# PRIMARY SEDIMENTARY STRUCTURES AND THEIR SIGNIFICANCE IN THE SEDIMENTARY BELT OF THE NORTHERN KUMAON HIMALAYA IN THE SARJU-PUNGAR VALLEY AREAS

R. C. MISRA AND A. R. BHATTACHARYA

*Department of Geology, Lucknow University, Lucknow*

## ABSTRACT

Various types of primary sedimentary structures have been studied from the sedimentary zone of the Sarju-Pungar valley areas of northern Kumaon Himalaya. The various rock-units of the area show the following primary structures:—(1) Berinag Group: ripple marks, cross bedding, graded bedding, pebbly beds and boulder beds; (2) Tejam Group: (i) Doya Dolomite: ripple marks, mud cracks, stromatolites, (ii) Hatsila Formation: ripple marks, cross bedding, load casts, groove casts, flute casts and mud cracks, (iii) Kapkot Formation: interference ripple marks, cross bedding, load casts, mud cracks, intraformational conglomerate and breccia, boulder beds, (iv) Saling Slate: rill marks (?); (3) Loharkhet Group: primary sedimentary structures practically absent. The above-mentioned primary structures have been found helpful in deciphering the top and the bottom of the beds and throwing light on the stratigraphic order of the sedimentaries in this sector of the Himalaya. They have also helped in understanding the sedimentation of the strata concerned.

## INTRODUCTION

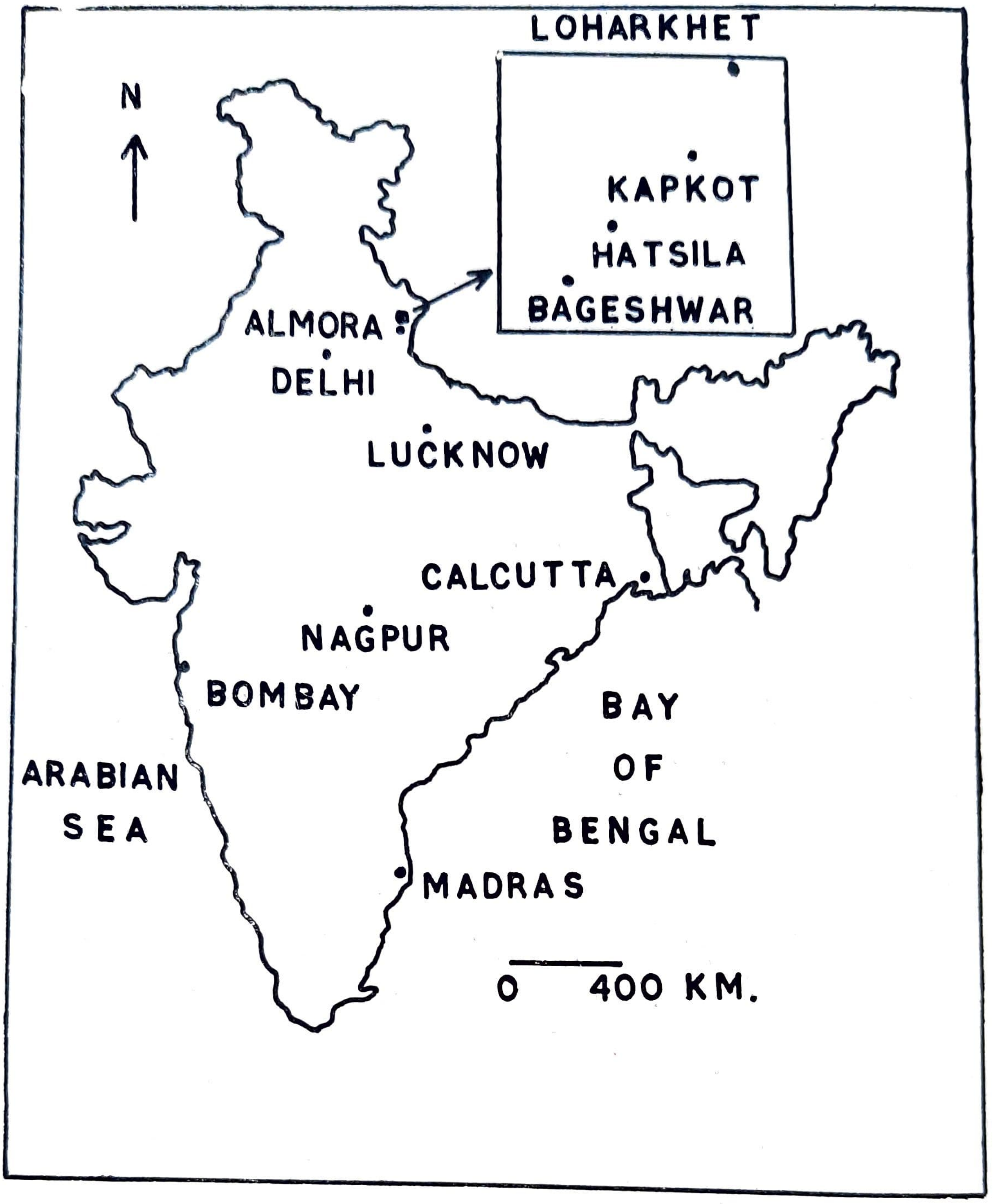
The present paper records the occurrence of various types of primary sedimentary structures present in the sedimentary formations of the Sarju-Pungar valley area, District Almora, Uttar Pradesh, together with notes on their origin and significance. The area under study (Text-fig. 1) is confined to the topo-sheet Nos. 53 0/13,9 and 53 N/16 of the Survey of India, between latitudes 29° 48′ to 30° 2′ and longitudes 79° 45′ to 80° 0′.

