JOURNAL GEOLOGICAL SOCIETY OF INDIA
Vol. 26, Feb. 1985, pp. 111 to 117

Algal structures from the Upper Krol-Lower Tal Formations of Garhwal and Mussoorie synclines and their palaeo-environmental significance

VINOD C. TEWARI AND M. FASIULLAH QURESHY
Wadia Institute of Himalayan Geology, Dehra Dun 248 001

Abstract

Algal pisolites, oncoids, columnar stromatolites and columnar layered stromatolites have been recorded from cherty dolomitic limestones from Upper Krol and Lower Tal formations. The algal mat facies show bird's eye structures and irregular fenestral fabric suggesting an intertidal-supratidal environment of deposition for Upper Krol (D and E) Formation of Garhwal syncline. The basal Lower Tal Formation of Mussoorie syncline also represents a complex algal oncoidal-stromatolitic (protected tidal flat/lagoonal) facies with restricted circulation. The association of phosphorite with stromatolites and oncoids proves the phosphorite to be deposited in a shallow water environment. The presence of pyrite and associated black shales indicate an erobic condition.

INTRODUCTION

The 350 km long Krol Belt which extends from Solan in northwest to Nainital in southeast is a highly controversial belt in lesser Himalayan stratigraphy. Krol-Tal Formations are exposed in the Mussoorie and Garhwal synclines of Garhwal Himalaya in the Central sector of Krol Belt. Auden (1934, 1937) studied in detail the structures and lithostratigraphy of Krol Belt in Himachal and Garhwal Himalaya. The Upper Krol sediments are mainly algal mat carbonates gradationally overlain by basal chert-phosphorite member of Lower Tal Formation.

In the present paper, algal structures are described and the palaeo-environment of deposition is interpreted from different algal mat microfacies. The age of the Krol-Tal Formations has also been discussed in the light of recent researches.

PREVIOUS WORK

Algal structures, oncolites and algal pisolites were recorded from Upper Krol succession of Mussoorie and Nigalidhar syncline (Bhargava, 1969; Gundu Rao, 1970; Mithal and Chaturvedi, 1972 and Singh *et al* 1980). Raha and Gururaj (1970) reported algal stromatolites from phosphatic limestone of Tal Formation, Mussoorie area. Later, Raha (1972) putting the phosphorite unit into Krol Formation described oncolites and stromatolites from Mussoorie syncline. Sharma (1976) described stromatolites from Lower Tal Formation of Mussoorie area. Fuchs and Sinha (1974), Singh and Rai (1977) and Kumar (1981) have recorded stromatolites from Upper Krol sediments of Nainital area. Recently, Tewari (in press) has disovered new forms of stromatolites from Lower Tal Formation of Mussoorie syncline.

GEOLOGICAL SETTING

The Tal Formation is the uppermost litho unit of the Krol Belt in Mussoorie and Garhwal areas. The Krol Formation is overlying the Infra Krol Formation

0016 - 7622/85/26-2-111/$1.00

and underlying the Tal. Black shale, chert, phosphorite and interbedded stromatolitic dolomite belong to basal Lower Tal Formation. Raha (1972), however, considers the Mussoorie phosphorite as the uppermost member of the Krol Formation in Mussoorie area. Fig. 1a and b show the geology of parts of Mussoorie and

