

2.1 Authors' Contribution: A Brief Review

Peculiar features of Azerbaijan geological and geomorphological development, its orographic plan and distribution of heights, and contemporary geomorphological processes have predetermined nearly all relief types at the Republic territory.

Intensive geomorphological researches started in Azerbaijan in mid-fifties of the twentieth and beginning of twenty-first century. Among the main publications can be noted Abasov (1955, 1970), Akhundov (1978), Alizadeh (1982, 1984, 1987a, b, 2007, 2011), Alizadeh and Tarikhazer (2014), Alizadeh et al. (2014), Antonov (1972, 1993), Budagov (1959, 1960, 1961, 1962, 1964, 1965, 1969, 1973, 1976, 1993a, b), Budagov and Alizadeh (1995, 1998), Budagov et al. (1984, 1988, 1993), Dumitrashko (1962), Dumitrashko et al. (1968), Gadjeiev (1980), Guluzadeh (1982), Kerimov (1982), Khalilov (1975, 1980, 1993), Kuliiev (1977), Lilienberg (1953, 1955, 1957, 1958, 1959, 1985), Mardanov (1980, 1981), Milanovsky (1960), Museibov (1973), Shirinov (1965, 1973, 1975, 1979, 1980), Vekilov (1956), and others.

2.2 Orography

One of the most specific peculiarities of the Azerbaijan topography is the direct reflection of its large geotectonic structural features. The following basic orographic elements that simultaneously serve as its large morphostructural units are isolated in the Azerbaijan relief (Fig. 2.1).

Main morphostructural units of Azerbaijan are the Gusar sloping plane and the Samur-Devechi lowland, the Greater Caucasus, the Lesser Caucasus, the Kur intermountain Depression (trough), the Garabagh volcanic upland, the near-Araz Ridges; the Middle Araz Depression, and the Talysh Mts.

The Gusar sloping plane is a monocline plateau with its highest peak, Large Suval Mt. (1910 m), and step-like structure with erosional, erosional-denudational, and gravitational relief. The Samur, Gusarchay, Gudialchay, Garachay,

Agchay, Velvelechay, and some other rivers that cross the plain, have well developed terraced valleys with landslide-complicated slopes. At the absolute height of 200 m the plain northeastern edge is limited by a bench, and northeastward of this bench, up to the Caspian Sea shore, the Samur-Devechi (now Shabran) lowland is situated, composed of the most recent alluvial-proluvial deposits (Budagov 1993a, b). The Samur-Devechi lowland is poorly broken, composed of clay loams, lying on the boulder-gravel deposits of the Samur, Gusarchay, Gudialchay, Velvelechay, etc., river fans. Along the seashore, in the lowland seaside part, bottom and hammock-ridgy sands are developed that prevent river water runoff to the Caspian Sea.

Within Azerbaijan borders, the Greater Caucasus is represented by the Main Caucasian and Lateral Ridges that gradually descend southeastward and are transformed into the Gobustan-Absheron peninsula with low undulated foothills.

In the southwest, along the Ganykh-Airichay valley northern edge and along the Ajichay-Alyat fracture zone, the Greater Caucasus borders the Kur intermountain Depression. The depression is composed by sedimentary rocks of the Mesozoic (Jurassic, Cretaceous), Paleogene, Neogene ages, and of the Quaternary deposits developed in river valleys, in water parting flat surfaces, and in intermountain depressions.

Main Caucasian Ridge with such peaks as Bazardyuzyu (4466 m), Tufan (Tfan) (4191 m), Guton (3648 m), Babadagh (3629 m), Akhvai (3481 m), Tinov-Rosso (3374 m), etc., has narrow dividing crest with Alpine highland, intensively broken nival-glacial relief. In plan, it corresponds to the Tufan horst-anticline composed of intensively metamorphically altered Jurassic and Cretaceous deposits, represented by clay slates, sandstone, and arenaceous limestone. From the south, the Tufan anticline is bound by the Malkamud thrust. At the Main Caucasian Ridge southern slope, the following morphological structures are outlined: the Govdagh (with inverted relief) and the Nialdagh (with direct relief) (Budagov 1993a).

Lateral Ridge serves orographically as the Greater Caucasus northern part. Its northwestern section with Shakhdagh

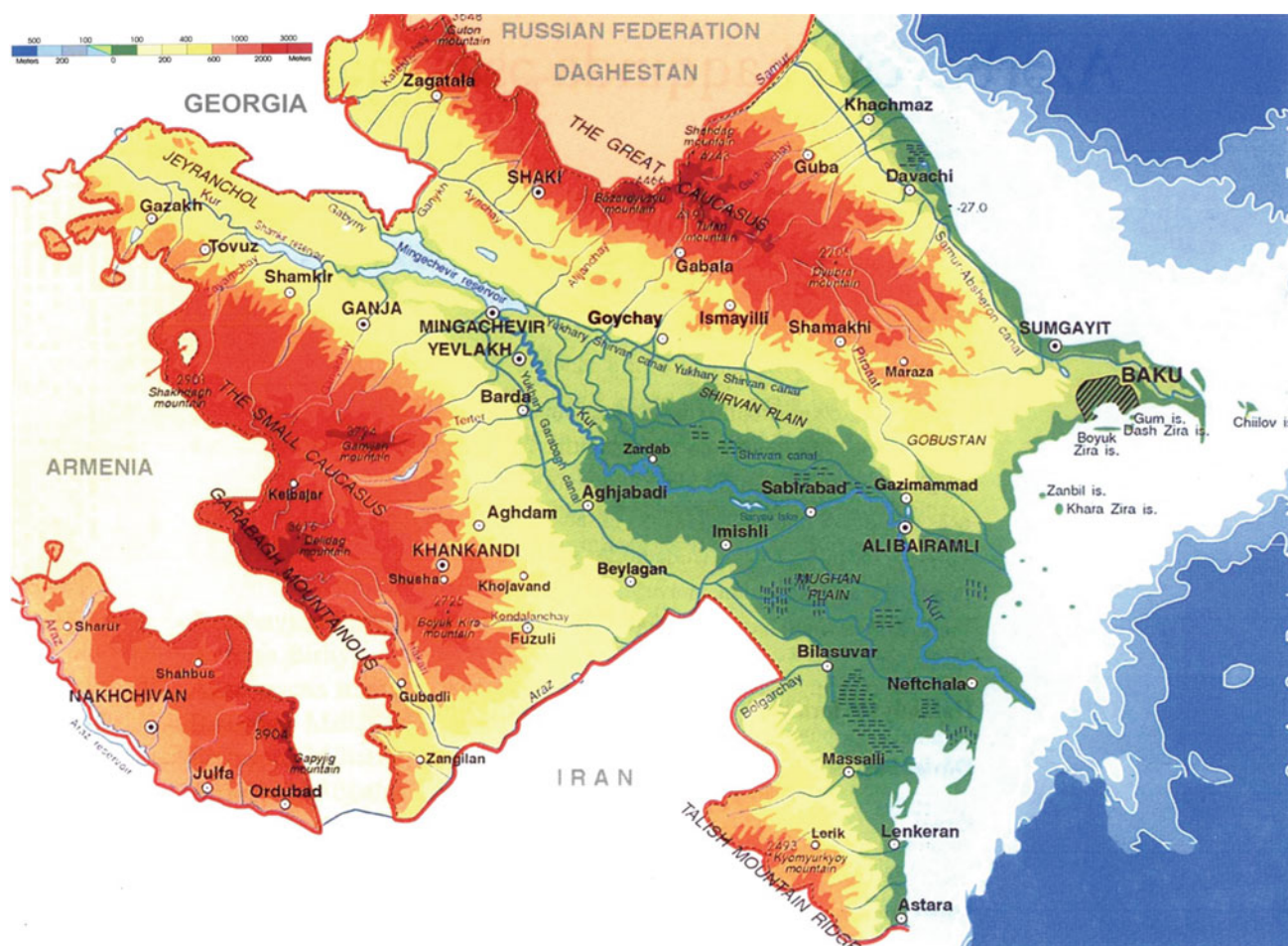


Fig. 2.1 Orographic map of Azerbaijan

Mt. (4243 m) corresponds in plan to the Shakhdagh-Khizi syncline (Fig. 2.2), composed of thick Upper Jurassic and Lower Cretaceous dolomite limestone that create a series of highland plateau with delimiting covered and steep slopes. The Lateral Ridge southeastern part—the Tengi-Beshbarmagh Ridge—looks like medium- and low-altitude mountain erosion–denudation relief, composed of the Jurassic and Cretaceous limestone and clays. The ridge extreme eastern peak is Beshbarmagh Mt. (440 m).

