TYPES OF RECENT MICROBIALITE IN SLIGHTLY ACIDIC SPRING IN RANYIA AREA, KURDISTAN, NE IRAQ

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Key words: Recent lake sediments, Large oncoid, Microbialite, Stromatolite, Thrombolite, Ooids, Rasha Baa wind, Arabian Gulf

ABSTRACT

The role of the microbes in precipitation of stromatolitic limestone and lime-sand in water of recent spring in the Kurdistan Region, Northeast Iraq is discussed. The spring mouth is forming a small circular lake (350 m in diameter) with slightly acidic water, and saturated with dissolved $CaCO_3$. Due to effect of the microbes and wind direction (and its related currents), the limestone and lime-sand are deposited mainly on the southwest bank of lake (spring mouth). The role of microbes can be seen in forming many types of the microbial limestones (microbialites), which consist of finely laminated (stromatolite) or clotted structures (thrombolite) or both. The existed stromatolite; forms well developed oncoids of different sizes, and micro-oncoids (ooids), which have diameter of (0.1 – 20) cm. The thrombolite consists of irregular clusters (clotted) of ooids (or micro-oncoids) encrusted by microbial micritic layers and separated by voids. On the lake bank, the small oncoids and thrombolites, which form clotted clusters of ooids mass are exposed on the shore, while large oncoids are exposed away from the shore; on the periodically flooded areas. Both types of limestone and lime-sand show the effect of wind energy in developing the rock with certain types of structure and texture; within the examined rocks, which are analogous with Arabian Gulf.

أنواع حديثة من الميكروبيلايت في ينبوع قليل الحمضية في منطقة رانية، إقليم كردستان، شمال شرق العراق

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المستخلص

نوقش في هذه الدراسة دور الميكروبات في ترسيب الحجر الجيري الستروماتوليتي والرمل الجيري في مياه ينبوع حديث في إقليم كوردستان، شمال شرق العراق. فوهة الينبوع تشكل بحيرة دائرية صغيرة (ذات قطر 350 متر) وذات مياه قليل الحمضية ومشبع بأيون الكاليسيوم. نظراً لتأثير اتجاه الرياح والميكروبات، تكون الحجر والرمل الجيري أساساً على الضفة الجنوبية الغربية للبحيرة. يمكن ملاحظة دور الميكروبات في ترسيب أشكال عديدة من الحجر الجيري، حيث يظهر بشكل ستروماتوليتي (التركيب الرقائقي) وثرومبوليتي (التركيب التخثري). يظهر الستروماتوليت بأحجام مختلفة وتكون بشكل الأونكويد والسرئيات التي يبلغ قطرها من (0.1 – 20) سم. تتألف الثرومبوليت من التجمعات الملتحمة وغير النظامية من الأونكويد الدقيق والسرئيات التخثرية، وهذه المجموعات مغطاة بطبقات ميكريتية ومفصولة بفراغات. يقع الأونكويد الصغيرة والثرومبوليت على شاطئ البحيرة، بينما تقع الأونكويد الكبيرة بعيداً عن الشاطئ على المناطق التي تجتاحها الفيضانات دورياً على جوانب البحيرة. وتظهر كل الرمال والحجر الجيري تأثير الطاقة الريحية في تزويد الصخور بأنواع معينة من التراكيب والأنسجة بحيث يشبه ما هو موجود في الخليج العربي من حيث الطاقة والمكونات.

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INTRODUCTION

Burn and Moore (1987) introduced the term microbialite for organo-sedimentary deposits of benthic microbial communities. According to this definition, stromatolite can be seen as a type of microbialite showing lamination as a specific feature (Dupraz *et al*., 2006). In geology, the science that explains the role of microbes (Cyanobacteria, algae, and fungi) and classifies them is called microbialite. Therefore, the science of microbialite is a new science, which is very useful for studying of recent and ancient carbonate rocks in addition to marine and non-marine (springs and lake) carbonates of Iraq. According to Flügel (2004), the microbes have played a major role in the formation of carbonate deposits at geological scale, during the Precambrian and the later ages. He added that their role is more prominent, in non-marine environments, in areas where CO_2 release is a faster process, such as springs and waterfalls, or where evaporation is more intense, such as lagoons.

Microbialites are produced by a microbial community as a biofilm, which is generated by the activity of the microbes (Chafetz and Buczynski, 1992). They added that, the microbes, in general, are mainly Cyanobacteria and other bacteria (including heterotrophic bacteria), but other organisms such as algae or fungi may also contribute to the biofilm. Under certain conditions, the microbes may induce carbonate precipitation. Schmid (1996) proposed a refined classification and nomenclature of microbialites, based on a combination of both microstructure (peloidal crusts) and macrostructure (e.g. thrombolites). He has suggested that growth forms depend mainly on sedimentation rate and water energy; for example, microbialites develop dendroid forms as a reaction to slightly elevated rate of the sedimentation at low-energy conditions (Schmid, 1996). In macroscopical scale, three types of microbialites can be distinguished: Thrombolites, stromatolites and leiolites (Braga *et al*., 1995), the latter being characterized by dense and non-laminated structures.

The present study deals with microbialite of a recent acidic lake. This lake represents a spring mouth; it is located at 8 Km to the southeast of Ranyia town; within Sulaimaniyah Governorate in northeastern Iraq. It is located at the intersection of latitude N 35º 51' 12" and longitude E 44º 45' 49", directly north of Dokan Lake. This area constitutes a part of Zagros Mountain Belt, where the high mountain chains are in NW – SE direction (Figs.1 and 2). In the same direction and between these mountains, there are narrow or wide subsequent (strike) valleys, most of which coincide with synclines, while few of them are developed along the axes of anticlines by erosion of their core, such as Bingird and Ranyia valleys. The acidic spring (Ganau Spring) yields from the bottom of the latter valley and surplus water flow into Dokan Lake (Figs.3, 4 and 5).

