Journal of The Palaeontological Society of India
Vol. 48, 1998, pp. 49-58

PROTEROZOIC STROMATOLITIC REEFS: POSSIBLE EXAMPLES FROM THE HIMACHAL HIMALAYA

O.N BHARGAVA[1] and U.K. BASSI[2]

1. 529, SECTOR 18-B, CHANDIGARH
2. GEOLOGICAL SURVEY OF INDIA, SCO 98-100, SECTOR: 17-C, CHANDIGARH

ABSTRACT

Proterozoic stromatolite carbonate bodies in the Himachal Himalaya form relief and show evidences of wave-resistant structures and early cementation. The microfacies present include boundstone, rudstone, packstone, grainstone (rare), grapestone (rare) and mudstone. These attributes are comparable with those of Phanerozoic Reefs. Future work should document the distribution, size, shape, microfacies, and microbiotas of these stromatolite bodies.

Key words : Proterozoic, stromatolites, microfacies, Himachal Himalaya.

INTRODUCTION

Stromatolites, known as organo-sedimentary structures, are abundant in Precambrian carbonate sequences in all continents (Cloud and Semikhatov, 1969). In the Himalaya (fig.1), they have been documented mainly from the Sirban, the Larji, the Shali, the Deoban, the Calc-zones of the Tejam and Pithoragarh, Naldera-Arki-Kakarhatti (Simla Group) and the Krol sequences (Bhargava and Ahluwalia, 1980; Valdiya, 1989; Tewari, 1991).

There is a near unanimity that stromatolites formed reefal build-ups during the Precambrian (Heckel, 1974, Cecile and Cambell, 1978). Hoffman (1971) found stromatolitic complexes closely comparable with the barrier-reef complexes. Although abundant, fossil stromatolitic complexes have received scant attention as possible reefs in comparison with Phanerozoic reefs.

In general terms, the reefs are carbonate accumulations of organic origin which have relief and have potential to build wave-resistant structures. Reefs can be divided into three facies (James, 1984): (1) reef core facies — massive unbedded, frequently nodular and lenticular carbonate comprising skeletons of reef-building organisms and a matrix of lime-mud; (2) reef-flank facies — bedded conglomerate and lime sands of reef-derived material, dipping and thinning away from the core; (3) inter-reef facies — normal shallow subtidal limestone unrelated to reef formation or fine grained siliciclastic sediments. Indentification of these facies helps in establishing the existence of reefal build-ups. Indentification, however, besides texture of the rock, is primarily determined by the presence of reef-building and encrusting organisms. Thus, recognising reefs has been much easier and apparent in the case of Phanerozoic build-ups. During the Precambrian, the only conspicuous sign of organic activity is in the form of stromatolitic columns. This absence of other organisms makes recognition of reefal build-ups difficult during the Precambrian.

This paper describes the general attributes of the stromatolites and microfacies of stromatolitic complexes encountered during a preliminary study of various Proterozoic sequences exposed in the Himachal Himalaya. The sampling of these sequences was carried out by UKB. The main aim of this sampling was to study the carbonate microfacies of these sequences.

STROMATOLITIC SEQUENCES

The Proterozoic carbonate sequences of the Himachal Himalaya and the stromatolites they contain are furnished in Table 1. Though several stromatolitic forms have been described from many formations, their exact vertical and lateral distributions within complexes have not yet been described. The lack of this information precludes elucidation of the vertical and lateral zonations of the