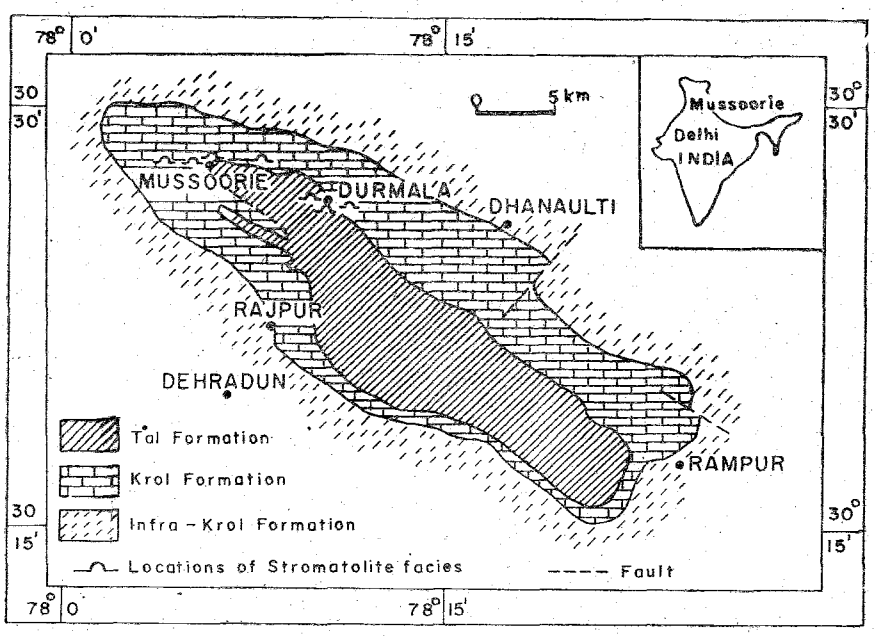


Figure 1 a.
Geological sketch map of Mussoorie syncline showing the location of stromatolites.

Garhwal synclines and the location of stromatolites and algal mat facies. The lithologic succession of Upper Krol (D), in which algal structures are recorded is shown in Fig. 2. The contact of Upper Krol and Lower Tal Formations is gradational in both Mussoorie and Garhwal synclines. The sedimentological setting of Krol-Tal Formations in which algal structures occur is given below:

TABLE I.

Lower Tal Formation	—	Phosphorite, chert, black carbonaceous shales often pyritic and, thin dolomitic limestone bands with phosphatic stromatolites and algal oncoids.
Upper Krol Formation	—	Grey to bluish grey, dolomitic limestone, bird's eye dolomite and associated shales, argillaceous limestone with purple, grey, green shale.

The Upper Krol (D) and Lower Tal sediments of this area are represented by algal mat facies and show good development of oncolites, columnar, domal, bulbous and stratified algal stromatolites. As most of the algal structures are small-scale

