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ALGAL STROMATOLITES FROM DEWALDHAR AREA, ALMORA DISTRICT U. P.

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ABSTRACT

Various types of algal stromatolites occur in a variety of carbonate rocks in the "Window" formations in the Lesser Himalayas. These stromatolites are grouped here on the basis of the gross form of structures, behaviour of the constituting laminae in the directions of lateral and vertical growth, as also the changes in the gross forms of stromatolites. It has been observed that the forms of stromatolites are broadly related to the composition of the enclosing carbonate rocks. The palaeoecology, including the possible role of algae, responsible for the formation of these structures has been reconstructed. Besides formative environment, the post depositional changes and the tectonic forces appear to have modified the forms of stromatolites.

INTRODUCTION

As a consequence of the detailed ecological studies carried out on the modern algal sediments in Bahamas (Black, 1933; Ginsburg, 1960; Roehl; 1967; Neumann *et al.*, 1970) Florida (Ginsburg, 1955, 1960), Canary Islands (McMaster and Conover, 1966), Bermuda (Gebelein, 1969), Shark Bay (Logan, 1961) and Persian Gulf (Kendall and Skipwith Bt., 1968), the algal stromatolites have of late, acquired considerable importance on account of their usefulness in palaeoecological interpretations, especially in late Precambrian. Presently, the efforts are being made the world over to look for the analogues of the recent stromatolites in the geological column and to establish their formative environment in the light of these studies. Recent developments in the Russian Precambrian stratigraphy, as a sequel to the bold and ambitious application of these structures as stratigraphic markers, have further enhanced the significance of stromatolites. The stratigraphic zonation of Precambrian rocks based on the distinctive forms of stromatolites attempted earlier by many Russian Workers and later by Cloud and Semikhatov (1969), Glaessner *et al.* (1969) and Valdiya (1969) have opened new challenging possibilities for the use of these structures.

The algal stromatolites are considered here as organo-sedimentary structures (Logan *et al.*, 1964). This approach is in conformity with the general absence of cellular framework in stromatolites. The observations on the modern laminated carbonate sediments reveal that the formation of stromatolites is basically a sedimentary process in which a definite role exists for algae (mostly blue-green) in binding detritus, precipitating calcium carbonate, as also in modifying the fabric of the surrounding sediments.

In this paper, algal stromatolites occurring in the various carbonate members around Dewaldhar area in Almora District in the Kumaon Himalayas have been described. Palaeoecological factors responsible for the formation of various stromatolitic structures have been reconstructed in the light of the available ecological knowledge based on the researches carried on the modern algal sediments.

DISTRIBUTION OF STROMATOLITES

Algal stromatolites extensively occur in various carbonate members exposed as a part of the tectonic window, termed here as "Someshwar-Dewaldhar-Bageshwar Window", around Dewaldhar (29°47'00" : 79°45'15") in Almora District of Uttar Pradesh. The rocks in the window include a variety of limestones and dolomites with interbanded shales, slates, and quartzites. These, in turn, are overlain by the overthrust metasediments of the Almora "Nappe". In the area under discussion the stromatolitic structures are noted in the following localities:—

No.	*Locality*
1.	Hill 6194 (29°46'00" : 79°45'15")
2.	North of Naini (29°46'15" : 79°45'45")
3.	Dewaldhar Estate (29°57'00" : 79°5'10")
4.	Footpath north of Batari (29°47'00": 79°44'30")
5.	West of Sigra (29°46'45" . 79°45'30")
6.	South of Sisakhani (29°48'10" : 79°44'40")
7.	Kathpuria Chhinasaadle (29°45'20": 79°46'45")

PREVIOUS WORK

A number of excellent papers on the algal stromatolites has been piling up for the last several decades. Some of the important contributions made till late fifties have been referred to in the works of Rezak (1957) and Maslov (1960). Various works on the modern stromatolites have been discussed by Gebelein (1969). In India also, a good number of papers have been brought out on this subject and some of the significant ones have been referred to in Valdiya (1969) and Chaudhuri (1970). Various aspects of stromatolites from the Himalayan region have been discussed by Misra and Valdiya (1961), Valdiya (1962 a and b, 1965, 1967, and 1969), Dixit (1966), Misra and Kumar (1967), Banerjee (1969), Gupta and Dixit (1970), and Pande, Dixit and Gupta (1970).

