Structural-Material Complexes as Indicators of Geodynamic Situations by Example of Eastern Part of Central Caucasus

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***Abstract*—The article assesses the individual geodynamic situations of the Wilson cycle. These situations formed one or another existing structural-material complex of the main microplates and structural-tectonic zones of the eastern segment of the Central Caucasus. The assessment was carried out on the basis of the concept of the tectonics of lithosphere plates and the corresponding geodynamic regimes. Such regimes are established at the boundary and internal parts of the tectonic plates subjected to various kinds of dynamic effects. Structural-material complexes are differentiated according to the geomorphological, tectonic, sedimentation, igneous bedrock, metamorphic and volcanic features. The mantle effects of vertical and (or) lateral direction on the crust are given. Dynamics of these effects are determined by the convective rising flow of mantle substrate that is heated by outer core. This flow is independent of convective currents jets from the lower and upper floors of the mantle, i.e. plums, according to the model of the double-level tectonics of the lithosphere. The effectiveness of seismic tomography is noted. This method allows constructing models of the mantle density thermal inhomogeneities using velocity propagation characteristics of elastic vibrations. The characteristic of a geodynamic situation is given as a generalization of the particularities of each of the described structural-physical complex.**

Keywords—geodynamic situation; structural-material complexes; convective currents; Central Caucasus

I. INTRODUCTION

Earth's crust is fractured into a large number of different-scale and shapeless plates. It is a modern geographical mosaic of the planet assembled from puzzles. Out of the 100 plates (according to R.M. Domenitskaya, not counting the terrains according to V.E. Khain), there is the only one oceanic tectonic plate - Pacific - 103.3 million km^2 and 6 continental plates (North American and North-Eastern Siberia - 75.9 million km^2, Eurasian - 67.8 million km^2, African - 61.3 million km^2, Antarctic - 60.9 million km^2, Australian - 47.2 million km^2, South American - 43.6 million km^2) [1, 2] totaling more than 90% of the Earth area. The ratio of the areas of continental crust and oceanic crust (including seas) is about 9 to 11. The main criteria for determining the boundaries of tectonic plates are seismic, volcanic, and tectonic activity zones, as well as mountains and oceanic troughs.

From the point of view of the nature dialectic, crushing the crust into plates is nothing but the principle of the least energy margin (energy gain) of the system for balancing integrity in a continuously pulsating state of the upper mantle. One can imagine the energy costs of such balancing solid crust with local vibrations of the uppermost mantle. On the other hand, it should be taken into account that the current tectonic scheme of lithospheric plates balances the energy unloading of intra-lithospheric radiogenic and geodynamic processes and core growth energies by iron deposition due to backlash in interplate joints, preserving the entropy of the system. In the case of continuity of the crust, the measure of irreversible dissipation of energy can be violated and, as a result, the thermodynamic equilibrium of the system will be disturbed.

The interaction of both different types and plates of the same type, caused by the corresponding geodynamic regime, determines the geodynamic state for the development of the geological structure and its structural-material complexes. The mantle effect on the crust of a vertical and (or) lateral directivity is the platform of such interaction. The dynamics of this effect is determined by the convective upward flow of the mantle substrate heated by the outer core and independent of convective currents by the jets from the lower and upper floors of the mantle - plumes [3, 4].

In the first case, the upward flow of the relative uncompacted and heated substrate forms an upward branch in the future convection cell. The movement of particles in this cell can occur along different trajectories depending on the density and temperature of the upward flow [5].

Due to the creep mechanism, the upward movement of matter takes place at the atomic and molecular level by jumping dislocation vacancies [6] from plane to plane. In the second case, the movement of the mantle material from the depths of the subsoil to the base of the lithosphere is considered in the form of advection, i.e. directional lifting of the material in the form of a “jet” that spreads along the base of the lithosphere, without forming a closed convection cell. Convective flows and mantle plumes are reflected in the materials of seismic tomographic studies [7, 8]. According to the velocity characteristics of the propagation of elastic vibrations, density models are compiled. With the help of these models thermal mantle heterogeneities in the form of vertical zones of excess density for descending flows and zones of decomposition for ascending flows are obtained.

A generalized investigation of seismic tomography data of the earth's interior allows us to draw the following conclusions:

• the modern Earth’s mantle is characterized by density and thermal inhomogeneities, which are recorded by a decrease or increase in the speed of seismic waves;

• heterogeneities in the form of columnar bodies can be traced over the entire cross section of the Earth’s mantle, i.e. they have a common mantle (through the mantle) nature;

• low-speed and high-speed heterogeneities of the mantle of the Earth are linked into a system of large-scale convection, which has a limited number of convection cells.

The structural-material complex elements of the Greater Caucasus, like any geological structure, are indicators, not only of the latest geodynamic setting that captured modern geological reality. They contain information about the complexes of previous geodynamic settings, the use of which allows classifying these settings [9, 10].

According to the concept of a tectonic scheme of lithospheric plates, the geological structure undergoes regularly alternating periods in the tectonic evolution of the Earth. These periods are characterized by a certain sequence of geological events and develop against the background of the general directional development of the planet due to its internal energy. The geological period of the completion of a complete revolution of tectonic evolution is called a cycle. The duration of cycle depends on the rank of the geological structure. For the structure of the Greater Caucasus, which has passed all known geodynamic settings, the Wilson cycle is of interest. The Wilson cycle is the longest in time and most significant in terms of geological results. It covers the time from the beginning of the formation of the ocean to its closure and includes events from continental rifting to the collision of continents, with intermediate stages of spreading and an opening of the ocean, subduction and the formation of a magmatic arc. The cycle has duration of about 600 million years. The mechanism of flow of each geodynamic situation of the Wilson cycle is described in detail in the geological literature and is not considered here.

The most characteristic isolated fold-tectonic blocks of the eastern part of the Central Caucasus, characterized by a specific structure and texture, tectonic localization, morphological features, material composition, layer thicknesses, are considered as structural-material complexes. These complexes are composed of associations of sedimentary and metamorphic formations and magmatic formations (formations), by consedimental (flexures, advection) and post-sedimentation (sliding layers, astroblemes, diapirs) structures.

Structural and material complexes of the first order (according to the classification of regional tectonic zoning) are generally oriented sublatitudinaly [11], according to the common Caucasian trend, the main of which are shown in Fig. 1. Differentiated structural-material elements of higher orders repeat the spatial orientation of the main structures.

