DEVELOPMENT OF STROMATOLITES IN A MIXED SILICICLASTIC-CARBONATE SUCCESSION: AN EXAMPLE FROM PALAEO-MESOPROTEROZOIC TADPATRI FORMATION, CUDDAPAH BASIN, INDIA

Rahul Mitra[1*] & Gopal Chakrabarti[2] & Debasish Shome[1]

[1*]Research Scholar, Deparment of Geological Sciences, Jadavpur University, Kolkata-700032

[2]Associate Professor & Joint DPI (S&S), Education Directorate, Govt. of West Bengal, Kolkata-700091

[1]Professor (Retd.), Deparment of Geological Sciences, Jadavpur University, Kolkata-700032

Received: May 18, 2018 Accepted: June 21, 2018

ABSTRACT *The thick succession of Palaeo-Mesoproterozoic Tadpatri Formation in an around Utakonda (15°16'08.80''N, 77°52'01.77''E) is represented by mixed siliciclastic-carbonate succession with mafic-ultramafic sill bodies. Stromatolites are commonly observed in an association with the carbonates. The vertical distribution as well as the changing patterns of the stromatolite in the studied section of the Tadpatri Formation is documented. Stratifera, domals and columnars are the most common types and these all are dominantly recorded in six different stratigraphic horizons of the studied section. Domals are small to large, hemispherical to slightly elongated and isolated to laterally link. Columnars are also small to large in size, laminae are convex-upward and branching is occasionally observed. In the lower most stromatolitic horizon (H-I) stratifera is dominant whereas in the upper horizons (H-V and H-VI) large sized domals and columnars are common. Small to medium sized domals and columnars are most common in the lower to middle stromatolitic horizons (H-II, H-IV). Branching in columnar stromatolite is also observed but restricted within the second stromatolitic horizon (H-II). Stratifera stromatolites are mainly formed in supratidal-intertidal environment whereas domals and columnars are formed in intertidal-subtidal environment.*

Keywords: *Tadpatri, Stromatolites, Carbonate*

1. INTRODUCTION

Stromatolite is commonly considered as one of the most interesting benthic microbial deposit which is generally formed due to the reduction in metazoan diversity; rise in sea-water saturation as well as due to biogenic mechanism (Kershaw et al., 2012; Liu et al., 2017). Within the earth history stromatolite was mainly developed during the Precambrian era with a greater abundance in Mesoproterozoic time period (Meng et al., 2017; Khelen et al., 2017). Cuddapah Basin, one of the Indian Proterozoic sedimentary basins also records such development of stromatolites and their occurrences are mainly restricted within Palaeo-Mesoproterozoic Vempalle and Tadpatri Formation. Previous works on stromatolites within this Cuddapah Basin are mainly focused within Vempalle Formation with a very little work in Tadpatri Formation. Sharma and Shukla (2003); Khelen et al. (2017) have reported the stromatolites from the southern part of the Tadpatri Formation and based on the morphology as well as geochemical features suggest their deposition in subtidal-intertidal-supratidal zone. A much more detailed study on the stromatolites throughout the Tadpatri Formation is further required to better understand their distribution, changing patterns and deposition within this formation. Hence, the present work has been taken up in the northern part of the Tadpatri Formation (a) to describe the stromatolite types and their vertical distribution within the studied section as well as (b) to depict the probable paleoenvironment during their formation.

2. METHODOLOGY

Geological setting of the study area

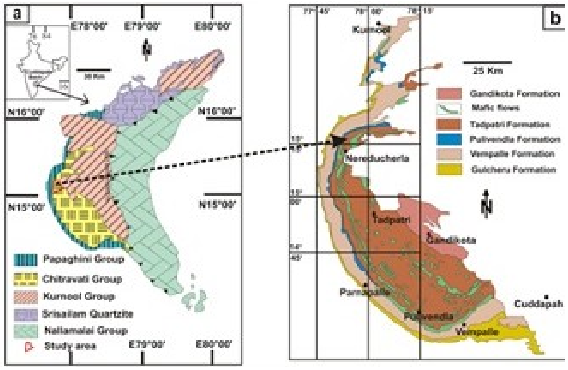

Fig. 1 Geological maps of the study area **(a)** Generalized geological map of the Cuddapah Basin (modified after Geological survey of India 1:2000000 scale map, 1998); **(b)** Geological map of western Cuddapah Basin showing the lower Cuddapah group of rocks (after Nagraja Rao et al., 1987 and Mitra et al., 2017)

The distinctly crescent-shaped, westwardly convex Cuddapah Basin is considered as the second largest within the Proterozoic intracratonic sedimentary basins of India. Lithostratigraphically Cuddapah Basin is sub-divided into older Cuddapah Supergroup and younger Kurnool Group (Nagaraja Rao et al., 1987). Cuddapah Supergroup is consisting of Papaghni, Chitravati, Nallamalai Groups and Srisailam Formation from base to top (Fig.1a). The studied Formation, Tadpatri Formation belongs to the Chitravati Group and conformably overlies the Pulivendla Quartzite (Nagaraja Rao et al., 1987; Mitra et al., 2017; Fig. 1b).

