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Geology

Duration of Mesozoic Orogenies (on the Example of Georgia)

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ABSTRACT. On the basis of litho-facies analysis of Mesozoic deposits that accumulated during the development of orogenies (phases of folding), the processes of sedimentation accompanying these phases of folding as well as some paleogeographic and structural changes have been considered. Each phase of folding was accompanied mainly by synorogenic regressive formations. They were a direct consequence and criterion of manifestation of the tectonic movements. The most important among the manifested orogenies in the considered territory in the Mesozoic was the Chegem orogeny. It formed the main morphostructural units and mostly predetermined the character and appearance of present-day structure of the region. With due regard to the age of regressive deposits and geochronological data the first attempt to determine the duration of each orogeny was made. As to the Cenozoic orogenies, they will be discussed in a separate article of the same journal. *© 2012 Bull. Georg. Natl. Acad. Sci.*

Key words: orogeny, phases of folding, regressive formation, paleogeography**.**

The deposits accompanying the phases of folding are represented mainly by regressive synorogenic formations that were a consequence and criterion of the duration of intensification of tectonic movements. On the territory of Georgia, it was illustrated with the example of Okriba (Western Georgia) and the Southern slope of the Greater Caucasus for the Chegem [1] and then for the Late Pyrenean [2] phases of folding, respectively (Fig. 1).

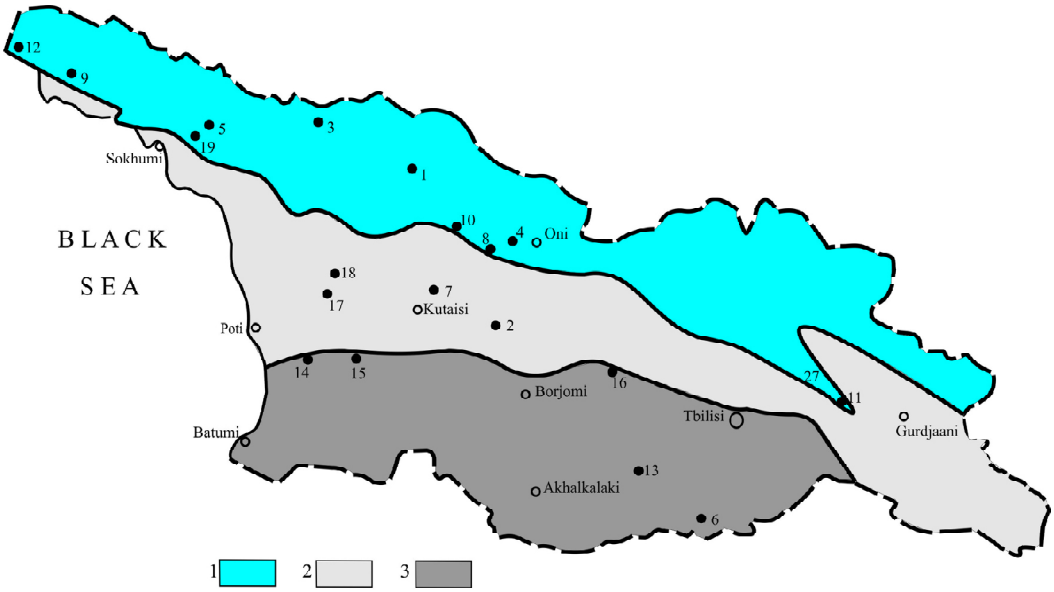
In the paper, based on litho-facial analysis of the Mesozoic sediments in the light of recent actual material and "plate tectonics", those facies and palaeogeographic changes that accompanied the orogenies are considered and to the possible extent the time of their manifestation is specified. According to geologic time-scale [3] the duration of each orogeny is defined (Fig. 2).

Before turning to the problem, it should be noted that in the study area, in the Mesozoic-Cenozoic time all the orogenies (except the Savian) distinguished by H.Schtille [4] as well as three new ones – the Donetsk, Chegem and Early Pyrenean (Trialetian) have been established.

Old Cimmerian Orogeny

The judgment on Old Cimmerian (Hindustani)) folding that manifested itself before the Liassic is connected with considerable difficulties, first of all because of the fact that the deposits of the Triassic age are preserved only in two areas.

According to the existing concepts in the Triassic time in the Caucasus, two separated basins existed – the Greater Caucasian in the north and the Armenian in the south [5]. While in Georgia from the first basin



1 - Foldsystem of the Greater Caucasus; 2 - Transcaucasian intermountain area; 3 - Foldsystem of the Lesser Caucasus

Fig. 1. Scheme of tectonic zoning of the territory of Georgia (I. Gamkrelidze, 2000)
•. location of some geographical names mentioned in the text.

only the Dizi series and "*lower tuffites*" (*the Narula suite*) are preserved, in the Lesser Caucasus sediments of this age are more widely represented.

