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PALENTOLOGY

UPPER EOCENE-LOWER OLIGOCENE SHAGHAP REEF (ARMENIA): COMPOSITION AND PALEOENVIRONMENT

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In this paper small Coralline algae reef from the Shaghap piggyback basin is described. The microfacies analyses, small size planktonic foraminifers are studied for the first time. Orthophragminids and Nummulites up to 10 cm in diameter are abundant in the reef framework. Reef type is defined as cluster, the main part of which was formed near the Eocene-Oligocene boundary occurring below the depth of wave action in mesophotic conditions.

The lower part of the studied section presented of Lower Oligocene (based on small planktonic foraminifers) high sedimentation rate deposition (limestone with conglomerates, breccias and blocks of reef construction). This unit is overlain by thrusted wackestone of late Middle Eocene, which covered by matrix supported (up to 15m) large Discocyclina, nummulitic limestones (rudstone). The latter is covered by bedded organogenic (Coralline red algae, rare Nummulites) sandy limestones (packstones, rudestone). Dome-shaped microbialites (thrombolites) developed in the upper most part of the section accumulated as a result of the abrupt climatic changes of that time.

The geological cross section passing through the reef construction, two north-dipping reverse faults of post Oligocene activation is identified. Due to tectonic activity folded block (reef talus) is observed in the reef body.

Key words: Coralline algae reef, Nummulite, Echinoderms, Discocyclina, microbialites, reverse fault

Introduction

The Shaghap synclinal is known to be composed of Eocene-Oligocene shallow marine deposits with significant tectonic disturbance and stratigraphic break (fig.1). The information about Paleogene reefs are well presented from the West-central Tethys area (e.g. Pomar et al., 2017 and references therein). Little is known about Eocene-Oligocene reefs development in the Lesser Caucasus (Armenia), which is known also as the “greenhouse-icehouse”

transition. Previous studies of Upper Eocene –Oligocene organogenic reefs of Arax river basin were focused on sedimentology, palaeontology (corals and mollusks) Sadoyan and Aslanyan (1981). Recently Shaghap reef was studied in terms of Large Bentic Foraminifers and Eocene/Oligocene transition is determined (Zakrevskaya et al., 2014). In the sections passing through the Shaghap village the nummulitids and discocyclinids were studied by Krasheninnikov et al., 1985; Grigoryan (1979, 1986), but it's not clear whether these studies include also the reef sections or not?

This study gives insight into the composition of Coralline algae reef from Shaghap area based on microfacies analyses. The framework, growth fabrics for reef structural classification, small-sized planktonic and large bentic for a-minifera for age definition and palaeoenvironmental implications are studied and discussed. Tectonic impact on reefal body is studied as well.

The aim of this work is the study of sedimentological, palaeontological characteristics and structural setting of the Shaghap reef for reconstruction of the paleoenvironmental history.

Geological setting

The collision between Eurasia and the South Armenian Block (SAB) in the Late Coniacian-Santonian interval (c. 85 Ma; e.g. Rolland et al., 2009; Sosson et al., 2010) conduced to the formation of Amasia-Stepanavan-Sevan-Hakari suture zone, situated in central part of Alpine-Himalayan orogenic belt. Collision is followed by the formation of Vedi-Vayots Dzor foreland basin in the southeastern part of Armenia. The Paleocene-Eocene boundary corresponds to tectonic inversion of the basin, at the onset of “hard” collision (collision of upper part of lithosphere) of Arabian – (namely SAB) and Eurasian continents (Sosson et al., 2010). Eocene magmatic rocks were formed in an extensional tectonic condition with basin formation and marine transgression (Sahakyan et al., 2017a).

The ENE-WSW elongated Shaghap syncline is limited by Lanjanist and Urts anticlines (fig.1), which are controlled by the thrusts (Avagyan et al., 2018). The Eocene-Oligocene transition corresponds to the Paratethys Sea, but the domains and the time of formation remains a matter of contention. According (Sahakyan et al., 2017b) during Middle Eocene-Oligocene the Shaghap basin was partly isolated, forming a piggyback basin on backlimb of a moving Urts-Aghbyur thrust (Avagyan et al., 2018).

The studied Shaghap small reef structure is positioned in 3km to the SSW from Shaghap Village, at an altitude of 1487m a.s.l. (39°52'8.11"N; 44°51'26.93"E; fig.1). It outcrops with a length of approximately 500m. Here the Lower Eocene conglomerates, organogenic limestones unconformably overlain the Permian limestones.