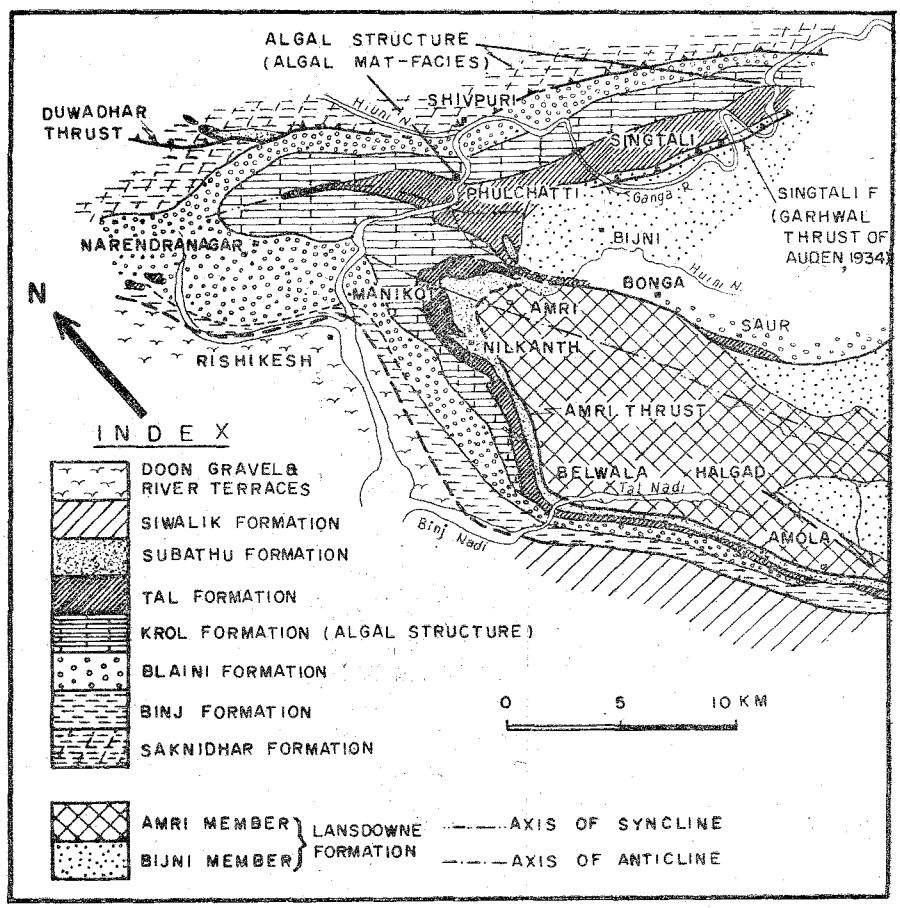


Figure 1 b.
Geological map of the part of Garhwal syncline showing location of algal mat facies.

and occur in a single specimen, the algal mat facies have been subdivided into various microfacies. Five algal mat and stromatolitic microfacies have been recognized in the Upper Krol and Lower Tal Formations of Shivpuri-Upper Kauriyala and Durmala areas, viz., (1) thinly laminated algal mat microfacies (2), domal laminated algal mat microfacies, (3) algal mat microfacies with spheroidal structures, (4) bird's eye pisolitic dolomite (Fenestral laminite microfacies) and (5) columnar stromatolitic and algal oncoidal microfacies.

Thinly laminated algal mat microfacies

This microfacies is characterized by smooth thin algal laminations and the laminites are few mm in thickness and show radial fibrous fabric (Plate I, Fig. 1b; Plate II, Fig. 1). This algal mat consists of various assemblages of blue-green algae and the radial sparitic fabric seems to be governed by original growth pattern of the algae. The radially elongated calcite crystals (sparites) also contain scattered dark organic matter. This microfacies represents deposition in intertidal environment.