The primary sedimentary structures have been found to be of much help in deciphering the top and the bottom of the beds and throwing light on the stratigraphic order of the sedimentaries in the present area. They have also been found helpful in elucidating the environment of deposition of the sediments. The importance of some of these sedimentary structures in ascertaining the current directions and the palaeoslopes of the basins, has not been taken into account, as the present sector of the Himalaya has suffered repeated and intensive tectonic movements, as a result, the original dispositions of the beds, and hence the palaeoslopes, have been disturbed.

The area has been mapped in detail for the first time by Bhattacharya (Misra & Bhattacharya, 1972). Earlier, Heim and Gansser (1939) referred the area in their work. Gansser's work (1964) gives a broad outline of the geology and structure of the entire Kumaon Himalaya on a regional basis. Recently, Misra and Bhattacharya (1973a) have reported some of the important sedimentary structures and their implications.

## LITHOLOGY

The rocks of the area have been divided into five Groups (Misra & Bhattacharya, 1972), three of which include the sedimentary rocks while the rest include the crystalline




Text-fig. 1: Map of India showing the area under study.

metamorphic rocks. The sedimentaries include: (1) the oldest Berinag Group, followed up by (2) Tejam Group, further subdivided into four formations: (i) Doya Dolomite, (ii) Hatsila Formation, (iii) Kapkot Formation and (iv) Saling Slate, and (3) Loharkhet Group, which is the youngest rock-unit of the area.

The Berinag Group is dominantly an arenaceous sequence consisting of orthoquartzites and a few argillaceous beds and basic rocks. The Tejam Group is a thick calc-argillaceous sequence. Its lowermost Formation—Doya Dolomite—mainly includes limestone and dolomite (often with chert and stromatolite) and subordinate slates and calcareous slates. The next overlying Hatsila Formation is composed of grey, green, olive, red, brown and black slates, together with a few inter-stratified and lenticular horizons of meta-arenites and also limestone beds. The Kapkot Formation broadly encompasses limestone and dolomite with subordinate slates, chert and talcose dolomite. The Saling Slate includes a calc-argillaceous Lower Saling member and an Upper Saling member with black carbonaceous slates. Orthoquartzites and basic rocks form the bulk of the Loharkhet Group.

