Geology

Some New Considerations on the Age, Composition, Geological Position and Genesis of Olistostromes of the Southern Slope of the Greater Caucasus (within Georgia)

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ABSTRACT. The Upper Eocene age of the Greater Caucasus olistostrome complex is confirmed on the basis of geological and paleogeographical data. The feeding source of olistostromes at present is completely overlain by overthrust nappes of the southern slope of the Greater Caucasus. It is shown as well that in places the olistostrome complex is squeezed out from the frontal part of the nappes and slumped gravitationally to the north forming in that way a retro-overthrust plate of olistostromes. © *2010 Bull. Georg. Natl. Acad. Sci.*

Key words: *olistostromes, nappes, retro-overthrust, Upper Eocene.*

1. Introduction. The peculiar rock complexes representing chaotic accumulation of redeposited unsorted fragments (olistoliths), from a few centimeters to thousands of cubic meters in volume, cemented with a fine-grained (pelitic and psammite-aleurolitic) matrix, having mainly sedimentary-slumping origin, are identified as olistostromes. They participate in the geological structure of many regions of the world and are developed at different stratigraphic levels from the Precambrian up to the present. In the Alpine area distribution of olistostromes in time shows that their formation is timed to the epochs of intensification of tectonic movements at the end of the Late Jurassic, at the boundary between the Lower and Upper Cretaceous, Upper Cretaceous and Paleocene, Eocene and Oligocene, Miocene and Pliocene, Pliocene and Anthropogene [1].

Numerous researches are dedicated to the geology of chaotic complexes. This question is best clarified in M.Leonov's monograph [1]. The author adduces a detailed characteristic of the olistostrome type chaotic complexes (mixtites), considers the questions of their genesis and typification. Olistostromes of different age of the Alpine fold area are described and the regularities of their placing in time and space defined. Gravitational and tectono-gravitational mixtites belong to the mixtites of olistostrome type.

Formation of gravitational mixtites is concerned with the activity of downfall-slumping processes. For its formation the presence is required of a morphologically well-expressed scarp or inclined surface, conditioning the difference in altitudes of the disintegration area and the area of sedimentation of the slumped material. The detrital material of gravitational olistostromes (intraclasts) is formed at the expense of destruction of the sedimentary basin, where these olistostromes are formed. In the geological literature the latter are known as "endoolistostromes". Insignificant volume, short extent and local spreading characterize this variety of olistostromes.

Tectono-gravitationally induced mixtites, whose clastic material has formed because of tectonic disintegration of tectonic nappes moving due to downfall-slumping processes, comprise rock debris, blocks (olistoliths) and slabs (olistoplacs), alien to the considered sedimentary basin, rocks of other facies zones (extraclasts). Olistostromes of such type – "exoolistostromes" – are material expression of the unity and interrelationship of tectonic and downfall-slumping processes, as a rule concomitant with the tectonic nappe formation. Olistostromes of this variety are characterized by wide spatial spreading, considerable thicknesses and intensive tectonic processing.

One of the authors of this paper (I.Gamkrelidze) had an opportunity to be completely convinced in the validity of this statement; for a long time (1976-1990) he had been in a position to investigate the nappe structures of the Caucasus, Outer and Inner Western Carpathians, Northern Apusenides, Rhodopian massif, Kryshtides, Western and Eastern Alps and the Northern Pyrenees [2, 3].

On the southern slope of the Greater Caucasus olistostromes occur at different stratigraphic levels. Most widespread among them is the Upper Eocene olistostrome complex, which is irregularly distributed and observed mainly in two localities.

Major part of Upper Eocene olistostromes developed in the eastern segment of the southern slope of the Greater Caucasus [Fig. 1] - in the eastern part of the Gagra-Java zone, within the limits of the Sadzeguri-Sakhvetila, Zhinvali-Pkhoveli tectonic nappes and the Ksani-Arkala parautochthone of Zhinvali-Gombori subzone of Mestia-Tianeti flysch zone (Fig. 1). The presence of the nappes is established on the basis of structural and boring data, paleogeographic reconstructions [4] and - recent geophysical researches – seismic reflection profiling and seismic tomography [Fig.2].

Eastwards, olistostromes extend far beyond the bounds of Georgia, to Azerbaijan, up to the environs of Shamakha, enclosing the Talistan and Shabian "cliffs" between the Agrychai and Akhsu rivers [5, 6].

2. Age of olistostromes. The age of olistostromes of the Greater Caucasus southern slope was defined on the basis of their position in the section between the faunistically dated sediments of the Middle Eocene and Lower Oligocene, and according to findings of nummulitic fauna in the matrix of block breccias [7- 10, 5], specifying their Upper Eocene age. Initially it was believed that the olistostromes embrace all the Upper Eocene or its basal part. Then, on the basis of new faunistic findings [11], in particular a complex of nummulites: Nummulites incrassatus de la Harpe, N. fabianii Prev., N. Striatus Brug., N. fabianii retiatus Roveda, N. Schavannesi de la Harpe, N. Variabarius Lamarck, N. Budensis Haut in the cement of olistostromes, they were dated to the Upper Eocene, predominantly as its uppermost part. Taking into account that the complex is covered from above with Lower Oligocene sediments, it can be assumed that the time of olistostrome-formation corresponds to the uppermost Late Eocene. F.Maisadze [12] came to the same conclusion on the basis of correlation of olistostromes and the coeval formations of the adjacent regions.

It should be noted that this level of olistostromes is of all Caucasian importance and, besides the Greater Caucasus, on the northeastern and southeastern slopes of the Lesser Caucasus at the same level similar formations are developed [6]. They are widespread in other parts of the Alpine belt (in the Alps, Carpathians, Dinarides and the Balkanides). In all fold systems Late Paleogene olistostrome complexes envelop the upper part of the Upper Eocene and their formation is related to the manifestation of the Pyrenean orogeny, with the exception of the Carpathians, where the olistostromes cover the entire Upper Eocene.

Formation of olistostromes in Western Baluchistan (Iran) is also connected with the end of the Late Eocene and the beginning of Oligocene. Thus, to attribute the major, most widespread part of olistostromes of the southern slope of the Greater Caucasus to the uppermost Upper Eocene from this point of view also seems natural.

However, lately, based on the analysis of a complex of marine flora (nannoplankton), the olistostromes, as well as sediments - marls, limestones, sandstones, argillites and arenaceous turbidities developed to the north and south of them, have been dated to the Upper Miocene-Lower Pliocene [13]. As to the nummulitic fauna, earlier found in these sediments and numerous Upper Eocene nannofossils discovered by these authors in the same sediments, they are considered as redeposited.