▪ Geological Setting

The study area is located in the Zagros Fold – Thrust Belt, directly to the southwest of the main Zagros Suture Zone. Structurally, the area is located at the boundary between High Folded and Imbricated Zones (Buday, 1980, Buday and Jassim, 1987 and Jassim and Goff, 2006). The area mainly consists of high amplitude anticlines and synclines, which have same elongation (northwest – southeast) of the mountains. Many of the anticlines are asymmetrical with the southwestern limbs steeper than the northeastern ones. The area around Ganau spring, is covered by alluvial deposits (clay, sand and gravels), which are underlain by the Jurassic formations, in the Ranyia valley bottom. These formations (as limestones and dolomites) include Sargelu, Barsarine and Naokelekan. In the valley, the Cretaceous formations are located in the high elevation along the valley sides such Sarmord (limestone and marl) and Qamchuqa Formations (dolomitic limestone). All these formations are described in detail, by Bellen *et al*. (1959).

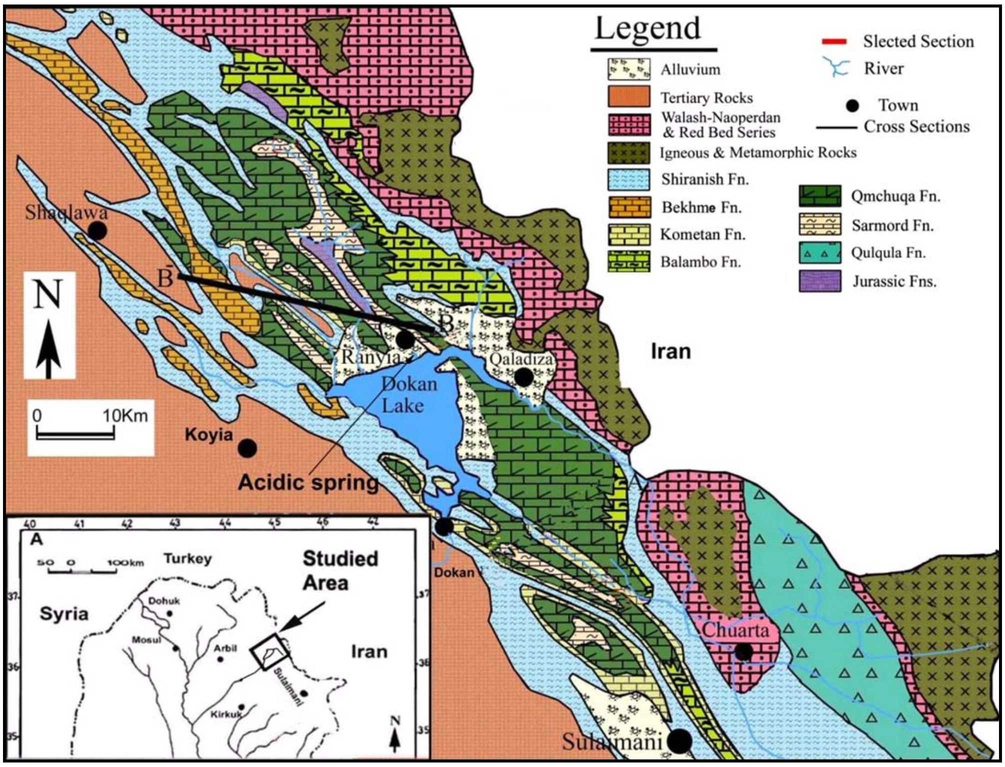

Fig.1: Geological map of northern part of Iraq (modified from Sissakian, 2000), showing location of the studied section

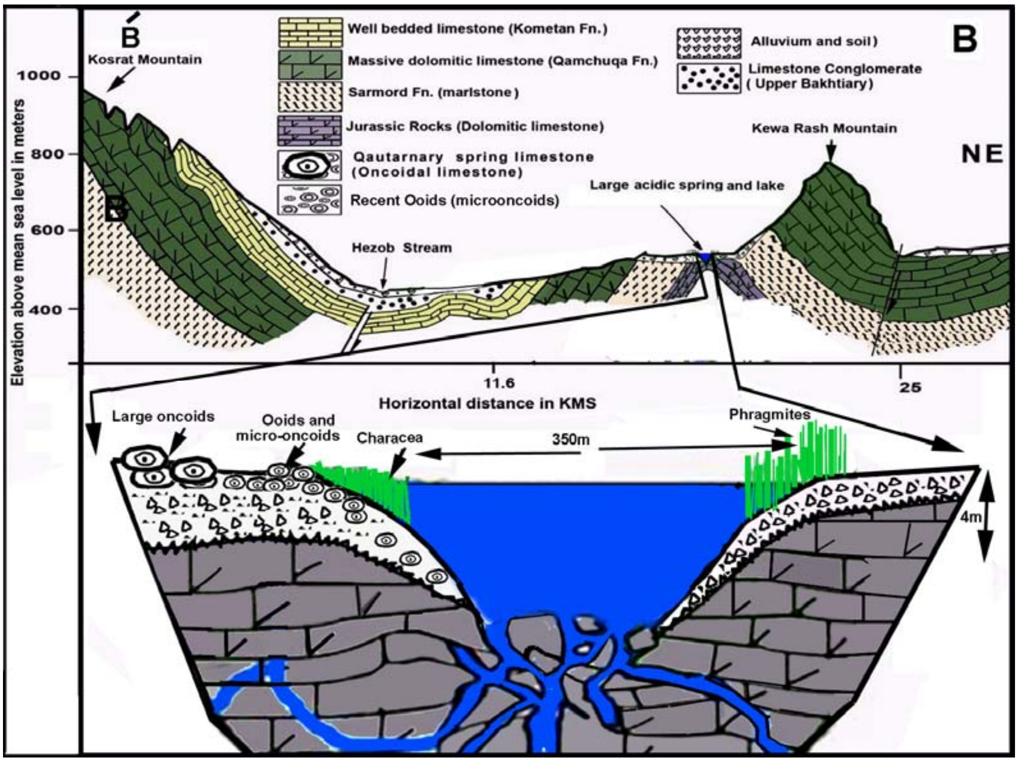

Fig.2: **Top)** Schematic geologic cross-section of the studied area passing through Ranyia (Kewa Rash) and part of the Kosrat anticlines
Bottom) Ganau spring Cross section within (modified from Manmi, 2008)