Triassic deposits of Georgia by nature (petrographically, by the degree of metamorphism) are more closely related to the Paleozoic than to the Jurassic formations.

The Dizi series, the age range of which is Upper Paleozoic - Triassic developed in Chkhalta-Layli subzones of the Main Range zone. It is exposed in the upper reaches of the rivers Enguri and Tskhenistskali (Fig. 1, dot 1) composing the cores of the echelon-likely arranged Upper Svaneti and Lower Svaneti anticlines. They are composed of relatively deep formations of the continental slope and its foot, which underwent regional and contact metamorphism [6].

Triassic age of the upper part of the *Dizi series* is defined mainly according to its stratigraphic position between the faunally dated Upper Permian and Lower Liassic.

In the *Dizi series* several suites were distinguished by different authors. The Triassic part is allocated under the name of Gvashkhara [7], or Gvadarash [8] suite.

The second, southern outcrop of Triassic formations, as already mentioned, is preserved in the Dzirula subzone of the South Caucasus intermountain area in the south-western periphery of the Dzirula crystalline salient (Fig.1, dot 2). These formations, known as the "*lower tuffites*" [9], are exposed in the Narula, Kvirila, Glinavisgele, Kotorula and Macharula river gorges. Later on, they were identified as the *Narula suite* [10]. The *Narula suite* is exposed most completely on the river Narula, where it transgressively overlies crystalline rocks of the basement with basal conglomerates (10 m).

The age of *Narula suite* remained controversial for many years. Until now, it was defined as the Lower Liassic due to the transgressive bedding of Pliensbachian or Sinemurian rocks on the sediments of the *Narula suite* and fossil plant data [11]. Recently, on the basis of review and synthesis of the whole Triassic-Bajocian paleobotanical material, an opinion in favor of the Upper Triassic age (Norian and Rhaetian stages) of the *Narula suite* was expressed [12].

Thus, it can be inferred that the Old Cimmerian orogeny was manifested rather strongly causing regression and extensive pre-Liassic erosion. That is