The assumption of the Late Miocene-Early Pliocene age of olistostromes and the adjacent sediments of the southern slope of the Greater Caucasus, to our mind, is at variance with numerous indisputable geological facts:

1. Olistostromes and the sediments enclosing them, as noted above, in many places in the section occur between the faunistically dated sediments of the Middle Eocene and Lower Oligocene. For example, according to N.I.Mrevlishvili [9, 10], on the river Samanis-khevi limestones, dated by I.V.Kacharava according to nummulitic fauna to the Middle Eocene, are directly overlapped with marls including the Upper Eocene nummulites, but T.T.Gavtadze, N.I.Mrevlishvili [13] along the new gas pipeline, on the basis of nannofossils identify them as Upper Miocene-Lower Pliocene. These sediments, in which in the river Chala-khevi (left tributary

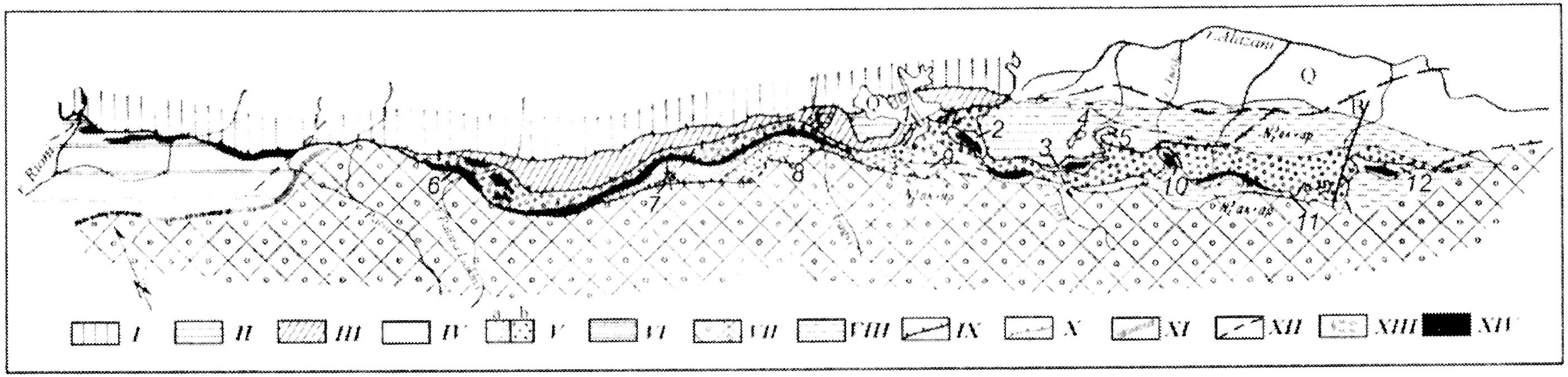

Fig. 1. Scheme of location of tectonic nappes of the southern slope of the Greater Caucasus within Georgia [4].
I-V - tectonic nappes: I - Utsera-Pavleuri, II - Alisisgori-Chinchveltha, III - Sadzeguri-Shakhvetila, IV - Zhinvali-Pkhoveli, V - Ksani-Arkala parautochthone; VI, VII - autochthone: VI - Gagra-Java zone, VII - Georgian Block, VIII - Aghchagyl-Apsheron deposits; IX - sole of nappes, X - sole of sheets, XI - deep fault, XII - shallow faults, XIII - gravitational slabs, XIII - olistostromes.
Tectonic windows: 1 - Kokhi, 2 - Kintiskhevi, 3 - Vashlovani, 4 - Iolaiskhevi, 5 - Bakana, 6 - Beloti, 7 - Ksani, 8 - Arkala, 9 - Gokhiani, 10 - Turdo, 11 - Chailuri-Kisiskhevi.

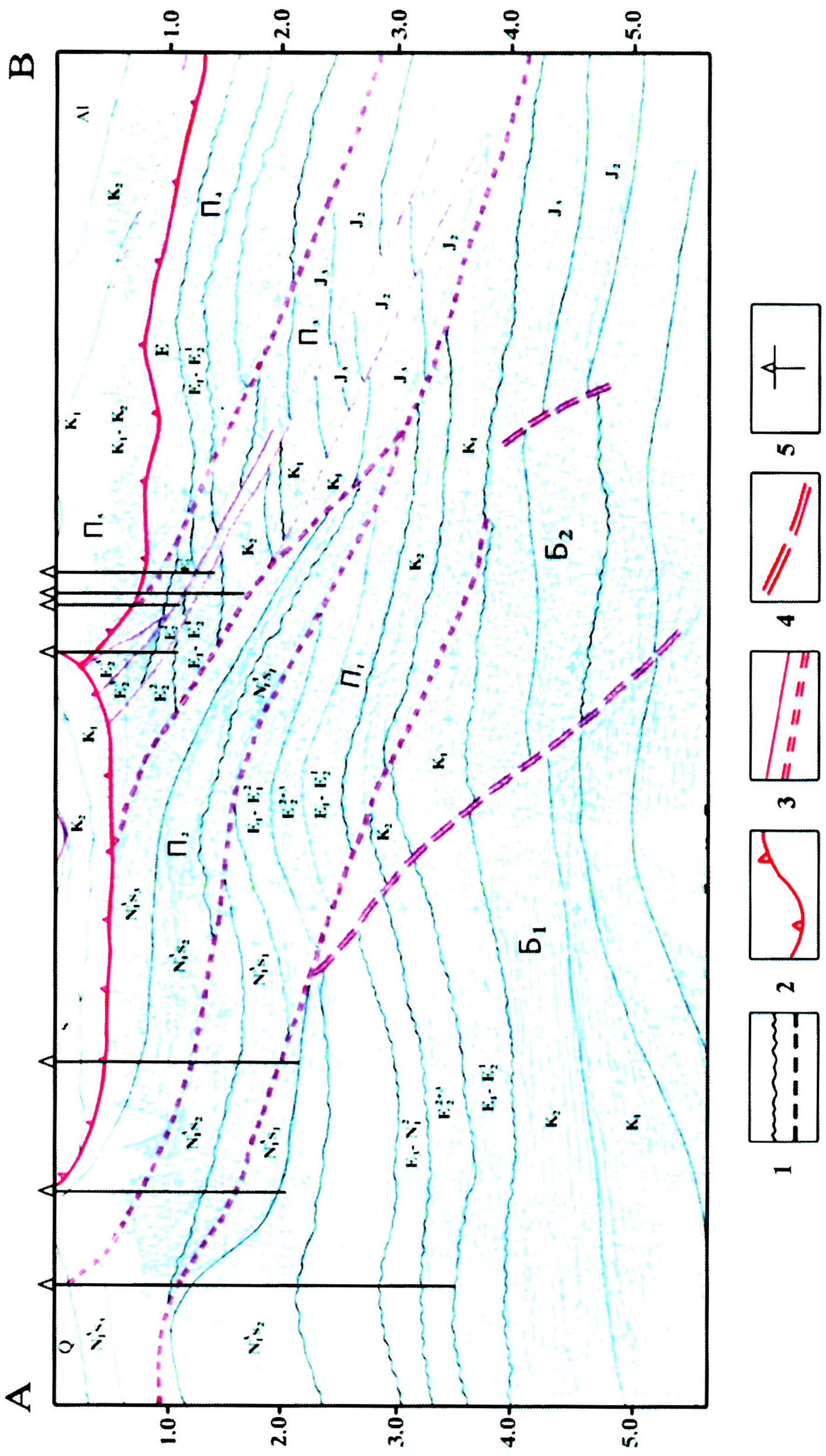

Fig. 2. RAMCO seismic reflection profile along the AB line (see Fig. 1) across the eastern part of Gombori ridge interpreted by N.P.Gamkrelidze.