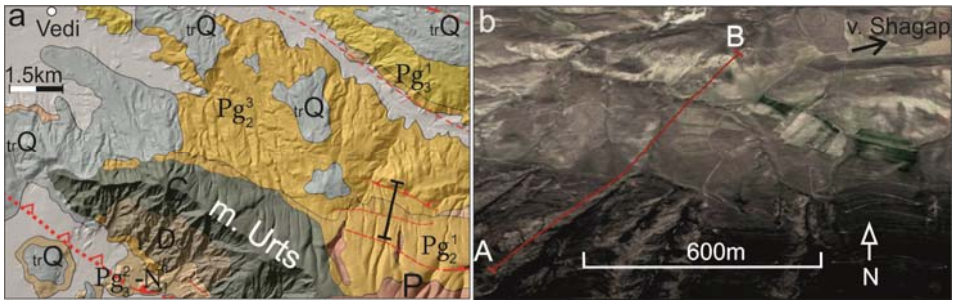

Fig.1. (a)- Simplified geological map of studied area (Avagyan et al., 2018); trQ- Quaternary travertines, colluvial, proluvial deposites; Pg^2_3-N^1_1-Upper Oligocene- Lower Miocene multicolored clays, siltstones, sandstones; Pg^1_3- Lower Oligocene clays, sandstones, siltstones; Pg^3_2- Upper Eocene (clayey sandstones, siltstones, marls with limestone lenses); Pg^1_2- Lower Eocene limestones, sandy limestones, siltstones, conglomerates; P- Permian limestones; C- Carboniferous limestones, sandy shales; D_3-Upper Devonian clay shales, limestones, quartz-sandstones, quartzites; black line corresponds to the cross section (fig.5). (b)-Google map with a red line of AB cross section (fig.5).

Middle Eocene is presented by marls, volcaniclastics, fine-grained sandstones, siltstones and nummulitic limestones. Shaghap formation of Oligocene age contains sandstones, clays, coral limestones which grade up into Quaternary volcanic rocks, travertines and recent alluvial, deluvial and colluvial deposits (fig.1).

Lithological log in the western part (fig.2, a; fig.3) and geological cross section (fig.5) in the eastern part of the reef body were carried out in order to describe its composition and tectonic impact.

Materials and methods

The Eocene-Oligocene sediments of Shaghap reef section were analysed using petrographic description based on thin section of 30 samples. The facies nomenclature follows the textural classification scheme of Dunham (1962). Carbonate facies are defined according to the dominant fossil assemblage and depositional fabric (Flügel, 2004). For architectural fabric we follow Riding's (2002) nomenclature.

Biostratigraphic analyses (planktonic foraminifers) were performed on 7 samples. To extract planktonic foraminifera shells from claystones, mudstones and wackstones the optimised procedure proposed by Grigoryan and Sahakyan (2019) is used. The systematic taxonomy of planktonic foraminifera is based on the atlas of Pearson et al. (2006) and Wade et al. (2018). The biostratigraphy is based on the biozonal definitions given by Berggren and Pearson (2005), Wade et al. (2011). Geological cross-section is based on published data and own field observation including litho-paleontological results.

Description of facies types

Reef terminology used in this paper, as the studied section is carbonate structure, formed *in-situ*, bounded by organic components and developed in topographic relief upon the sea floor (e.g. Kiessling et al., 2002).

