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Geology

Geological and Geomorfological Investigations of the Javakheti Plateau (South Georgia)

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ABSTRACT. In the article the territory of transport corridor on the Javakheti volcanic plateau (South Georgia) with its geological and geomorphologic structure and association of relief forms with young volcanism is considered. Neotectonic and morphotectonic structures, volcanic centers and modern exodynamic processes established by us in the region are characterized there. Volcanic activity in the study region was connected with interzonal and intrazonal deep faults. Volcanism was of subaerial type. Acid volcanism of Mio-Pliocene (Goderdzi suit) was replaced by heavy outpourings of basic lava in the Eopleistocene. Vast volcanic plateaus (sheets), stratovolcanoes and numerous small volcanic centers, extrusive cons, were formed. Among the outbursts of pulsation of volcanoes at the separate areas of land compensated troughs were formed in the lake basins. The second cycle that started, according to numerous isotopic, paleomagnetic and biostratigraphic evidence, about 3.5 Ma ago is characterized by outflow of huge masses of mafic lavas which formed extensive basaltic plateaus in South Georgia, West Armenia and East Anatolia. The centers of these basalts were mainly shield-shaped volcanoes of relative altitude 100-300 m. The most complete sections number up to 30 individual flows (5-15 m thick), with total thickness reaching 250-300 m. The uppermost flows are radiologically dated at 1.8-2.0Ma indicating their Eopleistocene age. Eopleistocene volcanism finished the relief planation in the areas of its spreading.

Key words: Goderdzi suit, Quaternary age, Eopleistocene, basaltic lava, volcanic cones

Increasing scopes of international cooperation has given possibilities of effective use of the South Caucasus and in particular Georgia, situated at the intersection of the East-West and North-South transport corridor connecting different regions of the Eurasian continent. Developing new transport corridor will undoubtedly result in the intensification of construction of industrial and civilian objects and corresponding infrastructure in the zone. Transport corridor (railways, highways, product and power mains) and all accompanying industrial and civilian objects must be constructed in such a manner to reduce possible risk caused by natural geodynamic processes.

The territory of Javakheti plateau comprises considerable part of the volcanic highlands of Eastern Anatolia and South Georgia. In the formation of the present-day relief and geological structure of these highland the main role belongs to neotectonic movements and associated with them intensive effusive subaerial volcanism – its products cover the greater part of the vast region. Geological units exposed within the study area consist of Upper Tertiary (Mio-Pliocene) volcanogenic continental rocks (tuff, tuff-breccia, tuff-conglomerate, etc) and overlaying Quaternary basaltic and andesite-basaltic lava flows that form the slightly undulated surface of the Kars and Akhalkalaki plateaus. The volcanic rocks with total thickness exceeding 1000 m unconformably overlie Paleogene-Cretaceous and older formations that are not exposed within the study area.

The geology of the Javakheti highland (within the limits of the study area) consists of Neogen-Quaternary continental (subaerial) volcanogenic formations. Lithologically, piroclastic rocks and lava flows of dacitic, andesite-dacitic, andesite-basaltic and basaltic composition represent them. These volcanic rocks unconformably overlie intensely deformed marine Paleogene and Cretaceous sediments that form the sublava substratum exposed locally in the Mtkvari River gorge and encountered in some drill holes (in the villages Khertvisi and Nakalakevi).

Outcrops of the volcanic rocks of the Goderdzi suite (Mio-Plioene) are observed in the western peripheral part of the Nialiskuri ridge (in the locality Sakun); here they are represented by tuff-breccias, tuff-conglomerates and tuffs with interformational flows of andesite-dacitic lava. Visible thickness of pyroclastic rocks reaches 300-400m. The suite is terminated by andesite-dacitic and dacitic lavas (Lower Pliocene) that are widespread over the whole volcanic province of South Georgia and Eastern Anatolia. These lavas are exposed on the northern slope of the Nialiskuri (Geoktape) ridge, south of the Kartsakhi Lake. In andesites a well expressed stratification of rocks is observed, they are presented by alternating parallel lava planes with thicknesses ranging from 1-5cm to 10-30cm. Strike of bedding is sublatitudinal (azm. 260-270°), they are dipping north under the angle of 25-40°. In some exposures the zones of increased jointing are observed; they are 1m thick and have a northwest strike (azm.315-320°) and southwest dip at an angle of 45-60°. To the north and east they are covered by younger lavas of the Akhalkalaki plateau and are exposed only in some erosion gorges of the rivers Kodala, Zagranichnaia etc.

