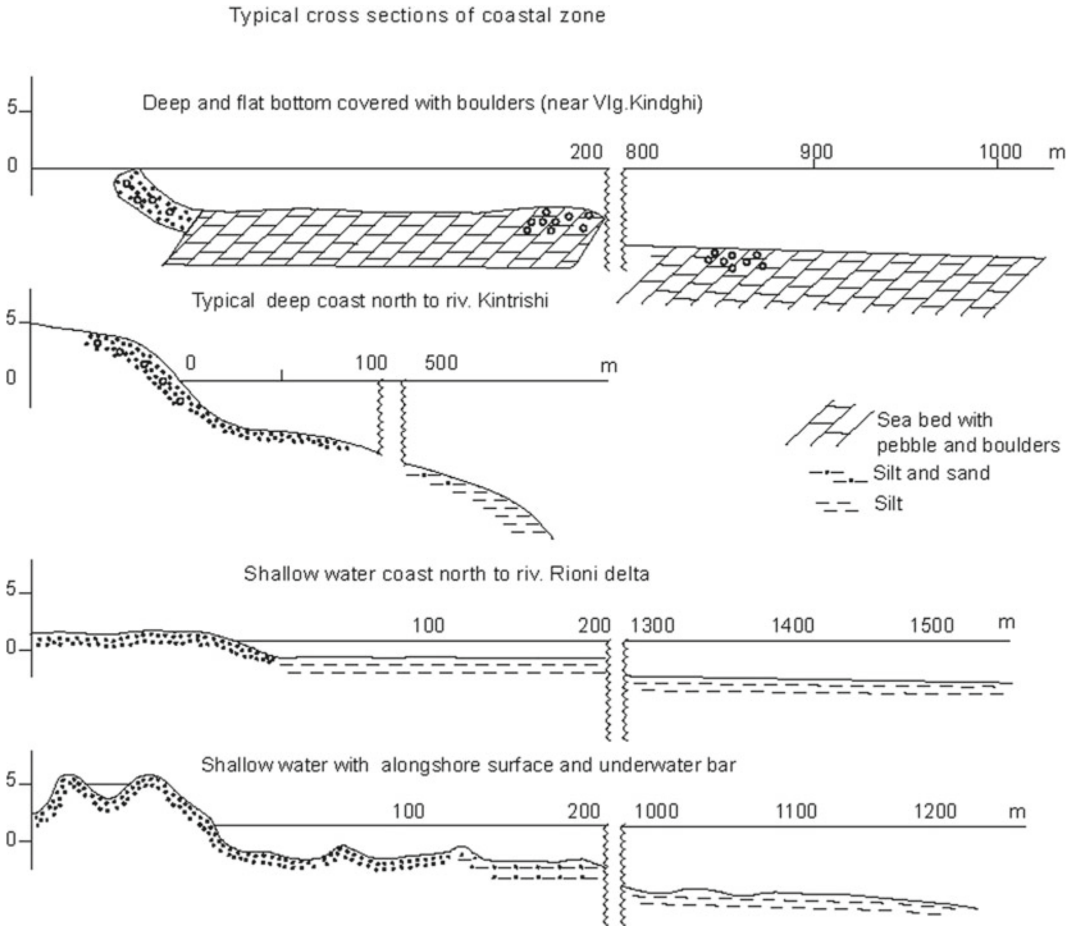

Fig. 9.4 Typical cross sections of Black Sea-coastal zone of Georgia (National Atlas of Georgia, 2012)

further disaster to the sea coast, since all organizations defended only their territory and only with concrete structures such as dykes, groins and breakwater piers.

These systems of protection were taken from the experience of foreign countries. In our reality, the coastal protective structures were very quickly damaged, and even in case they withstood the breaking waves, they were causing to washing the surrounding areas. For example, the groins and dykes hindered the distribution of materials in neighboring territories; and the breakwater piers reflected the waves and reinforced the backflow of the water, thus facilitating beach material to be washed into the sea. Finally, there remained washed and distorted beaches blocked with concrete fragments (Peshkov 2005) The construction of the dams on the rivers has greatly affected the coastal area, which significantly reduced the amount of beach constructing materials brought into the sea. This happened in the background of natural rising of sea level (transgression) when the amount and thickness of the materials brought into the sea by the rivers should have been reduced anyway (due to the reduction of the riverbed sloping). Naturally should have been changed the location of confluences and redistribution of the output materials on the coast as a result. For example, the confluence of the Chorokhi River was shifting to the

Fig. 9.5 Washed of sea shore 4 km south from Enguri river-mouth 2018 (photo by G. Lominadze)

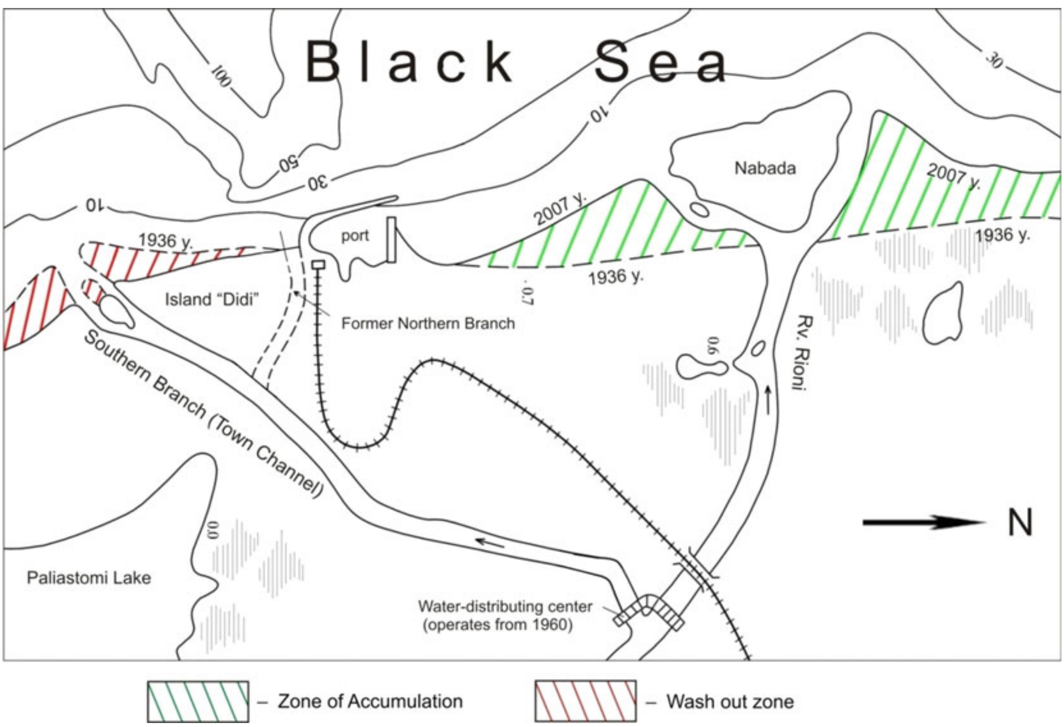

Fig. 9.6 Costal dynamics of r.Rioni river-mouth 1936–2007 (figure by Gr. Russo)

Fig. 9.7 Washed of seashore north from Supsa river-mouth 2009 (photo by G. Lominadze)

Batumi Cape during the regression of sea level, and during the transgression, it returned to the current condition.

In this case, the natural dislocation of the confluence has coincided with the real one that we cannot say about the other rivers of the Black Sea coast. The river confluence has been fixed at the location, where it was at the time of construction of frames.

The developed events in recent decades have put the final point on the natural development of the eastern coast of the Black Sea. According to the distribution areal of the main rivers that feed the beaches and the materials brought by them, this coast is divided into seven dynamic systems. In the northernmost, it is bordered by the northern dynamic system (the same Mzimta-Psou), and in the south—the Chorokhi dynamic system (Figs. 9.8 and 9.9).

Besides the Poti (Rioni) dynamic system, which has only sandy beaches, all the rest of the dynamic system beaches are composed of the gravelites-sandy mixture, where in most cases sands are not more than 30%. Among these dynamic systems, only the Bzipi dynamic system has less suffered the devastating impact on humans, if we do not take into consideration the fixation of the river confluence, which has a negative impact on the redistribution of the riverine material in the system. All the rest of systems are blocked with concrete structures, and to maintain the beaches the artificial feeding by riverine material is required in most cases.

The natural feeding of the beaches should be made by renewable sources, the river runoffs. Today we completely lack these circumstances on the Chorokhi and Enguri Rivers; on the Chorokhi River—due to the dam built by the Turks by our consent, and on the Enguri River—due to the dam built by us. The entire Kakhaberi Lowland is created by the Chorokhi River deposits. Today Chorokhi no longer deposits anything. There are no floods in the riverbed. The beaches are under the threat of washing away from the river confluence to the Batumi Cape. They can be maintained only by artificial

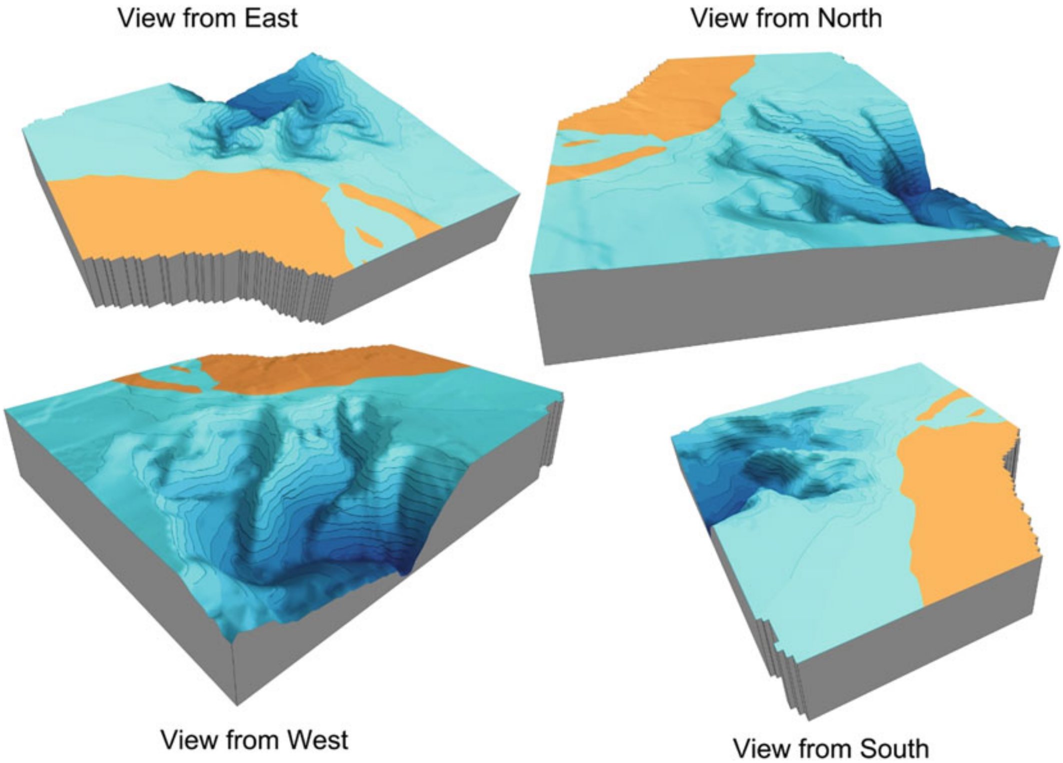

Fig. 9.8 riv.Enguri Canyon 3D. By G. KavlaShvili

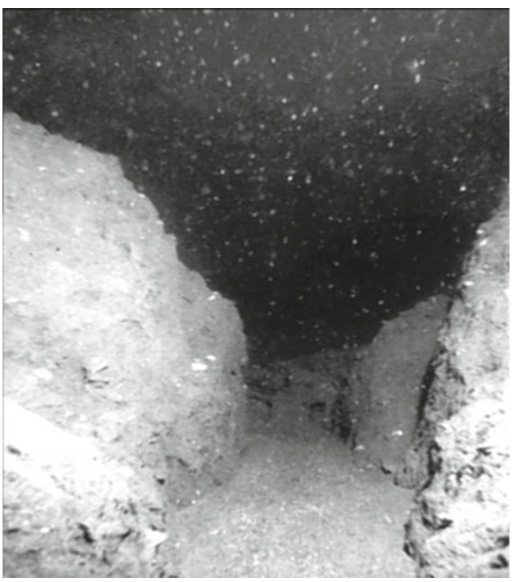

Fig. 9.9 Chorokhi Submarine canyon 50 m depth (photo by V. Menshikov and Gr. Russo)

feeding. The same situation is on the coast located to the south of the Enguri River (Anaklia—Khobi River) The feeding of the beaches of this coast with large materials was provided by the materials of the Mokvi and Ghalidzga Rivers, while the sand was supplied directly from the Enguri River. Since the port line of the Mokvi River and the Ochamchire dykes completely blocked the possibility of moving materials from the north and Enguri no longer deposits anything due to the dam, the feeding of the Khobi section beaches is possible only artificially.

For artificial feeding of beaches is required to include the same composition or the same thickness of the materials that build the beaches. The cheapest is the material of rivers that feed them. Unfortunately, this material is used for construction today. Almost in every river bed, one or several quarries are opened. The most disturbing is the fact that the quarries function on rivers where the material is no longer renewable. For example, on the Enguri River, at a distance of 15 km from the confluence, where the large gravelites are being extracted, this reserve will be exhausted in the nearest future, and then the price of the supply of beach material from hundreds of kilometers will be cost gold. The same situation is on the Chorokhi River and surrounding areas. Although the amount of materials is much more here, how the feeding of Adlia coast (the southern periphery of city Batumi) food requires five times -eight times more material than the Anaklia coast.

We can conclude that the unwise intervention of humans has almost destroyed the eastern coast of the Black Sea. Naturally, the rivers brought the beach building material to the sea coast, and its further distribution on the beaches was done by stormy waves; i.e., that waves have not a devastating function but of the creator. At present, this mechanism is completely disintegrated. Instead of the river, we ourselves should input the materials obtained from the quarry on the beaches and redistribute is by ourselves too, and then wait for a storm with excitement of the heart.

Today some of the yet active beaches should not deceive us. The beaches are washed and destructed during large storms, but sometimes the "preparation" for this washing is underway for several years. It cannot be seen by eyes because the deficit of the material first affects the underwater slope. It is washed and deepened, and this process almost is not noticeable on the surface beach. Once by all means the devastating storm occurs, the waves of which on the deepest underwater slope, approach the shore almost without deformation and break in the immediate vicinity. In this case, a large wave usually breaks hundreds of meters away; that is when the coast retreats by a dozens of meters.

In order to save the Black Sea coast of Georgia today, we should recall the principles under which the organization "Saknapirdatsva" ("Georgian Coast Protection")—where it is possible, dynamic systems should be restored in natural form.

The protection of the Black Sea coast of Georgia and the management of the processes on this coast should be in the hands of the state. There should be appropriate legislation that prohibits the acquisition of materials from the river confluences and riverbeds for construction purposes, construction in the wave influence zone, etc. Any protective measure should be considered in relation to the whole dynamic system.

Coast protection measures should be preventive and continuous, as it is cheaper and more correct. We do not have to be behind the events.

It should be remembered that the beaches of Georgia are unique and there is no analogy in the world.

95% of the world's accumulative shores are fed by sands brought out from the bottom, 5%—by sediments brought by rivers. From here the so-called Mediterranean type of shores are distinguished with gravels and gravelites along with sands, but neither the Mediterranean Sea nor the Black Sea coast, except the eastern Black Sea coastline, has no beaches built of such a large and vast stone-gravel-sandy mixture. Stormy waves on our coast are much stronger than on the Mediterranean Sea coast (the wave mileage is higher), the rivers bring much more materials and waves transport more materials along the shore. The coast protective breakwater piers that our tourists like very much on the Mediterranean coast are compulsory measures in the conditions of the deficit of beach forming material. Their shores are abrasive-accumulative and small beaches are stuck between capes, i.e., that the natural feeding of beaches is made by a small amount of riverine sediments and the abrasion material of the shores. The breakwaters protect the shores from this abrasion because the narrow beach cannot extinguish the wave. Due to above mentioned, the direct copying of experience of other countries in the field of coast protection is absolutely inadmissible toward the seashores of Georgia.

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10 Inland Waters

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Abstract

In this chapter, rich water resources of Georgia are presented. Main rivers, lakes, and reservoirs with their geographical properties are described on the basis of various literary sources. The main wealth of Georgia is rivers. There are mainly small (99.9%) and very small rivers. There are almost all types of rivers: plain, mountain, glacier, karst, wetland, drying, etc. There are about 856 small lakes in Georgia. The area of more than half of them is less than 0.1 km^2. In the reservoirs of Georgia, a significant part of its water resources are accumulated; 44 water reservoirs are currently in operation with the volume of over 0.5 million m^3.

Georgia is distinguished by the richness of freshwater resources. There are more than 26,000 rivers, more than 800 lakes, 40 water reservoirs, about 800 glaciers, and many other types of springs and wetlands. The total volume of water resources registered in the country is up to 100 km^3 (Khmaladze 2009) (Fig. 10.1). Among the European countries, Georgia is only behind Norway (1190 mm), Switzerland (1040 mm), and Austria (800 mm) by average height of freshwater layer (760 mm). In the Georgia's neighboring southern countries—Turkey, Armenia, and Azerbaijan, the mentioned indicator is 215, 280, and 110 mm, respectively. Water supply of population of Georgia is 4–6 times higher than in the above-listed countries (Geladze 2013).

The amount of water formed during the year on one square kilometer is unevenly distributed according to the territory: it is 1.34 million m^3/km^2 for western Georgia and 0.37 million m^3/km^2 for eastern Georgia. The average annual runoff, which is directly formed in the territory of Georgia, is 52.7 km^3. In addition, on average 8.68 km^3 of water per year enters from neighboring countries, including 7.75 km^3 of water, which enters from Turkey through the Mtkvari and Chorokhi Rivers. Including the transit runoff, Georgia's freshwater river resources of make 61.45 km^3, about 78% of which flow into the Black Sea and 13.4e 5%—flow through the territories of neighboring states—Azerbaijan and Russia (Khmaladze 2009).

The main wealth of Georgia is rivers, 99.9% of them are mainly small and very small rivers, the length of which does not exceed 100 km. There are almost all types of rivers: plain, mountain, glacier, karst, wetland, drying, etc.

The average density of the river network is 0.86 km/km^2. In general, along with the decrease in precipitation from the west to the east, the

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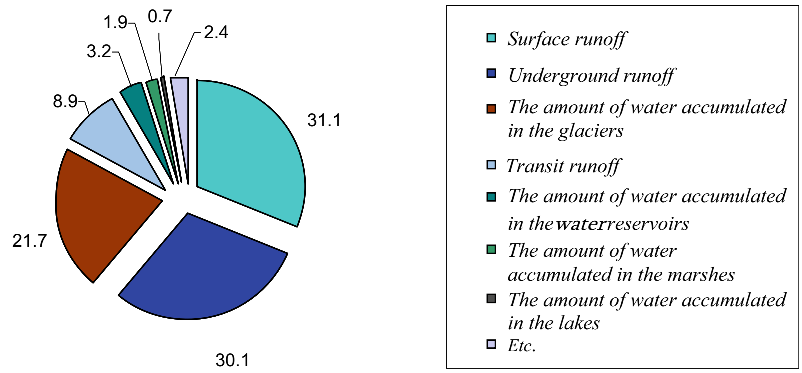

Fig. 10.1 Distribution of water resources of Georgia (%) (Khmaladze 2009)

density of the network is reduced. In western Georgia, its average amount is 1.08 km/km^2, while in the east—0.68 km/km^2.

The most watery river in Georgia is **Rioni**. It starts at the Mount Pasi, at 2620 m (southern slope of the Caucasus). Its length is 333 km and flows into the Black Sea at Poti. It throws 403 m^3 water per second or 12.7 km^3 water per year on average into the Black Sea. The Rioni River basin occupies almost half of the whole territory of western Georgia (basin area 134 thousand km^2). It is fed by snow, glaciers, rain, and underground waters. It is characterized by spring–summer floods and winter low water. The cascade of HPPs is built on the Rioni River, the oldest of which is the Rioni HPP. The Rioni River is characterized by catastrophic floods. The flood of January 1987 should be noted when the sudden flood exceeded 4600 m^3/s in the downstream of the river. The main tributaries of the Rioni River are: Kvirila (1.9 km^3), Tskhenistskali (2.5 km^3), Tekhuri (1.0 km^3), Khanistskali (0.7 km^3) and others.

Among the rivers of western Georgia the following rivers are also worth mentioning: Bzipi (3.0 km^3), Kodori (4.1 km^3), Enguri (5.9 km^3), Ghalidzga (0.8 km^3), Khobi (1.6 km^3), Supsa (1.4 km^3), Natanebi (0.8 km^3) and Chorokhi with Acharistskali (8.9 km^3) (Resursi 1974).

The main river in eastern Georgia is **Mtkvari** (Fig. 10.2). It begins in Turkey, at the height of 2720 m on the north-western slope of the Mount Kizil-Giadik and flows into the Caspian Sea. Its length is 1364 km; basin area 188 thousand km^2; its length within Georgia is 351 km (basin area 34,670 km^2). It is fed by snow, the rain, and underground waters. The Mtkvari River is characterized by strong floods. For example, in April 1968, the discharge of the Mtkvari River exceeded 2450 m^3 at Tbilisi city (average discharge 205 m^3/sec). The main tributaries of the Mtkvari River are: Didi Liakhvi (1.4 km^3), Ksani (0.4 km^3), Aragvi (1.8 km^3), Paravani (0.6 km^3), Ktsia-Khrami (1.6 km^3) Alazani (3.1 km^3), Iori (0.6 km^3).

On the northern slope of the Caucasus are also notable the following rivers: Tusheti Alazani (0.8 km^3), Tergi (0.75 km^3, Stepantsminda), Arkhotistskali (0.25 km^3, within Khevsureti), and Arghuni (0.17 km^3, within Khevsureti) (Gigineishvili 2000).

The territorial distribution of runoff is diverse. The average multi-year sum of the runoff of all the rivers of the country is 66 km^3, of which 75% is formed in western Georgia and the rest—in the eastern Georgia. 8.9% of the total river runoff enters from other countries. Most share of the transit runoff falls on the Chorokhi River (7.2 km^3), the catchment basin of which is almost entirely on the territory of Turkey.

The **altitudinal zoning of the runoff elements** is clearly expressed. The crestal zone of the western part of the Caucasus and the seaward slopes of the Achara Mountains are distinguished by abundant water. The average annual runoff reaches 3500 mm there, which is the highest value for the Caucasus. At the same time, on the Iori Upland, Kvemo Kartli Plain, and Mtkvari floodplains riverbeds, there are mostly dry gorges, where the water flows only during snow melting and heavy rains. The watersheds

Fig. 10.2 River Mtkvari in Tbilisi (Photo by L. Gadrani)

between the Iori and Mtkvari Rivers and between Iori and Alazani Rivers (the downstream) are considered the runoff less places.

Feeding sources. The rivers of Georgia are characterized by mixed feeding. Individual sources of feeding differ from each other by origin and moisture circulation speed. The runoff of the rain waters is formed fastest. The speed of its formation in the mountainous basins of Georgia is defined by minutes and hours. When feeding with snow and underground waters, the time spell between the falling of atmospheric precipitation and formation of river runoff greatly increases is defined by days and months, and during the formation of glacial meltwaters—it is defined by years (Gigineishvili 2000).

The share of feeding sources in the total runoff varies by taking into consideration the natural zones, the height of the place, and peculiarities of geological structures. The rainwater runoff on the southern slope of the Caucasus is reduced from west to east. With the increase in altitude, the runoff of snow and glacial meltwaters is reduced. The high underground runoff is characteristic for the rivers of highlands of southern Georgia.

The rivers of the Western and the Central Caucasus are distinguished by the high share of snow and glacial meltwaters. The main amount of glaciers is located in the basins of the rivers of Kodori, Enguri, Rioni, and Tergi, where the 95% of the glacial runoff is formed (Vladimirov 1991). The glacial runoff on the rivers of Eastern Caucasus is insignificant (Fig. 10.3).

The share of snow and ice meltwaters is especially high in the total runoff of small rivers flowing from the slopes of the Caucasus, the catchment basins of which are in the high mountainous zone. The high mountainous zone occupies only 16% of the entire territory of Georgia, but more than half of the snow meltwaters are formed there, which is due to the large amount of solid atmospheric precipitations.

The area of the glaciers of Georgia is 555.9 km^2 (Gobejishvili 2000). The area of 72.5 km^2 it covers the river basins on the southern slope of the Western Caucasus. In the western part of the southern slope of the Central Caucasus the glacial area is considerable and makes 396.4 km^2. The glacial area is smaller in the river basins of the eastern part of the southern slopes of the Central Caucasus and makes 4.8 km^2. On the northern slopes of the Caucasus, the Tergi River basin is distinguished—67.2 km^2. And the area of glaciers in the basins of the rest of the rivers is 15.0 km^2 in total. Glacial runoff varies according to the distribution of glacial areas. 91% of the glacial runoff is formed on the southern slope of the Caucasus, and only 9%—on the northern slope.

The glacial runoff is unevenly distributed according to individual river basins (Fig. 10.4). The Enguri River basin, where the 62% of the total glacier runoff is formed, is distinguished with the highest values both absolute and relative.

The rivers of the Black Sea coast are predominantly fed with rain waters. The share of

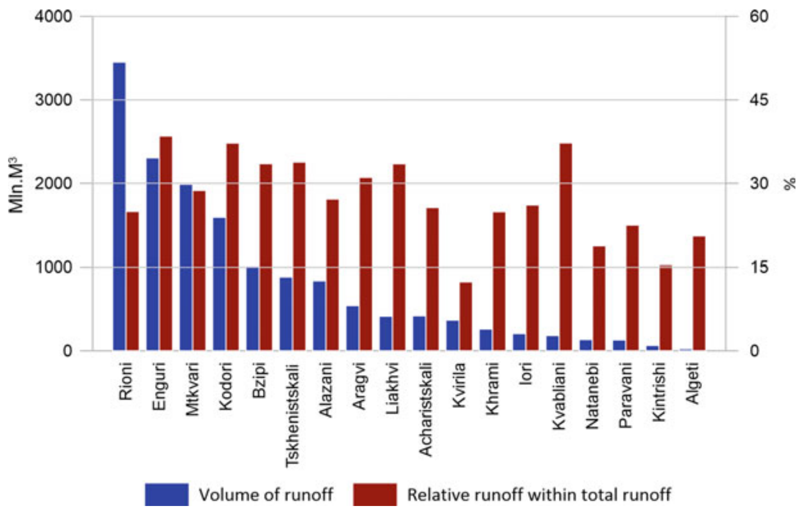

Fig. 10.3 Distribution of snow and glacial meltwater runoff according to the river basins

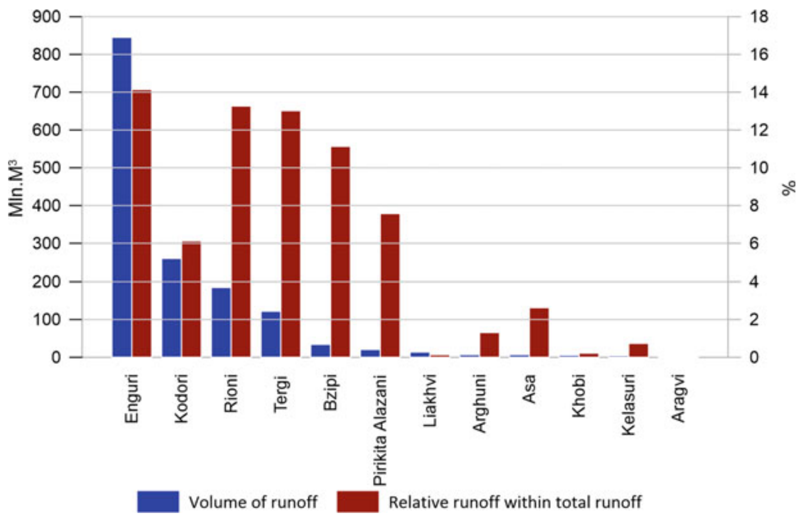

Fig. 10.4 Distribution of glacial runoff according to the river basins

rain waters in the total runoff is especially high (more than 70%) in the rivers of the plains of western Georgia that have the small water catchment basins. Such rivers are: Machara, Jumi, Chkhoushi, Ochkhamuri, Achkva, and others (Vladimirov 1991). The highest volume of rain waters is the Rioni River basin (Fig. 10.5). The highest relative values are in western Georgia, in the Kvirila and Kintrishi River basins. In this respect, the Algeti River is distinguished in eastern Georgia.

High groundwater runoff is typical for the river basins of southern Georgia, especially for Javakheti region. There are plenty of underground springs in the area spreading fissured lava rocks. Their total debit in the Paravani River basin reaches 12 m/sec, which is more than 60% of the total runoff of the river. The outflows of large springs in the Khrami River basin are concentrated mainly in its upstream, in the Ktsia River basin and their total debit exceeds 14 m/sec. (Vladimirov 1974).

The zonality of distribution of feeding sources is mainly violated by the heterogeneity of the structural rocks of river basins, and therefore, the rivers of both high and low relative underground runoffs are located side by side. The distribution of feeding sources is also violated in the karst

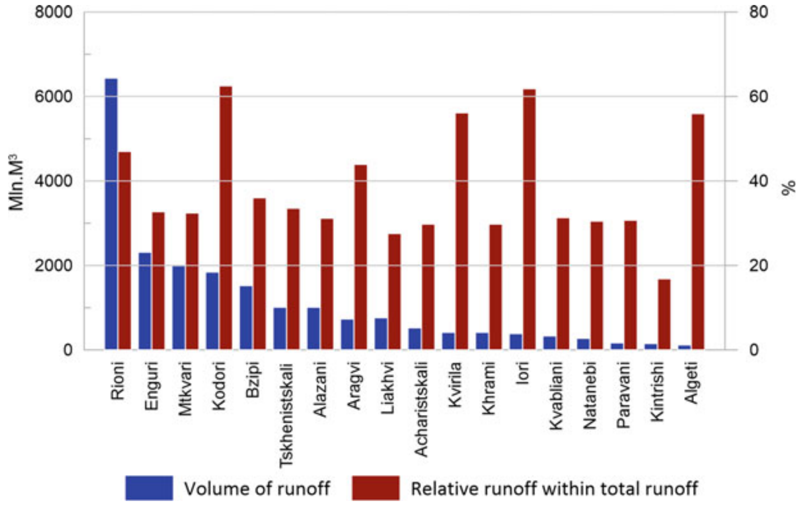

Fig. 10.5 Distribution of rainwater runoff according to the river basins

regions. Here the contours and areas of the water catchment basins of some of the rivers are different on the surface and underground. The underground water exchange between the river basins is characteristic for karst regions, and, respectively, the zonality is violated not only of the feeding sources but of total runoff as well.

Absolute maximum of underground runoff from the rivers of Georgia is in the Rioni River basin (Fig. 10.6). Rivers of eastern Georgia are distinguished by high relative underground runoff.

The rain waters dominate (44%), in the feeding of the rivers of Georgia then come snow and glacial meltwaters (31%). The Caspian Sea river basins are distinguished from the Black Sea river basins by the high relative underground runoff (Fig. 10.7).

Underground waters. Georgia is rich in underground freshwater resources. The underground freshwater used for drinking water supply is characterized by very low (0.2–0.3 g/l) and low (0.3–1.0 g/l) mineralization. The total reserves of these waters are 2.52 km^3, of which

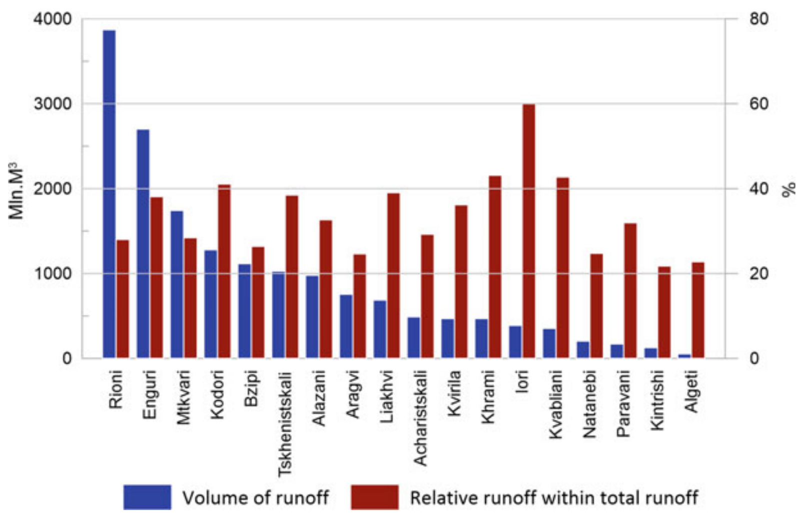

Fig. 10.6 Distribution of underground runoff according to the river basins

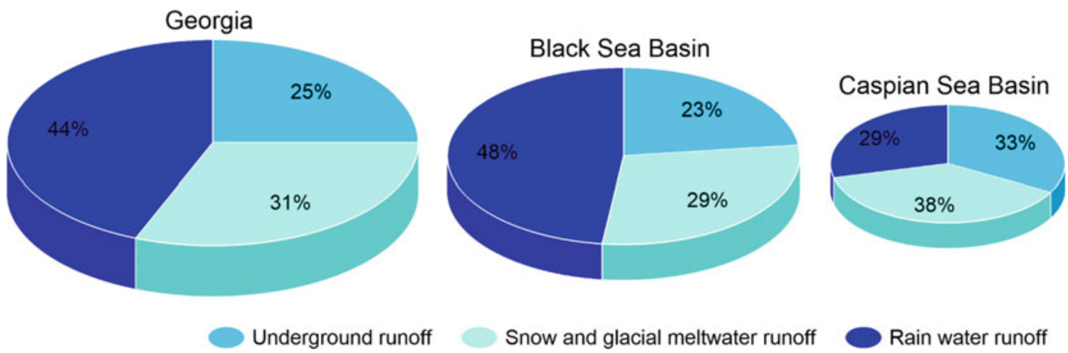

Fig. 10.7 The share of river feeding sources in the total runoff

one quarter belongs to very low mineralization waters. The total natural reserve of underground freshwater is 18 km^3 (Georgian SSR 1970), of which 2/3 is formed in western Georgia and the rest—in eastern Georgia.

It is notable that there is a tendency of increasing in water content of rocks along with the increase in elevation. This is explained by the fact that along with the increase in atmospheric precipitations by elevation, the role of condensation increases in the feeding the water-content horizon. As a result, the water-content complexes of high mountainous regions are more watery and have a large number of sources than the same complexes that have a lower location.

There are numerous karst springs and underground rivers in the areas of distribution of limestone massifs in western Georgia. The discharge areas of karst waters are usually at the feet of the mountain massifs. They are distinguished with high-quality drinking water. The karst springs with high debit are reliable resource bases for population water supply. The karst springs with stable regime are used for small HPPs. The debit of Mchishta—the most powerful karst spring of the Caucasus located in Abkhazeti near Gudauta is 10 thousand liters per second.

Very large freshwater outlets are related to the volcanic highland of southern Georgia—Samsari (2.0 m^3/sec), Ablari (2.0 m^3/sec), and Trialeti (3.0 m^3/sec) (Georgian SSR 1970).

10.1 Characterization of Some of the River Basins

10.1.1 Enguri River

Famous in the 17th-century French traveler Jean Chardin, after a long trip to the Caucasus and Georgia, publishes a considerable work, which gives information on waters of Georgia. In his work, Chardin describes the Enguri River, as a rapid and shallow river in its downstream. He writes: " Enguri, by which we have arrived, is a rapid river, one can travel very fast on it, but it is necessary to be cautious"; or in the second extract: "…We arrived at the mouth of the Atolphe River. Megrelians call this river Enguri. This is one of the big rivers in Samegrelo."

Archangelo Lamberti, a Roman Catholic Church missionary who was for 16 years in Samegrelo (1633–1649), published a special work in 1654 in Naples, dedicated to the description of Samegrelo. In this work, he describes the nature of Samegrelo, in particular, the rivers of Georgia including Enguri as well. He writes about Enguri River: "Enguri is rapidly flowing down from the mountains of Svaneti; in the hot days of the summer during the period of snow melting it becomes so watery that it is impossible to cross it by walking through water and it is convenient just to cross it by boats; the more the heat, the colder is the water that becomes very attractive among the cleansed stones. There are different species of fish in the river".

The Enguri River is described in Vakhushti Batonishvili's work: "Description of the Kingdom of Georgia". Vakhushti emphasizes the fast and turbulent flow and other peculiarities of the Enguri River.

The Enguri River (Fig. 10.8) **basin** is located in western Georgia. In the north, it is bordered by the Caucasus Mountain Range, in the south, in the upstream—by Svaneti Range, in the west—by Kodori and Akiba Ranges, in the east —by Samegrelo Range and its southern subranges, and in the southernmost—by the Black Sea (Resursi 1974).

The area of the Enguri River basin is 4060 km^2, which is 5.8% of total area of Georgia. 79.4% of the relief is average mountainous and high mountainous, only 20.6% is occupied by foothills and part of plains (up to the height of 800 m).

Hypsometric location of the Enguri River basin has a relevant effect on the vertical variability of meteorological elements. The average annual air temperature in the high mountainous, snowy, and glacier zone is 0 °C, and to the Black Sea along with the decrease in the elevation of the area, the average monthly and annual temperatures rise up to 14 °C. In the Enguri River basin, the temperature gradient is equal to 0.5–0.6 °C on each 100 m of elevation.

Annual absolute maximum air temperature is equal to 35 °C at Mestia; in the downstream of the basin, Zugdidi, and Anaklia it reaches 40–40.1 °C. Absolute annual minimum air temperature the upstream of the Enguri River basin falls down to −35 °C at Mestia, to −21 °C at Jvari, and in the Black Sea coastline the temperature

Fig. 10.8 River Enguri (photo by N. Kvirkvelia)

does not go below −12, −13 °C. The sum and duration of active temperatures over 10 °C, like the annual average air temperatures, increase from the upstream to downstream of the basin.

Atmospheric precipitations are characterized by uneven distribution in the Enguri basin; in the upstream of the basin, in the Svaneti basin it is 960 mm/year, in the foothills zone the amount of precipitations is much more—2158 mm/year, while in the Black Sea coastal zone it does not exceed 1458 mm/year.

Hydrothermal coefficient in all zones of the Enguri River basin is positive and is 2.0–2.5°, indicating that the farm crops do not require irrigation, but in some years, especially in the foothills and plain—terrace surfaces, the rain waters rapidly leak and soils dry out due to high temperatures; this is why the farm crops, especially the tea bushes, require additional water supply.

The main character of the hydrography of the Enguri River is defined by the Caucasus as a main watershed and at the same time the climatic barrier of the Caucasus. Here, the climate conditions change even over the smallest area, which together with the relief causes the sharp shift of the network of rivers both in horizontal and vertical directions.

The rivers mostly flow southwest and northwest. Due to the proximity of erosion basis, the length of the rivers is short; due to the heavy rains, they are distinguished with abundant waters creating dense networks and independent basins. The river network is particularly dense in the high mountainous zone; below the height of 700–2000 m, in the karst zone, the network becomes lighter and the underground river network is well developed. Below 700 m above sea level, the network becomes still dense at the coast of the sea.

The long rivers are originated in the eternal snow and glacier zone; in the upstream, they flow between the Caucasus Range and its parallel subranges. In the midstream, they break the mountain ranges and generate deep and narrow gorges. In the downstream they flow out in the Kolkheti swampy lowland, expand in the vast valleys and become too winded.

The Enguri River is a typical mountain river with its high sloping and rapid flow. It originates at the height of 2520 m above sea level with the junction of two streams flowing from the glaciers of Mt. Shkhara (5058 m) and Namkuani (4278 m) located in the Caucasus Range and flows into the Black Sea at the village of Anaklia.

The length of the river is 213 km, the total falling—2520 m, the average inclination—11.8 ‰, the catchment area—4060 km^2, and the average height of the river basin—1840 m. 242 tributaries with total length of 872 km conflow the river. Among them the following rivers are important: Adishchala (15 km long), Mulkhura (27 km), Dolra (20 km), Nakra (22 km), Nenskra (46 km), Tkheishi (18 km), Larakvava (17 km), Magana (24 km) Rukhi (21 km) and Jumi (61 km). The river basin is of asymmetric shape; the right side of the basin occupies the area of 2316.9 km^2 and the left side—1743.1 km^2. 74.5% of the basin is high mountainous and 25.5%—are foothills and plains. There are 174 glaciers in the high mountainous zone of the basin with the total area of 333 km^2.

The upper zone of the river basin from the head to the Nenskra River confluence is a mountain basin known as the Svaneti basin. From the north and north-east, this zone of the basin is bordered by the highest and glacial section of the Caucasus Range, with the average altitudes varying from 3000 to 3500 m. Here are the peaks of the main watershed mountain range of the Caucasus: Shkhara (5203 m), Tetnuldi (4851 m), Ushba (4696 m), Ailama (4544 m), and others.

The Enguri River gorge from the head up to the Ieli Village is box-shaped and then up to the Khaishi Village—V-shaped. The gorge becomes very narrow from Khaishi to Jvari Village. The width of the gorge bottom varies from 100–200 m to 10–30 m. The river terraces are found in separate sections. Their width is 100–200 m, and length—100–400 m. The slopes of the gorge are very steep and merge with the slopes of adjacent mountain ranges (Resursi 1974).

The Enguri River is fed by the glaciers and snow meltwaters, rain, and groundwaters. The glaciers and snow meltwaters and rain are

Table 10.1 Distribution of the Enguri River feeding sources

Station	Basin area, km^2	Basin average height, m	% from annual runoff				Annual runoff, million m^3
			Underground waters	Snow meltwaters	Glacier meltwaters	Rainwaters	
Dizi	1620	2490	21.8	28.3	25.8	14.2	2250
Jvari	3170	2220	30.0	32.0	21.0	17.0	4670
Darcheli	3660	2020	34.7	25.9	16.8	22.6	5300

important in the formation of annual runoff. The river water regime is characterized by floods during the warm period of the year and unsustainable low water during the cold period. Inundation caused by rains often coincides with the floods caused by melting of snow and glaciers. Inundation caused by rains is also frequent during the low water period as well. 80–82% of annual runoff flows during the warm period of the year when the snow and glacier melt intensely, and only 17–18%—in the cold period of the year. The icy phenomena on the river in the form of frost are observed only in January.