1 - boundary surfaces of seismostratigraphic horizons, 2 - sole of nappes, 3 - thrusts, 4 - interblock faults, 5 - boreholes; Б1,2 - tectonic blocks, $П_1$, $П_2$, $П_3$, $П_4$, $П_5$ - tectonic scales.

of the river Arkala), Upper Eocene nummulites are found by M.I.Varentsov and B.G. Mordovski [7], according to data of the majority of scientists and to our observation, in the mid-course of the river Arkala, are overlain by the Maikop suite of the Oligocene. This is evidenced by the presence of breccia-conglomerates (of olisrostromes), built up of blocks and boulders of Bajocian porphyrites, Upper Jurassic reef limestones, Cretaceous rocks and also by well rounded granite pebbles at the base of the Kinta suite where, near the village of Pkhoveli I.V.Kacharava [8] discovered Upper Eocene nummulites. In the ascending section, a typical Oligocene-Lower Miocene Maikop suite overlaps these olistostromes, which as is known, here belong to the Kinta suite as well.

2. It is difficult to imagine overall, including the territory of Azerbaijan, in these sediments the presence in secondary position exclusively of Upper Eocene nummulites and absence of their older and younger representatives.

3. In the sections, described by T.T.Gavtadze and N.I.Mrevlishvili [13] along the new gas pipeline (Fig.5), the left bank of the river Arkala and on the Georgian Military Road, to the south of the village of Ananuri, between the dated by the same authors, in the first case to the Upper Maastrichtian, in the second – to the Monsian and Thanetian stages and the Upper Miocene-Lower Pliocene sediments, according to these authors and also to our observations, there is no sign of break in sedimentation or any unconformity. This is difficult to explain if we admit the above-indicated considerable interval in sedimentation.

4. Ascription of the above-considered formations to the Upper Miocene-Lower Pliocene contradicts the unquestionable regional-geological and paleogeographical data. In particular, as is generally known, the Dusheti suite developed in the Kartli depression, now stratigraphically attributed by all the researchers to the Meotian-Pontian, both on the basis of its position in the geological section and also terrestrial freshwater mollusk and vertebrate fauna, is built up of pebbles and boulders of the Cretaceous flysch only and seldom Jurassic porphyrites. Hence, assumption of the existence at that time of a marine basin composed of rather

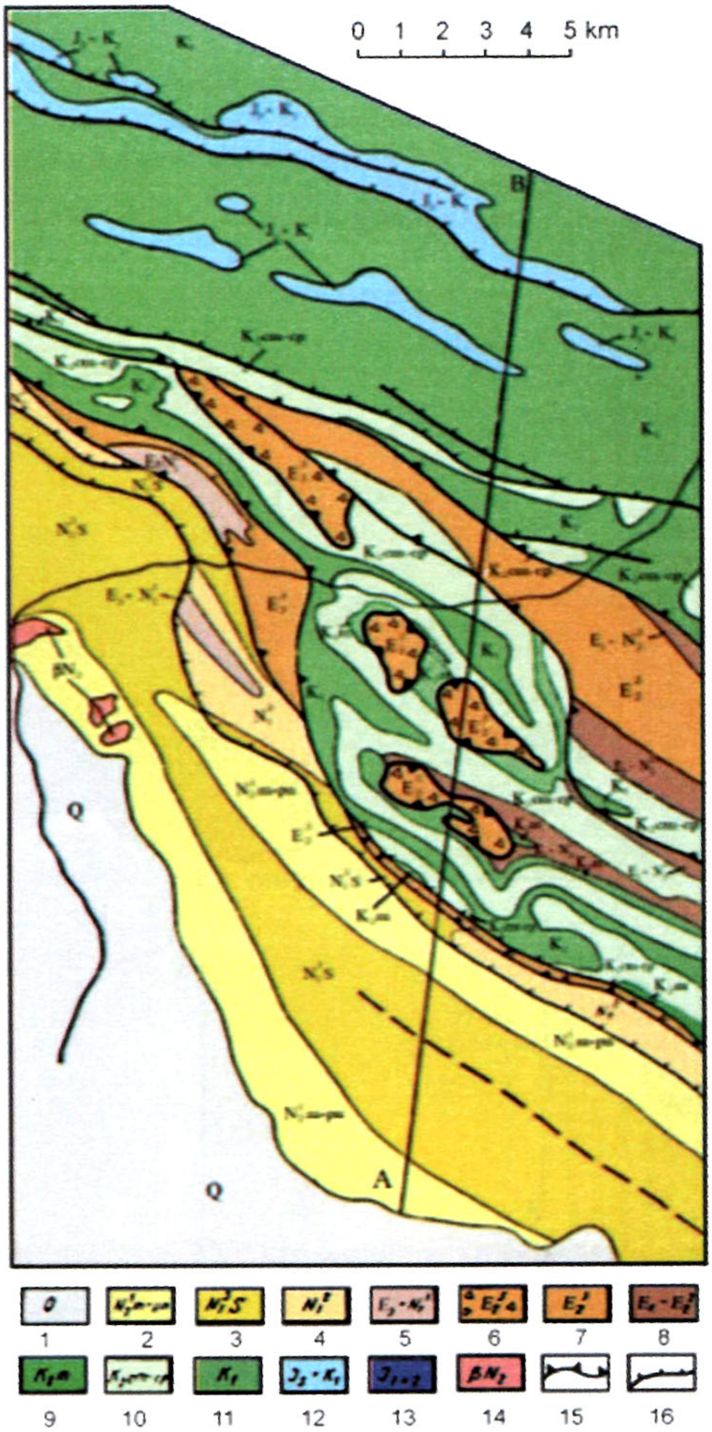

Fig. 3. Geological scheme of the Patara Liakhvi river head. 1 – Quaternary deposits, 2 – Meotian and Pontian conglomerates (Dusheti suite), 3 – Sarmatian sandstones and clays, 4 – Middle Miocene sandstones, 5 – Oligocene-Lower Miocene clays and sandstones (Maikop series), 6 – Upper Eocene (olistostromes), 7 – Upper Eocene (normalsedimentary suite), 8 – Paleocene-Middle Eocene (sandstone-siltstone flysch), 9 – Maastrichtian (Orbitoid suite), 10 – Cenomanian-Campanian (sandstone-siltstone and limestone flysch) and marls, 11 – Lower Cretaceous (sandstone-siltstone flysch), 12 – Upper Jurassic-Lower Cretaceous (flysch), 13 – Lower and Middle Jurassic sandy-argillaceous suite, 14 – Tertiary basalts, 15 – sole of nappes, 16 – sole of scales. Fragments of retro-overthrust: B – Beloti, Rkh – Rekhi, Or – Orbodzala.

deepwater sediments (marls, turbidites) within the flysch zone, is absolutely groundless.