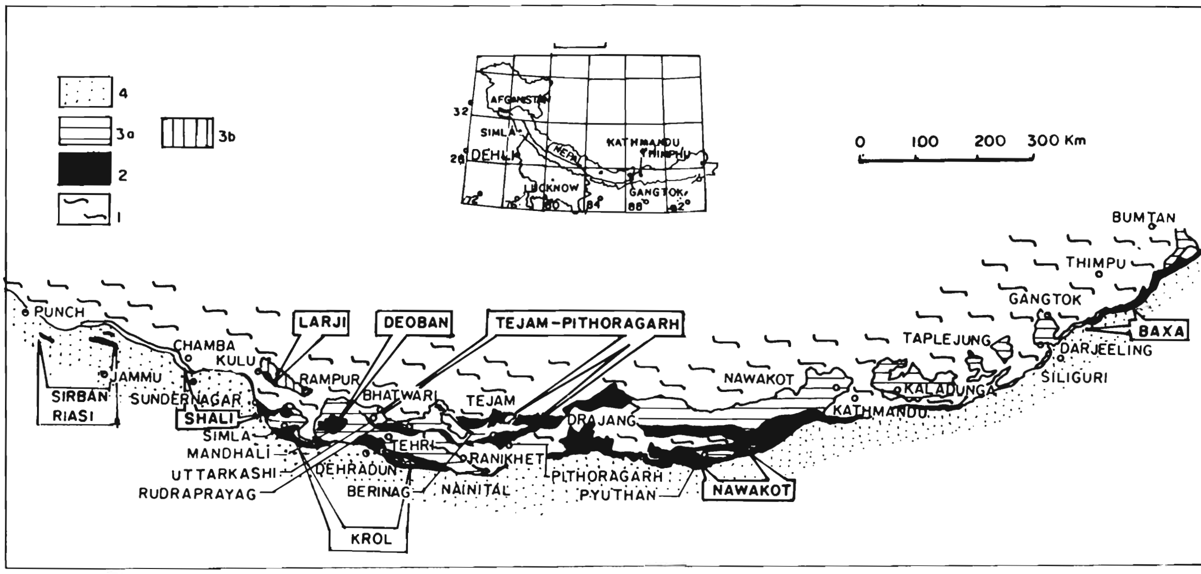


Fig.1. Map showing geographical distribution of Proterozoic Carbonate Belts (Modified after Srikantia and Bhargava, 1982). Expl. 1. Crystalline thrust sheets, 2. Proterozoic carbonate belts, 3a. Jaunsar, Simla, Daling, Shumar Sequences, 3b. Rampur Group, 4. Tertiary.

stromatolitic complexes, which is important for establishing the reefal nature and reconstructing the geometry of the build-up.

Though the microfacies of all the sequences listed in Table 1 were studied, only those of the Deoban Group, the Larji Group, the Kakarhatti Limestone of the Basantpur-Kunihar Formation (Simla Group), Khatpul, Parnali, Tattapani (Shali Group) are described here. Some of the stromatolite columns in the Deoban Group (Ranhat-Guma

Table 1 : Proterozoic Stromatolitic Sequences in the Himachal Himalaya.

Group	Formation	Valdiya (1969)	Srikantia and Sharma (1976)	Sinha (1977)	Bhargava and Ahluwalia (1980)	Tewari (1991)
Simla	Basantpur/Kunihar (Kakarhatti, Arki Naldera Limestone) --Unconformity--	*Collenia parva*	*Collenia*	*Jurusania himala-yica, Jurusania irregularia*	*Osagia tennuilamellata*	
	Bandla					
	Parnali Makri	*Jurusania, Collenia columnaris,*			*Baicalia, Colonnela*	
Shali	Tattapani	*Collenia symmetrica*		*Baicalia*	*Newlandia*	
	Sorgharwari				*Colonnella, ? Baicalia* Algal mat	*Conophyton cylindricus,*
	Khatpul	*Collenia columnaris, Collenia symmetrica*	*Collenia*	*Tungussia*	*Baicalia, Colonnella* and *Nucleella*	*Conusella* sp.
	Khaira Ropri		*Collenia*		*?Dalcophycus, Conophyton*	
Largi	Aut			*Colonnella Conophyton* ex. gr. *cylindrica*		*Kussiella* sp. *Kussiela kussiensis Conophyton cylindricus*
Deoban	Minas				*Jurusania*	*Baicalia* sp.
	Bijmal				*Baicalia Colonnella*	*Kussiella* sp. *Kussiella kussiensis.*

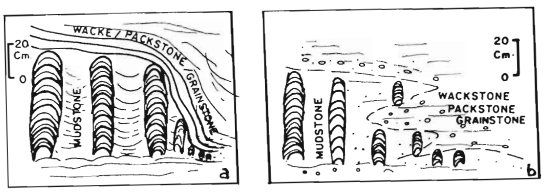


Fig.2. Schematic sketches showing relationship of stromatolitic complex with overlying bounding surfaces, a. Bijmal Formation, Ranhat-Guma Road, Minas, b. Aut Formation - Sainj section.

section) are over one metre high. The columns are both bounded and pass laterally into bedded carbonate (figs. 2a,b). In the Sataun area the top portions of the stromatolitic columns have been syndepositionally deformed, eroded and redeposited in the overlying beds (fig.3). In the Kakarhatti and Arki Limestones, the stromatolite columns are small and many are displaced.

REEF-LIKE ATTRIBUTES OF THE STROMATOLITE COMPLEXES

As stated earlier, absence of reef-building and encrusting organisms in the Proterozoic makes the task of identifying reef difficult. However, the followig attributes of the stromatolitic sequences suggest that stromatolites possibly did form reefs:

1. The stromatolitic colums formed relief, as can be seen near bounding surface (e.g., figs. 2a, b).
2. The role of mucilaginous algae and bacteria in trapping (baffling) and binding the sediment has been proved beyond doubt in their modern analogues.