GROUPING OF STROMATOLITES

As far as the classification of the algal stromatolites is concerned no proper understanding has been arrived at so far. For a long time, binomial nomenclature (simulating the biological one) with the names of genera and species had been a common practice. Some of the workers later on modified this practice to pave the way for "form genera" and "form species". Lately, Russian workers have devised a new binomial classification in which the terms "group" and "form" are used—a group may have several forms. Unfortunately, the binomial terminology was never standardised and the forms erected had greater reflection of authors' choice rather than the generalised characters of the structures. This is evident by the fact that similar forms have been named differently by different authors in attempting elaboration and comprehension. Even if the older classifications are followed, the difficulties arise when compound forms are encountered. Combinations of structures in many stromatolites have been noted by Logan *et al.* (1964), Kaufmann (1964), Mohan (1964), Dixit (1966), Krieger (1969) and by the present authors. A better perspective of such forms may be properly realised only when a horizon portraying algal stromatolites is examined as a whole.

The microstructures and textures, as used by Maslov (1960) could have been of some avail in the classification of stromatolites provided they had some relation with the morphology of these algal structures. Observations show that similar types of microstructures are associated in different morphological variations (Komar, 1966). On the other hand, stromatolites with similar morphological characters present different textures (Raaben, 1969). Microstructures, thus, make a classifying system only more complicated.

It has been experienced by many workers that various classification of stromatolites are hardly satisfactory. Cloud and Semikhatov (1969) have discussed this point to some length. Ta'ing various factorsi nto consideration, the following criteria in grouping the algal stromatolites in the field appear to be logical, practical and simple to the present authors:

(1) Gross form of stromatolites.

(2) Behaviour of constituting laminae in the direction of lateral and vertical growth of the structures.

(3) Change in the gross form of stromatolites as they are observed in the direction of growth.

As the grouping of these structures on the basis of the criteria cited above may bring out some difficulties for those who prefer one of the prevalent classifications, the forms described here have also been compared, as far as possible, with those erected by other authors from different parts of the world.

The principal forms of stromatolites occurring in the area under discussion have been grouped as follows:

(A) Simple undulating discoid structures.

(B) Laterally linked dome-like structures.

(C) Discrete columnar or club-shaped structures.

(D) Discrete cone-in-cone structures.

(E) Discrete spheroidal structures.

(F) Compound structures showing change in the morphology of the form in the direction of growth.

DESCRIPTION OF STROMATOLITES

A. SIMPLE UNDULATING DISCOID STRUCTURES:

These forms occur in Loc. 1 and 2 (pl. 1, 2 Figs. 1). The stromatolites are constituted by alternating laminae of shaly and purer carbonate material upto 1 mm and 1 to 4 mm in thickness respectively. The laminae are flat and parallel at the base of the stromatolite horizon The succeeding laminae show undulations which progressively become pronounced and finally result in the laterally linked flat topped discoid structures. The lateral linking is by the continuance of the laminae which at places become prominently notched. Some of the laminae get fused at the points of linking while others continue to some distance. The width of the discoid structures at the base and the top vary from 3 to 6 cm, and 5 to 10 mm respectively, while the structures attain the maximum height of 9 cm. The laminae of stromatolites straighten out and again become parallel to the bedding towards the top of the horizon.

Discoid forms exactly identical to the ones described here are hardly to be seen in the literature. Stromatolites occurring as flat laminated sheets have been termed by

Aitken (1967) as "cryptalgalaminates". The present structures are, however, undulating in nature and hence are different. Laminated structures with some similarity have been described by Fenton and Fenton (1937) as *Collenia expensa;* by Black as Type I; and by Ginsburg (1955) as Type A. However, only the forms described by Fenton and Fenton (1937) resemble, in some measure, the structures discussed here.

B. Laterally linked dome-likesructures.

Form 1: These structures are seen in Loc. 2, 3, 5 and 6 (Pl. 2, Fig. 2). The stromatolites are columnar in shape with hemispheroidal laminae being stac' ed one above another. The laminae are composed of carbonate and cherty materials and are, as a rule, laterally linked. There are some forms in which cherty laminae are widely spaced with intervening space being occupied by the finer laminae of the carbonate material (Fig. 2). On the bedding surface the structures show concentric rings of carbonate and cherty materials. The columns are generally slightly broader towards the top. In some cases, however, the hemispheroids in the basal part of these stromatolites range between 1.25 and 5 cm and of those in the upper part fraction of a millimetre to 2 mm. The growth of these structures is profuse and horizons up to 15 metres in thickness showing remarkably striking stromatolites are not rare. The stromatolite columns, in some cases, are arranged oblique to the bedding, the angle between the columns and the bedding being as much as 30°.