5. Overlapping ("sealing") of already folded and overthrust Cretaceous and Paleogene sediments (including olistostromes and the strata enclosing them) of the flysch zone by continental conglomerates of a thick (up to 1600m) Alazani series of Aghchagil-Apsheronian age, also contradict the Late Miocene-Early Pliocene age of olistostromes and the strata enclosing them.

The foregoing does not allow to share the opinion concerning the Mio-Pliocene age of olistostromes of the southern slope of the Greater Caucasus and to our mind, their Upper Eocene age is beyond any doubt.

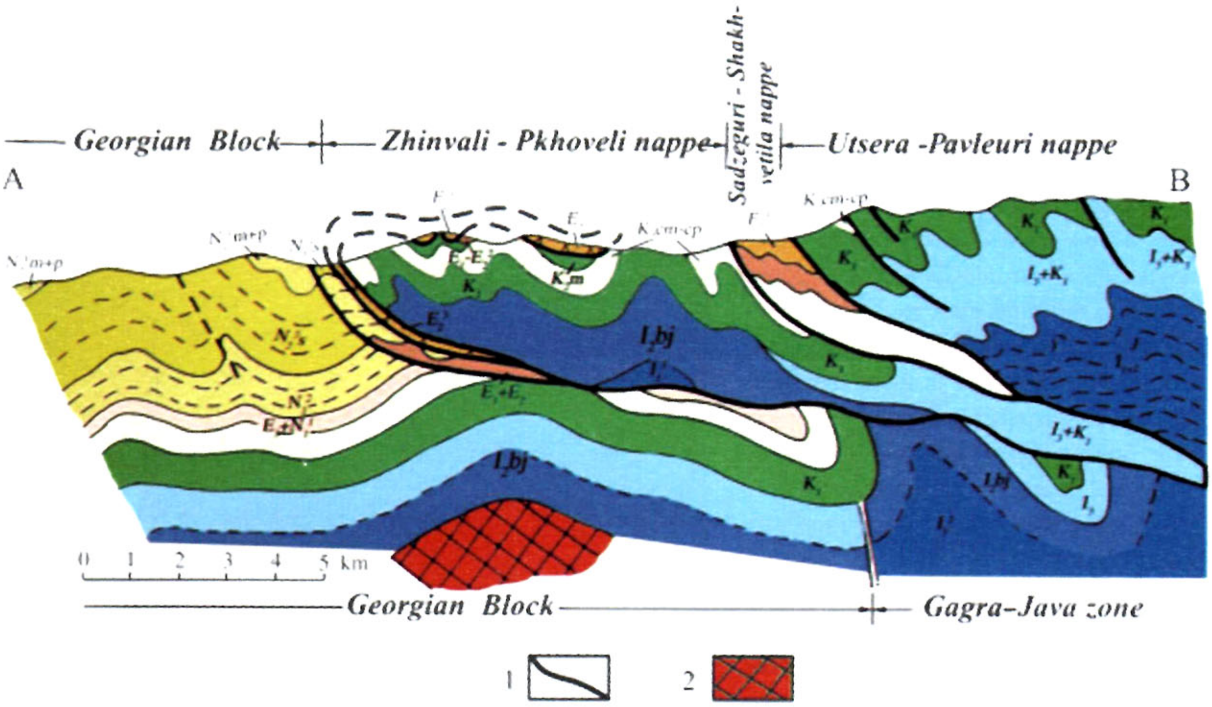

Fig. 4. Geological profile AB to Fig. 2. 1 – Thrusts, 2 – Pre-Jurassic crystalline basement of the Georgian Block. Other conventional signs see in Fig. 2.

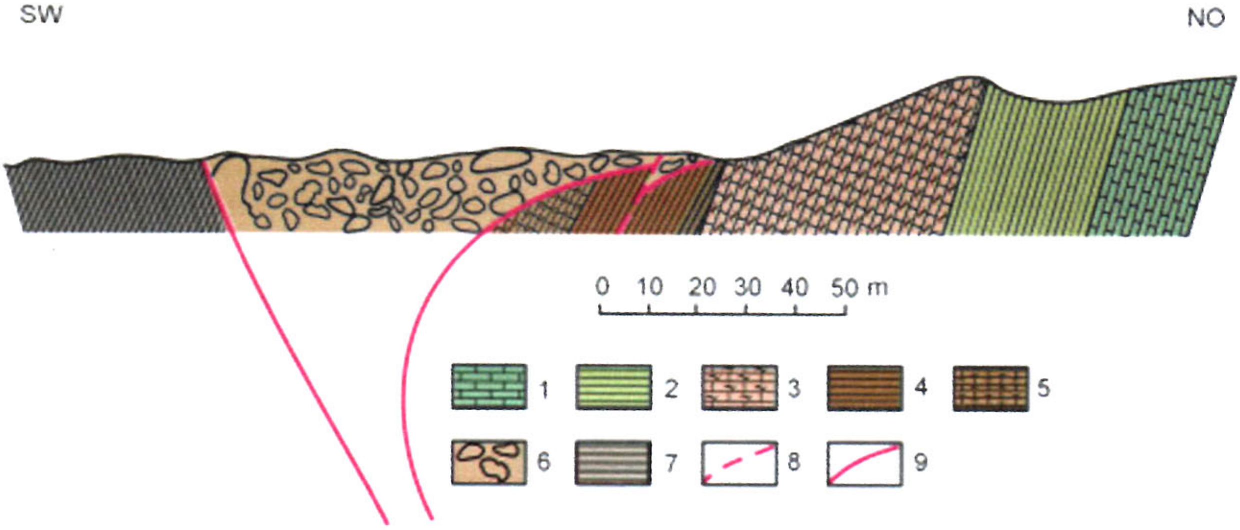

Fig. 5. Geological profile along the new gas pipeline (left bank of the river Arkala)
1 – Maastrichtian clastic-limestone turbidites, gritstones, conglomerates, particoloured marls, weakly carbonaceous argillites, 2 – Danian particoloured marls, 3 – Monsian and Thanetian clastic-limestone turbidites, marls, conglomerates, gritstones, 4 – Eocene – alternation of particoloured marls and non-carbonate argillites, 5 – Eocene – marls with lens-shaped intercalation of limestones, 6 – upper part of Upper Eocene – olistosromes, 7 – Upper Eocene – alternation of sandstones, argillites, marls and bituminous clays, 8 – reversed fault, 9 – overthrust.