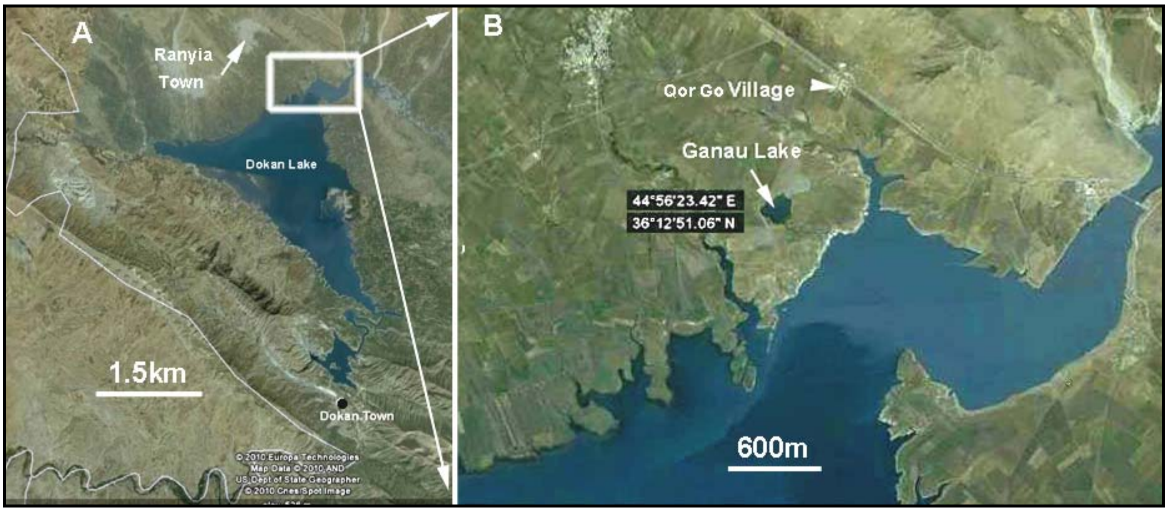

Fig.3: Location of the Ganau Lake as seen in the Google Earth Images

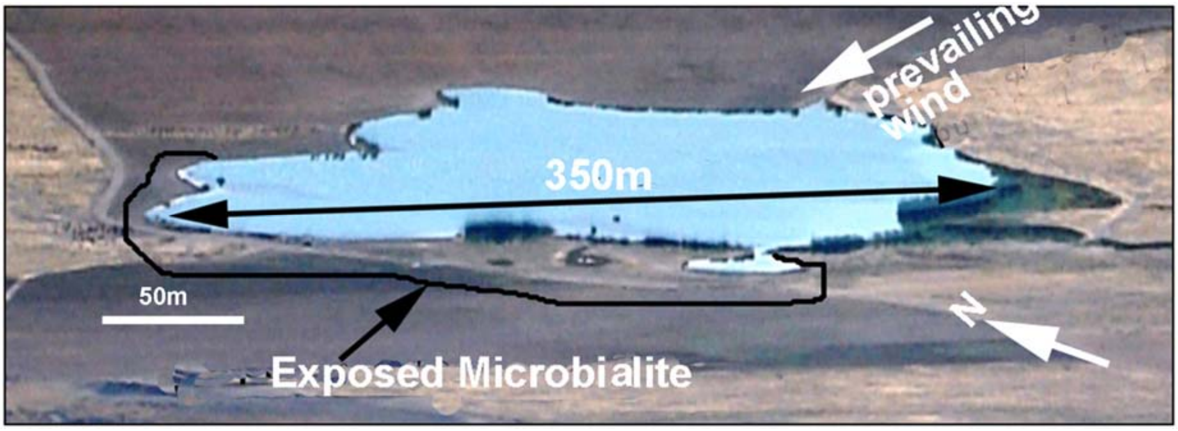

Fig.4: Lateral view of Ganau spring (or lake); as seen from northeast of Kewa Rash Mountain showing area of the exposed microbialite (irregular black line) and prevailing wind direction

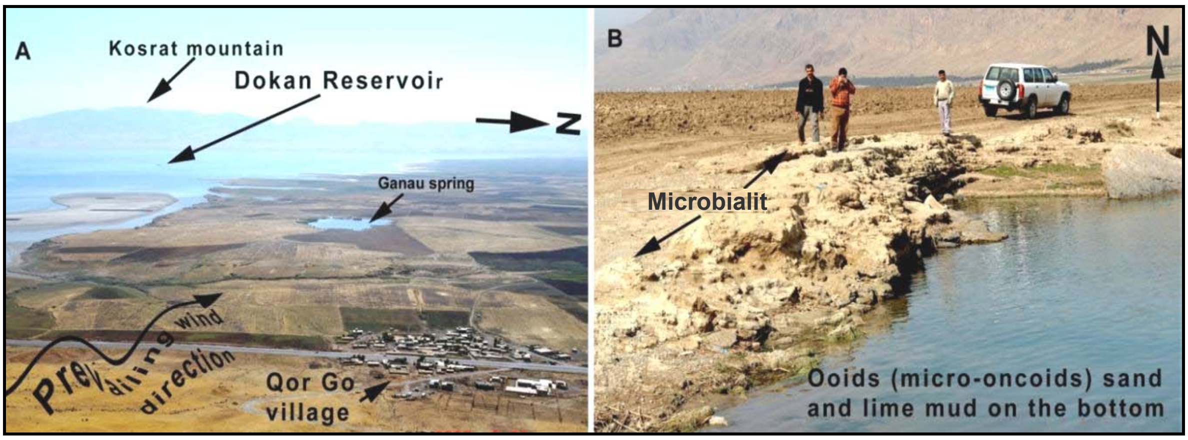

Fig.5: **A)** Lateral view of the area around Ganau spring, as seen from northeast of Kewa Rash Mountain

B) Western bank of the lake showing outcrops of microbialite and deposits

▪ **Ganau Spring Chemistry**

The spring mouth is wide and forms a lake, which is nearly circular with a diameter of about 350 m and about 20 m deep at its central part. The water comes out below the lake and has about 12 liters per second of overflow in summer, and discharges through a small channel to the Lesser Zab River, which is partially covered by Dokan lake (Figs.1 and 3). The water temperature is nearly constant (25º C) due to deepness of the aquifers. The flooding area (during spring season) of the southwestern bank of the lake is covered by microbialites (micro-oncoids and macro-oncoids), while the subtidal and intertidal parts (sea terminology is used) are covered by ooids and cross bedded microbial limestones (Figs.4 and 5B). Below the water, the microbialite is covered by mixture of lime-sand mud; in some places. The water of the lake is not affected by tide, but spring flood and summer drought may act as tides, as the low and high water level in the lake is concerned. The aquifers of the spring consist of highly bituminous Jurassic rocks (limestone, dolomite and calcareous shales) that are located to the north and northwest of the spring (Fig.2) (Manmi, 2008). According to Manmi (2008), the acidity of the spring is attributed to the organic matters and pyrite content of the aforementioned rocks, although the water is slightly acidic (pH 6.7) and sulfuric, yet it is used for irrigation and livestock drinking. The chemical composition of the spring water is shown in Table (1), as compared with normal sea water.