Most of these forms resemble LLH-C stromatolites of Logan *et al.* (1964) while a few of them fall in their LLH-S category.

Form 2: The argillaceous limestone of the Loc. 4 is the westward extension of the stromatolite bearing limestones of Loc. 5. In this limestone, individual stromatolitic horizons are not thick and continuous as in Loc. 5 and the structures are vertically stacked and laterally linked hemispheroids which have flattened tops (pl. 2, Fig. 3). The interconnecting laminae are rather bluntly notched unlike smoothly curved laminae of the Form 1. The laminae are noted to be progressively flattened both towards the base and the top of the stromatolitic horizons, thus finally becoming parallel to the composition planes of the limestone. The stromatolite columns are mostly narrow at the base and broader at the top. While the diameter of the hemispheroids ranges between 1 and 40 mm, the maximum height of the columns is recorded to be 80 mm. As many as 10 laminae are counted in one centimetre. Some of the columns are inclined to the bedding by upto 50°.

These stromatolites may be only roughly compared with the LLH-C structures of Logan *et al.* (1964). The stromatolitic laminae which are parallel to the bedding plane resemble the "cryptalgalaminates" of Aitken (1967).

C. Discrete columnar or club-shaped structures:

These stromatolites which are formec by stacking of haemispheroidal laminae one over the other, are abundant in the Loc. 7 (Pl. 1, 3, Figs. 3, 4 & 5). The structures consist of alternating laminae of pure and shaly carbonate materials. The diameter of the hemispheroids varies from 1 to 4 cm. at the base and 1.5 to 14 cm at the top. The height of these stromatolites ranges between 1.5 and 14 cm, a 49 cm high structure being an exception. Up to 16 laminae were recorded in one centimetre.

The form is comparable with *Collenia frequence* Walcott (1906), *Cryptozoon* of many authors and SH-V stromatolites of Logan *et al.* (1964).

D. Discrete cone-in-cone structures

These structures consist of conical laminae stacked over one another (Pl. 1, 4 Figs. 4, 6) and are composed of carbonate laminae which are alternatively rich in siliceous content. They are noted in the Loc. 2. The diameter of the base of the cones varies from 2 to 4 cm, while height of the structures goes up to 15 cm. Some of the innermost laminae are roughly oval in outline in the central region (Pl. 1, Fig. 4). Two such discrete structures showing typical conical form appear to have been deshaped to an elongated oval outline, perhaps due to deformation (Pl. 1, Fig. 4).

The form is similar to *Conophyton litius* (Maslov, 1937; *of* Rezak, 1957). The forms described by Maslov (1937) are however made up by the stacking of inverted cones. These stromatolites also resemble *Conophyton incinatius* n. sp. (Reeak, 1957) with the difference that in the present case the cones are neither inverted nor inclined to the bedding. Similar structures have also been described by Krieger (1969) as SC-V stromatolites.

E. Discrete spheroidal structures

Discrete spheroidal structures are noted only in one exposure in the lowermost unit of the Member 5 in the Loc. 5 (Pl. 4, Fig.7). They consist of carbonate laminae alternatively rich in siliceous content and show a circular outline in the transverse-sections. It is to be noted that the horizon portraying the discrete spheroidal structures are overlain by the units showing luxuriant growth of laterally linked dome-like stromatolites and discrete columnar or club-shaped stromatolites.

These stromatolites are comparable with oncolites of Pia (1933), simple oncolites of Aitken (1967), SS-C stromatolites of Logan *et al.* (1964), and "algal biscuits" of Ginsburg (1960).

F. Compound Structures:

In Loc. 3, some compound structures (Pl. 4, Fig. 8) are noted in which laterally linked stromatolites pass without any break into discrete club-shaped structures in the direction of growth. The compound structures are normally small and show poor development of laterally linked hemispheroidal stromatolites in the lower part of the horizon. The discrete heads vary in diameter from 5 to 12 cm and attain a height up to 35 cm. (Pl. 1, 4, Figs. 5, 8).