Nearly all the remaining part of the study area, including the northern slopes of the Nialiskuri ridge, is covered by basaltic and andesite-basaltic lavas of the Akhalkalaki suite (Eopleistocene). Similar lavas are widely developed in Turkey in the Kars region. The absolute age of these rocks according to the latest date, ranges between 2.5-0.8 Ma [1,2]. Petrographically, among the lavas of the Akhalkalaki suite, dominate olivine dolerites covering considerable part of the study area. They are developed around Akhalkalaki, Diliska, Kulalisi and also cover the Murakvali and Azmana ridges. From the village Dilifi to Akhalkalaki 3-5m thick alluvial-lacustrine sediments overlie these lavas. In the canyons of the rivers Dilifi (Kirkhbulakh) and Paravani one can observe 2-3 flows of olivine dolerites, each 3-5m thick. The flows are separated from one another by slaggy contact beds, 0.5-1.0 m thick.

Olivine dolerites are developed around the volcano (v) Kartsakhi (Ker-Ogly, 2213m) on the Murakvali ridge. Here, in outcrops occur several 1.5-2.0 m thick flows of dolerites; they are represented by dark-grey macroporous, full-crystalline rocks, inclined to southeast at an angle of <15-20°. The mount Kartsakhi is a typical polygenic volcano that at first erupted andesite-basalts and basalts and their breccias, and at the final stage - olivine dolerites. Besides the Kartsakhi volcano, there are some other volcanic centers in the axial zone of the Murakvali ridge that also produced olivine doleritic lavas.

A special interest represents 2 volcanic centers located 4 km northwest of the railway line Mzechabuki

(Didi Giuney – 2060m) and Mzekala (Patara Giuney – 2034m). The dome-shaped uplifts, with diameter at the base reaching 2-2.5km and relative height of 200-250m, rise sharply above the surrounding territory. They are composed of tuff and scoria breccias, volcanic bombs and sands. Dark-grey fine-crystalline basaltic lavas cover this clastic material. Such lavas are widely developed south of village Vachiani, in the vicinity of villages Patara-Gondrio, Dadeshi, Sulda, Bozali and Filipovka. South of Dilifi, these fine-grained basalts and dolerites overlie the erosion surface of andesite-dacitic and dacitic lavas of the Goderdzi suite.

In the closeness to the designed railway there are several other volcanic centers – two-headed Tsmindamta (Surp-Sar - 2001m), Kvatsihe (Tash-Kala – 1983m) and Dadeshi (2021m). These cone-shaped uplifts are built up of thick beds of red breccias containing fragments of pumice, scoria, lapilli, sand and fine-grained doleritic lava. Dark-grey basalts and dolerites cover the tops of these volcanoes.

Olivine dolerites and basalts in the central part of the Akhalkalaki plateau are overlain by thick lacustrine-alluvial sediments covering area more than 50 km in the visinities of Akhalkalaki, Vachiani, Martuni, Khospio and Mamtsvara. Most likely the greater part of these deposits has already been eroded as the pebble material is observed over the whole plateau in a form of well-rounded pebbles and boulders scattered in soil and diluvial beds. Maximum thickness of these lacustrine-alluvial sediments reach near the village Diliska - 6-7m. Southwards and westwards their thickness decreases and does not exceed 1-1.5m.

Younger volcanic rocks of Quaternary age are developed on the eastern shore of the Kartsakhi Lake and the northern slope of the Nialiskuri (Gektape) ridge. They are represented by andesite-basaltic flows and their pyroclasts and breccias. Volcanic centers producing these rocks are well preserved in the present-day relief. Most of them are located on the slopes of the Nialiskuri ridge. In all, three lava flows of total thickness up to 30m can be distinguished; small scarps separate them from one another. The uneven undulated surface formed by these lavas is characteristic of young volcanic formations.

Thus within the study area there is a great number (several dozens) of volcanic centers of Late Neogene and Eopleistocene age. Nearly all of them are located along definite lines that, most probably, correspond to faults and fault zones in the sublava substratum. Volcanic activity was of the aerial type and occurred in several phases of eruption separated by periods of relative calm that is evidenced by accumulation of inter-lava alluvium and lacustrine sequences.