The present study on Tadpatri Formation is carried out in the north-western part of the Cuddapah Basin (Fig. 1a,b). The studied section exposed near Utakonda (15°16'08.80''N, 77°52'01.77''E), 4.5 Km from Hussainpuram village (15°14'08.54''N, 77°49'35.15''E) and 12 Km from Dhone town of Kurnool district, Andhra Pradesh. The

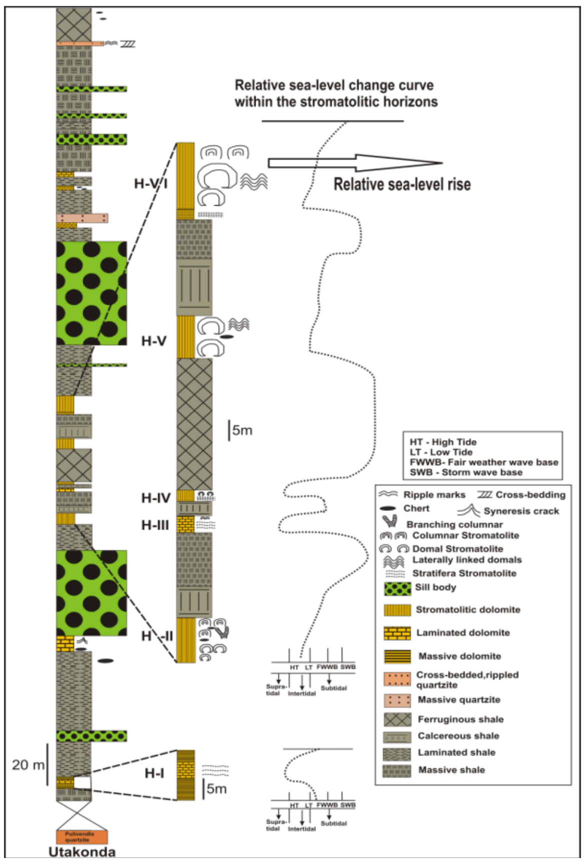

Fig. 2 Litholog of the studied section, located in northern part of the Tadpatri Formation. The diagram also describes the development of stromatolites in different stratigraphic horizons and their response to sea level fluctuations

studied section (Fig. 2) contributes crucial information regarding the vertical variations of lithology as well as stromatolite morphotypes. Within the studied area Tadpatri Formation principally consists with mixed siliciclastic-carbonate deposit with intruded sill bodies. The clastic units are dominantly shale and they are massive, laminated, calcareous and ferruginous in nature. The carbonate units are thinly laminated to domal and columnar stromatolite bearing.

3. TADPATRI STROMATOLITES AND DEPOSITIONAL ENVIRONMENT

In the studied section the stromatolites are mainly dominated in the lower to middle part of the succession and recorded in six different stratigraphic horizons. Stratifera, domal and columnar stromatolites are dominantly observed in the studied section. The laminae within the stratifera are thin, wavy and nearly parallel. Thin section studies reveal that the matrix is micrite to microspar dominated with medium sized calcite grains and sparite (Fig. 3a). The domal stromatolites are isolated as well as laterally linked. Thin section studies of the domals clearly show prominent banding of alternate layers of carbonate (micrite) and chert with irregularly distributed recrystallized sparite (Fig. 3b). The laminae of the columnar stromatolites are convex upward with the absence of branching. Occasionally branching is also observed within the columnar stromatolites. Under microscope the columnars show distinct banding of sparite and calcite grains within the micritic matrix (Fig. 3c).

