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# UPPER CRETACEOUS (MAASTRICHTIAN) MICROBIAL CARBONATES FROM MARTAKERT REGION (REPUBLIC OF ARTSAKH)


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Microbial carbonates (originated by bacteria processes, including cyanobacteria, with algae and biota) from Martakert region (NE Artsakh) are described in the article for the first time, representing an important case study of microbially-cemented boundstone/grainstone in the Maastrichtian.

Petrographic analyses revealed that pillows, domes constructions are formed in shallow environment and composed of sparry matrix of quartz and carbonate cement, microbial mat (clotted, peloidal), consisting of in situ branching algae (Thallus, Dasycladaceans?), growing bryozoans. Ostracods, foraminifers and detritus of few quantities are observed as well. The microbialites are characterized by a dark, micritic peloidal fabric with no internal lamination and are therefore classified as thrombolites.

## *Introduction*

Microbial carbonates (microbialites) are sedimentary deposits, of longest geological range formation and they are still forming today. They form in the different sedimentary environments, oxygenated the Earth's atmosphere, as well as they can produce and store hydrocarbons. However, they are intractable to study, being formed by the action or influence of microbes, and do not always preserve direct evidence for their mode of formation. The isotope studies of microbial carbonates of the Triassic sediment environment (in the aftermath of the end-Permian mass extinction) from v. Zangakatun (Republic of Armenia) area have been studied in recent years (article in revision). More recently, similar deposits of Upper Cretaceous (Maastrichtian) age near to city Martakert (Artsakh) have been discovered by Narek (citizen of Martakert).

The microbial (thrombolite) mounds of Maastrichtian age represent a few examples for sea setting, described in the literature (e.g. Kiessling et al., 2006). This is the first short report to focus on the processes involved in this microbialites formation and the type of microbial carbonate buildups, structures and fabrics in marine settings.

The term microbialite was introduced by Burne & Moore in 1987 to characterize organosedimentary deposits that have accreted as a result of a benthic microbial community trapping, inorganic precipitation and binding detrital sediment. The microbes in microbialites are dominantly bacteria, including cyanobacteria (which thrive in shallow-water and oxygenated environments) (Riding, 2000), together with small algae and were able to develop large domes, pinnacles, columns, crusts, pillows. According to their internal structure stromatolite (laminated), thrombolite (clotted), dendrolite (dendritric), and leiolite (aphanitic) types are distinguished (Riding, 2000). Broad range of the 3.4 Ga history of microbial carbonates, from Precambrian to modern examples, of rifts, foreland basins origin and of different scales are known (e.g. Hofmann et al., 1999). Occurrences of microbial carbonates examples mostly from lacustrine settings of latest Cretaceous age are noted (e.g. Rouchy et al. 1993; Camoin et al. 1995; Bahniuk et al., 2013). Modern microbialites are not as abundant and widespread as in the past, but can develop in settings of varying bathymetry, water energy, salinity and oxygen/nutrient concentrations, but organo-mineralization and chemical carbonate precipitation induced by microbial activities are the major mechanisms for the formation of mesoclots (Dongjie et al., 2013). Microbialites of about 40m high occur in the alkaline Lake Van (Armenian Highland) of Pleistocene age (Kempe et al., 1991, Lopez et al., 2005). The occurrence of microbial mats in a high-latitude but hypersaline Andean lake in Argentina with extreme environmental conditions also is described (Gomez, et al., 2014). Further studies should be focused also on understanding of the origin of microbialites, developed in western shoreline basin of Sevan Lake in Armenia (freshwater, high-altitude).

### *Methods*

We applied field studies and petrographical investigations of thin sections from pillow shape, contoured crust, onlap parts and from the surrounding limestones, using standard polarized light microscope.

