9. STRONATOLITES IN GEOLOGICAL HISTORY
3. STROMATOLITES IN GEOLOGICAL MAPPING

3.1 Basic criteria: The basic criteria that make the stromatolites useful in geological mapping lie in the fact that the stromatolites are generally made up of a series of upwardly convex or conical laminae which, together with erosional unconformity (if any) within the laminae, are the definite indicators of stratigraphic faceting (Vide article 1.3.1; Frazee, 1976, pp. 7-8) of a sequence of beds which have undergone tectonic episodes like folding, faulting and overturning (Fig. 9.1). The palaeocurrent directions can be established by determining the average direction of inclination of the stromatolite column (Plate 6.12 and 9.1) or from the orientation of the long axes of the ellipses of cross-sections of stromatolite
FIG. 9.1: Diagram showing relationship of stromatolites to stratigraphic facings in (a) horizontal beds of normal sequence, (b) beds at angular disposition, (c) vertical beds, (d) overturned horizontal beds, (e) overturned inclined beds, (f) folded beds of normal sequence, (g) folded beds forming a syncline, and (h) folded beds forming an anticline.
heads (Hoffman, 1967, p. 1044; Vidal, 1972, p. 361; Fig. 9.2).

The importance of the use of the stromatolites in geological mapping and structural interpretation was realised by the author when he came across with geological maps of some of the phosphorite bearing areas around Udaipur, Rajasthan (Fig. 4.1), and found that the phosphorite horizon was shown in those maps to run from the stromatolite dolomites to the associated and closely quartizes of the Aravalli Supergroup, like a mineralised vein. Foresare in charge of phosphorite investigation and exploration could not provide the author with satisfactory explanation about the behaviour of the phosphorite bed. Being unsatisfied with their maps and explanations about the nature of the stromatolite-bearing beds and the phosphorite horizon, and their inter-relationship, the author felt the necessity of checking up some of the available maps of the phosphorite bearing areas with the stromatolite data. So, he began to incorporate the orientation of the stromatolite columns on the geological map in addition to the other field data on dip and strike of the beds, joints, foliations, etc. Where possible, the orientation of the long axes of the ellipses of the stromatolite heads or cross-sections of the columns were measured and plotted on the geological map. To his delight the author found that the data on the stromatolites on the
FIG. 9.2: Idealized horizontal (a,c) and vertical (b,d) sections of stromatolites showing relation of shape to current directions (a-b= After Hoffman, 1967; c-d= After Vidal, 1972).
geological map clearly brought out the nature of the stromatolite-bearing beds and the behaviour of the phosphorite bed or horizon, and he realized that the other workers on the geology and phosphorite could not clearly make out the structural interpretation of the stromatolite-bearing dolomites and the phosphorite beds in the dolomites as well as in the overlying brecciated shorty quartzites because these workers did not take the stromatolites into consideration at the time of preparing the geological maps.

9.2 *Local mapping with stromatolite data*: Encouraged by the above-mentioned trial mapping, the author made thorough traverses in all the stromatolite-phosphorite-bearing areas at Badgaon, Dahan Kotra, Jhamar Kotra, Kampur, Xartaria-ka Gurha, Naten, Roosuch Nata and Sincuma around Udaipur (Fig. 4.1) for selecting areas for preparing model geological maps by using stromatolite data in addition to the conventional geological field data. Of these areas, Dahan Kotra, Jhamar Kotra and Kampur were found to be very rich in bichorbal stromatolites and, as such, model geological maps with stromatolite data were prepared for these three areas as detailed below:

9.2.1 *Dahan Kotra area*: The area is located at about 12 km. southeast of Udaipur city (Fig. 4.1) and presents excellent
development of bioclastic stromatolites, both non-phosphatic and phosphatic, for a strike length of about 600 m. in grey to dark bluish dolomitic limestones of the Debari Group (Aravalli Supergroup). The non-phosphatic stromatolites occur in grey to buff coloured dolomitic limestones in the lower part of the carbonate sequence, the upper part with dark bluish dolomites being dominated by the phosphatic stromatolites. The transitional zone between the non-phosphatic and phosphatic stromatolite horizons is sparsely populated by partially phosphatic stromatolites.