First stromatolitic horizon (H-I)

The stromatolites within the studied section are first recorded as stratifera and occurred in the lower most part of the succession (Fig. 2). The stratifera stromatolites are overlying and underlying by massive dolomite (Fig. 2). The laminates consist with fine, wavy or crinkly parallel laminations with occasional upward growth (Fig. 3d) and deposited in a supratidal-upper intertidal environment within an inner-ramp set-up

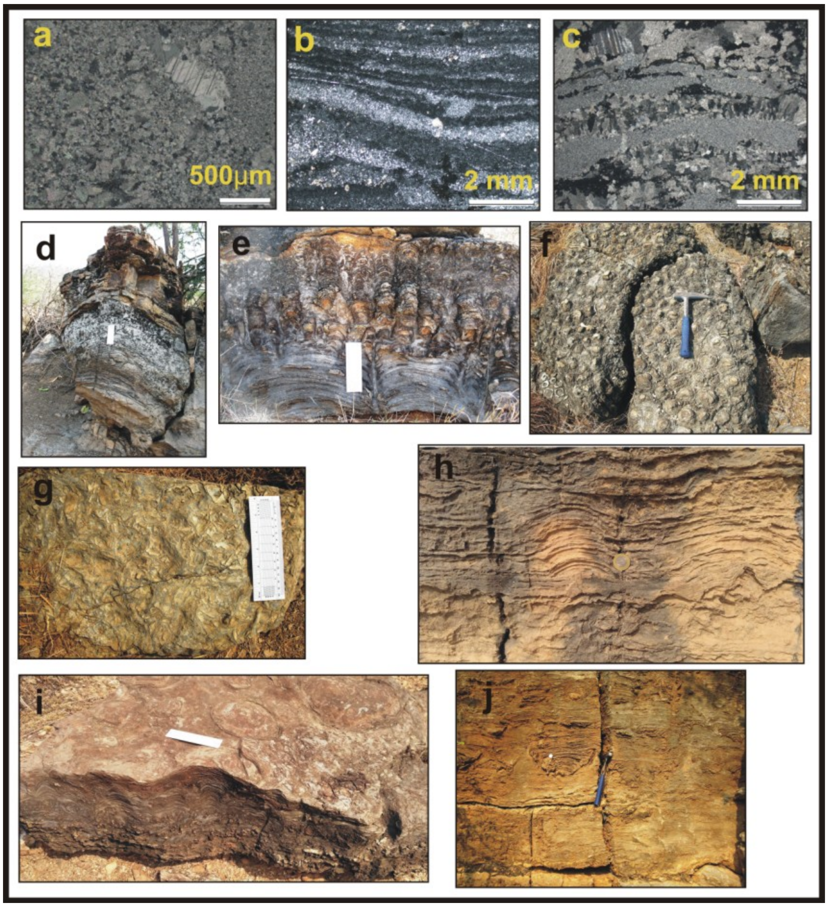

Fig. 3 Stromatolites from north-western part of the Tadpatri Formation (a) micrite to microspar dominated matrix with calclite grain in stratifera type of stromatolites; (b) alternate banding of micrite and chert in domal stromatolites; (c) banding of sparite, calcite grains within the micritic matrix of columnar stromatolites; (d) stratifera stromatolites are overlying by massive dolomite in the H-I stromatolitic horizon; (e) domal stromatolities are overling by columnar stromatolites in the H-II stromatolitic horizon; (f) planar view of the columnar stromatolites with egg-carton structures in the H-II stromatolitic horizon; (g) ripple marks within the stratifera stromatolites bearing carbonates, H-III stromatolitic horizon; (h) small sized, slightly inclined domals with stratifera stromatolites in the H-IV stromatolitic horizon; (i) laterally linked, hemispherical domals in H-V stromatolitic horizon; (j) Large sized domals with highly distorted laminae in H-VI stromatolitic horizon

(Chakrabarti et al., 2014, 2015). The deposition of the massive dolomite over the stratifera indicates a change in depositional environment from supratidal-upper intertidal to intertidal-subtidal (Panja et al., 2018) (Fig. 2).

Second stromatolitic horizon (H-II)

The stromatolites within this horizon are represented by small to medium sized domals and columnars. In the lower part of this horizon isolated to partially linked domal stromatolites are recorded which grade upward into columnar stromatolites (Fig. 3e). The height of the domes ranges in between 10 to

25 cm and the laminae thickness varies within 0.20- 0.90 cm. Domes consist of typical smooth laminae with occasionally crinkly in nature. The domals of this horizon are mainly deposited in intertidal environment and the smooth, regularly spaced thin lamination reflects deposition is in quiet water (Chakrabarti et al., 2014, 2015). The columnar stomatolites of this horizon are partially laterally linked and the individual column height varies from 30 cm to 70 cm. Branching within columnar stromatolites are occasionally observed and it indicates deposition in a high energy intertidal environment (Khelen et al., 2017). In planar view the columnar stromatolites are distinctly elliptical to semicircular in shape with prominent egg-cartoon structure (Fig. 3f). Deposition of columnar stromatolites over the domal stromatolites (Fig. 3e) indicates shifting in energy condition from low to high (Grotzinger, 1986) and the depositional area lies within intertidal to shallow subtidal regime (Chakrabarti et al., 2015; Panja et al., 2018). This H-II horizon is underlying and overlying by laminated shale and calcareous shale facies respectively (Fig. 2). Hence the formation of domals over the laminated shale indicates a sharp change in depositional environment from subtidal to intertidal (Krim et al., 2017).