### *Geological setting and studied section*

The Republic of Artsakh (southeastern range of the Lesser Caucasus mountains) is a part of Eurasian marginal plate, represented of Middle Jurassic – Upper Cretaceous volcanogenic, volcano-sedimentary and sedimentary sequences (called Somkheto–Karabakh Island Arc; Knipper, 1975; Adamia et al., 1987; Ricou et al., 1986; Sosson et al., 2010; Galoyan et al., 2013), originated due to the Neotethys subduction beneath the Eurasian margin. The subduction of Neotethys is evidenced by a thick and mainly calc-alkaline volcanogenic and volcanoclastic series dated from Bajocian to Santonian (e.g., Adamia et al., 1981; Galoyan et al., 2013).

To the South the Amasia-Sevan–Hakari suture zone (ASHSZ); and a Gondwana-derived terrane - the South Armenian Microcontinent (SAM) are distinguished (Sosson et al., 2010; fig. 1). The subduction of Tethys oceanic lithosphere under Eurasia followed by collision of the SAM with Eurasia started during the Upper Cretaceous (Rolland et al., 2012) and continued during the Palaeocene–Early Eocene (Sosson et al., 2010). In the valley of River Khachenaget, West of Vank village on radiolarians that overlie pillow lavas middle late Barremian - early early Aptian age obtained (Asatryan et al., 2011), suggesting submarine volcanic activity during this interval in the Tethyan oceanic realm preserved in Artsakh.

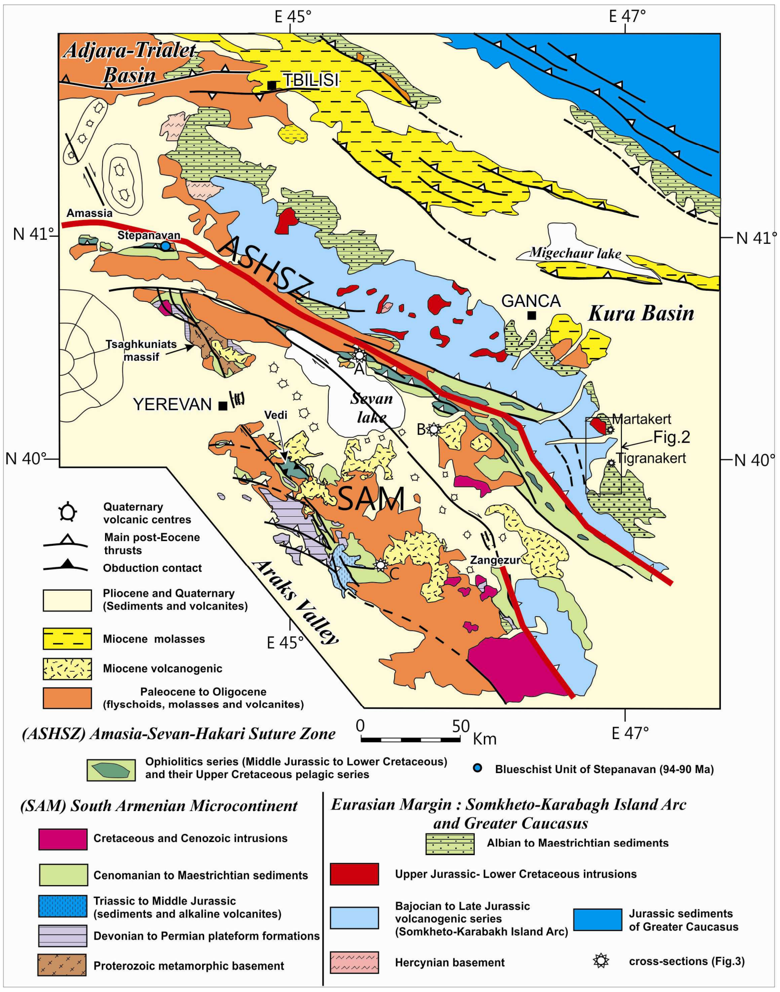


Fig. 1. Structural map of the Lesser Caucasus (Sosson et al. 2010). Vedi thrust according to Karakhanyan et al. (2013).