These structures may be classified as LLH-C-SH-V following Logan *et al.* (1964).

PALAEOECOLOGY

The studies carried out by Black (1933), Ginsburg (1955, 1960), Logan (1961), Monty (1965), McMaster and Conover (1966), Kendall and Skipwith Bt (1968) Gebelein (1969), Achauer and Johnson (1969) and Neumann *et al.* (1970) on the modern stromatolites have paved way to assess, with some certainty, the palaeoecological conditions of formation of these structures in the geological record. On account of these studies it is established that various forms of stromatolites are essentially governed by the physical factors of environment and that the role of any particular algae is hardly of any consequence. As different rocks require different formative environments, the logical conclusion would be to expect a possible predominance of certain forms of stromatolites in a particular type of rock, a fact amply demonstrated in the area under discussion. For example, the domed laterally linked stromatolites are associated with thickly bedded, comparatively pure carbonate rocks; while flat topped or discoidal stromatolites are enclosed in the shaly dolomite. It has also been noted that if there is a lateral transition in the compositional element of the rock, as happens in Loc. 3, the forms of the associated stromatolites also change in consonance. This, the authors believe, further demonstrates the deciding role the environment plays in the development of various forms of stromatolites. Besides, it would also be clear that the over all shape of stromatolites would as well bear marks of the post-depositional and tectonic events necessitating an account of all such stages in order to reach palaeoecological interpretations.

Broadly speaking, the formative environments of algal stromatolites are those prevailing in the protected marine basins in the intertidal zone between high and low water marks. These structures have, however, been also observed in the supratidal zone by Monty (1965), and Achauer and Johnson (1969), and in the subtidal zone by Gebelein (1969). The growth of stromatolites is caused by the sediment binding activity of algal mats, or by the secretion of carbonates on account of metabolic activity within the algal plants, or both. Though the growth of algae largely depends on the ecological conditions, the latter may be modified, in turn, to some extent by the former (Laporte, 1968, Gebelein, 1969). Thus, the exact conditions of stromatolite-formation may be masked to some degree due to modifying effects of the presence of algae in the environment. The palaeoecology of various algal stromatolites of the present area is discussed here within the frame work of the factors enumerated here.

Simple undulating discoid structures:

As these structures represent undisturbed algal mats, an environment that flows uninterrupted mat growth should be sought. In some measure, the environment would be similar to one needed for the cryptalgalaminates of Aitken (1967) and LLH structures of Logan *et al.* (1964). Such an environment is obtained in the intertidal mudflats protected from the waves and currents, or the locations behind the barrier reefs and in the entrant bays (Black, 1933, Logan *et al.* (1964). But a subtidal locale for their growth may as well not be ruled out as is clear from Gebelein's (1969) study in Bermuda. In any case, the energy of the environment is required to be at the minimum. It is also established by this study that the growth of the stromatolites is rather fast and that 1 cm of the vertical growth may be achieved in about 10 days time (Gebelein, 1969). This is also known that in the tidal flat areas where deposition is rapid peculiar type of small-scale interlayering of sand and mud occurs (Weller, 1960, p. 185). The alternate layers of dolomitic (coarser) and shaly (finer) materials in the present case conform to this view and might be due to different rates of supplies and settling velocities of carbonate and argillaceous materials and the aperiodic storms or floods (Pettijohn, 1957). The disappearances of the night time (Gebelein, 1969) might be caused by the diagenesis in which coarser grains of carbonates fused to form the dolomite laminations and the carbonaceous material dispersed in the rock, the presence of which has been proved during the process of chemical analysis of these rocks by Dixit (1969). The very fact that these structures did not obtain typical hemispheroidal heads and developed only undulations speaks for the process under which they were resulted as a consequence of the lateral expansion of the algal mats during their growth. The possibility that they grew over a rugged surface does not appear to be very convincing as the successive layers growing over an initially rugged substrata would have a tendency to become flattened progressively. Another cause for undulations in these structures may be ascribed to the differential gliding due to the presence of the impervious argillaceous layers during early diagenesis when compaction of sediments was in progress.

The forms presently observed also show convincing signs of deformation which must have been affected during the Himalayan orogeny.