The Enguri River is characterized by high speeds (1.8–5.5 m/s), characteristic of mountain rivers. The bottom of the bed is uneven; it is blocked with rocks and large boulders. The river banks are mainly rocky, collapsed, and very steep (Table 10.1).

10.1.2 Rioni River

The Rioni River completely flows through Georgia. Its length is 327 km, basin area—13,400 km^2. It starts from the Mount Pasi on the southern slope of the Caucasus at the height of 2960 m above sea level. It flows into the Black Sea at Poti. From the head to the village of Glola, it flows to the south-east through the deep gorge, which is of trough form before it confluences the Zopkhitura River. It generates the vast floodplain and ramifies. Below Saglolo, it flows firstly to the south, then to the south-west into the deep and narrow gorge and develops a narrow intermittent floodplain.

The Rioni River basin is characterized by the diversity of landscapes. This has a substantial influence on its hydrological regime. It is fed by glaciers, snow, rain, and underground waters.

Flooding is in spring and summer, which is caused by seasonal melting of snow and glaciers and also by rainfalls. In the upstream, flooding starts early in April, in the midstream—in the first half of March and in the downstream—at the end of February. The maximum of flooding in the upstream is in the middle of June, in the midstream—in the last decade of May, and in the downstream—early in May. Flooding continues until the end of August. By the end of September starts the flooding caused by heavy rains, reaching the maximum in October-June. The lowest level is in winter (December–February), though in the downstream it is violated by inundations caused by rainfalls.

Average annual runoff of the Rioni River at Glola is 27.3 m^3/s, at Kutaisi—134 m^3/s, and at Sakochikidze—406 m^3/sec. The maximum discharge at Glola is 345 m^3/s, at Kutaisi—1440 m^3/s, with Sakochakidze—3000 m^3/s. Minimum expenditures at Glola—16 m^3/s, Kutaisi—22.0 m^3/s, and at Sakochakidze—34.0 m^3/s (Resursi 1974).

In spring the 38.8% of annual runoff flows in the Rioni River basin, in summer—28.5%, in autumn—18.4%, and in winter—14.3%. Distribution of runoff according to the feeding components is as follows: underground waters—34.7%, rain—32.5%, snow meltwaters—28.2%, and glacier meltwaters—4.6%.

Annually, Rioni brings 12.9 km^3 of water and a large amount of solid runoff to the Black Sea. The average annual amount of solid runoff increases from the head to the estuary: it is 96 thousand tons at Ghebi Village, 2.2 million tons—at Khidikari, 4.9 million tons—at the village of

Nomokhvani, and 6.9 million tons—at Sakochakidze. Frost and ice flow are common on the Rioni River. In the upstream and midstream, especially in the severe winter, in some places, the ice cover is formed.

The water of Rioni is characterized by average salinity (150–300 mg/l) and belongs to the hydrocarbonate class according to ionic composition. The river water catchment basin comprises almost half of all western Georgia, where the Kolkheti Lowland occupies only 19%. Important tributaries conflow the Rioni River in the Kolkheti Lowland. The main tributaries are: Jojora (50 km long), Kvirila (140 km), Khanistskali (57 km), Tskhenistskali (176 km), Noghela (59 km), Tekhuri (101 km) and Tsivi (60 km). The length of the eight tributaries is from 25 to 50 km, the length of 14 tributaries is from 10 to 25 km, and the length of the rest 355 tributaries does not exceed 10 km separately. Their total length is 720 km (Resursi 1974).

Rioni River is widely used for energy and irrigation purposes. Right on it, the Gumati reservoir of energy purpose is built, which should have provided the productivity of Gumati HPP-I and Gumati HPP-II. There is also the head building of the Rioni HPP, which has been in exploitation since 1934. In the south of Kutaisi, at the confluence of the rivers of Rioni, Kvirila and Khanistskali the Vartsikhe reservoir is constructed, by means of which the water is supplied to the Vartsikhe HPP cascade.

A head of the Tskhenistskali River, the second in size, is located on the southern slopes of the Caucasus Range, in the central part of the Caucasus Range, in the south of the Sharivtsek Pass, at the height of 2700 m above sea level, and flows into the Rioni River from the right side, at the village of Sajavakho. The length of the river is 176 km, the total falling is 2684 m, the average sloping—15,0 ‰, the water catchment area is 2120 km^2, and the average height of the basin is 1660 m above sea level.

897 tributaries of different sizes flow into the river. Among them, the following rivers are important: Zeskho (19 km long), Gobishuri (12 km), Laskanura (20 km), Kheledula (34 km), Lektareshi (24 km), and Janaula (21 km). Among the other tributaries, the length of the 13 rivers exceeds 10 km. The area of glaciers in the river basin is 12.9 km^2 (Resursi 1974).

A large part of the river basin is located on the southern slopes of the Caucasus Range, while the lower smaller part (30–35 km^2) is located in the Kolkheti Lowland. The basin is sharply divided into high mountainous, mountainous, and lowland zones. The high mountainous zone is located at a height of 2200–4000 m and is characterized by rocky relief. The mountainous zone occupies a large area of the basin and is characterized by deep gorges of the tributaries and fragmented relief. The height of this zone varies within 2000–3000 m. The lowland zone, located in the eastern part of the Kolkheti Lowland, is characterized by lowland relief, with the height up to 15–18 m.

The geology of the mountainous zone is represented by granites, gneisses, sandstones, limestones, and conglomerates, and the geology of the lowland zone—with new alluvial layers. The clay soils are common in the basin. The vegetation of the basin is characterized by vertical zoning. In the lower zone of the basin, up to 800 m, the deciduous forest is widespread, from 2100 to 2300 m—the mixed forest and the alpine meadows are found in the upper zone. Within the basin, a large area of Kolkheti Lowland is used for farm crops.

In the heads the river gorge is V-shaped; below from Tsageri town—box-shaped and in the Kolkheti Lowland—it is not expressed clearly. Bilateral terraces are found from the village of Mele to the village of Sakdari. Their width varies from 50–100 m to 500–700 m and height—from 4 to 8 m. The width of the river floodplain ranges from 10–20 m to 200–400 m.

The river bed is winded in the heads and is not ramified, but it is ramified from Tsageri town to the village of Larchvala and from the village of Matkhoji to the village of Khunjulori and then flows in one flow in the Kolkheti Lowland. The width of the flow in the Kolkheti Lowland varies from 20 to 120 m, depth—from 0.6 to 1.5 m, and the speed—from 0.8 m/sec to 1.5 m/sec.

The river is fed by snow, rain, ground, and glacier waters. Its water regime is characterized by the spring–summer flooding and the well-expressed low water in the winter season. During spring and summer period flows the 70–75% of annual runoff, in autumn—18–20%, and in winter—8–10%.

The river is used for irrigation and energy purposes. Above Tsageri town, a 6.5 km long tunnel is constructed from the left bank of the river, through which the 60.0 m^3/s water is being supplied to the Lajanuri reservoir of energy purpose from the Tskhenistskali River. The reservoir created on the river of Lajanuri, which receives additional feeding from the Tskhenistskali River, operates the Lajanuri HPP, the wastewater of which flows into the Lajanuri River and then into the Rioni River. Thus, the throwing of water from the Tskenistskali River into the Rioni River basin takes place. It flows into the Rioni River on the right side at the village of Gautskinari.

10.1.3 Alazani River

The Alazani River originates on the southern slope of the Caucasus, near the Mount Borbalo, at 2750 m above sea level. It flows into the Mingachevir reservoir (Resursi 1974). From the source to the confluence the locals call it Tsiplovanistskali, and after the combination of both rivers—Alazani. At the village of Kortabude the river flows out from the narrow gorge and flows through the wide Pankisi gorge at 18 km to the Ilto River confluence. Then it flows to the southeast in the Alazani Plain (Fig. 10.9); it takes southern direction from the confluence of the Agrichai River and flows into the Mingachevir reservoir in the territory of Azerbaijan. In the south-eastern part of the right side of the river, dry ravines are common.

Sights of Alazani heads are represented by a very complex relief—deep, narrow, and in some places canyon gorge is almost impassable, slopes are either steep or cliffy. The structural rocks are sandstones and clay slates. In this section, extensive outcrops are found both in Alazani and its tributaries' gorges. Areals of distribution of slates is under the intense physical weathering. Weathered materials move to the gorge bottom in the deep dingles and small ravines on the slopes and accumulate at the base of the slopes in the form of debris cones. In general, in this section of the gorge, the crests of the mountain ranges or the slopes of the gorges are bare or covered with grass cover. More below, Alazani is conflowed by the typical mudflow rivers of Lamazuri and Kvachadala from the right side, and the Samkuristskali and Khorajo—from the left side. The slopes of the downstream of the river gorges are covered with dense forest and the upstream—with grass cover.

In the tributaries of the Alazani River, the heads of which are characterized by powerful mudflow generating centers, occur both the structural (Lamazuri and Kvachadala Rivers) and turbulent mudflows (rivers of Batsara, Samkuristskali, and Khorajo). Forests, pastures, and soil cover are becoming more and more affected by the mudflows of Alazani and its tributaries in this region.

In the north the Alazani River basin is bordered by the southern slopes of the Caucasus Range, in the south and south-west—Kakheti and Tsivi-Gombori Ranges and Iori Upland, and

Fig. 10.9 Alazani Plain (Photo by Z. Turmanidze)

in the south-east—Azerbaijan. There are three types of relief in the basin: steep slopes of bordering mountain ranges; foothills with sloped part of the plain, which is mainly built from the debris cones brought by the Alazani River tributaries; and smooth part of the plain.

The orography of the Alazani River basin and the direction of the prevailing air masses (western, south-eastern) define the peculiarity of its climate. The basin is surrounded by high and medium mountains from three sides that protect the plain and foothills from the intrusion of the cold air masses.

The basin is open to the south-east, and the warm air masses intruded from there have a proper influence on its thermal regime and in general, on formation of climate. The air masses intruded from both sides in the basin promote falling of abundant atmospheric precipitations.

The river length is 390 km, basin area—16,920 km^2, total falling—745 m, average sloping—2.12‰. There are more than 500 rivers in the basin with total length of 1770 km.

Important tributaries of the Alazani River are as follows: Ilto (length 43 km), Khodashniskhevi (length 31 km), Stori (length 38 km), Turdo (length 28 km), Lopota (length 33 km), Chelti (length 28), Kisiskhevi (length 37 km), Duruji (length 26 km) and Chermiskhevi (length 35 km).

The left tributaries of the Alazani River flowing down the southern slopes of the Caucasus are characterized by abundant waters, narrow and deep gorges, and beds with rapids and waterfalls. They perform enhanced depth erosion, bring out large amounts of deposit materials in the downstream and form debris cones, then ramify and flow into the Alazani River through the narrow bed near the confluence. The right tributaries are characterized by relatively few water content and have a low falling.

Feeding sources of the river are as follows: underground waters—40%, rain waters—31%, snow meltwaters—29%.

Floods are common in the spring, sustainable low water period—in winter, inundations—during spring and summer heavy rains.

Amount of the Alazani River water resources (within Georgia) is 3.10 km^3 (570 mm). Left tributaries of Alazani, which flow from the southern slopes of the Caucasus, are distinguished by the abundant water content. Mudflows are characteristic of the tributaries of both sides of the river. The runoff module ranges between 49.0 to 9.00 l/sec km^2.

10.1.4 Tergi River

The Tergi River originates on the Greater Caucasus Mountain Range, on the northern slopes of the Mount Zilgakhokhi (3856 m) at an altitude of 3400 m and flows into the Caspian Sea on the territory of the Russian Federation, to the north of the Agrakhan Peninsula (Resursi 1974).

On the territory of Georgia, the river is conflowed by the first rank of 34 tributaries with the total length of 210 km. Among them the following rivers are important: Snostskali, Baidara, Mnaisi, Suatisi, Gimara, Desikami, Amali, Chkheri, Kuro and Kistura. The following rivers are the mudflow rivers: Mnaisi, Suatisi, Desikami, Baidara, Narvana, Amali, Chkheri, Kuro, Gveleta, Kabali, and Kistura. It is known that on August 17, 1953, and on 6 August 1967, the mudflow stream that passed the above rivers and other tributaries of the Tergi River, blocked the riverbed, after breaking of which the Kazbegi region suffered serious damage.

The Lower, Middle and Upper Jurassic shales, sandstones, limestones, and marls participate in the geological structure of the Tergi River. Latest (Quaternary) effusives, lime tuffs, travertines, glacial, and river deposits are also significantly distributed. It is notable that young volcanoes are located on a mountainous, fragmented surface of erosive origin.

Alpine and subalpine meadows are mostly common in the basin. There is almost no forest here. In some areas, mainly in the lower parts of the gorges of tributaries, the deciduous shrubs are found. The soil cover of the basin is mainly represented by mountain-meadow greensward and mountain-forest-meadow soils, some of which are washed.

The glaciers are widely spread in the basin, which plays an important role in the feeding of rivers. Among the glaciers, the Suatisi, Mna, Ortsveri, and Devdoraki are relatively large glaciers.

River gorge from source to the village of Resi is V-shaped. Downward, to the village of Okrokana it extends and gains a box-like form. In this section, where the width of the gorge bottom is 1–1.3 km, the Tergi River ramifies and creates several islands. The gorge again narrows at the village of Okrokana at a length of about 2 km, and then again extends. The river bed is moderately winded and in the widened areas—ramified.

The river is fed by glaciers, snow, rain, and groundwaters. Its water regime is characterized by spring–summer floodings and unsustainable low waters in other periods of the year. Spring and summer floodings, caused by melting of snow and glaciers and rainfalls, usually start in April, reach a maximum in July and end in September. Minimum water levels are observed in February. It is notable that in the individual years, from November to March inclusive, when the air temperature dropped down to -6.80, the bottom ice and light freeze is observed in the river.

The geodynamic conditions of the territory are defined by the erosion and mudflow phenomena occurred there. In the periods of abundant precipitation and especially snow melting, the debit of the Tergi River and its tributaries sharply rises, which increases the energy of their depth and lateral erosion impact compared to the background one. At such a time, along with erosive phenomena, the rivers are also characterized by mudflow action.

It is particularly true of the right tributaries of the Tergi River that originate from the steep and erosive slopes of the Mount Kabarjina. The gullied and bare slopes of Kabarjina, inclined both toward the Tergi River and Terkhena River, are constructed of volcanic pyroclastolite, loose materials and provide temporary surface flows with abundant material with combination of which the powerful mudflow streams are generated periodically at the base of the mountain.

The mudflow solid materials produced by relatively small tributaries (some of which are dry gorges, in which mudflows are also formed) flowing down from Kabarjina are transported downstream by the Tergi River. In addition to this, there are relatively small mudflow streams of tributaries flowing from the left slope of the gorge in the same section, which, as a whole, substantially increase content of solid deposit materials in the Tergi River.

Flowing from the Mount Kabarjina, the longest tributary of the Tergi River–Terkhena River, where the most powerful mudflows are formed, flows into the Tergi River from the right side.

One of the most dangerous geodynamical phenomena in the area is snow avalanches in autumn–winter and early spring periods, although the snow avalanches can not reach low altitudes, in this regard are not a great danger.

Aragvi River basin occupies the southern slopes of the central part of the highland of the Caucasus of eastern Georgia and the easternmost part of the Shida Kartli Plain (Mukhrani Valley). Its area is 2740 km^2. In the north it is bordered by the main watershed mountain range of the Caucasus; in the east, it is separated from the Iori River basin by the Kartli Range and in the west, there is a Lomi-Alevi Range—the watershed of the Aragvi and Ksani Rivers. Inside the basin, the Tetri Aragvi and Shavi Aragvi are separated from each other by the Mtiuleti Range. On the other hand, the Gudamakari Range is watershed of the Aragvi River and its tributary—Pshavi Aragvi (together with the Khevsureti Aragvi River). The depth of the river gorges in the middle and upstreams of the river basins is 1000–1500 m. Accordingly, the slopes of the mountain ranges are a steep.

Within the basin, two climatic zones are distinguished: 1. Moderate humid climate zone with moderate cold winters and warm long summers (within the heights of 600–1100 m); 2. Moderate humid climate zone, with cold winters and long summers (up to the height of 1700 m). Altitudinal zoning is well represented in the Aragvi River gorge. In the lowlands, the average annual temperature of the air is 9–11 °C, while it is 0.1 °C below zero in the Jvari Pass. The amount of precipitations increases according to the height and its value varies between 600 and 1700 mm.

The snow cover height is 1–2 m on average in the upper part of the basin. The upper and middle parts of the basin are mostly characterized by quiet weather.

Winds are characteristic of a crestal part of the mountain ranges, passes, and Mukhrani Valley. The climate the downstream of the Aragvi River basin is dry subtropical; west and east winds are dominated here and the amount of precipitation is 600–700 mm on average per year. Droughts are frequent; in the warm period of the year, evaporation greatly exceeds the amount of precipitation. Snow cover does not last long and the sustainable snow cover is rarely formed.

The hydrographic network of the Tergi River basin is dense and is represented by rivers, lakes, glaciers, and underground waters. There are mountains, foothills, and plain rivers. The main river network is created by the four Aragvi Rivers—Mtiuleti—Gudamakari and Pshavi–Khevsureti, the most important of which is Mtiuleti Aragvi. The Mtiuleti Aragvi (length 41 km) originates in the Keli volcano upland from the slopes of the peak Khorisari at an altitude of 3180 m above sea level. Up to the town of Pasanauri its name is Tetri Aragvi. The main tributaries are as follows: Gudamakari Aragvi, Amirtkhevi, Dgnaliskhevi, Arkala, Eretostskali, Chabarukhi, Gvidake, Pshariskhevi, Chirikiskhevi, Khadistskali and Sonchoskhevi.

From the left side, the Mtiuleti Aragvi River is conflowed by the Gudamakari Aragvi River at the town of Pasanauri. The Gudamakari Aragvi River is formed by joining the rivers of Bakurkhevi and Bursachiri at 1250 m above sea level. The length of the Gudamakari Aragvi is 29 km. The Pshavi Aragvi River (length 56 km) flows from the southern slope of the Mount Didi Borbalo. Its main tributaries are: Khevsureti Aragvi, Tvaliura Botanistskali, Akhadistskali, Sharakhevi with its tributary–Tseratouli, Charglula, Tsatsado, Maturkhevi, Gomekheoba, Kishkhevi, Lashari and Chakiskhevi.

The Khevsureti Aragvi River (24 km long) originates from the western slope of the Khevsureti Range. The main compound heads of the Khevsureti Aragvi River are the rivers of Gudanistskali and Gorsheghmistskali. From the tributaries of the Khevsureti Aragvi River, the following rivers are important: Ustamale, Buchukurta, Roshkistskali with its tributary—Abudelauri, Datviskhevi, Blostskali, Akushoskhevi, and Likokiskhevi.

The length of the Aragvi River is 107 km, total fall—2683 m, average sloping—9.1%, network density—0.7 km/km^2, the catchment area in the section of the confluence—2740 km^2 and the average height—1600 m. In the Aragvi Basin, including the Mukhrani channel, there are 716 rivers with the total length of 1926 km. The Aragvi River flows into the Mtkvari River at Mtskheta (443 m above sea level). The Aragvi River is fed by rain, snow, ground, and glacial waters. The average multi-annual water runoff at the village of Zhinvali is 1369 million m^3 and in the heads—1763 million m^3.

It is noteworthy that runoff's underground component is 47.1%, while the rest—27.7% belongs to snow and 25.2%—to rainwater (Vladimirov 1991). The river regime is characterized by the spring–summer flooding, unsustainable low water, and sustainable low water in winter. The average multi-annual water discharge at the village of Mleta makes 5.48 m^3/sec, maximum—68.0 m^3/sec, at Pasanauri, respectively—12.1 and 173 m^3/sec. The average multi-annual water discharge in the heads is 54.8 m^3/sec with the maximum discharge of 1140 m^3/sec of 1% provision. Flooding starts from the month of March. The sharp rise in the level is observed at the end of April and the high indices of water level are maintained during the month of May; decrease in the level starts at the end of August and lasts until mid-September. From September starts the low water period, which lasts until the next year floods (Table 10.2).

Maximum discharges are mostly observed in May–June period. During the observation period, the largest measured water discharge (811 m^3/sec) was observed in Jinvali on June 25, 1952. Minimum water discharges are observed in January–February. At this time the river is fed with groundwaters (up to 70%). In April-August, the watery river passes through the 71% of the annual runoff on average. Winter season is distinguished by low runoff and makes 11% of the

Table 10.2 Hydrological Data, average many years discharges, m^3/sec. (Osnovnie 1986)

Month/amount	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Annual
Zhinvali watch													
Average	17.8	18.2	26.8	61.6	94.6	86.4	58.3	40.8	33.5	32.0	26.4	20.8	43.1
Maximum	32.9	36.5	52.6	125.0	129.0	192.0	126.0	81.6	59.1	73.2	64.0	36.5	192.0
Minimum	9.4	9.4	11.7	23.5	41.6	44.8	30.2	21.0	16.7	16.1	13.0	11.1	9.4
Shavi Aragvi, at conflow													
Average	2.53	2.52	3.77	11.9	19.3	17.6	11.2	6.59	5.42	5.04	3.96	2.93	7.72
Maximum	4.50	4.46	7.02	26.6	30.1	26.8	16.9	15.9	11.4	11.9	8.66	5.38	10.0
Minimum	1.14	0.99	1.03	6.27	12.4	8.87	6.33	3.22	2.68	2.00	2.04	1.08	4.80
Tetri Aragvi, Pasanauri													
Average	6.28	6.05	7.74	16.9	23.1	20.4	15.8	12.0	10.2	9.63	8.42	7.02	12.0
Maximum	10.8	9.07	11.4	31.1	39.0	35.7	23.0	23.4	22.2	22.1	13.4	11.8	16.6
Minimum	3.26	3.15	4.30	8.78	13.4	3.2	10.6	8.71	6.38	6.18	5.05	4.34	8.84

*The row of observations on Khevsureti Aragvi and Pshava Aragvi water discharges is short (3–4 years)

annual runoff. The main part of the drifted deposit material is brought by the river during the flooding period (45–130 kg/sec.). Water turbidity in separate years is 6800 g/m^3, and sometimes 43,000 g/m^3.

The icy phenomena are unsustainable. The entire river does not freeze. In winter the icy edges and frosts are observed. The number of days with icy phenomena makes 23 days on average, the maximum index is 53 days (1948–1949). Water temperature varies from 0.6 to 0.7 °C (in December-February) to 18.1–18.7 °C (in June–August). The maximum temperature reaches 27.2 °C.

10.1.5 Lakes

Georgia is a country of small lakes. There are about 856 lakes there. The area of more than half of them is less than 0.1 km^2, because of that the total area of the lakes is about 170 km^2, which is 0.24% of the country's territory.

The number of lakes with significant size is 1.7% of the total amount of lakes, while their total area exceeds 88% of the total area of lakes.

The lakes differ by depth. Along with the deep lakes, the depths of which reach several dozens of meters (Ritsa—101 m, Patara Ritsa—76 m, Keli—63 m, etc.) the 2–3 tens of centimeters deep shallow lakes are represented (saline lakes of the Iori Upland and others). Here mainly prevail the 2–10 m deep lakes.

In the arid zone of eastern Georgia, some of the lakes are dried up at all during the summer and only filled up with water during the snow melting and rains.

Because of the small size of the lakes of Georgia, the water volume of the most of the lakes is not large and makes about dozen million of m^3. The volume of only the Tabatskuri Lake is more than 200 million m^3. The water reserve of the lakes of Georgia makes 723.24 million m on average and certain part of this volume is involved in the formation of rivers runoff.

The lakes of Georgia are quite varied by genesis too. The lakes were formed as a result of endogenous and exogenous geological processes.

The endogenous processes led to the formation of tectonic and volcanic basins. The lakes of tectonic origin are the Kartsakhi, Bazaleti, and other lakes, the lakes of volcanic origin are mainly the Javakheti Upland lakes: Paravani, Kakhisi, Tsero, Mandiashvili, Saghamo, and others.

The exogenous lakes include the lakes of river floodplains ("narionalebi"—in the downstream of the rivers of Rioni, Khobi, Supsa, and Alazani) and karst lakes (Satsurblia, Shavmoreva, and Devi).

Glacial lakes (Adueda adzizhi, Levani, Okrotskali, Nakhevartba, Sasvano, and many nameless lakes) are found in the Bzipi and Kodori Ranges: pool lakes (Ritsa, Keli, etc.)—in the Bzipi, Ksani and other river basins; lagoon lakes—in the Black Sea coastal zone (Paliastomy Lake in the Pichori River basin, Anishkhtsara and Inkiti Lakes—in the Bichvinta Cape, Nurie Lake—in the city of Batumi and, etc.); landslide lakes—Turtle Lake in Tbilisi, Udziro Lake—in the Gombori Range, Tsunda Lake—in the Mtkvari River gorge and others.

Some lakes have been transformed into artificial reservoirs; for example, Tbilisi water reservoir was created on the bases of three saline lakes (Kukia, Ilguniani, and Avlabari); Shaori reservoir—on the bases of two lakes (Kharistvala and Dzrokhistvala) and, etc.

The lakes of Georgia can be divided into outlet and inlet types of lakes. The outlet lakes discharge most part of their water on river runoff and evaporation, while they are fed by small tributaries, filtration, and wetland waters and atmospheric precipitations. The outlet lakes are mostly located in the high mountain zone and in the lowlands of Kolkheti and Mtkvari.

The inlet lakes are located in the watershed and in lowland regions with low humidity. Important water loss from these lakes occurs at the expense of the evaporation and infiltration.

The following groups of the lakes of Georgian can be distinguished according to the feeding sources: the first group of lakes is mainly fed with meltwaters (Adueda adzishi, Levani, Okrostskali, and other lakes, located above 2500 m above sea level in the upstreams of the rivers of Bzipi, Kodori, Enguri and other lakes); the lakes of the second group are predominantly fed with atmospheric precipitations (Didi Bebesiri, Patara Benesiri, Inkiti, Alian and others); the third group of lakes is fed mainly with underground waters (Paravani, Tabatskuri, Kartsakhi, Kakhisi, Keli and other lakes); the river waters are involved in the feeding of the forth group of lakes (Ritsa, Patara Ritsa, Saghamo, Khanchali, Madatapa, and other lakes); the lakes of the fifth group are fed with atmospheric precipitations and wetland waters (Paliastomi, Patara Palastomi, Grigoleti, and other lakes).

The water level regime of the outlet lakes is significantly conditioned by the water regime of the rivers flowing through them. This group of rivers is characterized by a large amplitude of levels varying within 0.8–1.0 m and more.

The inlet lakes, which have unimportant tributaries, are characterized by rising levels only during heavy rains and snow melting. This rise in levels is defined by several dozen centimeters.

Water in the lakes of Georgia is unsuitable for drinking, as their mineralization does not exceed 500–700 mg/l in every season of the year. The exception is the smallest lakes without runoff of the Mtkvari-Alazani intermountain cavity, mineralization of which in some seasons (sometimes on average per year) reach 2500–2000 mg/l. (Khmaladze 2009).

10.2 Characterization of Some of the Lake Basins

The Ritsa Lake is located in the Bzipi River basin, in the deep gorge of the Lashipse-Iupshara River at a height of 884 m above sea level. This is the outlet lake.

The lake's water catchment area is 154 km^2. Its high mountainous, alpine relief is strongly fragmented. The earliest trace of old glaciations can be observed above 2000–2200 m. The river of Lashipse and its tributaries flow through the trough gorge. There can be found cirque forms of the relief that are often occupied by lakes (up to 15).

The forest, subalpine and alpine zones with their characteristic soil-vegetation covers are well represented in the basin. Subnival zone is located over 2700–2800 m above sea level.

The Ritsa Lake basin is characterized by a high density of hydrographic network (2.0–2.5 km/km^2), which is caused by the abundance of atmospheric precipitations and steep slopes. Out of the six rivers flowing into the lake the main river is Lashipse, the area of the basin of which (142 km^2) is 92.2% of the whole area of the lake basin. Its head is located near the crest of the Caucasus. The resort of Avadhara, famous with beauty and mineral springs is located in the river basin; there are several turquoise lakes of glacial origin at the head of the river. Famous with big and tasty trouts, the deep Mzi Lake feeds Mzimna—one of the tributaries of the Avadhara River.

Streams flow into the lake from the east, north, and northwest. Only one river—the Iupshara River is flowing out from the lake, which disappears in the limestones and boulders after 0.5 km and again flows out on the surface below 2 km.

The lake has the uneven shape. It is stretched from east to west and southwest. The bank line ruggedness coefficient is 1.7. The lake banks are mostly high. To the east, where the Lashipse River forms delta, and in the north-western part, in the confluences of the Psei and Atsetuka Rivers, the low banks are observed (Apkhazava 1969).

The southern slope of the Atsetuka Range, bordering the Ritsa Lake from the north, is followed by three gorges. The three tributaries of the Ritsa Lake flow into them generating numerous waterfalls on the slopes. Especially interesting and beautiful is the eastern stream, which represents the stairs of the waterfalls from the head to the confluence.

Ritsa is the deepest lake in Georgia. Its ultimate depth is 101 m. In the lake, its tributaries bring cold waters, although the water surface is heated anyway in the summer to 18–20 °C. In the depth, the temperature rapidly falls down and reaches 4.5–5.0 °C near the bottom. Because of the cold water, there is a lot of trout in the lake and its tributaries and there is no other fish found here.

The Ritsa Lake levels fluctuation regime is mainly determined by the water regime of tributaries. In the spring, the rise in the level due to intensive snow melting mostly begins late in March–early in April and coincides with the starting of flooding on its tributaries. The highest levels are observed in May, rarely—in the beginning of June. The rise in level in spring is 1.5–2 m on average. The maximum intensity of the rising in water level does not exceed 60 cm in 24 h. The reduction of levels is gradually underway and continues until the end of August and beginning of September. A secondary minimum of the level regime is observed in September, and the secondary maximum is caused by rains—in October, after which the decrease of the level begins until February–March.

The Ritsa Lake belongs to the number of lakes in Georgia with a weak mineralization. The average annual mineralization of water is 66 mg/l and mainly contains: HCO_3 (approximately 39 mg/l), Ca, SO_4, Na, K, Cl, and Mg.

The color of the lake water changes according to the seasons. In the spring, during high levels, it is green-yellow, and in winter—dark blue-blue.

According to scientists' opinion on the origin of the Ritsa Lake, once, as a result of a strong earthquake, the Mount Pshegishkha built with limestones collapsed and the formed boulders reached the Lashipse River gorge and blocked it with over 100 m high dam. The mountain collapsed due to the fact that the Pshegishkha limestone massif was full of fractures and karst cavities, generation of which is still extensively underway in the limestones. Similarly was formed the Amtkeli Lake on October 3, 1891.

Ritsa Lake basin is a Strict Nature Reserve. Fishing, hunting, and other activities that deprive the beauty of nature are prohibited there. Therefore, in the deep and untouched forest that surrounds Ritsa Lake, there are many wild animals and birds. Here, along with good and attractive nature, is a healthy climate that attracts many tourists.

The largest lake in Georgia according to the mirror area (37.5 km^2) is the **Paravani Lake** (Fig. 10.9).

"And the lake is largely full of fish, but tasteless, because in the summer in its vicinity there stay goats, cattle and other domestic animals' herds from Kartli and Kakheti, and their dungs get into the lake through the melted snow, and because of that it is said to be tasteless. Here is the spring, if someone is too belly full or fat and drinks it, it will melt him like fire does to fat" (Vakhushti Bagrationi 1997).

It is located at 2073.5 m above sea level. It is an outlet lake. From its southern part the Paravani River—the right tributary of the Mtkvari River flows out.

The basin area (excluding the lake area) is 234 km^2. The lake occupies the northern part of the Paravani depression between the Samsari and Javakheti Ranges.

Because of the heavily fissured terrain and dry climate, the hydrographic network is weakly developed here. There flow three permanent tributaries in the lake: the Shaori River (Shashka, Kirkh-Bulakhi), Sabadostskali, and one nameless small stream.

The lake was formed in the west due to the blocking the river gorge by a lava descended from the Samsari Range in Pleistocene.

The volcanic cone (Koyundag) located in the northeast of the Paravani Lake is called Chikiani by Vakhushti. It is completely volcanic glass (obsidian) mountain, with a different color volcanic glass under the soil and weathering crust, and abundant glass fragments are scattered on the mountain slopes.

According to the scientists, the Paravani Lake represents the deep and extensive lake that has appeared here several hundred thousand years ago. Then the depth of the Paravani Lake should not be less than 110–120 m and the surface area —less than 52 km^2. The lacustrine sediments on the lakebed indicate its deep depths in the past; the thickness of sediments reaches 90 m near the eastern shore. In addition, near the village of Pogha, the river Pharavani, which starts from the lake, has cut the 20–25 m deep gorge. It is obvious that the lake's level was higher than 20–25 m before the occurrence of the gorge and the same was the depth of the lake.

For many hundreds of thousands of years, the drying and permanent rivers that flow into the Paravani Lake, have brought a lot of debris material from the slopes of Samsari and Javakheti Ranges and almost completely filled it up. In addition, the Paravani River cut down the gorge and the level of the lake was decreased. As a result of this, instead of the deepest lake, there is a shallow lake with maximum depth of 3.3 m.

The weak development of algae is associated with the strong winds that lead to the waves during entire summer. Because of the constant waves, the water in the lake is always brown and its transparency is very low as well (0.3 m and sometimes even lower).

In winter the lake surface is covered with thick ice. Often its thickness is more than half a meter, and sometimes it reaches 70–80 cm. In such a time, the inhabitants of the coastal villages move on the lake with sledges and significantly shorten the road.

In winter the water in the lake is clean and transparent, while on the surface of the lake, during the frequent storms, there is such a snowstorm that it is impossible to see another bank of the lake (Fig. 10.10).

The Paravani Lake is in this condition from November to April. During this period, the fish in the lake covered with thick ice has no oxygen, and they move toward the north-western bank of the lake, where strong springs flow out and a narrow strip of lake remains ice-free for a long time.

In the second half of April, the ice cover starts melting. Wind also stipulates this, breaks the ice, and accelerates melting. In early May (sometimes even at the end of April) the smooth ice cover is no longer on the lake, the Paravani River is also released from the ice and it slowly carries away the ice fragments from the lake.

Soon the lake is completely free of ice. This is the time when snow starts to melt in the lake and even the dry gorges turn into the turbulent streams. The tributaries of the Paravani Lake become larger and the level of the lake rises rapidly.

In case the snow meltwater flows directly into the lake, its level will rise faster, but the

Fig. 10.10 Paravani Lake (photo by N. Bolashvili)

considerable part of the water flows into the fissured lavas and increases the groundwater supply. That is why the springs are abundantly flowing out of the western banks of the lake, or from other parts of the basin and feed the lake all year round with almost unchanged debit.

The rise of the lake level continues until the end of May or the first half of June. At this time a large part of the snow in the basin is already melted. From the second half of June, the level decreases until it reaches the minimum in August–September, and then there is the slightest increase in the level until the lake is not covered by ice in the end of November or early December. The temperature of spring waters is low (3–5 °C), but the spring waters still prevent the freezing of the lake. Strong winds also prevent to the creation of the ice cover that are not rare in the second half of the autumn. The windbreaks the thin ice and thus delays the occurrence of the ice cover. If not for the springs and the winds, the Paravani Lake would have been covered by smooth ice, at least 15–20 days earlier.

From the hydrochemical point of view, the Paravani Lake belongs to the number of lakes with weak mineralization. Average annual mineralization of water is 80 mg/l, which varies from 50 to 120 mg/l/year. Weak mineralization is caused by the basin's structural volcanic rocks, which are hard soluble, and by the fact that it is the outlet lake. From cations the quantity of HCO_3 is important, and from the anions—quantity of Ca. Maximum mineralization is observed in winter and summer, and minimum—in the spring.

The color of the river is very variable due to frequent waves. During the warm period of the year, water is mostly greenish-brown. In winter, under the ice, water is blue. Water transparency varies between 0.2–1.6 m (Apkhazava 1969).

Tabatskuri Lake. "The lake of Tbiskuri is pure water, sweet and good to drink; environment is coniferous, woody, grass-flowered, with springs and full in trouts, large and small ones and very tasty…" (Vakhushti Bagrationi 1997).

It is located at 1997 m above sea level. It is believed that the lake water flows into the southeast through the underground path and connects the Ktsia-Khrami waters with the Kizil-Kilisa and Ozneni springs. Therefore, the Tabatskuri Lake is included in the Ktsia-Khrami basin.

The water catchment area with the area of 83.1 km^2, is located in the northern part of the Samsari Range and is surrounded by volcanic mountains from all sides. In the northwest, the Mshrali Mountain is located that descends to the lake and forms a steep bank.

Shuamta is located in the north, which gradually descends to the lake and forms the north-eastern sloped banks. On the east of the lake, a few kilometers away from it the extinct volcanoes of Tavkvetili and Shavnabada are erected. The cut coned lava flow of Tavkvetili gradually descends to the lake and forms the wavy upland. As for the Shavnabada two-headed extinct volcano, at first, it descends sharply, and then in stairs from the north-western side, and from the southeast, it is bordered by a wavey, elevated plain, which forms the steep, cliffy banks. The surface of the basin is slightly fragmented.

Hydrographic network of the basin is poor, which is caused by its geological structure. The young andesite, basalt, and dacite lavas, which form a lake basin, are distinguished with frequent cracks that allow the rain and groundwater to leak easily. There are only two small permanent tributaries in the lake—one of them flows into the bay of the Tabatskuri Lake from the north and the other—into the Molity Bay from the west. There are several small lakes in Tabatskuri basin.

In the north of the lake, there are three small islands, two of which are covered during the rising in water level.

The banks of the lake are mostly high and steep, the underwater slopes of the basin are also steep everywhere, only the north-eastern part is exception, where the slope descends steeply toward the lakebed.

The average depth of the lake is more than 15.5 m, and the maximum depth of the lake exceeds 40 m in its western part.

The hygrophilous plants and algae are weakly represented on the lake. In the bays, the bottoms are covered with large pillows of blue-green algae.

Minimum water level in the lake is mainly in January–March. The most minimum—is in February. Rise in water in the lake is observed in the spring, in mid-April, which is associated with an intensive melting of snow in the lake basin. The monthly maximum level is recorded in June and lasts for 20–35 days.

Maximum average monthly temperature of the water surface is observed in August—14.9 °C. Water cooling starts from August. In December the water surface temperature approaches 0 °C. Lake is covered with ice in the third decade of December. The ice cover reaches 40–50 cm, which can reach 80 cm during a strong frost. At this time, residents of Tabatkuri Village cross it with sledges and shorten the distance to Akhalkalaki.

Waves are often on the lake. Wave height may reach 0.8–1 m. In the lake, there is a surface flow that is of drifting character.

Lake water is characterized by a weak mineralization. Total mineralization is 50–70 mg/l, which is determined by the sustainability of volcanic rocks.

Despite the frequent turbulence, the water is clean and transparent in the lake and the transparency is 3–4 m; in winter it increases and is 8–10 m. Watercolor is bluish-green, used for drinking, suitable for household and industrial purposes, as well as in agriculture.

In the lake, until 1930, only local trout was inhabited. In later years there were artificially bred common carp, ripus, whitefish, and European cisco (Table 10.3).

10.3 Reservoirs

The reservoir is an artificial water storage that serves to regulate the river runoff unevenly distributed by territories and periods of the year for optimal use of water resources.

In the reservoirs of Georgia, a significant part of its water resources are accumulated; 44 water reservoirs are currently in operation with the volume over 0.5 million m^3. Their total volume

Table 10.3 Hydromorphometric characteristics of the important lakes of Georgia (Apkhazava 1975)

No	Name	Height above sea level, m	Mirror area, km^2	Basin Area, km^2	Maximum depth, m	Medium depth, m	Volume, million m^3
1	Amtkeli Lake	512	0.58	153	65.0	29.6	18.5
2	Bazaleti Lake	878	1.22	14.4	7.0	4.5	5.55
3	Bareti Lake	1621	1.34	9.3	1.3	0.82	1.10
4	Didi Bebesiri Lake	15.9	0.61	17.5	4.5	2.3	1.40
5	Didi Okrotskali Lake	2421	0.10	2.2	26.5	12.0	1.20
6	Grdzeli Lake	1584	0.08	0.41	3.9	2.02	1.63
7	Kartsakhi Lake	1799	26.3	158	1.0	0.73	19.3
8	Lamazi Lake	2808	0.11	1.48	16.5	11.4	1.25
9	Lisi Lake	624	0.47	16.1	4.0	2.60	1.22
10	Madatapa Lake	2108	8.78	136	1.7	1.08	9.5
11	Mrude Lake	2545	0.26	7.8	8.3	5.3	1.42
12	Didi Mtsra Lake	2184	0.15	1.66	42.0	17.9	2.68
13	Paliastomi Lake	−0.3	18.2	547	3.2	2.6	52.0
14	Paravani Lake	2073	37.5	234	3.3	2.42	90.8
15	Partotskari Lake	−0.3	0.21	1.17	3.5	2.1	4.41
16	Didi Ritsa Lake	884	1.49	155	101	63.1	94.0
17	Patara Ritsa Lake	1235	0.10	2.95	76	33.8	3.25
18	Saghamo Lake	1996	4.81	528	2.3	1.6	7.7
19	Tabatskuri Lake	1991	14.2	83.1	40.2	15.5	221
20	Didi Tobavarchkhili Lake	2650	0.21	1.12	35.0	15.8	3.31
21	Khanchali Lake	1928	13.3	176	0.8	0.48	6.4
22	Didi Tsitelikhati Lake	2779	0.23	2.42	53	19.3	4.56
23	Tsurbliani Lake	1568	0.12	0.32	3.3	1.82	2.18
24	Keli Lake	2914	1.28	7.56	63.0	27.8	31.7
25	Abuli Lake	2176	0.8	8.30	1.35	0.9	0.76
26	Archvebi Lake	3078	0.13	4.89	7.9	4.2	0.55
27	Bughdasheni Lake	2040	0.39	69.3	0.9	0.42	0.16
28	Grigoleti Lake	−0.3	0.10	0.38	5.0	2.75	0.28
29	Inkiti Lake	−0.8	0.40	19.2	3.2	1.9	0.81
30	Jandari Lake	291	10.6				
31	Kartsakhi Lake	1799	26.3	158	1.0	0.73	19.3
32	Kvedi Lake	1567	0.09	11.8	14.5	8.2	0.71
33	Kelitsadi Lake	3196	0.05	0.14	9.3	5.5	0.28
34	Maltakva Lake	0.2	0.03	0.23	6.5	3.9	0.12

(continued)

Table 10.3 (continued)

No	Name	Height above sea level, m	Mirror area, km^2	Basin Area, km^2	Maximum depth, m	Medium depth, m	Volume, million m^3
35	Sakeni Lake	1273	0.01	3.1	4.2	2.1	0.02
36	Satsurblia Lake	1076	0.02	0.53	7.5	3.55	0.07
37	Tsero Lake	1808	0.02	0.62	6.6	4.2	0.09
38	Ertso Lake	1711	0.31	5.85	19.0	2.1	0.65
39	Leliani Lake	1554	0.07	0.18	2.7	1.43	0.10
40	Levani Lake	2815	0.06	1.38	2.8	1.8	0.12
41	Lurji Lake	2596	0.07	2.63	1.9	1.1	0.08
42	Godorebi Lake	2736	0.01	0.51	3.9	2.8	0.03
43	Gorapi Lake	2175	0.08	2.8	15.6	7.7	0.59
44	Ghrma Lake	1560	0.11	0.27	2.3	1.26	0.14
45	Dabadzveli Lake	1726	0.01	0.25	4.6	2.9	0.03
46	Datvi Lake	3066	0.06	0.22	5.2	3.1	0.19
47	Devi Lake	1370	0.02	0.78	10.5	4.9	0.10
48	Derikvaradzishi Lake	2531	0.08	0.4	22.0	8.1	0.65
49	Imnati Lake	0.6	0.06	0.48	2.0	1.2	0.07
50	Zresi Lake	1720	1.77	48.4	0.75	0.45	0.80

is 3.32 km^3, and the annual renewable useful volume—2.27 km^3.

