GIVETIAN MICROBIAL CARBONATES FROM THE CARBONATE-SULPHATE SUITE IN WELL R-119 KARDAM (NORTH-EASTERN BULGARIA)

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Abstract

Microbial carbonates (limestones and dolostones) are established in the Middle Devonian carbonate-sulphate suite in well R-119 Kardam (North-eastern Bulgaria). They are determined as stromatolites on the basis of the observed macrofabric (horizontal or crinkled laminae) and microfabric features (fine-grained and agglutinated laminae characterized by clotted fabric or composed of trapped grains). The available lithofacies association (carbonates and evaporates) testifies to deposition in an arid peritidal (sabkha) environment, whereupon the microbialites represent former intertidal microbial mats. Calcified cyanobacterial sheaths are the only preserved skeletal parts from microbes, but the observed clotted microfabric and at least part of the homogeneous micrite may also have microbial origin. A major problem still to be resolved is which particular microbes were involved in the formation of the non-skeletal parts of the initial mats. Most probably the latter were produced by cyanobacterial calcification, although heterotrophic bacteria and non-living organic macromolecules may have also favoured CaCO$_3$ precipitation. A bibliography review confirms that pre-Mesozoic carbonate microbialites have not been investigated in Bulgaria so far.

Key words: microbialite, stromatolite, microbial mat, sabkha, Devonian, NE Bulgaria

Introduction. Microbially produced carbonates (microbialites) are known in the geological record from Archaean to Recent time. They occur in a wide variety of depositional settings such as reefs, tidal flats, mud mounds, lakes, springs, caves and soils [1]. Major processes creating microbialites are calcium carbonate precipitation and locally important grain trapping. Microbes participating in their formation encompass bacteria (particularly cyanobacteria), fungi, small algae and protozoans.

A review of the Bulgarian sedimentological literature shows that microbial carbonates (laminites, stromatolites, oncocids and trombolites) have been described from Mesozoic [2–4] and Tertiary rocks [5–8], while pre-Mesozoic microbialites have not been investigated so far.

The present study is focused on Middle Devonian (Givetian) microbial carbonates established in a deep well R-119 Kardam from North-eastern Bulgaria. The main goals are to explain the origin of the described macro- and microfabrics as well as to interpret the microbialite formation in the background of the general depositional environment.

Geological notes. Paleozoic rocks in the Moesian platform are known only from deep wells drilled for oil and gas prospecting (Fig. 1) and their sedimentology was...
treated for the first time by Спасов and Янев [9]. According to Янев [10], during a part of the Middle Devonian epoch shallow marine carbonate and lagoonal sulphate sediments were deposited in the most north-eastern part of the present territory of Bulgaria. They comprise the bulk of the carbonate-sulphate suite and are further subdivided into first, second and third sulphate-bearing packages.

All these packages have Givetian age and are represented in well R-119 Kardam (Fig. 2). Predominating bedded anhydrites and fine-crystalline dolostones as well as subordinate limestones build up the first and second sulphate-bearing packages. Lithoclastic breccias (rudstones and floatstones), coarse crystalline dolostones and limestones are the leading lithotypes in the upper parts of the carbonate-sulphate unit. Microbial limestones and dolostones occur irregularly in the three sulphate-bearing packages as centimetre- to decimetre-scale layers.

Macrofabric and microscopical description of the microbialites. The observed microbialites are determined as stromatolites on the basis of their general macro- and microfabric features and by following the definition of Riding [11], e.g. “laminated benthic microbial deposits”. They are characterized by alternation of brown to dark grey subparallel laminae with variable thickness (from < 1 mm to 5 mm). The latter are horizontal or crinkled and may be locally discontinuous. Some small low-relief (up to 5 cm in height) dome shapes are also observed (Fig. 3). White to greyish spar-filled voids (fenestrae) with oval, spherical or irregular morphology and maximum size of 5 mm are common.