A series of mountain ridges (Gaitar-Goja, Shakhdagh, Aladash, Ilkhydagh, etc.) and intermountain troughs (Khy-nalyg, Gilgilchay, Khaltan, Lagich, Myudri, etc.) are prominent within the Greater Caucasus southeastern plunge characterized by the middle-altitude mountain denudation relief. Linearly elongated folded ridges and dome-shaped elevations alternating with large synclinal valleys (for instance, the Jeirankechmez depression corresponds in plan to the Shamakhy-Gobustan syncline eastern part) are typical for Gobustan (Fig. 2.3). The Jeirankechmez depression northwestern part is expressed in topography by the Baku age alluvial-proluvial plain, and its southeastern part—by a

younger abrasion–accretion marine plain, its relief being complicated by a series of large brachyanticline elevations, broken by longitudinal ruptures with located mud volcanoes. Along with direct topographic shapes, Gobustan features the inverted ones as well—the Gyuzdek, Kyafarandagh synclinal plateau, narrow intermountain valleys, etc. The Jeirankechmez depression is limited from the south by the Alyat range and the Lengebiz low-altitude mountain range, composed of the Paleogene, Miocene, Pliocene rocks. The Lengebiz Ridge faces the Kur-Araz lowland by its steep slope caused by the Ajichay-Alyat fracture. At the Alyat range, where the fault is broken by transversal ruptures, mud volcanoes are confined to their intersection point (Budagov 1993a, b).

The South-Eastern Caucasus ends in the Absheron Peninsula. Within the Peninsula, the northwestern site is prominent, westward bordering the Dyubrar system with preserved mountainous nature. Here, the Absheron peninsula maximal heights of 300–350 m are observed (at the border with Gobustan) such as Yunusdagh, Ylkhydagh, and Koun. The peninsula northern part topography is hummock-and-hollow, with mud volcano cones doming here and there. Salt



Fig. 2.2 The Shakhdagh-Khizi syncline

lake and flat salt marshes are met occasionally, as well. At the Peninsula southwest the synclinal plateaus are prominent, the Baku and Gyuzdek plateaus, etc., that drop en echelon to the flanking valleys such as the Gobi, Yasamal valleys, etc. Mud volcanoes are developed here as well—Akhtarma, Lokbatan, Bozdagh, etc.

The Absheron peninsula eastern part is flat, poorly hilled in places, with maximal height of 38 m. Some sites are situated below the sea level: Bina, Govsan, Tyrkyan, and Zirya.

The Lower Pliocene deposits, i.e., the productive strata, have extensive occurrence within the Absheron peninsula oil- and gas-bearing regions and serve as the major oil- and gas play. At the Absheron peninsula, except some local elevations, the entire productive strata section is oil- and gas bearing, at nearly 20 anticlinal structures. The most potential here is the following productive strata: supra-Kirmak sandy, sub-Kirmak. Kalin, associated with sandy horizon thinning zones in the plunged parts of syn-depositionally growing anticlinal zones and with individual local structures (Zire, Galin, Surakhany, Garachukhur, etc.) Horizon thinning in the

suite productive strata is observed in the Absheron western part (Bibi-Heybat, Garadagh, Lokbatan areas, etc.) as well as in the bottom horizons of the eastern and central parts (Gala, Turkan, Zire, Surakhany, Garachukhur areas, etc.).

The Lesser Caucasus mountain ridges, dissimilarly to the Greater Caucasus Ridge, are less high, do not form a single axial elevation and have more pronounced folded-boulder structure, caused by the presence of abyssal fractures of transversal and longitudinal striking.

In Azerbaijan, within the Lesser Caucasus, the Murguz, Shakhdagh, Murovdagh (Fig. 2.4), Eastern Goycha, Garabagh, and Mykhtekyan Ridges are prominent.

The Shakhdagh basin range has inverted relief and corresponds to the same-name syncline composed of the Upper Cretaceous, Eocene carbonate, and volcanogenic rocks. From Shakhdagh Mt. (2901 m) to Large Ginaldagh Mt. (3367 m) the range has northwestern—southeastern striping, and then joins en echelon the Murovdagh Ridge, having latitudinal strike. Its highest point is Gyamysh Mt. (3724 m). Kyapaz Mt. (3066 m) rises north of the Murovdagh Ridge.



Fig. 2.3 Gobustan

A number of spurs of northeastern strike and erosional origin such as Pant, Chyngyldagh, Kalteke, etc., are found at the Shakhdagh and Murovdagh Ridge northeastern and northern slopes.

The East Goycha Ridge, serving as water parting between the Lake Goycha and the Terterchay River left tributaries, extends meridionally south of Ginaldagh Mt. Structurally, it corresponds to the transversal elevation that dissects the Goycha-Hakeri syncline into two parts: the Goycha (north-western), and the Hakeri (southeastern). The ridge is composed by the Eocene and volcanogenic-sedimentary rocks and of Miopliocene volcanogenic thickness. The ridge's highest point is the Ketidagh Mt. (3399 m). The Mykhtekyan Ridge with its Dalidagh Mt. (3616 m) is situated at the Terterchay and Akera river water parting. It is a large anticline elevation composed of granitoids of thick Upper Eocene intrusion.

The Garabagh anticline ridge with its Beyuk Kirs (2725 m), Ziyarat (2478 m), Gyrkhgyz (2823 m), etc., peaks

extends in the general Caucasian direction in the central part of the Lesser Caucasus southeastern edge.

The Lesser Caucasus mountain slopes are characterized by intermontane troughs such as Bashkend-Dastafyur, Khankendi, Umudly, Sirik, etc. The Kelbajar superimposed depression, a young graben-syncline trough filled in its central part by the Garabagh volcanic upland Pleistocene lavas, is located in the Terterchay River upstream (Budagov 1993a, b; Antonov 1993; Alizadeh 1998; Khalilov 1999).

In the Shakhdagh, Murovdagh, and East Goycha Ridge highlands kars and troughs (the traces of the Upper Pleistocene glaciation) have developed. The river water parting have well preserved peneplanation surfaces of the Early-Middle Oligocene, Middle Miocene, and Late Pliocene (Akchagyl, Early Absheron) ages.

The Garabagh volcanic highland is situated southwestward of the Lesser Caucasus ridges and its relief is created by the Late Pliocene and Quaternary and andesite basaltic lava outflows. Major eruption centers are confined to abyssal



Fig. 2.4 The Murovdagh Ridge

fractures whereupon sit Upper Pliocene volcanoes and Quaternary cinder cones.