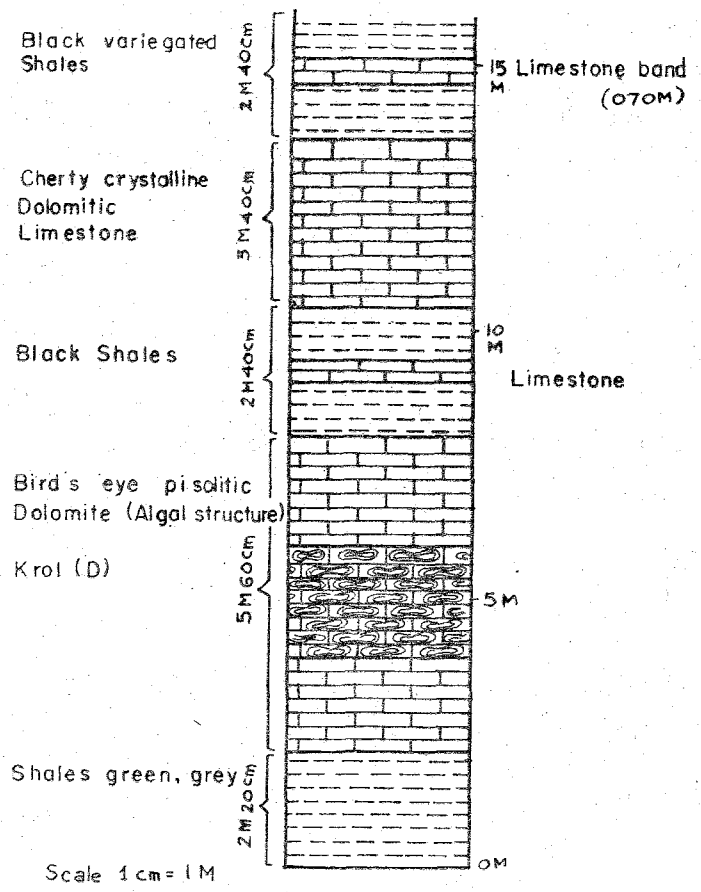


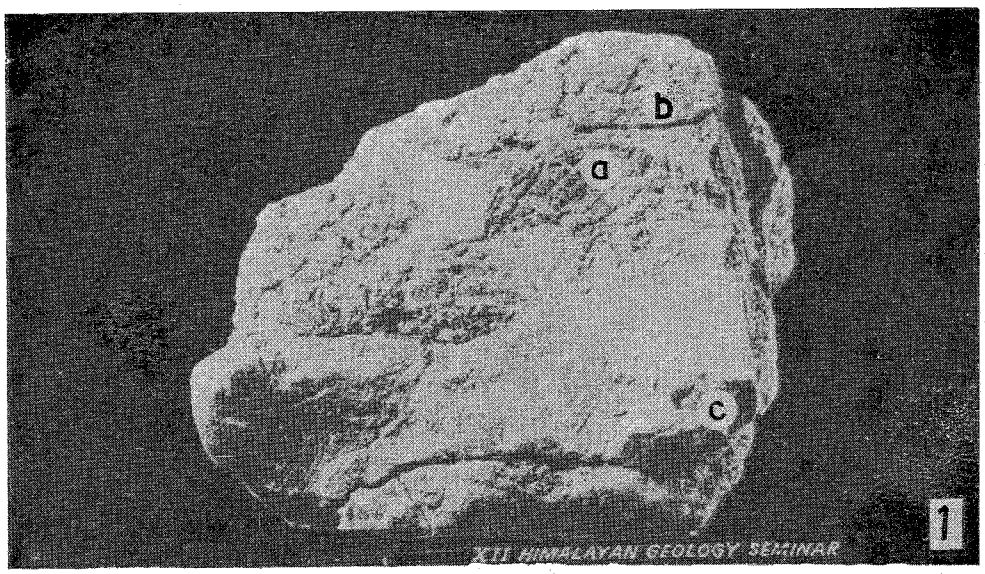
Figure 2. Lithologic succession of Upper Krol (D) between Shivpuri and Phulchatti area, Garhwal syncline.