II. Vladikavkaz Basin of the Terek-Caspian Foretrough

The Vladikavkaz Basin is located north of the Lesistyi Range. It is a deep trough, turning into the north wing of the Caucasian anticlinorium in the south. The beginning of the formation of the trough is followed by the Upper Sarmatian. At that time on the territory of the Terek-Caspian foretrough a steady deflection mode is established. This mode preserved against the background of the general uplift of the region, which began in the late Sarmatian-Meeotis [12-14]. Thus, the clay and marl of the Lower-Upper Sarmatian region of the region should be considered as a bed of the trough.

The Vladikavkaz Basin is made of a thick stratum, of continental Neogene and Quaternary formations [15], forming the upper molasses. At the base of this stratum there are deposits of pebble-sand-clay composition of the Upper Sarmatian-Pontian, uniting conglomerates and pebbles of the Lysogorsk suite. Its thickness varies from 1000 m to 200 m at the northern frame of the area until full termination at the southern boundary of the trough.

There are tuff-conglomerate deposits of the Ruhsdzuar suite on the conglomerates of the Lysogorsk suite.

A significant area of the hollow is filled with these rocks. Their thickness reaches 1450 m. The section of the upper molasse is completed by Quaternary Pleistocene-Holocene alluvial and fluvioglacial formations with a thickness from 0 to 750 m.

The southern border of the basin with the Northern monocline is determined by the Vladikavkaz fault [11, 16], which is a flexure with a raised south, lowered north wing (fall 75–80°) and a bend at a depth of about 7 km [17]. The Vladikavkaz structure, according to the deep seismic sounding [18], is marked by the appearance of intense diffracted waves, distortion of the relief of most of the deep boundaries and the disappearance of some extended seismic boundaries.

On microseismic sections, the boundaries of the above-mentioned complexes can be traced in fragments and only in certain areas. In the northern parts of both profiles, corresponding to the Ossetian Basin, at depths of 2.5–4 km, the first intermittent near-horizontal section of the high contrast of shear-wave velocities is distinguished. In the section of the sedimentary cover of the depression, this section presumably corresponds to the base of the terrigenous sediments of the Miocene molasse complex. Below, at a depth of 4.5–7 km, a second, more powerful and contrasting section can be distinguished, which in the Ossetian Basin presumably corresponds to the top of a limestone salt-bearing formation of Late Jurassic age [19-21].

Seismic observations within the Vladikavkaz Basin trace stratified boundaries from intra-Jurassic to Chokrak, in which erosion is not noted, which suggests the upward structural inheritance of elements and the uniform geodynamic environment of their accumulation. In the intersalt and subsalt deposits of the Upper Jurassic, anomalies have been identified that are associated with carbonate massifs, interpreted as possible reefogenic formations. Above the Upper Jurassic sediments, such structures are not traced.

The geodynamic mode corresponds to the collisional era of development, destruction and block movement by moving the Arabian protrusion deep into Eurasia, an outbreak of volcanism occurs [22-26], mainly of andesitic composition. Orogenesis is characterized by the formation of ridges and intermontane depressions. Intrusive activity is characterized by low activity.

III. Cimmerian Folding Zone

The Cimmerian folding zone is located east of the Sadono-Unal horst and Fiagdon anticline. From the north, it is limited to the underthrust of the “Rocky Ridge”, from the south of the Tsariit-Tsatadon and Belorechensk faults, separating it from the Shaukhokh-Darial uplift. The eastern boundary of the zone is outside the described area.

According to the lithological composition of the Jurassic basement in the Cimmerian folding zone, there are two subzones: Dagom-Dargavsk and Tsatadon-Arkhinsk. The boundary between them passes along the Dzhimara-Godtanadag fault.

The lower members of the Jurassic section in the Dagom-Dargavs subzone are represented by aleurolites and sandstones of the Mizur Formation, which are distinguished in the terrigenous marine formation of the Middle Lyas. In the Tsatadon-Arkhinskaya subzone, the mid-Lass shale of the Genaldonian stratum, containing a subordinate number of sandstones, is located at the base of the investigated part of the Jurassic. These rocks in present work without any justification are combined with Mizur suite. The rather sharp differences in facies and biocenosis, which allow making a conclusion about the various geodynamic settings for the formation of these sediments, seemed to be a sufficient argument for some researchers to assign the Tsatadon-Armkhin subzone to the Eastern Caucasus. The absence of any differences in the overlying Lower-Middle Jurassic sandy-clay sediments overlapping both the Mizur and Genaldon sediments suggests that the tectonic isolation of the subzones ended at the end of the Pliensbachian, and then they developed as a unified whole.

Naturally, another point of view is also not excluded, according to which the facial differences of “Mizur” and “Genaldon” sediments, as well as differences in biocenosis, are derived from the location of the sedimentation area relative to the coastline, and leveling the sedimentation conditions to the beginning of the Toarcian age is a natural process in an expanding marine transgression.

The tectonic structures, both in the Dagom-Dargavs and in the Tsatadon-Armkhinsk subzones, are the result of the predominantly Adygei phase of the Alpine orogenesis. They have already developed in a single, consolidated zone of Cimmerian folding, and therefore are characterized by a single plan of folded deformations.

Within the zone, a number of sub-latitude-oriented tectonic subzones characterized by a certain type of plicative and disjunctive disturbances are distinguished.

Here, from the north to the south, the subzones of the northern anticlines, intermediate grabens, central synclines, Fiagdon-Lars uplift, and the “southern” syncline are distinguished.

In general, in terms of its position in the geological structure of the mountainous part of the eastern segment of the Central Caucasus and in its structure, the “southern” syncline of the Cimmerian folding is analogous to the Shtulu-Hares graben-syncline that divides the Taymazy-Labagom (Central) and Balkar-Digor uplifts, and - apparently, to some extent, can be considered as its eastern segment.

The Cimmerian folding develops under the geodynamic regime corresponding to the Cimmerian stage of the collision of the southern microcontinent with the active continental margin of the Scythian Plate, with the collision era ending.

A subduction zone is formed to the south of the adjacent microcontinent, and the formation of the Little Caucasian volcanic arc occurs. Sedimentation takes place in an epicontinental sea basin.