The Garabagh volcanic highland is the Lesser Caucasus most highly elevated mountain structure as well as a large water parting for the Kur and Araz basin rivers. Its principal topographic shapes are the Beyuk Ishygly (3550 m), Gyzylbogaz (3381 m) volcanic massifs, lava plateaus, and lava flows. Lava plateau relief is characterized by step structure, “*chyngly*” boulder placers, having hummock surface. River valleys that deeply cut into lava plateaus have stepwise slopes and remind canyons. Trough valleys, kars, and morainic deposits (the traces of ancient glaciations) are developed at the highland high volcanic massifs and are preserved on Beyuk Ishygly and Gyzylbogaz mountain slopes.

The Daralagez and Zangazur folded-block and block ridges are located southwest of the Garabagh volcanic highland (Fig. 2.5).

The Daralagez Ridge, located in the Arpachay and Nakhchivanchay interfluvium, has nearly latitudinal course in the northeastern part, and meridional course in the southwestern part. The ridge is composed of the Paleozoic carbonate and Jurassic volcanogenic-sedimentary rocks. The ridge highest section is at its abutment joint with the Zangazur Ridge (Kyukyudagh Mt., 3120 m). The Zangazur horst ridge (its highest point is Gapyjig Mt., 3904 m) is composed of the Megri-Ordubad fracture granitoids, and in the east, it is cut by the East Gapyjig fracture. The Zangazur Ridge water divide part is characterized by powerful and deep differentiation, by intensive physical weathering processes resulting in accumulation of coarse material of rock falls and talus at foot slopes. At the Ridge northeastern slope, the Late Pleistocene kars and troughs are developed, with preserved bottom terminal moraines.

The Daralagez and Zangazur Ridge middle-altitude and low-hill terrains, due to sharp continental climate and poor



Fig. 2.5 The Zangazur Ridge

vegetation, are characterized by vigorous development of arid-denudation processes. Monoclinic ranges characterize low-hill terrains with slopes covered by thick talus of coarse gravel and rock debris (Abasov 1970; Budagov 1993a, b; Antonov 1993).

Specific peculiarity of the Daralagez and Zangazur Ridge low-hill terrains is the presence of extrusive domes, laccolites, of diversified sizes and shapes, e.g., the Ilandagh Mt. (2410 m), Khanagya Mt. (1910 m), Alinja Mt. (1815 m), etc.

The Middle Araz kettle filled with thick Miocene and Pleistocene deposits is a large superimposed structure divided by transversal elevations into a series of intermountain pits and accumulation–denudation plateaus and the Negram High. At the Wolfish Entry transversal elevation (Dalidagh Mt., 1240 m; Degne Mt., 1150 m) the Middle and Upper Paleozoic limestone outcrops, while in the Negram High the Permian, Triassic, Middle Jurassic, Upper Cretaceous, Eocene, Oligocene sedimentary, and volcanogenic-sedimentary deposits outcrop.

The Gyvrage and Duzdagh plateau beds are composed of the Miocene salt-bearing thickness rocks and overlapped by thick Late Pliocene–Early Pleistocene boulder-gravel deposits. Their slopes are differentiated by dense network of badland.

The Sadarak Plain is located between Degne spur and the Araz River. Average altitude is 930 m. The Sharur plain stretches from the Degne spur to Gyvrage plateau, the Beyukdyuz plain stretches southeastward of Gyvrage plateau to Degne spur and is covered by low-rise hilly uplands. The Nakhchivan plain with its average altitude of 890 m is located between the Nakhchivanchay and the Jagrychay River lower courses. The plain is occasionally crossed by hilly uplands and low-rise ranges. The Gyulyustan plain is located in the Alinjachay River lower course (southeastward of the Darydagh Ridge). The Ordubad plain is found at the Nakhchivan AR extreme southeast.

The Kur-Araz lowland is situated between the Greater and Lesser Caucasus and occupies a large intermontane lowering with a number of sites differing in their geological structure and topographic peculiarities.

The Ganykh-Airichay synclinal valley stretches in the North, along the Main Caucasian Ridge bottoms, as a sloping plain where basic topographic shapes are expansive debris conduits of the rivers descending from the Main Caucasian Ridge southern slope.

The Jeiranchel-Ajinour low-hill terrain with direct tectonic relief is situated south of the Ganykh-Airichay valley, with low-rise linearly elongated monoclinic ridges composed of the Miocene and Upper Pliocene argillo-arenaceous rocks. The rivers that cross the Jeiranchel-Ajinour low-hill terrain eastern part create the antecedent valleys.

The Ganja sloping alluvial-proluvial plain is situated south of the Kur River valley, between the Khrami River entry and the Ganjachay River valley.

The Kur-Araz lowland itself is located southeast of the town of Mingachevir, up to the Caspian Sea shores and looks like a deep intermountain trough filled with thick mass of the Neogene and Quaternary argillo-arenaceous rocks. The Kur and Araz river valleys dissect the lowland into the Shirvan, Garabagh, Mil, Mughan, and Salyan depositional plains. A zone of young brachyanticlinal elevations such as the Large and the Small Kharami, Mishovdagh stretches submeridionally in the Kur-Araz lowland eastern part. The southeastern Shirvan, flat alluvial marine plain, is located between this zone and the Caspian Sea shore. In the south, the Mughan and Salyan plains merge with the Lenkaran lowland surface. The Kur-Araz lowland is characterized by numerous topographic micro shapes such as “*chala*”, and elevations such as “*gobu*”, winding dells, and “*akhmaz*”, river-formed lakes. Eolian and salt marsh topographic shares are developed at the Mughan Plain and in the southeastern Shirvan. Beach barriers and dunes stretch as narrow strip along the Caspian Sea shore.

Talysh Mts. (Fig. 2.6) are the continuation of southeastern plunging of the Lesser Caucasus folded structures.

They are composed of thick Paleogene and Neogene volcanogenic deposits and by the Late Cretaceous deposits in the southeastern part. Unlike the Greater and Lesser Caucasus Mts., former glaciation relief shapes are absent in the Talysh Mts. part, since its highest peaks slightly exceed 2400 m (Kemyurkei, 2493 m). High mountains are situated in the development belt of poorly disseminated terrain, with flat water divides and smooth hillsides.

Representation of the Talysh hill features displays four ridges of northwestern–southeastern strike: the Talysh Ridge (with its highest peak of Kemyurkei Mt., 2493 m), the Peshtasar Ridge (Pashagol Mt., 2240 m), the Dizgoni Ridge (Dizgoni Mt., 1056 m), and the Burovar Ridge (peaks of up to 900–1000 m). The Dyman and Gosmalyan kettles are located between the Talysh and Peshtasar Ridges, and the Yardymly kettle, between the Peshtasar and Burovar Ridges. The kettles are composed of the thick Maykop argillo-arenaceous deposits that are superimposed by the Middle and Upper Miocene deposits in the northwest (Antonov 1993; Budagov 1993a).

The Lenkaran lowland (depression) is positioned between Talysh Mts. and the Caspian Sea, stretching as a narrow flat belt. The lowland seaside part lies below the sea level. The lowland is generated by sediments of the rivers descending from the Talysh Mts. Various lakes are extensively developed such as estuaries and bogs. The lowland seashore is generally flat, but steep and scarp in some places. Sand dunes are developed parallel to the sea coast.



Fig. 2.6 The Talysh Ridge

2.3 Morphostructural Configuration

Contemporary terrain of Azerbaijan Republic took shape within a prolonged geological period, under collision conditions of the Transcaucasian, Anatolian-Iranian, and Scythian geotectonic plates. Convergence of these plates resulted in horizontal compression of the Transcaucasian massif by the Anatolian-Iranian block from the south and by the Scythian Plate from the north. Crustal folding, compartmentalization, and warping are increased in these suture

zones that also resulted in vertical differentiation. Intensive seismic and volcanic processes accompanied generation of large mountain systems and intermountain troughs. Enhancement of horizontal compression and increased vertical differentiation amplitude in relatively weakened Earth crust sites resulted in the formation of tectonic fissures and fractures. They created conditions for volcano linear eruptions, played the role of migration channels for outcropping of magmatic-origin mineral deposits, and delineated the terrain large orographic units.