The territory of transport corridor in the Javakheti, along the southwestern part of the Akhalkalaki lava plateau also embrace northern slopes of the Nialiskuri (Geoktape) ridge extending in sublatitudinal (W-E) direction. The Akhalkalaki plateau is a slightly undulating high-mountainous plain gently sloping to the north. Minimal elevations of the plateau within the study area are observed near the village of Kulalisi (1770-1800m), maximum elevations – at the foot of the Nialiskuri ridge - 2000m. The ridge rises above the surface of the plateau at 400-500 m with many summits reaching 2400-2500m (the highest summit of the Nialiskuri ridge located to the east of the study area exceeds 2800m).

The generally gentle sloping of the surface of the plateau along the line of the railway is disturbed in several places by scarps (**I**), well reflected in the relief and extending in NW-SE direction. One of them, of relative elevation up to 25-30m, extends between the v. Mzekala, in the northwest and the village of Dadeshi in the southeast. North of this scarp, the surface of the plateau has elevations ranging from 1750 to1900m and is covered by doleritic lavas. On this surface there are several volcanic domes – Tsmindamta (Surp-Sar 2001m), Okami (1896m) etc. Volcano Tsmindamta located 8 km west of the village Kulalisi is composed of two scoria cones situated at a distance of 0,5km from each other and covered by lavas. Relative altitude of these cones is 180-200m. The lava flows go

down from the centre approximately at a distance of 3km, forming gentle slopes radially descending from its head. The railway bed passes on the southeastern slope of a subordinate volcano at a distance of about 1 km.

Volcano Okami (1896m) is situated 4.5km west of v. Tsmindamta. It is built of red scoria covered by basaltic lavas. Relative height of the volcano is 50-70m. In plan it is a horseshoe-shaped. In the ridge zone is distinctly alienated a crater-like low. Westward and northward moving lava flows are well expressed morphologically. On the eastern slope of the volcano there is a large quarry providing scoria and pumice used for construction of roads, buildings and other needs.

Another scarp (**II**) oriented in NW-SE direction, runs at a distance of 5-6 km to the SW of the first. The scarp, of a relative height 30-50 m, has a very strong morphological evidence of recent activity. Between the villages of Myasnikiani, Sulda and Bozali, at the foot of the scarp, there is a large, now dry lake, most probably of dammed origin. Such impounded lakes are generally characteristic of tectonic that mark the traces of rising active linear faults. The average elevation of the plateau between the above scarps is 1900-2000m. In this part of the plateau there are several v. Mzechabuki (2060m), Mzekala(2035m), Kvatsihe (1983m), Dzrohisi (Iniak-2139m), Dadeshi (2021m) and some others. Lavas produced by these volcanoes form the surface of these morphotectonic steps, which between the villages of Bozali and Sulda is cut by a network of ravines and gullies. The largest of them is a gorge of the river Kodala that flows from the axial zone of the Nialiskuri ridge.

In the south of the village Bozali the third (**III**) morphological level covered by basaltic and andesite-basaltic lavas is developed. The scarps relative height is 150-200m. The uneven undulated surface of this level has absolute elevations 2000-2200m gradually passing into the slopes of the Nialiskuri ridge. In the northwest the Murakvali anticline range extending in SW-NE direction bounds it. The range is of an asymmetrical structure, with steep NW slope and gentler SE slope. The Murakvali range has a relative elevation 200-300m above the surrounding area. In its axial part there are several volcanic centers – Karsakhi (2213m), Dafnia (2123m), etc.

The southern part of the study area is occupied by the Nialiskuri ridge; along its axial zone runs the Turkish-Georgian Frontier. Its northern slopes are intensely eroded and dissected by a dense network of river valleys, ravines and gorges. In the axial part of the ridge there is a great number of central volcanoes, while on the slopes parasitic volcanic centers are developed. It is assumed that along the crest of the ridge a large lineament extends that controls volcanic activity in the Mio-Pliocene and Anthropogenic (Quaternary period). The core of the ridge is made up of gently dislocated tuffaceous and lava formations of the Goderdzi suite (known in Turkey as Bingol and in Armenia as Vokhchaberd suits). These rocks are exposed in the vicinity of the locality Sakun in the western part of the Nialiskuri ridge. It is probable that in this area constructing of more then 3km long railvway tunnel is planned. Between the Murakvali and Nialiskuri ridges a syncline depression is situated; at present it is occupied by the Kartsakhi lake with its flat, locally swamped shores. The Kartsakhi depression is elongated in SW-NE direction, coinciding with the strike of the surrounding mountain ridges. Leaving the watershed area of the Nialiskuri ridge the railway runs along the southeast margin of the depression (2000m), crossing in its route about 20 erosion ravine forms of relief.