Magmatic activity is activated, the andesidacite tuff-lava volcanogenic formation is replaced by gabbro-diorite-granodiorite and gabbro-diabase dyke formations. Sedimentary complexes are shaped by knotty shale, meta sandstone, and quartzite.

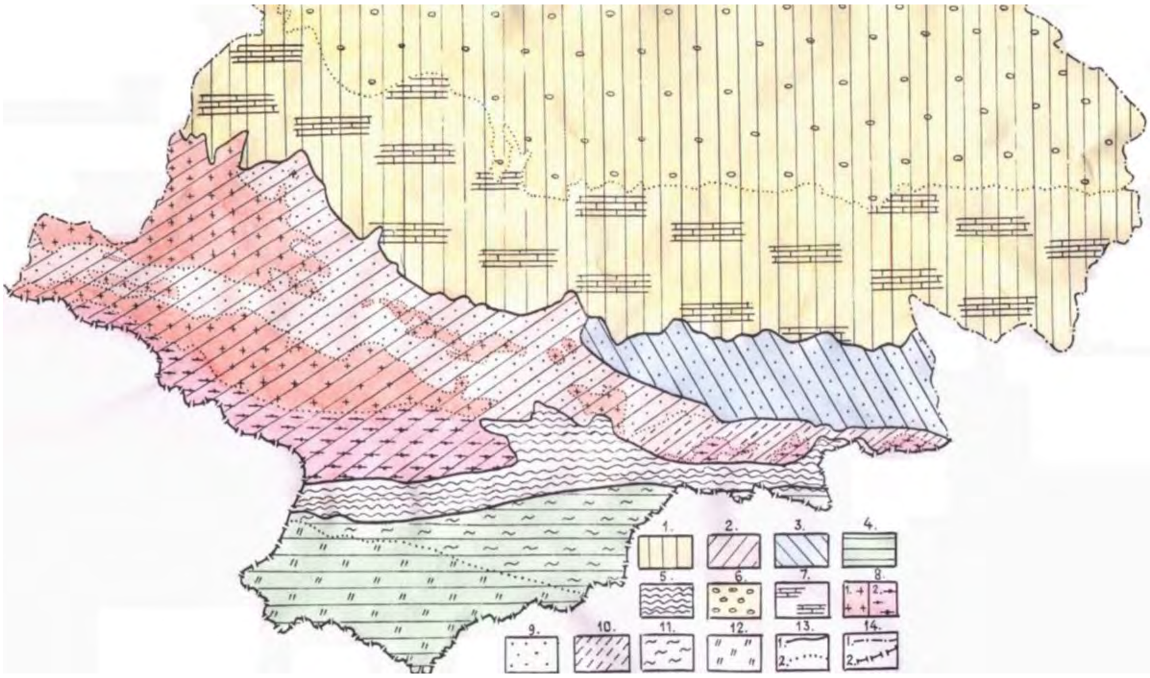

Fig. 1. Microplates and structural-tectonic zones of the eastern part of the Central Caucasus (according to Olkhovskiy G.P., Tibilov S.M.)
Legend: Microplates - terrains: 1. Pre-Caucasian; 2. Bechasynsk; 3. East Caucasian; 4. Transcaucasian.
Structural-tectonic zones: 5. Mamison-Kazbek (relic zone); 6. Vladikavkaz Basin; 7. Northern monocline; 8. Glavnyi Range (1 - Makher and 2 - Kassar subzones); 9. Digor-Osetinsk; 10. Ardon-Darial; 11. Southern slope; 12. Chiaur; 13. Contacts: (1 - microplate- terrains, 2 - structural-tectonic zones); 14. Borders: (1 - republics, 2 - state).

The interaction of the continental margin with the oceanic plate and the opening of the ocean basin associated with the spreading of basaltoid volcanism begins.

IV. Central Elevation. a) Taymazy-Labagom Elevation

The axial zone of the anticlinorium of the Greater Caucasus in the eastern part of the Central Caucasus shifts to the south, where it is expressed orographically by the most high-altitude Lateral ridge and occupies the southern part of the eastern end of the structural-tectonic structure of the Central Caucasus. The axial zone is represented here by two sublatitudinal horst elevations: Taymazy-Labagom and Shaukhokh-Darial.

The Taymazy-Labagom elevation is located in the southwestern high-mountain part of the segment, occupying here the slopes of the Glavnyi and Bokovoy Ranges, as well as the northern spurs of the latter. According to the lithological composition of its constituent rocks, it is divided into two tectonic subzones: Tanadon-Buronian and Laboda-Tsmiakom.

The Tanadon-Buron subzone covers the northern half of the Taymazy-Labagom elevation. It is limited in the north by the Shtula-Khares graben-syncline depression structure, and in the south of the Laboda-Karaugom and Tseydon faults, the junction of which is healed by the penetrated Karaugom and Tsey massifs of the Middle Jurassic Digor volcan-plutonic association. In the valley of the river Baddon subzone sinks beneath the sandy-clay rocks of the shale formation. The subzone is composed of Middle and Upper Paleozoic granitoids. The suprastructure rocks represented by outcrops, xenoliths, and relatively large blocks of maker shale series that compose the Kittiberda and Buron formations are of lesser importance. The magmatic rocks are represented by formations of the diorite formation and gabbro-diorite-granodiorite group of formations, which lead to zones of large faults of the all-Caucasian orientation and fracturing systems of the north-west trend. An insignificant role belongs to the volcanics of the lower-middle-Lasic andesite-dacitic and sandstones of the mid-sea marine terrigenous formations, which, are located in contact with the Shtulu-Hares graben-syncline and can be considered to belong to both the subzone and the southern wing of the graben-synclinal.

The Tanadon-Buron subzone consists of five tectonic blocks, of which the western blocks (Tanadon, Rudny and

Hupparin) are separated from the eastern ones (Sauhokh and Buron) by the deep Zgid fault, the superficial occurrence of which is Donisar uplift. Along the Zgid fault and, accordingly, on the Donisar uplift, the eastern part of the Tanadon-Buron subzone is raised not less than on 2.5-3 km. The western part of the subzone that is represented by the Tanadon, Rydny and Hupparin blocks, was tilted to the north at a 40° angle as a result of the rotation. A reasonable explanation for small patches, possibly tectonic residues of volcanic rocks of the lower-middle-hourly andesidacy formation and shale of the lower, middle Jurassic formations found among granitoids of the subzone in different parts of the Hupparin block still have not been found. As one of the hypotheses explaining this phenomenon, it is suggested that the rotation of the blocks occurred simultaneously with the movement of the masses of rocks from south to north. The latter evidently appeared due to more amplitude thrusts, what is confirmed by the outcrops of volcanogenic and sedimentary rocks, preserved only in places after the formation of the Glavnyi and Bokovoy Ranges and their subsequent intensive denudation.