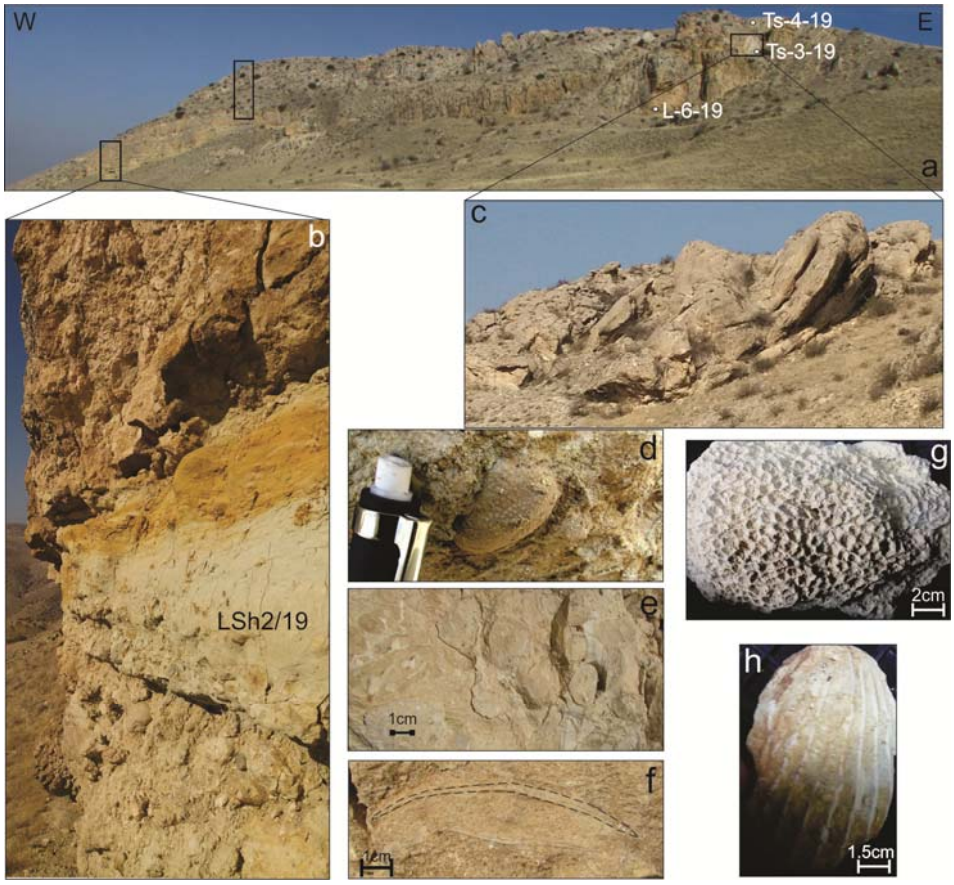

Fig.2. Field photos of the Eocene-Oligocene Coralline algae reef; (a)- panoramic view of the reef; (b)- section in the western part of the reef body; (c)- fallen block; (d, h)- Echinoderm, (sample LSh4/19); (e)- thick branching colonies of Corals; (f)- large (10cm) Discocyclina (sample LSh4/19), dot line shows the shape of Discocyclina; (g)- cylindrical body of Scleractinian corral.

On the basis of biogenic composition and depositional fabric eight Facies Type (hereafter FT) were identified: The basal part of the succession is represented by limestones whit the conglomerates and breccias (fig.2, b), marlstone, siltstone and coralline limestone blocks (fig.2, e).