LATERALLY LINKED STACKED DOME-LIKE STRUCTURES:

The environmental conditions for these stromatolites should logically not differ much from those described in the previous case. Protected locations, undulating topography of the substrata and luxuriant growth of algae appear to be indispensible. The hemispheroidal shape of the heads would necessitate best development of algae on the raised parts of the topography. Regarding the formation of sporadic layers of chert it is not logical to visualize the changes in the pH at the time of deposition to bring distinct changes in the chemistry of the environment. What seems more probable is the original deposition of the detrital silica layers which during diagenesis change into cherty laminations. Such sudden and sporadic influence of siliceous detritus are rather commonly noted during the limestone deposition. Presence of algal Plants perhaps helped in the process of chert formation.

The difference in the shapes of these stromatolites (Form 1 and 2) appear to show a strong influence of the degree of supply and nature of detritus in locations where these forms occur. While Form 1 does not call for special conditions of formation, in case of the Form 2, there appears to be enormous supplies of detritus. As a sequal to this, the primary function of the algal layers would be to trap and bind the loose material as soon as it was transported to the site of deposition. This phenomenon appears to obviate the necessity of secretion of their own carbonate by algae, a phenomenon which would normally be most pronounced on the top of the individual heads and hence its absence would cause the forms to remain flat. This also explains, in part notching of the laminae between the adjacent columns. The very fact that the stromatolites of Form 2 are essentially shaly in composition and the same are embedded in the limestones, speaks of their biohermal character. The inclination of the columns of stromatolites with respect to the bedding may be ascribed to the original surface morphology of the substrata or the initial surfaces of the mats on which the continuous stacking of subsequent growth of laminae gave rise to inclined columns. Another factor for the inclination of the columns may be current action (Hoffman, 1967).

DISCRETE COLUMNAR OR CLUB-SHAPED STRUCTURES:

These structures would require for their growth an environment in which the following factors appear to be very prominent: (1) Breaking of the mat in the interspaces between different columns by various agencies, and (2) Selective development of algal layers on the microrelief of the substrata and their subsequent growth. Logan (1961) suggests that inhibition of the mat growth in the interspaces between the columns may be due to induration of carbonate sediments on the sides and the lower portions of the colonies, prolonged wetting in semi-permanent—tide pools, run off tidal waters, and the translatory motion of the waves in the depressions between columns. Around the domes may occur dessication and cracking of algal mats and sediments (Black, 1933). The flooding of the areas between the columns by coarse sediments may also break the mat there (Logan *et al.* 1964). There is also a common experience that selective development of algae occurs on the domal highs and there is hardly any growth to be noted in the low areas. Even if there is some growth in such areas, the mat is broken on account of a number of factors enumerated above. Another factor requiring a consideration is that of dessication which invariably results into curling up of the upper layers of sediments or mats. Absence of such curled up layers in the present case speaks of two factors, viz, either there was no dessication and only other factors were responsible for the growth of these stromatolites or the curled up portions were broken off by the subsequent wave action and merely the central portion of the highs survived.

These factors, besides the presence of coarser material in the inter-columnar spaces are indicative of the fact that in relation to other forms described earlier, these forms grow in comparatively high energy environment. To be precise, this turbulence should not be as powerful as to break the columns altogether or for that matter lifting the coarser material to the top of the structures (Aitken, 1967). This is corroborated by another observation. In Kathpuria section (Loc. 7), a notch which developed on the top portion of the structure was not damaged by the turbulence of the environment and was allowed to be grown to over 15 cm (Pl. 1, Fig. 3).

Another important factor about these stromatolites is the general increase in the successive diameters of the stacked hemispheroidal laminae with the growth. This may be due to the development of the algal layers on the highs as also due to the hanging down of the layers to the sides. It is natural that successive piling of such layers would increase the diameters of the heads with the growth.

As in the previous case, the inclined columns of such discrete structures in respect to the bedding of surrounding rock may be ascribed to —(1) the growth of these structures on such relief that would permit the subsequent laminae to follow the inclined pattern, and (2) the current action during their formation as suggested by Hoffman (1967) and Chaudhari (1970).

DISCRETE CONE-IN-CONE STRUCTURES:

In absence of such structures in the present day algal sediments, no account of their ecology is known. This handicap is coupled by the fact that in most of the regions where the conical stromatolite occur, the structures are usually attached to the supporting strata by their apices. Palaeoecological interpretations for these stromatolites thus would not be comparable with the cone-in-cone structures of the area under discussion. The interpretation reached here is therefore more of a hypothetical nature.