The Loboda-Karaugom fault, which borders the western part of the Tanadon-Buron subzone from the south, is one of the largest disjunctives of the ancient foundation in this part of the region. It is traced in the south-east direction for 25 km, from the massif of the mountain of Laboda in the west to the mountain-glacial Karaugom plateau in the east. Further continuation of the fault was destroyed by the intrusion into its zone of granodiorite magma, which formed here the Karaugom massif of the Middle Jurassic Digor volcano-plutonic association. The fall of the fault is steep (75–88°), most often northern and sub-vertical. Small subintrusive bodies of the Pliocene diorite formation are located in this zone. The amplitude of the fault is not determined.

The Eastern Blocks of the Tanadon-Buron subzone underwent a more intensive rotation, as a result of which they turned to the north. Their surface acquired a southern dip at angles of 70–75°, which was established not only along the cuts of the river valleys but also from the mine workings completed by the Sadon Lead-Zinc Integrated Plant at the Student and Ursdon ore occurrences.

The Saukhokh block is the southern part of the Kion transverse lift. The block is composed mainly of Middle and Upper Paleozoic granitoids and crystalline shales of the Buron suite. Less important are the volcanics of the Sadonian, Mizur sandstones and shale Galician suites and numerous small bodies, stocks, and dikes of the intrusive and subintrusive facies of the Middle Jurassic Digor volcanic-plutonic association and the Kazbek dyke complex, as well as the Pliocene diorite Teplinsk complex. The block is limited in the west and north by the Donisardon and in the east by the Ursdon uplifts, along which it is not only raised but also shifted to the north. Granodiorites of the Tsey massif are penetrated in the zone of the Tseydon fault into the south-western part of the Saukhokh block.

The Buron block, which completes the Tanadon-Buron subzone in the east, is composed of formations of the Mamison-Kazbek superstructure, represented by crystalline schists of the Buron suite. The minor role belongs to the rocks of the gray-colored molasse, as well as andesidacite, marine terrigenous and shale formations. Magmatic formations are relatively rare and are represented mainly by dikes of the Middle Jurassic gabbro-diabase formation of the Kazbek dike complex. In structural terms, it is the most complex of many blocks of the eastern segment of the Central Caucasus. Judging by its eastern end, the block is wrinkled into folds, of which the Small and Big Bad anticlines are distinctly fixed and the Mashigkom syncline separating them. West of the river Ardon valley these folds are not documented. The Big Bad anticline is the dominant structure here. It stretches in the latitudinal direction for about 8-9 km. Its width is about 2 km. The axial plane of the fold is tilted north. Its northern wing falls to the south at angles of 70–85°, the southern one also to the south with angles of 40–70°. The core of the fold is composed of crystalline schists of the Buron suite, wings - by the conglomerates of Baddon, the volcanics of the Sadon and the sandstones of the Mizur suites.

To the Tanadon-Buron subzone from the south, along the Laboda-Karaug-Tseydon tectonic zone, the Laboda-Tsmiakom subzone is attached. The subzone is composed of Upper Proterozoic formations of the suprastructure, represented by crystalline schists of the Kassar suite, belonging to the Buulgen series, and also rocks of the granite-gneiss mid-Paleozoic formation of the Kassar complex. In addition, the granodiorite Karaugom and Tsey massifs, as well as stocks and dike complexes of the Middle Jurassic gabbro-diorite-granodiorite (Digor complex) and gabbro-diabase (Kazbek complex) formations participate in its structure. From the south the subzone is limited to the tectonic zone of the Main thrust, which is, in essence, a sub-move in which the geological formations of the more southerly zones move up under the Taymazy-Labagom structure, thus ensuring its uplifting. The Laboda-Tsmiakom subzone is divided into two blocks, divided by the Karaugom intrusive granodiorites. The Western (Watershed) block occupies the ridge part of the Glavnyi Vodorazdelnyi Range between the mountain-glacial massifs of Laboda (4320 m) and Burdzhula (4357 m).

The East Lagau-Tsmiakom block is located on the slopes of the Bokovoy Range, between the Lagau and Tsmiakomkhokh massifs. It is limited in the north by the Tseydon fault, in the east - by part of the Kolotin thrust, in the south by the zone of the Main thrust. Its western border is the juncture with the Watershed block, as noted above, is destroyed by the intrusion of the granodiorites of the Karaugom massif. The block is mainly represented by the Upper Proterozoic crystalline schists of the Kassar suite. Upper-Proterozoic formations of the Chanchakh suite are of less importance and the role of the Upper Paleozoic gray-colored molasse, tuffite-sandy and carbonate metamorphosed formations is quite insignificant. In the northern part of the block, the formations of the Middle Paleozoic granite-gneiss formation are predominant, while smaller bodies form eastern and southern edges. Magmatic formations, in addition to the above-mentioned granodiorites of the Karaugom and Tsey intrusions, are represented by their vein derivatives, as well as countless dikes of the Middle Jurassic gabbro-diabase formation (Digor volcanic-plutonic association). In the southern part, the block is complicated by sublatitudinal faults, and in its eastern part, the northeast fractures are widely developed. Structurally, a large part of the block is the Tsmiakom anticlinal fold, the south wing and the reclinal closure of which are complicated by large fault zones. The northern wing of the anticline is defined only in the extreme eastern part of the structure, where on the southern slopes of the Tsaduatin beam the northern wing, composed of Upper Permian marbles, passes into the southern wing of the Tsaduatin syncline, complicated by the Kolotin thrust. East of the Ardon-Bad watershed, the syncline and the north wing of the anticline are not traceable. The southern wing is complicated by the main thrust, in which the lenses and layers of marbles of the Permian period are located, has a steep (70–80°) fall to the north [27]. Alpine terrain and poor permeability limit the ability to investigate the block with the necessary completeness. Refinement of its structure, apparently, is possible only with the obtaining of additional factual material.