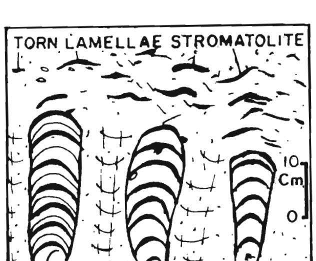


Fig.3. Stromatolitic columns in the Sataun Limestone, the cherty lamellae towards the top have been torn and redeposited in the overlying layers. Sataun section (observed in 1966, now possibly mined by CCI).

3. Some stromatolitic columns did rise up to wave zone as is evident from flattened/recumbent stromatolitic columns, material eroded from these columns and redeposited in lateral continuity and also formation of synsedimentary breccia above stromatolites and regrowth of upright columns above the breccia (fig. 3a-c).
4. Wave-resistant character is also evident by erosion of the top parts of the stromatolitic columns observed in the Sataun section (fig. 4).
5. Tall columns of stromatolites built by microbes could not have formed rigid structures unless they underwent early marine cementation.
6. Cavities of various origins were lined by early marine micritic cement.

MICROFACIES

1. *Boundstone Facies*: This facies shows variations in the shape of stromatolite columns, though overall the facies remains the same. The columns show dark and light layers and in some varieties cherty and partly phosphatic layers are also present. The width of the columns is variable. In some forms it increases upwards, while in others it remains constant (fig.5). In some cases, the stromatolitic columns show ferruginous linings indicating partial subaerial exposure (fig. 6). Columns show sparitic cement (fig. 5). Micritic material in between the columns is clotted. The interspace is filled mainly by micritic material which is well bedded and shows sagging towards the base (fig. 5). The associated sparitic material shows intertongueing with micritic material on the microscopic scale (fig. 5). These layers seem to merge with the stromatolitic columns and truncate against open spaces which are filled with clear sparitic material (fig. 5). The top portion is occupied by a peloidal layer — probably of stromatolitic parentage.

In transverse section (fig. 7), an open space has been found lined by cements of several generations, and the remaining cavity has been filled by sparite. The cement shows Liesgang ring-like and botryoidal — pseudo-ooidal structures, reminiscent of stalactite-stalagmite deposits (cf Bathurst, 1975, fig 243). The

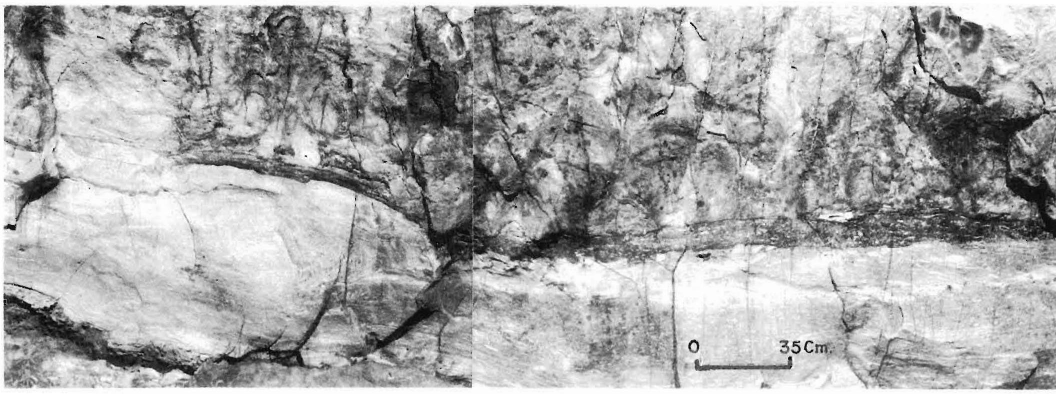


Fig.4a. Mudstone/packstone base, overlain by flattened and eroded large stromatolitic columns, possibly from which angular fragments have been derived to form a bed inlateral continuity, and also probably the overlying synsedimentary breccia. Above it grew colonies of stromatolitic columns. Note cavities with linings.

cementation of remaining open space possibly took place in the vadose zone.

2. *Stromatolitic rudstone/grainstone facies* : This facies comprises angular and subangular, disorientated stromatolitic fragments in sparite (locally micritic) matrix with ferruginous cement (fig. 8). One thin section shows desiccated (?) shrunken lamellae in which lamellar open space has been filled by sparite (fig. 9).