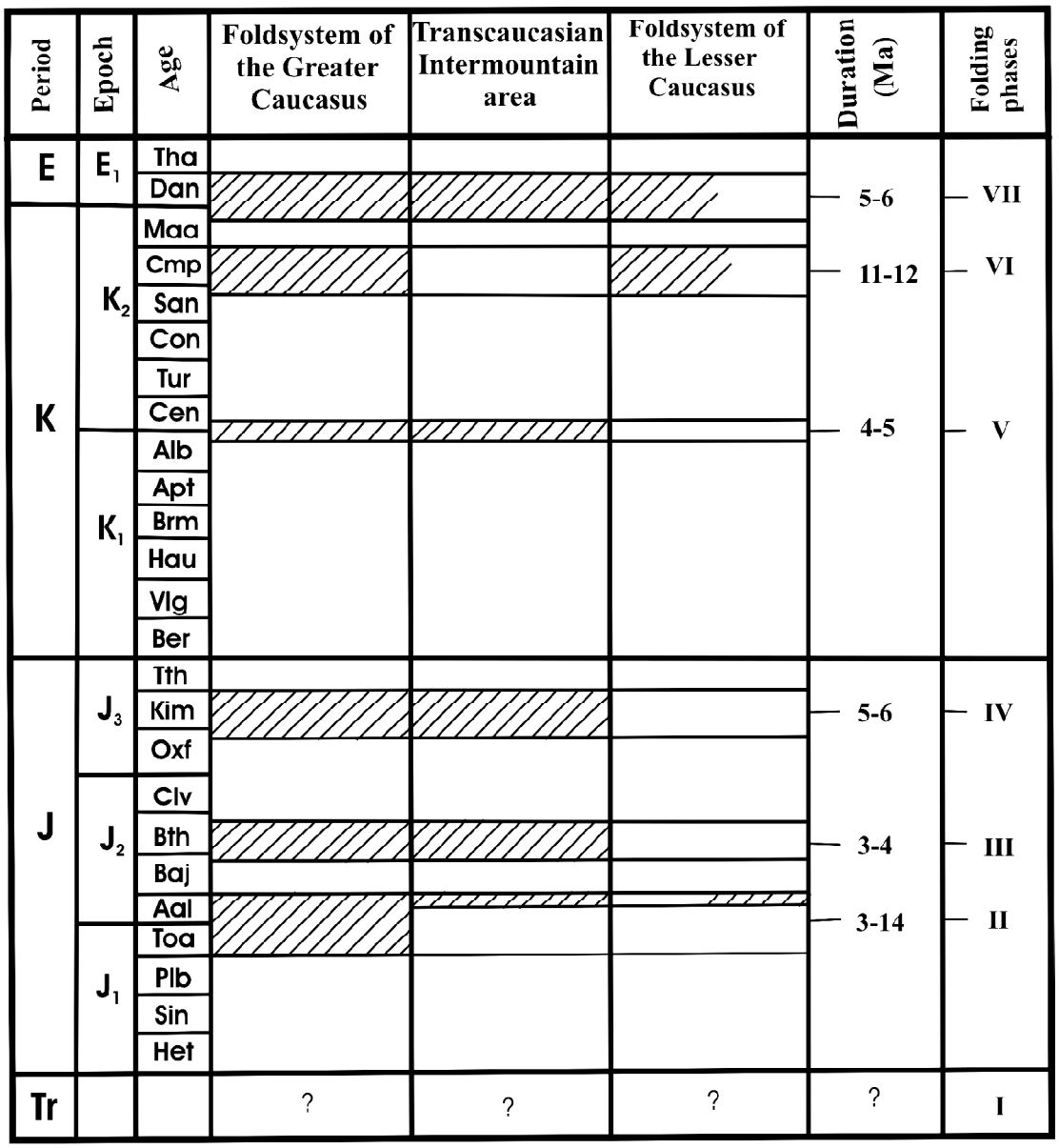


Fig. 2. Time and duration of manifestation of Mesozoic folding phases by regressive deposits

why the Triassic formations are preserved only in two areas. The latter does not allow to judge the character and duration of Old Cimmerian folding (Fig. 2).

Donetsk Orogeny

Before the Liassic, as a result of Old Cimmerian folding, paleogeographic reconstructions took place. By the beginning of the Liassic in the considered territory from the north to the south the following principal structural and sedimentary units were formed: 1) the Greater Caucasus island arc, 2) marginal sea or an intra-arc basin (remainder of the Tethys basin) and 3) the South Caucasian (Transcaucasian) island arc.

The first unit corresponds to the contemporary zone of the Greater Caucasus Main Range, the sec-

ond – to the northern part of the Southern Slope zone of the Greater Caucasus and the third – to the Gagra-Java zone, the Southern Caucasus intermountain area, the Achara-Trialeti and Artvin-Bolnisi zones.

In the Early Liassic, a large-scale transgression involved the greatest part of the territory under consideration, indicating the beginning of a new stage of geological evolution of the region.

Between the Middle and Late Liassic in the Donetsk basin, the Donetsk phase of folding was established. According to M.G. Lomize and D.I. Panov [13], based on the analysis of manifestations of magmatism during the Late Aalenian-Early Bajocian the Dzirula phase of folding was established in the North Caucasus. It was earlier distinguished in the South Caucasus intermountain area [14]. Because of lack of indication of specific sites and sections, where the angular unconformity between the Aalenian and Bajocian is recorded, it is impossible to discuss the nature and extent of manifestations of the Dzirula phase of folding within the limits of Georgia.

In the territory of Georgia, in contrast to the North Caucasus, the Donetsk orogeny was not so extensive and it was manifested in different ways. According to I.R. Kakhadze [15], the stratigraphic range of manifestation of the Donetsk orogeny corresponds to the interval from the Early Aalenian to the upper part of the Early Bajocian.

For the central part of the marginal sea of the Southern slope of the Greater Caucasus, according to magmatism [16], at the end of the Liassic and in the beginning of the Bajocian the following consistency of tectonic implications was determined: tension of the Earth's crust in the Late Pliensbachian with the eruption of tholeiitic magma, then the compression of the Earth's crust in the Toarcian-Early Aalenian and a complete cessation of volcanism (corresponding to the manifestation of Donetsk orogeny), then retension (Late Aalenian-Bajocian) and the resumption of tholeiite-basalt magmatism. In the eastern part of the marginal sea (east of the river Enguri) the Upper Liassic is represented by argillo-arenaceous rocks. In vertical direction an increase of sandstones and appearance of conglomerate packets is observed. Along with this, the content of plant residues also increased [17]. Together with the above-mentioned, that points to the regressive nature of these deposits induced by the Donetsk phase of folding.

In the western part of the marginal sea (North Abkhazia) in the Liassic clayey-volcanogenic-sandy formations of the *Lashipse* (Sinemurian), *Avadkhara* (Lower Pliensbachian-lower part of Upper Pliensbachian), *Atsgara* (Upper Pliensbachian-Lower Toarcian) and the *Achaean* (Toarcian) suites were deposited [18]. In the *Achaean suite* the increased number of sandstones points to the beginning of the regression. In the same suite the sections with the Upper Liassic clayey-sandy deposits contain stretched (over 2.5 km) lenses of granular crystalline limestones, pointing to the shallowing of the sea (the rivers Vostochnaya Gumista, Kelasuri, pass of Sanchar, etc.). In the upper reaches of the river Kodori (Fig. 1, dot 2), above these limestones there follow limestone breccias and conglomerates (up to 100 m) containing debris and pebbles of underlying limestones [9].