Based on a number of evidences, it has been pointed out (MISRA & BHATTACHARYA, 1972, 1973b) that the Berinag Group, Doya Dolomite and Hatsila Formation possibly occur in inverted position, while the Kapkot Formation, Saling Slate and the Loharkhet Group are in normal position. A thrust, named as the Kaphauli Thrust, separates these two sets of rock-units, and brings the inverted Hatsila Formation in contact with the Kapkot Formation.

## PRIMARY SEDIMENTARY STRUCTURES

The primary sedimentary structures are those larger features that, in general, are seen or studied best in the outcrop rather than hand specimen or thin section, i.e., they are the larger features of the rock (PETTIJOHN, 1957, p. 157). Depending on the mode of formation, these structures may be 'primary' or 'secondary'. The primary sedimentary structures owe their origin mainly to the current action, rate of sedimentation and the related processes. The secondary structures, on the other hand, are formed due to the chemical action at the time of, or shortly after, the sedimentation.

In the present paper, the various primary structures have been described in order of their abundance. Their frequency of occurrence in different rock-units has been summarised in Table—1. Following PETTIJOHN (1957) and POTTER AND PETTIJOHN (1962), the structures have been classified under the following groups:

(A) Planar bedding structures
(B) Linear bedding structures
(C) Sole marks
(D) Disrupted bedding features
(E) Organic structures

## (A) PLANAR BEDDING STRUCTURES

The planar bedding structures include bedding, cross bedding and graded bedding.

*Bedding and lamination*

Good examples of the former type are seen in the quartzites (Berinag and Loharkhet Groups, Hatsila Formation), limestones (Doya Dolomite, Hatsila and Kapkot Formations), sandstones (Hatsila Formation). Laminations (i.e., bedding units less than 1 cm. thick) are typically shown by siltstones and shales of the Hatsila Formation.

*Cross bedding*

Among the two major types of cross beddings—trough and planar—the former is of significance in ascertaining the top and bottom of the beds, in which case the concave surface of the units points towards the top.

The Berinag Group shows a very poor development of these structures. Trough type of cross bedding has been seen at a few places south and east of Bageshwar.

Table—1. Distribution of sedimentary structures (both primary & secondary)

| Group/Formation | Sedimentary structure | Occurrence |
|---|---|---|
| Loharkhet Group | Not seen | |
| Saling Slate | Rill marks (?) | Common |
| | Interference ripple marks | Common |
| | Cross bedding (trough type) | Common |
| | Load casts | Rare |
| | Convolute lamination | Common |

Table—1. (Contd.)

| Group/Formation | | Sedimentary structure | | | | Occurrence |
|---|---|---|---|---|---|---|
| Kapkot Formation | .. | Pinch and swell | .. | .. | | Common |
| | | Penecontemporaneous folding & faulting | | | .. | Common |
| | | Mud cracks | .. | .. | .. | Rare |
| | | Intraformational conglomerate | | | | Common |
| | | Intraformational breccia | | .. | .. | Rare |
| | | Boulder beds | | .. | .. | Impersistent horizon |
| | | Nodules & lenses of chert | | .. | .. | Common |
| | | Stylolites | .. | .. | .. | Rare |
| | | Ripple marks | .. | .. | .. | Poor |
| | | Cross bedding | .. | .. | .. | Common |
| Hatsila Formation | .. | Load casts | .. | | .. | Common |
| | | Convolute lamination | | .. | | Rare |
| | | Groove casts | .. | .. | .. | Rare |
| | | Flute casts | .. | .. | .. | Rare |
| | | Mud cracks | .. | .. | | Rare, faintly developed |
| | | Ripple marks | .. | | .. | Faintly developed |
| Doya Dolomite | .. | Mud cracks | .. | .. | .. | Rare |
| | | Nodules & lenses of chert | | .. | .. | Common. |
| | | Stylolites | .. | .. | .. | Rare |
| | | Stromatolites | .. | .. | .. | Common |
| | | Ripple marks | .. | .. | .. | Poor |
| | | Cross bedding | .. | .. | .. | Poor |
| Berinag Group | .. | Graded bedding | .. | .. | .. | Rare |
| | | Pebble beds | .. | .. | .. | Common |
| | | Boulder beds | .. | .. | .. | Impersistent horizon |