Amongst the recent geological processes developed in this part of the railway the most common are processes of thermal and physical weathering, rock falls and rock flows especially characteristic of the northern slopes of the Nialiskuri ridge.

Tectonically, the study area is situated within the two main structural units of the territory of Georgia – the Artvin-Bolnisi block and the Loki-Karabakhi fold zone. The former is considered to be an area of pre-Alpine consolidation; the letter is commonly regarded

as a zone of Early Alpine tectogenesis. The boundary between the Artvin-Bolnisi block and the Loki-Karabakhian zone is the deep-seated Loki-Agdam fault that passes along the crest of the Nialiskuri ridge [3,4]. To the east, the fault extends to the territory of Azerbaijan; to the west it can be traced in Turkey, where it represents a branch of the large North Anatolian fault zone.

The greater part of the study area is located within the Artvin-Bolnisi block. The structure of the lower part of the volcanogenic complex (tuffs, tuff-breccias of the Goderdzi suite of Mio-Pliocene) can be studied in detail in the west of the study area, in the canyon of the Mtkvari River. Here, the volcanic rocks of the Goderdzi suite are deformed in a series of WSW-ENE-striking wide and gentle anticlinar and synclinal folds. Intensity of the compression of these folds decreases from north to south, and near the Turkish frontier the beds of the Goderdzi suite from a gently dipping (10-15°) monocline inclined to the south. Several small-amplitude faults complicate the structure of the suite; the largest of them is a normal fault near the medieval cave town of Vardzia with a downthrown northern limb. The slip along this fault reaches 35-40m. Fold-forming processes within the Akhalkalaki highland practically were not manifested. Only in some areas over the ruptures small flexure-like fault-propogation folds occur.

The formation of the fold structures of the Goderdzi suite was completed by Late Pliocene time since they are unconformably overlain by nearly undeformed horizontally occurring basaltic lavas of the Akhalkalaki suite. By this time, most likely, look place the formation of the Samsari, Javakheti ridges and many other faults took place that cut the territory of Sout Georgia volkanic highland into a number of crustal blocks and condition the present-day morphotectonic setting and seismicity of the region. Linear alignment of volcanic centers and cones along certain lines together with morphological features enables us to imply the presence of dense network of faults of N-S, NW-SE and NE-SW orientation.

Tectonic movements of the Quaternary time had predominantly vertical block character and were responsible for the complication of generally flat surface of basaltic plateaus with various geomorphic forms such as tectonic scarps, anticlinal ridges, sag ponds, etc. In addition to the above-mentioned tectonic scarps directly crossing the rout of the railway, below is introduced the description of some most considerable Quaternary tectonic structures although located outside, but in close to, the line of the designed railway. The largest of them is the **Murakvali** anticline in the south-westernmost part of the Javakheti highland. 15 km long and 3.5 km wide ridge extends in SW-NE direction, its southwestern termination being located in the territory of Turkey. Made up of doleritic basalts, this ridge raises more than 350m above the surrounding depressions. The ridge is noticeably asymmetric, with steep north-west (20°) and gentle south-east (5°) slopes. The SE slope is complicated with a large volcano Kartsachi that is one of the centers of basaltic lavas of the Akhalkalaki suite.

The **Azmana** ridge located directly north of the Murakvali ridge, being separated from the letter by a narrow and deep syncline occupied by the river Kodala. By its structure, the Azmana ridge is a typical brachianticline, 8 km long, 2 km wide and a relative height of about 180 m. Its configuration resembles the Murakvali ridge expressed in a combination of relatively steep (about 20°) northern and gentle (5-8°) southern limbs. In its axial part and eastern termination, there are several volcanic cones – Mzechabuki, Mzekala, nameless volcano (1951m) and others that produced basaltic and andesite-basaltic lavas covering the Akhalkalaki plateau (Fig.1).