Under the microscope, it is observed that the microbialites are composed predominantly of fine-grained (micrite/microsparite or dolomicrite/dolomicrosparite) laminae with clotted microfabric (Fig. 4a,b). The latter is distinguished by sponge-like globular and irregular clots that grade into homogeneous micrite or individual peloids. Some laminae appear dark brown possibly due to the presence of more organics and/or non-carbonate admixtures (clay, ferric oxides). Poorly preserved tube-like structures occur only scarcely (Fig. 4c). Trapped ostracods shells, torn out rounded and sorted peloids, intraclasts with clotted microfabric as well as single calcsphers are also observed and locally built up irregular agglutinated laminae (Fig. 4d). Some of the bioclasts have been replaced by anhydrite, but elsewhere carbonate pseudomorphs after anhydrite crystals or aggregates are present. Scarc e fenestrae filled with calcspar, dolospar or evaporate minerals occur (Fig. 4a) and microscale vertical desiccation cracks locally crosscut the lamination (Fig. 4e).

General depositional environment and microbialite formation. The presence of evaporates in the sulphate-bearing suites (Fig. 2) indicates arid climatic conditions [10]. The available lithofacies association testifies respectively to deposition in a peritidal (sabkha) environment. This conclusion is supported by the well distinguished supratidal, intertidal and subtidal subfacies units [12]. Thus, the anhydrites represent supratidal (e.g. subaerial) deposits and further evidence for such interpretation (e.g. precluding alternative subaqueous origin) comprises their relatively small bed thickness, replacive/displacive nature as well as the presence of nodular (e.g. chicken-wire) structure (cf. Warren and Kendall [13]). Also of supratidal origin are the rudstones/floatstones which consist of clasts derived through desiccation and disintegration of intra/supratidal carbonates (cf. Shinn [14]; Chatalov [4]). The presence of abundant fine crystalline non-fossiliferous dolostones likewise supports the hypothesis for sabkha environment as

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Fig. 1. Location map of the major wells drilled through Devonian sediments in North-eastern
Bulgaria

Fig. 2. Generalized lithological log of the carbonate-sulphate suite in well R-119 Kardam

Fig. 3. Polished surface of microbial carbonate (dolostone) showing laminated macrofabric and small low-relief domes (arrows)
**Fig. 1**

Devonian

- Dolomitic packstone
- First sulphate-bearing package
- Tentative Dubrovnikian

**Fig. 2**

LTCS Limy-terrigenous-clayey suite

- CP Clayey-carbonate package
- FP First sulphate-bearing package
- SP Second sulphate-bearing package
- TP Third sulphate-bearing package
- Dolostones (fine- and coarse crystalline)
- Limestones
- Lithoclastic breccias (rudstones and floatstones)

**Fig. 3**

1.5 cm
they resulted from penecontemporaneous replacement of primary CaCO₃ (aragonite) sediments in the intertidal to lower supratidal zone. The associated limestones, which are represented by bioclastic mudstones, wackestones and packstones, contain well preserved thin-shelled bivalves, moravaminids, ostracods and gastropods plus sporadic crinoid fragments and echinoid spines. The initial sediments are interpreted as products of shallow subtidal deposition with the non-winnowed textures and relatively low biota diversity indicating restricted circulation and elevated salinity conditions.

The observed microbialites emerged through lithification of former microbial mats developed in the intertidal zone. Stromatolites composed of fine-grained and agglutinated laminae were produced which is also typical of modern sabkhas in the Persian Gulf [14]. The lamination resulted from episodic accretion related to seasonal microbial growth, periodical trapping of sediment material or both. The fine-grained laminae probably represent parts of former mats with relatively smooth morphology which trapped and bound only little amount of very fine grains. On the contrary, the occurrence of agglutinated laminae indicate locally irregular surface mat topography [1], facilitating the trapping and binding of coarser sedimentary material derived from disintegration of the microbial mats (peloids and intraclasts) or supplied from the shallow subtidal zone (ostracod shells) during stronger storm activity. Lamination of some mats was disrupted by small desiccation cracks produced during periods of their subaerial exposure. In turn, fenestral voids were formed by gas bubble release during organic decay and/or mat shrinkage during desiccation. The scarce evaporate crystal growth is probably indicative of the transition interval between the lower supratidal and the upper intertidal zone. However, the observed relicts of laminated microbialites in some anhydrites (Fig. 4f) rather testify to seaward progradation of the sabkha and are another solid evidence for existence of a peritidal setting.