Cross beddings are common in the Hatsila Formation. In the majority of the cases, they are developed within the sandstones and quartzites (Pl. 1, Fig. 1) that occur interbedded with the argillites at various stratigraphic horizons. In all these cases, the cross laminae show convexity upwards, indicating the inverted nature for this formation.

Within the Kapkot Formation, the distribution of the cross beddings is common, and all of these are of trough type (Pl. 1. Fig. 2). These structures have been seen within the Kapkot A and C members.

*Graded bedding*

The most significant character of the graded beds is a decrease in grain size upwards, within a single sedimentation unit, i.e., coarse at the base and fine at the top. Because of this important character, these have been found to be extremely useful in deciphering the top and the bottom of the disturbed strata.

Graded bedding appears to be rare in the present area. It has been seen at a nala about 2 km. S.E. of Bageshwar. The bed is about one metre thick. The underlying bed is relatively finer grained and the contact is abrupt. The overlying bed is relatively coarser than the topmost part of the graded bed. No internal structure excepting the gradation in grain size, is present within the bed in question. The granularity increases upwards, which is obviously a case of reverse graded bedding.

## (B) LINEAR BEDDING STRUCTURES

Two important types of bedding structures have been recorded: ripple marks and current lineations on the bedding surfaces.

*Ripple marks*

In a normal sequence, these occur on the upper traces of the beds concerned. In the area under study, the development of ripple marks has been markedly seen in the arenaceous, argillaceous and in the clastic carbonate rocks. All the three major types of ripples, viz., symmetric, asymmetric and interference or superimposed, are present.

Ripple marks are poorly developed in the Berinag Group. They are present only in the physically lower horizons. East of Bali Gad, in the Sarju valley, they have been seen in the milky white, fine-grained quartzites. In transverse sections, they appear to be relatively straight with subparallel crests. The crests are rounded to flattened. The ripple index (i.e., ratio of the length and amplitude) is 8.0. Faint development of ripples has also been seen in the quartzites south of Bageshwar and in the Lahor valley.

The Doya Dolomite, in general, appears to be devoid of well developed ripples. Faint development of these structures has been seen in the uppermost member, especially north of Bali Gad and on the northern ridge overlooking the Pungar valley.

The Hatsila Formation also shows a poor development of these structures, which are confined to some of the quartzite bands, especially those which are exposed on the northern ridge overlooking the Kanal Gad. The variation in the ripple index is from 7.0 to 12.0.

Ripple marks are common in the Kapkot Formation. Good development has been seen only in the Kapkot C member (Pl. 1, Fig 3). The ripple index has a variation of 4.0 to 6.0. Most of these are of the superimposed type, but a few are asymmetrical.

Although no good development of ripple marks has been seen in the Saling Slate, the lower argillaceous member has often been seen to preserve very small-scale ripples (rill marks ?), with 3-4 mm. length.

No ripple marks have been seen in the Loharkhet Group.

## (C) SOLE MARKS

Three major types of sole marks have been noticed: groove cast, flute cast and load cast. Since these structures are formed at the base of the beds, they are good indicators of top and bottom.

*Groove cast*

This term was first coined by SHROCK (1948) to designate 'sand fillings (casts) of rectilinear, V-shaped and U-shaped grooves existing in the upper few millimetres of the bottom sediment on which sand was deposited'. Kuenen called these structures as 'drag marks'. It is nowadays believed that possibly the groove casts are formed by turbidity currents.