Fig. 6. Geological map of the Aragvi river basin (in environs of Zhinvali and Ananuri villages)
1 – Quaternary deposits, 2 – Miocene and Pliocene conglomerates (Dusheti suite), 3 – Sarmatian clays and sandstones, 4 – Middle Miocene sandstones, marls and clays, 5 – Oligocene and Lower Miocene sandstones and clays (Maikop series), 6 – Upper Eocene olistostromes, 7 – Upper Eocene sandstones and shales, 8 – Middle and Upper Eocene sandstones and clays, 9 – Paleocene-Middle Eocene (sandstone-siltstone flysch), 10 – Paleocene and Lower Eocene sandstone turbidites, clays, marls, 11 – Maastrichtian and Danian clastic-limestone flysch, 12 – Cenomanian-Campanian clastic-limestone turbidites and silicites, 13 – Aptian and Albian sandstone-aleurolitic turbidites and shales, 14 – Bajocian porphyritic series, 15 – Aalenian sandstones and shales, 16 – tectonic nappes, 17 – reversed faults and thrusts.

3. Composition, inner structure, geological position and genesis of the Upper Eocene olistostromes. In the Gagra-Java zone rather widespread are Eocene formations, composed of two facies: a normal-sedimentary suite of the Middle and Upper Eocene age and the Upper Eocene olistostrome strata.

Normal-sedimentary suite of Eocene age (from 10 to 160m in thickness), with conglomerates in its base, is developed in the environs of the villages of Tsedisi, Tskhanari, Fasrago, Kemulta and in the crest part of the Val-khokh ridge; here, it overlaps the sediments of Upper Cretaceous and older age. This suite lithologically is represented mainly by sandstones and limestones.

Olistostrome strata, spread to the north of normal-sedimentary formations, is exposed in the form of isolated outcrops in the Gomrula river-gorge and in the vicinity of the mountain of Ukivleta, further it stretches as a narrow strip between the Jejora and Patara Liakhvi rivers, along the thrust of flysch deposits.

Olistostromes, exposed within the Gagra-Java zone, contain fragments and blocks of the Upper Jurassic reef limestones, Bajocian volcanogenic rocks, Cretaceous limestones, and in the Gomrula and Jejora river-gorges – fragments and blocks of flysch rocks as well. Blocks of the Upper Jurassic massive limestones reach sometimes thousands of cubic meters in size.

Near the village of Zemo Kemulta, in the olistostrome strata, in secondary position occur the Eocene flyschoid formations (of Ildokan suite type) as well. At the same time, as specified by F.D.Maisadze [14], a redeposited material of normal-sedimentary suite, today spread more to the south, is missing in block breccias.

Thus, it is obvious that in the Upper Eocene formations, the dimensions of clastic material increase from south to north: medium- and coarse-grained sandstones pass into block breccias. In addition, owing to the fact that in olistostromes there occur fragments and blocks of flysch rocks and lack redeposited material of normal-sedimentary Upper Eocene suite spread more to the south is absent, the location of a feed source in the northern part of the Upper Eocene basin is beyond doubt. The main source, supplying the suite of block-breccias, was a strip of cordilleras of the Gagra-Java zone, designated by F.D.Maisadze [15] as the Racha-Vandam cordillera, and of the southern part of the flysch zone (redeposited material by nature belongs precisely to these zones), at present is completely overthrust by flysch nappes [16, 14, 17, 4]. It is the existence of geomorphologic scarps in this strip that probably caused the formation of rudaceous downfall breccias and of "horizons with inclusions" along them. This uplift was the main source of rudaceous material not only in the Late Eocene but in the Cenomanian, Maastrichtian and Paleocene as well [4]. In particular, in the southernmost unit of flysch zone – in Zhinvali-Pkhoveli nappe, in the Tetrakhevi suite of Aptian age, its basal conglomerates (for example near the village of Orvili) are entirely composed of Upper Jurassic reef limestones and rocks of Bajocian porphyritic series [4]. Here, in the base of the Lower Cenomanian Ukughmarti suite, which in places transgressively overlaps the Navtiskhevi suite of Albian age (Ksani, Medjuda), breccia-conglomerates with inclusions of Upper Jurassic reef limestomes are observed, but in the village of Ukughmarti, gravelstones of the lowermost Cenomanian are entirely built up of the material of the Bajocian porphyritic series. The same situation is observed in the Orbitoid suite of Maastrichtian age. The inclusions of Upper Jurassic reef limestones are huge in size (e.g. on Mt. Kokhis-mta). There are inclusions of Paleozoic granites as well (for example to the east of Zhinvali, in the Aloti river-gorge granite block reaches 200 m^3).

In the Sadzeguri-Shakhvetila nappe, located to the north, at the base of Ukughmarti suite of the Cenomanian, microconglomerates and breccias are observed, built up of the above-named material. All olistostromes, observed in the Upper Cretaceous sediments of flysch zone, with inclusions of the Gagra-Java zone rocks, are typical exoolistostromes. However, more to the north within the limits of Utsera-Pavleuri nappe, the rudaceous sediments with "southern" material are absent in both the Cenomanian and Maastrichtian and the section is uninterrupted.

Location of the feeding source of Upper Eocene olistostromes in the cordillera part is defined also more easterly of the river Ksani, where the Upper Eocene sediments, composed of a thick (up to 200m) olistostrome stratum, in the Bantsurt-khevi, left tributary of the river Arkala, transgressively rest on Jurassic (Upper Liassic and Bajocian) rocks. In the ascending section, it is replaced by the Maikop suite of Oligocene, and to the north, an overthrust suite of block breccias (of olistostromes) is continuously traced. Hence, at present the cordillera in the west (to the west of the river Didi Liakhvi) as well as in the east is concealed under the flysch sediments overthrust from north, and partially, as will be shown below, is detached and displaced to the south. Predominantly olistostromes of the Upper Eocene have shifted to the south.

Thus, it is obvious that during the Late Cretaceous and Paleogene, the Gagra-Java cordillera, composed of rocks characteristic only of this zone, served as a source of clastic material. As in the greater part of the strip of development of the tectono-gravitational olistostromes in the recent structure, directly contact with each other molasse depressions of Kartli and Garekakheti and Mestia-Tianeti flysch zone, it should be assumed that the mentioned cordillera is completely overlapped with overthrust plates of the flysch zone.

Only the extreme western part of this cordillera, proved to be not completely overlapped within which Upper Eocene olistostromes of the Gomrula river-gorge (Fig. 1) and the environs of the Ukivleta mountain, at present located in situ, were formed.