The outcrop of pillow shape carbonates is located about 40 km to the N from capital city Stepanakert (Artsakh) (fig. 1, 2, altitude 480m, N 40° 3,655'; E 46° 23,010'). Here Bathonian deposits presented by pyroclastic facies with thin interlayers of terrigenous sedimentation and of small thickness lava layers. Upper Jurassic (Kimmeridgian) formation presented lava flows and piroclastic differentiations of about 500m thicknesses (Abdulaev, 1963), recording the ongoing magmatic activity on the Eurasian margin due to subduction. In Aghdam anticlinoria carbonate deposites of Tithonian age conformably overlain Kimmeridgian volcanogenic formation and uncomformably overlies by Albian deposites (Abdulaev, 1963).

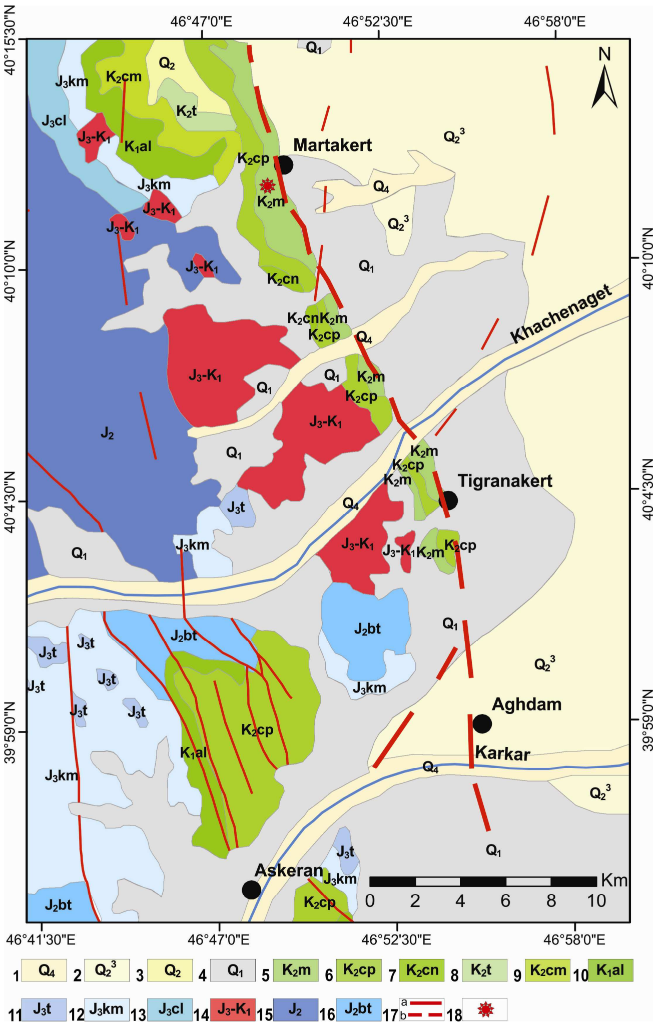


Fig.2. Simplified geological map of Martakert region (modified after geological map of Azerbaijan, Moscow 1976, faults according Baghdasaryan et al., 2007). 1. Modern sediments; 2. Middle and Upper Quaternary sediments; 3. Middle Quaternary sediments; 4. Lower Quaternary sediments; 5. Maastrichtian sandy –limestones, microbialites; 6. Campanian limestones, sandy -limestones; 7. Coniacian clay, sandstone, tuffites, gravelites and marls; 8. Turonian organogenic-detrital limestone; 9. Cenomanian volcano-sedimentary deposites; 10. Albian terrigenous and sedimentary deposits; 11. Tithonian carbonate sediments (?); 12. Kimmeridgian volcanic rocks; 13. Callovian terrigenous sediments; 14. Upper Jurassic- Lower Cretaceous granitoid; 15. Middle Jurassic volcanogenic, volcano-sedimentary rocks; 16. Bathonian piroclastic facies with terrigen sedimentary and lavas interlayers; 17. Faults; (a)- well expressed, (b)-supposed;18. Location of Microbialites.