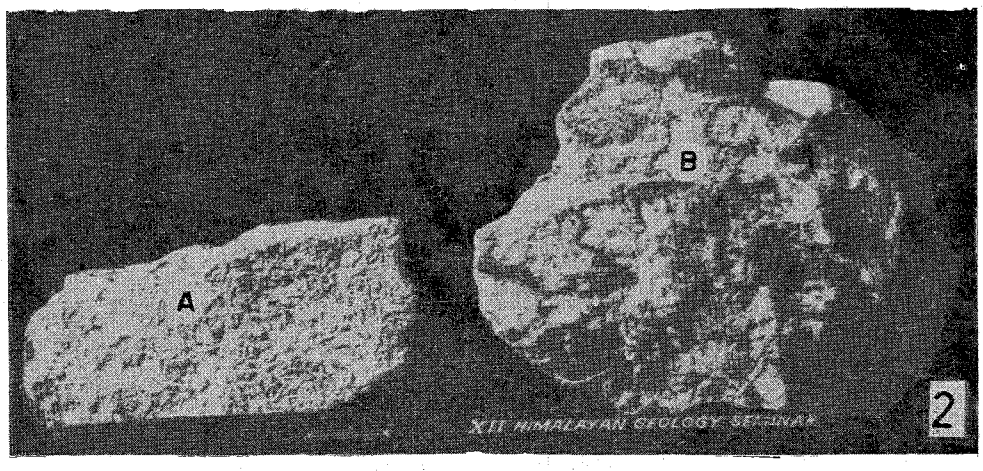
Domal laminated algal mat microfacies

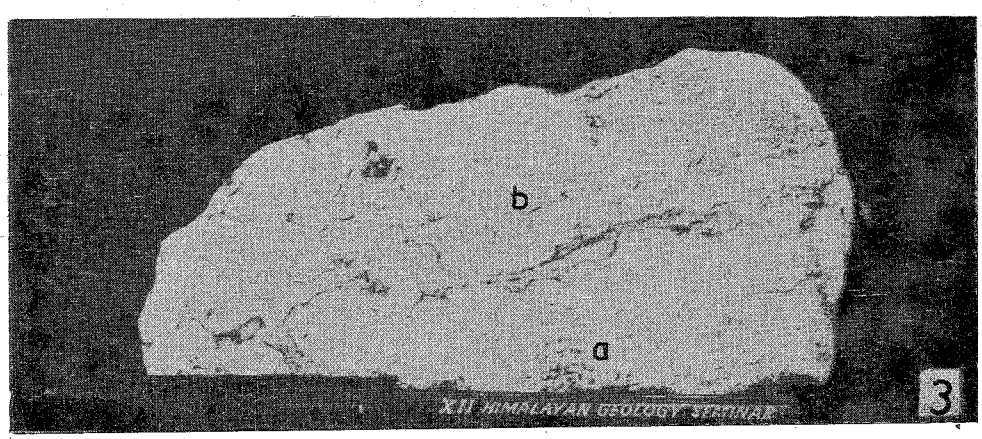
This microfacies shows convex upward laminations to develop domal stromatolites (Plate I, Fig. 1a). Small domal stromatolites up to 1 cm in height are recorded. This microfacies also represents low energy intertidal flat environment.

EXPLANATION OF PLATE I

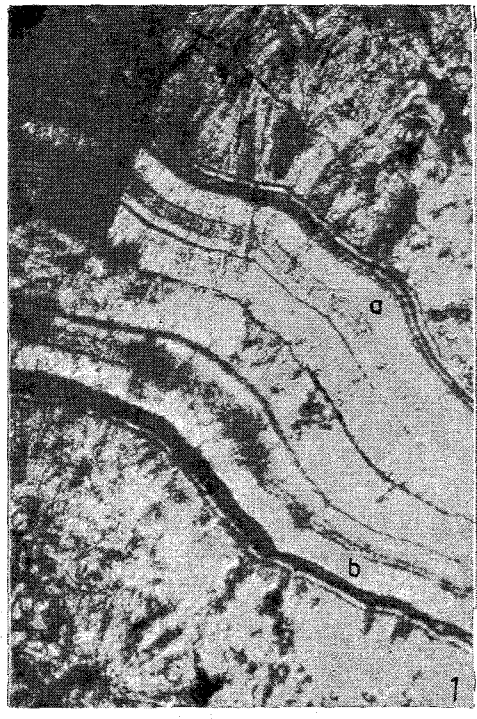
1. Algal mat microfacies of Krol D of Garhwal syncline. (a) algal mat with domal stromatolite, (b) algal mat with smooth thin laminations, (c) algal mat with spheroidal (Oncoidal) structures.
2. Fenestral laminite microfacies of Krol D. (a) Unlaminated dolomite with irregular fenestrae, (b) bird's eye dolomite with abundant dolomite spar-filled fenestral voids.
3. Bird's eye (pisolitic) dolomite. (a) algal pisolites enveloped by concentric laminae, (b) irregular fenestral fabric.