The **Khanjali** anticlinal ridge is situated east of the study area, in southeast part of the Akhalkalaki plateau, 2 km south of the settlement of Ninotsminda (Bogdanovka). In its eastern part the ridge extends in E-W direction, which in the west of the village of Mamtsvara abruptly changes into southwestern trend; thus, the ridge has an arcuate northward-con-

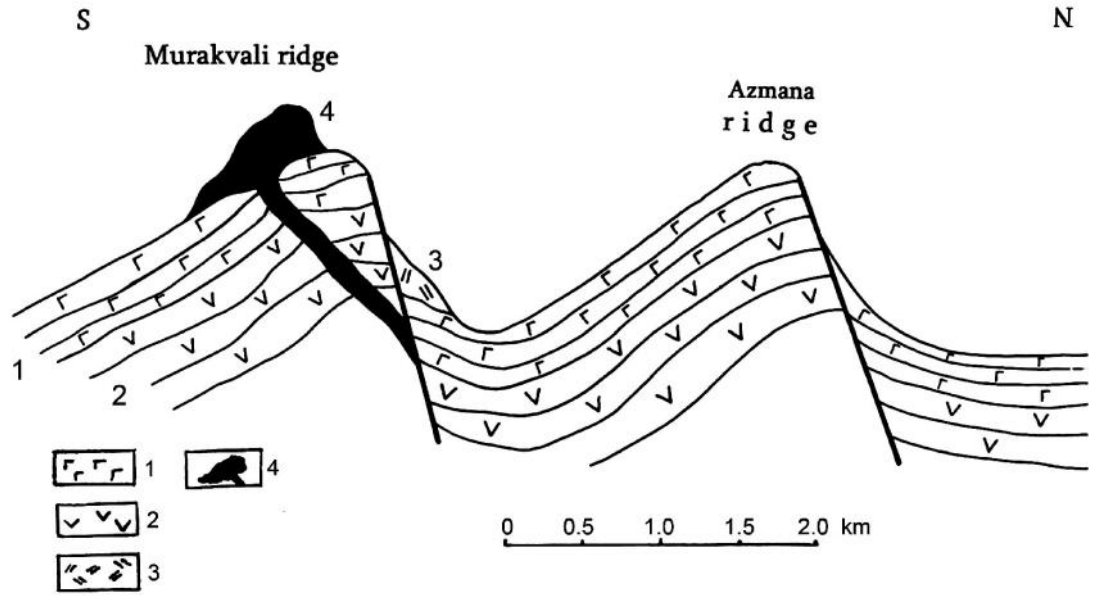

Fig. 1. Schematic geological section of Murakvali and Azmana morphostructures.
1 – Lower Pleistocene dolerites; 2. – Eopleistocene basalts;
3 – Deluvial deposits; 4 – Volcano Kartsakhi.

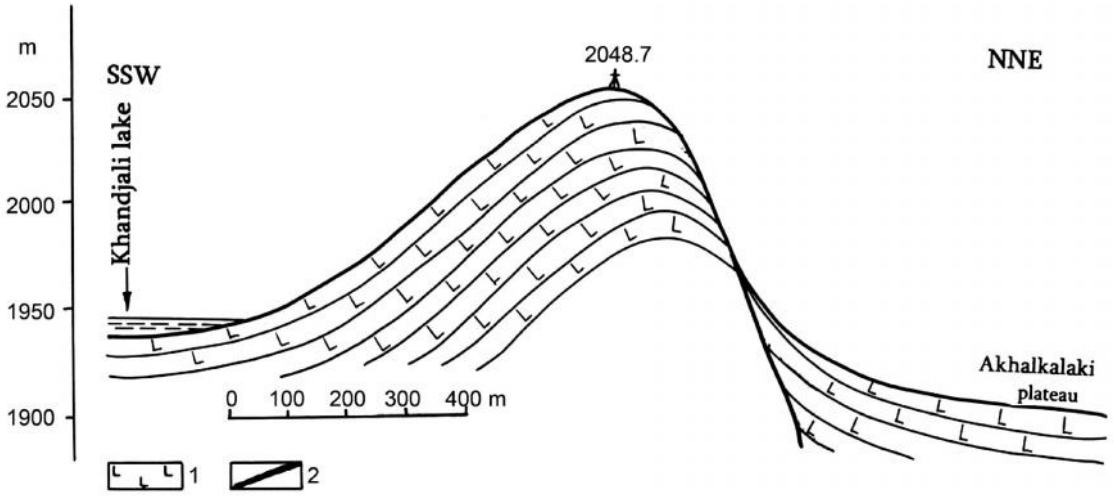

Fig. 2. Schematic geological section of Khandjali morphostructures.
1 – Eopleistocene dolerites; 2 – Fault Line.

vex configuration, 8 km long and 3-4 km wide (Fig.2).