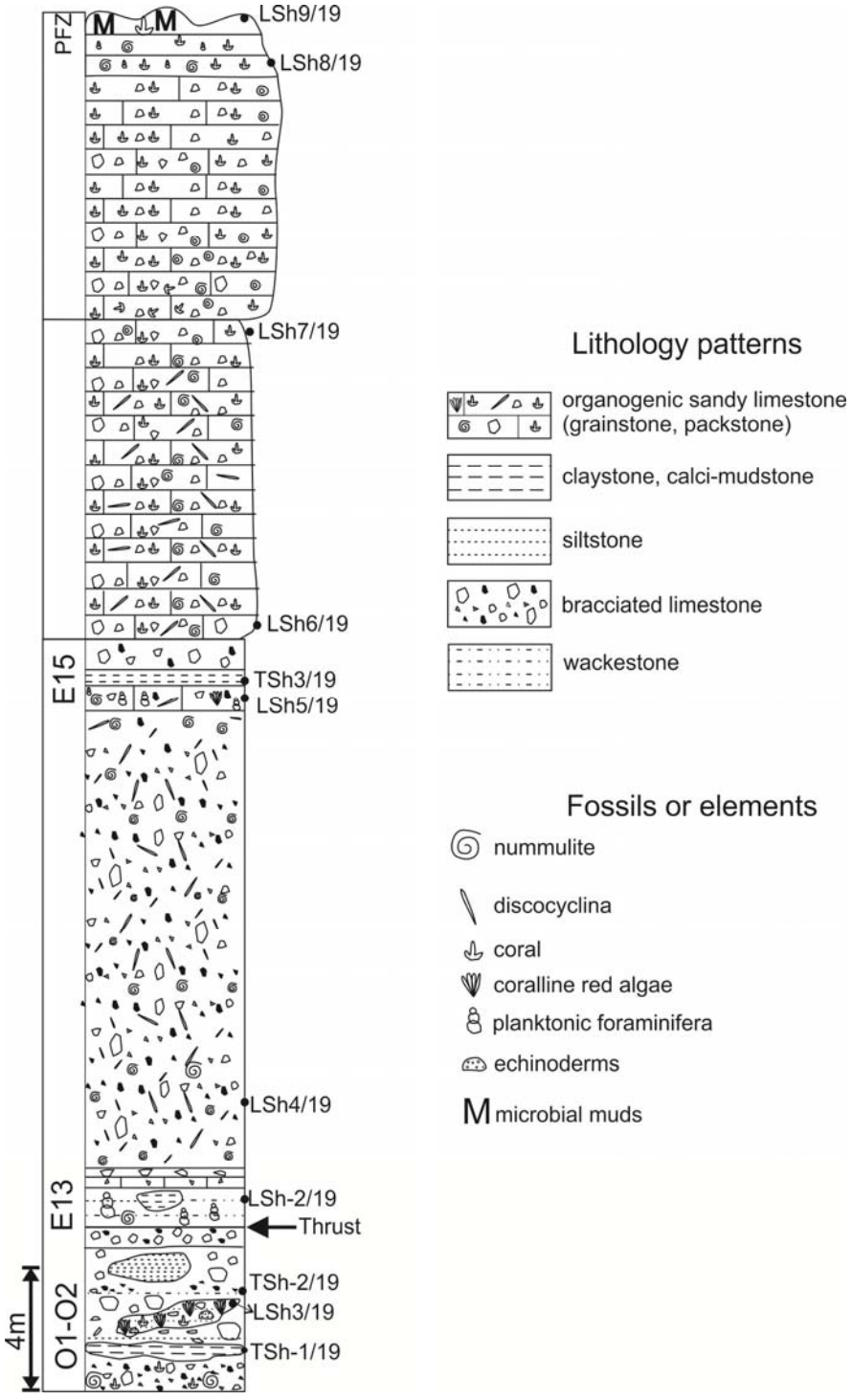

Fig.3. Litho-stratigraphic log of western part of Shaghap reef (fig.2, a). PFZ- Planktonic Foraminifera Zone. Arrow shows the thrust position.

On the litho-stratigraphic log the basal part is overlain by 1.60 cm thick wackestones (FT1) (fig.2, b; fig.3, sample LSh 2/19) which contain A-forms Nummulites, planktonic foraminifers, fragments of Bryozoans, quartz crystals and Fe oxide grains in carbonate mud matrix.