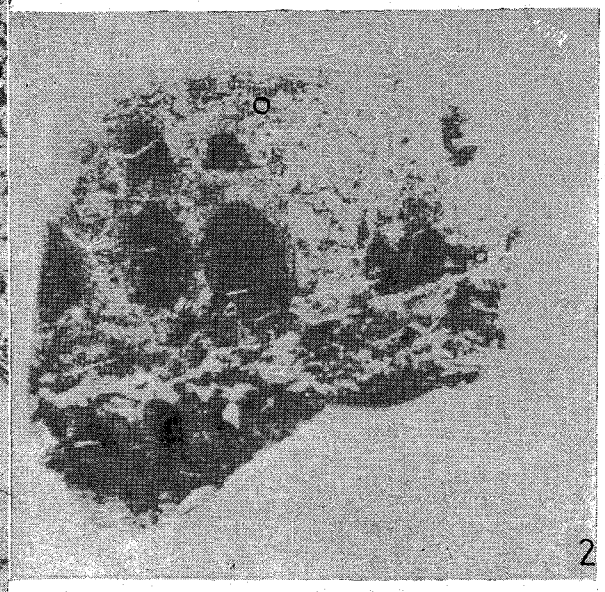


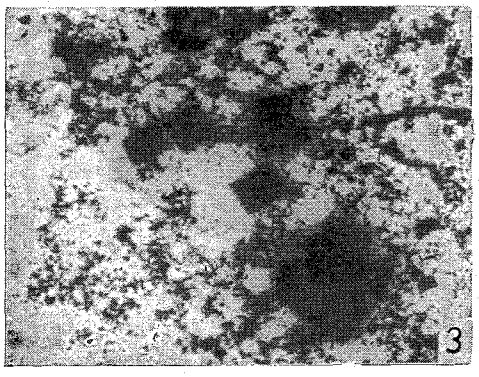


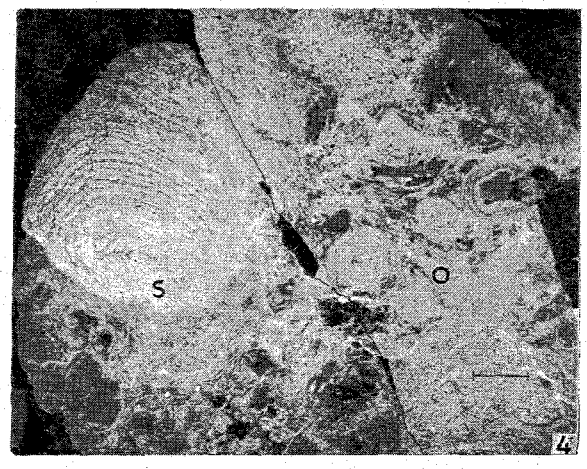


TEWARI AND QURESHY: ALGAL STRUCTURES IN UPPER KROL









TEWARI AND QURESHY: ALGAL STRUCTURES IN UPPER KROL

Algal mat microfacies with spheroidal structures (oncoids)

This microfacies is represented by the association of thin laminated and domal laminated algal mat microfacies with the development of spheroidal stromatolites (oncoids). The oncoids show concentric light (carbonate) and dark (algal) laminae with circular outlines (Plate I, Fig. 1c) and the diameter of the spheroid ranges from 0.5 to 2 cm. The spheroids (oncoids) are formed by entrapment of detritus by an enveloping algal mat. This facies represents a deposit of intertidal flat with somewhat moderate circulation.

Bird's eye (pisolitic) dolomite microfacies (Fenestral laminite microfacies)

The characteristic feature of this microfacies is the development of fenestral fabric in bird's eye dolomite (Plate I, Figs. 2, 3). This microfacies comprises unlaminated dolomite with irregular fenestrae (Plate I, Fig. 2a) and abundant dolomite spar-filled fenestral viods (Plate I, Fig. 2B). Algal pisolites are generally smaller in size (1-5 mm), spherical in shape and enveloped by concentric laminae (Plate I, Fig. 3). This facies is common in tidal flats (Fisher, 1964; and Singh *et al* 1980). The bird's eye (fenestral) fabric is characteristic of supratidal zone and results from desiccation and develops where carbonate sediments are subaerially exposed and subjected to intense periodic dryness. The fenestral fabric *(Loferites)* described by Fischer (1964), resembles fenestral fabric of Krol (D) bird's eye dolomite of Garhwal syncline. Singh *et al* (1980) describe this facies from Krol dolomite (D) on Jharipani-Mussoorie mule track and near Maldeota phosphorite mine, Dehra Dun. The senior author (V.C.T.) has traced this facies in Krol (D) dolomite at King Crab, Mussoorie ridge, Gunhill Camel's back and Dhobhighat-Chamasari localities of Mussoorie syncline. Algal oncoids, small laterally linked stromatolites and stratified stromatolite *Stratifera irregularis* have also been recorded from this facies.