Under tensioned compression, stretching, and folding the largest relief forms have been generated—such as the Greater and Lesser Caucasus mountain structures, Talysh Mts., and the Kur-Araz Trough. In other words, these intensive and complicated processes that occur in the Earth crust deep-seated layers have governed the generation of contemporary terrain outlines, typical for morphotectonic structure of the Alpine-Himalayan orogenic belt. Close interrelationship between morphotectonic structure and terrain shapes determined the formation of morphological structures of heterogeneous origin, typical for this orogenic zone, heterochronous, mainly folded-block, block and faulted ones, with general Caucasian, anti-Caucasian, and diagonal striking direction.

It should be noted that many specialists upholding various geotectonic views with regard to the Earth crust development have studied general regularities of Azerbaijan morphostructural configuration, reflecting the interaction between the Earth surface topography and its geological structure. Morphological structures were closely identified by Budagov et al. (1984, 1988), Budagov and Alizadeh (1995, 1998), Museibov (1968, 1973), Shirinov (1993, 1975, 1979, 1980), Shirinov and Dotduev (1976), Lilienberg (1985), Kuliyeu (1977), Khalilov (1980, 1993), Gadjeu (1980, 1999), Mardanov (1980, 1981), Alizadeh (1984, 1987a, b, 1991, 1998, 1999). Recently, however, due to enhanced assertions of plate tectonics role in the Earth crust development and development of theoretical foundations of the contemporary terrain generation as a result of plate horizontal shifts, the necessity to examine morphological structure formation from new positions, from the viewpoint of plate tectonics, has emerged.

After integration of information and morphotectonic interpretation of aerospace photographs we have delineated the following large morphostructural units in the Republic territory that differ in their origin, development history, and geomorphological features.

The Greater Caucasus vigorously upraised horst-anticlinal, folded-block-thrust, highly differentiated suture ridges are essentially composed of the Jurassic and Cretaceous sedimentary and volcanogenic-sedimentary rocks, and their margins are composed of the Paleogene—Neogene sedimentary deposits. It is a vigorously compressed mountain area, and tectonically is the Scythian Plate frontal part. It is the product of compression and folding at the Scythian Plate surface in the area of its collision with the Transcaucasian Plate. The Transcaucasian Plate, moving north- and northeastward along the Alazan (Ganykh) trough, plunges under the Scythian plate, i.e., the collision takes place.

Intensive compression of the Earth crust on the Earth's surface resulted in differentiated, multiple-elevation terrain. Earth crust was broken by heterogeneous and

heretochronous tectonic fracture of the general Caucasian and anti-Caucasian strike directions (Fig. 2.7).

Retrospective analysis within the Greater Caucasus eastern part permitted us to separate four generation stages of morphostructure modern framework: (a) the Lower Jurassic tension stage; (b) the Middle and partially Upper Jurassic compression stage; (c) the Upper Jurassic—Eocene stage of tension stabilization; (d) the Oligocene—Holocene compression stage.

Taking into account the interrelations and interdependences of geological structure and terrain in the Greater Caucasus Azerbaijan sector, a number of general Caucasian direction morphostructures have been revealed (Fig. 2.8). The Samur-Devechi graben-syncline plain that preserved its former shape, and the sharply elevated Gusar monoclinic plain as well as other relatively elevated piedmont plains were generated in the contact zone of the Greater Caucasus and the Scythian Plate, under weak folding and differentiation conditions. These monoclinaly shaped morphostructures contact the Greater Caucasus mountain structure due to the Kryz-Siazan abyssal fracture, and within their borders, height difference amounts to 2000 m. Within these plains a number of lower-order morphostructures is prominent (the Telebi-Gainarja horst-anticlinal low-hill terrain, the Zeikhur depression, the Yalama-Khudat elevation, etc.).

The Greater Caucasus Mts. of folded-block-thrust origin that experienced geotectonic stress were generated in the suture zone, which consists of several large morphostructures of general Caucasian direction.

Horst-anticlinal Tufan (watershed) ridges generated in the compression axial zone, along the Main Caucasian abyssal fracture and most intensively raised hypsometrically are the most pronounced in terrain. This mountain system is composed of the Jurassic and partially Cretaceous sedimentary deposits and plunges northwestward to southeastward. These sedimentary rock complexes, relatively unstable against weathering are exposed to intensive splitting. Some morphostructures of the Main Dividing Ridge southern slope are sharply lowered along the abyssal fractures and are, therefore, partially reflected in contemporary relief.

The Alpine-Himalayan suture zone of interplate contacts with horst ridge and graben intermontane and intramontane kettle systems. Central part of the Alpine-Himalayan suture zone of interplate contacts with young, intensively elevated, block-ruptured ridge systems, and intensively lowered graben depression systems of kettles.

(1) I. The Greater Caucasus folded-block-thrust, intensively elevated, suture, horst-anticlinal, intensively dissected mountain structure.

(2) I.1. The Sumur-Devechi marginal, graben-synclinal, superimposed, poorly dissected plain. (3) I.2. The Gusar, marginal, horst-monoclinic, highly elevated, dissected plain. (4) I.3. The Sudur horst-synclinal, residual, intensively