The total area of the reservoir water surface is 163 km^2, which is 23% of the territory of Georgia.

Among these reservoirs, eight are built in western Georgia and all are of energy purposes except for one irrigation reservoir. Their overall useful volume is 0.85 km^3. The relatively low level of humidity of eastern Georgia stipulates the fact that most of the reservoirs of eastern Georgia are of irrigation purposes. Construction of several water reservoirs has been suspended.

Complex purpose water reservoirs serve several types of water consumption. For example, the main purpose of Zhinvali water reservoir is the energy, irrigation, and drinking water supply. However, more or less all reservoirs, except for the main purpose, are used for fish farming, recreation, and mitigation of natural phenomena effects such as floods. It should be noted that in many countries the special dams and reservoirs are being constructed with the only purpose to fight with the floods (Fig. 10.11).

Some of the reservoirs of Georgia are created in the basins of former lakes. Among them are the Shaori, Tbilisi, and other reservoirs. Some artificial reservoirs are actually natural lakes, but conditionally they are considered as water reservoirs because they are fed by artificial channels. They include the Kumisi Lake (the high-mineralized (2700 mg/l) and useless for economy water of which has been released and is currently supplied by the Algeti River with the channel), Jandari Lake, and others.

A substantial part of the water reservoirs is created in the river gorges through the dams by blocking the river bed. Among them are the Jvari, Lajanuri, Tsalka, Zhinvali, and other reservoirs.

Most of the reservoirs of Georgia (Jvari, Tkibuli, Tbilisi, Zhinvali, Marabda, etc.) have been created for seasonal regulation of river runoff, while the reservoirs of Shaori, Sioni, and Tsalka—for multi-annual regulation. The Gali, Lajanuri, Gumati, Vartsikhe, and other reservoirs are able for only a daily regulation.

Fig. 10.11 Jinvali Reservoir (photo by N.Bolashvili)

Fig. 10.12 Enguri Dam (Photo by R. Tolordava)

The reservoirs are distinguished with fast turbulence and renewal of their water masses. For instance, in the Jvari water reservoir, renewal of water supply is made in 125 days, and in the Sioni reservoir—in one year (Khmaladze 2009) (Fig. 10.12 and Table 10.4).

Table 10.4 Characteristics of main reservoir of Georgia (Metreveli 1985)

#	Water reservoir	Feeding source	Mirror area, km^2	The year of entry into the exploitation	Volume of water reservoir, million m^3		Usage, purpose
					Full	Useful	
1	Zhinvali	Aragvi River	11.5	1986	510	370	E, I, D, annual, in complex with Samgori and Sioni reservoirs
2	Sioni	Iori River	10.4	1965	325	300	E, I, F, D, seasonal, in complex with Samgori water reservoir
3	Tsalka	Ktsia River	33.7	1946	312	292	E, I, multi-annual
4	Samgori	Iori and Aragvi Rivers	11.8	1954	308	155	I, D, F, D, seasonal, in complex with Sioni reservoir
5	Dali	Iori River		1992	140	133	I, seasonal
6	Algeti	Algeti River	7.2	1983	65.0	60.0	I, seasonal
7	Jandari	Mtkvari River	10.6	1967	52.0	23.0	I, F, seasonal
8	Zonkari	Didi Liakhvi River	7.6	1981	40.0	39.0	I, seasonal
9	Kumisi	Mtkvari River	5.4	1964	11.0	4.00	I, seasonal
10	Dmanisi	Dmanisi and Mashavera Rivers		1977	11.0	10.8	I, seasonal
11	Nadarbazevi	Didi Liaxvi River		1966	8.20	7.20	I, seasonal
12	Narekvavi	Narekvavi River	0.56	1978	6.80	5.60	I, seasonal
13	Shaori	Shaora River	13.4	1955	90.0	87.5	E, seasonal
14	Tkibuli	Tkibula River	12.1	1956	80.0	65.7	E, seasonal
15	Gali	Eristskali River	8.2	1978	145	110	E, daily
16	Gumati	Rioni River	2.4	1958	39.0	13.0	E, daily
17	Lajanuri	Tskhenistskali and Lajanuri Rivers	1.4	1966	26.4	17.6	E, daily
18	Vartsikhe	Rioni, Kvirila and Tskhenistskali Rivers	5.1	1976	14.6	2.40	E, I, dailY
19	Jvari	Enguri River	13.5	1984	1102	676	E, F, seasonal

E—Energy; I—Irrigation; F—Fish farming; D—Drinking water supply

The water reservoirs with dams of western Georgia are created only for using in energetic, in order to accumulate water resources for hydropower plants. Among them, the largest Jvari water reservoir was specially built for the Enguri hydroelectric power plant.

Reservoirs of eastern Georgia are mainly for melioration purposes. The only exception is Zahesi reservoir, which was built for the first power plant of the South Caucasus, and the Tsalka water reservoir, which feeds 1st and 2nd hydroelectric plants of Khrami HPP.

At the same time, the four water reservoirs of eastern Georgia—Zhinvali, Tbilisi Sea, Sioni, and Tazvaskaro—are of complex use.

Zhinvali water reservoir is used in energetics (Jinvali HPP), for water supply of Tbilisi and farmlands irrigation purposes.

The Tbilisi Sea is created for recreational purposes, but at the same time, it is used in water supply and melioration works of Tbilisi's eastern districts.

Sioni reservoir feeds the Sioni HPP and at the same time, it is used for farmlands irrigation purposes.

Most of the reservoirs are located in the ravines of the rivers; often (e.g, the Tbilisi Sea) near the heads of the rivers. At the same time, natural lakes that are fed by underground springs are used for some water reservoirs (e.g., Kumisi). Additional water resources are mobilized from the rivers, which are supplied with water channels and pumping stations.

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11 Glaciers

Ramin Gobejishvili

Abstract

Spatial distribution of the modern glaciers in the territory of Georgia is presented in this chapter. There are 725 glaciers in Georgia with a total area of 369.8 ± 8.7 km^2. Modern glaciers are unevenly distributed between the different river basins. Main glaciers, their physical features, and current movements are described below.

Spatial distribution of modern glaciers in the territory of Georgia is conditioned by the peculiarities of atmospheric processes, morphological-morphometric conditions of relief, and their interaction. The main centers of glaciation are associated with the higher elevated watershed range of the Caucasus and the Kazbegi massif. Separate centers are located in the sub-ranges of the Caucasus, such as: Bzipi, Kodori, Samegrelo, Svaneti, Lechkhumi, Pirikita, and others.

There are 786 glaciers in Georgia in total, with the total area of 555.9 km^2. The glaciers are mainly concentrated in the basins of Enguri, Rioni, Kodori, and Tergi River, where there are located at 4300 m and higher peaks (at this elevation starts the glacial zone in the Caucasus). 85.2% of the total number of glaciers and 94.9% of the total area of the glaciers registered in Georgia are located in these basins (Table 11.1).

Among the various river basins, the leader place occupies the Enguri River basin, the relief of which is the highest hypsometrically. 38.0% of the total number of glaciers and 57.7% of the total area of the glaciers of Georgia are located in this basin. The largest glaciers of Georgia are located in the Enguri gorge: Lekhziri (area 35.8 km^2, length 12.2 km), Tsaneri, Chalaati, Adishi, Khalde, and others.

Among the glaciers of the Caucasus, the tongue of the Chalaati glacier descends to the lowest height, to the forest zone, to 1850 m. The Adishi glacier (Fig. 11.1) is very beautiful (length 7.6 km, area 10.2 km^2); its firn valley is located in the glacial zone, higher than 4000 m. After leaving the firn, it develops 1500 m high and 800 m wide grandiose icefall, and the 2.5 km long slightly sloped glacier tongue ends fan-like at a height of 2380 m. By number the glaciers of the Kodori basin are in the second place—20.4%; then follow the glaciers of the Rioni (14.3%) and Tergi (12.6%) River basins. According to the glacial area, the share of the Rioni River basin is 13.5%, the Tergi River basin—12.1%, and the Kodori River basin—11.6%. The rest of the river basins are far behind the

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Table 11.1 Distribution of glaciers according to the river basins

Name of the basin	Number of glaciers	Glacier area, km^2
Bzipi	18	7.22
Kelasuri	1	0.74
Kodori	160	64.54
Enguri	299	320.47
Khobi	16	0.88
Rioni	112	75.1
Liakhvi	16	3.95
Aragvi	3	0.8
Tergi	99	67.19
Asa	9	2.59
Arghuni	17	2.7
Pirikita Alazani	36	9.7
Total:	786	555.88

Fig. 11.1 Adishi glacier (photo by R. Gobejishvili)

above-mentioned glaciers both by number of glaciers (10.1%) and by area (3.41%) (Gobejishvili 2000).

The following morphological types of glaciers are found in Georgia: the valley-complex, valley (Fig. 11.2), corrie, corrie-valley, hanging, and hanging-valley.

The morphological types of glaciers were originated mainly at the beginning of the nineteenth century when the maximal phase of the

Fig. 11.2 The Tbilisa glacier (photo by R. Gobejishvili)

last stadial glaciation was completed; according to the number, the leading place belongs to the corrie type glaciers (56.1%). It should be noted that there are only ten valley-complex types of glaciers and they occupy the area of 155.7 km^2. The hanging-valley type of glaciers is found only in the Kazbegi massif. Among them the Devdoraki glacier is distinguished (length 7.0 km, area 7.5 km^2). Devdoraki glacier is known for its powerful ice avalanches; sometimes the ice avalanches block the Tergi River.

Glaciers of Georgia are conditionally divided into three groups: small size glaciers—with up to 0.5 km^2, medium size—0.51–2.0 km^2, and large sizes—2.01 km^2 and more. Small size glaciers exceed in number (76.0%), while the large size glaciers dominate in area (53.5%).

Glaciers of all expositions are found in Georgia; by number (20.7%) and area (23.5%) the glaciers of southern exposition dominate.

Altitudinal location of firn and snow lines is of great importance in the identification of the regime character of modern glaciation and glaciers in Georgia. The average height of the firn line in the Western Caucasus is 3050 m, in the Central Caucaus (within western Georgia)—3350 m, in the Central Caucasus and Eastern Caucasus (within Eastern Georgia)—3450 m. The firn line in the Caucasus was upshifted by 180 m in the period of 1890–1980.

The location of snow line (the border between the nival and glacial zones) has been determined by different methods. It is located in the Western Caucasus at 4100–4200 m, in the Central Caucasus—at 4200–4300 m, and in the Eastern Caucasus—at 4300–4500 m. Along with the other factors, the upshift of the location of snow and firn lines from west to east is also conditioned by the sub-lateral direction of the Caucasus.

Global warming on the Earth has led to a reduction of glaciers in all regions of the world including the Caucasus. In 1890–1990, the area of glaciation in Georgia was reduced by 29.0%, while the number of glaciers increased by 51.7%. The increase in the number of glaciers is caused by their division while retreating. Table 11.2

Table 11.2 The dynamics of the glaciation in the Central Caucasus

Name of the river basin	Glacier area by topographical maps, km^2				Changing in the area of glaciation					
	Podozerski 1890	Gobejishvili 1946	Gobejishvili 1960	Gobejishvili 1990	1890–1946		1890–1960		1890–1990	
					km^2	%	km^2	%	km^2	%
Enguri	392.0	349.6	320.5	285.3	−42.4	10.8	−71.5	18.2	−106.7	27.2
Rioni	92.0	81.6	75.1	66.1	−10.4	11.4	−16.9	18.4	−25.9	28.2
Liakhvi	5.1	8.2	4.0	3.2	+ 3.1	60.8	−1.1	27.5	−1.9	37.3
Tergi	89.1	75.7	67.2	58.5	−13.4	15.0	−21.9	24.5	−30.6	34.4

clearly shows the variation of glaciation according to the individual glacier basin.

The glaciers of the Caucasus experienced great changes in the nineteenth-twentieth centuries (Fig. 11.3). The glacier tongues were reduced in length by 15% on average and their area was reduced by 16.0%. Glaciation reduction indicators differ significantly from each other both in length and in the area and volume.

Three groups of glaciers are distinguished according to the retreat rate: the first group includes the glaciers of the valley-complex type, the tongues of which retreated by 1.5 km and more.

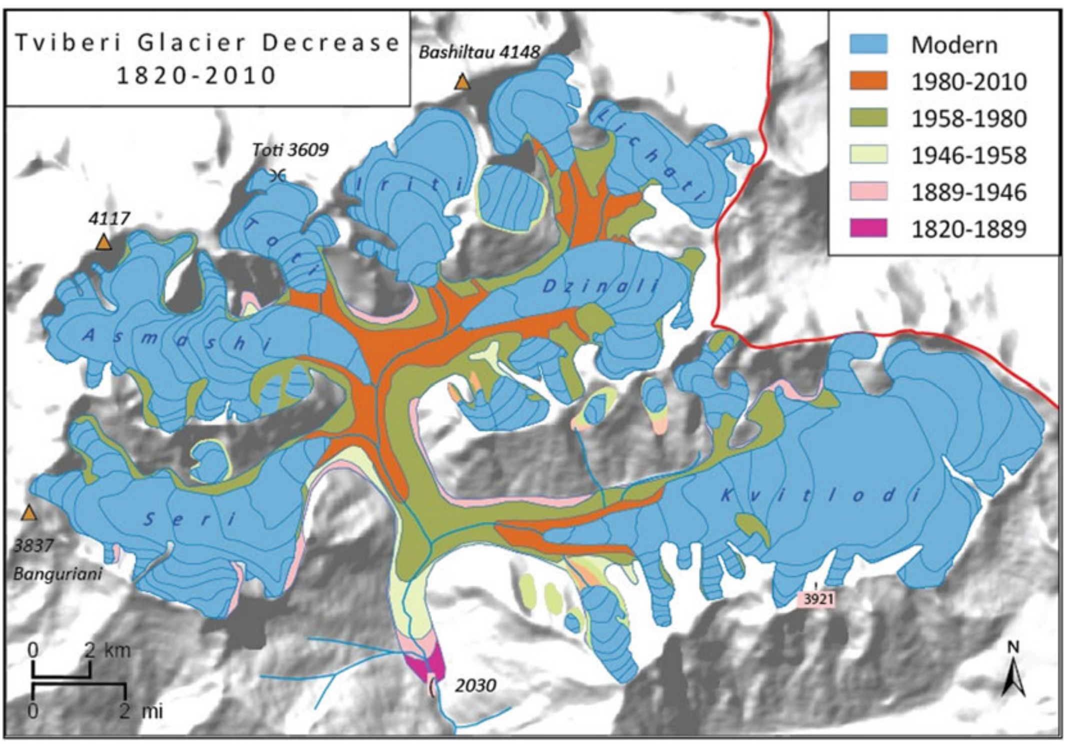

Fig. 11.3 Tviberi Glacier Decrease 1820–2010

The second group includes the valley-simple and hanging-valley types of glaciers, the tongues of which were reduced by 1.0–1.5 km.

The third group includes the corrie type of glaciers. The retreat of their tongues is less than 0.3–0.5 km. Against the background of the general retreat of glaciers, the advancement of glaciers is observed for a short time, which is related to the solar activity (Gobejishvili and Kotlyakov 2006).

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Soils

12

Lia Matchavariani

Abstract

This chapter presents the mosaic soil cover of Georgia. In a quite small territory, there are distinguished the dozens of soil nomenclature. Each genetic type is characterized by specific distribution and peculiar morpho-chemical properties. Below are provided the diagnostic indicators of the major soils and principle of their distribution.

Georgia is characterized by a wide range of soil cover, which is due to the diversity of soil-forming factors (Fig. 12.1). Complex geological structure and heterogeneity of bedrocks, the relief peculiarity and contrast climate conditions, specificity of vegetation cover and biodiversity, stipulate in complex the mosaics of soil cover of Georgia and peculiar geographical distribution. The diversity of soil cover of Georgia is also expressed in the fact that the teaching on horizontal and vertical (altitudinal) geographical and soil zoning is formed due to the study of the Transcaucasian soils. Here are represented the genetic types characterized for humid subtropical lowland areas of western Georgia and the arid regions of eastern Georgia as well as the ones common in the foothills, mountain-forest, and mountain-meadow zones. The diversity of soil cover in Georgia is the most obvious in the lowland and regions with plain relief; in the mountains, such difference is less evident.

Soil cover of Georgia is divided into three quite different soil regions (Western soil region, Eastern soil region, Southern soil region) with appropriate sub-regions, zones, and areas (Sabashvili 1968). Each of them has a complex of soil types characteristic to it (Fig. 12.2). Within the soil region of West Georgia, the three soil-geographical sub-regions can be distinguished (Caucasus, Intermountain Plains, and Transverse Ranges of southern highlands); within the soil region of East Georgia—the sub-regions of the Caucasus, Intermountain Plains, and Uplands and Transverse Ranges of southern highlands; and within the soil region of South Georgia—the sub-regions of Akhaltsikhe Intermountain Depression and Volcanic Uplands of southern Georgia. Each sub-region covers the corresponding soil zones and districts.

The soil cover of Caucasian region is characterized by the typical structure of vertical zonality. However, according to local climatic and other conditions, the soil types spectrum is different in single regions. In the southern slopes of the Greater Caucasus the Brown Forest Soils (Cambisols Eutric and Cambisols Dystric) prevail. More above the Mountain-Meadow subalpine and alpine soils are represented, reaching a

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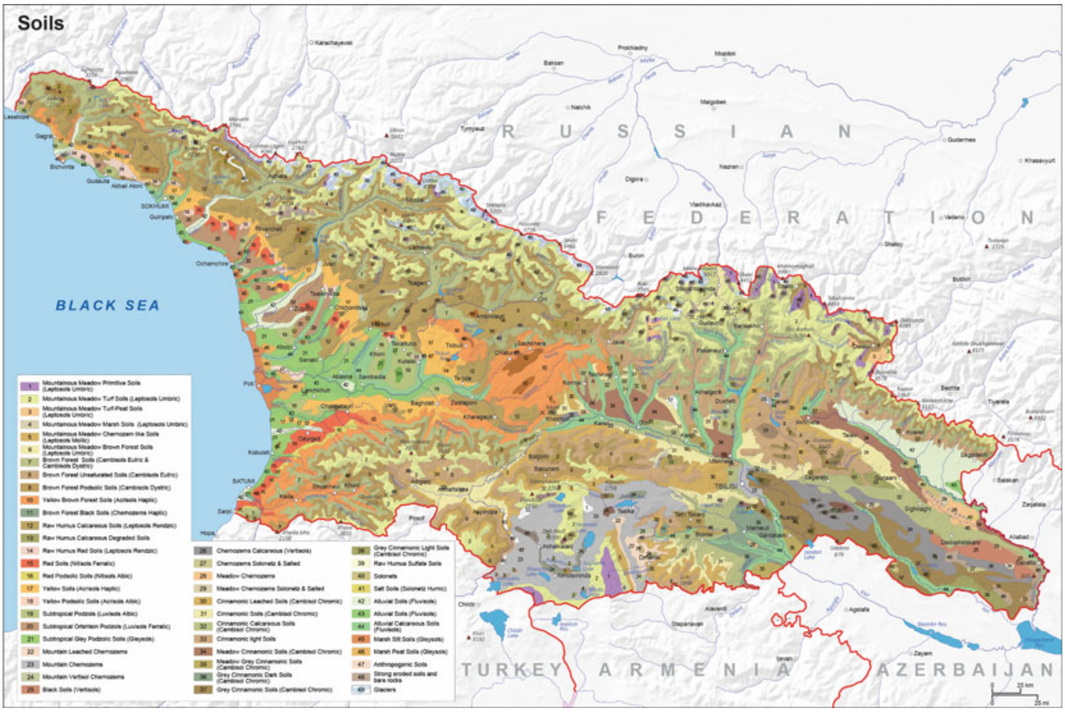

Fig. 12.1 Soil Map of Georgia (T. Urushadze, L. Matchavriani, G. Ghambashidze. National Atlas of Georgia, Steiner-Verlag, 2018, p. 74)

high mountainous nival zone in a form of primitive soils.

In the mountainous region of South Georgia, the Mountain Chernozems dominate. At the higher massifs, ranges, and slopes the Mountain Meadow (Leptosols Umbric) soils are developed. Lesser Caucasus outer slopes are characterized by Brown Forest (Cambisols Dystric), mountain-forest Cinnamonic (Cambisol Chromic), and Mountain Meadow (Leptosols Umbric) soils.

In the Kolkheti lowland hydromorphic soils are common, such as Marsh Soils (Gleysols), Subtropical Podzols (Luvisols Albic), and Alluvial Soils (Fluvisols), in the upraised parts of the lowland—the Red Soils (Nitisols Ferralic) and Yellow Soils (Acrisols Haplic) can be found.

Mtkvari lowland is characterized by the soils of semi-arid and partially arid subtropics—Gray and Meadow Gray Cinnamonic Soils (Cambisol Chromic), as well as Salt Soils (Solonetz Humic).

In the intermountain lowland sub-region of West Georgia's soil region, the Kolkheti lowland soil zone is mainly represented by several soil-geographical districts, where the *Marsh and Gley Podzolic Soils (Gleysols), Subtropical Podzols (Luvisols Albic), and Alluvial Soils (Fluvisols)* are common. Within the Caucasian sub-region of the same region, the following are distinguished: hilly foothill soil zone with *Yellow Soils (Acrisols Haplic)*, *Red Soils (Nitisols Ferralic), and Raw Humus Calcareous Soils (Leptosols Rendzic);* mountain-forest soil zone with *Raw Humus Calcareous (Leptosols Rendzic) and Brown Forest (Cambisols Eutric) soils* varieties; Mountain-Meadow soil zone with the *Mountainous Meadow Turf, Turf-Peat, and Primitive (Leptosols Umbric)* soils. Within the sub-region of southern mountainous transverse range of western Georgia's soil region, the hilly foothill soil zone is represented, where except the Red and Yellow soils the varieties of *Brown Forest (Cambisols Eutric and Cambisols Dystric), Yellow Brown Forest (Acrisols Haplic), Raw Humus Calcareous (Leptosols Rendzic) and*

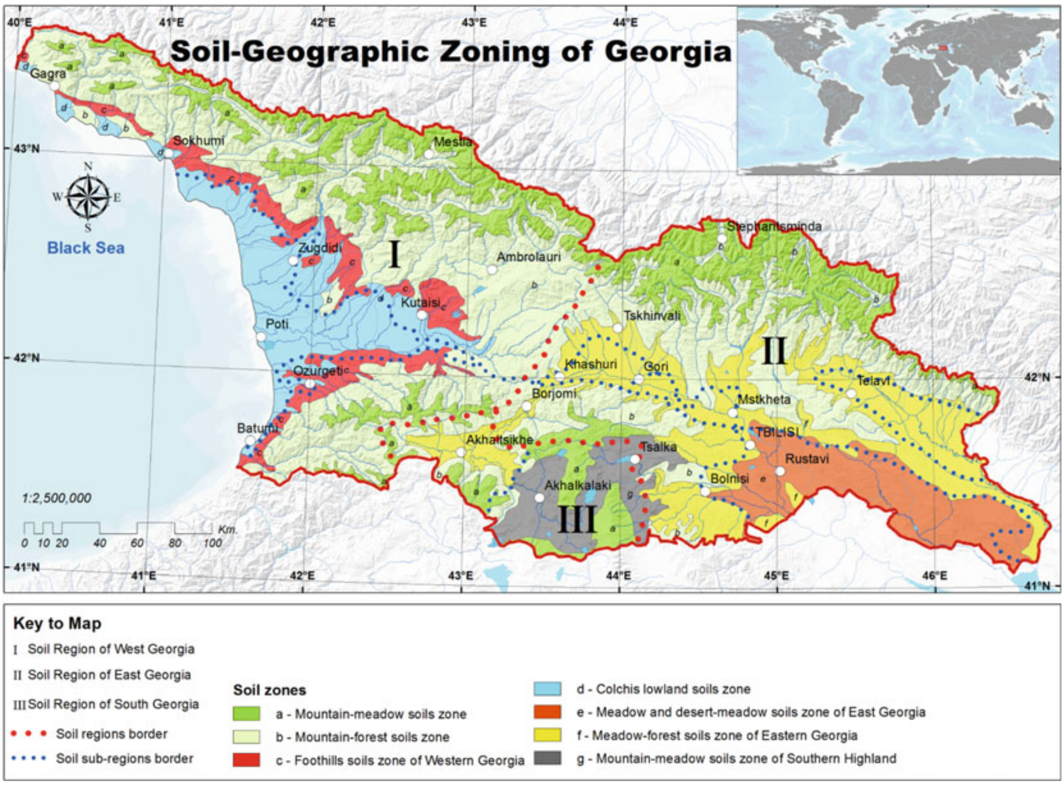

Fig. 12.2 Soil-Geographic Zoning (The Soils of Georgia (*Ed.* Lia Matchavariani), Springer, 2019, p. 68)

Mountainous Meadow (Leptosols Umbric) soils can be found.

In the sub-region of intermountain lowlands and uplands of East Georgia's soil region the two main zones are represented: the desert steppe and steppe soil zone with *Gray Cinnamonic and Meadow Gray Cinnamonic (Cambisol Chromic), Black (Vertisols) and Salt (Solonetz Humic)* soils; plains' transitional forest-steppe and forest soil zone with the *Meadow Cinnamonic (Cambisol Chromic), Chernozem-like Saline and Alluvial (Fluvisols)* soils. The Caucasus sub-region of the same region also includes three soil zones: foothills transition forest-steppe and forest soil zone with the *Chernozem-like Cinnamonic Forest, Gray Cinnamonic and Raw Humus Calcareous* soils; mountain-forest soil zone with *Cinnamonic Forest, Raw Humus Calcareous and Brown Forest soils;* mountain-meadows soil zone—with the varieties of *Mountain Meadows and Primitive soil* types.

Soil districts, united in the plain and mountain foothill transition forest-steppe and forest soil zone of Akhaltsikhe intermountain depression sub-region of southern Georgia's soil region, include the *Meadow Cinnamonic, Gray Cinnamonic, and Cinnamonic Forest soils*, and the mountain-forest zone—the *Cinnamonic Forest and Brown Forest* soils. The mountain steppe soil zone of the volcanic uplands sub-region of the same region includes the *Mountain Chernozems* soil-geographical districts; and the mountain-meadows zone—the *Mountainous Meadow Chernozem-like (Leptosols Mollic) soils.*

The soils, characteristic of the humid regions of Georgia, are common in the west of the country and in the most parts of the mountains. The soils, typical for the arid climate, are presented in the plain of eastern Georgia. As for the soils, typical for transition (semi-humid, semi-arid) conditions are widespread in the plain of western part of the Caucasus, in the peripheral lower parts of the mountainous areas and uplands.

Thus, the main genetic soil types that create the altitudinal, vertical zonation in soil structure of Georgia are divided into many subtypes, genus, and species according to the soil formation factors (Sabashvili 1968; Urushadze 1997; Soil Map of Georgia 1999). Formation of a zonal soils common in Georgia, which are not subject to the zonal principles, is stipulated by a variety of local factors: lithological (Raw Humus Calcareous Soils), hydrological (Marsh Soils, Salt Soils, Alluvial Soils), geomorphological (stony-skeletal soils), etc.

Soil resources world database (World Reference Base…, 2014), has been used for the compliance of the main soils of Georgia to the WRB-FAO indexing and classification, based on the project "Soil Investigation/Systematization of Georgia on the Base of World Reference Base for Soil Resources" (2010–2013), financed by Shota Rustaveli National Science Foundation of Georgia.

Thus, the dozens of types of soil nomenclature are distinguished in the territory of Georgia. Each genetic type is characterized by peculiar macro- and micro-morphological indexes (Matchavariani, et. al.). Below are provided the basic morpho-chemical indexes of the soils of Georgia.

Mountain Meadow (Leptosols Umbric) soils are common in the alpine and subalpine zones of Georgia; they are characterized by an undifferentiated profile of small or medium capacity, well-expressed dark soils organic matter horizon, fulvic or humatic-fulvic soils organic matter, acidic and weakly acidic reaction, medium and heavy loamy mechanical composition, skeletality of solidified illuvial horizon, high content of rock fragments. Morphologically the genetic profile is built from the following horizons: Ad-A-B-BC-C. Among them the turf, peat, and primitive subtypes are distinguished (Fig. 12.3).

Fig. 12.3 Mountain Meadow Soil (photo by B. Kalandadze)

Mountain-Meadow Forest (Leptosols Umbric) soils are common in the subalpine zone of Georgia; they are characterized by undifferentiated profile, high and deep humusing, dark color of the upper horizon and a large number of roots, small or medium capacity, powerful alkalization, shaky structure, acid reaction, loamy mechanical composition, high rate of detritus and participation of rock fragments. The vertical profile is distinguished by the following morphological structure: Ao-AB-BC or Ao-A-AB-CD (Fig. 12.4).

Mountain-Meadow Chermozem-like (Leptosols Mollic) soils, which are common in the subalpine and alpine zones of southern Georgia; they are characterized by the undifferentiated

Fig. 12.4 Mountain-Meadow Forest Soil (photo by B. Kalandadze)

profile of small or medium capacity, high content of humatic soils organic matter and deep humusing, weak acid reaction, high absorption capacity, loamy and/or clay (depth) mechanical composition. The vertical profile is distinguished by the following morphological structure: A1-A1“-BC or A1-A1”-B-BC.

Brown Forest (Cambisols Eutric and Cambisols Dystric) soils are common in the mountain-forests zone of Georgia; they are characterized by the profile of a weak differentiation, monotonous brown color, a well-expressed dead cover, dark accumulative horizon, lumpy-nut and grain structure, moderate composition of fulvic soils organic matter, deep humusing, loamy mechanical composition, noticeable loading toward the depth and skeletality, profile loaming, weak sediment movement in the profile, depth decreasing acid reaction and high content of iron moving forms. Morphologically the genetic profile is built from the following horizons: A-Bm-C.

Brown Forest Black (Chernozems Haplic) soils are common at the boundary of the forest broun soils of southern Georgia; they are characterized by blackish-brown colored soils organic matter horizon, lumpy-nut structure, loose construction, acid reaction, the average content of fulvic soils organic matter and deep humusing, loamy mechanical composition and even distribution of sediment in the profile. Morphologically the genetic profile is built from the following horizons: Ao-A1-A1”-A1”- BC2.

Raw Humus Calcareous (Leptosols Rendzic) soils are formed on calcareous rocks and are common in the mountain-forest as well as humid and dry subtropics and mountainous zones; they are characterized by profile’s weak differentiation, well-expressed accumulative horizon, granular or fine-lumpy structure, neutral or weak alkaline reaction, moderate and low content of humatic soils organic matter, deep humusing and high content of carbonates. Greensward-calcareous soils group includes red sub-type, the so-called Terra Rosa. Morphologically the genetic profile is built from the following horizons: A-AB-C or A-AB-BC.

Mountain Chernozems, which are common in the volcanic upland of the southern Georgia is characterized by a high content of soils organic matter and a black-colored accumulative horizon, lumpy-nut and lumpy-prismatic structure, weak alkaline reaction, profile claying, clay or heavy loamy mechanical composition. The vertical profile is distinguished by the following morphological structure: A1-A1”-AB-BC (Fig. 12.5).

Black Soils (Vertisols) are common in the intermountain steppe zone of eastern Georgia in the condition of dry subtropical climate. They are characterized by a weak differentiation of a profile, dark-colored powerful accumulative horizons, medium content of humatic soils organic matter, lumpy-angular or nut-prismatic structure, well-expressed carbonate horizon, heavy mechanical composition, forming clay in the middle part of the profile, noted carbonizing from the surface, slagging signs, neutral or weak alkaline reaction. The profile morphological structure is as follows: A1-A1”-AB-B-BC-C.

Fig. 12.5 Mountain Chernozems (photo by B. Kalandadze)

Cinnamonic (Cambisol Chromic) soils are common in the forest-steppe zone of the eastern Georgia, in the conditions of subtropical climate; they are characterized by a profile differentiation, dark color of accumulative horizons, lumpy or grain structure, claying profile, presence of metamorphic horizons, weak alkaline or neutral reaction, medium content of humatic type soils organic matter and deep humusing process. Morphologically the genetic profile is built from the following horizons: A-B_{Ca}-BC-(BC_{Ca})-C_{Ca}.

Meadow Cinnamonic (Cambisol Chromic) soils are common in the depressed sections of the brown soils areal in the conditions of ground surface gleying; they are characterized by a weakly differentiated profile with a dark brown color, lumpy-block structure, heavy mechanical composition, carbonate profile from the surface, weakly expressed carbon-illuvial horizon, weak alkali or alkaline reaction, low content of fulvic-humatic soils organic matter, deep humusing process, light, and weak loamy mechanical composition, well-expressed loaming in the profile's middle section. Morphologically the genetic profile is built from the following horizons: AB-B-BC-C, or A1"–B1-B2-BC.

Gray Cinnamonic (Cambisol Chromic) soils are common in the arid steppe zone of south-eastern Georgia; they are characterized by undifferentiated profile, powerful accumulative and calcareous horizons, low content of fulvic-humatic soils organic matter, gleying in the middle part of the profile, calcareous from the surface, powerful and well-expressed illuvial-carbonate horizon, weak alkali or alkaline reaction, heavy loamy mechanical composition and, satiety of basis. Morphologically the genetic profile is built from the following horizons: A1'-A1˵-AB-$B1_{Ca}$-C1-C2.

Meadow Gray Cinnamonic (Cambisol Chromic) soils are common among the Cinnamonic soils in the relatively moist areas, in the condition of moderate dry subtropical climate; they are characterized by undifferentiated and powerful profile, with the signs of glorying, weak alkali or alkaline reaction, low content of fluvic-humatic soils organic matter, though a deep humusing process, the enhanced calcareousity toward the whole profile depth, high absorption capacity, light and medium loamy mechanical composition, the loaming of the lower part of the profile. Morphologically the genetic profile is built from the following horizons: A_{Ca}-$B1_{Ca}$-$B2_{Ca,}$t,g-$BC_{Ca,}$g-Cg.

Saline/Salt Soils (Solonetz Humic) are common in the plain steppe zone of Georgia in the conditions of dry subtropical climate; incorporates a saline (salt) soils and solonetz (solonchak) types, which are characterized by heavy mechanical composition. Saline is distinguished by easily soluble salt content from the surface, and solonetz—from the depth. They are characterized by an abundance of calcium, low content and sharp reduction of soil organic matter in the profile, and considerable increase of chloride-sulfate easily soluble salts into the depth. Solonetz is distinguished by the presence of absorbed natrium in the absorbent complex and alkaline reaction. Solonetz and solonchak are characterized by the elluvial-illuvial type differential profile, alkaline reaction, dense solonchak horizon, the high content of absorbed natrium, and weak water permeability.

Red Soils (Nitisols Ferralic) are common in the hilly foothills of the humid subtropical zone of Georgia. They are characterized by a powerful profile, redish-orange color, lumpy structure, acid reaction, a high content of fulvic soil organic matter, medium and low absorption capacity, heavy mechanical composition, and abundance of one and a half of oxides (ferrum and aluminum hydroxides), and ferralitic exhaustion. Profile structure is as follows: A-AB-B-BC-C.

Yellow Soils (Acrisols Haplic) are common in the humid subtropical zone of Georgia in conditions of hilly foothills; they are characterized by a powerful profile of yellow color, lumpy structure, high content of fulvic soils organic matter, acid reaction, heavy loamy and clay composition, ferralitic and sialitic exhaustion. Profile is built of the following genetic horizons: A0-A-AB-B-BC.

Subtropical Podzolic (Luvisols Albic) soils are common in the humid subtropics of Georgia in the slightly elevated marine and river terraces. They are characterized by the profile texture differentiation, abundance of the iron concretions in the upper horizons, sometimes by the existence of a dense ortshtein layer among the profile layers of heavy and light mechanical composition, the acidic reaction, low and medium content of fulvic soils organic matter, low absorption capacity, clay, and loamy soil mechanical composition, sharp aggravation into the depth, and uneven distribution of oxides. The morphological structure of the genetic profile is complex: A1A2n-BSf-Bt,g-BGt or A1A2n-BSf-Bt,g-BGt-[B/Cg,h]).

Subtropical Gley Podzolic Soils (Gleysols) are more common in the lowered places than subtropical podzols; they are characterized by the profile texture differentiation, intense gleying, participation of concretions in the entire profile, sometimes in the form of the ortshtein layer, acidic, or rarely, neutral reaction, moderate and deep humusing of fluvic soils organic matter, clay, and loamy mechanical composition. Morphologically the genetic profile is built from the following horizons: A-A1A2-B1-B2-BC-CDg-G or A1A2-A2-A2B-BCg.

Marsh Soils (Gleysols)—silty and peat are common in the poorly drained areas of the relief's lowered elements; they are characterized by powerful profiles, with a high content of soils organic matter, the weak neutral reaction, heavy mechanical composition throughout the profile, high dispersion, and uneven distribution of oxides. The peat-swampy and silt-swampy soils can be distinguished. Morphologically the genetic profile is built from the following horizons: A-B-BC.

Alluvial Soils **(Fluvisols)** calcareous and non-calcareous soils are common in different natural zones of Georgia. Their different regimes, construction, and properties are due to the nature of the basin, where they were originated. They are characterized by profile layering according to the mechanical composition, skeletality, weak structural properties, deep humusing, medium or low content of soils organic matter, acidic, neutral, or alkaline reaction (according to the region's substrate). Morphologically the genetic profile is built from the following horizons: A-BC-C-CD.

In the territories of the country, which are subject to powerful industrial impact, the soils suffer immense changes and the so-called anthropogenic soils are formed, which occupy the area of 0.1% (> 80 km^2) in Georgia. They have lost the natural building capacity and the upper part of the profile suffers the anthropogenic impact. They are characterized by acidic, neutral, or alkaline reaction, small or medium content of soils organic matter, low or average absorption capacity, different mechanical composition and they are poor in food elements. Usually, anthropogenic soils are polluted by radionuclides, and water or wind erosion hazards are created in these areas.

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13 Flora

Revaz Gagnidze

Abstract

In Georgia, the diversity of vegetation cover is reflected in various types and variants of vegetation vertical zoning systems. This diversity is described in this chapter. The richness of Georgian flora is the high level of endemism. Approximately 21% or about 900 species of Georgian flora are endemic including about 600 species—endemic to Caucasus and about 300 species—endemic to Georgia. The number of endems in the Caucasus is up to 1500.

The physical-geographical diversity of Georgia, orogaphic contrast, the geographical and ecological isolation of the individual orographic units and river water catchment basins, as well as the diversity of vertical zoning of the phytolandscapes caused the diversity of flora and vegetation formations of Georgia.

The diversity of vegetation cover is reflected in various types and variants of vegetation vertical zoning systems. The vegetation of western Georgia forms the **Colchis type** of vertical zoning and the vegetation of eastern Georgia—the **Transcaucasian type** of vertical zoning. The transition version between Colchis and Transcaucasian types is represented in Kartli and Trialeti regions. It is true that a complete system of vertical zoning is not represented along the Caucasus, but the high mountainous zones (subalpine, alpine, subnival, and nival) are well expressed. The **central Ciscaucasian type** of vertical zoning is characteristic of Khevi; on the contrary, the **eastern Ciscaucasian type** of vertical zoning—is of Pirikita Khevsureti and Tusheti. There is a completely different system in the southern Transcaucasia (Meskheti and Javakheti), where the mountain steppe belt is developed in wide strips—the **southern Transcaucasian**, or the Western Asian type. Here the alpine belt is limited or the subnival belt is rarely expressed.

More than 4100 species (4130 species) of vascular plants are registered in Georgian flora including ferns—79; **gymnosperms**—17 and angiosperms—4034 (dicotyledons—3278 and monocotyledons—756); in the Caucasus 6350 species are registered, in the North Caucasus—3700 species, in Armenia—3700 species, in Carpathians—2000 species; in Scandinavian countries—2000 species, and in the world—270,000 species. The situation in Georgia's floristic-ethnographic regions according to the number of species is as follows: Apkhazeti—1978 species, Svaneti—1100 species, Racha-Lechkhumi—1200 species, Imereti—900

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species, Achara—1900 species, Khevi—1347; Tusheti and Khevsureti—1000 species, Shida Kartli (Ksani-Liakhvi)—1125 species, Kakheti—1400 species, Trialeti—1650 species, Meskheti—1400 species, Javakheti—1500 species and Gardabani—900 species.