Groove casts have been seen at many places within the Hatsila Formation. Their occurrence is common in the Kanal Gad valley, especially in the northern ridge. They have also been seen in the Sarju valley.

In the above mentioned localities, groove casts have been developed in those slates which are either interbedded or are underlain by protoquartzites. In most of the cases, they are characterised by straight, parallel to subparallel ridges with a maximum height of 1 cm. Some of these are sinuous with the development of load casts (Pl. 1, Fig. 4). It, therefore, appears that at the time of formation of these groove casts at the base of the sandstone beds, load casting phenomenon was also operative.

*Flute cast*

The term flute cast has been variously used as 'flow mark' (RICH, 1950), 'lobate rill marks' (SHROCK, 1948), 'scour cast' (KINGMA, 1958) and 'vortex cast' (WOOD & SMITH, 1959). Flute casts are typical sole marks produced at the base of the beds. They are thus reliable indicators of top and bottom of the beds. It is believed that most of the flute casts are the products of turbidity currents.

Flute casts are occasionally seen at the upper traces of the argillaceous beds of the Hatsila Formation at many places in the Kanal Gad valley. The length of these structures varies from 2 to 8 cm. They are mostly elongate and/or bilaterally symmetrical in out line. At places, they are associated with groove casts (Pl. 1, Fig. 4). In such cases, the flutes are parallel or subparallel to the groove casts.

*Load cast*

Load casts are structures that appear as swellings varying from slight bulges, deep or shallow rounded sacks, knobby excrescenses or highly irregular protuberances (POTTER & PETTIJOHN, 1963, p. 145). The term load cast has been variously used by different workers, e.g., 'flow cast' by SHROCK (1948, p. 156), 'load pocket' by SULLWOLD (1959, 1960), etc. KUENEN (1953, p. 1048) for the first time proposed the term 'load cast' for such structures. Since these structures are formed at the base of the beds, they are good indicators of top and bottom.

Good development of these structures has been seen in the Hatsila Formation at many places. They are seen in the slates (that are associated with the protoquartzites), siltstones and argillaceous quartzites of this formation. They are seen both in the Sarju and Kanal Gad valleys.

## (D) DISRUPTED BEDDING FEATURES

These features result from the breaking or dislocation or fragmentation of the bed before it is completely consolidated. Fragmentation of the beds may be due to desiccation; it may be due also to stresses induced by sliding or slumping (PETTIJOHN, 1957, p. 192). In the present area, the following features have been recognised.

*Intraformational conglomerate*

Intraformational conglomerates are produced due to fragmentation of the early formed beds contemporaneous with sedimentation (PETTIJOHN, 1957). Their occurrence has been seen at various stratigraphic levels of the Kapkot C and D members. In these beds, the cobbles and boulders of limestone and chert, which range in size from 4 × 2 cm. to 15 × 10 cm., lie either in carbonate matrix (Pl. 1, Fig. 5) or in the talcose (wholly or partly) matrix (Pl. 1, Fig. 6). While the former types are confined to the Kapkot C, the latter are seen in both the members. Generally, the constituents show a preferred orientation, in which case, they lie with their longer axis almost parallel to each other. Medium to small scale cross beddings are also present in some cases, indicating the role played by currents in transporting these pebbles. The beds are impersistent with a maximum thickness of about 8 metres.

*Intraformational breccia*

This term was used by FIELD (1916) to designate the thinly-bedded brecciated deposits. Their manner of formation is similar to that of intraformational conglomerates, described earlier.

Intraformational breccias have been observed in a few beds of the Kapkot C member (Pl. 1, Fig. 7). In these cases, broken pieces of limestone and chert are seen. These fragments show moderately sharp corners. Although, the breccia have no definite shape and size, there is a general tendency of length-wise alignment, which is approximately towards south. The pieces range in size from about 2 mm. to 5 cm. The associated bed is a coarse grained siliceous dolomite of bluish white colour, with a thickness of about 10-15 cm.