On the Southern slope of the Greater Caucasus (Gagra-Java zone), after deposition of Middle Liassic clay rocks, delivery of sandy material abruptly increased, causing the deposition of flyschoid *Sori suite* (Toarcian-Aalenian) with thickness 1,000-1,300 m. It is best represented in the basins of the middle course of the rivers Kodori (Fig. 1, dot 5) and Rioni (Fig. 1, dot 4) and is divided into two parts: the lower – alternation of medium- and thick-layered sandstone, argillites and aleurolites, and the upper part – massive and thick-layered sandstones with intercalations of argillites. All this undoubtedly points to the regressive nature of *the Sori suite*. The increase of psammitic material is observed both in the vertical direction and from north to south towards the Dzirula crystalline massif [16].

In the Southern Caucasus intermountain area tectonic movements of the Donetsk orogeny were most obvious within the limits of the Dzirula crystal-

line massif. In its greater part (except the north-east) an unconformity between the Bajocian and more ancient rocks, including the Toarcian and Aalenian, is observed. In the north-eastern part of the massif uninterrupted sections are observed, where the Aalenian gradually passes into the Bajocian. Here, the Toarcian-Aalenian deposits are represented mainly by clayey-sandy facies, in the upper part of which sandstones and conglomerates occur [15], indicating regression.

In the Loki-Karabakh zone, the Donetsk orogeny was expressed as a regression and also in the form of stratigraphic and angular unconformity. Within the limits of the Loki crystalline massif (Fig. 1, dot 6) sedimentation of the flyschoid *Jandara suite* took place during the Toarcian-Aalenian. It is built up of argillites, aleurolites and sandstones. As a result of regression and shallowing of the sea, the upper part of the suite is represented by coarse-grained sandstones, gravelites and conglomerates (the river Gorastskali). At the same time there occur sections (right bank of the river Akhkerpchay), where the red zoogenic limestones of the Aalenian pass upwards (in complete conformity and gradually) into the porphyritic series of the Bajocian [20].

Chegem Orogeny

The considered orogeny in the Caucasus was established by A.N. Gerasimov [21] at first as a Chegem folding and then as an Adyghe one. In Georgia, this folding was identified as the Bathonian [1], but in the literature it was more known as the Chegem orogeny. Its age was defined as the pre-Callovian.

The Chegem folding in the territory under study was one of intense orogenies. It caused significant changes in the structural-facial as well as in the palaeogeographic sense. After its manifestation the main morpho-structural units were formed. Later on, they largely determined the character of the geological development of the region.

One of such phenomena was the formation of the transverse-uplift of Svaneti, dividing the marginal sea of the Southern slope of the Greater Caucasus into two parts: the Abkhazian in the west and the Racha-Tianeti in the east [15]. Along with the facial changes, the Chegem orogeny caused partial inversion of the geotectonic regime and overall uplifting of the central parts of the Greater Caucasus and of the Georgian block, reflecting the tendency to transverse uplifting of the whole Caucasus [17].

On the territory of Abkhazia the formation of Akhtsu-Katsirkha cordillera took place, located along the southern periphery of the Western marginal sea associated with the Chegem orogeny. To the south of the cordillera, after the formation of volcanogenic-terrigenous sediments of the Upper Bajocian, in the Bathonian age the marine environment was gradually replaced by the continental-marine and continental environment, where the regressive *Betagian suite* represented by the alternation of sandy aleurolites and graywacke sandstones with rare interbeds of sandy limestones was deposited. The upper part of the suite comprises layers of microconglomerates and conglomerates composed of fragments of the Bajocian porphyritic series [19]. Regression and palaeogeographic reconstructions caused by the Chegem orogeny, determined the development of a coal-bearing formation and coal deposits (Bzibi, Tkvarcheli).

A distinct manifestation of the Chegem phase of folding was illustrated by A.I.Janelidze [1, 22] in Okriba (Western Georgia). The structural-facies analysis of Middle Jurassic deposits and their thicknesses has shown that the deposits accompanying the Chegem (Bathonian) folding are represented mainly by regressive synorogenic formations.

At the end of the Bajocian abrupt weakening of volcanic activity took place. By the beginning of the Bathonian age, in Okriba (Fig. 1, dot 7) low anticlinal uplifts (Bziauri, Shkmeri, Sori) appeared. They caused the formation of the Okriba lagoon. As a result of ongoing tectonic movements the Bziauri anticline turned into land and divided the Okriba lagoon into two separate lake-lagoons: the Gelati in the south and Tkibuli in the north, later turning into areas of coal accumulation [1].