Table 1: Comparison between chemical analysis of Ganau acidic spring and normal marine water

Chemical characteristics	**Ganau acidic spring** (Manmi, 2008)	**Normal marine water** (Blatt *et al*., 1980)
pH	6.7	7.9 – 8.2
Ca^{++} (ppm)	247	400
$H\,CO_3^-$ (ppm)	402	140
Cl^- (ppm)	305	18980
$SO4^{--}$ (ppm)	257	2649
Mg^{++} (ppm)	29	1272

LAKE DEPOSITS

In the field, the lake is associated with many types of limestone, especially on the southwestern bank. These limestones are all milky in color and their structures change away from the lake shore (beach). On the beach, generally they consist of sandy limestone and show both parallel and cross lamination. Few meters from the beach on peripheral zone, the limestone becomes nodular and the number of the nodules decreases; while their size increases (Figs.5b and 6). The sandy limestone contains occasional few imbricated flat pebbles. When these limestones are inspected by a hand lens and binocular microscope (Fig.7), the following types of microbialites are found.

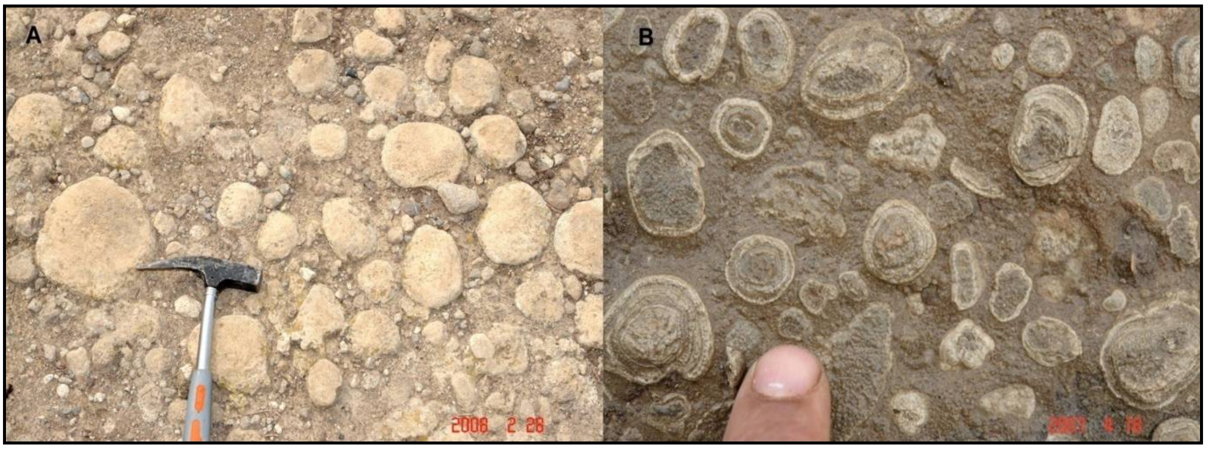

Fig.6: Discoidal oncoids on the southwestern side of Ganau spring
A) Complete top view
B) Equatorial view as cut by erosion,
which show that nucleus consist of thrombolite

Fig.7: Field examination of the recent microbialite
on the southwestern beach of Ganau Lake

▪ **Types of Microbialite**

This type of stromatolite is the prevailing type microbialite that can be seen around the spring on the area of the periodical flooding (equivalent to sea supratidal). The shape of the stromatolites is globular or discoidal, which have well developed concentric dark and light milimetric laminations. The laminae consists of alternating micritic laminae that are concentrically arranged around a nucleus. The nuclei mostly consists of a fragment of clotted oolitic limestone (fragment of thrombolite) or smaller oncoids. The sizes of the oncoids are variable, they range from 2 mm (sand size) to about 20 cm (saucer or boulder size), in diameter (Figs.6 and 8). There are micro-oncoids (Flugel, 2004), which are smaller than 2 mm (Fig.9). The shapes of large oncoids are double convex and lensoidal, and some of them have width more than twice longer than height. The smaller oncoids have more or less oral shape. Alternations of thin laminae (crypalgal laminae) of light and dark colored are arranged concentrically around the nucleus. The deposition is attributed to the processes of trapping and binding of sediments by microbial organisms during annual seasonal change. The organisms; such as primitive blue green algae (Cyanobacteria or blue-green bacteria) and fungi participate in the deposition with the aid of direct precipitation of carbonate minerals (Hoffman, 1976; Pettijohn, 1975; Blatt *et al*., 1980 and Selley, 1988).

In the present study, the most significant evidence that proves the microbial origin of the oncoids and ooids laminae is that the shape of the oncoids (especially large ones) is discoidal (Fig.6). The discoidal shaped oncoids cannot roll to precipitate physically concentric and continuous laminae around nuclei. Whereas, on the discoidal shaped oncoids, the direct precipitation of the carbonate as micrite, occurs on the upper surface only. The precipitation on one side of the oncoids was not observed in the lake, but it was observed that the laminae exist around the oncoids (Fig.8), which proves that they were formed by microbes.