3. *Packstone Facies*: (a) Cortoidal (?) ooidal packstone/floatstone: the ooids are both simple and compound; rounded, elliptical and elongated. Some elongated fragments are non-ooidal (do not show rims). Most of the ooids have been recrystallised and replaced by sparite (fig. 10). Most of the grains have dark rims and are possibly cortoids. Some forms show pressure welding and layers exfoliated during compaction (fig. 11). In some examples ooids are carbonaceous. These forms resemble *Osagia*

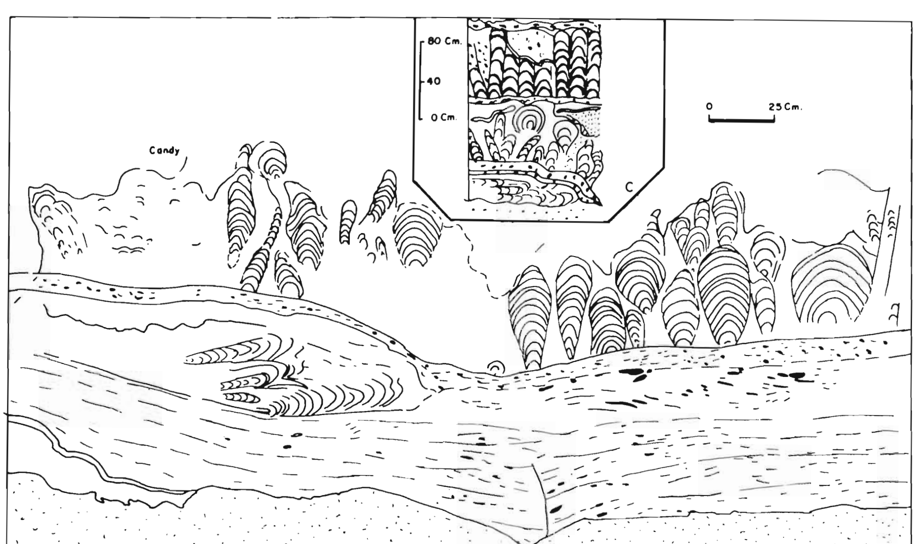


Fig. 4b. Sketch of a.c. (Inset in B) Diagrammatic representation of the stromatolitic sequence also includes part not photographed. Dislodged boulder of Aut Formation, Larji Group, Hurla. Sainj Valley.

irregularis. Open spaces are filled with coarse sparite.

(b) Ooidal-peloidal packstone/intraclast packstone/floatstone: These contain large intraclasts of ooids and packstone in a peloidal micritic matrix. It is difficult to interpret the parentage of the peloids, though these could be of algal parentage. Open spaces are filled with sparite (fig. 12).

(c) Peloidal packstone shows well rounded, moderately sorted to well-sorted intraclasts. Cement along the rims of the open cavities is finely spartitic and, in central part, turbid micrite.

(d) Ooidal - peloidal packstone with packstone intraclast shows rounded, poorly sorted peloidal grains; packstone intraclasts are angular; a few rounded quartz grains also occur and the cement is sparitic (fig. 18).

4(a) Intraclastic grainstone comprises poorly to moderately sorted, rounded intraclasts of micrite in spartite.

(b) Ooidal grainstone/packstone is made up of moderately well-sorted, several-layered deformed ooids/oolites. Some ooids have stromatolitic fragments as nuclei (fig. 13).

5. *Grapestone facies* : shows amalgamated, simple and compound ooids in a recrystallised micritic matrix forming a small fraction of the rock. All open spaces are filled with clear sparite (fig. 14).

6. *Brecciated mudstone with layers of ooidal packstone facies (synsedimentary breccia)*: This rock shows partial erosion of mudstone inter-bedded with ooidal packstone and *in situ* redeposition (fig. 15). The well-sorted ooidal packstone layers have also been broken. The nuclei of the ooids are of (a) earlier ooids, (b) peloids (c) detrital grains. Oolites have several-layered cortices, some of them are radial type. Together with ooids, a few peloids also occur (fig. 15). The cement is drusy. In one section, mudstone is inter-layered with peloidal packstone/grainstone (fig. 15).

7. *Mudstone with fenestral fabric facies*: The open spaces show four generations of cement, viz. (a) fibrous, (b) clear sparitic (c) fibrous and (d) clear sparitic. The mudstone shows a clotted appearcance (fig. 16).

8. *Cement in large cavities* (?): This shows radial fibrous growth in the outer part followed by similar growth but acquiring a mammillate, ooidal shape comparable with the growth of speleothem, and crusts in hot water-pipes of hardwater districts reported by Bathurst (1975, fig. 243). Some layers in the cement show dendritic layers, superficially resembling *Epiphyton*. The central space is occupied by clear sparite and a few clasts (fig. 17).

CONCLUSIONS

The environmental interpretation of the facies described above (Table 2) is akin to those found in well known Phanerozoic reefs described by various workers (Heckel, 1974; James, 1984).