The richness of Georgian flora is the high level of endemism. Approximately 21% or about 900 species of Georgian flora are endemic including about 600 species—endemic to Caucasus and about 300 species—endemic to Georgia. The number of endems in the Caucasus is up to 1500 (Gagnidze 2005).

The **main types of plant species** are: wetland, forest, shrub, meadow, high herbs, steppe, semi-desert, rock-fragment-detritus vegetation, and vegetation of coastal sand-**cobblestone** ecotopes.

Vegetations of western, eastern, and southern parts of Georgia sharply differ from each other (Ketskhoveli 1961; Kolakowsky 1961).

In the ecosystems of mesophylous forests, meadows and high herbs prevail the Caucasus, Mediterranean, Laurasian and Palearctic species; in the ecosystems of arid forests, steppes and semi-deserts prevail the Western Asian and Asia Minor species; in the water and wetland ecosystems—Laurasian (Holarctic) and Palearctic species. The rock-fragment-detritus vegetation is rich in endemic species of the Caucasus.

In western Georgia, the complete system of vertical landscape zones are well expressed, starting from the plain-lowland or the lower mountain belt to the nival-permanent snow or glacial and subnival snow lower belts inclusively. In the Black Sea coastal regions, a maritime or coastal belts are added to the phytolandscape belts, which are characterized with sandy-gravel and cobble dune vegetations (Gagnidze 1974). Their diversity is formed by the ephemeroids and ephemers of the circum-Mediterranean and Euxine coast.

In eastern Georgia, in contrast to western Georgia, semi-arid and arid belts of vegetation are represented, particularly the vegetation of semi-arid, steppe, mountain xerophilic, and arid light forests. Other belts are the same as in western Georgia.

13.1 Vegetation of Western Georgia

Vegetations of the Black Sea coastline sand, sand-pebble, and sand-cobble ecotopes. Coastal sand, sand-pebble, and sand-cobble ecotopes are one of the oldest and relic ecotopes. To these ecotopes and dunes are related peculiar vegetation and floristic complexes, characterized by different ecology, eco-bio-forms, and vegetation cover structure. This vegetation is not widely represented and extends within 100–200 m from the coast to the land. Vegetation is not dense; it is rich in spring ephemers and ephemeroids that are not characteristic of other parts of Kolkheti.

In the dunes, the groups formed from herbs and woody plants are developed. In the coastal sands, the circum-Mediterranean Sea and Black Sea coastal vegetations are grown, such as: sea daffodil (*Pancratium maritimum*), yellow horn-poppy (*Glautium flavum*), and others. Sea daffodil is a rare and dying relic that is sporadically found in Bichvinta Cape and on the coasts of Kobuleti and Batumi.

Giant cane (*Arundo donax*) grows on the sandy shore Between Bichvinta's Cape and Gagra. Among the vegetation grown in the dunes the narrowleaf cotton bush (*Gomphocarpus fruticosum*) is peculiar, which is found in the countries of Mediterranean Sea coast, the Asia Minor, the Black Sea coast, and China.

Sea spurge (*Euphorbia paralias*), sea holly (*Eryngium maritimum*), and Caucasus mullein (*Verbascum gnaphaloides*) create groups in the sand, directly in the high tide zone of the sea. The groups composed of ephemeral species—catchfly (*Silene euxina*), marine woundwort (*Stachys maritima*), as well as graminaceous-various herbs are developed in the sandy ecotopes, on which the soil formation processes have been developed; the groups of matgrass, hawthorn, and sea buckthorn are developed in well-developed sandy soils. Along with them, the ruscus (*Ruscus ponticus*) grows as well. The cenoses of the Pitsundian pine (*Pinus pithyusa*) of the Tertiary period with the subforests of pink rock rose (*Cistus cretica*), smoke tree and others are particularly notable.

Also, the cenoses of ruscus are notable, which, like Pitsundian pine, are developed in the areas that are not covered by waves during the sea-high tides. Pitsundian pine alters its location in the north of Gagra and shifts from sandy ecotopes to the limestone rocky ecotopes.

In the sandy dunes the blackberry and introductive timber plants grow, such as acacia, gleditsia, and tree of heaven; from herbs—the invasive crown grass (*Paspalum*), horseweed (*Coniza canadensis*), and others (Kolakowsky 1961; Sokhadze 1968).

Kolkheti Lowland, foothills, low mountain, and mountain vegetation

Before humans modified the vegetation cover of the country, the impassable lowland Colchis mixed-leaved "leshambi" forest (according to Keskhoveli's (1961) terminology) with liana vegetation and evergreen shrub subforest covered the areas of Kolkheti Lowland and foothills in western Georgia that were altered by wetlands in large areas (0–250 m above sea level).

This forest was composed of alder, zelkova, willow, aspen, and wingnut trees and in some areas—hornbeam, chestnut, and Imeretian oak. Today the natural vegetation of Kolkheti Lowland and foothills is no longer preserved; wetlands are dried and forests are cut down. Tea, citrus, fruits, and vegetables are cultivated in this territory. Natural vegetation is preserved in the intermountain gorges and in the lowlands in small remnants.

Even today the forests of Kolkheti Lowland are characterized by the spread of liana, smilax, silkvine, wild grapes, leather flowers, ivy, hop, and others. In the eastern part of the Kolkheti Lowland, the Imeretian oak—resistant to dry climate is spread, as well as zelkova. The evergreen subforest is relatively poor (250–500 m).

In the coastal area (Kobuleti, Poti, and Anaklia), the peat bogs, alder, and wingnut forests are preserved. The forest edges and shallow waters in Kolkheti are covered with giant cane, cattail, reed, sedge, and other groves.

In still and slow waters the water lily, duckweeds, pondweeds, water chestnut, and water buttercups grow, in the wetlands—the species of sedge and rushes, yellow iris, and others. The relic plant—royal fern (*Osmunda regalis*) grows in the bogs.

In Apkhazeti, in the Black Sea coast, there are also found the Mediterranean Sea coastal plant such as: Greek strawberry tree (*Arbutus andrachne*) and briar root (*Erica arborea*).

The main colorfulness of the forest landscapes of western Georgia, as well as in some parts of eastern Georgia, is formed by the mountain wide-leaved forests including: oak trees, oak-hornbeam trees, beech trees, chestnut trees, dark coniferous plants including fir and spruce, pine trees, birch trees, maple trees and rowan trees.

The nature and composition of the mountain's broad-leaved forests are different in the mountain's lower belt within 500 m to 700–1000 m above sea level. Broad-leaved forests distributed here are composed of Georgian oak, hornbeam, chestnut, and Persimmons, and in moist areas—of alder.

In the subforests of these forests, the deciduous shrubs are composed of yellow azalea, common hazel, Caucasian blueberries, Colchis bladder nut, Cornelian cherry dogwood, and others. It is well-developed evergreen shrub subforest with composition of cherry laurel, holly, and common rhododendron. There are many liana plants and different species of fern in this forest. In the lower zone of the mountain, in the limestone areas, especially in the river gorges, the boxwood is common. Boxwoods are preserved in the gorges of the Bzipi and Chakvistskali Rivers and in the vicinities of the Avadhara and the Ritsa Lakes. Their twigs and branches are almost entirely covered with mosses and lichens.

In western Georgia, from 600 to 1300–1400 m above sea level the beech forests are widespread. In moist areas, it inteis mixed with chestnuts, in dry areas—hornbeams. The evergreen shrub subforest is developed there.

There are also found the fragments of redwood—yew (*Taxus baccata*). Some moist and deep gorges are impassable due to the dense evergreen subforest. Such groves are called rhododendron shrubs. In the forests of Achara-Lazistan the endemic *rhododendron ungernii* is common.

From 1200–1300 m above sea level, the spruce (*Picea orientalis*) and fir trees (*Abies nordmanniana*) are found (Fig. 13.1), which form the dark coniferous forests belt, where the beech is found too. Evergreen and desiduous shrubs are characteristic of these forests, such as the Imeretian buckthorn, the Caucasian mountain ash, daphne, and others.

In Svaneti and Racha-Lechkhumi pine forests and spruce-pine forests are well developed. In the Achara-Imereti Range there are widespread the crooked forests of the Colchis-Lazistan relics of Pontic oak (*Querqus pontica*) and Medvedev's birch (*Betula medwedewii*) and in the Acharst-skali River gorge—oak and pine forests.

The upper boundary of the forest in western Georgia stretches at 1700–2000 m and in some areas—at 2200–2500 m above sea level. It is formed by high mountains so-called park or crooked forests. In such forests, shrubs, high herbs and meadows are spread along with birch, single beech, fir, high mountain maple, rowan, and high mountain oak; they create the subalpine belt. In the Achara-Imereti Range, the crooked forests are again created by Pontic oak and Medvedv's birch. The subalpine forests are peculiar due to the strong load of snow cover. Their rods stretch on the ground and in this condition they hibernate. The roots develop in the touching area of the rod with soil, which facilitates the vegetative propagation of wood plants. The crooked forests reach the extreme boundaries of distribution of forest vegetation. On the roads of movement of snow avalanches, they descend and intrude into the forest belt.

In the subalpes the colorful high herbs are characterized by high rods and diversity. The high herbs are formed by inulas, hogweeds, Larkspurs, ragworts, aconites and bellflowers. In the crooked forest, the rhododendrone often grows often. It often emerges from 1800 m above sea level and then intrudes into subtropical and alpine landscapes.

In subalpes, the highland meadows are wide-spread; they are ecologically and phytocenically diverse. They include graminaceous (stiff brome, bunch grass, bentgrass, and matgrass), diverse herbs, graminaceous-diverse herbs and sedge meadows.

Kolkheti endemic meadows created by *Carex pontica* and endemic genus of *Woronowia speciosa* are characteristic of limestone ecotopes. Groupings of cranesbills, globe flowers, and anemones dominate among the broad-leaved—various herbs meadows. Fescue meadows are widespread (western Caucasus) too.

In western Georgia, there is the alpine belt from 2400 m to 3100–3200 m above sea level created by shrubs and meadows. In the alpine belt, rhododendrons and cranberries are common.

Fig. 13.1 **a** Upper Svanti, Dark coniferous forest (Picea orientalis, Abies nordmanniana); **b** Pirikita Khevsureti. Shatili area. Derivats of high mountain oak (Quercus macranthera) (Photos by Sh. Shetekauri)

The main formations of alpine meadows are fescue-sedge, matgrass, kobresias, and other meadows. Cranesbills—the various herbs and meadows are widely distributed; the leaves of cranesbill form the whole carpet, which takes reddish color in August, and the plant is covered with large blue flowers that give the unique look to these meadows. In the second half of August, beauties of alpine meadows of western Georgia are the endemic dazzling yellow-flowered *Crocus scharganii* or orange and pink-flowered *Colchicum speciosum.*

The alpine belt ends with diverse low herbs and rock-scree vegetation, characterized by short, stretched stems and large flowers (e.g., buttercups and bellflowers). The role of mosses and lichens also increases, resulting in the creation of alpine meadows. They develop in the smooth relief and old glacier cirques.

The subniael belt is well expressed in Svaneti and Racha from 2900–3100 m above sea level to the permanent snow line. The snow line in Apkhazeti is very low and the subnival belt is weakly represented. Both in western and eastern parts of Georgia, primitive detritus soil ecotopes are developed in this belt; the vegetation cover is fragmented and light; the vital forms of plants are different and the stretched vegetation with dense fluff and succulent leaves prevails there. The percentage of endemic plants is high. Among the endemic genus of the Caucasus the *Symphyoloma graveolens*, *Pseudovesicaria digitata,* and *Trigonocaryum involucrata* grow in the subnial belt. Characteristic plants are mouse-ear chickweed, whitlow-grasses, Caucasian larkspur, rockfoils, veronica, *minuartsia*, etc. (Nakhutsrishvili 1999).

Nival belt starts from 3500–3700 m above sea level. Only one or two species of floral plants reach the mentioned belt. In the ice-free areas the moss and lichen cenotypes are developed.

The rock-fragment-detritus vegetation in Georgia is azonal, but it is basic and widely spread in the subnival and alpine belts. In other zones, it is developed in the erosive ecotopes, avalanches, rock cornices, moraines, and cirques free of snow and ice.

13.2 Vegetation of Eastern and Southern Parts of Georgia

Vegetation of lowland, low mountain hills, and uplands in eastern Georgia. In eastern Georgia, in contrast to western Georgia, the semi-arid and arid zone of vegetation is represented. There are the following belts: semi-deserts, steppe, mountain xerophilic vegetation, and arid light forests (150–600 m); forest (600–1900 m), subalpine (1900–2500 m), alpine (2500–3000 m), subnival (3000–3500 m) and nival (over 3500 m). The forestless formations of semi-arid vegetation—vegetation of mountain fields are spotted In the forest and subalpine zones of highland of southern Georgia.

In the lowland and most part of the foothills of eastern Georgia, the steppes, deciduous shrubs (Shibliak type), and mountain xerophile formations are spread. Most parts of these spaces are occupied by bluestem steppes and buckthorn steppes with domination of matgrass, which are fragmentary altered by feather grass-Fescue steppes. In saline soils dominate mugwort semi-deserts; in the areas, where the soil is very saline, the saline semi-deserts are widespread.

There are widespread groups of dry shrubs, created from black buckthorn, matgrass, and milkvetch (*Astragalus caucasicus*). Additionally, Oriental hornbeam trees, Iberian spireas, *Atraphaeta spinosae*, tamarisk, and others are developed in the floodplain, plain, and arid forest soils.

Steppe vegetation is relatively widely distributed in the Iori Upland (in Shiraki, udabno, and Kajiri plains). Bluestem steppes dominate in brown and chernozem soils. It is rich floristically. Feather grass steps are distributed over the plained crests (Ketskhoveli 1961).

In Zemo Kartli and Kvemo Kartli Plains and Alazani Valley, the steppes are fragmentary distributed and dominate fescue, bluestem-fescue and graminaceous-various herb stepps.

Semi-deserts are stretched in the southeastern part of the Iori Upland and Eldari-Chatmi Lowland in the saline soils and clay and loamy lands or badlands. The main formalities are *Salsola* *dendroides*, *Salsola ericoides*, etc. These formations are rich in ephemers and ephemeroides. In the hills and plains, in the saline soils the groups of *Salsola nodulosa*, *Petrosimonia brachiata* da *Salicornia herbacea* and other groups are formed The semi-deserts with *Statice meyeri*, *Glycerrhisa glabra*, *Nitraria schoberi*, etc., are mostly found in the saline soils of the Alazani (Ketskhoveli 1961).

Semi-deserts with mugwort are widespread in the hills and plains; they are also spread in the plain areas, saline clay, loamy and clay-rock badlands.

Steppe and semi-desert vegetation are developed on the areas of former floodplains and plain arid forests. The fragments of the floodplain forests are preserved in the bank areas of rivers.

The large areas of such forests are found in the Mtkvari, Alazani, and Iori floodplains. Their creators are: *Quercus pedunculifora* = *Q. longipes*, *Populus nigra*, *Populus alba*, etc. In the forests of Alazani floodplain, Colchis relic—*Pterocarya pterocarpa* is grown. The subforest is rich in shrubs. In the plains and plateaus, the oak forests (created by the Georgian oak—*Quercus iberica*) and oak-hornbeam forests are developed.

In the Iori Upland, the relic arid light deciduous (with Mt. Atlas mastic tree**,** acacia, and willow-leaved pear) and coniferous (juniper) forests are interesting. The remnants of arid forests are also found in the surroundings of Mtskheta (Shio-Mghvime and Karsani), Ktsia and Algeti river basins.

Mountain vegetation in eastern and southern parts of Georgia

The slopes of mountainous systems of **eastern Georgia** are covered by ecologically and phitolandcape diverse broad-leaved forest belts at a height from 500–600 m to 1800–1850 m above sea level.

In the foothills of the low mountain belt (1000–1200 m), the formation of oaks (Georgian oak), hornbeam oaks, and pine forests are represented. Chestnut forest is also developed in the Kakheti Caucasus, spruce, spruce-fir, and pine forests—in the Lesser Caucasus and in the Didi Liakhvi River gorge; spruce trees are preserved in the Ksani and Aragvi River River gorges, Trialeti Range and Algeti River basin. At those heights, the beech and hornbeam forests are also spread (e.g., in Lagodekhi and Saguramo Nature Reserves, where there is an eastern outpost of *Hedera pastuchowii*).

In Kakheti, in Babaneuri, and Lalikuri, the fragments of the relic zelkova forest are preserved and composed of *zelkova carpinifolia*, which is mixed with Georgian oak.

At the heights from 1100 to 1800–1850 m in the eastern sections of the Greater Caucasus and Lesser Caucasus, the beech, hornbeam-beech, and hornbeam mixed broad-leaved forest formations dominate. In the river gorges of the Kakheti Caucasus a lot of chestnut and lime trees are found. Kakheti Caucasus is distinguished by the fact that in the Batsara gorge—in the upstream of the Alazani River, the yew tree (*Taxus baccata)* forests are well-preserved too; The heights of the trees do not exceed 30 m, the thickness—1.5 m. They cover about 180 ha area, at the height of 1000–1500 m above sea level.

In the Didi Liakhvi River basin, in the Borjomi gorge, in northwest Trialeti, in beech forests, the relic Colchis subforest is developed with domination of common rhododendron**,** cherry laurel**,** Colchis holly**,** Caucasian whortleberry, and Colchis ivy. The birch and pine forests dominate in the forest and subalpine belts at the height of 1850 m high and above (2200–2500 m) on the northern slopes (Khevi, Khevsureti, and Tusheti) of the Central and Eastern Caucasus. The beech forests are not spread in these regions, while the beeches are preserved in the neighboring region of Tusheti—Dagestan.

The subalpine belt (1800–1850–2500 m) in eastern Georgia is created by subalpine forests with maples (*Acer trautwetteri*), high mountain oaks (*Quercus macranthera*), birches, rowan-birches (*Sorbus caucasigena*, *Betula litwinowii*, *B. raddeana*) and beech forests; in Tusheti—pine and bitch forests, as well as the poor in Colchis species high herbs, floristically diverse meadows, rhododendrons, cranberries and willows Fig. (13.2).

Fig. 13.2 **a** Tusheti, mountain forest (Pinus Kochiana, Betula Litwinowii, B. Raddeana, Acer Trautvtteri, etc.); **b** Kazbek, mountain crook-strem of Krumholz (Betula Litwinowii) (Photos by Sh. Shetekauri)

Alpine belt is represented in the mountain ranges of eastern Georgia at the altitudes of 2500–3200 m, which is made of graminaceous matgrasses (on the inclined slopes and plain areas) and fescues (on the southern steep dry slopes), in addition, kobresias and sedges (on the crests of the mountain ranges, where the winter winds prevail and snow is blown off), stretched fescues (on the crests of mountain ranges and northern exposition slopes). Rhododendrons are also spread on the northern exposition slopes.

Subnival belt is located in the Eastern and Central Caucasus from 2900 to 3300 m above sea level to the permanent snow line. In eastern Georgia, the rock-scree detritus is rich in endemic species. The subnival ultraoreophytes of the Caucasus endemic genus are the pseudovesicaria and pseudobetkea. There are lot of representatives of the genus of chickweeds, minuartsia, and veronica. The dense vegetation cover is not developed. The fragments of alpine meadows ca be found here and there. They are created by species of *Taraxacum*, *Campanula,* and *Alchemilla*.

The water and wetland vegetation in eastern Georgia is also azonal. The groves of *Phragmites* and *Typha* form the cenoses in the plains and swampy shores of water bodies, and in semi-deserts—halophytes, the salt-resistant vegettion.

In the mountainous regions, water and wetland vegetation is found in small areas in flatlands and lava plateaus. The Keli volcanic Plateau and Javakheti are especially rich. Sphagnum-scheuchzeria (Svaneti) and sphagnum wetlands are interesting that contains the interesting history of Holocene vegetation. Along the increase in altitude above sea level, the vegetations of water, lakes and wetland gradually become poor. The most characteristic vegetation of the mountain wetlands are: sedge, *Deschampsia caespitosa, Caltha palustris*, *Primula auriculata*, *P. algida,* and others.

The **vegetation of the highland of southern Georgia** is unique. Here are distinguished three zones of vegetation: the middle mountain zone—from 1400 to 1800–1900 m above sea level, subalpine zone—from 1800–1900 to 2500 m and alpine zone—from 2500 m. The narrow strip of the subnival zone is at the Abuli-Samsari Range. The middle mountain zone is a volcanic plateau-like area. It is almost completely utilized and is covered by field crops. Javakheti is distinguished by endemic species of Tetrobi-Chobareti limestone massif, feathergrass steppe formations, pine forests, and thorny astragalous xerophilic vegetation. Fragments of pine, birch, and spruce-pine forests are preserved from the forest vegetation (Javakheti and Tsalka). The former forest spaces are covered with bluestem, feathergrass, and fescue steppes. The subalpine zone of Javakheti Upland is characterized by peculiar mountain steppes. These are the turned into steppe meadows with various herbs and graminaceous formations, composed of different species of steppe, as well as the feathergrass species; from various herbs—Javakheti alfalfa, filipendula, thimes, clover, and sedge species (Fig. 13.3).

Fig. 13.3 **a** Javakheti high mountain meadow, **b** Pirikita Khevsureti, Subulpine Meadow (photos by Sh. Shetekauri)

Among the graminaceous meadows, fescues are notable. Unlike the Caucasus, they are associated with southern dry slopes. On the banks of the rivers, the species of *Agrostis karsensis* = *A. stolonifera* are developed. The mountain xerophile vegetation is widespread among rockfills in the rocky-detritus ecotopes. Alpine vegetation occypies small areas. As a result of grazing, here are presented the secondary meadows of Dwarf lady's mantle, matgrass, etc. On the mountain slopes prevail sedge and kobresia meadows. Alpine meadows hold the detritus slopes in the alpine and subalpine zones. The widely spread wetland and water vegetations are rich in boreal species, especially with the sedges; some of its species form marshes with dry hard clods of earth on large areas (Nakhutsrishvili 1966).

The diversity of vegetation cover is reflected in various types and variants of vegetation vertical zoning systems. The vegetation of western Georgia forms the **Colchis type** of vertical zoning and the vegetation of eastern Georgia—the **Transcaucasian type** of vertical zoning. The transition version between Colchis and Transcaucasian types is represented in Kartli and Trialeti regions. It is true that a complete system of vertical zoning is not represented along the Caucasus, but the high mountainous zones (subalpine, alpine, subnival, and nival) are well expressed. The **central Ciscaucasian type** of vertical zoning is characteristic of Khevi; on the contrary, the **eastern Ciscaucasian type** of vertical zoning—of Pirikita Khevsureti and Tusheti. There is a completely different system in the southern Transcaucasia (Meskheti and Javakheti), where the mountain steppe belt is developed in wide strips—the **southern Transcaucasian**, or the Western Asian type. Here the alpine belt is limited or the subnival belt is rarely expressed.

13.3 Botanical-Geographical Zoning of Georgia

On the basis of the diversity of flora and vegetation, the territory of Georgia is divided into botanical-geographical provinces and okrugs that are different from each other by the structure of vertical zoning of vegetation, floristic complexes, and composition of endemic genus and species (Gagnidze 1974, 1996, 1999, 2000; Gagnidze et al. 2002).

I. Kolkheti or Eastern Euxin Province includes western Georgia. From the north it is bordered by the crestal part of the main range of the Caucasus from Aibga to Mamisoni, from the east and from the south-east—by Likhi, Meskheti, Arsiani and Shavsheti Ranges, and from the west—by the Black Sea.

The province is stretched in the territory of Turkey up to the Melet-Ordu watershed. Due to humid climate and hilly relief, several vertical belts of vegetation are developed here, such as: coastal, summer-green subtropical, mixed broadleaved, dark coniferous forests, subalpine, alpine, subnival, and nival. This province is characterized by rich complexes of mesophile flora, in which dominate the endemic species of Kolkheti, Caucasus, and Caucasia.

There are also Mediterranean, Eurasian, East Asian, and other species, as well as several endemic genus of Caucasus and Caucasia, such as: *Charesia*, *Sredinskya*, *Symphyoloma*, etc. The endemic genus of the Kolkheti Province is *Woronowia*, *Alboviodoxa* and *Chymsydia*. Ecological structure of flora is diverse. Lithophytes, especially the calcephytes are infound there (e.g., in the okrug of limestone ranges and massifs of Apkhazeti-Samegrelo and okrug of limestone massif of Racha-Lechkhumi and Imereti). In the limestone ecotopes the endemic florocenotype of subalpine meadow is unique, which is created by *Woronowia speciosa*—*Carex pontica* and local calcephyte endemic species, such as: *Campanula mirabilis*, *Betula megrelica*, *Potentilla imerethica*, *Campanula radchensis,* etc. The meadow-high-herbs, forest mesophile, and hemixerophile florist complexes, as well as the dendroflora (cherry laurel, common rhododrndron, and Colchis holly) of the evergreen subforest, are rich in composition of species.

The Kolkheti Province is divided into seven okrugs in the territory of Georgia.

II. Elbrus-Kazbeg or Central Ciscaucasus Province includes the Tergi River basin on the southern slope of the Caucasus in the territory of Georgia. It is represented by one okrug. In the west, it extends to the peak of the Adai-Khokhi in North Ossetia; in the east—to the Mount of Borbalo. There are subalpine, alpine, subnival, and nival zones developed.

High mountain area is rich in species of rock-scree-detritus and moraines, meadows, various herbs, and graminaceous floristic complexes; the western and northern slopes are covered with birch trees (Litvinov's and Radde's birches) and rhododendrone shrubs. The characteristic species of high mountains is the mountain is *Cerastium kazbek,* and from the Caucasus monotype genus —*Symphyoloma* and *Triganocaryum.*

As above mentioned, the province is represented as one okrug in the territory of Georgia.

III. Tusheti-Dagestan or Eeastern Ciscaucasian Province is also represented as one okrug in the territory of Georgia. From the west, it is bordered by the watershed range of the rivers of Asa and Arghuni. In the east, the province is spread in Dagestan. Due to the medium and high mountainous relief, here are developed the forest, subalpine, alpine, subnival, and nival belts. For the forest belt (especially in Tusheti), a pine forest is common that is found in the subalpine zone too together with birch trees.

In the landscape, rhododendron's role is reduced. In the scree-detritus floristic complex of the subnival belt, the monotype endemic genus of the Cebtral Eastern Caucasus is found, such as *Pseudovesicaria*, *Symphyoloma,* and *Trigonocaryum* and rare, endemic genus of *Pseudobetckea*, characteristic of slate Dagestan. There are also found many xerophile species.

The province is represented as one okrug in the territory of Georgia.

IV. In the Iveria or eastern Transcaucasian Province, in the territory of Georgia are united the southern slopes of the Caucasus in the east of the Likhi Range, southern subranges of the Caucasus, and Kartli and Kakheti plain—lowlands. The province is characterized by semi-desert, arid forests, shibliak and mountain xerophile vegetation, summer-green deciduous and dark coniferous forests, subalpine and alpine belts.

In the western part of the province, the complexes of mesophile flora enriched in the Colchis species (Colchis holly, Cherry laurel, and common rhododendron) dominate. The florist complexes of arid forests (Mt. Atlas mastic tree and, juniper) are characteristic of the province; Caucasian endemic species prevail in forest and highland meadows and scree-detritus florocenotypes. The number of Colchis endems decreases; in the eastern part, e.g., in Kakheti Caucasus Okrug, there are found yew, wingnut, chestnut, etc. Some of the hirkani species reach this okrug. Among the rare species the *Iris iberica*, *Gentiana lagodechiana*, Kakheti endemic species—*Gymnospermium smirnowii,* and others are common. Akhaltsikhe hollow is rich in endemic species, where the species of Asia Minor xerophile complexes are also in big amount.

Due to the flora diversity, the province is divided into four okrugs.

V. **The Lesser Caucasus Province** includes the Trialeti and Somkhiti or Loki Ranges, as well as the mountain systems of Shua Khrami in the territory of Georgia. The latter is composed of Bedena massif, which is a watershed of the rivers of Khrami and Algeti, Belindag Barehead and Gomeri Ranges, Iragvi flatland, and Kviriketi and Shindlar massifs. The province continues in Armenia and Azerbaijan.

The province is represented by steppe, hemixerophile vegetation, semi-desert, and arid forests, broad-leaved (600–1400 m above sea level), and dark coniferous forests (1400–1800 m above sea level) and subalpine (up to 1800–2500 m above sea level) belts. The hemixerophile and xerophile floristic complexes are intruded in the broad-leaved and, sometimes, in the dark coniferous forest belts. The western part of the province is under the influence of the Kolkheti Province.

Climate is continental in the central and eastern directions of the Lesser Caucasus province; Climate and relatively low altitudes of this region of the province greatly influenced on vertical distribution of vegetation and floristic; the broad-leaved and subalpine belts are basic; the dark coniferous forest belt is limited, and in the east is completely dropped out. Original look of natural floristic complexes has been modified by the influence of anthropogenic factors. The steppe and shrub (hemixerophile) complexes with domination of Oriental hornbeams and black buckthorn prevailed at their stead. Subalps are mainly formed by the graminaceous-various herbs in secondary meadows. In the province, pine forest fragments are found as well.

The province includes two okrugs.

VI. **The Southern Georgia's highland and Western Asian Province** comprises the Javakheti Upland, Akhaltsikhe hollow and Eruzeti hill in the territory of Georgia,. The remnants of the florocenotype complexes of mountain steppe and steppe meadows are preserved here, which are composed of bridal veil, fescue, koeleria, bromes, alfalfa and sainfoin. The narrow strip of the subnival belt is expressed in the Abuli and the Samari Ranges. On the volcanic relief (in the lakes and marshes), the rich floristic complexes are developed.

Tetrobi limestone massif is rich in endemic species, such as *Scorzonera dzhavakhetica* and *S. ketzkhovelii,* etc. In this province, the species of Armenian highland and Western Asia are also grown.

There are two okrugs in the province.

VII. The Mtkvari-Aras province includes the Kvemo Kartli Lowlands and Eldari Plain-lowland in the territory of Georgia. The zonal type of vegetation is semi-desert fragments (mugworts, salsolas, and others).

The province includes one okrug.

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Fauna

14

Revaz Zhordania

Abstract

In this chapter types and spatial distribution of fauna are presented. High endemism is characteristic of Georgia, especially in the Greater Caucasus. 104 mammals, 304 birds, 42 reptiles, 12 spadefoot toads and 142 fish species are known in Georgia. There are thousands of invertebrate animal species, the full details of which have not been identified so far. Animals are distributed by zones, but species with large ecological valence often inhabit several zones.

The wildlife of Georgia is diverse. It is mainly represented by paleoactic elements, and in the southeastern section—by the Central Asian subzone fauna species or their related forms.

There are known 104 species of mammals in Georgia, 304 species of birds, 42—reptiles, 12—spadefoot toads, and 142 species of fish. There are found thousands of species of invertebrates. Their full composition has not been identified yet. Animals are predominantly distributed by zones, though the species of large ecological valency often inhabit several zones.

Among the mammals of the alpine zone (the Caucasus Range and the southern highland of Georgia) the Dagestan and Caucasian western turs (Fig. 14.1) are remarkable, which inhabit the Caucasus high mountains and are the endemic to the Caucasus. Wild goat is found in Pirikita Khevsureti and here-there in Tusheti, which is the endangered species and is included in the "Red Book of Georgia" (RBG). Both in the Caucasus and in the Lesser Caucasus the chamois is widespread; the long-clawed mole vole is found in the alpine meadows. The Caucasian snow vole inhabits Gudauri and its surroundings. Dagestan hamster inhabits Khevsureti. The Caucasian shrew and lesser white-toothed shrew are found in some areas of alpine meadows. Some predators go up there from the forest zone (Gurielidze 1997).

There are many birds in the alpine zone. Caspian snowcock (RBG) is remarkable, which inhabits the southern highland. In the Caucasus high mountains, the Caucasian snowcock is widespread. In some places, the rock partridge is found. The golden eagle, griffon vulture, bearded vulture, and Egyptian vulture (they are included in RBG) inhabit the same zone. In the alpine zone the chough, western jackdaw, Caucasian bullfinch, mountain skylark, alpine accentor, and others are found. Among the reptiles, it is worth mentioning the Caucasian rock lizard, in some areas—water snakes and others. Among the European spadefoot toads, the Transaucasian frog and the Caucasian parsley frog (USSR Red

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Fig. 14.1 Capra Caucasica cylindricornis (Photo by Z. Javakhishvili, *Source* Agency of Protected Areas of Georgia)

Fig. 14.2 Alcedinidae Rafinesque (Photo by R. Tolordava)

Book) are common. The trout are found in the high mountain rivers and lakes. There are many types of insects and mollusks there.

The forest zone occupies quite a large area in Georgia. This zone includes the southern slope of the Caucasus, starting in western Georgia from 500 m to subalpine meadows, and in eastern Georgia—from 800 m to subalpine meadows. This zone also includes the forests of Kartli-Imereti, Trialeti, and Gombori Ranges.

Among mammals of this zone, the following species are remarkable: wild boar, roe deer, deer, and wolf, which is almost everywhere, and in some places reach alpine meadows. Everywhere can be found the golden jackal and Transcaucasian mountain red fox, which are found in other stations. Wildcat and lynx are widespread.

Almost everywhere can be found the brown bear, Transcaucasian badger, and Caucasian yellow marten. One or two otters (RBG) are found in many areas. Almost everywhere can be found the weasel. In the forests and its outskirts, rabbits are found in some alpine meadows. In the deciduous and coniferous forests, the Caucasian squirrels are widespread, and several Caucasian ground squirrels are found in the forests of the Tergi River source. Almost everywhere can be found the edible dormouse and forest dormouse. The Caucasian birch mouse inhabits the Tergi River source, Gudauri, Svaneti, and Apkhazeti.

The eastern broad-toothed field mouse is characteristic of the same zone. The Dagestan hamster inhabits the vicinities of Shatili. In the Guria-Ajara range, there are often found the Pontian bank vole and European water vole. Some places are found the Dagestan pine vole, Eastern broad-toothed field mouse, and Transcauasian vole as well as the Nasarov's mountain vole. There are widespread the hedgehog, mole, and Caucasian shrew. The Radde's shrew (RBG) inhabits the vicinity of Bakuriani and Lagodekhi region, near Kutaisi.

The Caucasian white-toothed shrews are found in many places. In Lagodekhi region, Gudamakari gorge, and Ananuri surroundings, the Persian white-toothed shrews are found; in the neighborhood of Abastumani, the lesser white-toothed shrew (RBG) is found, in Mtskheta—the Mehely's horseshoe bat (RBG), in Zugdidi and in its vicinities—the brown long-eared bat (RBG), in Tbilisi, Zugdidi and Achara—the common bent-wing bat (RBG), in Borjomi Gorge and Apkhazeti—the tlying fox (RBG), in Kutaisi, Poti and Achara the common pipistrelle (RBG) s found, and the barbastelle (RBG) is common in Tbilisi and Borjomi gorge.

The forest zone is quite rich in birds. The Caucasian grouse (it is an endemic to the Caucasian and included in the RBG) is widespread. The Colchis common pheasants inhabit the very specific areas of forests and the lower zone (up to 750 m), mostly the floodplain forests and shrubs and bush woods. European turtle dove and common wood pigeon are found everywhere. Forests and lake banks are inhabited by Eurasian coots and common moorhens; in some areas—the rails and the little crakes. In wetlands and humid areas, there are found the northern lapwing, green sandpiper, wood sandpiper, Eurasian woodcock, common snipe, and others; in the banks of water reservoirs the seagulls are inhabited, while the common goldeneyes inhabit several areas; the greylag goose, mallard, and Eurasian spoonbill are inhabited near water reservoirs.

The black stork (RBG) is represented by single units; here are found the white stork, gray heron, great white egret, black-crowned night heron, falcon (RBG), northern goshawk, Eurasian sparrowhawk, and western marsh harrier. Egyptian vulture inhabits the hilly areas while the cinereous vulture—the dense forest. Here-there is found the greater spotted eagle. Common buzzard, Eurasian eagle-owl, Owl, common cuckoo, hooded crow, Eurasian magpie, Caucasian chiffchaff, several species of Eurasian reed warbler, Barn swallow and common house martin, and others inhabit many areas.

Among the forest zone the interesting reptiles are the Caucasian agamas, European legless lizards, slow worms, Caspian green lizards, three-lined lizards, sand lizards, and rock lizards; in many areas can be found the Eurasian blind snake, grass snake, water snake, yellow-bellied racer, Dahl's whip snake, Aesculapian snake (RBG), spotted whip snake and four-lined snake. Caucasian viper, horned viper, and tortoises with limited distribution areal is included in the RBG. Among amphibians are remarkable endemic species of Caucasian salamander, northern banded newt and parsley frogs (they are included in the RBG), lake frogs, longlegged wood frogs, tree frogs, Caucasian toads and European green toads and others are widely spread.

The trout, the Black Sea salmon, Oriental chub, Colchic nase, shemaya, Kura gudgeon, common carp, Colchic barbell, mursa, loach, Wels catfish, goby, and others are remarkable among fishes. Common perch and other fishes are found in some areas.

The forest zone is rich in various kinds of invertebrate animals (insects, mollusks, spiders, worms, etc.).

Various animals inhabit the plain and lowland zone of eastern Georgia, though the fauna of this zone is monotonic. Among mammals, the endangered species of gazelle inhabiting Shiraki Valley is noteworthy (RBG).

Wild boars, roe deer, and deer are found in the forests of Kakheti and Mtkvari floodplains in Gardabani. Eurasian hedgehog, Caucasian mole, Caucasian shrew, Caucasian white-toothed shrew, and lesser white-toothed shrew are widespread. There are numerous horseshoe bats, mouse-eared bats, and noctule bats, which are widespread in the forest zone too.

The European rabbit, common vole, steppe field mouse, golden hamster, and grey dwarf hamster are found in many places. The Libyan jird inhabits the Eldari and Samgori Valleys; the European water vole, hedgehog, Eurasian otter, and the least weasel are widely distributed. In the livestock breeding areas almost everywhere can be found the gray wolf. The jackals and the Transcaucasian field foxes are found in many places. Endangered species are the striped hyena and Transcaucasian leopard (RBG).

Many birds are found in this zone. The common quail, rock partridge, and gray partridge (RBG) are remarkable; the reacclimated black francolin (RBG) inhabit the small area of the Iori gorge. The common pheasant, rock pigeon, common wood pigeon, and European turtle dove are found in many areas. The vicinities of the water reservoirs are inhabited by western swamphen (RBG), Eurasian coot, spotted crak, etc.; also seagulls, sandpipers, etc. Rarely can be found the greylag goose, swans, and others. The pygmy cormorant inhabits some areas, while the Rosy pelican and Dalmatian pelican are rarely found during migrations. Endangered species are the eastern imperial eagle, tawny eagle, and osprey (they are included in the RBG). Wide distribution has the birds, such as Eurasian eagle-owl, black woodpecker, European green woodpecker, great spotted woodpecker, wrynecks, common swift raven, hooded crow, Eurasian tree sparrow, common chaffinch, several species of skylark, wagtails, Caucasian chiffchaff, Eurasian reed warblers, common blackbird, common nightingale, white-throated dipper, common house martin and barn swallow, etc.

The reptiles include Caucasian agama, European glass lizard, slowworm, medium, striated, sand, and meadow lizards. Rapid racerunner and others can be found in eastern Georgia. Among snakes the following are interesting: Eurasian blind snake, javelin sand boa (RBG), grass snake and dice snake, red-bellied racer, Dahl's whip snake and spotted wipe snake. Aesculapian rat-snake (RBG) is found in warm areas. Cat snake and meadow viper are found in many areas. The blunt-nosed viper inhabits some areas. The European pond turtle and Caspian turtle inhabit the water reservoirs and their surroundings, while the common tortoise (RBG) can be found in some areas.

Among amphibians the northern banded newt is remarkable. There are widespread the lakes and longlegged wood frogs, toads, and tree frogs.

Among fishes, the following species are remarkable: trout, common chub, nases, luciobarbus mursa, barbell, Caucasian scraper, carp, Wels catfish, Caucasian goby, and others.

Within the zone, there are many types of insects, spiders, mollusks, worms, and others.

The western Georgia's Plain and Lowland zone occupies an area from the Black Sea coast (Psou-Sarpi) to Zestaponi (to its east). It covers the Kolkheti Lowland (within 10–250 m) and Kolkheti evergreen subforest belt (250–500 m).

Among mammals there are found the European hedgehogs and European moles; the big white-toothed shrew is found in the Kodori Gorge, Zugdidi surroundings, and other areas. The lesser horseshoe bat is widely spread; the long-eared bats are common in Zugdidi and its surroundings; the vesper bats and noctule bats are in many areas, as well as the European rabbit, Caucasian squirrel, edible dormouse, forest dormouse; the wood mice and Pontian bank voles are found in many places; almost everywhere are found the Transcaucasian badger, Caucasian stone marten, least weasel, Eurasian otter, and others. The gray wolf areal has been reduced; everywhere are found jackals, red foxes, wildcats, lynxes, brown bears, and others. A wild boar can be found here- there, in some areas—roe deer and others.

Among birds, the common pheasant is characteristic of this zone. The common quail, common wood pigeon, European turtle dove, Eurasian coot, the common moorhen, spotted crake, northern lapwing, Eurasian woodcock, seagulls, horned grebe, greylag goose, and others are widespread here; in rare cases, while migrations, there are found rosy pelicans and Dalmatian pelican, as well as red, gray and white herons; here-there can be found the little bittern. In some areas there can be found the black storks, falcons, northern goshawk, Eurasian sparrowhawks, Syrian woodpeckers (RBG) and middle spotted woodpeckers, wrynecks, common swift, hooded crow, Eurasian reed warbler, goldcrest, Caucasian chiffchaff, common blackbird, African stonechat, common nightingale, European robin, Eurasian wren, barn swallow and many others.

Among the reptiles the long-cripple, meadow lizard, Acharian lizard are widespread. The European blind snakes are found in many areas, as well as the grass snake and dice snake, smooth snake, and the Caucasus Viper. Almost all the swamps and ponds are inhabited by the European pond turtles.

The smooth newt, northern crested newt, banded newt, lake frog, common and green toads, tree frog, and others are remarkable among amphybians.

Among the fishes, the following species are remarkable: the trout, the Black Sea salmon (which enters some rivers for breeding), bastard sturgeon, Colchic sturgeon, northern pike, roach, asp, Colchic nase, and many others, as well as several species of gobies and rare electric eel, etc.