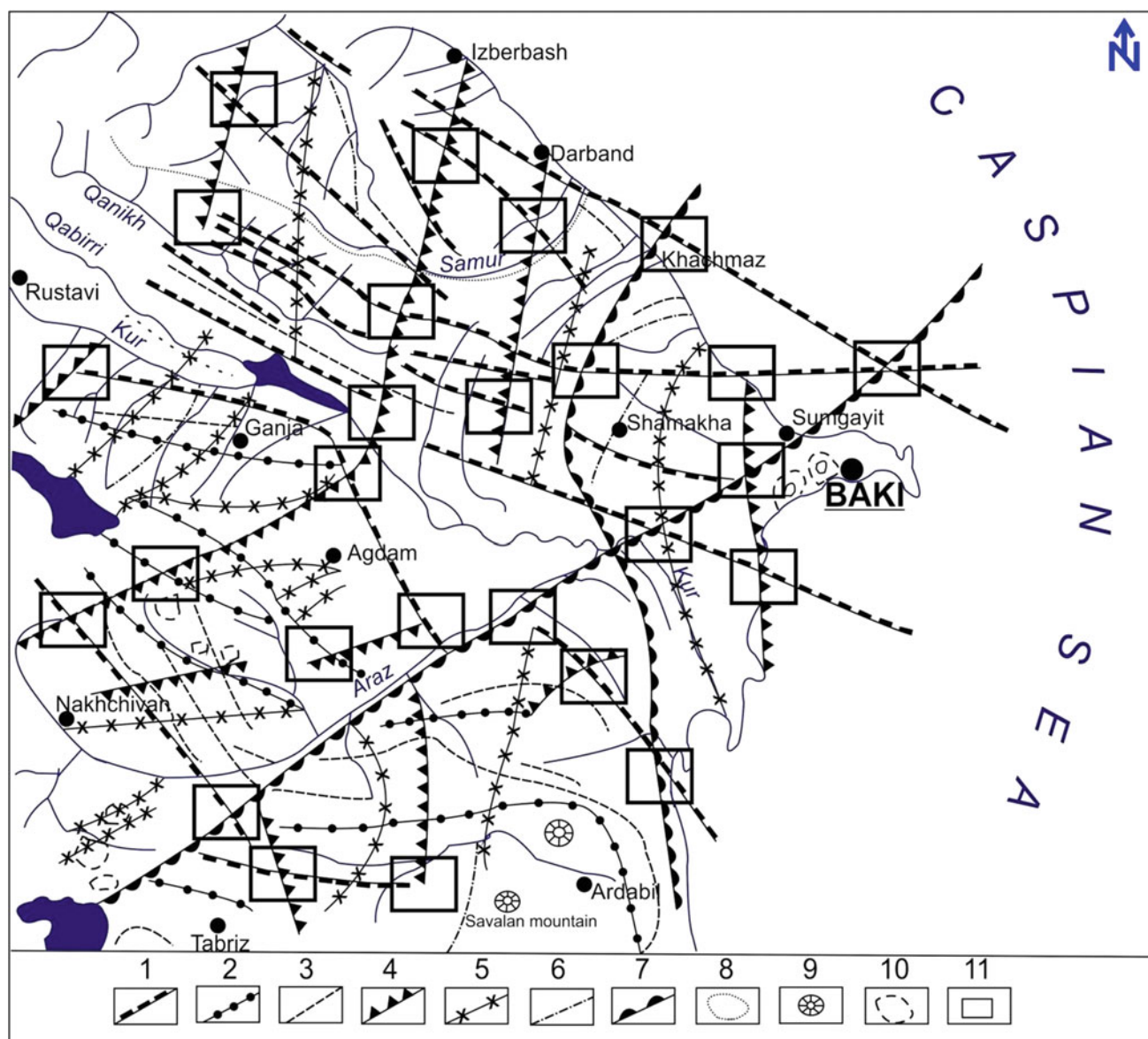


Fig. 2.7 Map-scheme of morphotectonic intensity of the Eastern Caucasus and adjacent territories (author: E.K. Alizadeh). Lineaments that correspond to faults (thrusts and overthrusts) of longitudinal (Lesser Caucasus) direction: (1) regional deep faults that limit large longitudinal folding and block steps, (2) local faults corresponding to the boundaries of longitudinal folding and block morphological structures, (3) faults that determine the details of morphological

structure. Lineaments that correspond to faults (*strike slips*) of the transverse (anti-Caucasus) direction, (4) regional deep faults that limit transverse megablocks, (5) local faults that correspond to the boundaries of transverse block segments, (6) faults, (7) large interregional diagonal volcanic centers, (8) contour of the circular object of Samur, (9) great volcanic centers, (10) ring structures (tectonic and volcanogenic), (11) geodynamically stressed fields

elevated, intensively dissected ridge. (5) I.4. The Tengi-Beshbarmagh sub-fractural (suture), rear, horst-anticlinal, intensively elevated, highly dissected ridge. (6) I.5. The Shakhdagh-Khizi, superimposed, horst-synclinal, intensively elevated, highly differentiated, complicated by large tectonic nappes, dissected mountain massifs and plateaus. (7) I.6. The Tufan (water dividing) central, most elevated, horst-anticlinal, highly dissected ridge. (8) I.7. Ridges, intramontane kettles, valleys of the

Zagatala-Govdagh synclinal zone foretrough. (9) I.8. The Vandam (Nialdag) front, horst-anticlinal, averagely elevated, partially plunged, dissected ridge. (10) I.9. Ridges, ranges, valleys, kettles of the Shamakhy-Gobustan marginal graben-synclinal dissected low-hill terrain.

The Greater Caucasus transversal (anti-Caucasian) block morphostructural segments.

(11) I.A. The Belakan-Kakh relatively lowered; (12) I.B. The Sheki-Gabala elevated; (13) I.C. The Babadagh-Dibrar

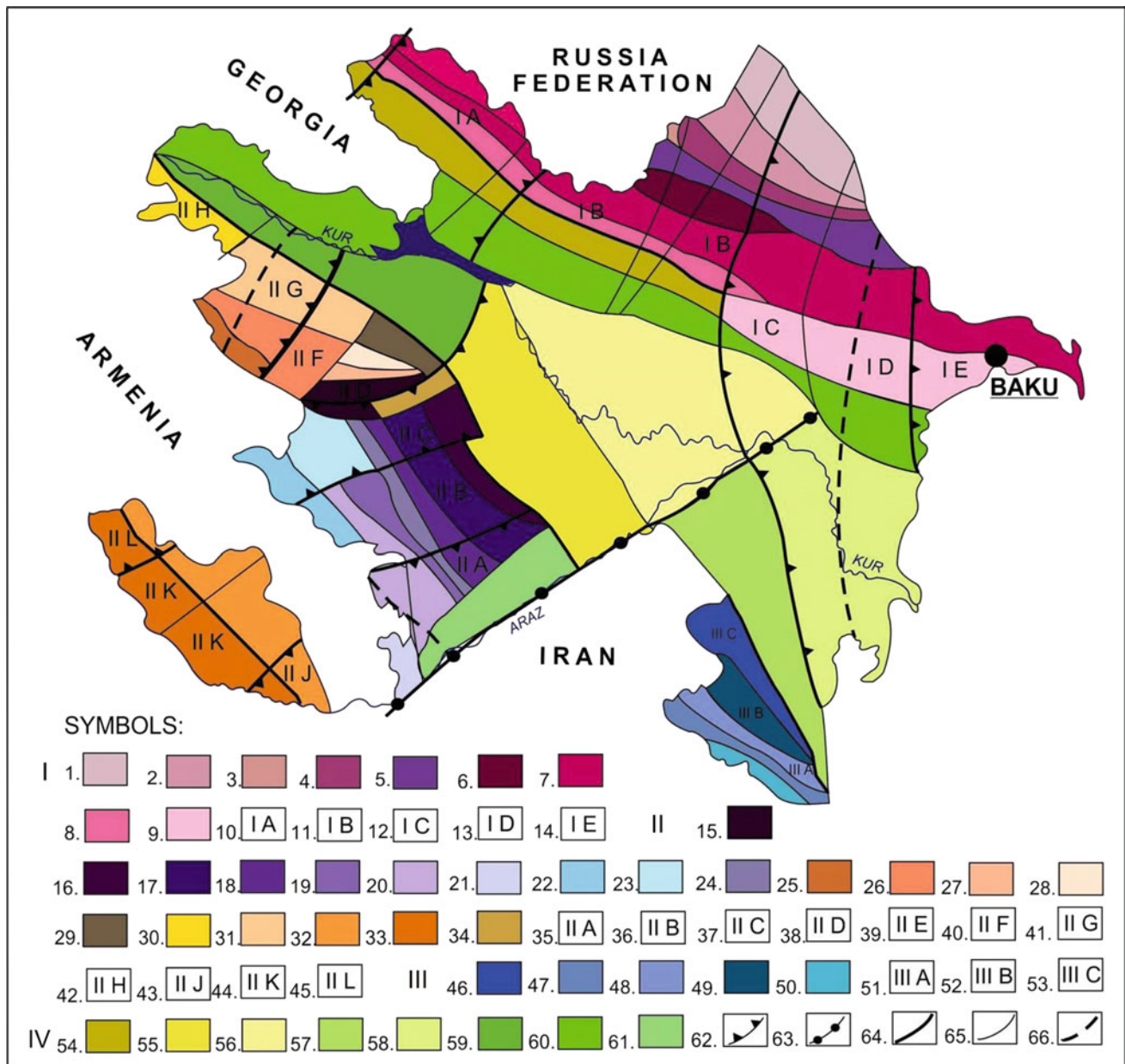


Fig. 2.8 Map of Azerbaijan morphostructures (constructed on the basis of space images analysis) (author: E.K. Alizadeh)

elevated; (14) I.D. The Maraza-Siazan lowered; (15) I.E. The Absheron most lowered.