The comparison of the present oncoids with those of Triassic, Jurassic and Lower Cretaceous of Iraq (Figs.9 and 10, as adopted from Karim, 2006; Ameen, 2008 and Daod and Karim, 2010, Fig.11) showed that the present oncoids have nearly similar characteristics of those cited in literature. However, with larger size (ten times larger than those mentioned previously in Iraq), and with better developed laminae. This might be attributed to the absence of effective grazing pelecypods and gastropods due to acidity of the water in the lake, in addition to calmness of environment and availability of dissolved calcium carbonate. The shapes of the oncoids depend on the types of nuclei, so that wherever the nuclei is elongated, then oncoids maintain nearly the same form. According to Lehrmann *et al*. (1998) and Oliver *et al*. (2002), oncoids indicate occasional wave agitation, probably near wave base, while Gunatilaka (1977) mentioned that oncoids are very likely a morphological and ecological adaptation of the mate forming communities to specific energy conditions.

▪ **Thrombolites**

The term thrombolites has been introduced by Aitken (1967) for that type of microbialite, which consists of clotted fabric and more or less rounded small bodies with general obscured internal structures. The laminations are disturbed and hard to be identified, but they contain a network of small-coated fenestral and coated grains (Aitken, 1967 and Shpiro, 2000). It is formed, like stromatolite, by products of trapping and binding of grains, by filamentous Cyanobacteria or they were an extensively burrowed form of stromatolite. Thrombolites are clotted algal or Cyanobacteria mats can be found in a range of aquatic environments: fresh water, marine and hypersaline.

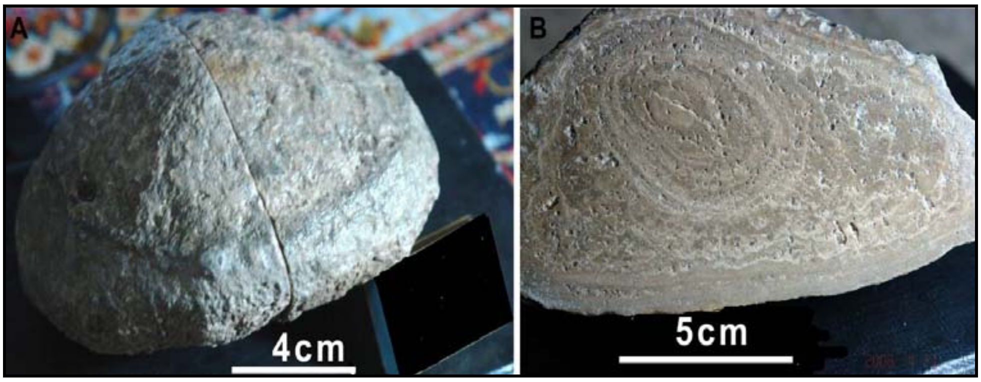

Fig.8: **A)** Large saucer-sized oncoids on the periodically flooding side of the lake
B) Polished surface after being cut into two equal halves showing internal structure of the left side, which shows development of lager oncoids around an older smaller one

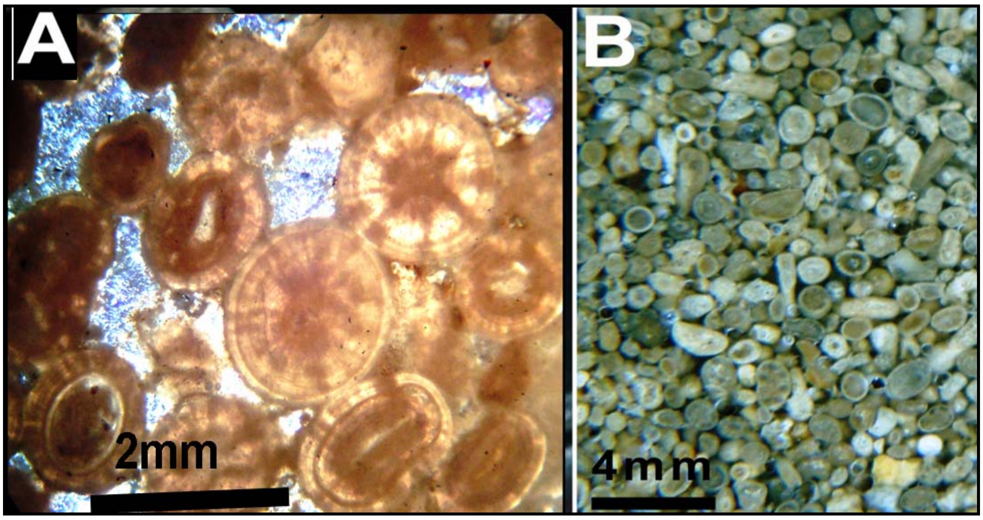

Fig.9: Ooids of Ganau spring as seen
A) In thin section showing concentric Microfabric
B) As polished slab of the lime-sand of the lake shore

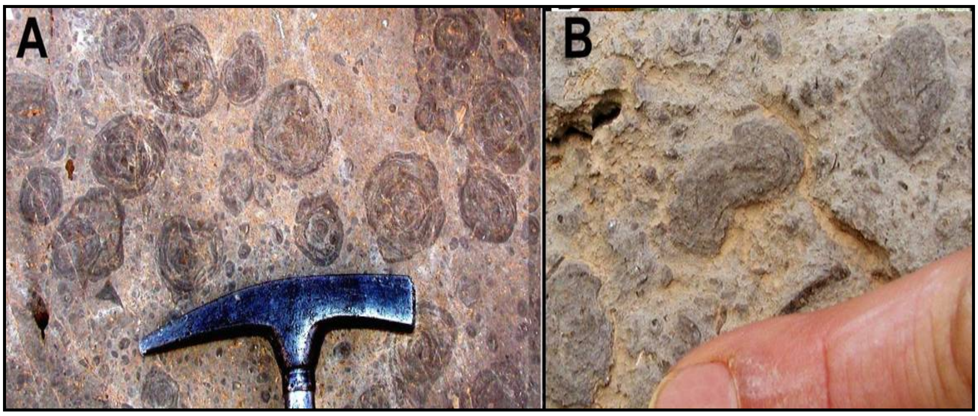

Fig.10: Oncoids of Kurdistan Region, Northeast Iraq
(adopted from Karim, 2006 and Ameen, 2008)
A) Triassic (Avroman Limestone)
B) Lower Cretaceous (Qamchuqa Formation)