Third stromatolitic horizon (H-III)

The third stromatolitic horizon is represented by stratifera and this is very much similar like the first horizon. The stratifera of this horizon is commonly found in association with ripple marks (Fig. 3g). Crests of the ripples are straight to sinuous. This ripple marks bearing laminated stromatolites mainly formed in the upper intertidal regime. This third stromatolitic horizon is underlying and overlying by massive and calcareous shale facies respectively (Fig. 2).

Fourth stromatolitic horizon (H-IV)

Small sized domes with alternate thin and wavy laminates (stratifera) represent the fourth stromatolitic horizion of this studied section (Fig. 3h). The domes are isolated and the height of the dome ranges from 7-10 cm with laminae thickness 0.10- 0.50 cm. Occasionally the domes show preferred inclination which indicates the presence of unidirectional waves or currents during the deposition (Hoffman, 1967). The relatively small sized domals with alternating stratifera mainly deposited in the upper intertidal regime (Chakrabarti et al., 2014). This stromatolitic horizon is underlying and overlying by calcareous shale and ferruginous shale of shallow to deep subtidal regime (Al-Juboury et al., 2015; Krim et al., 2017) (Fig. 2).

Fifth stromatolitic horizon (H-V)

This stromatolitic horizon is mainly represented by large sized domals. The height of the dome ranges from 25-60 cm with laminae thickness 0.80- 1.50 cm. In the lower part the domes are isolated but in the upper part they are laterally linked (Fig. 3i). Domes are hemispherical to slightly elongate (Fig. 3i). The laminae are crinkly and wavy in nature. Large sized domes are interpreted as a proxy of subtidal environment (Chakrabarti et al., 2014; Panja et al., 2018). These large sized domes are underlying and overlying by ferruginous shale and calcareous shale of subtidal environment (Fig. 2).

Sixth stromatolitic horizon (H-VI)

This one is the last stromatolitic horizon within the studied section, underlying and overlying by massive shale and laminated shale of subtidal environment (Fig. 2). The height of the dome ranges from 25-75 cm with laminae thickness 0.35- 1.50 cm. The lower part within this horizon is dominated by stratifera followed by large sized domes. The laminae are inclined as well as highly distorted (Fig. 3j). The domes are grade upward into columnar stromatolites. Individual column height is within 25 to 40 cm. Large size domes and columnar stromatolites of this horizon are mainly formed in shallow subtidal environment.

Therefore it can say that the stromatolites those are developed in the northern part of the Tadpatri Formation, mainly deposited in supratidal-intertidal-subtidal environment of inner-ramp set-up.

4. CONCLUSIONS

The Tadpatri Formation is well exposed in an around Utakonda area and represents the northern part of this formation. The studied section of the Tadpatri Formation is represented by thick succession of mixed siliciclastic-carbonate deposits.

Stromatolites are mainly occurred within the carbonate deposits and dominated in the lower to middle part of the studied section. Stratifera, domal and columnar are the most common types those are observed in the studied section. The horizontally crinkled, up-curving laminates (stratifera) are mainly deposited in supratidal to upper-intertidal regime. The smooth, regularly spaced thin lamination of domal stromatolite reflects deposition is in quiet water of intertidal environment. The occurrence of relatively large sized mounds indicates that the water depth is sufficient which further allow the upward growth of this stromatolite. Deposition of the columnars over the domals suggest a change in energy condition from low to high and considered deposited in lower-intertidal to shallow subtidal regime.

The development of the stromatolites is recorded in six different stratigraphic horizons of the studied section. The basal stromatolitic horizon, H-I is represented by stratifera; H-II horizon is composed of small to medium sized domals and columnars; H-III is with mainly stratifera types; H-IV is with small sized domals and stratifera; H-V is with large sized domals and the top most H-VI horizon is represented by stratifera, large sized domes and columnars from base to top. The laminae of the stromatolites within the sixth horizon are highly distorted. Therefore from these changing patterns as well as the vertical distributions of the stromatolites clearly suggest that the lower stromatolitic horizons (H-I, H-II, H-III, H-IV) dominantly reflect supratidal-intertidal environment whereas the upper horizons (H-V, H-VI) reflect subtidal environment.