The Eurasian otter inhabits the banks of lakes and rivers; the Transcaucasian badger, Caucasian stone marten, and least weasel are found everywhere. In the livestock farming regions are found gray wolves; almost everywhere can be found the Transcaucasian mountain red fox, in some areas—wildcat, lynx, and brown bear. Rarely is found the wild boar, roe deer, deer, and chamois.

The Meskheti-Javakheti Upland zone includes the belt of high mountain valleys of southern Georgia: Javakheti, Tsalka, Zurtaketi, Abulsamasari, and Kechuti Plateaus. Among mammals here are found the European hedgehogs, European mole, Eurasian pygmy shrew, horseshoe bat, brown long-eared bat, barbastelle, flying fox, European rabbit, Caucasian squirrel, and edible dormouse. Mole-rats are found in Akhalkalaki surroundings and in some other areas. There are many wood mice and different species of voles. Lakes and rivers are inhabited by Eurasian otter; in many areas can be found the Caucasian badgers, the Caucasian stone marten, and the least weasel. There are wolves in the livestock districts, almost all of them are the foxes of the Transcaucasian mountain, some forest cats, lynx, brown bears. Wild boar, rod, deer, and chamois are rare.

Caspian snowcock (RBG), common snipe, Eurasian woodcock, seagulls, etc. are found among the birds. Here-there are found mallards, red-crested pochards, falcons, goshawk, sparrow hawk, and black kite. In some areas, there can be found the cinereous vulture, Egyptian vulture, western marsh harrier, Eurasian eagle-owl, common cuckoo, European roller, Eurasian hoopoe, raven, Eurasian jay, common starling, wagtails, great tit, barn swallow, common house martin and many others. Rare species are the common firecrest and Asian crimson-winged finch (RBG).

Reptiles include the Caucasian agama, long-cripple, Caspian green lizard and wall lizards, grass snake and dice snake, four-lined snake, and others.

The Caucasian salamanders (Fig. 14.3) and here-there the Caucasian parsley frogs are found among the European spadefoot toad. The lake frog, toad, and tree frog are widely spread.

In the rivers and lakes, the trout, Mtkvari nases, Caucasian goby, barbell, luciobarbus mursa, rutilus, the Caucasian goby, and others are found.

Fig. 14.3 Mertensiella Caucasica (photo by G. Sulamanidze, *Source* Agency of Protected Areas of Georgia)

The Black Sea is quite rich in a variety of animals, a significant part of which is found along the coasts of Georgia as well.

Among mammals, there are numerous harbor porpoises, bottlenose dolphin, and short-beaked common dolphin. Among the pinnipeds the Mediterranean monk seal (RBG) is a rare, one sample of which was found in 1939 near Batumi (Bukhnikashvili and Kandaurov 2002).

Among fishes are remarkable sharks, thornback rays, common stingray, beluga, Atlantic sturgeon (RBG), several species of herring, European sprat, and the Black Sea salmon, rarely are found electric eels, flathead gray mullet is common, several species of sphinx blenny, various gobies; flatfishes; monkfish is few, sea pipefish, seahorses and others are found in big amount.

From the 20 s of our century, many animals have been acclimated to Georgia. Coypu is acclimated in some lakes of western Georgia. In 1938, a number of raccoon dogs were released in many areas, which became harmful after certain time. Now it is being exterminated everywhere. In 1952, in the Borjomi Gorge, the red squirrel was acclimated, which inflicted great damage to forestry.

Red squirrel was inhabited and widely spread in Georgia from the North Caucasus. The European turtle dove also inhabited our territory. In 1925, the mosquitofish was acclimated to number of areas of Georgia, which subsequently widely inhabited almost all the country. The mirror carp is acclimated in the Bazaleti, Jandriti, and other lakes. Whitefish was bred everywhere.

Rainbow trout, silver carp, and others are bred in a number of water reservoirs in Georgia. Insects are also acclimated in Georgia: parasitoid wasp, ladybird beetle, mealybug ladybird, and others. The great spruce bark beetle was spread in the Borjomi Gorge that inflicted great damage to forestry.

As a result of direct or indirect human impact on the nature of Georgia, the areal of some animals has been significantly reduced, and some have been exterminated at all; in the 1st quarter of the twentieth century, the last bison were killed, and 200 years ago, in the farmlands of western Georgia, the European beaver has been exterminated. In the 2nd half of the twentieth century, the goitered gazelle (Fig. 14.4) has been exterminated, while the areas and total amount of striped hyenas, West Caucasian turs, wild goats, and common pheasants have been reduced.

Fig. 14.4 Gazella Subgutturoza, Vashlovani protected Areas (Photo by V. Cherkezishvili)

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15 Landscapes

Dali Nikolaishvili

Abstract

Georgia is a very interesting country in respect of the biological and landscape diversity. There are two classes, 20 types, 40 subtypes, and 71 genera of landscapes in Georgia. The distribution of the landscapes in different regions of Georgia is also extremely uneven. General overview of basic landscape types, landscape diversity, virgin landscapes, phytoresources of the landscapes, and anthropogenic transformation of the landscapes are discussed in this chapter.

15.1 Georgia on the World Background

Georgia is a small country and with its social-economic or physical-geographical properties, is not much remarkable in the world arena. Georgia occupies only 0.02% of the total land area of the world. Due to its small area, Georgia does not outstand either with great areas of forests, agricultural lands (38%), protected areas, or great number of flora or fauna species (Nikolaishvili and Matchavariani 2011); however, on the other hand, the country is diversified, specific and even unique in many respects. The major reason for the outstanding nature and uniqueness of Georgia is its geographical location and versatile natural conditions.

Georgia is a very interesting country in respect of the biological and landscape diversity. As a part of the Caucasus, the country is on the lists of: (1) 25 biologically richest and endangered "hot spots" of the world (CI, CEPF), (2) 200 sensitive and vulnerable eco-regions of the world, (3) locations of endemic bird habitats (BirdLife International), (4) one of the world centers of agro-bio-diversity, (5) "hot spots" of large herbivores (WWF) (An Ecoregional Conservation… 2006; Bio Diversity of the Caucasus… 2001). This list can be made longer if considering such factors as well-preserved diversity of species and ecosystems in the country, richness of Georgia in endemic, relict, medicinal, and decorative plant species, forests occupying over 40% of the territory of the country on the one hand and the environment of the country not subject to major changes like many regions of the world on the other hand. Therefore, in an environmental respect, Georgia looks a much "cleaner" region in the world (Beruchashvili et al. 2002). Besides, Georgia is one of the outstanding countries in the world in respect of landscape diversity, and with the rich biodiversity, Georgia is ahead of many countries (Beruchashvili 2000a, b). These natural values are still less studied and the ecological function

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Georgia can play on a global scale is not thoroughly realized yet.

15.2 Principal Landscapes of Georgia

According to N. Beruchashvili's Landscape map of the Caucasus, there are two classes, 20 types, 40 sub-types, and 71 genera of landscapes in Georgia (Beruchashvili 1979, 1980, 2009). Mountain and plain landscapes on the territory of the country are distributed very unevenly. Mountain landscapes occupy 53.1 thousand km^2 making 76% of the country area. Even according to the altitudinal zoning, the landscapes are distributed too unevenly in the mountains (Fig. 15.1): the low-mountain landscapes occupy 3% of the total territory of Georgia, mountain depressions occupy 1%, lower-mountain landscapes occupy 12%, middle-mountain landscapes occupy 24%, upper-mountain landscapes occupy 7% and High Mountain subnival and nival landscapes occupy 1% of the total territory of Georgia (Nikolaishvili and Matchavariani 2015). The landscapes of meadows and meadows-and-steppes occupy almost equal areas in the plains, lowlands, and mountains. These landscapes are most common in the mountain depressions of the Great Caucasus and high plateaus of South Georgia. Karst and volcanic landscapes occupy little areas, with 8% and 6% of the total territory of Georgia, respectively (Nikolaishvili and Chikhradze 2017).

The distribution of the landscapes in different regions of Georgia is also extremely uneven (Table 15.1). Plain landscapes occupy largest areas in Kakheti region (5.4 thousand km^2 making over 40% of the total territory of the region) (Nikolaishvili and Chikhradze 2017). Kakheti is also outstanding with the areas of low-mountain and upper-mountain forest landscapes. Mtskheta-Mtianeti region falls little back with the area of the upper-mountain forest landscapes. The middle-mountain forest landscapes occupy the largest area on the territory of Apkhazeti amounting to almost 30% of the total territory of the region. The high mountain subalpine landscapes occupy the largest areas in Imereti and Samegrelo-Zemo Svaneti, while high mountain alpine landscapes occupy the largest area in Mtskheta-Mtianeti (Nikolaishvili and Chikhradze 2017). Middle-mountain forest landscapes and high mountain subalpine landscapes occupy larger areas in West Georgia (Abkhazeti, Samegrelo-Zemo Svaneti, Imereti, Adjara, Guria, Racha-Lechkhumi -Kvemo Svaneti), while lower- and upper-mountain landscapes are mostly spread in the east of the country. As for the alpine landscapes, they occupy almost equal areas in the both regions of Georgia (Nikolaishvili and Matchavariani 2015).

Fig. 15.1 Distribution of landscapes according to altitude

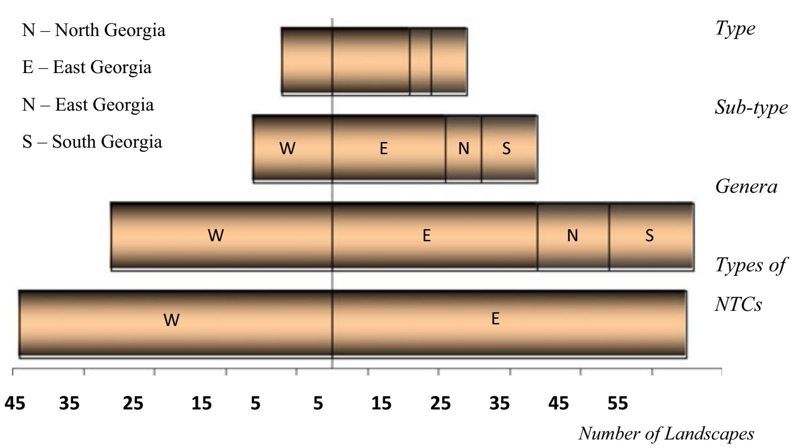

Table 15.1 Area of landscapes of Georgia according to the regions (thousand square km)

Regions of Georgia	Plain	Mountain depression	Middle mountain				High mountain subalpine, High plateau	High mountain alpine	Other	Sum
			Low mountain	Middle-mountain	Upper mountain	Sum				
Abkhazeti	2.959	0.000	0.876	2.506	0.237	3.619	0.990	0.191	0.667	8.426
Samegrelo-Zemo Svaneti	2.624	0.010	0.126	1.800	0.144	2.070	2.474	0.456	0.809	8.443
Imereti	2.865	0.144	0.195	2.427	0.143	2.765	2.564	0.092	0.000	8.430
Adjara	0.768	0.000	0.709	0.718	0.272	1.699	0.219	0.046	0.000	2.732
Guria	1.443	0.000	0.043	0.444	0.156	0.643	0.387	0.600	0.000	3.073
Racha-Lechkhumi -Kvemo Svaneti	0.000	0.055	0.000	1.106	0.618	1.724	0.564	0.351	0.088	2.782
West Georgia	***10.659***	***0.209***	***1.949***	***9.001***	***1.570***	***12.520***	***7.198***	***1.736***	***1.564***	*33.886*
Kakheti	5.396	2.571	0.756	1.846	0.963	3.565	0.982	0.165	0.287	12.966
Shida Kartli	1.045	0.000	1.137	0.328	0.078	1.543	0.336	0.203	0.087	3.214
Mtskheta-Mtianeti	0.371	0.000	0.614	1.640	0.920	3.174	1.056	1.247	0.642	6.490
Samtskhe-Javakheti	0.144	0.901	1.626	0.856	0.253	2.735	1.923	0.671	0.161	6.535
Kvemo Kartli	1.814	0.193	0.867	2.162	0.000	3.029	1.615	0.099	0.000	6.750
East Georgia	***8.770***	***3.665***	***5.000***	***6.832***	***2.214***	***14.046***	***5.912***	***2.385***	***1.177***	*35.955*
Total	**19.429**	**3.874**	**6.949**	**15.833**	**3.784**	**26.566**	**13.110**	**4.121**	**2.741**	69.8

Source Nikolaishvili and Chikhradze (2017)
Bold / Italic express the sum of West ans East Georgia

The Major Landscapes of Georgia Are

Plain and Piedmont hilly subtropical humid (Kolkhish forest) landscapes are spread in West Georgia—on Kolkheti Lowland and in the zone of its adjacent piedmont, mostly at 0–600 m asl and at 0–800 m asl in the eastern part of Kolkheti—Imereti Plateau. These landscapes occupy 9.64 thousand km^2, making almost 14% of the total territory of Georgia. Their original natural appearance is strongly changed and agricultural plots of field cover vast areas. Virgin NTCs have survived only in the reserves and bogged areas of Kolkheti.

Plain and Piedmont hilly sub-Mediterranean semi-humid landscapes with forest and shibliak (dry shrubs) are spread mostly within the limits of plains of Shida Kartli and Kvemo Kartli and on the adjacent hilly piedmont, as well as Bichvinta Cape and Kovaluki upland. In West Georgia, they occupy 0–300 (600) m asl, and 400–800 (900) m asl in East Georgia (Kakheti, Shida Kartli, Mtskheta-Mtianeti, Samtskhe-Javakheti, Kvemo Kartli). In the vegetation period, due to relatively less atmospheric precipitations, the effect of sub-Mediterranean climate occurs, and as a result, they are attributed to the sub-Mediterranean type. The largest area is occupied by steppe vegetation, as well as shibliak, phrygana, and sparse arid forests. The areas of mixed-hardwood forests are limited and they are mostly found in West Georgia. The landscapes are intensely modified as a result of economic activities. The landscapes found on Kovaluki Plateau have maintained their original natural appearance better.

Plain and piedmont hilly subtropical semi-arid landscapes with steppe, shibliak, and semi-desert vegetation are spread within the limits of plains in East Georgia, at 200–600 (800) m asl. They cover the plains of Shida Kartli and Kvemo Kartli and Iori Plateau. Steppes and shibliak dominate with dominant semi-desert vegetation at some locations. Almost the whole areas of the landscapes are modified: they are intensely crossed with the irrigation systems and are covered with agricultural plots of field (vegetables, fruit, winter pastures). Due to the near location of roadsides and settled areas, the ecological situation with these landscapes is very severe. These landscapes have maintained their original appearance a little better within the limits of Iori Plateau.

Plain and piedmont hilly subtropical arid desert and semi-desert landscapes spread in the south part of Iori Plateau, in the zone bordering Azerbaijan. They are more vastly spread on the territory of Azerbaijan. They occupy 0.09 thousand km^2 making only 1.2% of the whole territory of Georgia. Despite being unpopulated, these landscapes are subject to a strong impact due to intense grazing. The amount of phytomasses here is one of the least in Georgia. The phytomass reserve makes 0.054 mln. t (0.01% of the total phytomass reserve of Georgia), productivity is 2.5–3.0 t/ha annually.

Moderately warm plain semi-humid forest landscapes transient to the subtropical type are spread within the limits of Alazani Plain, at 200–600 m asl. They occupy an area of 1.27 thousand km^2 making only 1.8% of the total area of Georgia. The landscapes of the plains in East Georgia receive the most amounts of atmospheric precipitations. This is why the natural vegetation has more or less Kolkhish appearance. A significant part of the territory is modified owing to the human's economic activities.

Hydromorphic and sub-hydromorphic marsh, meadow and tugai landscapes are spread at the locations with high humidity—in the central part of Kolkheti Lowland and along the gorges of the rivers in East Georgia. They occupy 1.74 thousand km^2, making only 2.5% of the total area of Georgia. The vegetation cover is hydromorhpic, with dominating marshes and floodplain forests. The degree of anthropogenic transformation is particularly high along the gorges of the rivers.

Mountain subtropical semiarid steppe, shibliak, arid sparse forest landscapes are spread in East Georgia, in the eastern part of Iori Plateau, and in Azerbaijan beyond the borders of Georgia. Hypsometrically, they occupy 300 (400)—900 (1100) m asl and 2.31 thousand km^2, making only 3.3% of the total area of Georgia. Their original appearance is well preserved.

Mountain subtropical arid semi-desert and desert landscape spreads in East Georgia, on the northern edge of Eldari Lowland, over the southern slope of Eldari Ridge. It occupies much larger area on the territory of Azerbaijan within 200–700 m asl altitudinal range, covering 0.05 thousand km^2. Its original natural appearance is well preserved.

Mountain moderately warm humid landscapes are spread both, in west and East Georgia—over the Great Caucasus and the Lesser Caucasus, at 300 (600)–1500 (1700) m asl in East Georgia and 700–1800 (2000) m asl in West Georgia. They occupy 19.36 thousand km^2, what is almost 28% of the total area of Georgia. They are less modified due to human's economic activities. This is particularly true with the middle-mountain forest landscapes. Within the limits of the lower-mountain forest landscapes, the agricultural plots of field (vineyard, orchards, watermelons, melons and gourds, plantations) occupy vast areas.

Moderate mountain semi-humid middle-mountain shibliak, arid sparse forest, phrygana, meadow-steppe landscapes are spread in South Georgia—over the northern and eastern slopes of Erusheti mountainous area, at 1600–1900 m asl. They occupy 0.19 thousand km^2, making 0.3% of the total area of Georgia. They occupy vast areas in Armenia. They are mostly used as pastures. They partly occupy the agricultural plots of fields, mostly cereals.

Moderate mountain semiarid landscapes transient to the moderately warm type with steppes, meadow-steppes, phrygana, and shibliak are spread in South Georgia, within the limits of larger areas within the limits of Armenian Plateau. They occupy 1.85 thousand km^2 what is 2.7% of the total area of Georgia. Their original natural appearance is strongly changed. They are mostly used as pastures, and partly as agricultural plots of field (cereals, vegetables, potatoes).

Moderately cold mountain landscapes are spread over the southern slopes of the Great Caucasus and northern slopes of the Lesser Caucasus, mostly in West Georgia. They are spread at (1000) 1400–2000 (2200) m asl altitude and occupy 9.73 thousand km^2 what is 13.9% of the total area of Georgia. Their original natural appearance is well preserved. Hypsometrically, dark coniferous and beech forest-dark-coniferous forests are spread at lower altitudes, while pine forests and birch forests grow at higher locations. The areas with dark-coniferous forests are less modified what is hardly true with pine or birch forests.

High mountain meadow subalpine forest-shrub-meadow and alpine shrub-meadow landscapes are spread over the southern slopes of the Great Caucasus and northern slopes of the Lesser Caucasus. They are spread at (1500) 1800–3000 (3200) m asl altitude and occupy 14.7 thousand km^2 what is 21% of the total area of Georgia. Their vast areas are occupied by summer pastures and hey-meadows.

High mountain subnival landscapes are spread mostly in the Great Caucasus Mountains and as fragments over Abul-Samsara and Javakheti Ridges. They are spread at 3000–4000 m asl altitude and occupy 14.7 thousand km^2, what is approximately 2.1% of the total area of Georgia. These landscapes are unsettled and in fact, are not under the impact of any economic activity. Their original appearance is well preserved.

High mountain glacial-nival landscapes are spread in the ridge zone of the Great Caucasus and as fragments over its southern slope. They cover the territories of the mountainous areas of Apkhazeti, Svaneti, Racha, and East Georgia. They are stretched as an almost continuous strip from Bzipi Valley to Mamisoni Pass. They are the area of eternal snow and glaciers. They occupy 3.47 thousand km^2 what is almost 5% of the total area of Georgia.

15.3 Landscape Diversity in Georgia

"*Every corner of Georgia and nature of this country generally, is the most beautiful on earth*", —wrote Arthur Leist, a German write, publicists, and translator. The nature of Georgia is indeed rich and diversified, and it is fairly called the country of contrasts. The Kolkhish forests are extremely rich in species, high-productive fir and pine forests, virgin forest massifs, bulk of mineral sources, rare, endemic and relict flora and fauna species, fruitful soils of East Georgia, unique red soils (krasnozems), buried rare monuments of flora and fauna, natural nutrition areas, high hydroelectric potential, great biological and landscape diversity—are an incomplete list of the natural riches of Georgia, which are so much in the country. It should also be noted that the specific weight of the areas, which are under intense anthropogenic impact, is little. The ecological problems of Georgia have a more local nature and with their severity fall much back many regions of the world. This is why they say that Georgia has high environmental potential, which can be used to further develop recreation and tourism in the country.

Georgia is located in the Alpine-Himalayas geotectonic zone of Eurasia, which is stretched for almost 12 thousand km between the coastlines of the Atlantic and Pacific Oceans. In addition to the Great Caucasus and Lesser Caucasus, there are the Pyrenees, the Alps, the Apennines, the Carpathians, Elbrus, Kopet Dagh, the Pamirs, Tian Shan, the Himalayas and other mountain ranges stretched here. The mountain ranges on the territory of the Caucasus form a kind of group, with Georgia located in its key section. Such state of affairs has had a peculiar impact on the geological structure and relief of Georgia.

High, average and low mountains, upland regions and plateaus at different altitudes, plains and lowlands, mountain depressions, and dissected and fractured deep gorges are all found on the territory of the country. Georgia is fairly referred to as a mountainous country. ¾ of the territory of Georgia is occupied by mountains. In an economic respect, the plain and lowland zones are most important, with over 80% of the country population living there and with almost all cities and towns, settlements, and agricultural plots of field: plantations, orchards, vineyards, and arable lands found here.

With the types of relief, there are four large units identified on the territory of Georgia: the Great Caucasus, intermontane plain, the Lesser Caucasus, and Javakheti Plateau. North of the country, there are the Great Caucasus Mountains with eternal snow and glaciers stretched for almost 900 km. Its tallest and most cliffy part is its central section (the tallest mountain is Shkhara (5203 m)).

In the southern part of the country, there stretches volcanic Javakheti Plateau, a flattened surface at 1500–2100 m above sea level filled with lava flows. Javakheti, Samsara, Erusheti, and Nialiskure Ridges are found only in the extreme zone of it. The Lesser Caucasus—high ridges of Ajara-Trialeti, Arsiani, and Shavsheti and average-mountain massif of Khrami border Javakheti Mountains as an arch. The highest peak is mount Kanlismta (3307 m) on Arsiani Ridge.

Georgian intermontane plain stretches between the Great Caucasus and the Lesser Caucasus and creates a kind of a corridor between the eastern and western parts of the country. Its highest location is Likhi Ridge, the watershed of the Black and Caspian Seas.

The mountain rivers of Georgia, which are quite narrow and flow through steep-sided gorges, often form ravines, passes, and canyons. Some rarest monuments of inorganic nature are: Enguri ravine, Dashbashi and Okatse Canyons, Dariali, Khidikari, and Akhatskhi passes. Some of them, as the objects protected by the state, are included on the Red List of Georgia.

Despite the small territory, the landscape spectrum in Georgia is extremely diversified under the influence of various factors: the history of geological development, complex orographic conditions, great hypsometric amplitude, and location on the brink of floristic zones (Mediterranean, Central European Plains, Iran Mountains, and Central Asia). In Georgia, there are landscapes ranging from coastline dunes, beaches, and marshes in West Georgia and semi-deserts and steppes in East Georgia and through high mountain subnival and nival landscapes. The landscapes typical to various soils and grounds with calcific, psammophyte, petrophilous, hydrophilic, and other types of vegetation spread locally.

With the number of landscape groups, Georgian ranks the 14th in the world, and with the types of landscapes, it ranks the 12th (Isachenko and Shliapnikov 1989). With these features, Georgia is among the leading regions of Europe. As for the landscape diversity per unit area, with this indicator, Georgia ranks the first not only in Europe but all over the world. As the scientists have estimated, average of two types of landscapes is spread per 90 thousand km^2 of land in the world, while 22 types of landscapes are seen on 69.7 thousand km^2 of the territory of Georgia. This is why Georgia was named “the world landscape laboratory” (Beruchashvili 2000a, b). With its landscape diversity, Georgia is much ahead of other, even bigger countries, such as Germany, Italy, Spain, Greece, Ukraine, Peru, Columbia, Venezuela, etc.

It is known that mountainous areas commonly have more diversified natural conditions than lowlands. This is also true with the landscape diversity of Georgia—the diversity gets richer from plains toward the mountains. With the total number of the types of the vertical structures of the natural-territorial complexes (NTCs), mountain landscapes twice exceed the plain landscapes. In addition, an increase in the landscape diversity as the absolute altitude increases mostly occurs from plains to piedmont and lower-mountain landscapes, and from middle-mountain to the upper- and high mountain landscapes at higher altitudes. However, at a certain classification grade of landscapes (e.g., genera), in some cases, plains show more diversity than mountain landscapes (Fig. 15.2).

The greatest diversity is observed in Kakheti, and this is not surprising, as this region has absolutely different physical-geographical units: (1) Iori Plateau and Eldari Lowland with steppe and semi-desert vegetation, (2) Alazani Valley and Great Caucasus of Kakheti with mesophytic humid NTCs, and sometimes with NTCs typical to Kolkheti (partly, Hyrcanian), (3) Tusheti depression with closed barrier ridges and high mountain subnival and nival landscapes. Such a contrast in natural conditions cannot be found in

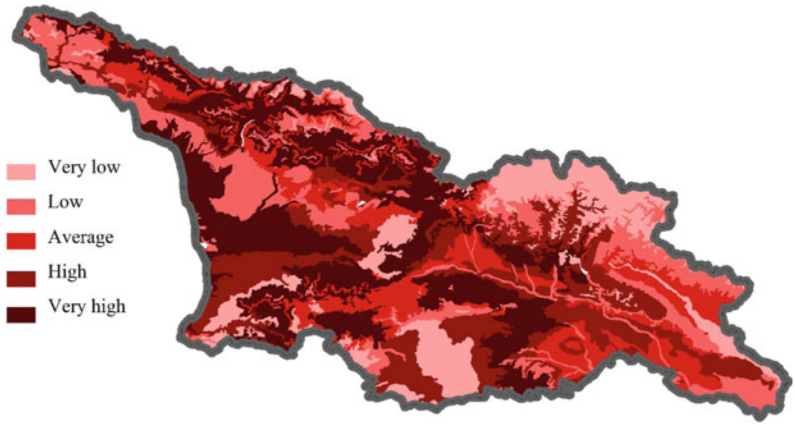

Fig. 15.2 Landscape diversity of Georgia

any other region of Georgia (Beruchashvili 2000a, b; Nikolaishvili 2008a, b). With the landscape diversity, the second outstanding region is Apkhazeti with the landscapes from Sub-Mediterranean NTCs and those typical to Kolkheti through high mountain subnival and nival NTCs. The least number of the types of vertical structures of NTCs is fixed in Samtskhe-Javakheti, while in other regions, this indicator is average.

Among mountain landscapes, the most diversified are lower-mountain forest landscapes. Such diversity is associated with the fact that these landscapes are located between the piedmont and middle-mountain landscapes. Consequently, the NTCs typical to different hydrothermal conditions can be seen there. The highest diversity is observed with the lower-mountain forest landscapes in Shida Kartli, which are stretched on the southern slope of the Great Caucasus and northern slope of the Lesser Caucasus. These landscapes are located between the semi-humid piedmont and middle-mountain moderately warm humid landscapes (Nikolaishvili and Matchavariani 2015). The near location of the piedmont semi-humid landscapes results in the presence of semi-humid NTCs near its lower limits, while the near location of the middle-mountain forest landscapes results in the presence of humid NTCs at its upper limit (Nikolaishvili, 2009).

The middle-mountain forest landscapes are more homogenous. However, the difference between the landscape genera is seen even with them. In particular, the greatest diversity can be observed with the middle-mountain forest landscapes spread on the northern slope of the Lesser Caucasus. The least diversified landscapes are observed along Adjara-Guria section, with dominant beech forest ecosystems with Kolkhic sub-forest or hemihiles. A bit more diversified are the middle-mountain forest landscapes located on the boundary between the areas of beech and dark-coniferous forests (Nikolaishvili and Matchavariani 2015).

15.4 Virgin Landscapes

For the history of mankind, owing to the anthropogenic impact, the areas, structure, process of functioning, natural potential, social-economic functions, and degree of anthropogenic transformation of different landscapes have been changed significantly. The same is true with the landscapes of Georgia. However, the anthropogenic changes of the environment in Georgia had no such large scales as in many regions of the world—in Eastern Europe, Central America, South-East Asia, etc. This is also evidenced by the fact that the specific weight of the virgin landscapes in Georgia is high. It is estimated that the proportion of virgin forests is 10% of the whole territory of the country (Beruchashvili 2000a, b). This is quite a high indicator making Georgia look quite solid in the world without an analog in Europe. The greatest proportions of the Georgian forests are preserved in the mountains and they have soil protection, water regulation, environmental protection, resource-production, and recreational functions.

Under the aegis of the World Bank, the results of the study accomplished to estimate the dynamics of the forest cover in the central part of the Caucasus (the comparison of Landsat imagery of 1989 and 2000) identified no major changes. Relatively intense changes were observed in the environs of Bakuriani, Adigeni, and Khaishi. In other areas, some minor changes in the forest cover were fixed. It is interesting to note that due to the population migration from the mountainous areas to the lowland, the areas of the upper-mountain landscapes and partially, middle-mountain landscapes have increased at certain locations. For instance, the area of the pine forest on the Great Caucasus of Racha increased by 5–10% (Beruchashvili et al. 2002).

15.5 Phytoresources of the Landscapes

The landscapes of Georgia much differ **with the amounts of phytomasses**. The maximum amount of phytomass (500 t/ha) is typical to the average-mountain beech-dark-coniferous forests, while the minimum amount (1–2 t/ha or less) is typically found in the semi-desert and high mountain subnival landscapes. A particularly large interval of variation of the amount of phytomass is seen in the landscapes with dominant forest NTCs. The primary reason is that there are NTCs without forests (degraded forests massifs, secondary meadows) beyond the forests, as well. Therefore, these landscapes are characterized by a great variation in the amounts of phytomass. The greatest range of the phytomass amounts is typical to the lower-mountain and upper-mountain forest landscapes. The natural-territorial complexes with less than 50 t/ha and more than 600 t/ha amounts of phytomass are typical to the lower-mountain forest landscapes what can be explained by the fact that these landscapes border the landscapes with little forest or no forest at all (Nikolaishvili and Matchavariani 2015). With the amount of phytomass, middle-mountain forest landscapes with abundant beech forests (300–500 t/ha) rank the second (Nikolaishvili 2009), and the lower-mountain Kolkhish landscapes rank the third (with 250–300 t/ha of phytomass) (Beruchashvili 1995; Tediashvili 1984).

The highest ***productivity of phytomass*** is common in the middle-mountain forest landscapes of West Georgia with dominating beech-dark-coniferous forests (Landscapes Nos. 125, 126) with average amount of 15–20 t/ha annually. This is caused by long productive conditions with active functioning of needles phytomass (Tediashvili 1984). The beech-dark-coniferous forests of East Georgia fall somewhat back. The productivity of phytomass is also high in the middle-mountain forest landscapes with dominating beech forests. With this indicator, west and East Georgia do not differ much. This can be explained by the almost equal duration of productive daily conditions for middle-mountain forest landscapes. The productivity of phytomass is the lowest in the arid landscapes of East Georgia with semi-desert vegetation (2.5–3.0 t/ha on average). The duration of productive daily conditions here amounts to only 40–45% of the total annual duration. The duration of these stexes is also small in the high mountain subalpine and alpine landscapes (approximately 40% and 30–35% of the total annual duration, respectively). The productivity of phytomass is accordingly low here.

15.6 Anthropogenic Transformation of Landscapes

Due to the anthropogenic impact, the landscapes of Georgia were subject to significant changes. Some critical sites were formed in some landscapes—the fragmented and degraded sites. On the background of extinction of a number of species of flora and fauna, degradation of landscapes, and reduction of their areas, the landscapes get more and more fragmented and diversified. High level of fragmentation is typical

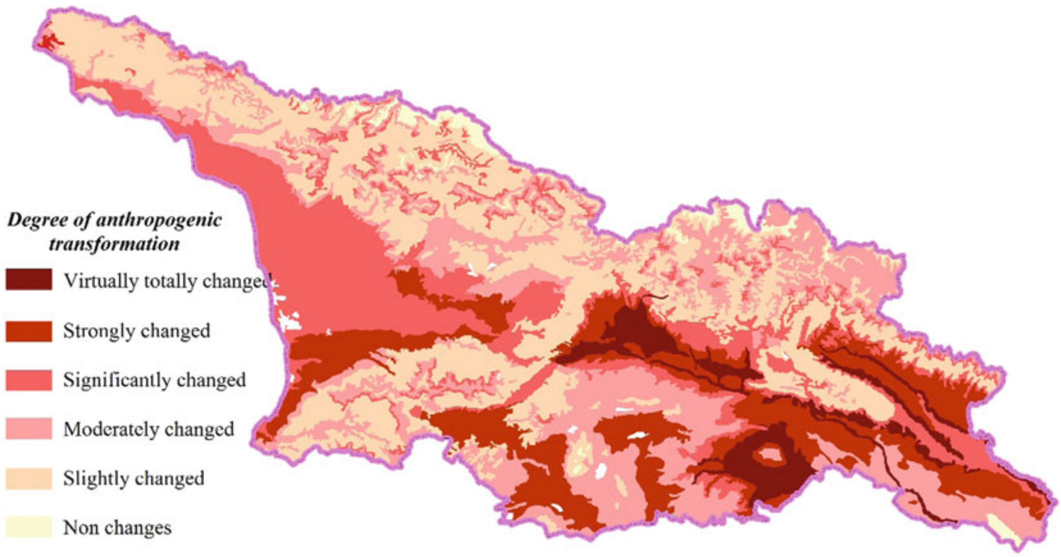

Fig. 15.3 Anthropogenic transformation of landscapes of Georgia

to the plain landscapes, which are transformed significantly as a result of economic activity and are fragmented with a complex network of infrastructure. In the mountains, the most fragmented are lower-mountain forest landscapes rather than middle-mountain forest or high mountain subalpine landscapes located at higher hypsometric altitudes.

The identification of critical sites, particularly, NTCs in the landscapes, is based on several criteria: (1) the condition, which will cause undesirable ecological trends in the landscape. This means the sensitivity of the landscape and its instability to the natural or anthropogenic impact, (2) uniqueness/rarity necessitating its special protection (Beruchashvili et al. 2006a, b; (3) the territories with conservative value—the ability to maintain stable structure and ecological stability of the landscape, and (4) green plants in the urban area and in urban environs.

The indicator of critical NTCs is quite high in Georgia. They cover over 70% of the total territory of Georgia with 90% of the supply of phytomass of the country. This is quite a high indicator resulting from the large areas of vulnerable NTCs.

The major proportion of critical NTCs (over 90%) is found in mountain landscapes. Particularly high proportions are found in middle-, upper- and high mountain subalpine landscapes. The primary reason for this is instable NTCs found here, with typical trans-elluvial migration regimes and high surface inclination. Besides, the largest areas in the middle-mountain forest landscapes are occupied by virgin NTCs and NTCs with a particularly high conservative value. The number of critical sites in the landscapes with large areas modified by the human activity is relatively less. Such are plain landscapes in the first instance with 25–27% of their total area as the critical areas.

The degree of anthropogenic transformation of the landscapes much depends on the population density, agricultural plots of field, number of industrial enterprises, and density of the transport network (Nikolaishvili et al 2010). Based on the analysis of these factors, one can identify six categories of the degree of anthropogenic transformation of the landscapes of Georgia (Fig. 15.3) (Nikolaishvili 2009).

I. *Virtually totally changed landscapes* with high population density (300 men or more per 1 km^2), high specific gravity of the agricultural plots of field (over 80% of the total landscape area) and with 18% of the industrial enterprises of Georgia (Nikolaishvili and Matchavariani

Table 15.2 Some demographical parameters of landscapes of Georgia

Landscape types	Area, thous. km^2	Size of population, thousand	Percent of the population	Population density, 1 per km^2	Number of settlements
Subtropical humid	9.64	2087.1 1712.8	38.6 36.2	292 266.8	1572 1150
Sub-mediterranean semi-humid	2.58	1603.3	29.7	929	495
Subtropical semiarid with steppe, dry shrubs and semi-deserts	2.24	814.1	15.1	363.4	219
Subtropical arid with deserts and semi-deserts	0,09	–	–	–	–
Thermo-moderate, transitional to subtropical forest	1.27	137.5	2.5	108.3	107
Plains Landscapes	17.56	4642	86	323.4	2393
Hidromorphic and subhidromorphic with swamp, meadow, and tugai	1.74	–	–	–	–
Subtropical semiarid with steppe, dry shrubs, and open woodlands	2.31	–	–	–	–
Subtropical arid with deserts and semi-deserts	0.05	–	–	–	–
Low-mountain forest with hornbeam-oak and polydominant forests	8.14	314	5.8	30.4	895
Middle-mountain with beech and hornbeam-beech forest, partially with evergreen understory	11.22	115.3	2.1	10.2	589
Semi-humid, transitional thermo-moderate with open woodland, dry shrubs and meadow-steppes	0.19	4,6	0,1	24,2	12
High plateau with steppe and meadow-steppes	1.85	246.3	4.5	128.3	256
Thermo-moderate with beech-dark coniferous and birch, partially with pine and oak forest	9.73	59.3	1.1	11.9	189
High mountain meadows	15.19	19,3	0,4	1,8	92
Glacial-nival	3,47	–	–	–	–
Mountain Landscapes	52.15	758.8	14	36.9	2033
Total	69.71	5400.8 4371.5	100	77.5	4426

Source Nikolaishvili et al. (2010)

2015). 2 genera of landscapes are such landscapes and they are presented by plains and hills of Shida Kartli and Kvemo Kartli. These landscapes occupy small areas amounting to 1% of the total territory of Georgia; however, a significant number of the population of Georgia (13%) is concentrated on them (Table 15.2). The landscapes are intensely fragmented with agricultural plots of field and transport networks.

II. *Strongly changed landscapes* with high population density (150–200 men per 1 km^2), high specific gravity of the agricultural plots of field (60–80% of the total landscape area), and with the majority of the industrial enterprises of Georgia (63%). 15 genera of landscapes are such landscapes occupying quite large areas (19% of the total territory of Georgia): a major part of plain and piedmont landscapes—Kolkheti Lowland (without hydromorphic landscapes), a part of Shida Kartli and Kvemo Kartli and piedmont and Javakheti Plateau, as well as the territories of Alazani Valley and Iori Plateau adjacent to Gombori Ridge. The floodplain landscapes of East Georgia (unsettled, but intensely exploited by agricultural plots of field) are also such landscapes. These landscapes are significantly fragmented with agricultural plots of field and transport networks.

III. *Significantly changed landscapes* with average population density (100–150 men per 1 km^2) and high specific gravity of the agricultural plots of field (40–60% of the total landscape area). 5 genera of landscapes are such landscapes occupying almost 8% of the total territory of Georgia. 12% of the population of Georgia is concentrated on such landscapes. It covers Racha depression, Zemo Imereti Plateau, Odishi Plateau, and Apkhazeti Piedmont. 9% of the total number of industrial enterprises of Georgia and over 5% of extremely polluting plants of all plants of the country is found on such landscapes. The number of enterprises per 10 km^2 is insignificant and is 0.4, and the number of extremely polluting plants is as little as 0.1.

IV. *Moderately changed landscapes* with low population density (50–100 person per 1 km^2) and 20–40% of the agricultural plots of field of the total landscape area. 10 genera of landscapes are such landscapes. Such landscapes cover mostly low-mountain forest landscapes and house only 6% of the total population of Georgia. The number of enterprises is also little.

V. *Slightly changed landscapes* with low population density (less than 50 persons per 1 km^2) and less than 20% of the agricultural plots of field of the total landscape area (Nikolaishvili and Matchavariani 2015). Most landscapes (36) are such landscapes, in particular, Eldari Valley semi-desert landscapes, a major territory of Iori Plateau where there are winter pastures, as well as middle-mountain forest and high mountain forest landscapes. The great proportion of high mountain subalpine and alpine landscapes used as winter pastures also belong to this category.

Thus, virtually totally changed landscapes occupy only 1% of the territory of Georgia, while strongly changed landscapes occupy 19% of the territory of the country; the shares of the significantly and moderately changed landscapes are the same and equal to 8%. Most territory of Georgia, over half of it (58%) is occupied by slightly changed landscapes.

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16 Tourism and Recreation

Nino Pavliashvili and Mzia Tutberidze

Abstract

This chapter presents the resort and tourist-recreational resources created by country's healthy climate, complex orographic relief, and variety of landscapes, dense hydrographic network and Black Sea coast, mineral waters of various compositions, large areas covered by forest and protected areas, and speleological objects. Physical-geographical characteristics of the territory of Georgia give opportunity for increase in number of resorts, moreover, there are already several places, which the official circles and residents call "resorts", although they are not mentioned in the list adopted by the law.

A special physical-geographical conditions of Georgia determine the country's varied and distinguished touristic and recreational resources on its territory. Country's healthy climate, complex orographic relief, variety of landscapes, dense hydrographic network, Black Sea coast, mineral waters of various compositions, large areas covered by forest and protected areas, and speleological objects create a combination of the resort and tourist-recreational resources. Tourist-recreational resources (TRR) are natural and all human-made objects and phenomena, which can be used for a certain time by a certain group of people to meet their tourist and recreational needs.

The climate plays an important role among the natural TRR, as human's any activity, especially tourist-recreational, goes under the local climate conditions. The climate in Georgia changes from humid subtropical in the west to moderate transitional in the east. The annual average air temperature in the western part of the country is 14–15 °C, and in the east is 12–13 °C. Due to the low cloudiness, the duration of sunshine per year everywhere is more than 2000 h, and in eastern part of Georgia, it is 2.4–2.5 thousand hours. During the whole year (according to the seasons) the sharp transitions of temperatures are not observed. Neither average annual precipitation, nor the wind regime goes beyond the mark, during which it is impossible to conduct any tourist-recreational activities—the climate promotes to carry out tourist-recreational activities throughout the year. Therefore, at the beginning of the twentieth century, the famous Russian climatologist A. Voeikov for that time predicted a great future for unknown Georgia's tourism market (Danilova 1971).