The described Taymazy-Labagom elevation is of considerable interest due to the fact that there is a direct contact of the Maker and Buulgen series rocks. Even a rough speculative bringing the surface of the uplift into a sub-horizontal position, approximately corresponding to the Pre-Lias one, shows that the formations of the Maker series lie on the Buulgen and that the Laboda-Karaugom-Tseydon tectonic zone separating these salic and mafic series is nothing more than a large thrust.

V. B) Shaukhokh-Darial Elevation

The elevation is located in the south-eastern part of the territory, where it covers the ridge and slopes of the Bokovoy Range. From the Taymazy-Labagom elevation, it is separated by a relatively wide (12 km) Kolotinsky cover. The Shaukhokh-Darial elevation consists of relatively large Shaukhokh and Darial massifs separated by the Chachsk cover. The Shaukhokh massif is located between the rivers Fiagdon and Gizeldon. An array from the north is bounded by the southwestern part of the Dzhimara-Godtanadag fault and Tsariit-Tsatadon uplift. Its southern border is represented by Syrhubarzond overthrust. The core part of the block is composed of sediments of Late Carboniferous molasses and Late Carboniferous-Early Permian tuffite-sandy and Late Permian carbonate metamorphized formations. They overlap with the formations of the early-lethal formation of meta-sandstones, quartzites, knotty and spotted shales, as well as of the average-low-slidded formation. The listed rocks are split by numerous dikes of the Middle Jurassic gabbro-diabase formation of the Kazbek complex. The base of the massif that is represented, as noted above, by Paleozoic formations, is exposed in tectonic wedge-shaped blocks and in the core of the Gizeldon anticline. The Gizeldon anticline is located in the valley of the river Midagrabyndon and stretches along it from the tongue of the glacier of the same name to the north for 3.5 km. Its width is from 1 km in the north to 2.5 km in the south. At the Lartsykom site, the core part of the fold extends to 4 km due to the “squeezing” of the marbled limestones of the Gizeldon Formation into the supposed cavity of an opening in the process of tectonic movements of the block. From the north and from the south, the anticline is terminated by the Chizhfandag-Scarons and Syrhubarzond faults, respectively. The Chizhfandag-Skaron reverse fault extends from the valley of the river Fiagdon to the origins of the river Tsatadon for about 15 km. The strike of the fault is sublatitudinal, the fall is steep (75–80°) southern. The southern block is fractured for about 0.5 km. From the south, the Syrhubarzond fault limits both the Gizeldon anticline and the entire Shaukhokh massif and can be traced from the valley of the river Fiagdon to the origins of the river Genaldon for 22 km. Reaching in the sublatitudinal direction, the fault arches toward the south. Its fall is subvertical, northern. It is represented by a series of contiguous discontinuities, forming a single disjunctive zone with a capacity of up to 50 m, in which blocks and plates of rocks of the Gizeldon and Midagrabyn formations are often clamped and “pulled apart”. The rift in the west and east is obviously flattening out and moving into thrust structures. However, the possibility of the overlaping of the Syrhubarzond fault by independent thrusts is not excluded. Along the fault, geological formations located to the south, move up under the Shaukhokh massif.

The Gizeldon anticline is a typical brachyfold of latitudinal orientation with the immersion of the axis in both directions with a relatively gentle (15–25°) angle. Its northern wing that is composed of the early Lias formation of metasandstone, quartzite, knotted and spotted shales, is torn by contact with the underlying Marbles of the Late Permian carbonate marbled formation and often the fall of the wing rocks does not correspond to the falls of the Paleozoic core. In general, core rocks have a general dip to the north with an angle of 45–50°. Falls of the Mesozoic wing rocks, as a rule, are steep (60–80°), often overturned to the north and often isoclinally crumpled. The southern wing of the anticline is torn off by faults.

Other outcrops of the Paleozoic basement of the Shaukhokh massif are tectonic blocks with monoclinally-occurring rocks, the fall of which is predominantly southern steep, rarely flat.

In general, the Shaukhokh massif is characterized by a block-folded structure with “broken” contacts between the suites, with a steep occurrence of faults dividing the massif into blocks and having, as a rule, a southern dip. A characteristic feature of the northern blocks of the massif is the wrinkle of the Mesozoic rocks in overturned and inclined folds with a wingspan of up to 400–500 m.

Along the Tsariit-Tsatadon fracture, rocks of the massif are pulled over to the sandy-clay deposits of the Cimmerian folding zone.

Darial massif occupies the extreme southeast corner of the described territory and is located in the valley of the river Terek. It is separated from the Shaukhokh massif by the Chachsk cover. From the north, the massif is bounded by Belorechensk, and from the south by the Gvilet faults. An array of rocks of the Middle Paleozoic granite-gneissic formation and formations of the early Lias formation of metasandstones, quartzites, knotty and spotty shales, and Middle Lias, slate formations are complex. The minor role is played by hornfelses, formed, presumably, by the rocks of the Midagrabyn suite. Granitogneisses and hornfelses form the crystalline base of the massif and form the North and South Darial blocks, as well as being exposed in the Gvilet-Kistin block. The rocks of the formation of meta sandstone, quartzite, knotty and spotted shale, combined into the Kist suite, form a peculiar cover of the Paleozoic core. Formations of the schist formation, including the Belorechensk suite, outline the rocks of the Kitsky Formation from the north. The width of the Darial massif along the valley of the r. Terek is 7 km, and the length within the described area is 20 km.

The main features of the rocks of the Kassar strata of the Central Elevation are the following: density and fine grain size; poorly developed crystallization shale and the prevalence of granoblastic, nematoblastic and lepidoblastic structures; well-defined relic lamination, underlined by the alternation of bands of different composition; the rarity of gradual transitions between rocks and the insignificance of diaphragmatic processes; one-stage metamorphism of rocks in the quartz-albite-epidote-almandine subfacies of the green shale facies of the metamorphic series.

The structural-material complex of the Central Elevation in the Proterozoic stage is characterized by the ultrametamorphism of volcanogenic and terrigenous rocks and the formation of the infrastructure and suprastructure constituting the fundamental principle of the crystalline basement of continental plates.