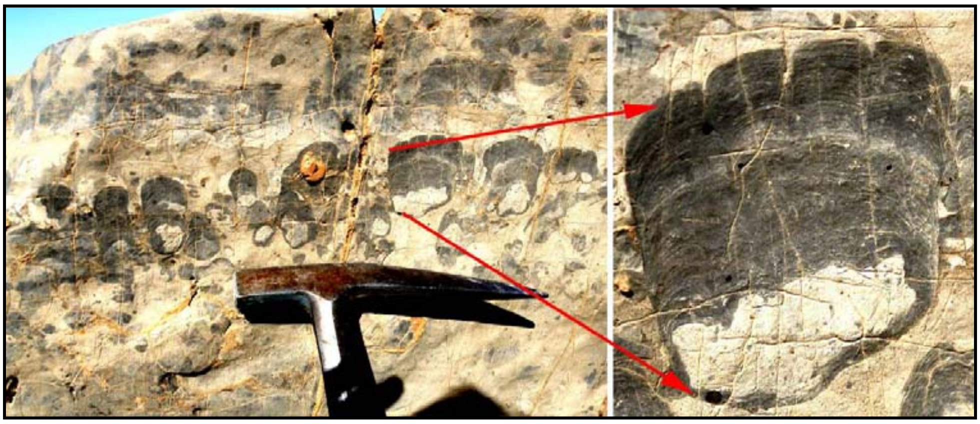

Fig.11: **A)** Several oncoids developed around irregular rip up clasts (white) in Jurassic Barsarine Formation (Barzinja Area)
On the oncoids a columnar stromatolite are developed too
B) One of the oncoids enlarged to show growth of the columnar stromatolite
(Daod and Karim, 2010)

Feldmann and Makenzie (1998) mentioned that the thrombolites are formed by microbes, algae and metazoans, and also mentioned that Phanerozoic thrombolites have been interpreted as unlaminated stromatolites constructed by Cyanobacteria. Environmental conditions must favor growth of thrombolite to accumulate thickly enough, to be recognized in the fossil record. Such conditions may include a super saturation of calcium carbonate in the water, slow rates of sediment accumulation, or elevated salinity and temperature conditions. Modern thrombolites are found in a variety of environments including hypersaline lagoons, tidal channels and fresh water lakes.

When the aforementioned characteristics are considered, the thrombolite in the present study shows some similar and different characteristics. The similarities are manifested by the fact that a part of the limestone of the spring has porous (coated fenestral) and structureless bodies of different sizes, which are bound by micritic material of microbe organisms (Figs.12, 13A and 14).

The bodies consist of clusters of well sorted micro-oncoids (small-coated grain of Aitken, 1967). The only difference is that the clotted grains are not pellet, but micro-oncoids or ooids. The association of the ooids and microbialite (as oolitic cryptalgal laminate) are mentioned by Lehrmann *et al*. (1998) from Great Bank of Guizhou in South China. The location of the thrombolites notifies that they are deposited in higher energy than the large and medium size oncoids. The high energy and association of the thrombolite with cross bedding are mentioned by Grotzinger *et al*. (2000) in Nama Group of Namibia. The thrombolite of the present study is similar to that mentioned by Riding (2000), which consists of calcified microbial thrombolite. It is possible that gradation between stromatolite and thrombolite exists in the sediments of Ganau lake so that the classification of Schmid (1996) (Fig.15) can be applied to Ganau lake. According to the aforementioned authors, it displays well defined clots, which consist of coarse agglutinated thrombolites and incorporated sand and even gravel-sized sediments (Fig.14).

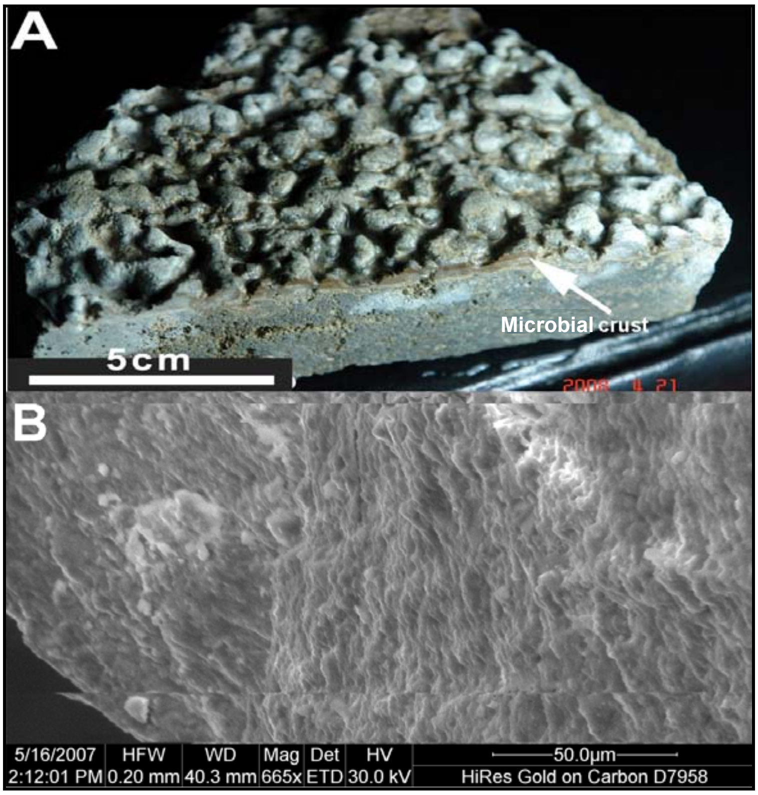

Fig.12: **A)** Clotted clustered oolids that are developed as thrombolite (Bound and covered by microbial crust, Fig.13C)
B) Image of scanning electronic microscope shows fibrous biogenic micrite of the thrombolite