The observed tubular structures represent calcified cyanobacterial sheaths and are the only preserved skeletal remains from former microbes. However, at least part of the micritic matrix in the stromatolitic fine-grained laminae is assumed to have microbial origin such as calcified bacterial cells or from whiting precipitation (cf. RIDING [1]). In this context, the relative amount of trapped and bound carbonate mud is impossible to determine. In turn, the clotted microfabric may have resulted from calcification of microbially produced EPS (extracellular polymeric substances). The peloids within some laminae with clotted fabric are also interpreted as microbially induced in situ precipitates. Such microbial peloids are considered by CHAFETZ [15] as calcified bacterial aggregates rimmed by euhedral calcite crystals. According to DUPRAZ et al. [16] the micrite nucleation is initiated within a polymer biofilm embedding microbial communities and undergoes discontinuous calcification generating micropeloidal structure. Meanwhile, the observed clotted fabric gradations from homogeneous micrite to individual peloidal grains may have resulted from different intensity of the microbial mat calcification. According to KAZMIERCZAK et al. [17] mats growing in conditions of high calcium carbonate supersaturation produce almost homogeneous micrite, whereas in less intensively calcified mats micritic peloid-like bodies are formed. On the other hand, the relatively better roundness and sorting of peloids from agglutinated laminae indicate slight transport and redeposition processes. These particles are interpreted as possible individual calcified cell aggregates that have been teared out from the mat due to hydrodynamic events (bottom currents, storms) and redeposited as peloid grains and intraclasts (cf. KAZMIERCZAK et al. [17]).

A major problem of this study still to be resolved is which microbes were involved

--- Fig. 4. (A) Clotted microfabric and fenestrae (f) in fine-grained laminae; (B) Fine-grained laminae with clotted fabric, demonstrating gradation from homogenous micrite to individual peloids; (C) Tube-like structures (arrow) representing calcified microbe sheaths; (D) Trapped ostracod shells (arrow) and torn out peloids in agglutinated laminae; (E) Microscale dessication crack (arrow) crosscutting the lamination; (F) Relic microbial laminae (m) in bedded anhydrite (a)
in the formation of the non-skeletal parts of the initial mats. Most probably these were cyanobacteria whose calcification appears to result from creation of alkalinity gradients in mucilaginous sheaths associated with photosynthetic uptake of CO₂ and/or HCO₃⁻ uptake that raises alkalinity [18]. However, a wide range of other bacterial processes (ammonification, denitrification, sulphate reduction and anaerobic sulphide oxidation) can also lead to raised alkalinity favouring CaCO₃ precipitation [19]. They result in the formation of fine-grained carbonate and are localized within decaying mats as heterotrophic bacteria degrade organic matter. Finally, an assumption should be made that precipitation of “automicrite” in association with non-living organic macromolecules (so-called organomineralization by TRICHET and DÉFARGE [20]) may have also played a significant role.

Conclusions. The reported occurrence of Paleozoic stromatolites helps to more precisely clarify the general depositional environment for part of the Middle Devonian sequence from North-eastern Bulgaria. Thus, their presence and some characteristics of the associated carbonate and evaporitic rocks testify to the existence of an ancient sabkha whereupon the microbial mats were formed in the intertidal subenvironment. The described Givetian microbialites were deposited during a time interval which was close to one of the major cyanobacterial calcification events of the Phanerozoic – the Late Devonian epoch [1].

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REFERENCES


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