(16) II. The Lesser Caucasus folded-block-thrust, intensively elevated, suture, horst-anticlinal, predominantly volcanogenic, averagely dissected mountain structure.

(17) II.1. The Murovdagh horst-anticlinal, articulated, suture, thrust, highly elevated, intensively dissected ridge. (18) II.2. The Agdam horst-anticlinal, rear, low-hill, averagely dissected ridges and ranges. (19) II.3. The Aterk (Umudlu)-Khojavend rear, graben-synclinal, en echelon located kettles and plateaus. (20) II.4. The Garabagh suture, partially ophiolite, highly elevated, highly differentiated,

horst-anticlinal, highly dissected, asymmetric ridge. (21) II.5. The Lachin near-fracture, horst-anticlinal, highly broken ridges and plateaus. (22) II.6. The Gochaz rear, superimposed, synclinal, highly differentiated kettles, valleys, ranges and plateaus. (23) II.7. The Gafan (Bartaz-Oskyulyum) horst-anticlinal highly differentiated and dissected ranges and ridges. (24) II.8. The Garabagh volcanogenic, highly elevated, horst, poorly sloped, poorly dissected highland. (25) II.9. The Kelbajar transversely superimposed, volcanogenic trough (graben-synclinal) with intensively dissected ridges, kettles and valleys. (26) II.10. The Sarybaba horst-synclinal, suture, highly mylonitized,

ophiolite, intensively differentiated and dissected ridges, plateaus and intramontane kettles. (27) II.11. The Shakhdag horst-synclinal, intensively elevated, averagely dissected ridge. (28) II.12. The Bashkend-Dastafur graben-synclinal, front, lowered, dissected series of kettles, ridges and plateaus. (29) II.13. The Kyapaz horst-synclinal, intensively elevated, averagely dissected ridge. (30) II.14. The Goygol horst-anticlinal, averagely dissected elevation (plateau and ridges). (31) II.15. The Agjakend block-synclinal, front, poorly dissected series of superimposed kettles, ranges and monoclinical plains. (32) II.16. The Gazakh graben-synclinal transversely superimposed, relatively lowered, poorly dissected kettle. (33) II.17. The Shamkir horst-anticlinal, rear, dissected elevation—ridges, ranges, and plateaus. (34) II.18. The Daralagyozy-Zangazur horst-anticlinal, intensively elevated, highly dissected range. (35) II.19. The Middle Araz graben-synclinal, marginal, superimposed, differentiated, intramontane kettle. (36) II.20. The Touragchay suture, sub-thrust, intensively differentiated, ophiolite, block-synclinal, dissected ranges, ridges and kettles.

The Lesser Caucasus transversal (anti-Caucasian) block morphostructural segments.

(37) II.A. The Bazarchay-Garasu lowered; (38) II.B. The Ishykly-Kirss elevated; (39) II.C. The Terterchay relatively lowered; (40) II.D. The Zod-Murovdagh highly elevated; (41) II.E. The Ganja-Murovdagh relatively intensively elevated; (42) II.F. The Ganja-Shamkir elevated; (43) II.G. The Shamkir-Tovuzchay relatively lowered; (44) II.H. The Tovuzchay-Afstafa lowered; (45) II.I. The Ordubad intensively elevated; (46) II.J. The Shakhbuz-Julfa elevated; (47) II.K. the Sharur lowered.

(48) III. The Talysh-Bogrovdagh folded-block-thrust, marginal, slightly elevated, horst-anticlinal, averagely dissected ridge.

(49) III.1. The Burovar rear, horst-anticlinal, relatively poorly elevated, poorly dissected ridge. (50) III.2. The Deman-Gosmalyan graben-synclinal and anticlinal, narrow series of intramontane kettles and valleys. (51) III.3. The Peshtasar horst-anticlinal, volcanogenic, elevated, averagely dissected ridge. (52) III.4. The Yarymly graben-synclinal, superimposed, intramontane differentiated kettle. (53) III.5. The proper Talysh horst-anticlinal, volcanogenic, relatively intensively elevated, highly dissected ridge.

The Talysh-Bogrovdagh Ridge transversal block morphostructural segments.

(54) III.A. The Astara-Gyzyurdu poorly elevated; (55) III. B. The Gyzyurdu-Kemyurkei relatively intensively elevated; (56) III.C. The Vilyashchahi-Bolgarchay lowered.

(57) IV. The Kur folded-block, graben-synclinal, greatly lowered, intermountain, differentiated series of kettles.

(58) IV.1. The near-Lesser Caucasian graben-synclinal, relatively poorly elevated, proluvial, alluvial, differentiated, sloped plain. (59) IV.2. The Garabagh graben-synclinal

poorly lowered, differentiated, hilly-range, alluvial-proluvial, piedmont sloped plain. (60) IV.3. The Kyurdamir graben-synclinal, median, lowered, alluvial-proluvial, poorly sloped lowland. (61) IV.4. The near-Talysh piedmont, graben-synclinal, differentiated plain. (62) IV.5. The Lower Kur graben-synclinal, greatly lowered lowland. (63) IV.6. Kettles, valleys and ranges of the Alazan (Ganykh)-Agrichay marginal graben-syncline. (64) IV.7. the Jeiranchyol-Ajinour-Alyat horst-anticlinal, frontal, suture, low-mountain ridges and ranges. (65) IV.8. The Lower Araz intermountain, superimposed, graben-synclinal, sloped plain.

(66) IV.9. Abyssal transversal ruptured dislocations. (67) IV.10. Regional diagonal fracture. (68) IV.11. Abyssal longitudinal ruptured dislocations. (69) IV.12. Local ruptured dislocations. (70) IV.13. Ruptured dislocations.

Intensively elevated, horst-synclinal, complicated by tectonic nappes, highly dissected Shakhdag-Khizi Mts., plateaus and valleys are prominent at the Greater Caucasus northeastern slope. These morphostructures with complicated interior configuration unite the Shakhdag-Gyzylkai massif, the Yerfi monoclinical range, the Khizi, Sokhyub, Alayaz, etc., depressions elevated to various hypsometric heights.

During the Lower Cretaceous age, under the Greater Caucasus vigorous southwestward compression conditions, subaqueous gliding of organogenic and marbleized rocks of the “Sudur” origin that are abundant in its northeastern part, took place. As a result, a gravitational-tectonic nappe generated in lieu of the contemporary Shakhdag-Budug plateau.

During subsequent periods, particularly after the Sarmatian (Upper Miocene) age, crucial differentiation in tectonic movement intensity along the Shakhdag, Siazan and some other depressions of anti-Caucasian direction takes place. As a result of these movements, a certain section of this large morphostructure, situated northwestward of the Velvechay transversal fault, and particularly, of the Shakhdag-Gyzylkai massif, being compressed on all sides, is squeezed out and rises to 3500–4000 m height. Southeastward of the Velvechay, the terrain heights and differentiation decrease, and here, the Shakhdag-Khizi zone morphostructures, via the Germian abyssal fracture, encounter the Zagatala-Govdagh zone morphostructures that serves as the principal morphotectonic units of the Eastern Caucasus southern and southeastern slopes.

At the Greater Caucasus northeastern slope, at the boundary line of orogenic zone and the Scythian Plate, along the Siazan abyssal fracture, southeast of the Garachay River, the Tengi-Beshbarmagh horst-anticlinal (monoclinical) ridges have developed, composed essentially of the Cretaceous and Jurassic sedimentary thicknesses.