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The length of the Black Sea coastline of Georgia is more than 300 km. Black sea water temperature in summertime in Batumi and Sokhumi is from 22 to 26 °C, while the Baltic Sea's similar index in Riga is changed from 14 to 18 °C (https://seatemperature.info/black-sea-water-temperature.html, https://seatemperature.info/baltic-sea-water-temperature.html). From this data, it is clear how much more comfortable and favorable is the Black Sea for mass bathing (Fig. 16.1). In addition, there is no dangerous ichtiofauna in the coastal area of Georgia and due to the prevailing winds, the waves rarely exceed three balls. Basically, a wide range of mixed beaches are added to this on the most of its sections; the beach sand between the rivers Supsa and Natanebi contains up to 4% of magnetite, which has a very good influence on children's organism and cardiovascular system. Excellent esthetical resources, combination of mountain and sea landscapes, evergreen subtropical vegetation make Georgia's coastline even more attractive. During the year, the number of favorable days for mass bathing at the end of the last century was within 130 days, however, to the latest research, this indicator has decreased to 126 days, which is conditioned due to the cooling of the Black Sea surface.

On the Black Sea coast, tourists are treated with many recreational actions: swimming and diving in the sea, air and sunbathing, walking on the beach, riding on boats or scooters, fishing, taking pictures of the sea, and of nearby breathtaking landscapes, etc.

From the internal waters, it should be noted many rivers, lakes, and water reservoirs, which are attractive to tourists and holidaymakers. For recreational activities actively are used the rivers of Mtkvari, Aragvi, Rioni, Iori, and Liakhvi, as well as the lakes of Paravani, Ritsa, Bazaleti, Paliastomi, Turtle, and Lisi. Because of proximity to big cities, the water reservoirs of Tbilisi, Sioni, Shaori, Tsalka, and Algeti have an important recreational purpose. People go to such places for the weekend or on vacation time, in order to rest and be healthy—for swimming, sunbathing, fishing, rafting, making picnics and so on.

From ancient times mineral waters and therapeutic muds existing on Georgia’s territory were used. For example, Borjomi water was used for

Fig. 16.1 Black Sea coastline (Photo by M. Tutberidze)

Fig. 16.2 Tskaltubo (Photo by M. Tutberidze)

bathing already in the first century, and the mineral waters of Tskaltubo—from twelfth century (Fig. 16.2).

More than 2.3 thousand mineral sources with debit of about 130 million liters a day are studied in the country (Pavliashvili 2003). Due to their wide range (different composition, mineralization, and temperature), they are used to treat various diseases.

The forest is used for recreational purposes from immemorial time. More than 300 tree species are presented in the forests of Georgia spread over 2.7 million hectares (Pavliashvili 2003). Our forests are composed mainly of broad-leaved trees; only 35.7% are coniferous. 57% of forests are spread in western Georgia, where they change from Colchis to subalpine forests. Forests are rich in such plant, animal and bird species, which are important in terms of tourist and recreational activities.

At present time 13 National Parks operate in Georgia, which perform simultaneously environmental protection and tourism-recreational functions. They have routes of different duration and difficulties, in order to satisfy the tourist-recreational needs of people with different possibilities and interests. The diversity of the protected areas will predetermine different recreational actions. For example, the bird-watching is successfully established in the Kolkheti and Javakheti National Parks; for tourists' attraction a zip-line, as an innovation, was introduced in Mtirala National Park; the special interest of scientists is caused by Ispani sphagnum marsh protected area; in most of them hiking, horse riding and bike riding are possible.

In recent years, the special attention is paid to the tourist usage of mountainous regions, where snow is considered a valuable tourist-recreational resource. It is known that Georgia is a typical mountainous country, where 54% of its territory is located above 1000 m.

For today a mountain ski resort Bakuriani and several tourist complexes, such as Gudauri, Goderdzi, and Mestia are functioning. The best conditions for winter leisure and sports development are also in Bakhmaro, Racha, and Achara mountainous regions, in Tusheti and Abastumani.

The caves are an important tourist-recreational resource because they can be used for cognitive, medical, and sports purposes. They are mainly located in the western part of the country and most importantly—in the vicinity of the main resorts and tourist centers. More than a thousand speleological caves (with about 280 km length) are cadastred in Georgia. The most important for tourist-cognitive purposes are Akhali Athoni, Sataplia, Tskaltubo (Prometheus), and other caves, and for treatment –Satsurblia cave is already used. The fact that on the relatively small territory of Georgia, radically different ecosystems—starting with wet subtropics (in western Georgia) and semi-deserts (in the eastern part of Georgia) and ending with the snowy mountains and glaciers, can be visited in a few days, is especially attractive for tourists.

On the bases of the above mentioned diverse natural resources of Georgia, by the Edict of President and the Law on "Tourism and Resorts" in 2005, 103 resorts and more than 180 resort places were distinguished; however, the difference between them is conditional. In the same law, the resort is defined as a place rich in medical resources, which has the relevant infrastructure, and the resort place is the area with medical resources without appropriate infrastructure (Edict of President 2005). Today at many resorts infrastructure is ruined or does not exist at all, though a number of resort places have got a proper infrastructure.

The territorial structure of different types of resorts is characterized by certain regularities: the most of balneological and mud therapy resorts are concentrated in the zone of intermountain lowland, but mixed and climatic—on the seashore or in the foothills (Neidze et al. 2017).

According to the resort zones, resorts are distributed as follows: most of the resorts are located in the lowland zone, including all seaside climatic resorts, for example, Akhali Athoni, Batumi, Bichvinta, Gudauta, Mtsvane Kontskhi, Kobuleti and Tsikhisdziri; coastal climato-balneological resorts—Gagra and Sokhumi; with magnetic sands—Grigoleti and Ureki; there are important balneological resorts in the same zone—Tbilisi, Menji, Nabeglavi, Tsaishi, Tskaltubo and the both peloid resorts of Georgia—Akhtala and Kumisi.

Low mountain resort zone is distinguished by the abundance of mixed-type balneo-climate resorts; for example, Borjomi, Lagodekhi, Nunisi, Sairme (Fig. 16.3), Kvishkheti, and Tsaghveri. Also here are several climatic resorts —Okrokana, Surami, Tsavkisi and Tskneti.

In the lower belt of middle mountain zone it should be noted climatic and climate-balneological resorts—Abastumani, Vazhas Tskaro, Kiketi, Kojori, Manglisi, and Tsemi; balneological resorts—Aspindza, and Vardzia.

In the upper belt of middle mountain zone seasonal climatic resorts, such as Bakhmaro, Gomis Mta, and Beshumi are located; balneo-climatic resorts—Lebarde, Torghvas Abano and all year round functioning Bakuriani, Utsera and Shovi (Table 16.1).

Among the resorts of Georgia (Table 16.2) six are of international importance, three of them (Kobuleti, Akhali Athoni, and Bichvinta) are the coastal climatic resort with humid subtropical climate, with seawater, subtropical and coniferous vegetations. The coastal resort Gagra is of a climate-balneological type, because together with subtropical climate and vegetation here is thermal (43 °C), nitrogenous, sulfide mineral water and also a sapropel and peat mud. Balneological resort Tskaltubo is distinguished with exceptionally rare type of radioactive, radon, chloride-hydrocarbonate-sulfate mineral water. Considering that there are some important karst caves around the resort, we can add speleo-therapy to balneological treatment. Balneo-climatic resort Borjomi from immemorial time is known with volcanic origin of carbonic acid, hydrocarbonate, sodium mineral water with lowland forest climate.

Here are all conditions for the purification of the body, the strengthening of immunity, the prevention and treatment of various diseases. Here it should be noted that currently the resorts of Gagra, Bichvinta and Akhali Athoni are located on the territory that temporarily is not under the Georgian jurisdiction. At resort Tskaltubo, after the 1990s crisis, the processes of restoration of spa services are expanding and there are all conditions, which could help to reach the old level of development.

Resorts Kobuleti and Borjomi are distinguished with relatively stable development. During recent years, the development of resort industry showed that Batumi, Bakuriani, and

Fig. 16.3 Sairme (Photo by M. Tutberidze)

Table 16.1 Distribution of resorts by resort zones

Resort zone	Altitude (above sea level) (m)	Resorts		Resort types		
		Amount	%	Climotological	Balneological	Mixed
Lowland	<500	44	43	22	18	4
Low-mountainous	500–1000	27	26	9	5	13
The lower belt of middle mountain zone	1000–1500	19	18	7	6	6
The upper belt of middle mountain zone	1500–2000	13	13	6		7
Total		103	100	44	29	30

Sairme may be also considered international resorts.

As for all nature-oriented branches of industry, the ecological factor is of particular importance for tourism development. For example, a significant part of the Black Sea coast due to rough anthropogenic interferences is damaged (large areas of beaches are washed away). On one hand, this is a construction of hydraulic structures in river basins (for example, construction of Jvari and Deriner dams) and on the other hand, the result of the functioning of existing ports and also constructing of new ones (Tutberidze et al. 2014).

Certain hindering factors for full relaxation are abundance of rainfalls in Achara (2500–2800 mm/y) and wetlands in the central part of the coast, which limit the number of bathing hours. In recent years, a big amount of holidaymakers create a certain threat for the seaside resources. As there are no exact statistics about the number of tourists on the beach resorts, it is difficult to determine the load factor, however, scientists and experts claim that this danger is real.

It is of great importance to protect the mineral waters, climate, and other resources of resorts from the pollution. Law on “Tourism and Resorts” takes into account the special land use

Table 16.2 Resorts of Georgia (Edict of President 2005)

№	Resort name	Municipality	Resort type	The height above sea level (m)
1	2	3	4	5
1	Abastumani	Adigeni	CB	1340
2	Agudzera	Gulripshi	C	8
3	Avadhara	Gudauta	CB	1600
4	Amaghleba	Vani	B	80
5	Anaklia	Zugdidi	C	3
6	Arkhiloskalo	Dedoplistskaro	C	700
7	Aspindza	Aspindza	B	1090
8	Akhaldaba	Borjomi	CB	760
9	Akhali Athoni	Gudauta	C	50
10	Akhaltsikhe	Akhaltsikhe	B	1000
11	Akhtala	Gurjaani	B	412
12	Bazaleti Lake	Dusheti	C	900
13	Batumi	Batumi	C	3
14	Bakuriani	Borjomi	C	1700
15	Bakhmaro	Chokhatauri	C	2000
16	Bagiata	Java	B	1200
17	Besleti	Sokhumi	BC	120
18	Beshumi	Khulo	C	1900
19	Biisi	Gori	CB	1080
20	Bichvinta	Gagra	C	7
21	Borjomi	Borjomi	BC	800
22	Bugeuli	Ambrolauri	BC	560
23	Gagra	Gagra	CB	7–50
24	Gantiadi	Gagra	C	40
25	Gomis Mta	Ozurgeti	C	1900
26	Gorijvari	Gori	BC	600
27	Gormaghala	Samtredia	B	200
28	Grigoleti	Lanchkhuti	C	3
29	Gudauta	Gudauta	C	25
30	Gulripshi	Gulripshi	C	40
31	Gumista	Sokhumi	C	10
32	Eshera	Sokhumi	C	30
33	Vazhas Tskaro	Dusheti	BC	1100
34	Vardzia	Aspindza	BC	1300
35	Zekari	Baghdati	BC	650
36	Zvare	Kharagauli	BC	700
37	Tbilisi Balneological Resort	Tbilisi	B	420
38	Tetritsklebi	Telavi	CB	1200

(continued)

Table 16.2 (continued)

№	Resort name	Municipality	Resort type	The height above sea level (m)
39	Torghvas Abano	Telavi	BC	1750
40	Kvereti	Sachkhere	BC	570
41	Kiketi	Gardabani	C	1200
42	Kindghi	Ochamchire	CB	40
43	Kodibini	Java	B	1120
44	Kojori	Gardabani	C	1350
45	Kumisi	Gardabani	B	500
46	Kursebi	Tkibuli	BC	350
47	Lagodekhi	Lagodekhi	B	435
48	Lashichala	Tsageri	BC	800
49	Lebarde	Martvili	CB	1600
50	Leselidze	Gagra	C	6
51	Libani	Borjomi	C	1370
52	Maltakva	Poti	C	3
53	Manglisi	Tetritskaro	C	1200
54	Makhinjauri	Khelvachauri	C	15
55	Menji	Senaki	B	29
56	Miusera	Gudauta	C	100
57	Muashi	Lentekhi	BC	1300
58	Mtsvane Kontskhi (Green Cape)	Khelvachauri	C	90
59	Nabeghlavi	Chokhatauri	B	470
60	Nagutni	Kornisi	B	970
61	Nasakirali	Ozurgeti	B	105
62	Nokalakevi	Senaki	B	150
63	Nunisi	Kharagauli	B	920
64	Okros Napiri	Gudauta	C	10
65	Okrokana	Gardabani	C	760
66	Ochamchire	Ochamchire	C	5
67	Patara Tsemi	Borjomi	C	1370
68	Ritsa	Gudauta	C	950
69	Sairme	Baghdati	B	950
70	Samtredia	Samtredia	B	25
71	Simoneti	Terjola	B	360
72	Sioni	Tianeti	C	1000
73	Sortuani	Oni	CB	788
74	Sokhumi	Sokhumi	C	5–140
75	Sulori	Vani	B	250
76	Surami	Khashuri	C	740
77	Skuri	Tsalenjikha	B	480

(continued)

Table 16.2 (continued)

№	Resort name	Municipality	Resort type	The height above sea level (m)
78	Tba	Borjomi	C	1100
79	Tkvarcheli	Ochamchire	B	350
80	Ureki	Ozurgeti	C	4
81	Utsera	Oni	BC	1050
82	Ujarma	Sagarejo	BC	770
83	Pasanauri	Dusheti	CB	1050
84	Kvishkheti	Khashuri	CB	730
85	Kobuleti	Kobuleti	C	5
86	Kazbegi	Kazbegi	CB	1740
87	Kanchaveti	Akhalgori	BC	1000
88	Kvareli	Kvareli	B	450
89	Shovi	Oni	CB	1520
90	Chitakhevi	Borjomi	C	950
91	Tsaishi	Zugdidi	B	50
92	Tsemi	Borjomi	C	1120
93	Tsivi-Koda	Sagarejo	C	1550
94	Tsikhisdziri	Kobuleti	C	20–40
95	Tsikhisjvari	Borjomi	C	1640
96	Tsavkisi	Gardabani	C	900
97	Tsaghveri	Borjomi	BC	1030
98	Tsodoreti	Mtskheta	C	800
99	Tskaltubo	Tskaltubo	B	120
100	Tskneti	Tbilisi	C	950
101	Khidikari	Ambrolauri	B	680
102	Khovle	Kaspi	B	720
103	Java	Java	B	1125

Resort type
B—Balneological
C—Climate
BC—Balneo-climate
CB—Climate-balneological

conditions on resorts, establishment of sanitary protection zones, where the activities, which will have a negative impact on medical resources, are prohibited. The rehabilitation works are underway to maintain resources, but in the conditions, when almost half of the resorts are not functioning, the requirements of law are not fulfilled actually.

Natural disasters characteristic for the high mountain regions such as avalanches, landslides, and mudflows, are the threats for the functioning of high mountain resorts. Maintaining ecological sustainability in future will positively impact on the quality of tourism resources and their successful use.

Physical-geographical conditions determine not only the resort type and its medical profile, but also its spatial development opportunities. Location of the resort area, relief, and vegetation cover may impede or promote the construction and operation of resort infrastructure. For example, the resorts located in narrow gorges

(Zekari, Nunisi, Torghvas Abano, Khidikari) have less opportunities for expansion and reception of the large amount of tourists. Construction and development of high mountain resorts is hampered because of the sharp fragmentation of the territory, the difficult accessability, and the strict climate conditions (long snowy winters) (Lebarde, Gomis Mta). The seaside resorts have their own specifics, which are "forced" to be built not in the depths, but along the coastline (Kobuleti, Ureki, and Grigoleti).

Physical-geographical characteristics of the territory of Georgia give opportunity for increase of number of resorts, moreover, there are already several places, which the official circles and residents call "resorts", although they are not mentioned in the list adopted by the law. Such places are Gudauri, Mestia, Tetnuldi, Goderdzi, Lopota, Sarpi, Kvariati and Gonio.

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17 Protected Areas and Remarkable Features of Inorganic Nature

Koba Kharadze and Elene Salukvadze

Abstract

According to landscape diversity, Georgia is in the 12th place in the world and in one of the 1st places in Europe. 14 Strict Nature Reserves, 11 National Parks, 19 Managed Reserves, 42 Natural Monuments, and two Protected Landscapes are presented in this chapter. in addition, there are many other interesting nature sightseeing that can be granted the status of natural monuments in the future, such as natural freezers, volcanic forms of relief, natural bridges, etc.

Georgia's diverse natural complexes (landscapes) and their individual components (vegetation cover, animal world, mineral resources, mineral waters, etc.) have been given wide possibility to use them since long ago that is approved by legislative acts.

The protection of nature has a long history in Georgia. Still in the King Tamar's Deed of 1189 AD, "forest guards" are mentioned, and even in the earlier Deed (1078)—a "Head of forest guards". The issues of water, forest, and pasture protection were envisaged in the "Book of Laws" of the King Vakhtang VI (1675–1737). In the mountainous regions, there were so-called "icon forests" (Georgian Soviet Encyclopedia 1981) under the strict protection.

The environment protection and rational use of natural resources of the country were substantially improved by the law adopted in 1996 by the Parliament of Georgia on the "System of Protected Areas", one of the main objectives of which is to adapt Georgia to the international categories (Strict Nature Reserve, National Park, Managed Reserve, Biosphere Reserve, Wetland Reserve, etc.) of protected areas elaborated by IUCN (International Union for Conservation of Nature).

The status of the first protected area in Georgia was granted to Lagodekhi Nature Reserve in 1912. The State Policy on establishing, functioning, and management of Protected Areas in Georgia is implemented by the Ministry of Environment Protection and Agriculture of Georgia and included in its Legal Entity of Public Law—Agency of Protected Areas. Currently, the total area of Protected Areas of Georgia is 595.963 ha, which is 8.55% of the country's territory. Approximately 75% of Protected Areas are covered by forests. There are 14 Strict Nature Reserves, 11 National Parks, 19 Managed Reserves, 42 Natural Monuments, and two Protected Landscapes (http://apa.gov.ge/ge/protected-areas/reserve); in addition, there are other types of areas in Georgia, where the certain regime of protection is being implemented, these

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are recreational forests (395.90 ha) including resort forests (119.40 ha) and green zones (276.50 ha) (Kajaia 1999).

The share of Georgia in total land area is only about 0.002%. Because of its small area, it is distinguished neither by the areas of forest, farm lands (38%), and the protected areas, nor the total number of flora and fauna species, but on the other hand, the country is specific, and in some cases unique in many ways. The main reason for this distinction and uniqueness is its geographical location and diverse natural conditions.

Georgia is a very interesting country in terms of biological and landscape diversities. As part of the Caucasus, it is included: (1) in the world's biologically richest and endangered 25 “hotspots” (Cl, CEPF), (2) in the world's sensitive and vulnerable 200 ecoregions (WWF), which is characterized by high biodiversity; (3) in the endemic bird's habitat (Bird Life International), (4) in one of the centers of agrobiodiversity of the world, and (5) in the “hotspot” of the large herbivorous animals (WWF); this list is even more extensive since in Georgia, first of all, the diversity of species and ecosystems and the rich endemic and relic, medicinal and decorative vegetation species are maintained and almost 40% of the area is covered by forests; and secondly, the environment of the country has not experienced such great anthropogenic changes as it was in many parts of the world. Therefore, in ecological terms, it looks like a relatively “clean area”. In addition, Georgia is one of the most distinguished countries in the world with landscape diversity and it is ahead of many other countries rich in biodiversity (Beruchashvili 2000).

According to landscape diversity, Georgia is in the 12th place in the world and in one of the 1st places in Europe. Georgia is even more distinguished by its landscape diversity, and it is in the first place in the world. By calculation of scientists, there are two types of landscapes per each 90 thousand km^2 on average, while in Georgia there are 22 types in 69.7 thousand km^2. That is why Georgia was fairly named “the landscape laboratory of the world (Beruchashvili 2000). By landscape diversity, Georgia exceeds even the major countries such as Germany, Italy, France, Spain, Greece, Ukraine, Peru, Columbia, Venezuela, and others.

56 species of flora of Georgia are included in the Red List, status of 36 species is vulnerable, 18 species are endangered and two species are critically endangered, among the 135 species of fauna included in the Red List of Georgia, 87 species are vulnerable, 32 species are endangered, 11 species are critically endangered and five species are regionally extinct.

(Ordinance of the Government of Georgia on approval of the “Red List” 2014, https://matsne.gov.ge/ka/document/view/2256983).

Forests of Georgia have a specific nature, which is expressed in their special purpose. Almost all forests—98.3% of Georgia belong to the first group of forests located on the slopes of the mountains and have soil protection, water protection, resort, sanitary-hygienic, aesthetic, and other social-protective functions. The remaining 0.7% of the forest belongs to the second group and is mainly located in the Kolkheti Lowland.

Georgia is actively involved in the international projects on global ecological safety of environment protection, maintenance of ecological balance, ecosystem protection, and providing sustainable development principles. The country is joined to the world's important international (UN, Ramsar, Kyoto, Basel, Stockholm, etc.) conventions on environmental protection.

Currently, five types of protected areas are presented in Georgia: Strict Nature Reserve, National Park, Natural Monument, Managed Reserves, and Protected Landscape.

In Georgia, a special phenomenon of nature is the inorganic nature monuments of the country, which are scattered in different parts of the country in big amount. Among them the three groups are distinguished: geomorphological, geological, and hydrological. They include unique karst caves, replaced glacial and mudflow boulders, natural bridges, canyons, waterfalls, vaucluse sources, travertines, and fossil elements of flora and fauna.

There are 14 strict nature reserves (Babaneuri, Batsara, Bichvinta-Miusera, Borjomi, Vashlovani, Tusheti, Kintrishi, Lagodekhi, Liakhvi, Mariamjvari, Sataplia, Ritsa, Pskhu-Gumista, and Kobuleti) in Georgia with total area of 139.048 thousand ha.

Babaneuri Strict Nature Reserve (area 862.1 ha) is located at the foot of the main range of the Caucasus, in Akhmeta municipality at the villages of Babaneuri and Argokhi, on the bank of the Alazani River, at the height of 439–985 m above sea level. The reserve was established in 1950 to protect the rare massive of the Tertiary age relic—the hornbeam left Zelkova (Zelkova carpinifolia).

Batsara Strict Nature Reserve (area 2.986 ha) is located in the gorge of the Batsara River (the right tributary of the Alazani River) in Akhmeta municipality. It was established in 1935. The untouched groves of the relic species —yew (Taxus baccata) are preserved in the strict nature reserve, which has a great scientific value.

Bichvinta-Miusera Strict Nature Reserve (area 165 ha), was created in 1966 to protect the Bichvinta relic and Colchis broad-leaved forests. The strict nature reserve is located on the Black Sea coast of Abkhazia and consists of three sections– Bichvinta, Miusera (218 ha), and Lidzava (1296 ha). The main beauty of the Bichvinta-Miusera Strict Nature Reserve is the Bichvinta Pine (Pinus pityusa), from the root of which the name Bichvinta is derived.

Borjomi Strict Nature Reserve (area 17.948 ha) is located on the southern slopes of Achara-Imereti range, in Borjomi municipality. It was established in 1935 to protect, restore and reproduce the red deer, as well as to preserve the forest massifs of endemic species. Many relic and endemic plants grow in the territory of the strict nature reserve, many of which are rare and endangered. These are Georgian hazel, European hop-hornbeam, yew, chestnut, Colchis bladdernut, and common bladdernut, Caucasian oak, sea buckthorn, wild grape vine.

Vashlovani Strict Nature Reserve (area 10 142 ha) is located in the Iori Upland, in Dedoplistskaro Municipality. It was established in 1935 and since 2003 the unified complex of strict nature reserves, national parks, and natural monuments is included in the Vashlovani Protected Area. The strict nature reserve was created for the protection of arid light forests. Here grows the rarest pistachio trees (Pistacia mutica), hackberries, weeping pear, a variety of junipers, endemic Georgian Iris (Iris iberica), and tulips (Tulipa eichleri). Among mammals, there can be found brown bears, gray wolves, red foxes, Eurasian lynx, and wild boar. There are many reptiles in the strict nature reserve: common tortoise, Schneider's skink, and Caucasian agama; from the snakes: the javelin sand boa, the four-lined snake, the grass snake, and the Lebetine viper. In the reserve there are many birds, for some of them Vashlovani and its surrounding is a homeland, and for some of them it is a wintering area and place of temporary shelter. Here are found buzzard, eastern imperial eagle, etc.

Tusheti Strict Nature Reserve (area 12,627.2 ha) is located in Akhmeta municipality; established in 1961. The strict nature reserve was created to protect and preserve the species of biodiversity, rare and endangered animals, and endemic and relic plant species presented there.

The forests of the strict nature reserve are distinguished by species diversity, high endemism, and very specific bio-ecological, relic species. Here are the subalpine birches and rhododendrone complexes. The strict nature reserve is important as the habitat of rare animal species of Tertiary period.

Kintrishi Strict Nature Reserve (area 10,703 ha) was established in 1959; it is located in the Kintrishi River gorge, in Kobuleti municipality, Achara. In Kintrishi Strict Nature Reserve, the climate is very humid; there are many rivers and gullies, waterfalls, and the Tbikeli Lake. The strict nature reserve was founded to protect the Colchis flora and fauna of the Tertiary period. There are many endemic and relic species preserved in the strict nature reserve.

Lagodekhi Strict Nature Reserve (area 19,749 ha) is located on the southern slopes of the main range of the Caucasus in the territory of Kakheti. It was established in 1912. The forest covers the area of 12,346 ha (72%) and the remaining 5322 ha are covered by alpine pastures. It extends to the height of 450–3500 m above sea level. The forest belt (up to 450–2300 m) with Georgian oak trees and oriental beech trees and the alpine belt (2300–3500 m above sea level) with meadows, meadow grasses, and rhododendrons are sharply distinguished. Between these belts are the subalpine light forest (mountain oak and sycamore maple) and crooked (birch) forest belts (1700–2300 m above sea level). There is a subnival belt (3000 m above sea level) with very light herbs above the alpine belt. Lagodekhi is famous for its best-preserved forests, most of which are almost untouched including the less-modified (untouched) forests of beech and hornbeam trees.

Due to the moderately humid subtropical climate, the elements of the Colchis and Talishi vegetation have been maintained here, such as: wingnuts, common walnuts, chestnuts, etc. There are about 1500 species of floral plants in the strict nature reserve; it is rich in endemic species, where 121 species of flora are endemic to Caucasus and nine species—to Georgia endemic, from which seven are found only in Lagodekhi. There are 42 species of mammals, 120 species of birds, four species of amphibia, and eight species of reptiles recorded in the strict nature reserve. The museum of flora and fauna is located in the strict nature reserve, as well as the high mountain meteorological station. There are many waterfalls and lakes in the territory of the strict nature reserve; among lakes, the "Black Rock Lakes" are notable (about 2850 m above sea level).

The World Wide Fund for Nature (WWF) has been identified as one of the most important global ecoregions (ecoregion of Caucasian mixed forests), the Important Bird Area (GE 024), and a hot point of biodiversity according to the conservation. The Lagodekhi Protected Areas are also recognized as a potential candidate for "Emerald Network", and also it is qualified for "Natura 2000" according to the obligations taken by Georgia under the Association Agreement between Georgia and the European Union (Fig. 17.1).

Liakhvi Strict Nature Reserve (area 6388 ha) was established in 1977 for the protection of subalpine forests. The strict nature reserve is located in the north-eastern part of Tskhinvali municipality, in the upper stream of the Patara Liakhvi River. In the Liakhvi Strict Nature Reserve, the deer inhabits that is found only here within the area of the Central Caucasus.

Mariamjvari Strict Nature Reserve (area 1040 ha) is located in the Sagarejo municipality, on the southern slopes of the Gombori Range. It was established in 1935 for preservation of rare massif of the relic Caucasian pine (Pinus sosnowskyi Nakai). There are four forms of the Caucasian pine (different forms of crowns—polymorphisms): pyramidal, compact, oval, and umbrella.

Sataplia Strict Nature Reserve (area 330 ha) is located in the Tskaltubo municipality, in the Sataplia mountain, at a height of 500 m above sea level; it was established in 1935; its area is 330 ha. The strict nature reserve is of complex character and includes geological, paleontological, speleological, zoological, and botanical monuments. Its relief is a mountainous. 95% of the area is covered by relict Colchis forest. The strict nature reserve area is rich in karst caves. There are found about 200 footprints of predator and herbivore dinosaurs on the marl limestones. The biospeleological museum is located I the strict nature reserve.

Ritsa Strict Nature Reserve (area 13.893 ha) is located in the Gudauta municipality (60 km away from Gagra), in Apkhazeti. The strict nature reserve is represented in the southern subrange of the main range of the Caucasus. The Ritsa Strict Nature Reserve is located at a height of 928 m above sea level and covers the area around the Ritsa Lake. The strict nature reserve was created in 1957 to protect the Ritsa Lake and the relic forests around it. In the forest massifs the oaks, hornbeams, lime trees, box trees, and others prevail. The groves of Caucasian fir and pine trees and oriental beech trees are spread at a height of 600–1800 m, and Caucasian fir and Oriental spruce forests at the height of 1800–2200 m above sea level.

Phskhu-Gumista Strict Nature Reserve (area 27.334 ha) is located mainly on the southern slope of the main range of the Caucasus, in Sokhumi region, in the gorge of the eastern Gumista River. The Gumista Strict Nature Reserve was established in 1978 to protect the

Fig. 17.1 Lagodekhi strict nature reserve (Photo by R. Tolordava)

biodiversity of the untouched deciduous and coniferous forests in Apkhazeti. The Pskhu Nature Reserve is situated in the hollow of the Pskhu River, which is bordered by the Bzipi range and the main range of the Caucasus.

Kobuleti Strict Nature Reserve is located in the Achara Autonomous Republic and includes the north-eastern part of the Kobuleti coastal plain; it was established in 1998 to save and preserve the unique wetland ecosystems of international importance, as a natural heritage of high value, especially as a waterfowl habitat, the status of which is recognized by the Ramsar Convention. These peat bogs are distinguished by the diversity of waterfowl birds and plants. There are important habitats for migrating, nesting, and wintering species of waterfowl birds.

The first national park in Soviet Georgia, named "**Saguramo National Park" (Tbilisi National Park** nowadays), was created in 1973. Tbilisi National Park (Area 21 030.81 ha) is located in the territory of Mtskheta-Mtianeti region, Tbilisi (partly), and Kvemo Kartli region. Tbilisi National Park is rich in representatives of fauna. The following mammals are widespread: red fox, wolf, roe deer, rabbit, forest marten and least weasel as well as the rare species such as Caucasian red deer, lynx, and brown bear. 46 endemic species of mammals in the park are common. Among the ornithofauna the following species are found: Eurasian magpie, common blackbird, and several kinds of woodpeckers. From the predatory birds, the Eurasian sparrowhawk is spread in the park. Representatives of the "Red List" are: imperial eagle, spotted eagle, and Levant sparrowhawk.

There are 12 species of reptiles in the park area. The most common among them is the European legless lizard; there is found grass snake, Caspian whipsnake, and smooth snake.

In 1995 the first national park was established, which was named "**Borjomi-Kharagauli National Park**" by the assistance of the World Wildlife Fund (WWF) and the German Government. This was the foundation of the first national park in the Caucasus region. Renewed in

2001. The Borjomi-Kharagauli National Park is located in the central part of the Caucasus ecoregion. Because of the distinctive biodiversity and vulnerability, the ecoregion is included in the list of 35 preferential ecoregions of the World Wildlife Fund and 34 hot spots of international conservation. Borjomi-Kharagauli National Park (area 60 576.4 ha) is located in the central part of Georgia, in the region of the Lesser Caucasus, located in the territories of Samtskhe-Javakheti, Imereti, and Shida Kartli regions. It is one of the largest national parks in Europe.

The main wealth of Borjomi-Kharagauli National Park is forest (75% of the territory). There are preserved the large areas of untouched mixed forests of the Caucasus; there are found the fragments of unique, relict Colchis forests. Almost a quarter of the park is covered by subalpine and alpine meadows, as well as the rhododendron shrubs (the relic Georgian snow rose shrubs), where there is also subalpine crooked Litvinov's birch (Betula litwinowii).

Forests and high mountains are rich in relic, endemic, rare and vulnerable species of not only flora but fauna as well. There are documented 64 species of mammals on the territory of Borjomi-Kharagauli National Park, 11 of which are endemic to Caucasian, and eight species are listed in Georgia's "Red List". There are can be found 217 species of migratory and nesting birds 13 species of which are included in the Georgian "Red List". 30 species of reptiles inhabit in humid forests of the protected area, three of which are endemic to the western Caucasus, and two species are included in the "Red List".

In the Borjomi-Kharagauli National Park herpetofauna includes almost all species of amphibians and four rock lizards that are common in Georgia. The diversity of amphibian species is not observed anywhere else in Georgia. The Borjomi-Kharagauli National Park is an important habitat for the diversity of amphibian species. In Borjomi-Kharagauli National Park about 17 species of reptiles and amphibians are common, including the endemic to Caucasus—the Caucasian salamander (Mertensiella caucasica), which is a rare and endangered species. It is included in the "Red List" of Georgia and IUC.

In the rivers of the Borjomi-Kharagauli Protected Areas are found brown trouts (Salmio fario trutta), common barbel (Barbus barbus), and common roach (Rutilus rutilus).

In 1998 **Kolkheti National Park** was founded, in 2003—Tusheti and Vashlovani National Parks, and in 2006—Mtirala National Park. Machakhela and Javakheti National Parks have been created in recent years and Algeti, Saguramo, and Kazbegi Strict Nature Reserves have been granted status of National Park. In the nearest future, Kazbegi and Algeti National Parks will be expanded.

Algeti National Park (area 6822 ha) is located in historical Kvemo Kartli, Tetritskaro municipality, 60 km away from Tbilisi. it was established in 1965, and renewed in 2007. It is situated in the Algeti River gorge and covers the southern slopes of the eastern part of the Trialeti Range at the height of 1100–1950 m above sea level. The highest point is Kldekari (2000 m). The national park is characterized by a humid climate. It was founded for the protection of the Oriental spruce and Caucasian fir's eastern border. Among the deciduous species beech, oak, hornbeam, ash, and birch trees are spread. Here are 1664 species of plants; three species are endemic to Georgia and Caucasus. The fauna of the National Park is also rich. Here inhabit the animals of the "Red List" of Georgia: brown bear, Caucasian grouse, eastern imperial eagle, and others.

In the vicinity of the Algeti National Park numerous archaeological sites have been discovered, most of the earliest of which are of the Eneolithic and early Bronze Ages. The Bronze Age cyclopean fortresses, the active churches and the ruins of the churches, the ruins of the Kldekari fortress of the ninth century, the fourth-century Manglisi Cathedral, the beautiful and inaccessible Birtvisi town- fortress of the eleventh century, and others are preserved.

The national park has quite a good potential for organizing the photo-video, birdwatching, ecological, botanical, and motor-adventure tours. In the protected areas are developed the forms of tourism such as hiking, horseback riding, and archeological tours.

Vashlovani National Park (area 24 610 ha) is located in Kakheti, Dedoplistskaro municipality; it was established in 2003. The climate is dry and moderately dry there. It was created to preserve the arid ecosystem in the natural condition and to protect and restore rare species of plants and animals spread throughout the territory.

The Vashlovani National Park (Fig. 17.2), along with the Vashlovani Strict Nature Reserve, covers the less-modified natural ecosystems with sharply distinguished four vegetation types: semiarid, arid light forest, steppe, and deciduous forest. In addition, there are intrazone types as well: rocks' xerophytes, floodplain, or riparian forests, Jerusalem thorn, and other vegetation of foothills. Savanna-type arid light forest is preserved, the main component of which is the Mt. Atlas mastic tree (Pistacia mutica) and juniper.

The only habitat of the Tertiary period relic—desert poplar (Populus euphratica) in Georgia is the Vashlovani National Park. Ornitho-fauna of Vashlovani National Park is very diverse—Rock partridge, woodpecker, Griffon vulture, Cinereous vulture, sparrowhawk, European nightjar, golden oriole, bee-eater, and mistle thrush.

After some time, he lost the status of the National Park but was it was reestablished in 2007 on the basis of the part of the former National Park and Saguramo Nature Reserve. It is spread over 600–100 m above sea level. Dendroflora of the Tbilisi National Park is interesting because of the distribution of the representatives of Tertiary period Colchis flora, such as: Colchic holly, Colchis ivy, and Pastukhov's ivy, eastern viburnum, ruscus, yew, the Caucasian rhododendron, cherry laurel and more. Pine trees and unique yew groves are artificially cultivated in the park. Forests are characterized by vertical zoning in the National Park of Tbilisi. From rare and endangered species in Tbilisi National Park are spread: boxwood (Buxus colchica), yew (Taxus baccata), a bare elm (Ulmus glabra), a small elm (Ulmus glabra), walnut (Juglans regia), Pontine oak (Quercus pontica) and others (Kikodze 2007).

Tusheti National Park (area 69.515 ha) is located in the Eastern Caucasus. It comprises the northern slopes of the main range of the Caucasus, including the Tusheti basin and the Speroza Range. The northern and eastern borders coincide with the Georgian state border with the Russian Federation. It was established in 2003. The lowest point of Tusheti National Park is located at 1600 m above sea level and the highest—at 4275 m.

The park includes the Tusheti Strict Nature Reserve, which comprises the gorges of the rivers: Pirikita Alazani, Gometsari Alazani, and Chanchakhovani. Alpine meadows, glaciers, river heads, separate important cenoses, rare and endangered animals, and endemic and relic species are preserved in Tusheti National Park, as well as the unique pine forest and the presented forest's forming species: birch, high mountain oak, rowan and goat willow.

Tusheti National Park is characterized by landscapes of high aesthetic values (Fig. 17.3), beautiful alpine meadows, and very well preserved pine forests; summits of the mounts of Tebulo (4492 m), Diklo (4785 m), and Sakisto (2456 m).

In the gorge of Pirikita Alazani, in the areas of the village of Dartlo, there are several places where powerful deposits of the limestone travertines are presented. There are many small lakes of different origins. The high mountain wetlands are found in Shenako, Omalo, Tursiekhi, and Khakhabo vicinities. Tusheti is rich in mineral waters in the villages of Omalo, Shenako, Parsma, Chontio, Chigho, Dochu, Khakhabo, and others.

Tusheti Protected Areas are characterized with astonishing landscape diversity. Here we encounter the ecological "mosaic" created by pine forests, subalpine shrubs and forests, subalpine and alpine meadows, and glaciers.

Kolkheti National Park (Fig. 17.4) (the total terrestrial area of Kolkheti National Park is 28 571 ha and sea water area—15 742 ha) is located in western Georgia. It was established in 1998. It includes the Black Sea eastern coastline and the Paliastomi Lake basin. The national park is created for the preservation and maintenance of the wetland ecosystems of international importance in Kolkheti. The sections of the national park are

Fig. 17.2 Vashlovani (Photo by V. Cherkezishvili)

Fig. 17.3 Tusheti (Photo by N. Bolashvili)

Fig. 17.4 Kolkheti National Park (Photo by R. Tolordava)

located in the territories of five municipalities—Zugdidi, Khobi, Senaki, Abasha, and Lanchkhuti and are the parts of Samegrelo and Guria–the two historic regions of Georgia.

Kolkheti wetlands primarily are important because to their relic origin. The lowland is a remnant of the Cenozoic period's tropical and subtropical landscapes that were stretched as a continuous strip across the entire Eurasian continent about 10 million years ago. The plants, characteristic only to the distant northern tundra and taiga swamp ecosystems, have been preserved in Kolkheti.

The areas of Kolkheti National Park are especially interesting from botanical point of view. There are preserved the complexes of phytocenoses quite diverse by florist composition and rich in relic and endemic species—different vegetation groups of sandy dunes located along wetlands, wetland forests, and coastline. 194 species of birds inhabit the Kolkheti National Park.

There are also a number of bird migration routes in the park: in the autumn—from north to south, in the spring—from the warm countries to their nesting places, and for some species, Kolkheti is a wintering (they do not need to fly more south). During the massive migration of birds, it is possible to observe many rare birds (Birdwatching).

In the Kolkheti wetland floodplains, forests, and shrubs the following large mammals are common: golden jackal (Canis aureus), wild boar (Sus scrofa), roe deer (Capreolus), and Eurasian otter (Lutra lutra). The European tree frogs and the pond frogs are notable among the Kolkheti inhabitant amphibians. From the reptiles, the smooth newt, northern banded newt, the water snake, the Aesculapian snake, and European pond turtles are spread. The ichthyofauna of the national park area is represented by 88 species of fish (23 passing species, 21 freshwater fish, and 44 the Black sea fish species). Among the cartilaginous fishes the Atlantic sturgeon is remarkable and among the osseous fishes—the Black sea salmon, herring, flathead gray mullet, pike, mackerel, and others.

6 species of mammals of the "Red List" of Georgia are spread in the Kolkheti National Park, and 16 mammals of the endemic species are inhabited there. Administration of Kolkheti National Park offers the tourists the boating tours

on the Paliastomi Lake and in the Pichori River gorge, as well as the sport fishing, birdwatching and eco-educational tours.

Machakhela National Park (area 7333.18 ha) is located in Achara Autonomous Republic, in the Machakhelastskali River gorge, in the territory of Keda and Khelvachauri municipalities at about 300–350 m above sea level. It was established in 2012 to preserve the unique biological and landscape biodiversity, the long-term protection of the Colchis mixed deciduous forests (with the domination of beech), ecological safety and provision of development of tourist and recreational activities in the safe natural environment.

About 95% of the park's area is covered by forests of chestnut, beech, horn, and alder. There is a rare diversity of endemic and relic species there; 13 out of timber species are included in the “Red List” of Georgia. The park is rich in animals too: brown bear, gray wolf, Eurasian lynx, etc.