Mekhmana granitoid of about 60 km$^2$ outcrops (Fig. 2, (14)) within the limits of Aghdam anticlinoria and according to U-Pb dating, the zircon crystallization age is 154-147 Ma (Galoyan et al., 2013). The granitoid massive unconformably by Cenomanian volcano-sedimentary deposits is covered.

The thin-bedded limestones and sandy limestones accumulated during the Late Campanian – Maastrichtian accordingly are devoid of any intercalated lava flows and they therefore attest of the end of the magmatic activity on the Eurasian margin of the Lesser Caucasus. According the Geological map of Artsakh (M 1:500 000) microbialites are of Maastrichtian age (Fig.2).

Microbialites have 1-3,5m diameter, pillow shape part is about 0,5-1,5m and the thicknesses are 0,3-1m (Fig.3, A-C). The microbialites visibly in an area of more than 0,4 km$^2$ are exposed.

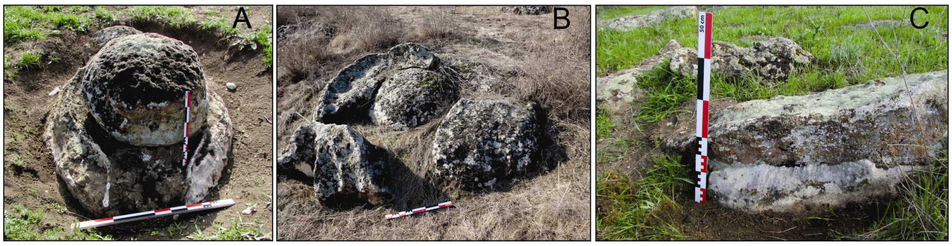


Fig.3. Field photographs from the investigated outcrop at Martakert. (A, B) Microbialitic limestones of pillow shape, covered by «crust»; (C) Onlap between a microbialite and the surrounding limestone.

***Results and discussion***
***Petrography***

Thin sections from pillow, covered part, as well as from onlap and surrounding limestones have been studied to investigate the patterns of microbialite growth and relation with other skeletal and encrusting components.

Pillow carbonate is boundstone, composed of peloidal particles (mesoclots - 30%) of irregular shapes (fig.4; a-f). The peloids forming in microbialites are regarded to be in situ in origin and they constitute the microfabric of microbialites (e.g. Riding, 2000). The peloids are surrounded by calcite microsparite. Branching Lithotamnium, dasycladaceans (?) algae (A) are the most important constituent (about 60%) of the total rock volume (fig.4; f, h, k). Matrix presented by 5% quartz (Q in fig.4), a variable fauna, such as bryozoans (fig.4; e, L), benthic rotaliids foraminifers (F- fig.4; c,e), double layered serpulids (S, fig.4; d), articulated ostracods of few quantities were observed.

Covered part of pillow is fecal pellet grainstone with clotted micrite (fig.4; g,h). Pellets are elliptical, rod-shaped (50-60%) of different size. In some places matrix presented by crushed quartz, due to compaction (15%). The algal flora consists of about 20% and is intercalated by mesoclots. Skeletal fossils are not much and they are presented by good preserved bryozoans colony, serpulids (by double layer microstructure, field by quartz, carbonate and particles of algae, fig.4; d), dasycladaceans alga (?), rotaliid foraminifers (total about 5%).

Onlap limestone is organo-detrital packstone with micritic intraclasts and diverse bioclasts (fig.4; g, h). The rock composed of bioclasts of Lithtotamnium algae (55-65%) and micritic carbonate intraclasts (15%) in carbonate microspar matrix, which has a uniform crystal size and equant crystal shapes (15%). The fossils are presented by bryozoans colony (3-5%), small benthic rotaliid foraminifers (1-2%), ostracods (1-2%). Fauna field by recrystallized calcite crystals, small grains of iron oxides appear scattered throughout the whole limestone from onlap part.