Further to the east, in the Racha-Tianeti basin (Eastern marginal sea), where from the Liassic to the Late Eocene inclusive uninterrupted sedimentation took place, the Chegem orogeny was manifested in the formation of separate cordilleras and of corresponding regression. In Upper Racha, Bathonian formations are represented by the regressive "*Talakhiani horizon*" (in the north) and volcanic-terrigenous "*diabase horizon*" (in the south). Due to the Chegem folding, in the greatest part of the Eastern marginal sea, cordilleras appeared along its southern edge, creating a cordillera zone. Later on it played (Late Jurassic - Late Eocene) an important role in supplying flysch (in the North) and epicontinental (in the South) basins with terrigenous and detrital material. This cordillera zone was first distinguished by P.D.Gamkrelidze [23] and is known as the Gagra-Java cordillera [24], or the Racha-Vandam [25] cordillera zone, which is now completely covered with flysch formations overthrusting from the north.

The first signs of manifestation of Chegem folding, as already mentioned, appeared in the Late Bajocian, when intensive volcanic activity had stopped and sedimentation of arkose sandstones started. In the Bathonian age they were replaced also by regressive paper shales and a coal formation, which as thought earlier [20], accumulated during the Bathonian age. Then follow a transgression and unconformable bedding of Callovian sediments with conglomerates in the base. Based on these facts (villages of Tsesi, Sori, Zhoshkva, the Baklanovka river-gorge, Tskhanari syncline, etc.), the age of the Chegem folding was defined as the pre-Callovian. However, new factual material [26] requires a new approach to the question of the upper boundary of regressive deposits and respectively to the age of Chegem folding.

In uninterrupted sections of the Middle Jurassic (upper reaches of the rivers Psou and Gega, Okriba, Racha) the boundary between the Bathonian and the Callovian was usually drawn according to lithological features, in particular in the base of rudaceous rocks (mainly conglomerates) attributed to the lowermost Callovian. However, in the village of Tsesi (Racha) in the rocks related to the Lower Callovian (40 m) ammonite fauna of the Upper Bathonian was found [20]. On this basis, the age of regressive formations and duration of the Chegem orogeny according to new concepts covers the stratigraphic range from the Late Bajocian to Middle Bathonian inclusive. How this inference can be applied to the entire region, depends on the results of a critical review of the factual material.

Andean Orogeny

The Andean orogeny was manifested before the Tithonian and was much weaker than the previous one, although it covered a significant part of the territory. Western and Eastern marginal seas, from the Late Jurassic to Late Eocene inclusive turned into areas of accumulation of flysch formations.

In the Western flysch basin (upper reaches of the rivers Psou and Gega) flysch formations of the Upper Oxfordian-Tithonian follow above the Callovian-Lower Oxfordian *Aibgin suite*. Lithologically they are divided into two parts: the lower - terrigenous and the upper - carbonate [19]. The lower, terrigenous part (argillites, aleurolites with intercalations of graywacke sandstones and marls) located between the carbonate rocks (Upper Oxfordian sediments as well as the Tithonian are represented by limestones), by stratigraphic position corresponds to the Kimmeridgian and is represented by regressive formations.

In the Eastern flysch basin (to the east of the river Enguri), where deposition of flysch began from the Late Jurassic, any facies changes pointing to the regression is not observed, except for the presence of intraformational conglomerates (lower part of the *Tsipori suite*) confined to intrabasin cordilleras appearing due to the Andean orogeny [20].

Southwards of the flysch basins (Gagra-Java zone) due to the Andean orogeny a barrier, mainly coral reefs, was formed [20]. They developed around the cordilleras (Akhtsu-Katsirkha, Racha-Vandam cordillera zone), restricting the flysch basins from the south.

On the territory of Abkhazia, most of the reef structures formed in the Late Oxfordian-Kimmeridgian, with the exception of separate areas (the western slope of mountain Akhi-bakh), where reef-formation continued in the Early Tithonian [27]. To the south and east of limestone facies of the Upper Jurassic as a result of Andean orogeny the depressions formed that are most distinct in Western Georgia (Racha and Bzyb bays) and in the South Caucasus intermountain area (town of Tkvarcheli, vil. Okumi, the river Tshenistskali, Okriba, Racha, Lechkhumi, etc.), where from the end of the Oxfordian sedimentation of freshwater formations of the *"variegated suite"* began. Lithologically they are represented by alternation of sandstones, clays, limestones, dolomites and marls, having variegated coloring and containing plant residues. In the Kimmeridgian part of the suite, an increase of the terrigenous component and emergence of gypsum interlayer are observed, pointing to its regressive nature.