Acknowledgements:

The first author is thankful to the UGC for the fellowship vide UGC Non-Net scheme. The authors are also grateful to Department of Science and Technology, Government of India for financial support vide PURSE (Phase-II) program (No. F4/SC/20/15). Sincere thanks are also being accorded to Jadavpur University, Kolkata for providing infrastructural support.

References

1. Al-Juboury, A.J., Al-Haj, M.A., Jabbar, W.J. (2015) Facies analysis and depositional environment of the Geli Khana Formation (Middle Traissic), Northern Iraq. Arab J. Geosci, 8: 4765-4777.
2. Chakrabarti, G., Eriksson, P.G., Shome, D. (2015) Sedimentation in the Papaghni Group of rocks in the Papaghni sub-basin of the Proterozoic Cuddapah Basin, India. Precambrian Basins of India: Stratigraphic and Tectonic Context, Geological Society of London, Memoris, 43: 255-267.
3. Chakrabarti, G., Shome, D., Kumar, S., Stephens, GM. III., Kah, L.C. (2014) Carbonate platform development in a Paleoproterozoic extensional basin, Vempalle Formation, cuddapah basin, India. J Asian Earth Sci, 91:263–279.
4. Grotzinger, J.P. (1986) Cyclicity and paleoenvironmental dynamics, Rocknest Platform, northwest Canada. Geological Society of America Bulletin, 97:1208-1231.
5. Hoffman, P.F. (1967) Algal stromatolites: use in stratigraphic correlation and palaeocurrent determination. Science, 157:1043-1045.
6. Kershaw, S., Crasquin, S., Li, Y., Collin, P.Y., Forel, M.B., Mu, X.N., Baud, A.,Wan, Y., Xie, S.C., Maurer, F., Li, G. (2012) Microbialites and global environmental change across the Permian–Triassic boundary: a synthesis. Geobiology, 10:25–47.
7. Khelen, A.C., Manikyamba, C., Ganguly, S., Singh, Th.D., Subramanyam, K.S.V., Ahmad, S.M., Reddy, M.R. (2017) Geochemical and stable isotope signatures of Proterozoic stromatolitic carbonates from the Vempalle and Tadpatri Formations, Cuddapah Supergroup, India: Implications on paleoenvironment and depositional conditions. Precambrian Research, 298:365-384.
8. Krim, N., Bonnel, C., Tribovillard, N., Imbert, P., Aubourg, C., Riboulleau, A., Bout Roumazeilles, V., Hoareau, G., Fasentieux, B. (2017) Paleoenvironmental evolution of the southern Neuquen basin (Argentina) during the Tithonian-Berriasian (Vaca Muerta and Picun Leufu Formations): a multi-proxy approach. Bull. Soc. Geol. Fr., 188, 34.
9. Liu, S., Wang, J., Yin, F., Xie, T., Hu, S., Guan, X., Zhang, Q., Zhou, C., Cheng, W., Xu, J. (2017) Early Triassic stromatolites from the Xingyi area, Guzhou Province, southwest China: geobiological features and environmental implications, Carbonates and Evaporites, 32:261-277.
10. Meng, F.W., Zhang, Z.L., Yan, X.Q., Ni, P., Liu, W.H., Fan, F., Xie, G.W. (2017) Stromatolites in Middle Ordovician carbonate-evaporite sequences and their carbon and sulfar isotopes stratigraphy, Ordos Basin, northweastern China, Carbonates and Evaporites, https://doi.org/10.1007/s13146-017-0367-0.
11. Mitra, R., Chakrabarti, G., Shome, D. (2017) Geochemistry of the Palaeo-Mesoproterozoic Tadpatri shales, Cuddapah Basin, India: implications on provenance, paleoweathering and paleoredox conditions. Acta Geochimica, https://doi.org/10.1007/s11631-017-0254-3
12. Nagaraja Rao, B.K., Rajurkar, S.T., Ramalingaswami, G., Ravindra, B.B. (1987) Stratigraphy, structure and evolution of Cuddapah Basin. Purana Basins of Peninsular India. Geological Society of India, Bangalore, Bulletins, 6:33-86.
13. Panja, M., Chakrabarti, G., Shome, D. (2018) Earthquake induced soft sediment deformation structures in the Paleoproterozoic Vempalle Formation (Cuddapah basin, India). Carbonates and Evaporites, https://doi.org/10.1007/s13146-017-0412-z
14. Sharma, M. and Shukla, M. (2003) Studies in Palaeo-Mesoproterozoic stromatolites from Vempalle and Tadpatri Formations of Cuddapah Supergroup, India. Vistas in Palaeobotany and Plant Morphology: Evolutionary and Environmental Perspectives (Professor D.D. Pant Memorial Volume), 1-25.