Observation on the internal structure of the bed reveals that these breccias typically taper downwards, and are tabular to irregular in shape. It appears that these breccias are the torn-off pieces of the earlier formed rocks and have been brought to the site of deposition, by currents within the environment. A shallow water environment of deposition for these beds, is thus suggested. Coarse sandy nature of the bed also corroborates this contention. On the other hand, a tectonic origin for these breccias can obviously be ruled out on the ground that the associated bed, as well as those immediately overlie and underlie it, show no sign of tectonic disturbances, neither on the megascopic nor on the microscopic scale. Besides, the lithology of the host bed is altogether different from that of the breccias.

*Mud cracks*

Occurrence of mud cracks is very rare in the area under study. They have been noticed in a few slate beds of the Hatsila Formation (Pl. 1, Fig. 8) and rarely, in a few calcareous beds of Doya Dolomite and in a few calcareous beds of the Kapkot Formation. In all these cases, they are in the form of small bifid or trifid ridges or in the form of polygonal pattern. The depth of the mud cracks is upto about 0.5 cm., and the breadth is up to 1 cm. Generally, they are discontinuous and almost straight to slightly curved in outline.

*Boulder beds*

Occurrence of boulder beds is not a common feature in the area. In the Berinag Group, however, they have been seen at many places in the lower most horizons. The boulders range in size from 5 mm. to 25 cm. in length and from 3 mm. to 15 cm. in breadth. They are white in colour, quartzitic in composition, and are embedded in fawn to pinkish white quartzites. They are generally ellipsoidal and show a down-dip alignment. The exposures are impersistent.

Impersistent boulder beds have also been noticed within the carbonate rocks of the Kapkot Formation. The boulders are mostly made up of limestones, shales, slates and cherts, and show no preferred orientation. The host rocks are bluish grey limestones.

In all these cases, the boulder beds appear to be channel deposits of local extent.

(E) ORGANIC STRUCTURES

The organic structures seen in the area occur in the form of stromatolites, which are calcareous bodies showing definite laminated structure. Their formation is believed to be due to the activity of blue green algae. Significance of stromatolites as a reliable top and bottom criterion, has been emphasised by various workers (SHROCK, 1948; JOHNSON, 1961), because in a normal sequence, the convexity of the stromatolite laminae points upwards.

The various forms of stromatolites, as seen in the present area, fall under the group *Collenia*. This is believed to be a good stratigraphic marker, being restricted in rocks up to Lower Palaeozoic in age. It is interesting to note that *Collenia* has also been reported from various carbonate sequences of Lesser Himalaya. The present find has thus a significance in regional correlation.

ORIGIN AND SIGNIFICANCE

It has already been mentioned that primary sedimentary structures have helped in deciphering the top and the bottom of the beds and throwing light on the stratigraphic order of the sedimentaries in this sector of the Himalaya. Brief notes on the origin and significance of these structures are given below.

Laminations are typically displayed by a number of beds of the Hatsila Formation. They are distinctly marked by the alternation of (i) coarse and fine particles, e.g., silt and clay, (ii) dark and light coloured silt, and (iii) by the seggregation of carbonaceous and non-carbonaceous layers. These laminations, thus, indicate variations in the rate of supply of silt, clay, etc. or rhythmic changes in the depositional conditions mainly due to (i) changes in the depositing currents, or (ii) alternation in chemical and non-chemical sedimentation. Most of the well preserved laminations of the Hatsila Formation show uniformity in their lithologic character and texture, which may be attributed to quietness of the sea water during sedimentation. As, the effects of any slight change in the bottom currents would change the previously formed laminations, the latter are thus the record of deposition below wave-base (PETTIJOHN, 1957, p. 163).