Basaltic flows that form the Khanjali ridge are dipping in the south slope at an angle of 5-7° gradually passing into the bottom of a lake that now is almost completely dried up. The northern slope, near the crest, is considerably steeper (up to 30-35°), but somewhat below, it experiences an abrupt flattening (down to 10-12°) with well-expressed morphological step that is clearly observed along the whole extension of the ridge. This distinct break in relief is most likely associated with rising fault; this supposition is confirmed by strong fragmentation of lava flows in this part of the ridge. Besides, the axial part is complicated by two transverse short faults stepwise subsiding in western direction.

Thus, all the above-described anticlinal ridges can be attributed to the category of the co-called fault-propagation folds that are associated with intensely

rising faults, having specific geomorphologic expression in the relief as elongated linear asymmetric ridges with their steep slopes complicated by faults.

As was mentioned above, the dense network of active faults developed within the Javakheti highland conditioned a high degree of fragmentation of its basement into individual crustal blocks that, in turn, caused a specific character of seismicity in the region, one of the main peculiarities of which is a great number of small and medium (of magnitude less 4) earthquakes (several hundreds per year) with relatively rare occurrence of large shocks. Nearly all strong seismic events of magnitude 5.5-6.0 in the region such as Akhalkalaki earthquake, 1899 (magnitude M-6.0, intensity I=VIII), Tabatskuri, 1940 (M-6.1, I=IX), Madatapa, 1957 (M-5.7, I=VIII), Dmanisi, 1978 (M-5.6, I=VIII), Paravani, 1986 (M-5.0), Spitak, 1988 (M-7.2) and others are related to the Samsari, Javakheti and other faults of regional importance, seismically most active areas being the tectonic knots of intersection of faults of different orientation.

გეოლოგია

გეოლოგიური და გეომორფოლოგიური გამოკვლევები ჯავახეთის ზეგანზე (სამხრეთ საქართველო)

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ნაშრომში განხილულია ჯავახეთის ვულკანურ ზეგანზე (სამხრეთ საქართველო) სატრანსპორტო დერეფნის ტერიტორიის გეოლოგიური, გეომორფოლოგიური აგებულება და რელიეფის ფორმების კავშირი ახალგაზრდა ვულკანიზმთან. დახასიათებულია რეგიონში განვითარებული და ჩვენ მიერ გამოვლენილი ნეოტექტონიკური და მორფოტექტონიკური სტრუქტურები, ვულკანური ცენტრები და თანამედროვე ეგზოდინამიკური პროცესები. ვულკანური აქტივობა რეგიონში დაკავშირებული იყო შიდაზონალურ და ინტრაზონალურ სიღრმულ რღვევებთან. ვულკანიზმი ატარებდა სუბარეალურ ხასიათს. მიო-პლიოცენური ასაკის (გოდერძის წყება) მჟავე ვულკანიზმს ეოპლეისტოცენში ენაცვლება ფუძე ლავების (ბაზალტები, დოლერიტები) ამოღვრა. სიღრმული რღვევები აკონტროლებდნენ ლავების ცენტრალური და ნაპრალოვანი ამოღვრის კერებს. ფორმირებას განიცდიან ლავური პლატოები, მსხვილი სტრატოვულკანები და მცირე ზომის მრავალრიცხოვანი ვულკანური კერები და ექსტრუზიული გუმბათები. ვულკანების აქტივობის პულსაციის ფონზე ზედაპირზე ყალიბდებოდა კომპენსაციური ტაფობები, სადაც გროვდებოდა ტბიური ნალექები. ვულკანური აქტივობის მეორე ციკლის დროს მიღებული ეფუზიური წარმონაქმნები იზოტოპური, პალეომაგნიტური და ბიოსტრატიგრაფიული მეთოდების გამოყენებით თარიღდება 3,5-1,8 მლნ. წლით. ფუძე ეფუზიები

ფართოდაა გავრცელებული როგორც სამხრეთ საქართველოში ასევე დასავლეთ სომხეთსა და აღმოსავლეთ ანატოლიაში. ეოპლეისტოცენურმა ვულკანიზმმა დაასრულა რეგიონის თანამედროვე რელიეფის ფორმირება და პლანაცია.

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