Columnar stromatolitic and algal oncoidal microfacies

This microfacies is described from Lower Tal chert, phosphorite, shale member of Durmala phosphorite mine. The algal mat carbonates of Upper Krol show gradational contact with the Lower Tal Formation and represent facies change from intertidal-supratidal to protected tidal flat or shallow lagoon with restricted circulation.

The outstanding features of this microfacies are the development of columnar, columnar layered, stratified, passively branching, domal, laterally linked, stromatolites

---

EXPLANATION OF PLATE II

1. Microphotograph of laminated algal mat. (a) Radial fibrous fabric showing original growth pattern of algae, (b) large fenestrae.
2. Photograph of polished slab showing columnar stromatolites (s) and Oncoids (o) Durmala phosphate mine, Mussoorie.
3. Microphotograph of stromatolitic phosphate showing euhedral crystals of pyrite.
4. Transmitted light microphotograph of association of phosphatic oncoids (o) and stromatolites (s). Phosphate grains are present in the matrix as well as in the stromatolitic laminae. Scale 1 cm.

and algal oncoids (Plate II, Figs. 2, 4) with phosphorite. Lower Cambrian (Tommotian) stromatolite form *Collumnaefacta vulagaris* is recorded from this facies, (Tewari, in press). The laminae of stromatolites are made up of phosphatic (black) and carbonate (light) laminae. The inter-columnar space is occupied by phosphate grains, oncoids, pyrite grains and chert (Plate II, Figs. 2, 4). The small domal forms are confined to pyritic bands. The laminae are phosphatic as well as pyritic. Petrographic studies show euhedral crystals of pyrite associated with phosphatic stromatolites (Plate II, Fig. 3). This microfacies represents reducing environment which stopped further growth of algae. The carbonaceous shales associated with phosphorite also confirm existence of anaerobic conditions. Oncoids of 0.5 to 2 cm in diameter are also found in association with smaller columnar phosphatic stromatolites (Plate II, Fig. 4). The concentric laminae of oncoid are phosphatic and pyritic and the core is filled with chert. Scattered grains of collophane are found in the matrix as well in the algal laminations. This microfacies represents moderate (restricted) circulation on sheltered tidal flat.

PALAEOENVIRONMENT

The Krol Formation of Solan, Mussoorie and Nainital areas are tidal flat deposits especially in intertidal-supra tidal zone (Singh *et al* 1980).

The lithofacies of the Krol A, B and C of Garhwal syncline indicate that these sediments were deposited in low energy shallow subtidal to intertidal flat environment. The algal mat microfacies of Upper Krol Formation (D and E) show deposition in intertidal and supratidal zones of carbonate tidal flat. The algal mat microfacies recognized in Mussoorie syncline were also traced in Garhwal syncline (M.F.Q.).

In Mussoorie area, the intertidal-supratidal environment of Upper Krol changed over to protected tidal flat or shallow water lagoonal setting of Lower Tal (chert, phosphorite, shale) Formation. This is a facies of restricted circulation in which highly variable conditions like increased salinity, subaerial exposures, alternation of reducing and oxygenated conditions prevailed. Such conditions are favourable for the growth of oncoids and stromatolites. This environment changed over into reducing environment which is represented by pyrite bands, pyritic laminae of bolh oncoids and stromatolites and black shales associated with phosphorite. The growth of stromatolite columns was stopped by such reducing conditions. The Mussoorie Tal phosphorite represents shallow water environment, possibly in lagoon or protected tidal flat.