The Paleozoic stage in the Hercynian cycle of orogenesis was marked by the closure of the ocean and a collision with the East European continental plate of the Central Caucasus and Bechasyn microplate- terrains. Fragments of the Bechasyn microplate are represented by the Kassar suite and, apparently, the Vasakhokh-Donifar metabasites. As a result of the collision (the Breton, Prednamyur and Sudeten phases of the Hercynian cycle of orogenesis), the Main Ridge zone, the main Transcaucasian transverse rise zone, uptake of granitoids and the formation of powerful tectonic covers formed by rocks of the Maker series, ophiolites and island-arc complexes [28, 29]. Presumably, the Pfalsk and Labinsk phases of orogenesis are responsible for the tectonic contact of the rocks of the Buron suite (the Maker series) with the metamorphic formations of the Kassar suite (the Buulgen series) and its granitized differences. The destruction of the mountain system led at the end of the Paleozoic to a peneplenization of a region in which terrigenous-carbonate and carbonate sediments were accumulated in shallow marine and lagoon conditions. As a result, the pre-Jurassic crystalline basement of the Greater Caucasus is being formed.

VI. Mamison-Kazbek Relic Scar

Mamison-Kazbek relic scar or geo-suture is the tectonic expression of the collision zone, usually containing ophiolites, metamorphic rocks of high pressure and tectonic mélange. It is an indication of a previously existing and subsequently closed marine basin. The zone has a regional all-Caucasian value and can be traced for about 550 km.

In the eastern part of the Central Caucasus, the Mamison-Kazbek relic scar extends from the Mamison Pass in the west to the Maili-Kazbek mountain range in the east. Geo-suture is limited to fault zones in the north of the Main thrust, Kolotinsky, Syrhubarzond, Kaidzhan and Gvilet, and in the south - Adaykom-Kazbek and Tsey.

The Adaykom-Kazbek fault plays the role of a peculiar barrier for Mesozoic igneous occurrences, which are widely developed north of the fault. Mesozoic igneous occurrences are completely absent to the south of this fault. The geological formations located to the south move up along this fracture under the Mamison-Kazbek geo-suture. A relict scar is filled with the rocks of the Arnag and Cyclaur formations, transformed in the process of subduction of the oceanic bottom and, especially, the collisions of continental plates, into a chaotic complex or mixtite.

The geo-suture is made of tectonized terrigenous material containing blocks of different size and blocks of volcanic-sedimentary rocks and remobilized olistostromes of the ophiolite complex. At the same time, in varying degrees, serpentinized picrites, never occurring without andesite-basalt or diabase membrane (Kliatkom, Arsikom, Midagrabyn), fit well into the scheme of the process of diapirism, which took place at the first stage of tectonic mobilization of ophiolites. A minor role in the structure of the Mamison-Kazbek zone belongs to the subintrusive formations of the Pliocene diorite formation.

The movement of relict scar rocks under the crystalline basement located to the north of the continental plate, in which all researchers agree, sedimentary-volcanogenic formations can probably be partially subducted along with the “absorbed” plate. The excess part of the rocks is “pressed” between continental plates, forming here a kind of pillow, and advancing on the edge of the northern plate in the form of tectonic plates or covers in areas favorable for this process.

Depending on the conditions of occurrence of rocks in the Mamison-Kazbek geo-suture, Bubudon-Lyadon, Midagrabyn-Maili and Kurov tectonized intervals and, separating them Kolotinsky and Chachsky covers are distinguished.

The tectonized intervals are in the rear parts of the Taymazy-Labogom uplift and the Shaukhokh and Darial massifs, which, ultimately, were peculiar thresholds for sedimentary strata moving from the south. The latter, “resting” on these thresholds, were crushed, folded, shattered, cataclassed and melonitized. They acquired a subvertical inverted bedding parallel to the fault planes that bound these thresholds from the south. Unfortunately, the lack of specialized observations makes it impossible to judge the scale of tectonic changes of rocks in the zone. From the available data, it is still possible to conclude the possible predominance of weakly tectonized or unchanged rocks over matrix tectonite. In general, for Bubudon-Lyadon, Midagrabyn-Maili and Kurov intervals, plicative forms are not characteristic. The rare folds found here do not exceed the first tens of meters in amplitude and only a few reach 150–300 m. The axial planes of the folds, as a rule, fall to the north. The strike of their axes is sublatitudinal (260–280°).

The Kolotinsky and Kaidzhan tectonic covers are located in areas where the blocks of the Central Elevation are apparently submerged. Despite the lack of direct facts about the structure of the edge of the northern plate as a whole, it is noted:

• a flood-like, prominent to the north form of the areas of volcanic-sedimentary rocks development in the interfluves of Baddon-Fiagdon and Genaldon-Terek;

• clearly thrusting character of occurrence in the northern parts of these areas of volcanic-sedimentary rocks that is mapped on the watershed ridges of Archondon-Kaydon, Tsaziudon-Fiagdon, and Genaldon-Terek;

• more gently sloping, in general, the occurrence of rocks with a flattening, in some places, up to 40° and less;

• wide development of plicative dislocations with a predominance of compressed isoclinal folding in the southern parts, and heteroclinal and brachiform structures in the northern parts. The amplitude of the horizontal movement of the Kolotoin cover reaches 7 km, and the Kaidzhan area - 4 km.

The Kaidzhan cover is an overthrust fault. Three southern scales are composed of relict scar rocks and, according to the Chachsk thrust, they are pulled over deposits of the Kistin and Belorechensk formations of the Darial Massif.

In the Mamison-Kazbek relic scar, in terms of the composition of igneous rocks and in terms of their saturation, three types of olistostrom are distinguished [2]. The first type is represented by relatively small clumps of gabbroids, located without visible orientation in the thin peperite clay- aleurolitic matrix. Relatively large blocks composed of 70–80% parallel dykes of diabases and gabbro-diabases, often silicified and intensively pyrrhotinized, are related to the second type of olistostrom.

The third type of olistostrom includes blocks composed of frequent layer-by-layer interlaying shale with sills and flows of gabbroids and andesite-basalt, as well as blocks completely composed of these igneous rocks. The peculiarity of these olistoblocks is that the igneous rocks in them are represented mainly by effusive facies, which is characterized by spherical separation. Subintrusive formations in these olistoblocks are rare and are represented by single dykes of diabase composition.