In the Tithonian age, despite the cessation of folding, in separate parts of lagoons, apparently the preceding facies conditions were preserved and the *"variegated suite"* continued to settle. In the Neocomian it is replaced with arenaceous and brecciated limestones. In the territory of the Kaldakhvara ridge (Abkhazia) (Fig. 1, dot 9), Oxfordian arenaceous limestones were replaced by variegated sandstones and clays, alternating with sandy limestones, dolomites and marls of the Kimmeridgian [15]. In the western part of the Racha syncline, the "*variegated suite*" is overlapped by the transgressive sandy-carbonate stratum of the Late Tithonian age. In the central part of this structure (Fig. 1, dot 10) Neocomian carbonate deposits are transgressed on the Lower-Middle Kimmeridgian and Upper Oxfordian-Lower Kimmeridgian (village of Chibrevi) rocks of the *"variegated suite"* [28].

In some sections (west of the village Tsesi, in Okriba and further to the west) the *"variegated suite"* transgressively and with angular unconformity overlies the Middle Jurassic formations, contrary to Late Oxfordian-Kimmeridgian regression. According to A.I. Janelize [1], this inconsistency was a result of ingression conditioning transgressive bedding of regressive formations.

Age of the *"variegated suite"* remained disputable for many years and various authors interpreted it in different ways: the Kimmeridgian [1, 15], the Kimmeridgian-Tithonian [20], the Callovian-Tithonian [29, 28], the Middle Oxfordian-Middle Tithonian [28]. Thus, it is impossible to judge the duration of the Andean orogeny according to the *"variegated suite*". Considering the palaeogeographic situation induced with the Andean and Chegem phases of folding, the "variegated suite" in my opinion, has lower and upper boundaries moving from the Callovian to the Tithonian inclusive. Based on this assumption, the formations under consideration represent a facies of "variegated deposits" without strictly defined stratigraphic boundaries, which does not allow distinguishing them as a suite.

As to the duration of the Andean folding, according to the available data it should cover a stratigraphic range from the Oxfordian to the Kimmeridgian inclusive (Fig. 2).

Austrian Orogeny

The exact age of Austrian folding is disputable due to the lack of angular unconformity between the Lower and Upper Cretaceous.

In the Western flysch basin (Abkhazia) mainly identical sediments (sandy marls, carbonate clays) were deposited in the Aptian and Albian and any signs of regression are missing.

In the Eastern flysch basin (east of the river Enguri) sandstone-aleurite flysch was deposited in the Aptian. It is known as the *Dgnali (Tetrakhevi) suite*. The above following Albian deposits are represented also by sandy-aleuritic flysch (*Pavleuri or Navtiskhevi suite*), consisting of alternating sandstone-, gravelite- and aleurolite-bearing turbidites and pelagic argillites and marls. Sandstone turbidites in the upper part of the suite are more coarse-grained and multiple [20]. Among them interlayers of sandy and organogenic-detrital limestones and volcanogenic-terrigenous rocks also occur [30].

The age of the *Dgnali (Tetrakhevi)* suite is defined as the Aptian-Lower Albian, of the *Pavleuri suites (Navtiskhevi)* – as the Middle and Upper Albian [31.32]. Along with regressive character, the Albian sediments differ from the Aptian ones in multicoloring. Regression, which began from the Late Albian, continued in the Early Cenomanian, as shown by the lithologic character of the Lower Cenomanian sandy-aleurolitic *Ukughmarti suite* composed of alternating sandy-aleurolitic, rarely gravelite-bearing turbidites and pelagic argillites. The sandstones contain glauconites in places. In the Kakheti region (the Cheremi syncline) (Fig. 1, dot 11) the *Ukughmarti suite* consists of thick-layered gravelites and coarse-grained sandstones with intercalations of argillites and conglomerates. The suite is crowned by the layer of conglomerates containing Upper Jurassic zoogenic limestone debris [33]. In the southern facies of the flysch (Zhinvali-Gombori subzone), *the Ukughmarti suite* is built up of breccia-conglomerates and sandstones (sometimes containing glauconite), interlayers of volcanic rocks occur rarely.

Thus, the Austrian orogeny in the Eastern flysch basin was manifested in the form of regression, which lasted from the Late Albian to the Early Cenomanian inclusive.

In the epicontinental basin, particularly in its western part (the rivers Arkva and Psou) Aptian and Albian rocks are built up of marls with rare intercalations of argillaceous limestones. Further to the south (village of Khashupse) (Fig. 1, dot 12) the Aptian is represented by brecciated limestones and the Albian comprises marls with interlayers of sandstone (upper part of the section).