The dolomitic limestones with non-phosphatic and phosphatic stromatolites are unconformably overlain by brecciated shaly quartzites, on two mounds to the east and west of the area. A reworked stromatolitic phosphorite bed occurs towards the base of the brecciated shaly quartzites.

For preparing the model map of the area, a large scale (1:2,000) lithological outcrop map was prepared with the help of tape and compass. The normal geological field data such as dip and strike of the beds, and small scale folds and faults, wherever were seen and measured, were plotted on the geological map. Since the beds occur with considerable high dip (60° - 80°), the stromatolite columns were found to occur prostrate on the ground with
about right-angle relationship to the host rock beds. The orientation (trend) of the axes of the stromatolite columns were measured and plotted on the geological map (Map 1). The stromatolite data thus superimposed on the geological map brought out a clear picture of the structure of the area. It has been found that the area presents a north-west-easterly plunging anticlinal fold with some small scale sympathetic folds in the eastern part of the area. The study of the stromatolites also helped in delineating some minor local faults in the area. The stratigraphic facing of the stromatolite bearing beds was determined with the help of the upwardly convex laminae (microstrata) of the stromatolites (Vide article 9.3.1; Fig. 9.1).

The geological map thus prepared along with the stromatolite data helped in interpreting the nature of the stromatolite biherms and the behaviour of the stromatolitic phosphorite horizon within the dolomites. The reworked stromatolitic phosphorite horizon in the brecciated and shorty quartzites, as exposed on two hillocks to the eastern and western part of the area, appeared to belong to a separate bed of phosphorite occurring in the younger horizon of the stratigraphical sequence.

9.8.2 Farakka Loin Area: The area lies at a distance of about 23 km. to the east of Ulapur (Fig. 4.1) and presents
a succession of orthoquartzites, dolomitic limestones, phyllites, graywackes and brecciated shelly quartzites of the Debari Group (Aravalli Supergroup). The stromatolitic phosphorite horizon (with in situ stromatolites) occurs within the dolomitic limestones. Reworked stromatolitic phosphorite comprising angular to subangular fragments of phosphatic stromatolites occur within the brecciated shelly quartzites. The total strike length of the phosphorite horizon runs for a distance of about 16 km in an arcuate belt whose shape simulates the shape of the letter "S".

Since the bedding planes in the quartzites have entirely been obliterated and fairly so in the stromatolite-sum- phosphorite bearing dolomitic limestones, due to metamorphism, the phosphorite horizon has so long been regarded as a single mineralized zone (Sethi, 1969).

The apparent continuity of the phosphorite horizon from the stromatolitic dolomites to the brecciated and shelly quartzites posed a problem in the interpretation of the depositional history of the two different types of sedimentary rocks, such as the dolomites and the quartzites. In order to solve this problem, a geological map of the area was prepared on the scale 1:50,000 with the aid of tape and compass. As was done in Dahan Vehra (Vide article 9.2.1), the orientation of the axes of the stromatolites columns
were plotted on the geological map along with other field
data, e.g., the dip and strike of the beds. The map thus
prepared helped in delineating the nature and behaviour of
the phosphorite horizon. It was found that the phosphorite
horizon actually consisted of two separate beds, the two
having been brought to the same strike continuity due to
depositional features and post-sedimentary tectonic
episodes.