Chaotic complexes of sedimentary and tectonic origin are indicators of geo-morphologically and structurally contrasting tectonic zones [30]. Melanges mark the placement of ophiolitic and unfiltered seams, rendezvous and collision of lithospheric plates, microplates, terrains, and blocks. Chaotic complexes of sedimentary origin of olistostrome indicate the location of underwater ledges and slopes, which distribute geodynamically diverse sedimentation basins.

The alternating geodynamic settings of the Wilson cycle at the site of the future structure of the Greater Caucasus were created by the interaction of two lithospheric plates - the Scythian continental and southern (Transcaucasian) microcontinent - terrain, and the suture zone (suture) between them. The Early Mesozoic stage begins, apparently, with the rise of the mantle diapir in the Labinsk orogenic phase, which led to the establishment of conditions for stretching and, as a consequence, to the activation of volcanism in the initial stages of rifting (Adaykom Andesite-Basalt Horizon). The continued opening of the rift and its transformation into the ocean basin is accompanied by intense basaltoid magmatism (Fiagdon volcano-plutonic complex). In the early Cimmerian orogenic phase, the tension conditions are changed by compression conditions. The contraction of the ocean basin begins. An absorption zone is formed along the southern edge of the Scythian plate, along which the oceanic plate moves under it. After the plunging oceanic plate reaches a depth of about 150 km or more the pressure-temperature conditions were created in the base of the Scythian plate to generate calc-alkaline magma in the marginal part of the Scythian continent, at the end of the lower Lias andezidacite volcanism erupted, intensively flowing through almost the entire Lias (Sadon suite). Attenuation of volcanic activity at the beginning of the Domer led to a cooling of the southern edge of the Scythian plate and, as a result, to the expansion of the marine transgression that captures more inland areas of the continent. By the end of the Lias, there is established a relatively stable regime of the epicontinental sea (the Greater Caucasus basin), in which the terrigenous strata of the Mizur, Galician and stratigraphically overlying formations accumulate. In the south-facing and declining oceanic basin, basaltoid volcanism ceased with the establishment of compression conditions and in the middle and upper Lias epoch, amagmatic stratum of shale from the upper sub-suite of the Cyclaur suite accumulates there. As a result of incessant subduction at the end of the bayos, the South (Transcaucasian) microplate, the terrane, faces the southern edge of the Scythian plate. There is closure in this part of the ocean basin and the formation of the Small Caucasus microplate. The geodynamic setting of the collision caused the separation of the southern edge of the Scythian Plate into shol (“the shol tectonics” according to J. Dewey and A. Senghor from the German Scholl - a piece of land), i.e. microplates and microblocks interleaved by the intracrustal horizons of the asthenosphere, and intense pain tectonics with humming, crowding, rotation and crushing of sholi, as well as with the formation of wedge-shaped zones of stretching - minishenochasms, accompanied, as a rule, by basaltoid effusions (Khod anamides). Apparently, during this period, activation of Middle Jurassic magmatism occurs with the introduction of massifs, rods, and dykes of the subintrusive and intrusive facies of the gabbro-diotrit-granodiorite formation along numerous fault zones. The latter is supposed to be genetically connected with the lead-zinc mineralization of Mountainous Ossetia, which placement in space is controlled by structures of sphenochasms (with the exception of the Kadat-Khanikom ore zones). In this orogenic phase, the tendency to the elevation of the main Transcaucasian transverse uplift is intensified. As a result, a mountain system has emerged in the Central Caucasus. The oceanic basin closed in the south was transformed into a narrow suture zone, made by a melange of tectonized oceanic rocks and ophiolite olistostromes of various sizes.

VII. Conclusion

The structural-material complex of the Vladikavkaz Basin is an indicator of the collisional era of development, the destruction and movement of blocks due to the advance of the Arabian protrusion deep into Eurasia, characterized by an outbreak of volcanism mainly andesitic composition. Orogenesis is characterized by the formation of ridges and intermontane depressions. Intrusive activity is characterized by low level.

Structural and facial elements of the Cimmerian folding indicate development in the conditions of a collision of the southern microcontinent with the active continental margin of the Scythian plate, with the collisional period ending. A subduction zone is formed to the south of the adjacent microcontinent and the formation of the Lesser Caucasian volcanic arc occurs. Sedimentation takes place in an epicontinental sea basin. Sedimentary complexes are shaped by knotty shale, meta sandstone and, quartzite. The interaction of the continental margin with the oceanic plate and the opening of the ocean basin associated with the spreading of basaltoid volcanism begins.

The Central Elevation Complex in the Proterozoic stage is characterized by the ultrametamorphism of volcanogenic and terrigenous rocks and the formation of infrastructure and suprastructure, which are the primary basis of the crystalline basement of continental plates. The Paleozoic stage in the Hercynian cycle of orogenesis was marked by the closure of the ocean and a collision with the East European continental plate of the Central Caucasus and Bechasyn microplate-terranes. As a result of the collision, the introduction of granitoids and the formation of powerful tectonic covers formed by rocks of the Maker series, ophiolites and island arc complexes occur. The destruction of the mountain system leads at the end of the Paleozoic to a peneplenization of a region in which terrigenous-carbonate and carbonate sediments accumulate in shallow marine and lagoon conditions. As a result, the pre-Jurassic crystalline basement of the Greater Caucasus is being formed.

The Mamison-Kazbek relic scar complex seems to be the most convincing indicator of the collision zone in terms of the characteristic content of ophiolites, high-pressure metamorphic rocks and, tectonic melange. It is confirmatory evidence of the previously existing and subsequently closed sea basin.

References

[1] S.V. Aplonov, “Geodynamics,” Saint Petersburg State University, 2001, pp. 124-128.

[2] V.P. Parnachyov, “Fundamentals of geodynamic analysis,” Tomsk: NTL, 2014, pp. 243-277.

[3] L.I. Lobkovskij, “Geodynamics of spreading and subduction zones and two-tier plate tectonics,” Moscow: Nauka, 1988, p. 251.

[4] L.P. Zonenshajn, M.I. Kuz'min, and L.M. Natapov, “Tectonics of lithospheric plates in the USSR, Book 2,” Moscow: Nedra, 1990, pp. 168-175.

[5] O.G. Sorohtin and S.A. Ushakov, “Nature of Earth's tectonic activity,” Findings of science and engineering. Series Physics of the Earth, vol. 12, p. 151, 1993.