The algal reef mounds of the Pennsylvanian Paradox Basin are capped by ooid-rich grainstone and/or packstone (Choquette, 1983) which is similar to the stromatolitic bodies described here. In the Paradox Basin, packstone also occurs at the margins of the mounds. The inter-mound facies are mudstone and wackestone. Another characteristic aspect of the algal reef mound described by Choquette (1983) is the occurrence of breccia and conglomerate of algal plate material and entrained fine carbonate sediments, which resemble the breccias found in stromatolitic bodies of the Himachal Himalaya (fig. 4).

The microfacies, together with the attributes of stromatolites described, thus suggest that apart from the types of organisms involved, the stromatolitic complexes described here are highly comparable with Phanerozoic reefs.

RECOMMENDATIONS

Since the present work is of preliminary type, it is suggested that a few selected stromatolitic complexes be studied in detail as follows:

1. The complexes should be mapped in detail to show the distribution/variation of the different stromatolitic forms vertically and laterally.

Table 2 : Environmental interpretation of microfacies associated with stromatolitic complexes of Himachal Himalaya.

Facies	General Environmental Interpretation,
1. Stromatolitic Boundstone.	Shelf Margin conditions simulating reef flat
2. Stromatolitic rudstone/floatstone associated with shale.	Proximal foreslope to reef-flat area of shelf margin
3. Packstone	
a Ooidal	
b Ooidal-peloidal c Peloidal	Open platform/shelf margin bays/open lagoons in interstromatolitic areas and behind the stromatolitic complex (back-reef).
4. Intraclastic grainstone.	Channel between stromatolitic growth areas
5. Grapestone (rare)	Protected area on shelf with restricted circulation
6. Brecciated mudstone with layers of ooidal packstone.	(a) Intraformational breccia in channel within inter-reef area (b) during subaerial exposure in between two cycles of stromatolitic growth.
7. Mudstone with fenestral fabric.	Inter-reef area.

2. The exact dimensions and shapes of the stromatolitic bodies should be determined.

3. Detailed microfacies variation interval of the stromatolite interspace, and of the underlying, overlying and laterally equivalent strata, should be studied.

4. Microbiotic studies of the stromatolitic bodies should be made to search for possible binders and encrusters during the Proterozoic.

ACKNOWLEDGEMENT

Grateful thanks are due to Dr. Robert Riding for a critical review of the original manuscript.

REFERENCES

Bathurst, R.G.C. 1975. *Carbonate sediments and their diagenesis* (*Developments in Sedientology*) 12. Elesvier.

Bhargava, O.N. and Ahluwalia, A.D. 1980. Stratigraphic distribution, palaeoenvironmental significance and economic minerals of the stromatolites in Himachal and a part of Garhwal - A Resume. *Geol. Surv. India. Misc. Publ.* **44:** 188-200.

Cecile, M.P., and Cambell, F.H.A. 1978. Regressive stromatolite reefs and associated facies, Middle Goulburn Group (Lower Proterozoic) in Kilohigok Basin, N.W.T., *Bull. Can. Petrol. Geol.* **26**: 237-267.

Choquette, P.W. 1983. Plate algal reef mounds, Paradox Basin, p. 454-462. In: *Carbonate Depositional Environment* (Eds. Scholle, P.A., Bebout, D.E., and Moore, C.), *Mem. A.A.P.G* 33.

Cloud, P.C. and Semikhatov, M.A. Proterozoic Stromatolite Zonation, *Amer. Jour. Sci.* **267**: 1017-1061.

Heckel, P.H. 1974. Carbonate buildups in the geologic record: A Review, p. 90-155. In: *Reefs in time and space.* (Ed. Laporte, L.F.) *Soc. Econ. Pal. & Mineral. Spec. Publ.* 18.

Hoffman, P. 1971. Proterozoic carbonate reef complex, Green Slave Lake Northwest Toronto, Canada. *VIII Int. Sediment Cong. Heidelberg, Abstract*, 42.

James, N.P. 1984. Reefs, p. 229-244. In: *Facies Model.* (Ed. Walker, R.G.), 2nd Ed. *Geosci. Can. Repr. Ser.* 1. Toronto, *Geol. Assoc. Can.*

Sinha, A.K. 1977. Riphean stromatolites from western Lower Himalaya, p.60-100. In: *Fossil Algae*, (Ed. Flügel, E.) Springer-Verlag, Berlin, Heidelberg.

Srikantia, S.V. and Bhargava, O.N. 1982. Precambrian Carbonate Belts of the Lesser Himalaya: their geology, correlation, sedimentation and palaeogeography. *Rec. Res. Geol.*, **8**, *Hind. Publish Corpn.* New Delhi: 521-581.