There are cultural and historical monuments in the vicinity of the national park, such as: arched bridges of different periods, fortresses, winepresses, and wine cellars built from stone and lime. From the Mount Mtavarangelozi in the territory of the park, the most beautiful views of the city of Batumi, the Machakhela River valley, and the confluence of the Chorokhi River with the Black Sea are seen.

Mtirala National Park (area 15,698.8 ha) was established in 2006 and is located in Achara, between the Mount Mtirala, Black Sea, and Achara mountain system at the crosswater of the rivers of Chakvistskali and Korolistskali. The climate is very hot, with 4520 mm of precipitation all year round. The toponym “Mtirala” (“Crying”) was given the mountain because of abundant precipitation.

In the area of the national park, the forest vegetation represented by chestnut, beech, and Colchis type mixed forests is common, as well as the evergreen common rhododendron shrubs characteristic to Kolkheti.

In the Colchis forest, the beech, lime, chestnut, alder, and hornbeam are found. The subforest is covered with common rhododendron, which consists of cherry laurel, a Colchic holly, a Colchic box, and several types of lianas.

In the territory of Mtirala National Park, rare and endemic species of Achara-Lazeti and the “Red List” of Georgia are spread.

Javakheti National Park (area 13.498 ha) is located in Samtskhe-Javakheti region; it was founded in 2011. It includes certain areas of Akhalkalaki and Ninotsminda municipalities. It is located in the Javakheti Plateau, where there are many lakes including the Paravani Lake—the largest lake in Georgia.

Javakheti is a forestless region. There are found artificially planted pine groves and small fragments of natural forest. The most important natural subalpine forest is located in the area of the Kartsakhi Lake. There are documented almost 40 species of mammals in Javakheti highland including 10 predators and two hoofed animals.

In Javakheti there are many nesting waterfowl birds (a significant part of which remains here in winter and moves from frozen lakes to rivers). Seasonally, especially in autumn, this area is filled with predatory water or swamp birds.

Pshav-Khevsureti National Park (area 75 842.7 ha) is located on the northern and southern slopes of the Caucasus Mountain Range on the territory of Dusheti municipality and includes the gorges of the rivers of Asa, Arghuni, Andagistskali, Khevsureti Aragvi and Pshavi Aragvi, as well as the populated areas—Anatori, Mutso, Kistani, Lebaiskari, Kalotana, Amgha, Chimgha, Andaki, Kino, Bindaurta, Archillo, Chechketi, Shatili, and Ardoti. It was founded in 2014.

The aim of the creation of the Pshav-Khevsureti National Park is to protect, restore, and preservation of biological diversity of Pshav-Khevsureti natural ecosystems, animal and plant worlds, and also to create favorable conditions for education and scientific research. In addition, the protection and restoration of historic-cultural monuments and the survival of unique ecosystems should be ensured. The traditions of folk art should be maintained and developed.

In the national park, the vegetation cover is represented by deciduous forest. In Piraketa Khevsureti can be found oak, aspen, beech, goat willow, willow, alder, birch, lime, rowan, walnut, pear, apple, cherry plum, hazel, cherry, elm, juniper, and pine. Pirikita Khevsureti is poor in forest; the pine and birch are grown at a higher altitude and the yew—in the village of Katsalkhevi (Pshavi); the lime tree, rowan, goat willow, elm, maple, common ash, juniper, rhododendron, willow, and alder. In this area, there are many subalpine and alpine meadows.

Kazbegi National Park (area 8 685.3 ha) is located in the historic gorge on the northern slopes of the Caucasus Mountain Range. It was established in 1976 and renewed in 2007. Only 35% of the national park is covered by forests, the rest are covered by alpine meadows, moraines, permanent snow-covered peaks, and inaccessible rocks. The rocks and mountains of the national park represent a shelter for rare and unique species of animals and birds. Kazbegi National Park is high mountainous and its lowest point is located at 1400 m above sea level.

The vegetation cover of the Kazbegi National Park is represented by 1347 species, 26% of them are endemic plants. Alpine, subalpine, xerophyte, and many other ecological groups of vegetation are spread here, some of which are included in the "Red List" of Georgia. There are also relic and endemic species here.

The national park is rich in fauna. Most of the animals presented found here are represented by rare, endangered, and included in the "Red List" of Georgia species.

In addition, there are two types of globally important birds in the national park: great rosefinch (Carpodacus rubicilla) and Güldenstädt's redstart (Phoenicurus erythrogaster).

The category of Managed Reserve did not exist in Georgia until 1996. At that time, the state forest and hunting farms were created that were governed by the Main Administration of Protected Areas, Strict Nature Reserves, and Hunting Farms of Georgia. The first hunting farm was created in 1957 in the Gardabani region. The managed reserves were created in 1997 according to the Georgian Law on Animal World, on the basis of the state forest and hunting farms.

Currently, in the managed reserves, where previously forestry and hunting farms were operating, hunting farms have been established based on the special license. These managed reserves are—Gardabani, Iori, Chachuna, and Korughi Managed Reserves. Nowadays there are 19 managed reserves in Georgia (Asa, Ajameti, Bughdasheni, Gardabani, Tetrobi, Kartsakhi, Katsoburi, Ilto, Iori, Lagodekhi, Madatapa, Nedzvi, Sataplia, Sulda, Kobuleti, Korughi, Ktsia-Tabatskuri, Chachuna, Khanchali, etc.) and their total area is 71,530.45 ha (http://www.apa.gov.ge/ge/protected-areas/managedReserve).

Asa Managed Reserve (area 3943.38 ha) covers the left slope of the Asa River gorge and the origins of the gorges of its left tributaries (Aragvistskali, Akhielistskali, etc.). it was established in 2014. The territory of the Managed Reserve consists of virgin coniferous forest massifs, which is a permanent habitat of the species of "Red List" of Georgia—bear, wild goat, and chamois. This area is likely particularly important for leopards. Exactly in these areas was noted the last case of the killing of the leopard and the footprint of this animal was recorded during the last years.

Ajameti Managed Reserve (area 4990.57 ha) is located in the Imereti region, in the territory of Baghdati and Zestaponi municipalities; it was established in 1929, renewed in 2003, and is made up of two massifs: Ajameti oak forest (3824 ha, between the Kvirila and Khanistskali Rivers—the left tributaries of the Rioni River) and Vartsikhe massif (1166 ha, on the left side of Khanistskali). The goal of its establishment was to preserve the rare Colchis forest and the Tertiary relics—Imeretian oak, Zelkova, and Strandzha oak, as well as protection, reproduction, and scientific study of fauna. The famous oak forest is very old. The age of some trees is more than 250 years.

Bughdasheni Lake Managed Reserve (Area 119.3 ha) is located in the territory of Javakheti National Park. It includes a part of the Ninotsminda municipality territory. It was established in 2011. There are many varieties of birds of different species in the Managed Reserve. The lake freezes in winter.

Gardabani Managed Reserve (area 3 733.7 ha) is located at the border of Gardabani and Marneuli municipalities near the border with Azerbaijan. The Managed Reserve was established in 1957 and renewed in 2007.

The Gardabani Managed Reserve was established to maintain forest groves in this area, improve their condition and protect the fauna inhabiting there. The main wealth of the Gardabani Managed Reserve is the floodplain forests, the main trees of which are: gray poplar, black poplar, quaking aspen, floodplain oak, elm and small wych elm. In the protected area of Gardabani there can be still found a red deer, which is included in the "Red List" of Georgia.

Tetrobi Managed Reservoir (area 3100 ha) is located in the Javakheti Upland, to the northern from Akhalkalaki, on the crossroad of the historical regions of Tori and Javakheti. The Managed Reserve was created in 1995 to protect forest massifs and local endemics in Javakheti Upland. The Managed Reserve is very interesting in florist terms, and scientists call it even the nest of endemics.

Kartsakhi Managed Reserve (area 157.5 ha) established in 2011 is located in the territory of Javakheti National Park and includes part of the territory of Akhalkalaki Municipality. A natural subalpine forest represented in the surroundings of the Kartsakhi Lake is important in the territory of the Managed Reserve, where the Litvinov's birch, Caucasian mountain ash, cotoneaster, and the shrubs of dog rose and raspberry are presented. It is one of the main routes of birds' migration.

Katsoburi Managed Reserve (area 270.8 ha) established in 1964 and renewed in 2007, is located in Abasha municipality. The area of the Managed Reserve is mainly plain with the maximum height of 40 m above sea level.

The Managed Reserve was established in order to protect the heavily modified remnants of Colchis forests. The main background of vegetation in Katsoburi Managed Reserve is created by the alder trees, where the wingnuts, ash, and others are associated with main forest species. black locusts, alder, and willow are also found in the areas covered by forests.

Ilto Managed Reserve (area 6971 ha) covers the part of the head of the Ilto River gorge in Akhmeta municipality and is located at the height of 900–2000 m above sea level. It was established in 2003 in order to protect and restore the beech forests and the groves of precious species of yew tree, sycamore maple, lime tree, maple, common ash tree, and elm, and the founa characteristic to these forests.

Iori Managed Reserve (2126.8 ha) is located in Gare Kakheti, in Sighnaghi municipality. It was established in 1965 and renewed in 2007. The forests of the Managed Reserve are located in the Iori River gorge. The Managed Reserve was established to protect the floodplain (Tugai) forests. The floodplain forests occupy the first and the second terraces in the river bed. The main forest-producing species are the floodplain oak, the poplar, the elm, and the Mt. Atlas mastic tree. Mountain slopes and plots away from the river are deprived of forest vegetation. Here grow the grains and the individual groves of Jerusalem thorn. The Georgian iris, Eichler's tulip, common barberry, salt cedar, weeping pear, juniper, oriental hornbeam, and others are common here. From mammals here are found wild boar, wolf, otter, reed cat, and others. From birds here are found pheasant, black francolin, partridge, Egyptian vulture, Eurasian magpie, Eurasian jay, griffon vulture, forest owl, and common kestrel; from the reptiles—the common tortoise and macrovipera lebetina.

Lagodekhi Managed Reserve (area 4702 ha) is located in the north-easternmost part of Georgia on the southern slopes of the Caucasus along the villages adjacent to the Lagodekhi Strict Nature Reserve, in the territory of Lagodekhi municipality; It extends up to 590–3500 m above sea level. It was established in 2003, The Lagodekhi Managed Reserve is distinguished with beech-hornbeam broad-leaved forest, with Gurgeniani waterfall; it also includes the system of pathway connecting forests and alpine meadows.

Madatapa Managed Reserve (area1398 ha) is located in the territory of Javakheti National Park. Includes part of the territory of Ninotsminda municipality. It was established in 2011. The Madatapa Lake (Mada) is located in the south-eastern part of the volcanic highland of

Javakheti at an altitude of 2108 m above sea level. There are many waterfowl birds in the summer. Lake banks are low and are covered with hygrophilous vegetation. Madatapa is included in the Madatapa Lake Managed Reserve. During the warm period of the year, a large number of amphibious migratory birds are gathered on the lake.

Nedzvi Managed Reserve (area 9212.5 ha) is located in Borjomi municipality; it includes Nedzvi, Rveli, and Akhaldaba forest lands of the forest fund; it was created in 2007 for the protection of coniferous forests (pine, spruce, and fir trees) in the Nardzikhevi River gorge (right tributary of Mtkvari). Apart from the coniferous trees, there are also wide leaved forests. Winter is moderately mild and with little snow. The thermal mineral water springs (boreholes) are located in the Nedziviskhevi River gorge with the temperature from 32.50 to 44.80. The mineral waters are used in the form of baths.

Sataplia Managed Reserve (area 330 ha) is located in the Tskaltubo municipality in Imereti region, where the footprints of both the predator and herbivorous dinosaurs of different epochs are found. The dinosaurs of Sataplia differ from the world's famous species and are known as “Satapliazaurus”. It was established in 2011. There is a dinosaur footprint conservation construction in the territory of the Managed Reserve, as well as the Sataplia karst cave, Colchis forest and rare and endangered timber trees included in the Red List of Georgia, almost half of which is relic.

Sulda Managed Reserve (area 309.3 ha) is located in the territory of Javakheti National Park. It includes part of Akhalkalaki municipality territory. It was established in 2011. Birdwatching and riding on horseback are available there. Family guest houses are functioning in the village of Sulda. The Sulda wetland Managed Reserve area is a Ramsar site similar to four other managed reserves of Javakheti Protected Areas.

Kobuleti Managed Reserve (area 466.3 ha) is located in Achara Autonomous Republic, along the Black Sea, in the north of Kobuleti city. It was established in 2011. There are unique wetlands on the territory of the Managed Reserve. It is distinguished by the diversity of waterfowl birds and plants. By the botanical point of view, the following species are interesting here: sphagnum, or white moss, and insect-eating sundew.

The Kobuleti Protected Area includes the Ispani peat deposit. The Shavighele and Togoni Rivers flow through the territory of the Managed Reserve. Climate is typical marine, humid subtropical with annual rainfall of 1500–2500 mm.

“Ispani II” is located in the Kobuleti Managed Reserve, which is the unique percolating domed wetland of the world’s importance, which is fed only by rainwater. The general background of the wetland is formed by peat mosses—the sphagnum species, the so-called “Imeretian sedge”, white rhynchispora, peat sedge, water clover, round-leaved drosera, and others.

The Managed Reserve is distinguished with diversity of migratory waterfowl bird species. There are found many species, included in the “Red List” of Georgia (5 species) and Europe scales (28 species) rare and endangered species, such as European bee-eater, kingfisher, little cormorant, yellow heron, ibis, black stork, and others. Here are represented seven species of globally endangered birds, such as: Valley Montagu’s Harrier, Lesser Kestrel, field lawping, great snipe, corncrake, and others.

Kobuleti Protected Areas are distinguished by the variety of species of waterfowl migratory birds.

Visitors in Kobuleti Managed Reserve have the opportunity to conduct educational and scientific tours. It is possible to rent wetland skis and walk on a peat moss.

Ktsia-Tabatskuri Managed Reserve (area 22,000 ha) is located on the volcanic upland of Javakheti in southern Georgia. It was created in 1995 to maintain the vegetation characteristic to the humid climate and to protect the birds that are spread in this area: black and white storks (Ciconia nigra and C. ciconia), common crane (Grus grus), corn crake (Crex crex), and velvet duck (Melanitta fusca) and their habitat—the unique wetlands and high mountain ecosystems. The Managed Reserve also is a resting place for a number of migratory waterfowl birds.

The International Association of Bird Conservation (Bird Life International) granted the Tabatskuri Lake international status of An Important Bird and Biodiversity Area (IBA). Georgia has been proposed the wetlands of Ktsia-Tabatskuri Managed Reserve for inclusion in the list of areas protected by Ramsar Convention due to the high value of wetlands ecosystems existed there.

There are many small and large lakes in this area, but among them the Tabatskuri Lake is notable. The surrounding of the Managed Reserve is also rich in historical monuments. To the north of the Managed Reserve, the thirteenth-fourteenth century's cave monastery Vardzia is located. Managed Reserve has the best conditions for birdwatching, as well as tourism development.

Korugi Managed Reserve (area 2068 ha) is located in the south-eastern part of Georgia, in the territory of Sagarejo municipality of Kakheti region. It is located in the Iori gorge, on both sides as a narrow strip. It was founded in 1965 and renewed in 2007. The main goals of its creation are: protection, maintenance, and reproduction of unique floodplain forests (Korugi), flora, and fauna.

Chachuna Managed Reserve (area 5200 ha) is located in Dedoplistskaro municipality. It was established in 1965 and renewed in 2007. It was established mainly for the protection of arid and semiarid type of flora and fauna. Flora is quite diverse in the Managed Reserve. Along the river Iori, the Tugai-type floodplain forest is growing, and the fragments of various types of arid light forests, semi-desert and steppe vegetation are presented on the surrounding hills and terraces.

In the Chachuna Managed Reserve, there are important monuments, such as: early medieval Khornabuji fortress ruins, 11th-century Ozaani Ascension Temple, etc.

Khanchali Lake Managed Reserve (area 727.3 ha) is located in the territory of Javakheti National Park, in Ninotsminda municipality, in the central part of the volcanic highland of Javakheti, at the height of 1928 m above sea level. It was established in 2011. The area of the surface of the lake is 13.3 km and the area of its basin is 182 km^2; the maximum depth is 0.8 m, and the water volume is 6.4 million m^3. The lake basin, especially its southern part, is characterized by a rather dense hydrographic network. The lake is rich in algae. During the warm period of the year, a large number of waterfowl and amphibious migratory birds that are the object of protection gather on the lake.

There are currently two Protected Landscapes in Georgia. The first Protected Landscape –the "Tusheti protected Landscape" was established in 2003 (31.518 thousand hectares), and in 2009—"Kintrishi Protected Landscape" (3.190 thousand ha). In this type of Protected Areas a sustainable use of natural resources and development of eco-tourism is possible in order to facilitate the achievement of conservation aims.

Tusheti Protected Landscape (area 27.903 ha) is located in the territory of Akhmeta municipality in 2003 and includes all the villages of Tusheti. It is designed to maintain the traditional appearance of Tusheti villages and preserve historic-cultural and natural-cultural landscapes, and at the same time, encourage tourism and traditional economic industries without damaging the environment.

The Tusheti Protected Landscape is distinguished by the beautiful historical villages of Tusheti. In the villages of Tusheti there are unique monuments of cultural heritage maintained, as well as the former villages, samples of folk handcraft, agricultural tools, and household items. In terms of spectacularity, Tusheti differs greatly from other Protected Areas, because there, along with the natural monuments, the historic and cultural buildings, traditions and customs are considerably combined. That is what attracts most the visitors there.

Kintrishi Protected Landscape (area 3190 ha) was established in 2007 based on Kintrishi Strict Nature Reserve. The Kintrishi Protected Landscape is located between the Black Sea and Achara-Imereti mountain system; these mountains hinder the sea moisture and determine Kintrishi's highly humid climate. Throughout the year there fall almost as much precipitations (3000 mm), as on the coast of Achara. It was established for protection of

Colchis flora and fauna of the Tertiary age. Many endemic and relic species of plants have been preserved. The subtropical vegetation belt (500 m) is altered by the oak-hornbeam (500–1000 m) and oak (1000–2000 m) belts; higher can be found the subalpine light forest (2000–2200 m) and alpine meadows (2200–2600 m). Strandzha oak, gray alder, hornbeam, yew, box-tree, pontic oak, Medvedev's birch, guelder-rose, buckthorn, mountain ash, thyme, juniper, and others are found there. Animals—roe, chamois, bear, res fox, marten, wildcat, least weasel, Caucasus viper and Caucasian salamander, tetrao, and Eurasian woodcock. There are many trouts in the rivers. Two tourist routes are located at a height of 300–2000 m above sea level on the territory of the Protected Landscape. Movement on the path is possible both on foot and by horse. The picnic and camping areas are organized along the route; the areas for making bonfires are also allocated.

The special phenomenon of nature is the nonlife (inorganic) monuments of nature, which are scattered throughout the different parts of Georgia in big amount. Three groups are distinguished among them: geomorphological, geological, and hydrological. They include the unique karst caves, displaced glacier and mudflow boulders, natural bridges, canyons, waterfalls, vaucluse springs, travertines, fossil elements of flora and fauna, as well as the old trees, such as: 1200 years old three yew trees in Tsedisi Village (Oni municipality), 800 years old plane tree in Telavi, zelkova of the same age in the village of Chkhari (Terjola) and others.

Due to the diversity of natural conditions of Georgia, many interesting monuments of nature have been created during the centuries; monuments of nature are the phenomena equal to the national treasure. All regions of Georgia are very rich in all the wonders of nature. Many of them deserve great attention because of their grandiosity and beauty.

The first three nature monuments in Georgia were established in 2003 with the total area of 314.5 ha. These are: Alazani floodplain (area 204.4 ha), Artsivi gorge (area of 100.4 ha), and Takhtitepa (area 9.7 ha) nature monuments. At present 42 objects were granted status of nature monuments. As of 2018, the total area of nature monuments is 2941.43 ha.

17.1 Karst Caves

Today there are about 1400 caves in Georgia, the total length of which is 275 km and the depth is 80 km (Tsikarishvili and Bolashvili 2013). Tskaltubo Cave (total length 15.5 km) occupies the first place according to the length in Georgia (and in the Caucasus). The length of Akhali Athoni Cave is 3.3 km, but by volume, it is one of the largest in the world (1.5 million m^3). According to the cave floors, Tsutskhvati Cave is the first in the world (1113 floors).

According to the depth, the first place in the world occupies the Krubera abyss (Apkhazeti), where the Ukrainian speleologists registered the depth of 2197 m. Among the deepest caves in the world that are over 1000 m deep, other cave-abysses of Georgia are listed too: Sarma (1830 m), Snowy-Mezhen (1753 m), Pantyukhin (1508 m), Ilyukhuin (1275 m), "Moscow" (1125 m), Arabika (Kuibyshev/Heinrich bottomless, 1110 m) and Dzou (1090 m).

In Georgia, the well-equipped caves are: Akhali Athoni, Tskaltubo (Prometheus) Sataplia, and Navenakhevi.

As for the volcanic caves, their number is not much in Georgia; Dashbashi Cave is important, where the rare forms of lava speleothems ("shelves") are preserved; Phinezauri fortress-cave is also notable with preserved lava "orghan pipes", etc.

Clastokarts caves are predominantly distributed in Samegrelo, where they are related to the Upper Tertiary conglomerates and sandstones. The clastokarst caves are: Nazodelavo, Kalichona, Garakha, Kortskheli, Savekuo and others.

Today the status of Nature Monument in Georgia has been given to 19 caves:

The Bgheri Cave Nature Monument is located in the neighborhood of the Melouri Village, Tskaltubo municipality, at 458 m above sea level. The nature monument is a cave with the length of 1700 m and the area of 14,000 m^2, which has been generated by the Bgheristskali River in thin and medium-sized limbs of subage The river will eventually cross the entire cave and the thin and medium-layered limestones of Lower Cretaceous Age. The river crosses sects the entire cave and disappears at its western end in debris and siphon of small depth. Trace of the erosion effect of flows is well observed in the Bgheri Cave.

Didghele Cave Nature Monument is located in Tskaltubo municipality, In the neighborhood of Melody Village, at 418 m above sea level. The cave is generated in the by the Osunela River in the Barremian limestones. There are plenty of boulders, clay deposits, etc., fallen from the cave ceiling. Through the crack at the entrance of the cave, the Kinkile stream leaks, and the temporary lake is formed.

Tetra Cave Nature Monument is located in Tskaltubo municipality, in the northeast, 1.6 km away from Tskaltubo, at 140 m above sea level. The cave is 25 m long and 3.5 m high generated in the Lower Cretaceous limestones distinguished with speleothems. It is interesting for diversity of old siphon channels. The cave is distinguished with healing properties. In the past century, patients with bronchial asthma and hypertonia were treated. It is an important archaeological monument, where the remnants of cave bear, deer, bison, wolf, fox, and rabbit bones are found, as well as the remains of ceramics.

Iazoni Cave Nature Monument is located in the city of Kutaisi, in the southernmost part of the Tskaltsitela canyon, at the bridge of the Godogani Village, on the right bank of the Tskaltsitela River, at 135 m above sea level. The cave is 40 m long and at the end, it is blocked by debris. The cave is inhabited by many troglobiont animals. The animal bone and flint tools found here indicate that the cave was a dwelling for humans of the Paleolithic Age.

Melouri Cave Nature Monument (Fig. 17.5) is located in Tskaltubo municipality, in the neighborhood of the Melouri village, at 418 m above sea level. It is one of the largest caves in Georgia. At the end of the halls, the canyonic gorge is stretched at several kilometers, where a permanent stream flows. This stream forms whitewater and waterfalls while flowing through the canyon, and in the final section creates the siphon lake. Stalactites and large size stalagmites are characteristic for the front section of the cave. The cave is inhabited by bats, spiders, and beetles. The cave has a number of unknown corridors and sub-corridors, the study of which is the subject of additional research.

Motena Cave Nature Monument is located in Martvili municipality, in the vicinities of the village of Balda, at 473 m above sea level, on the left bank of the Abasha River gorge. It is a two-storied cave with permanent stream, which conflows the Abasha River. Here is built the stone wall with embrasures. Here are many stalactites, stalagmites, travertine cascades, curtains, and large boulders, as well as local weathering materials. Spiders and other insects inhabit the cave. The historical building was used as a fortress in the Middle Ages.

Nagarevi Cave Nature Monument is located in the area of Godongani Village, in Terjola municipality, on the left ban of the Cheshura River at 199 m above sea level. It consists of narrow corridors and small halls. The front part is two-storied. A small stream occurs at junction of terraces. During the rains, it is completely filled with water. The cave is easy to pass. In some places, one needs to creep.

Navenakhevi Cave Nature Monument is located in Terjola municipality, in the area of the Natengkhevi Village at 320 m above sea level. It is a 250-long two-storied and 4-hall cave distinguished by distinctive and nice-shaped stalagmites, stalagnates, and stalactites. The cave is divided into two parts at 30 m from the entrance. The second floor is connected with the hall by small stairs. The cave does not have the exit; it is closed with a stalagnate with thickness of 7 m.

Nazodelavo Cave Nature Monument is located in Chkhorotsku municipality, in the surrounding areas of the Akhuti (Lemampore) Village, in the Zana River gorge, at 290 m above sea level. The nature monument, the largest clastokarst and pseudokarst 600 m long cave,

Fig. 17.5 Melouri cave (Photo by R. Tolordava)

generated in Meotian conglomerates, is one of the distinctive caves in Georgia with its parameters. A long and cold underground river flows through the erosive canyon cut into the bottom of the main corridor of the cave. The depth of the canyon reaches 78 m in some areas.

Oniore waterfall (Fig. 17.6) and Toba 1st Cave Nature Monument are located in the northeast of the Meore Balda Village of Martvili municipality, in the gorge of the Toba River– the right tributary of the Abasha River at 680 m above sea level.

The complex of nature monuments is a combination of Toba 1st Cave and the Oniore waterfall falling from the cave. The cave is generated in the Upper Cretaceous layered limestones. The entrance (12 m × 5 m) is opened along the cliff. There is a 21 m high underground waterfall 70 m away from the entrance, where the height of the ceiling is over 30 m. The width of the tunnel reaches 1215 m in some areas. The underground river flowing out from the cave forms the 67 high Oniore waterfalls after 15 m.

Prometheus Cave Natural Monument is located in Tskaltubo municipality, in the territory of the Kummavi Village, at 175 m above sea level. The cave is distinguished by the most beautiful speleothems; there are found stalactites, stalagmites, stalagnates and helictites of particular forms, stone waterfalls, and hanging stone curtains. The cave area is 46.6 ha. The "Prometheus Cave" is characterized by wide corridors, unlike other caves. Here are 17halls of different sizes. The length of the path in the cave is 1.420 m, and the total length of the cave is

Fig. 17.6 Oniore waterfall (Photo by Agency of Protected Areas of Georgia)

20.000 m. The cave has two exits: one is ended with the river on which the boating is possible, and the second exit is pedestrian and it goes out of the cave hall.

Sakazhia Cave Nature Monument is located in Terjola municipality, in the area of the Godongani Village, on the left bank of the Tskaltsitela River gorge, at a distance of 1.5 km southwest from the Motsameta monastery, at 204 m above sea level. It is a cave rich in archaeological, paleobotanical, and paleozoological findings. Signs of the Paleolithic period have been confirmed in the Caucasus for the first time, where there are a number of representatives of paleozoologic ungulates (bison, deer, and roe deer), predators (cave bear, cave lion, lynx, etc.) and rodents (otter and porcupine). The quantity of animal teeth and bones obtained there has reached several tens of thousands. This material belongs to the Upper Paleolithic.

Satsurblia Nature Monument is located in Tskaltubo municipality, in the neighborhood of the Kummavi Village, on the left bank of the Sami River, at 287 m above sea level. It is a cave rich in stalactites, stalagmites, travertines, and other speleothems of large size. There is a 5-m cliff in 125 m from the entrance, which is followed by a large hall (30X25). In the Middle Ages, the cave was used as a shelter.

Solkota Cave Nature Monument is located in Tskaltubo municipality, in the neighborhood of the Kummavi village, on the left bank of the Sami River, at 379 m above sea level. Particularly large sizes of speleothems attract attention. The circumference of stalactite, which is cut off from the ceiling by the force of gravity, is 5 m. Stalactite of this size is rare in Europe. At a distance of 160 m from the entrance, the 8-m stalagmite is erected from the bottom of the bed, with a circumference of 8.5 m at the foot and

4.5 m in the middle. The cave is also a paleontological monument, as the bones of cave bears were found here.

Toba Waterfall and Arsen Okrojanashvili Cave Nature Monument are located in Martvili municipality, in the northeast of the Meore Balda Village in the Toba gorge –the right tributary of the Abasha River, at 707 m above sea level. The cave is hard to access and it is not recommended to go there without special equipment, and to travel inside, the rubber boat is needed. There are several halls in the cave. Among them, the following are notable: "Nona Hall", "Nana Hall", "Salon", "University 50", "Tbiani", and other halls. Chemical deposits are presented in diverse forms. The height of one of the stalagmites reaches 7 m. The total length of the cave is 1300 m. The river flowing from the cave that forms the four lakes under the ground, generates 234 m high (the highest in Georgia) Toba cascade waterfall.

Ghliana Cave Nature Monument is located in Tskaltubo municipality, in the Kumistavi Village, adjacent to Prometheus Cave, at 142 m above sea level. At almost all length the ceiling is covered with speleothems. This watery gallery generates several siphon passages to the end of the cave and at the end, the 2030 m long passage is very difficult to pass because of the low ceiling. The debit of the underground stream of Ghliana is 5055 l/s. (during low water); this stream joins the vaucluse springs of the Kumi River after flowing out from the cave. In the dry corridors of the cave, there inhabit numerous colonies of bats.

Tsutskhvati Cave Nature Monument is located in the south of Tsutskhvati Village of Tkibuli municipality, in the Chishura River gorge, at 320 m above sea level. The cave consists of 13 floors. The first floor from the bottom of the floor is a narrow hole impassable for the man, through which the permanent stream—the Shabatghele flows. The second floor (main tunnel) is characterized by the features of enormous natural tunnel (length—200 m, width—1030 m, and height—1028 m). The water flows through it only during the flooding of Shabatghele. The remnant of the old cult building with the beams fixed by human is preserved at ceiling. Archaeological monuments from the Middle Paleolithic (from the Moustier epoch) to the Bronze Age and historical epoch, as well as the bones of animals of more than 40 species, have been found there.

The Tsutskhvati Cave is one of the first in the world in its age and number of floors.

Khomuli Cave Nature Monument is located in Tskaltubo Municipality, in the neighborhood of the Khomuli Village, at 160 m above sea level. There is a lake originated by sinking of the surface in front of the cave entrance with the depth of 5 m and circumference of 30 m. The cave is divided into two parts with a 4-m stair. The front part is extensive with sinkholes on the bottom. The second part is a narrow hole, moving is only possible by creeping. The cave is dry. The footprints of temporary flows are observed. There is a small lake at the end of the tunnel.

Jortsku Cave Nature Monument is located in Martvili municipality, in the northeast of the Meore Balda Village, in the gorge of Jortsku—the left tributary of the Abasha River at 653 m above sea level. It is a two-storied cave with a stream flowing into the cave, which is joined by the second flow and after passing the 15 m, it flows out as a spring on the left side of the Jortsku River. The cave is interesting with its characteristic fauna and paleontological specimens, and at the same time, it was the dwelling for people. Here are found the bones of the cave bear, lynx, bisons, and other animals.

17.2 Canyons and Gorges

The canyons of the rivers of Georgia are of different depths, shapes, and distributions. Most parts of the rivers have deep rock gates and canyons on certain sections. One of the deep canyons is Akhatskha in the Bzipi River gorge (Gudauta municipality) with the depth of 200 m and the width—78 m. Important canyons are as follows: Abasha (Martvili municipality), Iupshara (Gudauta municipality), Okatse (Khoni municipality), Kvirila (Chiatura municipality), etc.

Canyon gorges are found in Svaneti too in the lower part of the Mestiachala River gorge. In the area of Mestia and lower, in the bottom of the Mulkhura gorge, the narrow and very deep canyon is cut, through which the river flows with noise. The upper part of the Enguri River flows through the rock-gate-like gorge. The canyon gorges associated with volcanic rocks are abundant, especially in the Javakheti Upland, Kvemo Kartli—Ktsia (Tetritskaro and Bolnisi municipalities), Dashbashi (Tsalka municipality), Paravani (Akhalkalaki municipality) and others.

Georgia is famous for its gorgeous valleys. In this regard, among them, the gorges of Khde (Kazbegi municipality), Kurtskhana (Adigine municipality), and others are notable, which are distinguished by vegetation, animals, nature monuments, and landscape. At present, there are six canyons in Georgia granted status of a natural monument.

Balda Canon Nature Monument is located in Martvili municipality, in the area of the village of Meore Balda, in the Abasha River gorge near the Balda Monastery, at 295 m above sea level. The nature monument is a canyon generated by the Abasha River in the limestone rocks in the southern part of the Askhi massif. The length of the canyon is 1400 m, width—510 m, and the cut depth—2530 m.

Dashbashi Canyon Nature Monument is located in Tsalka municipality, in the Khrami (Ktsia) River gorge, in the surroundings of the Dashbashi Village at 1110–1448 m above sea level. It is a canyon gorge distinguished by rare biodiversity that was generated in the bed cut in the volcanogenic rocks of the Dabasbashi lava hill by the Ktsia (Khrami) River.

The ecosystems around the canyon are quite poor in vegetation, and the vegetation on the steep slopes of canyon and breathtaking waterfalls create a completely different micro landscape with its characteristic microclimate and peculiar fauna.

Martvili Canyon Nature Monument (Fig. 17.7) is located in Martvili municipality, in the territory of the Gachedili Village in the Abasha River gorge, near the central road of Martvili-Chkhorotsku, at 210 m above sea level. The nature monument is a canyon gorge cut by the Abasha River in the anticline built by the Abedati limestone rocks. The length of the canyon is 2400 m, the depth of the cut is 2030 m, and the width is 510 m.

The natural limestone bridges are preserved in two places in the canyon, which indicates that the karst cave was collapsed here. In addition, in the middle pert of the canyon there are 1215 m high small waterfalls.

Okatse Canyon Nature Monument (Fig. 17.8) is located in Khoni municipality, in the areas of the Gorda Village, at 520 m above sea level. The nature monument is a complex with complicated paleogeographical, geological, and distinguished with particular geomorphological structures, including neotectonic structures, lacustrine deposits, and breathtaking cluse-canyon. Its depth is 3550 m and its width—4 m on average; in some areas, the canyon walls almost merge with each other and form natural stone bridges. One of them is "Boga", from where the canyon bottom can be seen.

Samshvilde Canyon Nature Monument is located in Tetritskaro municipality, in the area of Samshvilde Village, near the Samshvilde former town, in the gorges of the Khrami and Chivchavi Rivers, at 548,605 m above sea level. The depth of the canyon cut is 300 m on average and in the middle stream of the Khrami (Ktsia) River it represents the combination of the deep canyon gorge, generated in lava rocks, and the Chivchavi River canyon.

The Samshvilde canyon begins with the outcropped quartz-porphyritic intrusion; as a result of the weathering of these rocks, the magma quartz's beautiful bipyramidal crystals fall on the ground. These crystals of quartz are the true wonder of nature.

An interesting historical monument—the former town of Samshvilde is located near the natural monument.

Tskaltsitela Gorge Nature Monument is located in Kutaisi, Tkibuli, and Terjola municipalities, in the Tskaltsitela River gorge from Gelati Bridge to Godagani Bridge, at 130–200 m above sea level. The nature monument is a beautiful canyon gorge of the Tskaltsitela River, covered with the beautiful Colchis forest. The gorge is of great interest because of the following

Fig. 17.7 Martvili canyon (Photo by R. Tolordava)

Fig. 17.8 Okatse canyon (Photo by R. Tolordava)

monuments of historical culture: Gelati Monastery Complex and Saint Martyrs David and Constantine Monastery.

17.3 Rock Columns and Towers

The rock columns and towers Such formations of relief are often found in many areas of Georgia. All of them are the object of protection. The Katskhi column (Chiatura municipality) (Fig. 17.9) is hard to access as well as the Bodorna column (Dusheti municipality), Sairme cliffs (Tsageri municipality), Kvispapa (Aspindza municipality), Kvakatsa (Shuakhevi municipality), Udabno column (Sagarejo municipality), Betlemisberi (Kazbegi municipality), and others. These forms are generated in almost all rocks. They are found in limestones and conglomerates, volcanic tuffs and sandstones, tuff-breccias, volcanic rocks, and others. Some of them are historically important along their natural features. For example, the Katskhi column and the Bodorian column (5th-6th c.) should be related to the life of the columnar (recluse).

The natural rock columns and towers are much more in the nival belt. Such sharp forms of weathering can be counted in hundreds in this zone.

Bodorna Rock Column Nature Monument (Fig. 17.10) is located in Dusheti municipality in the territory of the Bodorna Village, near the Mtskheta-Stepantsminda-Larsi highway at 796 m. The rock column with the height of 15 m is generated in the Neogene conglomerates, or in the naturally cemented cobblestones. In the lower part of the Bodorna column, there is a double room cave with a niche cut into the wall. 150–200 m away from the column, there is the Bodorna Virgin Mary Church built in the seventeenth century. On the slopes adjacent to the nature monument, there are many handmade caves, which had the purpose of cult or shelter in our historical past.

Sakhizari Cliff Nature Monument is located in Kazbegi municipality, in the Tergi River gorge, in the area of the Sioni Village, at 3136 m above sea level. It is a complex of erosive columns distinguished by interesting geological structure, which was formed on the washed by rich precipitation Mount Kabarjina. The mountain is a flat crested hill of volcanic flow.

Birtvisi Nature Monument is a rocky peak erected on one of the sub-ranges of the Trialeti Range that borders the Algeti River with its slope with two villages: Tba and Pirtskhisi (Tetritskaro municipality). A fortress tower with embrasures is built in the inaccessible rocks; a baptizing pool is cut into the porphyritic tuff. On the way to the Birtvisi peak, the ravine is built out with a wall with embrasures; the walls repeat the words spoken by the man with the remarkable peculiar acoustics.

17.4 Mud Volcanoes

In Georgia, the mud volcanoes are in Kakheti, in the Iori Upland, and on the slopes of the Gombori Range. Among those following are notable: Akhtala, Pkhoveli, Kilakupra, etc. The mud volcanoes are notable for their special forms. Mud, water with gas, and oil erupt from the 1.52 m high cones. Among the mud volcanoes, only the Takhti-Tepa has a status of Nature Monument (Fig. 17.11).

The Takhiti-Tepa Nature Monument is located in Dedoplistskaro municipality, On the right bank of the Iori River, from Dali water reservoir to southwest, at 541 m above sea level. It is a group of craters of mud volcanoes (pseudo or, exo-volcanoes), from which the mixture of water, oil, mud, and gases constantly erupts.

17.5 Travertines

Travertines (lime-tuffs) are formed by the deposition of travertine or lime-tuff. In some areas natural dams are originated in the cave river beds; siphon sections are often associated with those dams. There are especially many travertines in the Motena (Martvili municipality), Tsutskhvati (Tkibuli municipality), Abrskili (Ochamchire municipality), and other caves.

Fig. 17.9 Katskhi column (Photo by I. Julakidze)

Under the open sky, the travertines are predominantly distributed in the Caucasus and its foothills. Especially notable is the upper part of the Liakhvi gorge (Britata travertines), Patara Liakhvi (Atsriskhevi travertines), Lekhura, Ksani, and upper parts of Aragvi. Diverse forms of travertine are found on the northern side of the main watershed range of the Caucasus—in the upper part of Tergi (Truso gorge); the footprints of plants in the travertines here indicate that in the past there were forest plants in this area. In some areas, they are karstified and the atmospheric precipitations have generated small funnels in them.

Travertines are widely spread in the areas of the Jvari Pass, Khevsureti, and Tusheti. In addition, travertines are found in such areas, where the carbonate rocks are not outcropped. For example, in the Kaloani and Arkhotistskali gorges (Khevsureti), at the villages of Juta (Kazbegi municipality) and Dartlo (Tusheti), etc.

Travertines are also widespread in western Georgia including Svaneti (in the Khalde gorge, at Becho), Imereti (Kvirila gorge, below Chiatura), Racha (Kvabtkari, Ambrolauri municipality), etc.

Truso Travertines Nature Monument is located in Kazbegi municipality, Truso gorge, on the right bank of the Tergi River, near the central road, to the south-east from the Keterisi Village at 2093 m above sea level. In many areas, there are heaps of lime travertines deposited by springs in many areas.

There are many travertine “meadows” in the intensive development process, modeled by water. The thin layer of transparent water covers the dazzling white surface of the travertines and forms a lot of small sparkling lakes.

Fig. 17.10 Bodorna Rock Column (photo by K. Kharadze)

Jvari Pass Travertine Nature Monument (Fig. 17.12) is located in Kazbegi municipality, Bidara River gorge, near the Kobi-Gudauri road at 2197 m above sea level. In some places in Bidara River gorge, there are deposits of travertines deposited by springs. One of the most important and breathtaking places of travertines is located on the left bank of the Bidara River near the road tunnel. The transparent water flows down in a thin layer on the white surface of the slope and creates the breathtaking travertine, which is in the intensive development process.

Fig. 17.11 Takhiti-Tepa (Photo by V. Cherkezishvili)

17.6 Displaced Boulders

Displaced boulders, or the erratic (erraticus – Latin, "wandering") boulders. The number of boulders displaced by glaciers and mudflows is considerable after the number of caves. They are one of the most interesting phenomena of nature, which are displaced sometimes even tens of kilometers away. That is why often the huge boulder at any area is composed of rocks that are not characteristic of this area.

The displaced boulders are scattered along the southern slope of the Caucasus, mainly between the Bzipi and Aragvi gorges, and on the northern slopes in Tergi and Arkhoti gorges. A small number of such boulders is found in the highland of southern Georgia –in the Samsari and Erusheti Ranges, etc. Particularly many huge boulders are represented in the upper parts of the gorges of Chkhalta, Nenskra, Nakra, Dolra, Mestiachala, Enguri, Mulkhuri, Adishchala, Tskhenistskali, Rioni, Chveshura, Abudelauri, and Jutaskali. Some of them belong to the largest erratic boulders of the world. Huge boulders are often found in unexpected areas. They are of great importance to determine the boundaries of the old glaciation. They are interesting objects for mass tourism.