The stromatolite-bearing dolomites, particularly
in 'A' and 'B' blocks of the mining areas, show the
development of non-phosphatic columnar stromatolites in
grey to brownish dolomites followed by dark bluish dolomites
with bioclasts of both branching and non-branching types of
phosphatic stromatolites (Plate 3, 1). These phosphatic
stromatolites, together with their non-phosphatic
inter-spaces constitute the main mass of the phosphorite.
In the uppermost part of the stromatolitic phosphorite
horizon, specially in 'B' block of the mines area, there
occur a bed of angular fragments of phosphatic stromatolites
and encrinites. Phosphorite with in situ stromatolites are
well developed in 'A', 'A-Extension', 'N' and 'P' blocks
of the mines area at Shamar Petra. The reworked stromatolitic
phosphorite occurs within the brecciated and chalky
quartzites in the eastern part of the area, particularly
in 'O', 'R' and 'P' blocks. Here the fragmentary
stromatolitic phosphorite has been subjected to tectonic
activity with the result that the phosphorite has been
swolled and it usually crumbles to fine particles even on
slightest touch. This retrograded stromatolitic phosphorite
once its origin to the deposition of a bed of detritus of
broken pieces of the phosphatic stromatolites due to
their break-down eavesdropped erosion and subsequent
transportation and deposition of the broken material.

9.2.5 \textbf{Leaving area:} The area is located about 8 km east
of Visapur (Fig. 4.1). Here a sequence of dolomite-
limestone occurs between the underlying phyllites and
the overlying brecciated and shaley quartzites, and shows
the development of both phosphatic and non-phosphatic
forms of stromatolites.

The non-phosphatic stromatolites (Plate 6.1A)
can be seen in silicious gray dolomites in the lower part
of the dolomite limestone while in its upper part the
phosphatic varieties of stromatolites occur in dark bluish
dolomites. The phosphatic stromatolites, surrounded by
non-phosphatic dolomitic matrix in the inter-spaces between
the columns, constitute the sole mass of the phosphorite.

The rocks of the area have undergone some
metamorphism as well as tectonic disturbances with the
result that the bedding planes in the dolomites are
slightly tilted. The foliation planes in these rocks are seen
to occur parallel to the stromatolitic structures. Moreover,
the bedding planes in the dolomites can be distinguished
when the stromatolites are taken into consideration (Vide
article 1.3.1).

For delineation of the geological structure as
well as the behaviour of the stromatolitic phosphorite
horizon in the dolomites and the overlying brecciated
and shaley quartzites, detailed geological mapping of
the area was carried out on 1:12,000 scale with the help
of tape and compass. The orientation of the stromatolite
columns was superimposed on the geological map as was
done in the case of Dakua Petra and Jhamar Petra. Taken
together, the geological and palaeontological (stromatolitic)
data have revealed that the area presents a N - S trending
anticlinal fold, the southern side of it exhibiting a
tightly folded nose, while the northern side of the fold
is open with widely separated limbs (Map 3). On either
side of the anticline, two synclines have been formed.
The limbs of the anticlinal fold can be discerned when
the stromatolites are taken into consideration along with
the attitude of the dolomite beds. On the southern
extremity of the area, the dolomite beds are overturned
with the result that the stromatolites are also overturned
and their laminae show downward convexity. The phosphorite horizon is made up of a number of lenticular bicherts of stromatolites in the dolomites and follow the limbs of the anticlinal fold.

In the syncline to the east of the anticlinal axis, there occurs a thick pile of brecciated and shelly quartzites, which unconformably overlie the stromatolite and phosphorite bearing dolomites, with a bed of reworked stromatolitic phosphorite in the basal part. This reworked stromatolitic phosphorite bed comprises angular to subangular fragments, as well as pellets, apparently derived from the break-down of the phosphatic stromatolites, and this phosphorite is distinctly separate from the stromatolitic phosphorite in the dolomites. Since the bedding planes within the quartzites are obliterated due to metamorphism and tectonic episodes, earlier workers (who did not take the stromatolites into consideration) thought that "... there is only one phosphorite horizon which has been refolded into a complex pattern of folds thereby giving a false impression of several such horizons" (Director General, Geological Survey of India, 1967, p. 64).
PLATE 9.1

A. Stromatolite columns showing angular relationship with beds of dolomitic limestone of the Aravalli Supergroup at Shamar Khetra, Udaipur District. (X 1/50).

B. Cross-sections of non-phosphatic stromatolites in the dolomitic limestone of the Aravalli Supergroup at Kanwar, Udaipur District. (X 1/7).