As, the current beddings are the result of current action, their presence indicates the role played by currents in transporting the sediments. Cross-bedded rocks are thus deposited in wave-agitated waters, or, in other words, above the wave-base. Further, in a normal sequence, the individual laminae of the cross beddings show convexity upwards; a reverse disposition, on the other hand, indicates that the beds in question, are in inverted position. This property is well exhibited by the trough type of cross beddings.

Based on the disposition of the laminae of the cross beddings, it may be said that the Berinag Group and the Hatsila Formation are possibly disposed in inverted position, while the Kapkot Formation is in normal position.

The graded bedding, although very rare in the area, is also of some significance. It has been noticed only in the Berinag Group. In this case, increase in granularity upwards is obviously a case of reverse graded bedding. This adds one more evidence in favour of the probable inversion for these beds of the Berinag Group. In contrast to the cross bedded units, the graded beds are the products of calm water sedimentation in deep water environments.

Ripple marks are also indicative of wave action and they typically occur in the upper traces of the beds concerned. Thus, on the basis of their occurrence, it may be said that the Berinag Group and the Hatsila Formation are possibly disposed in inverted position, while the Kapkot Formation and the Saling Slate are in normal position.

It has already been suggested (MISRA & BHATTACHARYA, 1973c) that during most of the basinal history of the Doya Dolomite, the environment embraced calm water chemical conditions. The rarely developed ripple marks (and current beddings) indicate, on the other hand, intervention of short-lived periods of wave agitation.

The three major types of sole marks recorded from the present area, viz., groove casts, flute casts, and load casts, are typically formed at the base of the beds. While the groove casts and flute casts are conspicuous linear structures of current origin, the load casts are the result of differential loading of the originally cohesive sediments at the bases of the beds. On the basis of the disposition of these structures, the Hatsila Formation, in which their occurrence is common, appears to be disposed in an inverted position.

Mud cracks are shrinkage cracks, which, in their typical development, form a network dividing the surface into irregular polygonal areas (SHROCK, 1948). The cracks are later filled up by sandy material. These structures form a reliable criterion of top and bottom. According to SHROCK (1948), the formation of these incomplete mud cracks takes place if shrinkage is not carried to completion. He, therefore, takes them to be incipient contraction polygons.

Occurrence of mud cracks at the base of a few beds of the Hatsila Formation and the Doya Dolomite, might indicate the inverted nature for these beds; while, on the other hand, their occurrence on the upper traces of some limestone beds of Kapkot Formation, implies that the Formation is in normal position.

Origin and significance of the other sedimentary structures described in the paper, have already been discussed in the previous pages.