Srikantia, S.V., and Sharma, R.P. 1976. Geology of the Shali Belt and the adjoining areas. *Mem. Geol. Surv. India.* **106** (1):31-116.

Tewari, V.C. 1991. Precambrian and Lower Cambrian stromatolites of the Lesser Himalaya, India. *Geophytol.* **23** (1): 19-39.

Valdiya, K.S. 1969. Stromatolites of the Lesser Himalayan carbonate formations and Vindhyans. *Jour. Geol. Soc. Ind.* **10**: 1-25.

Valdiya, K.S. 1989. Precambrian stromatolites of India, a review. *Him. Geol.* **13** (8): 1-21.

Manuscript Accepted June 1998

EXPLANATION OF FIGURES

(Photofigures 5 to 18 Negative slide prints)

5. Stromatolitic columns mostly have same width, one in left bottom corner expands towards top, growing at different levels, surrounded by muddy micritic layers intertonguing with fine clear sparitic material. Layers truncate against open spaces filled with clear sparite. Aut Formation (Larji Group), Downstream of Aut. (x5)

6. Stromatolitic columns lined by fine ferruginous material, intervening space filled by clotted micrite. Note peloidal layer in upper part. Cements are (a) fibrous (b) micritic. Aut formation, Aut-Larji section. (x5)

7. Cracked shrunken stromatolite (transverse section) sorrounded by open space filled by cements of several generations. Aut Formation (Larji Group), Aut-Larji section.(x4)

8. Stromatolitic grainstone showing disoriented angular, subangular fragments of stromatolite. Cement is ferruginous. Kakarhatti Limestone (Kunihar Formation), Simla Group, Kakarhatti. (x5)

9. Stromatolitic grainstone showing open spaces in between desiccated and shrunken lamellae filled with sparite. Kakarhatti Limestone, Kakarhatti. (x5)

10. Cortoidal ooidal packstone, ooids are compound, rounded, elliptical and some filamentous. Some filamentous fragments are non-ooidal, open space filled with coarse sparite, forms resemble *Osagia irregularis*. Deoban Formation, Minas (x4.5)

11. Cortoidal ooidal packstone showing replacement by sparitic cement. Note pressure welding in some grains. Khatpul Formation, Tattapani. (x5)

12. Ooidal-peloidal, packstone - intraclast packstone. Khatpul Formation, Slapper. (x5)

13. Ooidal grainstone packstone moderately well sorted with one or two fragments of stromatolite-forming nuclei, Oolites/ooids deformed show several rims. Kakarhatti Limestone, Kakarhatti. (x4.5)

14. Grapestone - lumps of ooids/oolites. Bijimal Formation (Deoban Group) Minas. (x5)

15. Breciated mudstone layered with ooidal packstone layers; nucleus for later oolites are older oolites, peloids, lithoclast. Parnali Formation, Nauti Khad. (x4)

16. Mudstone with fenestral fabric, Bijmal Formation (Deoban Group), Ambota. (x5)

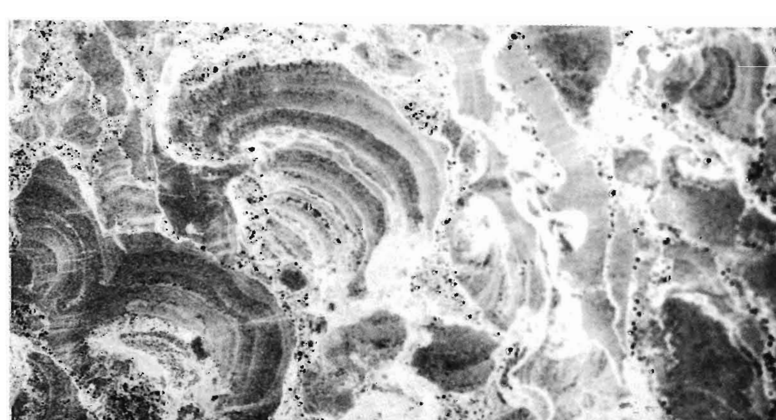
17. Speleolithic type cement. Note *Ephiphyton*-like growth and pseudo-ooidal growth in right bottom corner. Parnali Formation, Nauti Khan. (x6)