The tidal flat deposits are often characterized by rich benthonic communites, trace fossils and bioturbated horizons (Reineck and Singh, 1980). The micaceous siltstone, pebbly quartzite with slates and quartzites overlying the Tal phosphorite represent thorough bioturbation facies and off shore bar facies indicating traces of metazoan activities.

ACKNOWLEDGEMENTS

Authors are thankful to Dr. V. C. Thakur, and Prof. I. C. Pande, for going through the manuscript and discussions. One of the authors (V. C. T.) is indebted to Prof. R. C. Misra, President, Wadia Institute of Himalayan Geology for encouragement. Dr. S. C. D. Sah, Director, W. I. H. G. is thanked for providing facilities and financial assistance to one of us (M. F. Qureshy).

References

AUDEN, J. B., (1934) The geology of the Krol Belt. *Rec. Geol. Surv. India*, v. 67, pp. 357-454.

——— (1937) The structure of the Himalaya and Garhwal. *Rec. Geol. Surv. India*, v. 71, pp. 407-433.

BHARGAVA, O. N., (1969) Algal pisolites in the Krol E Stage, Nigali Dhar syncline, Sirmur district, H.P. *Bull. Indian Geol. Assoc.*, v. 2, pp. 120-121.

FISHER, A. G., (1964) The Lofer cyclothems of the Alpine Triassic. *In:* D. F. Merriem (Ed.). Symposium on cyclic sedimentation. *State Geol. Surv. Kansas, Bull.*, v. 169 (1), pp. 107-149.

FUCHS, G. R. and SINHA, A. K., (1974) On the Geology of Nainital (Kumaun Himalaya). *Him. Geol.*, v. 4, pp. 563-580.

GUNDU RAO, C., (1970) A note on the oolites in the Krol Series and their age significance. *Publ. Centr. Adv. Stud. Geol.*, v. 77, pp. 127-129.

KUMAR, A., (1981) Upper Krol stromatolites from Nainital Hills, Kumaun Himalaya, India. *In:* Claude Monty (Ed.). *Phanerozoic stromatolites*, Springer Verlag, Berlin-Heidelberg, pp. 36-44.

MITHAL, R. S. and CHATURVEDI, R. S., (1972) Possible algal structures in the Upper Krol Limestones of Mussoorie area, Uttar Pradesh. *Geol. Surv. India Misc. Publ.*, v. 15, pp. 265-268.

RAHA, P. K., (1972) Algal stromatolites from the Krol Formation of the Mussoorie syncline, Uttar Pradesh. *Palaeobotanist*, v. 21, pp. 227-230.

RAHA, P. K. and GURURAJ, M. N., (1970) A note on occurrence of algal (stromatolitic) structures in the phosphatic limestones of the Tal Formation of Mussoorie syncline near Mussoorie, U.P. *Indian Minerals*, v. 24, pp. 396-399.

REINECK, H. E. and SINGH, I. B., (1980) *Depositional Sedimentary Environments* (2nd Edition), Springer Verlag, Berlin, p. 549.

SHARMA, K. K., (1976) On the occurrence of stromatolitic limestones, Lower Tal Formation of Pari Tibba, Mussoorie (Uttar Pradesh) and their palaeoecological significance. *Chayanica geologica*, v. 2, pp. 91-99.

SINGH, I. B. and RAI, V., (1977) On the occurrence of stromatolites in the Krol Formation of Nainital area and its implications on the age of Krol Formation. *Curr. Sci.*, v. 46, v. 736-738.

SINGH, I. B., RAI, V. and BHARGAVA, A. K., (1980) Some observations on the Sedimentology of the Krol succession of Mussoorie area, Uttar Pradesh. *Jour. Geol. Soc. India*, v. 21, pp. 232-238.

(Received: Aug. 25, 1983; Revised form accepted: Mar. 15, 1984)