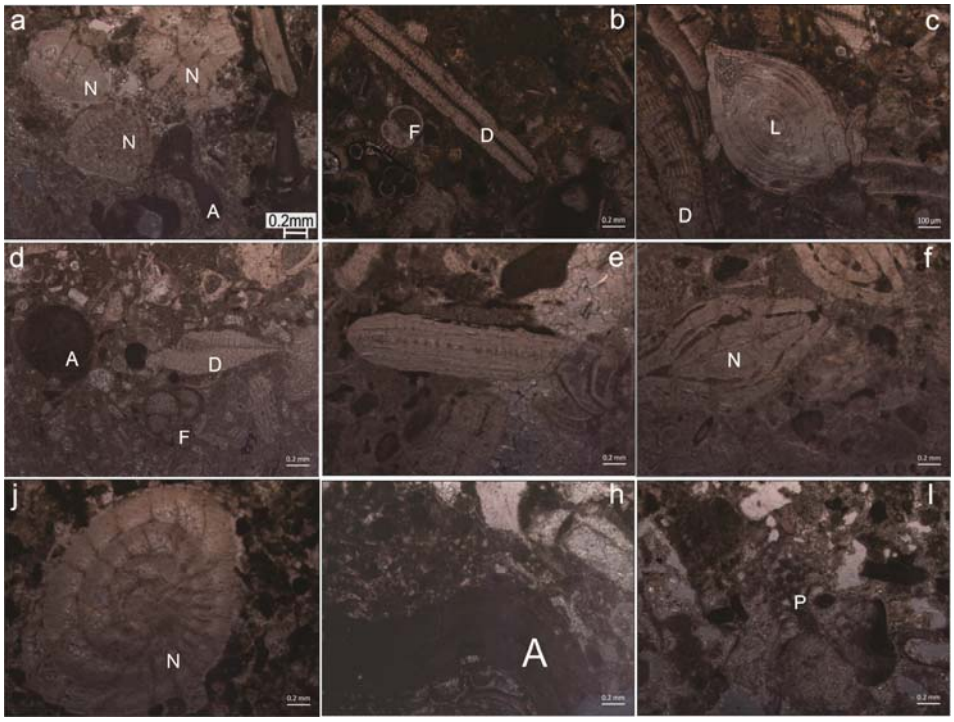

Fig.4. Microphotographs in thin sections of representative samples. Limestone block (a) LSh1/19 - unsorted biosparite (boundstone) from lower part of the section; (b, c) - rudstone with a packstone/grainstone matrix (sample LSh4/19); (d)- packed biomicritic limestone (LSh5/19); (e, f) Discocyclina-Nummulites rudstone (LSh6/19); (j)- coralline algal grainstone (LSh7/19); (j, h)- packstone (LSh8/19); (I)- microbialite (LSh9/19).
N-Nummulites, D-Discocyclina; A- Coralin red algae; F- planktonic foraminifers; L. – Lenticulina; P- microbial peloids.

Upward, the next facies (FT2) is rudstone (coarser, grain-supported biogenic limestones) with packstone/grainstone matrix up to 15m thick, (LSh4/19) (fig.2, f), composed mostly of large Discocyclinas and Nummulites (up to 10 cm in diameter), Lenticulina, red algae fragments. Associated biotas are mostly small bioclasts, coralline algae, echinoid plats, smaller planktonic and benthic foraminifers (fig.4, b, c). This unit is overlain by grainstones (FT3, 50cm thick, fig.4, d) with small planktonic foraminifers, discocyclinids as well as numerous red algal, coralline algal fragments. Additionally, some echinoids, bryozoans, bivalve fragments and gastropods are present.

Calci-mudstone (FT 4) of 20cm (sample TSh3/19) overlay by Discocyclina-Nummulites rudstone (LSh 6/19, fig.4 e, f) with packstone matrix (FT 5). This microfacies is characterized by the occurrence of Discocyclina and

some species of Nummulites and coralline red algae. Other bioclastic components are fragments of echinoids and bryozoans.

Bedded rudstone (FT5) with dominant red algae fragments (thalli, laminar plant of *Mesophyllum mengaudii*), B form Nummulites (fig.4, f), Discocyclinas (sample LSh6/19) is characterised. Bryozoans, Chapmanina (fig.4, a) of subordinate components are presented as well.

Sample LSh7/19 is bedded limestone (coralline algal grainstone (FT 6) characterized by the occurrence of coralline red algae, bryozoans' fragments, individual B-form Nummulites (fig.4, j). Upper part of the section presented by packstones (LSh8/19), with dominated coralline red algae fragments (fig.4, h-rhodoid). Individual A form Nummulite fragment, biserial foraminifer is observed as well. The matrix of the rock is composed by peloides (FT 7) and other small skeletal fragments (mainly echinoderms). Packstones are covered by microbialites (sample LSh9/19, fig.3). The size of hemispherical domes microbial build-ups ranges from 0.5 to 1 m (FT 8). The trapped materials include carbonate fecal pellets, cavities and microbial peloids without skeletal fragments. Few fragments of Bryozoans are observed in microbialites. Microbial peloids and encrusting filaments form incipient branching structures (fig.4, i).

Planktonic foraminifera

Examined micropalaeontological samples have been positioned on the litho-stratigraphic log and geological cross section (figs. 2,3 and 5).

In the sample TS-0-19 (39°51'59.9"N, 44°51'19.5"E, fig.5) the following planktonic foraminifera associations are described: *Dentoglobigerina prasaepis, D. taci, D. larmeui, D. globularis, D. tapuriensis, D. baroemoenensis, D. galavisi, D. pseudovenezuelana, D. eotripartita, Subbotina corpulenta, Catapsydrax unicavus, Globigerina officinalis, Globigerinella obesa.,* which indicate O1-O2 zones (Lower Oligocene).

Planktonic foraminifers association in sample Ts-3-19 (39°52'7.20"N, 44°51'25.91"E, fig.2) presented by *Subbotina angiporoides, S. crociapertura, S. patagonica, S. roesnaesensis, Acarinina bullbrooki, A. praetopilensis, A. boudreauxi, Globigerinatheka subconglobata, G. index, Dentoglobigerina galavisi, Globigerina officinalis*, corresponding to E10-E11 zones.

In the sample Ts-4-19 (39°52'8.4"N, 44°51'24.2"E, fig.2) the following planktonic foraminifers are recorded: *Hantkenina nanggulanensis, H. alabamensis, H. primitive, H. compressa, Dentoglobigerina pseudovenezuelana, D. eotripartita, D. galavisi, Globigerina officinalis, Globigerinella obesa, Subbotina projecta, S. corpulenta, S. tecta, S. yeguaensis, Turborotalita carcoselleensis.* Such assemblages indicate the Upper Eocene age (E16 zone).