The most significant pioneering work on the conical stromatolites is that of Maslov (1938) wherein he states that they are formed in shallow seas with an envirnmoent similar to the red coloured facies, i.e. transitional betweer the open sea and the brackish lagoon. Maslov (1960) further states that like all other stromatolites, *Conophyton* type structures are also resulted on account of the algal activity. Rezak (1957) believes that these structures must have grown in an offshore or possibly lagoonal environment but suggests further that the embayments in which these stromatolites grew must have received a plentiful supply of well-oxygenated water. Korde (1933, in Maslov, 1960) is of the opinion that gases evolved by the activity of algae at the substrata are responsible for the rising of the algal layers in some places in such a way that a conical structure is resulted. In the present case, however, the formation of conical stromatolites appears to be due to some modification in the stacking arrangement of algal layers in discrete stacked head-like structures which were converted as a result into cone-in-cone stromatolites. The very fact that the conical structures of these stromatolites had been maintained bears, however, testimony to the fact that their formative environment should have been comparatively calm.

DISCRETE SPHEROIDAL STRUCTURES:

These structures, which may be termed oncolites, are comparable with SS-C stromatolites of Logan *et al.* (1964) and algal biscuits of Ginsburg (1960). It is commonly believed that these structures are formed submerged in the marine environment and are generally indicative of permanently submerged shoal water areas or areas that are low in the intertidal zone (Ginsburg, 1960). In order to take a spheroidal shape, these structures require almost continuous motion which is provided by the energy of oscillatory currents which might have been produced either by swells or internal waves or both (McMaster and Conover, 1966). As the structures in the present case are almost spheroidal (Pl. 4, Fig. 7) with a concentric arrangement, it is logical to believe that they must have formed by continuous growth of algal layers around certain nuclei and the same were kept in a perpetual movement throughout the course of their formation. It is also clear from the size of these stromatolites that conditions favourable for the oncolite formation existed for a long time.

COMPOUND STRUCTURES:

From palaeoecological point of view these stromatolites are very significant. They clearly indicate a set of conditions which differ in time. To begin with, the laterally linked stromatolites indicate a calm environment in the intertidal of subtidal zone as has been discussed earlier. The development of discrete club-shaped structures in continuation with the earlier structures indicate definite regressional shift pushing the area of algal growth in the supratidal zone or very near to the high water mark. Occasional tides, storm waves and breakers are sought to do the job of breaking the mat in the intercolumnar species while the discrete stromatolites formed.

CONCLUDING REMARKS

The study of diversified forms of stromatolites along with associated carbonate lithologies in the "Window" formations in the Lesser Himalayas (Kumaon) has brought out some interesting and significant results. Some of the more important conclusions follow here:—

(1) The forms of stromatolites are broadly related to the composition of enclosing carbonate rocks, e.g. laterally linked dome-like structures are normally associated with the thickly bedded purer carbonate rocks, while the flat topped laterally linked stromatolites and the discoid forms occur in argillaceous dolostones.

(2) The forms of algal stromatolites are essentially governed by the formative environment in which the role of algae is restricted to the extent that they only bind the detritus.

(3) The flat and undulating discoid structures associated with the shaly dolostones developed in the near shore mud flats possibly between high and low tides in an environment with low wave energy and rapid influx of terrigenous material.

(4) The laterally linked dome-like stromatolites associated with fine grained carbonate rocks grew in protected locations with low wave action and subordinate influx of clastic material.

(5) Increase in the wave energy and shallowing of depositional basin resulted in the formation of discrete columnar or club-shaped stromatolites.

(6) The growth of cone-in-cone stromatolites appears to be due to modifications in the stacking arrangement of algal layers in discrete columnar or club-shaped structures in the calm off-shore environment.

(7) The locale of the discrete spheroidal forms are deeper parts of the basin where due to persistent oscillatory motion of the currents the structures underwent constant rolling on the sea floor while growing layer by layer.

(8) The compound forms depict the changes in environment and its energy.