Tectonic overlapping took place apparently in the main phase of nappe-formation, before the Late Pliocene (Rodanian phase); however, taking into account the enormous volume and length (from the environs of the village of Utsera to Azerbaijan) of Upper Eocene olistostromes, it seems natural to assume the beginning of horizontal movements already at the end of the Late Eocene (Pyrenean phase) [15].

Upper Eocene olistostromes are most widespread in the Zhinvali-Pkhoveli nappe, where their outcrops not only along the overthrust flysch formations, but also to the north, within the flysch zone are observed in the form of three isolated outcrops in the Patara Liakhvi river basin (Fig. 3, 4). These are the outcrops of olistostromes in the areas of Mt. Orbodzala, Rekhi and the Beloti village. We recorded also small outcrops in the Arkala river basin, near the villages of Shua-Alevi, Kochiani and Gudatsveri.

The Orbodzala ridge is composed entirely of huge blocks of Upper Jurassic massive limestones. The diameter of individual blocks reaches 50m. In the lower horizons smaller blocks of Bajocian volcanogenic rocks are present. The entire mass of clastic breccias is firmly cemented by calcareous matrix, creating the impression of a continuous massif. The thickness of block breccias is up to 100m. In the eastern and western directions, sharply decreasing in thickness (3-10m), they are replaced by normal conglomerates. Eastwards, between the horizons of massive limestones and breccia-conglomerates, nummulitic clay sandstones crop out with interlayers of conglomerate.

Similar formations of the Upper Eocene are developed on the Rekhis-mta mountain, where the olistostrome strata contain pebbles and blocks of Upper Jurassic and Upper Cretaceous flysch limestones. Here the sediments participate in the structure of a syncline fold. Herein, the thickness of the entire Upper Eocene is 150-200m [4].

The next, northernmost outcrop of Upper Eocene olistostromes is preserved to the north of Beloti village, where they alternate with marl packets. Along the strike of olistostromes consisting of fragments of Bajocian volcanogenic rocks, they are replaced by analogous formations built up of pebbles and blocks of Upper Jurassic reef and flysch zone limestones.

Study of the aforementioned outcrops of Upper Eocene olistostromes showed that in one case they are located at different horizons of the Upper Cretaceous flysch (Beloti, Rekhi), and in another – on the Cretaceous and Paleocene sediments (Orbodzala) (see Fig. 3, 4), and in the Aleura river basin - on the sediments from the Aptian-Albian to Santonian. According to all features, they are in secondary bedding [18] in the form of small tectonic slabs and represent fragments of retro-overthrust [15] of tectono-gravitational origin. The plates moved from south to north, and therefore have the opposite sign of movement towards the general direction of displacement of the masses on the southern slope of the Greater Caucasus.

To understand the mechanism of retro-overthrusting of the mentioned tectonic slabs, in our view, especially interesting is the situation observed along the new gas pipeline, on the left bank of the river Arkala (Fig. 5, 6).

Here are exposed the Upper Cretaceous and Paleogene sediments of the Zhinvali-Pkhoveli nappes (see Fig. 6). At hypsometric levels of the gas pipeline the width of the outcrop of Upper Eocene olistostromes, built up predominantly of Upper Jurassic reef limestone fragments of different size (olistoliths) and rarely of Bajocian volcanogenic rocks and sandstones and clay shales of Liassic pattern, amounts to 100m. However, hypsometrically lower (at a deeper level of the section), on the left slope and right in the Arkala river-gorge, gradual narrowing of the outcrop of olistostromes is clearly observed (in the Arkala river-gorge it does not exceed 11 meters). At the same time, in the northern, very gentle tectonic contact olistostromes overlap a steeply dipping packet of grey marls with lenticular limestone interlayers, which by the stratigraphic position and lithological character, most likely, belong to the normal-sedimentary strata of the Upper Eocene. Olistostrome sequence from the southwest is limited also by tectonic dislocation, well known in the western part of flysch sediments as Orkhevi thrust and to the east of the river Liakhvi – as Ananuri-Pkhoveli overthrust. At present, this tectonic dislocation is identified as the sole of Zhinvali-Pkhoveli overthrust. Along this nappe, flysch sediments, together with olistostrome strata, pressed between two thrusts, tectonically overlap the sediments of extremely different age of the Georgian block and Ksani-Arkala parautochthone, beginning from the Patara Liakhvi river basin to the Aragvi river-gorge. Thus, along the gas pipeline a tectonic squeezing-out of the Upper Eocene olistostrome strata is observed, which to the north along the low-angle thrust (retro-thrust) overlaps steeply dipping coeval sediments. One can assume that here we have the roots of retro-overthrust, parts of which apparently remained as the above-mentioned tectonic slabs located within the flysch zone (Orbodzala, Rekhi, Beloti). The gravitational factor seems to have played a definite role in the northward displacement of the retro-overthrust as well, nor did the volume of the Upper Jurassic limestones play a lesser role in it.

Thus, on the basis of these data it becomes obvious that the Upper Eocene olistostromes developed to the south of the river Didi Liakhvi, never overbuild flysch section and therefore cannot be regarded as a wild flysch, as previously considered [11, 4].

It may be assumed that the olistostromes on the entire territory of the southern slope of the Greater Caucasus were formed in the same paleogeographic and tectonic conditions, in the basin with subplatform regime of sedimentation.

To the wild flysch can be attributed only that part of the Ildokani suite, which comprises the horizons of conglomerate-breccias, composed mainly of rocks of the flysch zone (the rivers Aleura, Mejuda and so on) and complete the section of Paleogene flysch sediments [19].

The inner structure of the Upper Eocene olistostrome complex is very complicated. For the first time M.G.Leonov [11] noticed that separate parts of this section of the strata thrust over each other, stratified varieties of rocks are intensively kneaded, competent strata are fractured, boudinaged, brecciated, broken up. If taken into account the irregular placement of debris (olistoliths) and slabs (olistoplacs) in the matrix, in general chaotic character and tectonic processing, the presence of tectonized fragments and, as noted, great volume and immense spread, these olistostromes should be attributed mainly to tectono-gravitational olistostromes. Nevertheless, M.G.Leonov [1] notes the presence of lenticular bodies of peculiar breccias of small thickness (1-2m) and extent (20-30m), coarse-grained part of which is composed of absolutely unrounded, curved, oddly deformed fragments of sandstone beds, but the matrix is composed mainly of clayey material. These breccias are characterized by the presence of clayey pellets and absence of allothigenic material. The composition of breccia fragments and matrix corresponds to that of the enclosing sediments. Proceeding from these features, these locally developed bodies of breccias are attributed to gravitational mixtites.

The structural features of the Upper Eocene sediments of the southern slope of the Greater Caucasus prove the existence of two simultaneous processes of sedimentation. On the one hand, there took place accumulation of clayey-carbonaceous layers with admixture of different amount of sandy material, on the other – against the background of this thin sedimentation there sporadically took place delivery of huge masses of clastic material into the basin, which was deposited in the form of lenses, interlayers and thick horizons of block breccias.