Sample TSh1/19 (39°52'08.6"N, 44°51'12.0"E; fig.3) presented by *Turborotalia ampliapertura, T. increbescens, Dentoglobigerina larmeui, D. tapuriensis, D. galavisi, D. pseudovenezuelana, Catapsydrax unicavus, Globoturborotalita pseudopraebulloides, G. paracancellata, Globigerina archaeobulloides,*

Subbotina eocaena, S. projecta, S. corpulenta. Planktonic foraminifers presence suggest their possible attribution to the O1-O2 zones.

In sample TSh-2/19 (39°52'08.9"N, 44°51'11.7"E; fig.3) *Ciperoella ciperoensis, Parasubbotina hagni, P. varianta, Subbotina projecta, Turborotalia increbescens, T. ampliapertura, Turborotalita praequinqueloba, T. quinqueloba, Catapsydrax dissimilis, Paragloborotalia pseudocontinuosa, Dentoglobigerina galavisi, D. eotripartita, D. venezuelana, D. sellii, D. baroemoenensis, D. prasaepis, D. tapuriensis, Subbotina corpulenta, S. eocaena, Streptochilus martini, Catapsydrax unicavus, Globoturborotalita gnaucki, G. ouachitaensis, G. occlusa, Globorotaloides quadrocameratus* are presented, corresponding to O1-O2 zones.

Sample LSh 2/19 (fig.3) is presented by the following planktonic foraminifera associations: *Globigerinatheka korotkovi, G. index, G. tropicalis, Globanomalina australiformis, Subbotina linaperta, S. jacksonensis, S. corpulenta, S. linaperta*, *Catapsydrax africanus, C. globiformis, Parasubbotina inaequispira, P. varianta, Paragloborotalia nana, Globorotaloides quadrocameratus, Hantkenina alabamensis, Globoturborotalita gnaucki, Turborotalia possagnoensis? T. Inc rubescens, T. cer-roazulensis.* The assemblage belongs to the late Middle Eocene (E13 zone).

TSh3/19 (39°52'09.8"N, 44°51'12.5"E; fig.3) sample is presented by *Globigerinatheka index, G. tropicalis, Dentoglobigerina eotripartita, D. galavisi*, *Pseudohastigerina micra, Subbotina eocaena.* The age can be determined as Upper Eocene (E15 zone).

Larger benthic foraminifers

The detail study of the larger benthic foraminifers from reef limestones was not carried out yet. The specific identification of Nummulites and other LBF was done for nummulitic llimestones from eastern part of the reef (Zakrevskaya et al., 2014). In nummulitic limestones, abundant Nummulites fabiani iretiatus, usual N. striatus, rare N. incrassatus and N. vascus, rare Chapmanina and Sphaerogypsina were observed. The orthophragminids are absent in these limestones. Their absence and the presence of transitional forms of Nummulites allow us to refer the limestones with N fabiani iretiatus to Late Eocene – Oligocene ages.

Tectonic impact on the reef

North-south oriented geological cross-section (fig.1, a-black line b- red line) passing through the reef has been compiled (fig.5). It shows the presence of two north-dipping reverse faults as a result of north-south shortening. The observed faults are the western segments of “Vank fault” with similar kinematics and dipping (Avagyan et al., 2018). The post-reef faults activation evidenced by cross cut Upper Eocene and Lower Oligocene (Rupelian) formations. Our observation at about 350m to the west from cross section line

shows that the Upper Eocene (Priabonian) reef deposits have trusted over the Oligocene claystones proving thus the post-Oligocene fault activation.

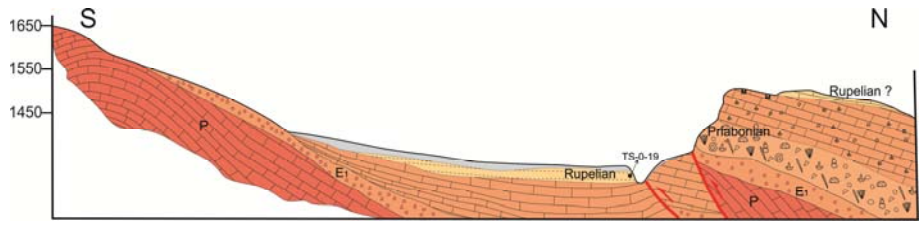

Fig.5. N-S oriented cross section through the eastern part of the reef (cross section line is shown on fig.1). P - Permian limestones; E_1 – Lower Eocene conglomerates, organogenic limestones. For lithology patterns and fossils see fig.3; sample Ts-0-19- claystone.