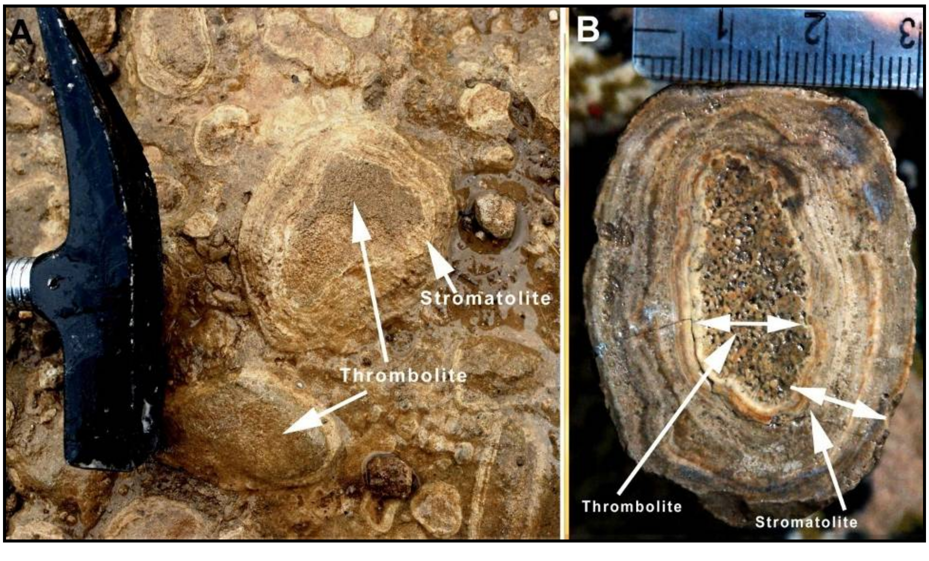

Fig.13: **A)** Details of large oncoids that obtained its shape from the nucleus (thrombolite fragment)
B) Well developed concentric stromatolite laminae around thrombolite nucleus

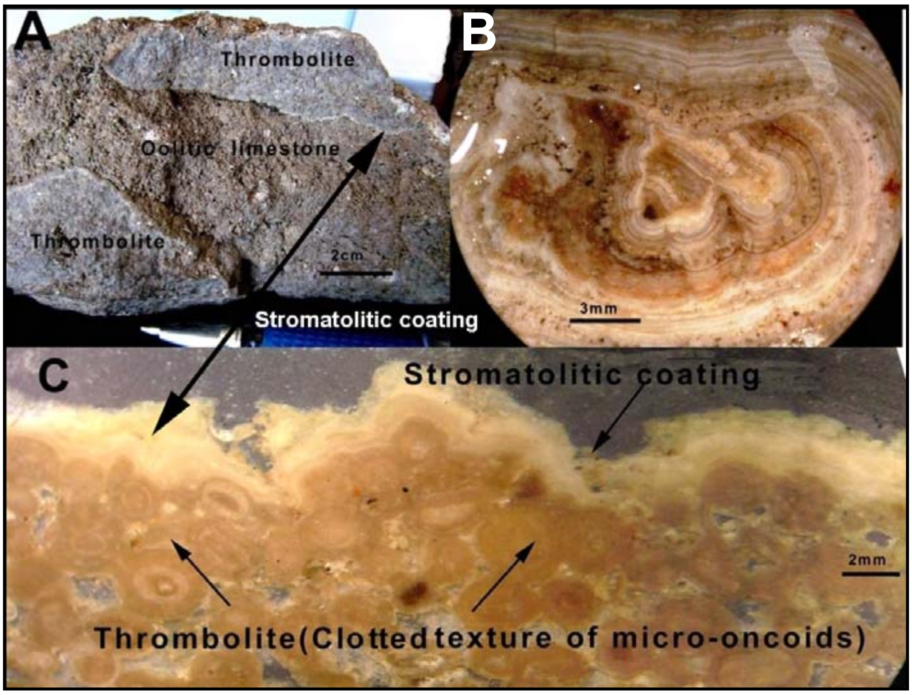

Fig.14: **A)** Clotted ooids as thrombolite surrounded fragment by oolitic limestone
B) Well developed micritic laminae (stromatolite) and spongy laminae (thrombolite) in medium size oncoids
C) Clotted texture of oncoids arranged as clotted texture (thrombolite) with coated voids under normal light

WIND INFLUENCE

In the area of Ganau spring and lake, the wind has many directions, such as southwest, northeast. The most prevailing, powerful and turbulence one is the latter one, which is cold in winter and warm in summer. Because of these negative properties, it is called as "Rasha Baa" which means black wind which blow from northeast. Around the lake, the role of the wind, as main energy input, can be seen in three features. The first is lime sand (with some lime mud), limestone and oncoids are accumulated only on the southwestern part of lake (Fig.15). This part of the bank is located in the far side and in the direction of southwestern wind (Rasha Baa). By this wind the lime-sand is transported to the mentioned bank and accumulated to form limestone after binding by cementation with the aid of the microbes. The second is that the current direction (as measured by cross bedding) is towards southwest. Cross beddings are found in the oolitic limestone on the southwest lake bank (Fig.16).

The third is that the large oncoids are developed on the supratidal area, which is separated by cross bedded oolitic sand bars. The oncoids show some degrees of asymmetry, which have longer diameter parallel to the direction of the wind. Even the stromatolitic layers are thinner and show smaller angle of curvature, in the side of the wind (Fig.5A and B). Therefore, the effect of the wind energy is very clear in localizing the limestone grains on the lake bank and giving certain type of directional structures. This consequence of wind direction and velocity is similar to the stromatolite and lime-sand that exists in Arabian Gulf. At the far side in the direction of the wind (on the coast of United Arab Emirates), which is accumulated on the coast of United Arab Emirates where the "Shimal wind" (blows from northwest) (Purser, 1973 and Reading, 1986) and has the same role of the "Rasha Baa" in localizing and accumulation of lime-sand and stromatolite on Ganau lake.