[6] R.R. Feynman, R.V. Lejton, and M. Sends, “Feynman lectures in physics. Physics of continuous media,” vol. 7, Moscow: Mir, 1966, pp. 7-23.

[7] S.V. Aplonov, “Geophysical analysis of the evolution of the lithosphere,” Saint Petersburg State University, 1998, pp. 75-77.

[8] Yu.M. Pushcharovskij, “Seismotomography, tectonics and deep geodynamics,” RAN reports, vol. 360, pp. 518-522, 1998.

[9] D.N. Chistyakov, V.V. Russ, D.A. Kirikov, E.N. Yanov, A.P. Kropachev, E.S. Kutejnikov, N.B. Dortman, A.K. Hudolej, S.P. Tihomirov, A.M. Zanin, G.A. Gur'ev, R.B. Umitbaev, V.A. Unksov, A.L. Konovalov, and E.A. Borkovaya, “Typical conventions for tectonic maps,” Moscow, 1997, pp. 9-12.

[10] V.E. Hain and M.G. Lomize, “Geotectonics with the basics of geodynamics,” Moscow: Knizhnyj dom, 2005, p. 560.

[11] E.E. Milanovskij and V.E. Hain, “Geological structure of the Caucasus,” Moscow State University, 1963, pp. 222-296.

[12] A.G. Shempelev, S.U. Kuhmazov, Kh.O. Chotchaev, and L.N. Nevskii, “The structure of the Greater Caucasus is the result of the flat slope of the earth's crust of the Scythian Plate on the consolidated crust of the microplates of the South Caucasus,” Geology and Geophysics of the South of Russia, vol. 4, pp. 129-146, 2015.

[13] A.G. Shempelev, V.B. Zaalishvili, and S.U. Kukhmazov, “Deep structure of the western part of the Central Caucasus from geophysical data,” Geotectonics, vol. 51, pp. 479-488, 2017.

[14] V.B. Zaalishvili, N.I. Nevskaya, L.N. Nevskii, and A.G. Shempelev, “Geophysical fields above volcanic edifices in the North Caucasus,” Journal Of Volcanology And Seismology, vol. 9, pp. 333-338, 2015.

[15] A.A. Steklov, “Terrestrial mollusks of the Neogene of the Pre-Caucasus and their stratigraphic significance,” Moscow State University, 1963.

[16] Kh.O. Chotchaev, V.B. Zaalishvili, L.N. Nevskii, and A.G. Shempelev, “Geomorphology as a sign of heredity of the structural features of the Earth's crust,” Geology and Geophysics of the South of Russia, vol. 1, pp. 141-158, 2016.

[17] A.N. Ovsyuchenko, A.V. Marahanov, S.S. Novikov, and E.A. Rogozhin, “Zone of the Vladikavkaz active fault on the territory of the RNO-A,” Bulletin of Vladikavkaz Scientific Centre, vol. 8, pp. 44-56, 2008.

[18] G.V. Krasnopevceva, “The deep structure of the Caucasian seismically active region,” Moscow: Nauka, 1984, p. 107.

[19] A.V. Gorbatikov, E.A. Rogozhin, M.Y. Stepanova, Y.V. Kharazova, N.V. Andreeva, F.V. Perederin, V.B. Zaalishvili, D.A. Melkov, B.V. Dzeranov, B.A. Dzeboev, and A.F. Gabaraev, “The pattern of deep structure and recent tectonics of the Greater Caucasus in the Ossetian sector from the complex geophysical data,” Izvestiya, Physics of the Solid Earth, vol. 51, pp. 26-37, 2015.

[20] V. Zaalishvili, D. Melkov, A. Kanukov, and B. Dzeranov, “Spectral-temporal features of seismic loadings on the basis of strong motion wavelet database,” International Journal of Geomate, vol. 19, pp. 1656-1661, 2016.

[21] V.B. Zaalishvili and E.A. Rogozhin, “Assessment of seismic hazard of territory on basis of modern methods of detailed Zoning And Seismic Microzonation,” Open Construction and Building Technology Journal, vol. 5, pp. 30-40, 2011.

[22] N.V. Koronovskij, “Geodynamic setting of Cenozoic volcanism in the Caucasus and in the alpine fold belt,” Moscow: Nauka, 1982, p. 47.

[23] V.B. Zaalishvili, O.G. Burdzieva, and A.K. Dzhgamadze, “Geothermal waters of North Ossetia,” Ecology, Environment and Conservation, vol. 21, No. 5, pp. 151-155, 2015.

[24] V.B. Zaalishvili and D.A. Mel'kov, “Reconstructing the Kolka surge on September 20, 2002 from the instrumental seismic data,” Izvestiya-Physics of the Solid Earth, vol. 50, pp. 707-718, 2014.

[25] K.K. Khulelidze, Yu.I. Kondratiev, V.B. Zaalishvili, and Z.S. Bertorozov, “Assessment of indigenous and technogenic deposits of RNO-Alania as possible objects of application of technology of underground and heap leaching,” Sustainable development of mountain territories, vol. 8, pp. 46-51, 2016.

[26] O.G. Burdzieva, V.B. Zaalishvili, O.G. Beriev, A.S. Kanukov, and M.V. Maisuradze, “Mining impact on environment on the North Ossetian territory,” International Journal of Geomate, vol. 10, pp. 1693-1697, 2016.

[27] A.G. Shempelev, Kh.O. Chotchaev, and S.U. Kuhmazov, “Data from deep geophysical surveys along the Chegem profile (Central bloc, Greater Caucasus),” Geology and Geophysics of the South of Russia, vol. 2, pp. 129-134, 2017.

[28] G.I. Baranov, “Pre-hercinian structure of the Greater Caucasus,” Abstracts of VII Conference on Geology and Minerals of the North Caucasus, Essentuki, pp. 104-106, 1991.

[29] G.I. Baranov, “Geodynamic development of the Greater Caucasus in the Paleozoic. The main problems of geological study and use of the subsoil of the North Caucasus,” Materials of VIII Conference on Geology and Minerals of the North Caucasus, Essentuki, pp. 54-56, 1995.

[30] S.S. Shults, Sh.E. Ergashev, and V.A. Gvozdev, “Geodynamic reconstructions,” Leningrad: Nedra, 1991, p. 144.