In the territory of the Dzirula salient of the crystalline basement the Aptian is represented by limestones and marls and the Albian – by clays, marls, carbonate-bearing and glauconitic sandstones. The thickness of the latter in the upper part of the section reaches 1.5-2 m. They are unconformably overlain by quartz-glauconitic limestones of the Cenomanian [34]. At the same time, here (the northern periphery of the massif), as well as in the Eastern flysch basin, the regression continued in the Cenomanian, as indicated by the pre-Turonian break in sedimentation [20].

In the western and northern parts of Okriba (villages of Gordi, Kinchkha, etc.), among the Albian marls, lenses and intercalations of conglomerates with fragments of underlying marls appear. In the uninterrupted sections (southern limb of the Racha-Lechkhumi syncline, the western part of Okriba) deposits of the Cenomanian conformably follow above the Albian rocks and are represented by glauconitic sandstones, rarely by glauconitic limestones

Against the general background of the Albian-Early Cenomanian regression in some parts of the territory transgression took place (city of Kutaisi, the river Kvirila, Southern Okriba, Dzirula massif, etc.), which spread locally. As a result of transgression, at places Albian and Aptian deposits are missing (town of Chiatura, vil. Chkhari) (Fig. 1, dots 13,6). Similar movements took place in Southeastern Georgia (Khrami and Loki crystalline massifs), where at different stratigraphic levels of the Upper Cretaceous separate transgressions and regressions are observed.

Among the folded structures formed due to the Austrian folding, a Satsalike anticline separating the Racha-Lechkhumi syncline (in the north) from the Dzirula massif should be distinguished. Another anticline, formed on the southern periphery of the mentioned massif, separated the Kharagauli (in the north) and Molisi (in the south) synclines.

A significant episode, presumably taking place in the Albian age, was the appearance of the Black Sea - Achara-Trialeti rift zone in the central part of the Southern Caucasus island arc earlier subject to washout. In the eastern part (in the contemporary Achara-Trialeti zone) thick (up to 2000 m) volcanogenic formations accumulated during the Albian [34]. Due to the appearance of an intra-arc rift the South Caucasian island arc was divided into the northern and southern parts.

Sub-Hercynian Orogeny

The sub-Hercynian orogeny was manifested before the Maastrichtian and it completed the Mesozoic cycle of orogenesis. Its first impulses on the Southern slope of the Greater Caucasus and in the Achara-Trialeti zone were observed already before the Late Santonian [20].

In the Eastern flysch basin, this folding is fixed mainly in the areas of cordilleras and submarine uplifts. In the Shovi-Pasanauri subzone the Campanian is represented by clastic-limestone *Tsitliani suite* of flysch (limestones, marls, argillites), in the upper part of which at places (the village of Sakobliano in Kakheti) material of the eroded Upper Cretaceous flysch is attested [33]. In Kakheti (the village of Cheremi), angular unconformity is observed also under the Maastrichtian *Sabue (orbitoid) suite* [20]. In the synclinal structures, where the Campanian (*Jorchi suite*) gradually passes into the Maastrichtian (*Sabue suite*), between them signs of regression are not observed (Daradavi syncline in the Zhinvali-Gombori subzone). At the same time, in the section of the river Mejuda, the *Jorchi suite* is composed of clastic and biomorphic-detrital greywacke-sandy turbidites and shaly marls.

To the south, in the epicontinental basin in the Campanian age descending movements caused the contraction of Dzirula land and its gradual overlap by the younger members of the Campanian. These descending movements went on concurrently with Sub-Hercynian folding taking place in adjacent tectonic zones (Southern Slope of the Greater Caucasus and Achara-Trialeti zone). In the rest of the epicontinental basin sedimentation of shallow water limestones and marls took place.

In the Achara-Trialeti zone pre-Maastrichtian movements are well recorded in the northwestern part of the Trialeti Range, causing erosion and deposition of coarse-grained material. Deep washouts took place in the northern part of the Achara-Trialeti zone (town of Lanchkhuti, village of Dapnara) (Fig. 1, dots 14, 15), where the Maastrichtian (*Kheoba suite*) with a basal conglomerate overlies the rocks of the Campanian age. In some sections, as a result of pre-Late Santonian washouts (Gorisjvari-Khvedureti anticline) (Fig. 1, dot 16), Campanian deposits and in some places the Maastrichtian ones unconformably overlie the older rocks. Washouts are evidenced on the river Tedzami as well and they all associate with the Sub-Hercynian movements [20].

It should be noted that the Sub-Hercynian folding is connected with the tendency to overall compression taking place at that time in the Mediterranean belt, when splitting of the African-Arabian continent and the development of rifts of the Red Sea and Gulf of Aden began [35].