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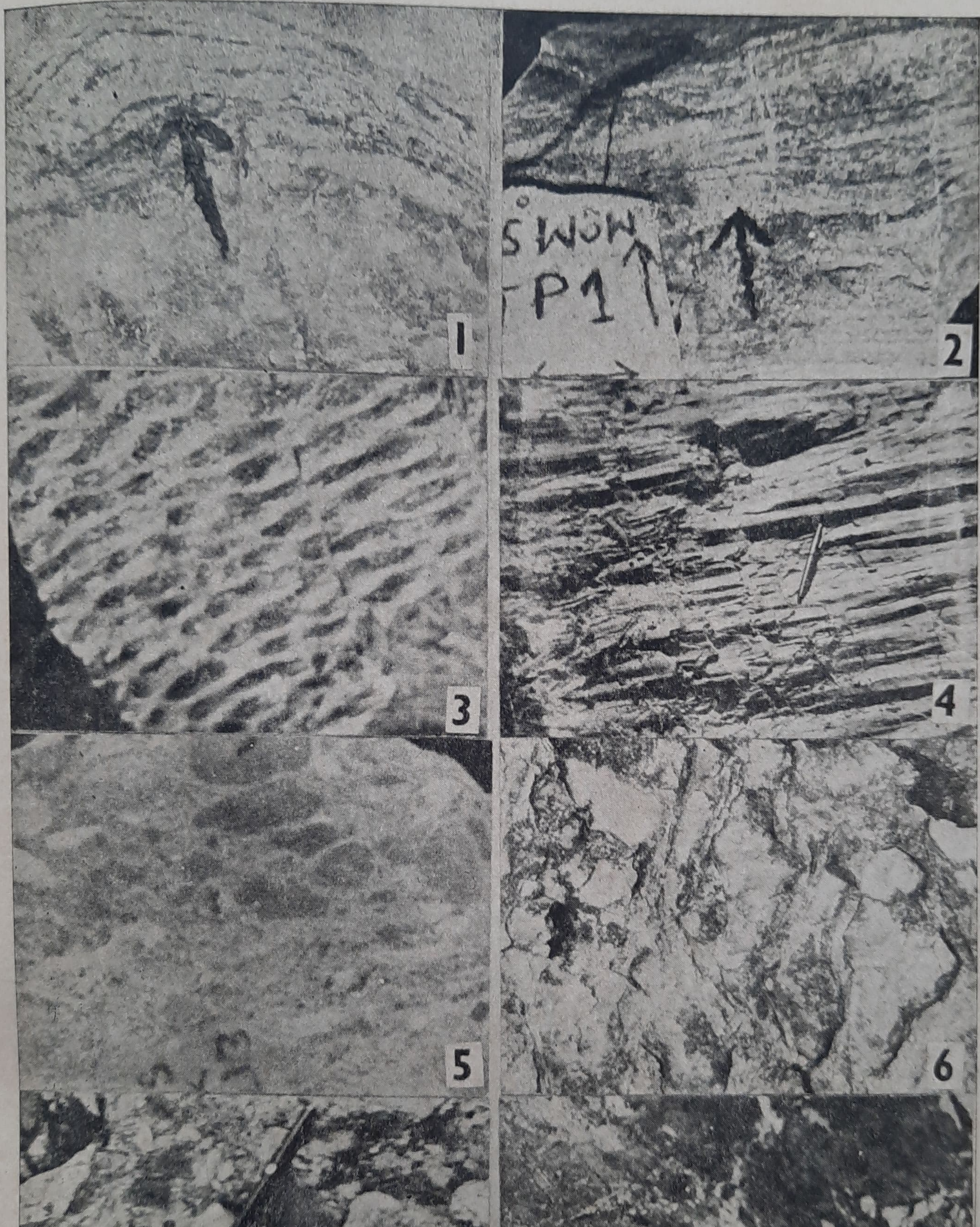
## EXPLANATION OF PLATE 1

1. Cross beddings with convexity of the laminae pointing upwards in the sandstones of the Hatsila Formation, implying the inverted position of the beds. The arrow indicates the physical top of the beds. Length of the sample is 15 cm.
2. Partly developed trough type of cross beddings in the limestones of · Kapkot Formation. Convexity of the laminae being in the downward position, the beds are thus in normal position. Arrow (thicker one) indicates top of the bed.
3. Interference ripples in the limestones of the Kapkot Formation (Kapkot C). Length of the exposure is about 50 cm. Ripple index is 4.0 to 6.0.
4. Groove casts (partly loaded) in the slates of the Hatsila Formation. A few flute casts may also be seen, especially in the lower right corner of the photograph. All these sole marks are typically developed on the upper traces of the beds, implying that the beds are in inverted position.
5. Intraformational conglomerate in Kapkot C member showing broken pieces of limestone and chert embedded in siliceous dolomite. The fragments have sharp corners. A more or less length-wise alignment of these pebbles may also be seen. Length of the sample is 20 cm.
6. Intraformational conglomerate in Kapkot D member showing pebbles, cobbles and boulders of limestone and chert in talcose matrix. Length of the exposure is about 1.5 metres.
7. Intraformational breccia in the Kapkot C member of the Kapkot Formation. The pebbles are composed of chert and cherty limestones/dolomites embedded in coarse-grained siliceous dolomite of bluish colour.
8. Incomplete mud cracks in the slates of Hatsila Formation.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