The ridge southern slopes, violently compressed by the Siazan fracture in the northeast, and by the Garabulagh

fracture in the southwest, complicated by fractured ruptures, are very steep. It resulted from subsidence of the horst-anticline northwestern wing along the Siazan abyssal fracture. The Lateral Ridge subsides intensively southeast of Beshbarmak Mt.

Specific trait of the Greater Caucasus southern slope morphostructures increased clarity of their eastward reflection in topography. Structurally complex relief of this area west of the Damirapanchay River is prominent for its high steepness. The area exposed to intensive folding, south of the Tufan (water dividing) Ridge, displays mountains and intramontane kettles of the Zagatala-Govdagh horst-syncline that are mostly composed of the Cretaceous rocks. This large morphostructural unit is north delimited by the Malkamud-Germian morphotectonic thrust, and South delimited by the Zangi-Geradil morphotectonic thrust. Due to drastic vertical compression, the horst-anticlinal ranges and graben-synclinal depressions are formed in its western part. East of the Damirapanchay, morphotectonic units are relatively well defined in the relief. Here, such morphostructures are prominent as the Babadagh horst-anticlinal, the Govdagh horst-synclinal, the Guzducha-Alatash horst-anticlinal ridges, as well as, the Demirchilyar, Astrakhan (Gyzmeidan) and additional synclinal, occasionally superimposed, kettles.

It should be noted that it is in this zone that the Zagatala-Govdagh morphotectonic unit, covering the Greater Caucasus water divide part, partially transfers to the northeastern slope of this mountain structure. East of the Girdymanchay-Velvelechay belt, starting from the West Caucasian transversal suture zone, differentiation of horizontal and vertical tectonic movements increases, and morphostructure intensive subsidence takes place. The Zagatala-Govdagh morphotectonic step played the role of autochthon for thrust nappes abundant at the southeastern slope. The well-known Astrakhan thrust nappe was generated here, owing to horizontal shift of more ancient (Cretaceous) rock systems onto the younger (Miocene—Quaternary) deposits along the Zangi-Geradil rupture. The Vandam horst-anticlinal ridge belt composed of the Middle Jurassic volcanogenic and volcanogenic-sedimentary rocks is prominent at the Greater Caucasus orogenic zone margin. Its western part is poorly pronounced in contemporary relief due to subsidence along the North Alazan (Ganykh) abyssal fracture. The Nialdagh horst-anticlinal lateral ridge, the Lagich graben-synclinal kettle and alternative morphostructures of relatively lower order stand out in the Vandam zone. Intensively dissected and highly complicated by contemporary landslides ridges and intramontane depressions, located in the Vandamchay-Akhsuchay interfluvium are well pronounced in topography. The Vandam morphostructure sharply subsides at the town of Shamakhy meridian, and

eastward is not morphologically pronounced in contemporary terrain.

Morphostructural analysis of terrain and of morphotectonic structure of the Greater Caucasus orogen serving as the interface between the Scythian and the Transcaucasian plates, shows that compression and tension intensities are also evident in anti-Caucasian direction, and as a result, morphostructural segments of the same direction have generated in this mountain system. Within the Greater Caucasus eastern part, the most dramatic morphotectonic and morphological differences have generated to west and east of the Western Caucasian morphostructural node, with its center in the Girdymanchay-Velvelechay fractured dislocation.

With due account for the relief morphotectonic and morphological peculiarities, resulted from the investigations conducted, and from the literature data analysis, the following relatively large transversal morphostructures are delineated within the Greater Caucasus: (a) the Belakan-Sheki relatively lowered; (b) the Sheki-Gabaly most elevated; (c) the Babadagh-Dibrar elevated; (d) the Maraza-Siazan lowered; (e) the Absheron most lowered one.

The Lesser Caucasus mountain structure, whose southeastern part is situated within Azerbaijan, has been developed in the Alpine-Himalayan zone, under contact and collision conditions of the Anatolian-Iranian microplate and the Transcaucasian microplate.

It should be emphasized that the Lesser Caucasian mountain system that underwent a complicated and prolonged way of morphotectonic development consists of a number of drastically differing by their origin large morphotectonic units. The Lesser Caucasus mountain structure composed by rocks of different composition (volcanogenic, volcanogenic-sedimentary, sedimentary, etc.) and age (Lower Paleozoic—Quaternary) according to its peculiar features, intensity of morphotectonic development and morphostructural genesis is subdivided into three large parts: (a) The Lok-Garabagh horst-anticlinal ridges generated in the highly compressed zone of the Transcaucasian plate southern margin between the Murovdagh-Garabagh and the near-Lesser Caucasian abyssal fractures; (b) the Tourachay-Sarybaby morphostructural zone, generated—starting from the Lower Cretaceous age—as a result of closure, and subsequently experiencing the folding of the Tutkhun rift that was confined to the Mesotethys Ocean northern part; (c) The Miskhan-Gafan zone morphostructures (ridges, highland, kettles) generated by folding and block formation at the site of the Anatolian-Iranian plate collision with the Transcaucasian plate.

Within the Lesser Caucasian mountain belt, foundation formation, and development for the contemporary morphostructures can be subdivided into two significant stages: (1) The subduction period—foundation formation for large

pra-morphostructures possessing the Earth crust of oceanic and continental types (the Middle Jurassic—Upper Cretaceous ages).

(2) The collision period—formation of contemporary morphostructural carcass (the Upper Cretaceous—Quaternary age).

At the first stage, compression processes and general relief elevation typical for the Hercynian period were replaced by divergence and subsidence of the Lesser Caucasus great morphostructures.

At that period, the Miskhan-Gafan zone of the Anatolian-Iranian plate that encompasses frontal shelf zone separated from the Lok-Garabagh great morphostructure. The eugeosynclinal system of the Tutkhun Rift with the earth crust of oceanic type has formed in the tension zone. The relatively elevated Miskhan-Gafan and Lok-Garabagh zones were expressed by arc-like islands, whereas the Tutkhun rift looked like a narrow trough valley of 2000–3000 m depth that was exposed to continuous subsidence.

Development and formation of the Lesser Caucasus contemporary morphotectonic structure and laying the foundations for contemporary morphostructures start in the second half of this stage. During the Lower Cretaceous (Albian) age, horizontal movements changed their directions, and the Lok-Garabagh and Miskhan-Gafan zones interaction started, which resulted in subsequent closing of the Lesser Caucasus Tutkhun rift. During the period of vigorous compressions, folding, mutual thrust of heterogeneous rocks of the Earth crust oceanic and continental types, linear and areal lava eruptions, the oceanic rocks have compressed, separated from their roots, and underwent horizontal transfer at large distances. It resulted in the formation of the Sarybaba and Touragachay morphostructures of ophiolite composition.

Contemporary carcass of the Lesser Caucasus morphostructures is the product of collision that began, essentially, in the Upper Cretaceous period and is continuing until now. Thus, after compression of oceanic rift zone is over, the Anatolian-Iranian and the Transcaucasian plates finally collide, and the Miskhan-Gafan microplate starts plunging under the Lok-Garabagh zone. Orogenesis characterized by intensive magmatism, folding horizontal, and vertical movements has enhanced, starting from the Upper Eocene age, and folded-block, block, volcanic suture morphostructures of tectonic, and nappe origin were generated. Taking into account all morphotectonic development regularities within the Lesser Caucasus Azerbaijan part, the following morphostructural units can be separated in the collision zone of the Anatolian-Iranian and the Transcaucasian plates.