Especially interesting is the rolling boulder, namely the limestone boulder "Kvakantsalia" in the Kvira massif (Tsalenjikha municipality).

Roshka Nature Monument includes the Roshkistskali River gorge from the village of Roshka to the direction of the Caucasus. Effective landscapes are created by the slopes of the Caucasus and number of erratic boulders. The two huge diabese (magmatic rock) boulders, represented here, belong to the largest erratic boulders in the world. The relatively small size, but impressive erratic boulders are scattered in big amount in the upper parts of the gorge and in the vicinity of the Roshka Village.

In the territory of the Roshka Nature Monument, visitors are allowed to carry out the

Fig. 17.12 Jvari Pass Travertine (Photo by N.Bolashvili)

nonampunipulatory scientific research and educational activities.

17.7 Fossil Flora and Fauna

Fossil flora and fauna are known in Georgia both by traces of leaves and horns (Kisatibi diatomite) and brilliantly preserved seeds (Apkhazeti; Guria Pliocene deposits).

Georgia is distinguished by the richness of the locations of fossil vegetation. Especially notable is the flora of Jurassic, Sarmatian, Pontian, and Pliocene periods.

The fossil flora's unique location is the "petrified forest" on the eastern slopes of the Goderdzi Pass. The remnants of wood plants are also preserved in Kazbegi municipality, on the right side of Tergi, and in Gori region, in the Atreva gorge.

The country is rich in locations of fossil fauna too. In the vicinity of Kutaisi, near the Sataplia karst cave, on the surface of Cretaceous limestones, there are the footprints of dinosaurs—the giant reptiles, in Dzusa (Terjola municipality) gorge—the footprints of one of the species of crocodile, and in the vicinity of Benara (Adigeni municipality), a rich habitat of Oligocene vertebrates are found. The habitats of Oligocene mammals are: Eldari, Udabno, Arcneti, Iaghluji, etc.

It is interesting to resound among scientists the discovery of Udabnopithecus garedziensis in the areas of Davit Gareji and the remnants of tropical animals and the million eight hundred thousand years old human skulls in the former town of Dmanisi. The relatively young—the Pliocene Age mammals' remnants are found in Kvabebi (Sighnaghi municipality), Bazaleti (Dusheti municipality), Kotsakhauri (Dedoplistskaro municipality), and Tsalka habitats. The most complete in the world skeleton of southern elephant (preserved in the Janashia State Museum) is also found in the Kotsakhuri Range. Rich remnants of the Quaternary fauna are preserved in the Stone Age archaeological monuments, especially in the cave dwellings. In some of them (Sakazhia, Tsutskhvati, Jruchula, etc.), the remnants of the Stone Age human—the Neanderthals are found.

17.8 Flora

Alazani Floodplain Natural Monument is located in Dedoplistskaro municipality, on the right bank of the Alazani River, to the southeast from the village of Pirosmani, at 165 m above sea level. It is represented in the Alazani River bay in the area of 204.4 ha, in the form of the liana floodplain forest of natural origin. There are plenty of walnuts, ash trees, oaks, elms, and a shrub characteristic for floodplain Forest.

Goderdzi Petrified Forest nature Monument (Fig. 17.13) is located in the area of Adigeni and Khulo municipalities near the Goderdzi Pass, close to Batumi-Akhaltsikhe central highway. It is a unique place of petrified flora and fauna of the Pliocene period, which is presented in three sections within the area of the nature monument, at an altitude of 1600–2100 m above the sea level, with a total area of 365 ha. In the outcropped volcanogenic suites, the constituent parts of the petrified forest are visible, which contain the large amount of vegetation remnants of Lower Pliocene Age (palm tree, magnolia, laurel, and others on the one hand, and the willow, birch, hornbeam, and beech on the other hand). The vegetation remnants are seen in a gray volcanic tuff, with petrified and semi-petrified stems and leaves of trees.

17.9 Fauna

Artsivi (Eagle) Gorge Natural Monument is located in Dedoplistskaro municipality, 0.5 km north to the Dedoplistskaro town, at 762 m above sea level. It is a unique complex consisting of two objects. One part is a limestone rocky canyon and the second is the adjacent forest area, where the Khornabuji fortress (5th c.) is located. The canyon, which is distinguished by its beautiful landscape, is inhabited by numerous predatory birds (eagles, cinereous vultures, etc.). On the cliffs of the rocky slopes of the gorge, it is possible to see the nests of the griffon vultures and rare and endangered plants that are not found anywhere on the territory of Georgia (Fig. 17.14).

17.10 Hydrographic Monuments

There are many hydrographic monuments to be protected by the state of Georgia. In addition, most of them are wonderful tourist-excursion objects. Only six lakes, three vaucluses, and five waterfalls are included in the already published “Red Book of Georgia” from these types of monuments. However, dozens of other objects deserve protection and popularization.

17.11 Lakes

860 lakes are registered in Georgia. Their total area is 170 km^2, which is 0.24% of the country's territory. They are fed mostly by snow, rain, and underground waters; therefore, the fluctuation of water level in them depends on the distribution of precipitation.

Highland of southern Georgia is distinguished by the abundance of lakes. The Paravani Lake, the largest in area, is located there. There is also Tabiskuri (Tabatskuri), which is the largest lake in water volume. The lakes of Saghamo, Mada, Khanchali, Kartsakhi, Samsari, Abuli, Zresi, Tsunda, Levangeli, and others are also notable.

The Paliastomi Lake is located in the Kolkheti Lowland, the Ertso Lake—in the lower part of the Tskhinvali-Oni road and the Bazaleti Lake—in the Aragvi gorge. There are several lakes in the Keli plateau, the largest of which is the Keli Lake and Archvebi Lake. Mineral lakes are also found there. Among them are the Britati Lake (Java municipality), Abano Lake (Kazbegi municipality), and others. The Ritsa, Amtkeli, Kvarashi, and other lakes are located in Apkhazeti, TobaVarchkili—in Samegrelo, Kveda Lake—in Racha, Green Lake in Achara and, etc. (Fig. 17.15).

All lakes essentially require protection; however, not all of them are suitable for tourist and excursion purposes. There are 13 lakes with the area of more than 1 km^2 in Georgia and 50 lakes of more than 10 hectares. For tourist and excursion purposes notable are: Ritsa, Bazaleti, Tabatskuri, Tsunda, Bateti, Mtsvane (Green)

Fig. 17.13 Goderdzi Petrified Forest (Photo by N. Kvirkvelia)

Lake, and other lakes. The nature monument status is given to two lakes: Abano Mineral Lake and Gabzaruli Lake.

Abano Mineral Lake monument is located in the Kazbegi municipality, Truso gorge, on the left bank of the Tergi River, in the east from the village of Abano, at 2127 m above sea level. It is a small lake generated by spring with carbon dioxide flowing on the earth's surface from the Upper Jurassic carbonate rocks, which "boils" noisily due to the carbon dioxide gas bubbles. The spring debit is 2.5 million liters a day. The lake area is 0.04 ha. The gas emissions in calm weather cause the accumulation of carbon dioxide in the lower layers of the air. Little animals die when approaching the lake; therefore, here one can find the dead bodies of mice, lizards, frogs, and birds.

Gabzaruli Lake Nature Monument is located in Tskaltubo municipality, in the village of Kumistavi, at 1.7 km northwest of the Kumi vaucluse springs, in the Kumi River basin, at 166 m above sea level. The nature monument is generated in Lower Cretaceous limestones, and the shaft is opened in the form of a crack on the slope covered by deciduous forest. The length of the crack stretched to the north is 60 m and the width is 225 m. On the bottom of the crack, a

Fig. 17.14 Artsivi (Eagle) Gorge Natural Monument (Photo by V. Cherkezishvili)

Fig. 17.15 Tsunda and Green lakes (Photos by K. Kharadze)

45 m deep siphon lake is located at 25 m from the surface. The crack siphon is one of the components of the cave system. The siphon lake level coincides with the level of the outflows of the Kumi River.

17.12 Vaucluses

Vaucluses are high debit springs and their outlets are in many areas. The high debit springs are also known in the territories built by volcanogenic suites too. The first of them is widespread in western Georgia—in the zone of the Caucasus and its foothills, and the lava vaucluses—in Javakheti volcanic highland and the areas built with fissured lavas. Vaucluses are characteristic of the foothills of both sides of the Caucasus in eastern Georgia. The debit of some of them is so high that the mills are built on them as well. For example, a cascade of water mills is built on the stream generated from the Keterisi vaucluse.

Apkhazeti (Mchishta, Reproa, Rechkhi, etc.) is especially rich in karst vaucluses. The Eristavtskali tributary Rechkhi flows out from the foot of the Okhachkue limestone massif in the form of a powerful but variable debit vaucluses. The Vaucluse Rivers are used for population water supply.

Strong vaucluse springs are common in Odishi too. There are many karst vaucluses in territories of the villages of Inchkhuri, Mukhuri (Fig. 17.16), Chkvaleri, Tsachkhuri, Rukhi, Turchutobi and others. The Intsra gorge is also rich in vaucluses (Tsalenjikha municipality). Intsra, by itself, starts from the two karst caves and creates a large waterfall in the heads. The high debit spring flows out at the ruins of the Rukhi fortress (Zugdidi municipality) and Turchobi, the length of the underground section of which reaches 3 km, is the largest manifestation of Samegrelo Karst Rivers.

The vaucluse springs are also found in Imereti; the Tkibula River, which was lost in a narrow tunnel, was flowing out in two powerful vaucluses with the name of Dzevrula River. The Tsutskhvati multistorey cave is now generating a new floor, from where the water flows out in the form of three vaucluses at the foot of the southern slope of the hill with the name of Chishura. There are periodically active vaucluses at the village of Kvatsikhe (Chiatura municipality). The underground karst rivers flow through the tunnels of the caves of Sataplia, Kumistavi, and Kvilishori (Tskaltubo municipality), as well as the Chishura springs, etc.

The lavish vaucluses are in the Javakheti Upland; the strongest springs flow out from the heads of the rivers of Kulikami and Abulistskali and on the banks of Paravani and Saghamo Lakes, especially in the area of the villages of Dlivi and Gandza. The rivers with positive water cycle in these areas receive the excess amount of water at the expense of the other basins, which is caused by the hydrological regime of cracked and porous volcanogenic suites.

The high debit springs are found in the Tsalka basin (springs of Oliangi, Dashbashi, Nardevani, Aiazmi, etc.). In the Truso (Keterisi, Kazbegi region) gorge the vaucluses flow out from beneath of lava boulder, which was named "Narzanvaucluse" by researchers. Its daily discharge is 2530 million liters. Similar vaucluses are also in the heads of the rivers of Didi Liakhvi, Ksani, and Tetri Aragvi.

Keterisi Mineral Vaucluse Nature Monument is located in Kazbegi municipality, Truso Gorge, on the right bank of the Tergi River, in the area of the Keterisi Village at 2168 m above sea level. At the foot of the Caucasus Main Mountain Range, beneath the lava boulders, a group of powerful springs flow out from the Upper Jurassic carbonate flysch that was named "Narzanvaucluse" by the researchers. The spring gives 2530 million liters of hydrocarbonate-calcium water daily, which corresponds to 300–350 l/s. The river originates from that spring that flows across the Keterisi Village, where the cascade of water mills is arranged.

17.13 Waterfalls

The long rivers of Georgia almost do not form high waterfalls. Most of the waterfalls are associated with the old glaciations and the

Fig. 17.16 Deidzakhi Vaucluse (Photo by K. Tsikarishvili)

distribution regions of karst and young volcanoes, and therefore they are mostly represented in the Caucasus.

There are many waterfalls in Apkhazeti. Here, the water on the Klichi River falls down from almost 100 m. Waterfalls are on the left tributary of Chkhalta River and the short right tributaries of the Kodori-Gvandra—on Atsapi, Chkhaltadziri, Ketskvara, etc. There is a great waterfall in Apkhazeti on the Bzipi, Gega, and other rivers. There are also many waterfalls in the Abasha River basin and its surrounding area. Important waterfalls are on the rivers of Turchu, and Toba flowing out from the caves in the Askhi massif. Ochkhomuri (threestep) waterfall is in western Georgia, as well as in the heads of the Intsra River (Fig. 17.17), Okatse gorge, in the heads of Lekhidari, etc. The waterfalls falling down from the caves of Kinchkha and Ghvirisha create rare picturesque view.

There are several waterfalls in the Lagodekhi Strict Nature Reserve in eastern Georgia, as well as at the heads of the Chartliskhevi and Iori Rivers, on Eretostskali—the tributary of the Tetri Aragvi River, on the tributaries of the Tergi River (Arshi, Shtsavali, Gveleti, Khde, etc.); in Kvemo Kartli, in the Gomareti plateau, the Egri (Kaflanishvilis), Kldeisi and other waterfalls. The waterfalls are in the Gujaretistskali River gorge, in the vicinity of Tbilisi, etc. Most of the waterfalls are tourist-excursion objects. They are very impressive for tourists. Sometimes even the rainbow occurs in the water splashes. The nature monument status is granted to the following four waterfalls:

Abasha River Waterfall Nature Monument is located in the Balda Village of Martvili municipality, in the territory of the site of Rachka, in the heads of the Abasha River, at 895 m above sea level in the southwestern part of the Askhi Massif. The left tributary of the Abasha River flows from the cave through the limestone cliff falling nearby from about 40 m. The waterfall generates 12 m diameter pit at the falling area. The water is boiling in the pit. The waterfall sparkles often create a rainbow.

On the right side of the main waterfall, there are two small waterfalls (Fig. 17.18). A 200 m tall limestone cliff overlooks the waterfalls. The nearby areas of the waterfalls are covered by dense forests. The thick groves of box trees attract attention; they are quite difficult to pass

Fig. 17.17 Intsra waterfall (Photo by R. Tolordava)

through. Here is the site Rachkha with a lot of outflows of karst waters.

Mukhura and Tskalmechkhera Waterfalls Nature Monument are located in the vicinity of the Mukhura Village of Tkibuli municipality near the road at 886 m above sea level. The threestep 6070 m high waterfall flows from the cave located at the eastern exposition slope. There is one small and one large lake in the cave (Kharadze 2014). Waterfalls are covered with mixed broad-leaved forest. There are many endemic animals inhabited here, namely: Caucasian mole, Radde's shrew, Volnukhin shrew, and Transcaucasian water shrew (Fig. 17.19).

Okatse (Kinchkha) Waterfall Nature Monument (Fig. 17.20) is located in Khoni municipality, in the neighborhood of the Kinchka village, at 843 m above sea level. It is a threestep waterfall cascade falling from the eastern cliff of the Askhi limestone massif in the Satsiskvilo River gorge. The upper two steps are formed on the right tributaries of the Satsiskvilo River; the height of the first one is about 25 m and the height of the second waterfall reaches 70 m. After joining the stream with the Satsiskvilo River, in 20 m the third 35 m high step of the cascade is formed.

Ochkhomuri Waterfall Nature Monument is located in Martvili municipality, in the north of the Kuruzu Village, at 550 m above sea level, in the southern part of the Migaria limestone massif, in the heads of the Ochkhomuri River. The height of the three step cascade is 100,120 m. Every step of the waterfall develops small lakes at the bottom while falling down. The moisture around the waterfall causes the development of a peculiar flora and fauna in its surrounding areas, where there are many rare, endemic or relic species; the box-tree groves are important there.

Fig. 17.18 Abasha river canyon (Photo by R. Tolordava)

17.14 Nature Sightseeings

In Georgia, in addition to the above-mentioned natural monuments, there are many other interesting nature sightseeings that can be granted the status of natural monuments in the future, such as natural freezers, volcanic forms of relief, natural bridges, etc.

Natural freezers are found in almost every part of Georgia—in Shida Kartli and Kvemo Kartli, Racha, and Javakheti, Samegrelo and Apkhazeti, Achara and Samtskhe, etc. Morphological peculiarities of natural freezers and conditions of origin are different. The main sign is that all of them are producing ice in summer season.

Natural freezers in eastern Georgia are mainly found in small pockets of destructed volcanic structures; sometimes they form complex labyrinths; typically, the size of such freezers is not very large (depth is 1.5–2.5 m, sometimes even smaller, and diameter is from 80–130 cm to 30–50 cm).

Natural freezers in western Georgia are largely related to karst wells and caves. Snow falling in winter and spring here often become in firn and ice.

Natural freezers are formed due to a certain match of the relief and climatic conditions of the site. These monuments of nature are rare formations created for thousands of years and have scientific and aesthetic significance.

Volcanic terrain forms are best presented in southern Georgia. In addition, these forms are found in Achara-Trialeti mountain system, Zemo Imereti plateau, and the Caucasus region. They are presented in cone and dome mountains, plateaus and streams, etc. Extensive lava plateaus are the Akhalkalaki, Kvemo Kartli, Gomareti, Keti and other plateaus.

In contrast, the lava flow is of elongated form and sometimes are extended to considerable distance: the flow from Javakheti Range extends at about 120 km and goes to the village of Ilmazlo (Marneuli municipality), the right bank of the Mtkvari River. In addition, the remnant of dolerite flow is known at the village of Kakliani

Fig. 17.19 Tskalmechkhera waterfall (Photo by K. Kharadze)

(Dmanisi municipality), as well as the lava streams flown from the Javakheti Range and Bakuriani, also the lava streams of Gujareti, Khorisari, Tkarsheti, and Kaishauri.

The following volcano centers are notable in the Keli Upland: Didi Khorisari (3830 m above sea level), Mtsire Khorisari (3741 m), Didi Mepiskalo (3694 m), Patara Mepiskalo (3536 m), Keli (3628 m) and others.

Badlands and cuestas. Badlands are formed in the areas with arid climates due to the influence of atmospheric precipitations and temporary streams on waterproof clay rocks. In Georgia, the badlands are common on the southern slopes of Kvarnakebi (Shida Kartli) and in the eastern part of Gombori Range.

Cuestas (the asymmetric hills) are well-expressed in the karst regions of Georgia; they are also found in the area of Tbilisi.

Layer disorders (olistostrom). Example of **layer disorders** or 'olistostrom' is the Middle Eocene sediments in Tbilisi and its surroundings, which is crowned by the boulder-breccias of very peculiar nature that was named „conglomerates with layer disorder "by Hermann Abich (1870). Within the city, these formations construct the left rocky bank of the Mtkvari River in the rock at the Metekhi Cathedral. The „conglomerates with layer disorder" are located in the arch part of Mamadaviti anticline and cover the upper part of the Middle Eocene.

Fig. 17.20 Okatse (Kinchkha) waterfall (Photo by Agency of Protected Areas of Georgia)

Pseudokarst. Such forms of relief only externally resemble karst forms. Their distribution is related to noncarbonated rocks. The pseudokarst (Fig. 17.21) in Georgia is quite common. Terrestrial forms in the form of sinkholes, wells, caves, natural bridges, and other forms are created in the areas of Tbilisi (Zahesi, Gldani vicinities), Marneuli Plain, Algeti-Ktsia lower part, Kvernaki (Kaspi municipality), Iori Upland, Alazani Gorge (mainly in clays), Gldani areas (in sandstones), etc.

Corrie fields. Corries or serums are the limestone surfaces dissected by the chemical impact of water and corrosion that are characterized by the surface microforms. They are widespread in western Georgia; especially interesting are the limestone valleys spread in the Arabika, Bzipi Range, and other limestone massifs.

Physical-geographical conditions have played a major role in the occurrence and evolution of corrie gorges of high mountain massifs. Among them, we should name the leveling of the crest of the limestone massif by Quaternary glaciers and heavy fissuring of rocks, in which the severe climatic conditions (temperature and frosts, etc.) have a great role along with the tectonic tension.

Cryogenic forms. The cryogenic forms of relief (hillocks, solifluction terraces, polygone formations, stone runs, etc.) are characteristic to the highlands of Georgia. One of the widespread forms—the stone run is characteristic to the Javakheti highland, on the slopes of which there are the “stone seas”, “stone rivers” and “stone fields” formed by weathering processes.

Natural bridges. A peculiar formation of nature—the natural bridges are characteristic mainly for karst regions. Once in these places the ceiling of the bed of the underground river flowing through limestones was collapsed and washed due to the action of erosive and gravitational forces, and the only bridge-like narrow strip and its pillars were preserved.

There are several natural bridges in Georgia. Among them, the notable are: the Semi-bridge on the rivers of Semi (Tskhenistskali left tributary, Tskaltubo municipality), Kheori, Pshitsa and Akhatskha. A small natural bridge is located at the Cherami rocks, on the river of Mshrali Khevi, etc.

Fig. 17.21 Pseudokarst, Tbilisi (Mukhatgverdi) (Photo by K. Kharadze)

In the two places of Abasha canyon the remains of natural limestone bridges are preserved; this circumstance confirms that the canyon is partially formed due to the destruction of karst cave ceiling. A peculiar "bridge" is in Racha as well, on the Shareula River, in the area of the Gogoleti Village (Ambrolauri municipality). The gorge is narrowed and the limestone boulder fallen from the cliff turned into a bridge.

Rapids and erosive islands. Rapids—the low water and whitewater sections of the river are found on the Rioni River, Chakvistskali River, etc. and the erosive islands are found in the rocks forming the bed due to the destructive effect of water stream; this monument of nature formed in Kutaisi, is the object of aesthetic enjoyment besides the fact that it is interesting from scientific viewpoint.

Landslides. Landslides occur in different conditions and at different stages of development; they occur more frequently while the alternation of the waterproof (clay) and the water content rocks. The landslides of Sairme, Lailashi, Tsablana, and others are known for their power.

Agate ore. Agate is found in the area of Shurdo Village (Akhaltsikhe municipality). Agate belongs to the so-called quartz group (flint). The existence of the ore is associated with the transformed black andesites of the Tertiary Age, which is cut in the sedimentary rocks like a wedge and is extended over a long distance. Here agate is colorful—black, brown, blue, red, pink, honey, light gray and, etc. In addition, its forms are also diverse. One of its interesting sites is to be protected.

Agate has been known in Georgia since the Bronze Age. It adorns the items discovered in Trialeti, as well as the items discovered in the Bronze Age Cemetery on the "Amirani hill", at Akhaltsikhe, etc. Especially in large quantities are found the agate item in the Antique Time monuments. Currently agate is used for making the most accurate devices, namely, in geophysical equipment, in the artificial satellites of the Earth and in the clock industry.

Crystals. crystals are fascinating creations of inorganic nature.

Mountain crystal is related to quartz veins in the slate regions of the Caucasus.

Interesting quartz crystals are characteristic to the area at Samshvilde (Tetritskaro municipality), on the right side of the Chivchavi river, at an altitude of 820–860 m above sea level. They are found in Kazbegi municipality, on the both sides of the Tergi River from the village of Kobi up to the Dariali gorge. The mountain quartz is also common in the Khde gorge (Kazbegi municipality), Shodakedela Range (Oni municipality), Svaneti, Khevsureti, etc. Quartz sand can be found in the areas of Khashuri, Chiatura, and Kharagauli municipalities, quartz crystals—in the Bolnisi municipality, etc.

Samshvilde quartz crystals. At Samshvilde, there are plenty of hexagonal bipyramidal crystals of quartz, which are found in great amounts into the quartz-porphyritic outcropped intrusion. As a result of the weathering of these rocks, the magma quartz's beautiful bipyramidal crystals fall on the ground. A large number of crystals of magma quartz are splashed in them, which was noticed by Georgian scientist Vakhushti Bagrationi in the beginning of the eighteenth century.

Jewelry and souvenirs can be made from crystals. They can be applied in technique. Moreover, their industrial mining is not allowed, because it is a protected object and is included in the "Red Book of Georgia".

Bodorna molasses deposits. Georgia clod (the crystalline substrate) is deeply sunk at 700–1000 m above sea level on the left section of the Georgian Military Road in the Bodorna Village, and covered by the Upper Eocene—Lower Mio-Pliocene molasses deposits that are particularly well outcropped at the village of Bodorana (Dusheti municipality). Vertical walls are constructed with noncategorized conglomerates with clay lenses in them. Mollasses deposits end at the village of Zhinvali. Its maximum thickness is up to 2 km. The Bazaleti Lake is located on these deposits.

Gordi Pleistocene lacustrine deposits is located in the east of the village of Gordi (Khoni municipality), in the Okatse River gorge (the right tributary of Tskhenistskali), at 520 m above sea level.

The Okatse gorge was blocked by a tectonic thrust in the Middle Quaternary Period and made a lake in it. In the lake the clay sands were deposited, the thickness of which exceeded 27 m. After tens of thousands of years, the water found the exit in the limestone fissures, expanded it, and the lake was emptied. The washing of the lacustrine deposits started and the canyon was formed, and the lacustrine deposits remained only in some places. The seasonal stratification is well represented in the deposits. Each pair of the layers corresponds to one year. Palinological study of the deposits (the microscopic research of the dust and spores of fossil plants) revealed the remnants of the disappeared species of ancient flora that are preserved in the lower part of the suite—bald cypress (*Taxodium distichum*), Engelhardtia, cedar (*Cedrus*) and others. According to the analysis of plants stamens, after 500–600 years from the lake occurrence, there was a sharp falling in air temperature in the area of Gordi, which led to the total extinction of heat-loving species.

According to these deposits, scientists have the opportunity to find the peculiarities of the Quaternary Period—the last phase of the Earth's development history.

Jgali Miocene deposits. Outcrops of rocks interesting in the geological and paleontological terms were detected and described in 1934 in the site of Maidan at the village of Jgali (Tsalenjikha municipality) in the Tsertskari River gorge. The deposits contain rich remnants of mollusks' fauna. It is unique not only in Georgia but also in the Caucasus and Mediterranean Sea basins. The Lower Miocene, Middle Miocene, and Upper Miocene (several layers) are represented in the section of the Tsertskari gorge Miocene deposits that are located between the Maikop suite's (Oligocene) jarosite clays (underneath) and Meotian-Pontian conglomerates (they are placed on the Upper Miocene-Sarmatian).

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18 Environment Protection

Elene Salukvadze and Mariam Tsitsagi

Abstract

The protection of nature has a long history in Georgia. Its natural environment is now substantially modified, which was conditioned by the development of production, by increase of cities, industrial centers, means of transport, and population, which in its turn caused the violation of environmental regularities and relation between the environmental factors and natural resources established for centuries—variation of natural environmental components, quantitative and qualitative changes of its individual factors: soil, air, and water basin pollution, forest fires, floods, activation of erosive processes, landslides, mudflows and, etc.

The environmental protection and the reasonable use of natural resources are of particular importance to such a mountainous country like Georgia. Its natural environment is now substantially modified, which was conditioned by the development of production, by increase of cities, industrial centers, means of transport, and population, which in its turn caused the violation of environmental regularities and relation between the environmental factors and natural resources established for centuries—variation of natural environmental components, quantitative and qualitative changes of its individual factors: soil, air, and water basin pollution, forest fires, floods, activation of erosive processes, landslides, mudflows and, etc.

Today, the implementation of environment protection measures in the country is directed to ensure stabilization of the components of nature and entire environment, during which the normal conditions will be established for human health, labor, and life. Climate, water resources, soils, mineral resources, vegetation cover, animal world, etc. are the main natural treasures of Georgia and their protection is of great economic and nationwide importance.

Considering the factor of urbanization is important in environmental protection. Urbanization and its related processes (concentration of population and industry in big cities, car park growth, etc.) have certain negative impact on the environment.

The separate components of the environment (climate, water, soil, etc.) are closely linked with the exchange of substances and energy, so that

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imbalance of any of them, e.g., contamination, causes the degradation of another one.

Atmospheric air pollution source is a thermal power plant, industrial enterprises (metallurgical, chemical, oil processing, cement (Fig. 18.1), and other plants), and transport. As a result of their functioning, a large number of substances are released, such as: CO, CO_2, SO_2, O_2, NO, NO_2, O_2, Pb, soot, etc., as well as more toxic substances (phenol, formaldehyde, etc.).

The main air pollution of atmospheric air is the emission by the transport, which is 80–90% of total pollution. The rate of industrial and transport contamination reached its peak at the end of the 80s of the last century, and in the 90s—it has been gradually reduced due to economic decline, and now in the conditions of relative economic stability, it has increased again. In this respect, it should be specially noted so-called "Hot Spots"—urban territories (with high density of population, industry, and transport concentration)—the capital and industrial towns: Rustavi, Zestaponi, Kaspi, and others (Fig. 18.2).

Protection of water resources and their rational use is one of the most important problems in the overall environmental protection complex and is considered the main direction of our country's economic strategy. The current law on "Water in Georgia" (1997) determines water economy activities and ensures water protection.

Due to the influence of anthropogenic factors, the physical and chemical compositions of underground and surface waters, especially within the settlements, are substantially modified. The following rivers are most contaminated: Mtkvari, Mashavera, Vere, and Debeda. In the water of Mtkvari, organic compounds and heavy metals (copper, zinc, and molybdenum) dominate, and in the area of Rustavi city—oil products, phenols, and caprolactam; index of bacteriological pollution is high as well.

Level of surface water pollution by heavy metals is high in the Kazreti ore zone (concentration of copper is increased by 50–70 times, of iron—by 18–20 times, and of zinc—by 110–130 times).

The Black seawater is also significantly polluted by anthropogenic influence, which leads to a number of negative consequences, some of which have an irreversible character. Bacteriological contamination of seawater has become a common occurrence. Petroleum products were considered to be the main pollutant of seawater and now remain so. The influx of alien species of warty comb jelly (*Mnemiopsis leidye*; its total

Fig. 18.1 Asphalt plant

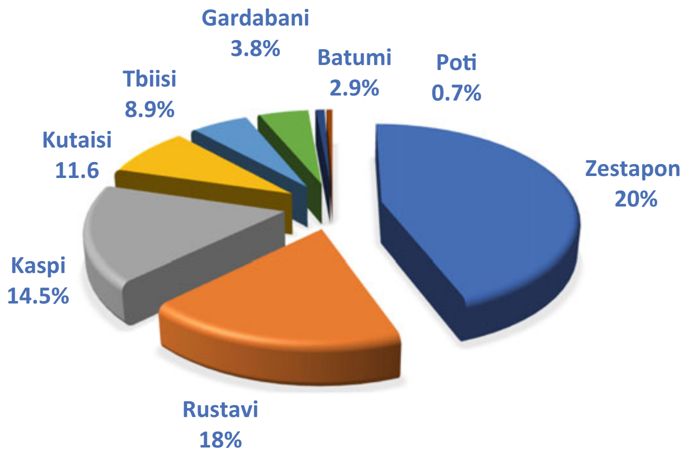

Fig. 18.2 The share of individual cities in the pollution of atmospheric air

biomass reached 900 million tons) and the alien species of jellyfish (Atlantic Ocean inhabitant) have destroyed the most share of zooplankton that affects the flora and fauna of the sea. However, now their number is reduced. The transportation of Caspian oil and oil products provided by the "TRACECA" program also has a significant effect on the contamination of the Black Sea water by oil.

For Georgia, as a mountainous and land-poor country, soil protection is of great importance. The area of arable lands is 0.14 ha per capita in Georgia. The area of arable lands has been significantly reduced; the reasons for this include: erosion, concession of farmlands to the industry, construction, etc. Arable lands are lost by cultivating perennial crops on them, as well as turning them into fallow lands, etc.

Erosion rates are especially high in mountainous areas. In Georgia, in the agricultural zone, 308.2 thousand hectares are under erosion, including 205.7 thousand hectares—underwater erosion and 102.5 thousand hectares—under wind erosion; eroded pastures are 496.6 thousand ha and hay lands—50.2 thousand ha (Nakaidze and Makharadze 1999). Nowadays this indicator has increased significantly because of the activation of erosive processes caused by "accelerated anthropogenic" impact.

With the development of water and wind erosions, powerful landslides and mudflows are generated in mountainous regions, causing harm to Georgia's environment and economy. Soil salinization and solonetzization have increased in Georgia. If in 1928 such soil area was 8.7 thousand ha, in 1966 it was 33.7 thousand ha, and in 1980—205 thousand hectares, i.e.,—22 times and more. This is 7.4% of the total area of agricultural lands, i.e., 3.0% of the entire territory of the country (Gogoberidze 1984). Therefore, the fight against the salinization of soils is a special task.

Nowadays soil contamination with heavy metals and other inorganic pollutants is one of the serious ecological problems. The influence of the Zestaponi ferroalloy plant and the Madneuli ore-dressing and processing enterprise is significant on region's pollution by heavy metals: Cd, Cu, Mn, Ni, Pb, Zn. The residual quantity of mineral fertilizers and toxic chemicals is recorded in many regions of the country on the lands intensively used in agriculture.

Industrial and household wastes cause environmental pollution and worsening of ecological conditions. Three thousand tons of wasted (garbage) were taken from Tbilisi daily. In the past century, the polygons were allocated for wastes without taking into account the geological, hydrological, and landscape-geochemical conditions. Currently, these polygons are officially sealed, but their negative impact on the environment continues.

In Tbilisi, pollution of surface waters and underground waters is high at the polygons of

Gldani solid household wastes. Concentrations of some heavy metals (Pb, Cu, Co) exceed the maximum allowable concentration, a high concentration of aromatic hydrocarbons is observed, among which the carcinogenic and toxic compounds exceed the maximum permissible concentration (Dvalishvili 2011). Sometimes the landfills are **spontaneously** arranged directly in the river floodplains (Figs. 18.3 and 18.4) that further increasing the technogenic impact on surface waters.

Mineral resources need a stable protection and care because it belongs to the category of exhaustible resources. One of the strong land destructive activities is the extraction of minerals in open quarries; the area of such lands exceeds 6 thousand ha. Only a small part of them (0, 08%) are recultivated.

Vegetation, as an important component of the environment, is greatly changed and its current look reflects the influence of both the natural development and anthropogenic factors. 56 species are included in the "Red List" of Georgia; among them, 36 species are granted vulnerability status, 18 species are endangered, and 2 species are critically endangered (Ordinance of the Government of Georgia on approval of "Red List" 2014, https://matsne.gov.ge/ka/document/view/2256983).

The present situation of the animal world has been greatly conditioned by the influence of spontaneous household activity of humans in the past and the facts of poaching; and this component of the environment has been modified the most than other ones. 135 species of fauna are included in the "Red List", 87 species of which are vulnerable, 32 species—endangered, 11 species— critically endangered and 5 species are extinct at the national level (Ordinance of the Government of Georgia on approval of "Red List" 2014, HTS: https://matsne.gov.ge/ka/document/view/2256983).

About 40% of the territory of Georgia is covered by forest. The forests of Georgia have a specific nature, which is expressed in their special purpose. Almost all forests of Georgia or 98.3% belong to the first group of forests located on the slopes of the mountains and have soil protection, water protection, resort, sanitary-hygienic, aesthetic, and other social-protective functions. The remaining 0.7% of the forest belongs to the second group and is mainly located in the Kolkheti Lowland.

The total forest fund of Georgia includes forest and non-forest areas with the total area of 3005 thousand ha, including 1738 thousand ha or 57.89% in western Georgia, and 1267 thousand ha—in eastern Georgia. Most of the forest areas

Fig. 18.3 Landfill on the Mtkvari Riverbank (Photo by E. Salukvadze)

Fig. 18.4 Landfill in the area of the Gldani Lake (Photo by E. Salukvadze)

are in Apkhazeti—507 thousand ha or 16.9%, followed by Kakheti– 384 thousand ha or 12.8%, Imereti—344 thousand ha or 11.8% and, etc. Out of entire forest fund, the 2770 thousand ha or 92.3% is covered by forest. The highest indicator of regional forest rate (65.5%) (relation of the forestland area with the whole territory of the region) is in Achara, where the 188.96 thousand ha is covered by forest; 57.8% (265.63 thousand ha)—in Racha-Lechkhumi-Kvemo Svaneti, 55.7% (479.9 thousand ha)—in Apkhazeti, etc. (Kandelaki 2013).

The reserve of timber is 418.6 m^3; the average increase of timber is 3.8 million m^3, including 0.9 million m^3 for coniferous forest, 2.3 million m^3—for strong leaved forest, 0.4 million m^3—for soft-leaved forest, and 0.2 million m^3—for the remaining varieties. Although the rate of decrease in the area has been reduced in the recent years and the activities of forest restoration have increased, they still can not achieve the desired level.

During the last 10–15 years the forest was planted on more than 20 hectares, but it is still 5–6 times behind the forest areas to be restored. Recently the forest areas have been significantly reduced due to uncontrolled exploitation, cutting, and forest fires.

Especially intense deforestation took place around towns and transport highways during energy crises in the 90s of the twentieth century. In 1990–2008, timber was mostly exported to Iran (37.8%), Armenia (26.6%), Turkey (21.3%), and Italy (9.7%) (Kandelaki 2013).

As the main part of the forests of Georgia have a nature-protective function, the deforestation is strictly limited by law; though the illegal cuts of forests are common. (Table 18.1; Fig. 18.5).

Not only the old and over-aged trees are being cut, but also the young precious species that result in the violation of biodiversity of species, among which the endemic and relic species are particularly vulnerable.

In some regions (Racha, Lechkhumi, Svaneti, and Guria) decrease in the number of population (last 20–30 years) and their depopulation is observed, which is why forest areas began to increase. The area of the former farmlands was replaced by pine, hornbeam, lime, and others. In this respect, forest areas have increased by 5–6% (Beruchashvili 2002).

Forest fires have increased in the last decade (2000–2010). During the war with Russia, the fire was spread over the 950 hectares of land in Borjomi municipality and 70% of the forest was

Table 18.1 Illegal deforestation

Year	1990	1995	2000	2001	2002	3003	2004	2005	2006	2007	2008
Amount of deforested wood, m^3	4506	47,562	43,021	43,278	53,212	57,733	47,484	47,345	45,432	42,255	32,356

Fig. 18.5 Deforested young spruce-fir forest, resort Bakhmaro (Photo by E. Salukvadze)

destroyed in 700 hectares. The endemic and relict forest massifs were destroyed, including the untouched forest sections, as well as the fertile soil layer, restoration of which requires hundreds of years. Many animals were also killed, including the ones listed in Red Book of Georgia. Their habitat environment was destroyed. The fire was spread even in the nature reserve territories of Borjomi-Kharagauli National Park, where the 4 centers of fire were reported (Amiranashvili et al. 2008) (Fig. 18.6).

In February 2010, 150 ha forests were burned in Gonio (Achara), 30 hectares—in Kvareli, and 25 hectares—in Baghdati municipalities. Particularly frequent cases of forest fires (23) were recorded in 2017. Especially extensive was a fire

Fig. 18.6 Forest in Borjomi after fire, 2008 (Photo by N. Bolashvili)

in 2017 in Borjomi municipality—at more than 100 hectares (https://sputnik-georgia.com/georgia/20170907/237228448/) (Table 18.2).

The new Forest Code and the National Strategy are adopted, which will regulate forest use in the state forests.

Protection of natural hay lands and pastures that provide the main part of the food for cattle breeding is of great importance. The hay lands and pastures occupy about 1638.4 thousand ha in Georgia. Among them, 159.1 thousand ha or 7.9% are hay lands and 1479. 3 ha or—90.2%—pastures, 310. 6 thousand ha or 21% occupy winter pastures, and 1168.7 thousand ha or 79%—summer pastures (high mountains).

Georgia is distinguished by diversity of landscapes; as a result of anthropogenic impact, they are significantly transformed (natural-agricultural areas, recreational-territorial complexes, complexes related to industry, transport). In spite of this, there are still preserved the untouched (potentially possible) primitive landscapes in Georgia with a total area of 7024 km^2, which is 10% of the entire area of Georgia

Table 18.2 Forest fires in Georgia

Years	1995	2000	2005	2008	2011	2012	2013	2014
Number of fire cases, unite	1	34	16	32	4	11	35	69
Forest area in fire, ha	7	85	26	126	7	199	88	705
Damage caused by fire, thousand GEL	0.3	11.3	0.6	170.4	–	–	–	–

(Beruchashvili 2000). They are natural wealth of Georgia and their rational use will give the country a significant economic benefit.

Different types of protected areas are distinguished on the territory of Georgia to protect individual representatives of landscapes, flora, and fauna. These territories and main activities carried out there, are defined by the "Law on Protected Areas" (1996), according to which the Georgian protected areas were adapted with the categories established by the International Union of Nature Conservation (IUCN). For the protection of nature, the first area was allocated in 1912—the Lagodekhi Nature Reserve was established, and in later period the nature reserve became the main form of protection of natural territories in Georgia.

Today there are 14 Strict Nature Reserves in Georgia with the total area of 139, 048.80 ha, which is 2.4% of the territory of Georgia. Except for Strict Nature Reserves, there are other types of protected areas in Georgia: National Parks, Managed Reserves, Nature Monuments, and Protected Landscapes.

Currently, the total area of Protected Areas of Georgia is 593.063 ha, which is 8.55% of the country's territory (http://apa.gov.ge/ge/protected-areas/reserve). In addition, there are other types of areas in Georgia, where the certain regime of protection is being implemented; these are the recreational forests (395.90 ha) including the resort forests (119.40 ha), and green zones (276.50 ha) (Kajaia 1999).

For the preservation of natural diversity in the Caucasus, including Georgia, the World Wildlife Fund (WWF) implements the works supported both by international and regional organizations. The first national park in the Caucasus region—the Borjomi-Kharagauli National Park (Area 60,576.4 ha) was created in 1995 with the help of the WWF and the Government of Germany, which made a basis for establishment of national parks in the Caucasus region.

Environmental protection and restoration are reflected in special legislation, which includes the legal bases for the use of natural components and resources. The public demand for healthy environment is strengthened by the Clause 3 of the Article 34 of the Constitution of Georgia, which states that "everyone has the right to live in a healthy environment, enjoy the natural and cultural environment; all are obliged to take care of the natural and cultural environment."

The law on "Environmental Protection" (1996) is the main document regulating the protection of natural resources and their effective use, thus protecting the soil, forest, water, water resources (rivers, lakes, underground waters, etc.), living and non-living nature monuments (rare plants, waterfalls, unique geological formations, etc.), unique landscapes, etc. The law proves the basic ecological requirements of agricultural activities carried out in various fields and determines the role of the public during the implementation of ecological monitoring and control.

Georgia is actively involved in the international projects on global ecological safety of environment protection, maintenance of ecological balance, protection of ecosystems, and providing sustainable development principles. Our country is joined to the world's important international conventions on environmental protection (UN, Ramsar, Kyoto, Basel, Stockholm, Europe, etc.) (Chikhradze 2002).

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