The landslide or rockfall development is triggered by tectonic uplifting of the area. According the study of benthic foraminifers the age of rockfall beds (reef talus) correspond to E10-E11 zone (Middle Eocene, sample Ts-3-19).

Discussion and Conclusions

Based on sedimentary matrix and coral skeletons relationship the Shaghap reef may be classified as Cluster Reef, i.e. matrix-supported, where skeletons are adjacent, mostly disarticulated (Riding, 2002).

The reef lower horizon (L-6-19) in the eastern part of the outcrop (fig.2, a) presented by Rhodolith limestones. These rhodoliths are encrusted and show warty growth forms. In places encrusting bryozoans are visible in rhodolith construction. Here, in the upper part of the section according to planktonic foraminifers the latest Late Eocene (E16 zone) is identified (sample Ts-4-19) from the soft part of the deposits (fig.2). The structural pattern of the outcrop is complicated by fallen folded limestone block (fig.2, c) most probably triggered by the tectonic uplifting of the area. The age of this block is corresponds to E10-E11 zone (Middle Eocene, sample Ts-3-19, fig.2).

In the lower part of the studied section from western part of the outcrop (fig.2, a) the limestones with conglomerates and breccias, reefal blocks of branching coralline limestones, siltstones, claystones and calci-mudstones of Lower Oligocene is determined. Here Dentonglobigerina taxa are identified, providing evidence of warm- temperate environment (Sotak, 2010). On this formation wackestone of 1.60cm (fig. 2, 3, sample LSh 2/19) is thrusted, which contain Nummulites, small planktonic foraminifers, fragments of Bryozoans, quartz minerals, Fe oxides in carbonate mud matrix. According planktonic foraminifera, the wackestone corresponds to E13 zone (late Middle Eocene). In this sample the *Globigerinathekids* and *Subbotina* were found and as subtropical and cooler water forms can be interpreted (Sotak, 2010 and references therein). The wackestone is covered by reefal deposits with large Nummulitic-Discocyclina contents. According benthic foraminifer complexes

the age of lower part of the reef formation is post late Middle Eocene. The calci-mudstone of 20 cm (TSh3/19) in the middle part of the section corresponds to E15 zone (Upper Eocene).

The sedimentary succession of Shaghap outcrop (its western part) is composed of eight main facies.

Nummulites of N. fabianii indicate the Priabonian age, but the absence of N. orthophragminids and the occurrence of the Priabonian Chapmanina the age of reef defined as transition of Eocene-Oligocene. The latest Late Eocene epoch by planktonic foraminifers assemblages is determined in the upper part of the Shaghap succession.

Rudstone with packstone/grainstone matrix (FT2) interpreted to be formed in a low-energy environment, below the wave-base level. The presence of giant Nummulites and abundant discocyclinids is interpreted as an indication of stable, normal marine environment (Cosovic et al., 2004). The abundance of red algae and the presence of flat larger benthic foraminifers within the matrix, suggest the mesophotic conditions (Pomer et al., 2017). FT3 facies is deposited in the environment characterized by higher energy, possibly controlled by sea level fluctuations.

According to small planktonic foraminifera the middle part (FT4 facies) of the reef corresponds to Upper Eocene (sample TSh3/19, fig.3). The matrix-supported textures (mudstone (FT4) and packstones (FT5) of the reef sediments indicate that the Shaghap reef grew in a relatively low-energy environment. The studied reef deposits are matrix-supported that developed below the depth of wave action environment.

The upper part of the reef is built by fragments of coralline red algae (Lithothamnion), with little content of Nummulites (FT6). Bryozoans fragments (Stigmatella personata (?)), echinoids are also present in this part of the section. Based on the bedding patterns, skeletal composition and textures, we interpret FT6, FT7 to have also been deposited in a high-energy zone.

Development of microbialites can characterise the abrupt climatic changes of that time.

Two north-dipping reverse faults are proposed in the site based on the local structural, geological, morphological particularities. Thrusting of reefal deposits on Lower Oligocene claystons (according planktonic foraminifera from the sample Ts-0-19 corresponds to O1-O2 zones, fig.5) observed in the valley indicating the post-Oligocene fault activation.

Detailed study of large benthic foraminifera and corals require separate studies.