Delivery of rudaceous material did not occur gradually over a long time, it was connected with oft-recurring short-term catastrophic processes (lightning in geological sense). This is indicated by sharp contacts of breccias with the surrounding sandy-argillaceous sediments, and it can be seen as the blocks press in underlying, probably not consolidated sediments. Proceeding from the above-stated, F.Maisadze [20] attributed the Upper Eocene olistostromes and a wild flysch of a part of the Alpine area (the Swiss and French Alps, the Dinarides, the southern slope of the Greater Caucasus) to the event deposits formed due to oft-recurring catastrophic events associated with the thrusting.

At the same time, huge blocks (olistoliths) and slabs (olistoplacs) of older rocks also got into the basin. These are predominantly most competent reef limestones, which in places reached such huge dimensions that some researchers recognized them as original exposure of Upper Jurassic limestones. In particular, the limestones in the environs of Mt.Alevis-klde, were previously considered to be an Upper Jurassic original exposure [21]. However, according to P.D. Gamkrelidze and I.P. Gamkrelidze [4], these huge limestone massifs (olistoplacs) are in secondary position and are included in Upper Eocene sediments in the process of their accumulation.

Thus, in the described strip, all outcrops of Upper Jurassic limestones are exotic blocks or olistoliths included in Upper Eocene sediments. For the Azerbaijan part of the development of Upper Eocene block breccias this opinion was first expressed by A.V. Mamedov [5].

Upper Eocene deposits are rather wide-developed in the Ksani-Arkala parautochthone as well (Fig. 6) Their most complete sections are in the Arkala river gorge, where in the Arkala and Pote river basins they are composed of mainly gypsiferous shales and sandstones, gravelstones, microconglomerates, conglomerates, and in some cases, olistostromes. They unconformably overlap all underlying deposits - from the Liassic to Middle Eocene. In Kakheti, along the Turdo river-gorge and in the Gombori area they were recognized as Kinta suite.

It is noteworthy that blocks of the Upper Jurassic limestones (olistoliths) included in the Upper Eocene sediments because of their enormous size here also were considered as original exposure of the Upper Jurassic deposits. For example in the environs of v. Aranisi an original exposure of Upper Jurassic limestones was described [9]. According to our observations, the Aranisi limestone massif consists of two outcrops, separated by conglomerates composed of fragments of Upper Jurassic reef limestones, Bajocian porphyrites and Paleozoic granites. The northwestern outcrop of limestones consists of separate blocks cemented with conglomerates and sandstones. Thus, the Upper Jurassic reef limestones here are in secondary position in Upper Eocene sediments. We believe that these blocks are displaced owing to underwater slumping over several kilometers from the exposed part of the Racha-Vandam cordillera located in the north.

Such seem to us also the conglomerate-breccias of the Pantiani massif along the Turdo river-gorge, lying at the base of the Kinta suite. Outcrops of olistostromes are identified near the villages of Nojiketi, Dzirkhviani, Evzhenti and Kinta along the river Turdo – Mt.Pantiani, along the rivers Kisis-khevi and Tkhilis-khevi. In this rudaceous sequence blocks and boulders of Bajocian porphyrites, Upper Jurassic reef limestones, Cretaceous rocks as well as well-rounded pebbles of granite are observed. The thickness of this formation varies from several tens to 200m.

The upper part of the Kinta suite section differs little from the Maikop suite of the Oligocene. Hence, the possibility is not excluded that in some areas, where more complete sections of the Kinta suite are preserved, its uppermost parts are dated as the Lower Miocene. The Kinta suite is most developed in the east, in Kakheti in all tectonic windows and semiwindows, where it directly overlaps the volcanic formations of the Bajocian, and in its turn, it is tectonically overlapped by the Cretaceous formations of the Zhinvali-Pkhoveli nappe (Fig.1).

Outcrops of the Upper Eocene sediments are also present in the western part of the Ksani-Arkala parautochthone (Fig.6). In particular, in the Ksani-Aragvi interfluve the Liassic and Bajocian deposits with basal conglomerates in its base are transgressively overlain by Upper Eocene thin-layered polymictic sandstones, and in places - by schistose carbonate clays, whose visible thickness does not exceed 50-60 meters. From the north they are everywhere overlapped by Upper Eocene rocks, and in the east by older (Cretaceous) deposits of Sadzeguri-Shakhvetila nappe. Here they directly pack with the outcrops of Upper Eocene sediments of the river Arkala, where, as noted above, the Upper Eocene, apparently its upper part, represented by a thick (up to 200m) olistostrome stratum in the left tributary of the river Arkala, in the Bantsurt-khevi river-gorge, directly overlaps Liassic sediments, and the overlying argillo-arenaceous sediments, probably refer back to the Oligocene, which from the north is overlapped by the Zhinvali-Pkhoveli regional thrust (Fig.6).

The Ksani-Arkala unit, with its adjacent areas is considered also by M.G.Leonov in detail [11, 22]. In the Upper Eocene sediments of the Aragvi-Ksani interfluve, he has distinguished the Northern, Arkala, Jurassic, Southern and Ksani tectonic scales. The author made an inference that the sediments of the Northern, Arkala and Southern tectonic scales are the members of united section, which is framed between the underlying formations of the Cretaceous-Paleogene flysch and the overlapping sediments of the Maikop series of the Middle Oligocene - Lower Miocene.

As to the Jurassic scales;, it is enclosed within this single series of rocks of the Upper Eocene, finding itself there during their accumulation, as well as the smaller slabs noted by the author within the limits of the Southern and the Arkala tectonic scales.

Rudaceous rocks of the Upper Eocene were formed, according to Leonov, at the expense of destruction of overthrust sheets during their overthrusting the flysch basin. Overthrust sheets represent frontal parts of a larger thrust of the Georgian Block torn away from the roots.

The impossibility of such an assumption is reviewed in detail in [4]. Tectonic scales of the Jurassic rocks (Jurassic scales, etc.) are not torn away from the Georgian Block, but from the cordillera part of the Gagra-Java (Racha-Vandam) cordillera and flysch zone and represent blocks that did not get into the Upper Eocene marine basin, but later tectonic scales torn away and displaced along the thrusts to the south.

The Ksani-Arkala unit, as mentioned above, is considered by us as parautochthone, since it undoubtedly is part of the autochthonous complex of the eastern continuation of the Gagra-Java zone.

Summing up the main features of the Late Eocene olistostrome formation, we can note the following.