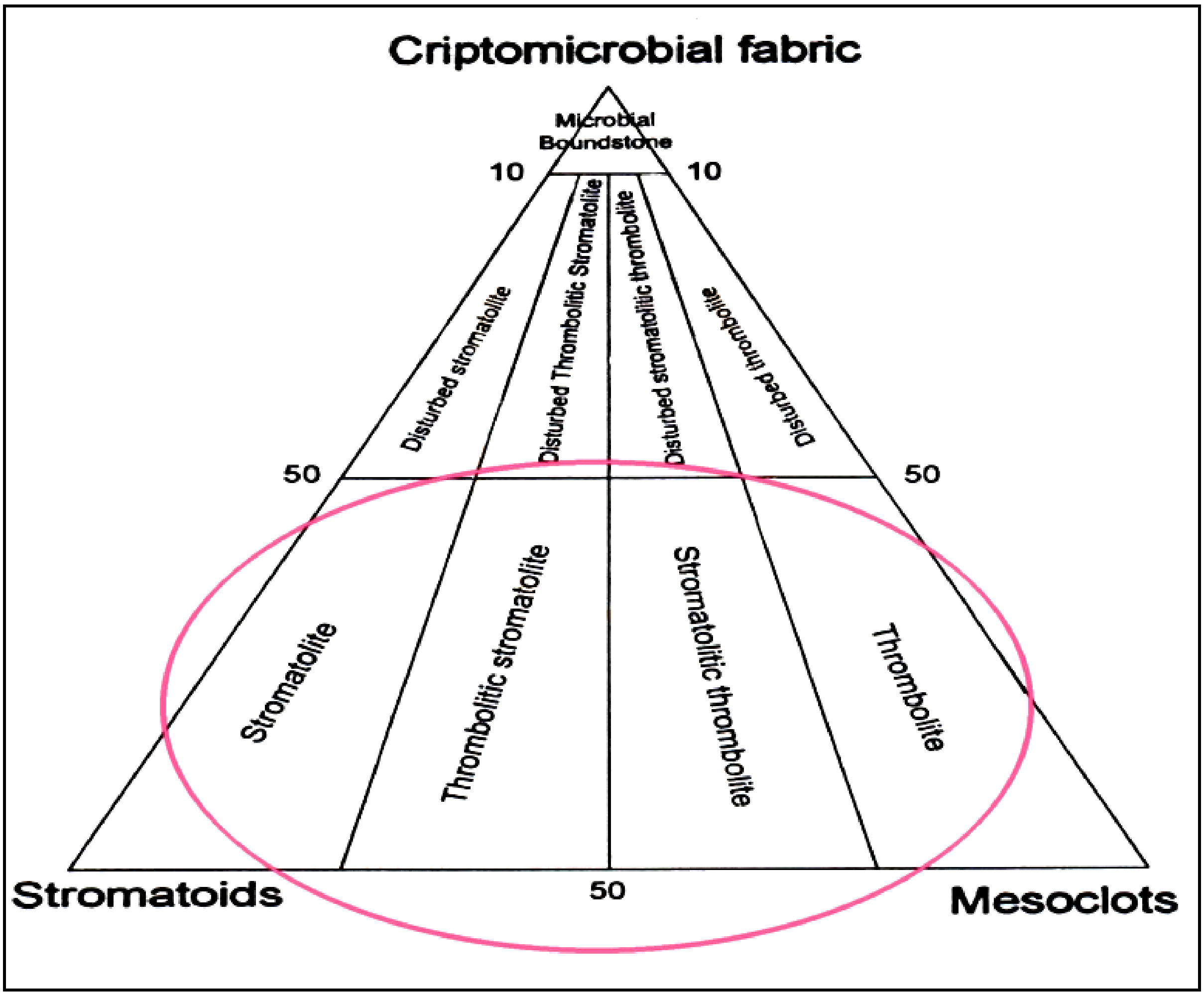

Fig.15: Types of microbialite in the Ganau spring (Orange circle) within microbialite classification of Schmid (1996)

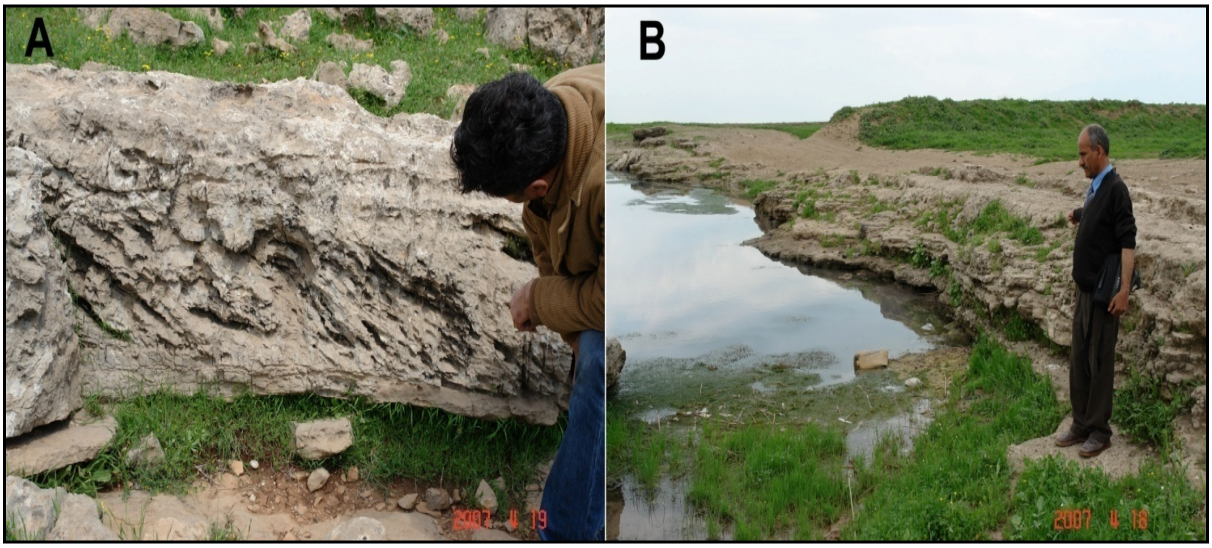

Fig.16: **A)** Cross bedded ooids (micro-oncoids) on the southwestern bank of Ganau Lake **B)** Bedded and laminated ooids limestone, contain both stromatolite and thrombolites

CONCLUSIONS

- Both micro-oncoids (less than 2 mm) and large oncoids (2 mm – 20 cm, in diameter) are found on the bank of the slightly acidic lake that formed around a mouth of a vertically issuing spring.
- The lake is saturated with dissolved $CaCO_3$ and precipitates microbially induced micrite as a stromatolite and as binder of thrombolite.
- The lime-sand and thrombolite occur near the shore, while the large oncoids exist on the periodically flooded area around the lake.
- The role of the wind direction and agitation is nearly similar to that of Arabian Gulf in precipitation of annual verve of stromatolite and laminae of lime-sand, in addition to transporting of sand to the southwestern bank of Ganau Lake that are located in the far side in the direction of the wind.

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