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Սահակյան Լ., Գրիգորյան Տ., Ավագյան Ա., Զակրևսկայա Ե., Ստեփանյան Ժ., Հայրապետյան Ա.

Ամփոփում

Հոդվածում նկարագրվում է Շաղափ պիջիբաք (piggyback) ավազանում ձևավորված փոքր կորալ-ջրիմուռային ռիֆը: Առաջին անգամ տրվել է ռիֆի միկրոֆացիալ անալիզը, նկարագրվել են փոքր պլանկտոն ֆորամինիֆերները: Ռիֆային կառույցում առատ են մինչև 10 սմ տրամագծով Orthophragminids և nummulites: Որոշվել է ռիֆի տեսակը (կլաստային), որի հիմնական հատվածը ձևավորվել է էոցեն-օլիգոցեն անցումային ժամանակահատվածում՝ ալիքների գործունեության մակարդակից ներքև, մեզոֆոտիկ պայմաններում:

Ուսումնասիրված կտրվածքի ստորին հատվածը ներկայացված է ստորին օլիգոցենի հասակի (ըստ պլանկտոն ֆորամինիֆերների), արագ նստվածքակուտակմամբ բնորոշվող կրաքարերով՝ կոնգլոմերատների, բրեկչիաների և ռիֆային կառույցի բլոկների պարունակությամբ: Այս միավորը ծածկված է ուշ միջին էոցենի վրաշարժված վակստոնով, որը հերթափոխվում է մատրիքսի առկայությամբ մեծ դիսկացիկլինա-նումուլիտային կրաքարերով՝ ռուդստոններով (մինչև 15մ հզորությամբ): Վերջինս ծածկված է շերտավոր օրգանածին (կորալ-ջրիմուռային, հազվադեպ նումուլիտների առկայությամբ) ավազային կրաքարերով (պակստոններ, ռուդստոններ): Կտրվածքի ամենավերին հատվածում ձևավորված գմբեթաձև միկրոբիալիթները (տրոմբոլիթներ) կուտակվել են կլիմայի կտրուկ փոփոխության արդյունքում:

Ռիֆայի կառույցը հատող երկրաբանական կտրվածքում առանձնացվում են երկու հետ օլիգոցեն ակտիվության, դեպի հյուսիս անկմամբ վերնետքներ: Կառույցում դիտարկվել է տեկտոնական ակտիվությամբ պայմանավորված ծալքավոր, ռիֆային քարաթափվածք (reef talus):

ВЕРХНЕЭОЦЕНОВЫЙ-НИЖНЕОЛИГОЦЕНОВЫЙ ШАГАПСКИЙ РИФ (АРМЕНИЯ): СОСТАВ И ПАЛЕОСРЕДА

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Резюме

В статье описывается небольшой кораллово - водорослевый риф из Шагапского пиджибак (piggyback) бассейна. Впервые дан микрофациальный анализ, описаны мелкие планктонные фораминиферы. В каркасе рифа обильны Orthophragminids и nummulites диаметром до 10см. Тип рифа определяется как пучковидный, основная часть которого развивался на границе эоцена и олигоцена, ниже глубины действия волн в мезофотических условиях. Риф состоит из карбонатов, в которых преобладают кораллово-водорослевые рудстоны, пакстоны и грейнстоны с нуммулитами и дискоциклинами. Кораллы, красные водоросли, нуммулиты, дискоциклины и эхинодермы доминируют в каркасе рифа, а гастроподы, мшанки и моллюски имеют второстепенное значение.

Нижняя часть исследуемого разреза представлена отложениями нижнего олигоцена (на основе планктонных фораминифер), обладающими высокой скоростью осаждения (известняки с конгломератами, брекчиями и с блоками рифовой постройки). Это часть перекрыта вакстонами позднего среднего эоцена с надвигом, которые в свою очередь перекрыты матрицсодержащими рифоподобными отложениями (до 15м) с крупными дискоциклинами - нуммулитовыми известняками (рудстон). Это же часть толщи перекрыто пластовыми органогенными коралловыми, с редкими нуммулитами песчаными известняками (пакстон, рудстон). Куполообразные микробиалиты (тромболиты) развиты в самой верхней части разреза, накопленного в результате резких климатических изменений того времени.

В геологическом разрезе, проходящем через риф, очевидно наличие двух северонаправленных взбросов постолигоценового периода. Из-за тектонической активности в рифе наблюдается складчатый блок, осыпь (reef talus).