18. Ooidal peloidal packstone - intraclast grainstone, Khatpul Formation Slapper. (x5)

6

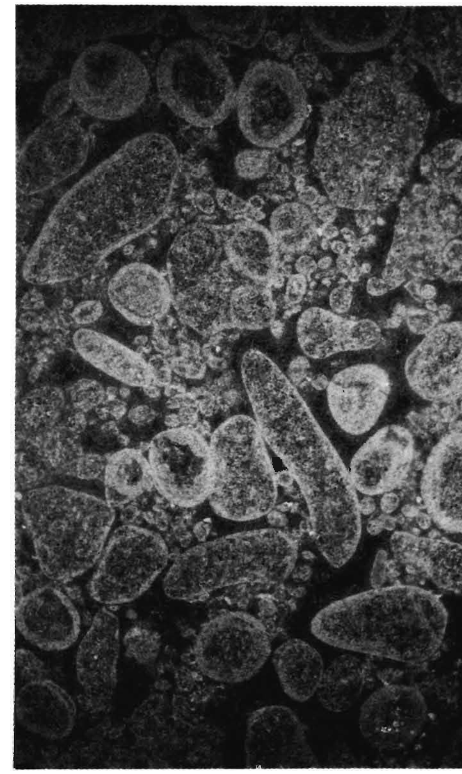
7

9



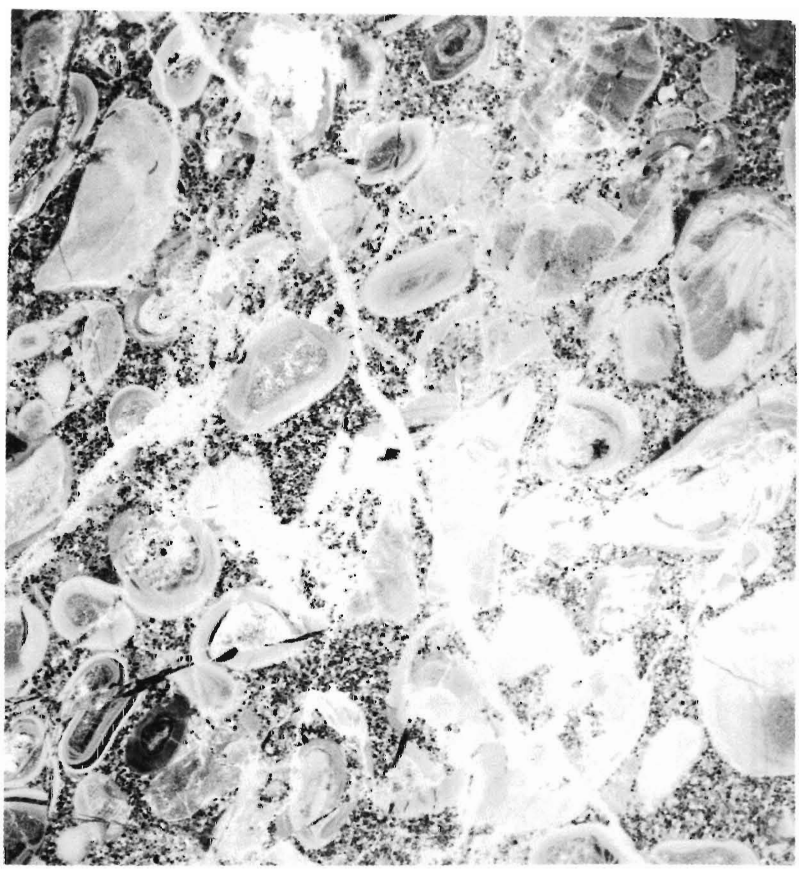
8

10

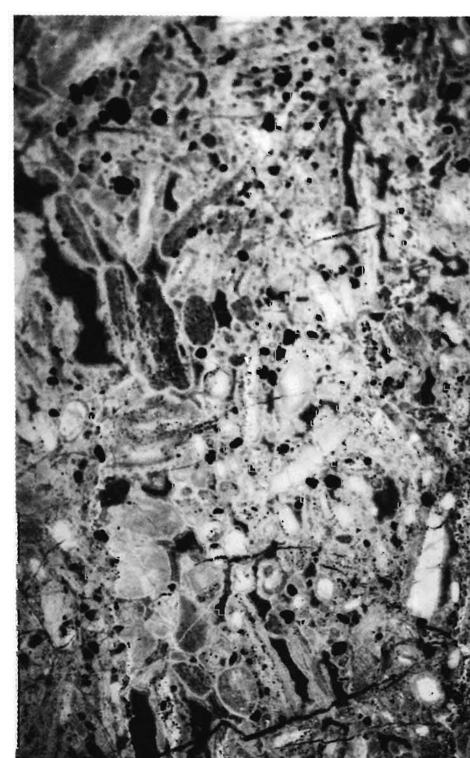