Laramide Orogeny

The Laramide folding involved the greater part of the territory under consideration. As a result of this folding, a remarkable reduction of the Eastern flysch basin (the Enguri and Liakhvi interfluve) took place and it turned into a part of the Greater Caucasian land.

The considered phase of folding caused an overall regression, which began from the end of the Maastrichtian and lasted during the Early Paleocene (Danian). Lithologically, the regression was manifested in the replacement of the Cretaceous carbonate sedimentation (limestones) by more terrigenous (clays, marls) in the Paleocene.

In the Eastern flysch basin the regression most distinctly manifested itself in the Zhinvali-Gombori subzone, where the regressive part of the Maastrichtian, occupying the upper horizons of the clastic-limestone *Sabue (orbitoid) suite* is represented by rudaceous facies - conglomerate-breccias and olistostromes composed of rubble and boulders of underlying flysch rocks and rocks of the Gagra-Java zone, in particular, of the products of erosion of the Racha-Vandam cordillera zone. Olistostromes of the Upper Maastrichtian (rivers Sakanapeskhevi, Mejuda, Ksani, Aleura, etc.) by their structure and appearance are similar to those of the Upper Eocene formations of the Southern slope of the Greater Caucasus [25].

In the deepened areas of flysch basin, where uninterrupted sedimentation took place, facies changes indicating regression are still observed. In the Daradavi syncline *the Sabue suite* is represented by the alternation of sandstone- and gravelite-bearing turbidites and pelagic limestones and clays. In the upper part of the suite an increased number of turbidites and, instead of limestones, deposition of sandstones or microconglomerates took place [33].

In the epicontinental basin (the Gagra-Java zone) the regression is manifested in replacement of carbonate sedimentation by carbonate-terrigenous one. The Abkhazian part of the basin was an exception, where in the Maastrichtian (*Mokvi suite*), as well as in the Danian age (*Tsebelda suite*), sedimentation of limestones continued. In this part of the basin signs of regression are observed in the sections of the Eki and Nokalakevi anticlines (Samegrelo) (Fig. 1, dots 17,18), where in the *Mokvi suite* terrigenous material in the form of quartz and limestone fragments was attested [33]. In the vicinity of the village of Tsebelda (river Kodori) (Fig. 1, dot 19) in the upper part of Maastrichtian limestones a considerable amount of quartz-arkose material is observed – a product of erosion of the Kelasuri granitoid massif. Terrigenous component in limestones increased in vertical direction and they are replaced by carbonate quartz-arkose sandstones. In the Achara-Trialeti zone the *Zguderi suite* of the Santonian-Maastrichtian age developed; it is built up of limestones with marl intercalations. In the upper part of the suite intraformational conglomerates are present, pointing to the activation of tectonic movements in the Late Maastrichtian. Here, as in the Dzirula subzone, due to the regression from the end of the Maastrichtian and throughout the Danian, "variegated marls" accumulated instead of limestones. As a result of Laramide folding, folded structures in the form of Tsiteltskaro, Satskhenisi, Gorisjvari, Khvedureti and other cordilleras appeared for the first time in the Achara-Trialeti rift basin [34]. Thus, according to the regressive deposits the time of development of Laramide folding was determined within the interval of Late Maastrichtian-Early Paleocene (Danian) inclusive.

გეოლოგია

მეზოზოური ოროგენული ფაზისების ხანგრძლივობა (საქართველოს მაგალითზე)

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ოროგენული (დანაოჭების) ფაზისების დროს წარმოქმნილი ნალექების ლითო-ფაციესური ანალიზის საფუძველზე განხილულია იმ დროის სედიმენტაციური პროცესები, პალეოგეოგრაფიული და სტრუქტურული ცვლილებები. დანაოჭების ყველა ფაზისს თან ახლდა სინოროგენული რეგრესიული წარმონაქმნები, რომლებიც ტექტონიკური მოძრაობების გააქტიურების პირდაპირ

შედეგს და დროში მათი ხანგრძლივობის საზომს წარმოადგენს. საქართველოს ტერიტორიაზე დადგენილ მეზოზოურ ოროგენულ ფაზისებს შორის ყველაზე მნიშვნელოვანი ჩეგემური დანაოჭება იყო. მის შედეგად ჩამოყალიბდა ის ძირითადი მორფოსტრუქტურული ერთეულები, რომლებმაც შემდგომში მნიშვნელოვნად განაპირობეს რეგიონის თანამედროვე გეოლოგიური აგებულების ხასიათი. რეგრესიული ნალექების ასაკისა და გეოქრონოლოგიური მონაცემების გათვალისწინებით აღნიშნულ სტატიაში პირველად განისაზღვრა მეზოზოური ოროგენული ფაზისების საყარაულო ხანგრძლივობა.

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