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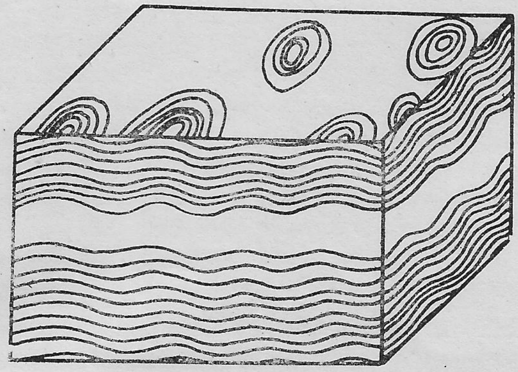

Fig. 1 , Type A

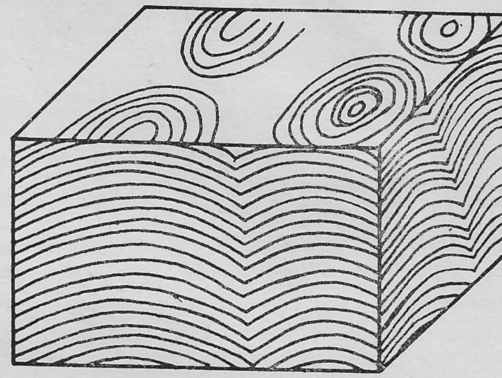

Fig. 2 , Type B

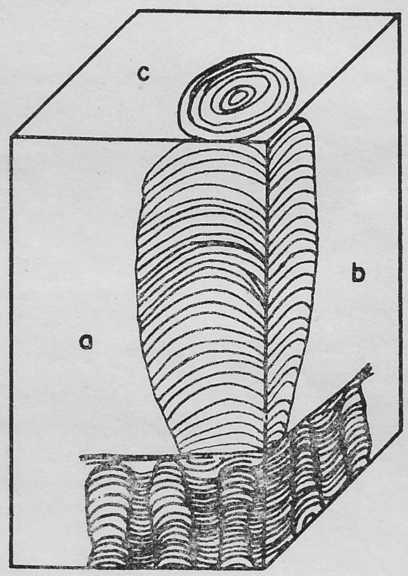

Fig. 5 , Type F
a & b = Longitudinal Sections
c = Transverse Section

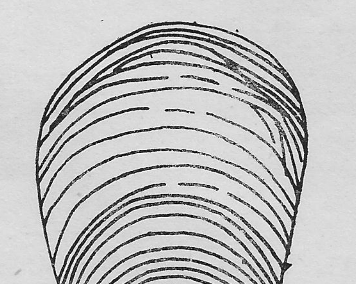

Fig. 3, Type C

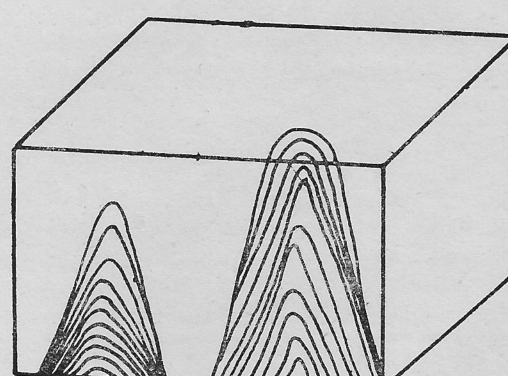

Fig. 4 , Type D

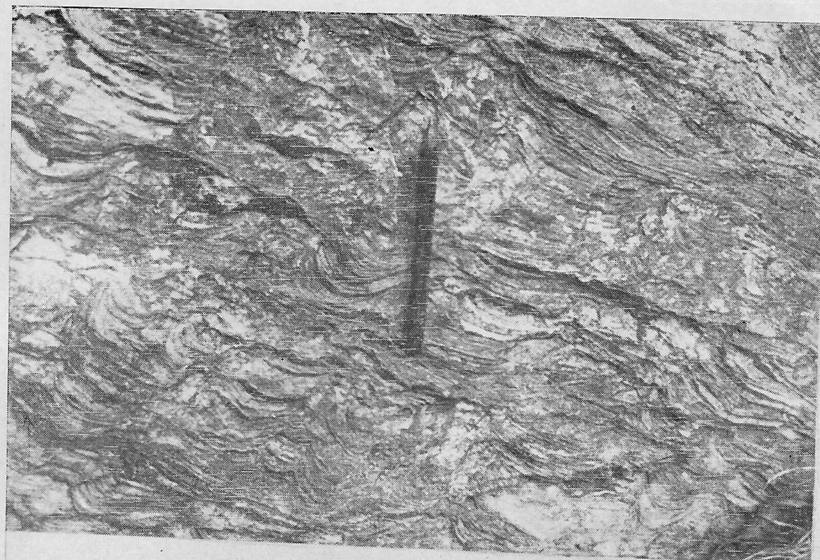

Fig. 1
Type-A

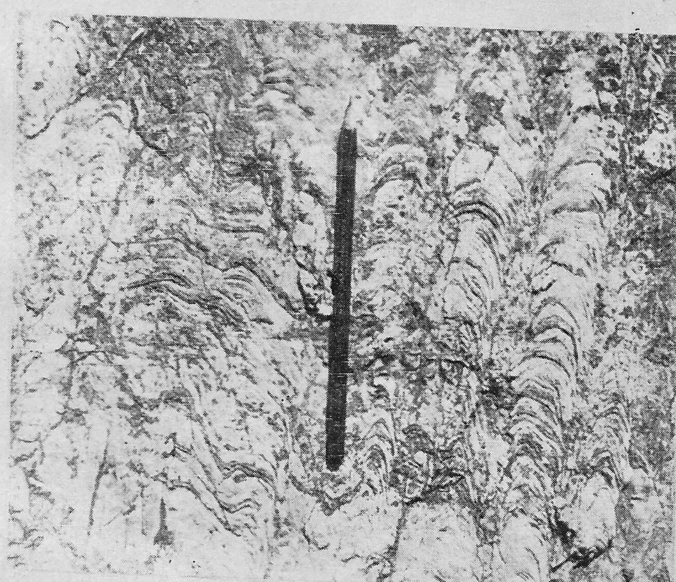

Fig. 2
Type—B
Form-1

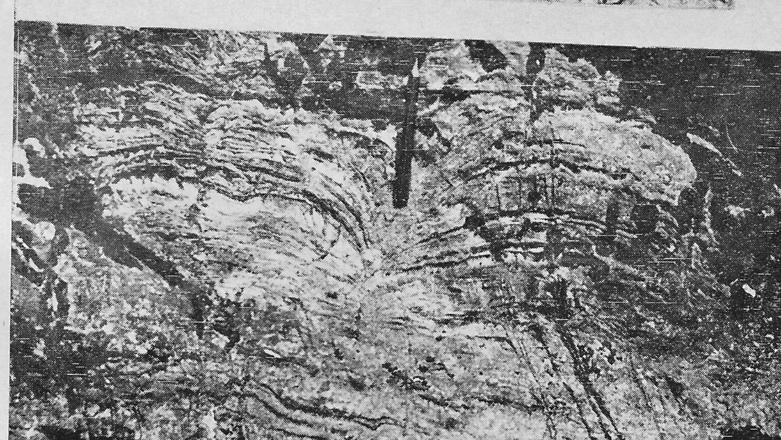

Fig. 3.
Type-B
Form-2

Fig. 4
Type-C
Form-1

Fig. 5
Type-C
Form-2

Fig. 6
Type-D

Fig. 7
Type-E

Fig. 8
Type-F

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EXPLANATION OF PLATES

PLATE 1

1. Diagrammatic sketch of simple undulating discoid structures—type A.
2. Diagrammatic sketch of laterally linked dome-like structure type B. It is comparable to LLH-C structures of Logan *et. al.* (1964)
3. Diagrammatic sketch of discrete columnar or club shaped structure—type C.
4. Diagrammatic sketch of discrete cone-in-cone structures type D—showing conical laminae stacked over one another.
5. Diagrammatic sketch of compound structure—type F, comparable to LLH-C-SH-V, Logan *et. al.* (1964); a & b longitudinal sections, c transverse section.

PLATE 2

1. Simple undulating structure—type A. Note flat and paralleled laminae at the base.
2. Laterally linked dome-like structure—type B, form I, stromatolites are columnar in shape with hemi-spheroidcal laminae stacked over one another.
3. Structures with vertically stacked and laterally linked hemispheroids, which are flat at the top.—type B, form 2.

PLATE 3

4 & 5. Discrete columnar or club shaped structures formed by stacking of hemispherial laminae over one another.

6. Discrete cone-in-cone structure—type D, showing conical laminae stacked over one another. Some of the inner most laminae are roughly oval in out-line in the central region.
7. Disscrette spheroidal structures—type D, showing a circular outline in the transverse—section.
8. Compound structure—type F, showing small and poor development of laterally linked hemispheroidal structures in the lower part.