Below of microbialites the thin-bedded limestones (grainstone) are exposed (fig.4; k-L) with a microspare calcite matrix (5%). Bioclasts of Lithtotamnium algae of different sizes (65-70%), pellets (10%), Bryozoans (15%), foraminifers (+), Ostracods (+) has been observed in thin sections.

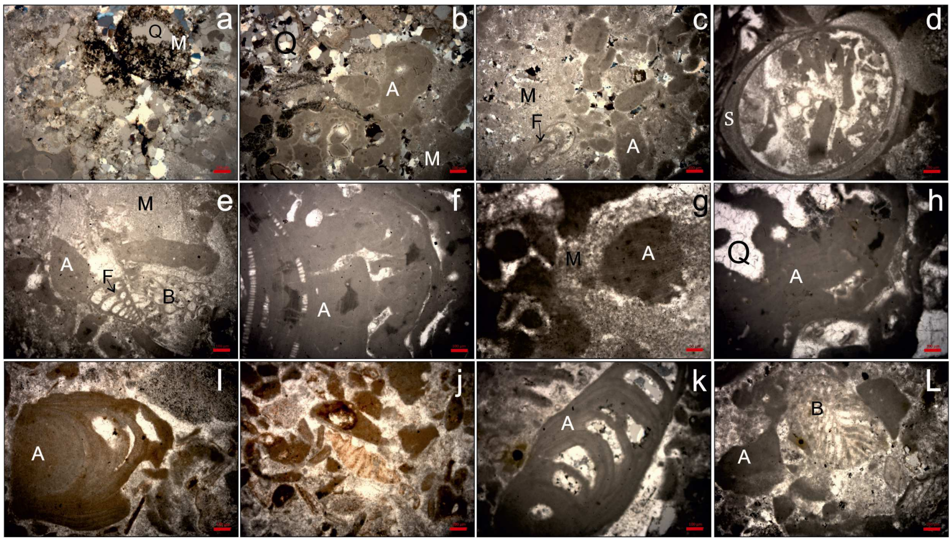


Fig.4. Thin section microphotographs of the microbialites (scale bar for all photos is 100 μm, g-50 μm) (a-f- from pillow; g,h- from crust; i,j- onlap; k-L- thin-bedded limestone). F- Foraminifera, Q- Quartz, A-Algae, B- Bryozoa, M- Mesoclots, S- Serpulids. Microphotographs a,b under cross polarised light (XPL).

### *Microbialite growth history*

The processes involved in construction of studied microbialites is the detrital sediments input, biologically influenced (or biochemical) and inorganic (physical–chemical) precipitations. They are inhabited by a diverse skeletal and soft-bodied fauna, growing on top of sediments in a low sedimentation rate, but do not develop well-defined branching forms. Quartz matrix indicates weathering from granitic massive but terrigenous supply could be also related to tectonic activity of that period with foreland basin complex development, which is result of collision processes and the evolution of the advancing orogenic wedge. Red algal thalli occur within the thin-bedded limestones and microbialites, suggesting their development in the photic zone. The water circulation and light levels increasing due-to water level decreasing is possible result of the transition from thin-bedded type to thrombolitic microbialites, leading to regular microbialite growth. The intercalation of microbialite crusts with red algal thalli (*Lithothamnion* sp.) indicates that the red algae and the microbialites developed coevally in the same environment. Bryozoans and serpulids are cryptic (bored) habitats. Bryozoans are known as sessile, filter-feeding organisms adapted to a wide salinity range (Scholle, 2003). During the deposition of the mounds the salinity might have been normal, indicated by the co-occurrence other organisms. The microbialites must have grown before the foraminiferes settled down.