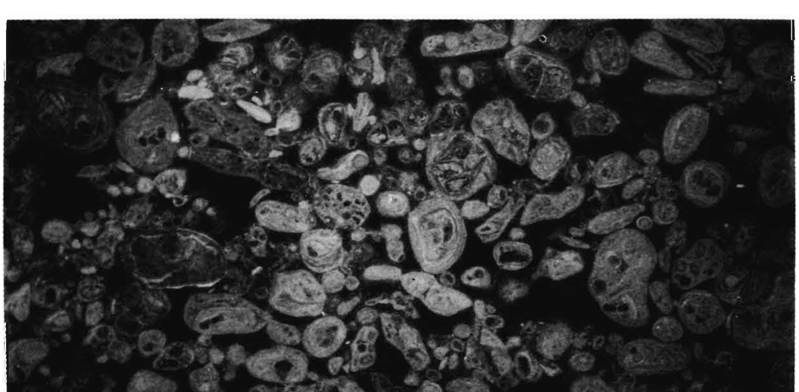
11

13

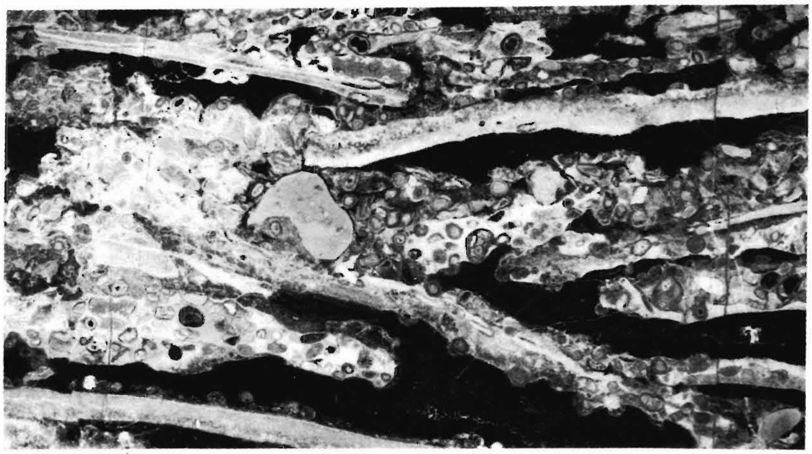


12

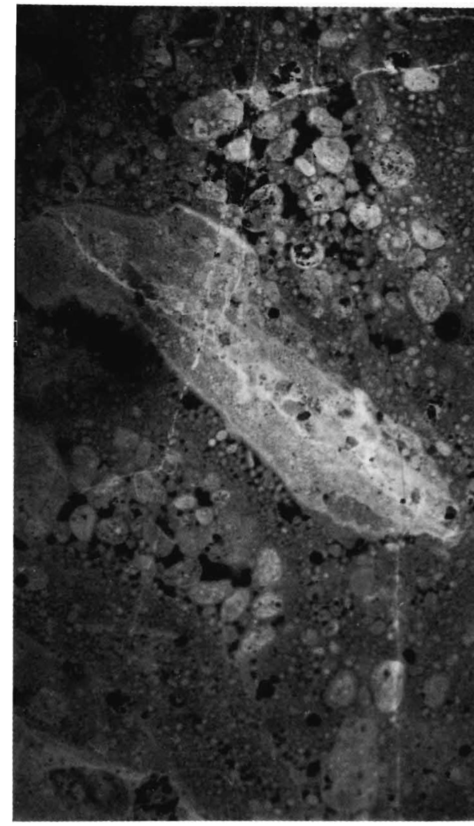




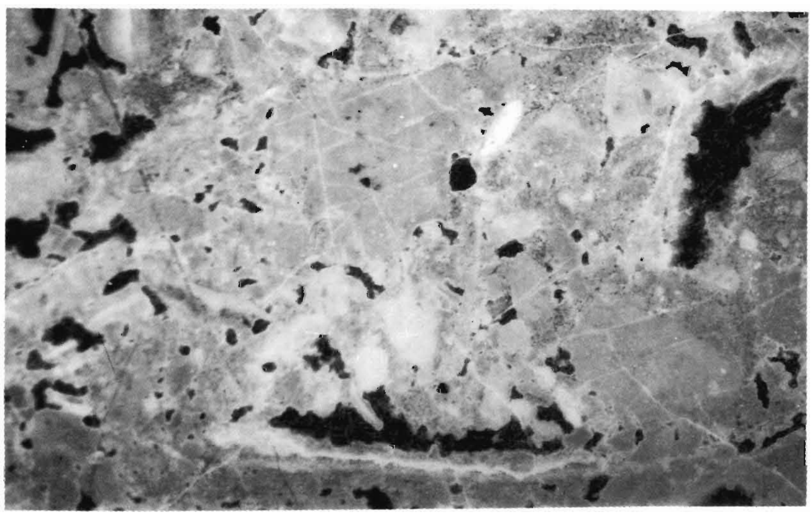
14



15



18



16

17