In the eastern segment of the southern slope (east of the river Rioni) the Racha-Vandam cordillera zone, located in the northern peripheral part of the Gagra-Java

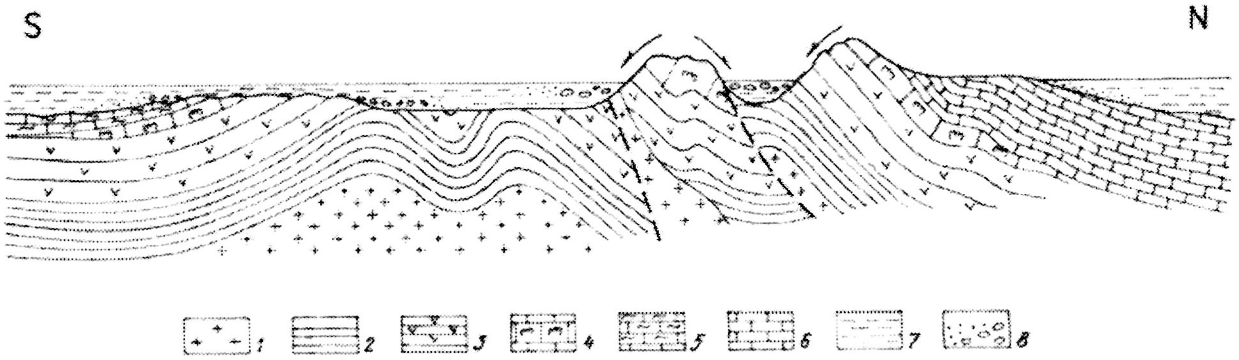

Fig. 7. Paleogeographical profile of the end of the Late Eocene
1 – Pre-Alpine crystalline basement, 2 – Lower Jurassic-Aalenian sandstones and shales, 3 – Bajocian porphyritic series, 4 – Upper Jurassic reef limestones, 5 – Cretaceous limestones (Gagra-Java zone facies), 6 – Aptian-Paleogene flysch sediments, 7 – Upper Eocene normal-sedimentary suite, 8 – Upper Eocene olistostromes.

zone, now completely overthrust tectonically by flysch deposits, was the main source of clastic material for the Upper Cretaceous and especially in large quantities for the Late Eocene sediments (Fig.7).

In the second half of the Late Eocene, as a result of manifestation of the New-Pyrenean orogeny, on the southern slope of the Greater Caucasus significant changes of paleogeographic and facies character took place. To the east of the River Didi Liakhvi, where the Paleogene flysch basin continued to exist, the cordillera zone separated the subplatform and flysch basins. It was composed mainly of Mesozoic and partially Paleogene deposits of the Gagra-Java zone. In the eastern part the rocks of the crystalline basement of the Gagra-Java zone also participated in the structure of the cordillera. By the end of the Late Eocene, when the New Pyrenean orogeny reached its peak as a result of the beginning of horizontal movements and catastrophic earthquakes, downfall-slumping events developed widely. As a result, a large mass of clastic material accumulated around these areas of land and olistostromes were formed in the basin with subplatform regime of sedimentation (Fig. 7).

In the straits that existed between the cordilleras, where the clastic material was delivered in limited quantities and smaller size, during the olistostrome-formation an accumulation of conglomerates, gravelstones, sandstones and lutites took place that in the lateral direction were facially replaced by olistostromes.

The cordillera zone supplied with terrigenous material the flysch basin as well. Here, in the second half of the Late Eocene sedimentation of the rudaceous rocks of the upper part of the Ildokani suite took place. Within the basin, apparently, there were small areas of washout, which during the periods of maximum tectonic activity delivered clastic material into the flysch basin causing deposition of horizons of conglomerate-breccias there (Fig. 7).

New-Pyrenean movements already at that time were apparently connected with the northward advance of the Transcaucasian massif and its underthrusting under the fold system of the Greater Caucasus, which is manifested most clearly and extensively in the main pre-Late Pliocene (Rodanian) phase of nappe-formation. Issues of the underthrusting mechanisms of the formation of tectonic nappes of the southern slope of the Greater Caucasus (continental subduction) are discussed in detail in [3,4], hence they are not broached here.

The second locality of the development of olistostromes on the southern slope of the Greater Caucasus is Adler depression, where they are comparatively less spread. They are part of the regressive Matsesta suite, which is lithologically divided into three parts: sandy-argillaceous, a "horizon with inclusions" and argillo-arenaceous [23]. Olistostromes consist mainly of olistoliths of the underlying rocks, among which prevail the lirolepis-containing marls (Kumi suite). The Upper Eocene age of the Matsesta suite is established by the content in it of nummulitic fauna [24].

A "horizon with inclusions" (olistostromes), being typical underwater landslide formations (gravitational mixtites), as well as the entire Matsesta suite, are synorogenic deposits and their formation is related to the manifestation of the New-Pyrenean orogeny [12].

გეოლოგია

ზოგიერთი ახალი მოსაზრება კავკასიონის სამხრეთი ფერდობის ოლისტოსტრომული კომპლექსის ასაკის, შემადგენლობის, გეოლოგიური პოზიციისა და გენეზისის შესახებ

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არსებული ფაუნისტური მინაცემების, გეოლოგიურ ჭრილში განლაგებისა და რეგიონულ-გეოლოგიური მოსაზრებების საფუძველზე დადასტურებულია კავკასიონის სამხრეთი ფერდობის ოლისტოსტრომული კომპლექსის ზედაეოცენური ასაკი, დეტალურად არის აღწერილი ოლისტოსტრომების შემადგენლობა, შიგა სტრუქტურა და გეოლოგიური პოზიცია. დადგენილია, რომ ოლისტოსტრომების კლასტური მასალით კვების წყარო განლაგებული იყო გაგრა-ჯავის ზონის ჩრდილო ნაწილში (რაჭა-ვანდამის კორდილიერა), რომელიც ამჟამად თითქმის მთლიანადაა გადაფარული კავკასიონის სამხრეთი ფერდობის ფლიშური ზონის სამხრეთისკენ გადაადგილებული შარიაჟებით.

გამოთქმულია მოსაზრება, რომ ოლისტოსტრომები მიეკუთვნება ე.წ. მოვლენითი ნალექების განსაკუთრებულ კატეგორიას და მათი წარმოშობა დაკავშირებულია აღნიშნული კორდილიერისა და კავკასიონის სამხრეთი ფერდობის შარიაჟების ფრონტალური ნაწილის დეზინტეგრაციასთან და ნატეხოვანი მასალის სწაფ და მრავალჯერად მეწყრულ გადაადგილებასთან გვიანეოცენურ სედიმენტაციურ აუზში.

ნაჩვენებია აგრეთვე, რომ ზედაეოცენური ოლისტოსტრომების გამოსავლები, რომლებიც ამჟამად მოთავსებულია ფლიშური ზონის შიგნით (ორბოძალის, რეხის და ბელოთის) წარმოადგენს ფლიშური ზონის შარიაჟების ფრონტალური ნაწილიდან გამოწზერილ და შემდეგ სამხრეთიდან ჩრდილოეთისკენ გრავიტაციულად გადაადგილებულ რეტროშარიაჟის ფრაგმენტებს.

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