### *Conclusion*

Few case studies of Cretaceous microbialites outcrop analogues are presented. This new data will contribute to the knowledge about the distribution, environment and composition of Maastrichtian thrombolite mounds of the northern Tethyan domain. The studied microbial mounds from the Martakert (Upper Cretaceous) of Artsakh developed in a shallow water open marine environment. The microbialites are classified as thrombolites of bacterial origin. They can develop in settings of varying bathymetry, water energy, salinity and oxygen/nutrient concentrations, but for interpret marine condition stable isotope analyses (C, O) need to perform. Microbialites can be as indicators of environmental and ecological changes related to variations in nutrients and relative sea level. Besides microbialites can be important hydrocarbon reservoir rocks. Future work should focus on the three-dimensional modeling, isotopic composition, porosity and permeability of the studied mounds also needs to be studied.

### *Acknowledgements*

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***Reviewer S.Kershaw***

## ՄԱՐՏԱԿԵՐՏԻ ՇՐՋԱՆԻ ՎԵՐԻՆ ԿԱՎՃԻ (ՄԱԱՍՏՐԻԽՏ) ՄԻԿՐՈԲԻԱԼ ԿԱՐԲՈՆԱՏԱՅԻՆ ԱՊԱՐՆԵՐԸ (ԱՐՑԱԽԻ ՀԱՆՐԱՊԵՏՈՒԹՅՈՒՆ)

Սահակյան Լ.Հ., Պետրոսյան Հ.Լ., Գրիգորյան Տ.Ե., Երանյան Ն.Ա.

Ամփոփում

Հոդվածում, առաջին անգամ նկարագրվում են Մարտակերտի շրջանի (Արցախի Հանրապետության հյուսիս արևելյան հատված), միկրոբակտերիալ կարբոնատները բակտերիաների գործունեության արդյունքում առաջացած, ներառյալ ցիանոբակտերիաներ, ջրիմուռներ և այլն: Ներկայացված են մաաստրիխտի ժամանակաշրջանում ձևավորված միկրոբիալ-ցեմենտացված բաունդստոն/գրեյնստոն (boundstone/grainstone) տեսակներով: Պետրոգրաֆիական ուսումնասիրությունները ցույց տվեցին, որ ծանծաղ ջրային միջավայրում առաջացած գնդաձև, գմբեթաձև առաջացումները կազմված են քվարցային բյուրեղային մատրիքսից, կարբոնատային ցեմենտից, միկրոբիալ նյութից (կլորացված, պելոիդալ), տեղում աճող ճյուղավորված ջրիմուռներից (Thallus, Dasycladaceans?), մամռակերպերից (bryozoans): Նկարագրվում է նաև հազվադեպ օստրակոդներ, քիչ քանակությամբ ֆորամինիֆերներ և դետրիտային նյութ: Միկրոբիալիթները ունեն սև, միկրիտային պելոիդալ կառուցվածք, առանց ներքին շերտայնության և հետևաբար դասակարգվել են որպես թրոմբոլիթներ:

## ВЕРХНЕМЕЛОВЫЕ (МААСТРИХТ) МИКРОБИАЛЬНЫЕ КАРБОНАТНЫЕ ПОРОДЫ ИЗ МАРТАКЕРТСКОГО РАЙОНА (РЕСПУБЛИКА АРЦАХ)

**Саакян Л.Г., Петросян Г.Л., Григорян Т. Е., Еранян Н.А.**

Резюме

В статье впервые описываются микробиальные карбонатные породы (возникшие в результате бактериальных процессов, в том числе цианобактерий, водорослей и т.д.) района Мартакерт (северо-восточная часть республики Арцах), представляющие интерес при изучении микробно-цементированных (баундстон/греинстон) в маастрихте.

Петрографические исследования показали, что подушечные, куполообразные проявления исследуемых образований, сформированые в мелководной среде состоят из кристаллического кварца и карбонатного цемента, слоев микроорганизмов (комковатые, пелоидальные), разветвляющихся водорослей (in situ Thallus, Dasycladaceans?), растущих мшанок. Наблюдаются также остракоды, фораминиферы в и небольших количествах другой детрит. Микробиолиты характеризуются темной микритовой пелоидной тканью без внутреннего ламинирования, классифицирующиеся как тромболиты.