Among the Lesser Caucasus morphostructures exposed to vigorous compression and folding are the Murovdagh horst-anticlinal, suture, elevated, intensively dissected ridges and the suture, partially ophiolite Garabagh-Sarybaba

elevated and highly differentiated horst-anticlinal and horst-synclinal highly dissected, asymmetrical ridges, and plateaus. The Sarybaba and the Touragachay morphostructures situated in this area and associated with the Murovdagh and Garabagh abyssal fractures are confined to the area where the compression and closing of the oceanic type Earth crust took place, therefore, ophiolites have been found among their constituting rocks.

The Lachin morphostructure and the morphostructures located southeastward of the Lachin-Bashlybel abyssal fracture were generated at the Miskhan-Gafan microplate marginal part and were exposed to intensive compression and folding (the Gochaz, Garabagh highlands, the Zangazur, Daralagyoz, Bartaz, Ask'yulyum ridges, etc.).

Heterogeneous morphostructures (Agdam, Aterk (Umudly), Khojavend, Shakhdag, Bashkend-Dastafur, Kyapaz, Goygel, Shamkir, etc.) situated northward of the Murovdagh Ridge and eastward of the Garabagh Ridge, were formed in the collision area in the Transcaucasian microplate southeastern part.

It should be marked that tectonic faults of anti-Caucasian direction that began their development in the Upper Cretaceous period (at the time of collision), played important role in the formation of the Lesser Caucasus contemporary topography. During the highest collision increase period (the Eocene—Pliocene and the Miocene—Quaternary periods), Earth crust dissection on this direction enhanced and consequently, development of endogenous and exogenous processes in the terrain resulted in the predominance of anti-Caucasian elements. In this manner folded-block, block morphostructures and morphostructural segments (map) were generated, typical for this trend and prominent in contemporary geomorphological features. For instance, the Kelbajar and the Gazakh graben-synclinal troughs, the relatively lowered Bazarchay, Garasu, Terterchay, Shamkir-Tovuz, Sharur, and elevated Ishykly-Kirss, Ganjachay-Shamkir, Ordubad, etc., morphostructural segments.

The Talysh Mts., located at the southeast of Azerbaijan, are especially prominent among the Azerbaijan morphostructures by their morphotectonic characteristics. The reason is that this mountain system was generated in another morphotectonic zone, where the Iranian and Transcaucasian microplates of the Earth crust continental type collide with the South Caspian rift (graben) of the Earth crust of suboceanic type. Here, during the periods of collision and subduction enhancement (Upper Cretaceous, Paleogene—Eocene), intensive linear and areal volcanism, compression, and folding were observed. The Talysh horst-anticlinal suture ridge, limited by the pre-Talysh abyssal fracture, was a constituent part of the Talysh-Bogrovdag-Elburs suture mountain system and generated at the Iranian microplate northern margin. This mountain system composed of volcanogenic and volcanogenic-sedimentary rock complexes

Table 2.1 Geomorphological zoning (after Budagov 1993a, b)

Province	Region	Subregion	District
1	2	3	4
The Crimean-Caucasian Mountain Land			
Piedmont depressions and uplands	I Samur-Devechi (Shabran)		1. Samur-Devechi lowland 2. Gusar sloping plain
The Greater Caucasus	II Eastern Greater Caucasus	II ₁ Southern slope	3. Zagatala 4. Sheki 5. Lagich
		II ₂ Southeastern slope	6. Bazardyuzu 7. Shakhnabad-Khizi 8. Shakhdagh 9. Tengi-Beshbarmag 10. Dyubrar 11. Shamakhy 12. Gobustan 13. Absheron
South Caucasian depression	III Kur trough	III ₁ Ganykh-Airichay valley	14. Ganykh 15. Ismailly
		III ₂ Jeiranchel-Ajinour submountain region	16. Jeiranchel 17. Ajinour 18. Lengebiz-Alyat 19. Kharamy
		III ₃ Kur-Araz trough	20. Shirvan plain 21. Southeastern Shirvan 22. Near-Kur plain 23. Mughan plain 24. Salyan plain
		III ₄ Pre-Lesser Caucasus sloping plain	25. Ganja-Gazakh plain 26. Garabagh plain 27. Mil plain
Western Asian Highlands			
The Lesser Caucasus	IV Outer western ridges	IV ₁ Northeastern slope	28. Agstafa 29. Shamkir 30. Dashkesan-Agjakend 31. Shakhdagh 32. Murovdagh
		IV ₂ Eastern slope	33. Lower Araz
		IV ₃ Southwestern slope	34. Kelbajar 35. Mykhteken 36. Kharmin
	V Inner Lesser Caucasus	V ₁ Garabagh volcanic upland	37. Gyzylbogaz-Ishygly 38. AlageI-Chalbayir 39. East Goycha 40. Yazyn
		V ₂ Near-Araz ridges	41. Daralagez 42. Zangazur 43. Bargushad
		V ₃ Nakhchivan (Middle Araz) trough	44. Sharur 45. Negram 46. Ordubad
	VI Talysh Mts.		47. Lenkaran lowland 48. Burovar ridge 49. Yardymly 50. Peshtasar ridge 51. Zuvand 52. Talysh



Fig. 2.9 Geomorphological zoning of Azerbaijan territory

created elevated to 2000–2400 and 1000–1200 m, respectively, heights, the intensively compressed, dissected Pesh-tasar, Talysh, Burovar horst-anticlinal ridges and the Yardymly and Deman-Gosmalyan intramontane graben-synclinal kettles that separate them and are generated in relatively lowered areas.

The Kur intermontane graben-synclinal trough plays important role in the development of contemporary morphostructural carcass within Azerbaijan and in the creation of general morphological layout of contemporary terrain. In the Kur Depression northern part, in the collision zone of the Transcaucasian and Scythian plates, along the North Alazan (Ganykh) and Zangi-Geradil fractures, the Ganykh-Airichay and the Shamakhy-Gobustan morphostructures have been formed that are exposed to intensive subsidence and compression. Eastward of the Girdamanchay River valley, in West Caspian zone of tectonic faults, and southward of the Zagatala-Govdagh microstructure, the Shamakhy-Gobustan morphostructural step has developed that is relatively weakly compressed. It underwent subsidence to 1.5–2 km along the South Nialdagh and Zangi-Geradil abyssal fractures. Plateaus, ranges, hills, and kettles of nappe-thrust-folded genesis are prominent in the relatively poorly differentiated Shamakhy-Gobustan zone. Relatively southward of this zone the terrain is complicated by the Jeiranchyol-Ajinour-Alyat anticlinal low-mountain ridges and ranges that northward encircle the Transcaucasian microplate. Taking into account contemporary peculiarities of relief and foundation development and based on the electric resistivity log and other geophysical data analysis we can distinguish the Garabagh, Kyurdamir, near-Talysh, Lower Kur graben-synclinal, sharply lowered, and poorly dissected plains within the Kur trough.

Summarizing the above said, we note that we made an attempt to explain certain formation regularities in contemporary morphostructural configuration of Azerbaijan area from the viewpoint of “global plate tectonics” theory, on the basis of combined geophysical data analysis. However, the work was not intended for the clarification of all aspects of origin and specific development features of morphostructure in the region under study. Undoubtedly, in-depth study will further contribute to the development of these problematic issues of contemporary geomorphology.

2.4 Geomorphological Zoning

The proposed geomorphological zoning scheme (Budagov et al. 2011) is based on the principles of terrain morphostructural analysis and area dissection into variously ranked morphostructures—in view of their age, structural and developmental peculiarities, intensity, sign and

manifestation manner of recent tectonic movements, depositional nature (for subsidence regions), erosional dissection, and the complex of genetically similar morphoscultures complicating the morphostructural configuration (Table 2.1; Fig. 2.9).

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