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THE NATURE OF GROOVED PAVEMENT AND PALYNOLOGY OF OVERLYING TALCHIR AND KARHARBARI SEDIMENTS IN WEST BOKARO COALFIELD, BIHAR, INDIA

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ABSTRACT

A sequence of Talchir Formation overlying the polished pavement of metamorphic rocks has been palynostratigraphically studied from the Dudhi River section of West Bokaro Coalfield. The groove-like markings on the pavement, trending S 60°E in direction, have been observed. The tillite, rafted boulders and the thick laminated shales suggest glacial as well as fluvio-glacial conditions during Talchir sedimentation. The thin carbonaceous beds, associated with the sandstone at the top of this formation, have been found to contain a *Callumispora*, *Microbaculispora* and *Parasaccites* rich mioflora. Palynologically this resembles the Lower Karharbari miospore assemblages known from other areas. The Talchir mioflora is less diverse while the subsequent one shows significant complexity in quality as well as quantity.

Key-words — Palaeopalynology, Grooved pavement, Permo-Carboniferous., West Bokaro Coalfield (India).

सारांश

पश्चिमी बोकारो कोयला-क्षेत्र, बिहार (भारत) में खाँचेदार, आचित तल की प्रकृति एवं उपरिशायी तालचिर तथा करहरबारी अवसादों का परागाणु अध्ययन—आनन्द प्रकाश, सुरेश चन्द्र श्रीवास्तव एवं राम शंकर तिवारी

पश्चिमी बोकारो कोयला-क्षेत्र के दूधी नदी खण्ड में कायान्तरित चट्टानों के पॉलिशयुक्त आचित तल पर उपरिशायी तालचिर शैल-समूह के एक अनुक्रम का परागाणुओं द्वारा स्तरविन्यास का अध्ययन किया गया है। आचित तल पर दक्षिण 60° पूर्व की ओर उन्मुख खाँचे-सदृश चिह्न देखे गये हैं। टिलाइट, बेड़ेदार गोलाश्म तथा मोटी स्तरित शेलें तालचिर अवसादन के समय हिमनदीय एवं सरिताहिमी स्थितियां प्रदर्शित करती हैं। इस शेल-समूह के शिखर पर बलुआ पत्थरों से सहयुक्त कार्बनमय संस्तरों में **केल्यूमिस्पोरा, माइक्रोबेक्यूलिस्पोरा** एवं **पेरासेक्काइटिस** से परिपूर्ण परागाणु समूह पाया गया है। परागाणविक अध्ययन के आधार पर यह अन्य क्षेत्रों से ज्ञात अधर करहरबारी के मिओबीजाणु समुच्चयों के समरूप हैं। तालचिर परागाणु समूह विभिन्नता में कम है, जबकि उत्तरकालीन समूह विशेषता एवं मात्रा में सार्थक जटिलता दर्शाता है।

INTRODUCTION

TALCHIR Stage represents the basal part of the Lower Gondwana Sequence in India. The lowest member of this formation is a tillite having ill-sorted, unstratified angular clastics. In general, the Talchir Formation is characterized by varied type of sediments, the tillite being followed by a sequence of greenish sandstones, khaki-green shales, varve clays and the gritty sandstones. The recurrence of boulder beds have also been recorded in certain areas. Blanford *et al.* (1856), for the first time, recognized the glacigene nature of the basal part of the Talchir Formation. Although the subsequent studies have confirmed the glacial and / or periglacial origin of these depositions, the records of pavement striations still remain insufficient so as to reconstruct the extent and direction of the glacial

movements in India during Permo-Carboniferous times. The evidences of striae so far known, are from the Penganga River at Irai, near Chanda, Maharashtra (Fedden, 1875; Smith, 1963); Adjai (or Ajai) River, north of Asansol, Raniganj Coalfield (Smith, 1963a) and Manendragarh as well as Baikunthpur, Madhya Pradesh (Ahmad & Hashimi, 1974). From the extrapeninsular Gondwanas a striated pavement has been described for the first time from the Giri River section below the Blaini Boulder beds in Himachal Pradesh (Singh, 1975).

The evidences of glacial environment generally include the varve clays, rafted boulders, tillites, chatter marks, roches moutoneés, and pavement grooves and striations. The latter structure is the most important one in being a direct document of ice movement while, individually, the other structures are usually circumstantial proofs and therefore do not exclude the alternative probabilities.

The depositional history and nature of sedimentation in the Talchirs of the Dudhi River section in West Bokaro Coalfield has been studied by Ghosh and Mitra (1967, 1975). In the present communication, the presence of groove-like markings on the metamorphic pavement below the Talchir tillite, in association with almost all other sedimentary features in the sequence indicative of glacial and fluvioglacial conditions, has been observed. A palynological analysis has also been attempted for these sediments.

GEOLOGY

The Talchir succession in Dudhi River, near Mandu, Hazaribagh District (Survey of India Toposheet no. 73E/5), forms the western part of West Bokaro Coalfield. It lies between the latitudes 23° 48′ to 23° 49′ N and the longitudes 85° 26′ to 85° 28′ E and is situated on the Ranchi-Hazaribagh road at about 25 km north of Ramgarh. The nearest place of stay is Mandu (23° 47′ 30″: 85° 28′). About 3 km north of Mandu, the Talchir sediments are exposed in Dudhi River (a tributary of Bokaro River) from the road bridge up to the Jarwa Village.

Talchir and Karharbari formations in Dudhi River section include the following important members.

KARHARBARI		Sandstone
	8	Carbonaceous shales/coal
		Sandstone
TALCHIR	7	Upper Boulder Bed
	6	Sandstone
	5	Khaki-green shale
	4	Sandstone
	3	Laminated shales
	2	Sandstone with bands of conglomerates
	1	Tillite
		Metamorphics

In Dudhi River one of the most complete successions of Talchir sediments is exposed. The beds are generally dipping on low angles between 5° to 12° towards east. Nearly 2 km east of Jarwa Village the beds are folded forming a plunging anticline. Near the road bridge splintery shales are affected by a fault and a crushed zone of few meters is exposed below the Upper Boulder Bed. These features, however, seem to be only of local importance.

METAMORPHICS

The metamorphics form the basement over which the Talchir sediments were deposited. These are mainly composed of coarsely crystalline granites. Near the contact with the lowermost Talchir member, the tillite, the surface of the metamorphics has become smooth and polished having groove-like markings (Pl. 1, figs 1, 2) which are prominent, 2-3 cm wide and deep, mostly trending NW-SE. Some prominent joints and veins are also present.

TILLITE

The term tillite has been used to represent sediments deposited by a glacier (Schwarbach, 1975), usually associated with the basement and are of indurated, nonstratified and nonsorted nature. The boulders are of various sizes and shapes. Their size varies from few meters to few centimeters and are mostly of quartzite and granite. Most of them are sharply angular to subangular in shape and some of them bear striations (Pl. 1, fig. 3). The angularity of the clasts are more pronounced in the basal part of the member as compared to its upper part. This unit forms a consistent bed at the

base and does not grade laterally into other facies.

Sandstones

Sandstone (member 2) in the lower part is medium grained but in the upper part, becomes coarse grained, gritty, dark green to light green in colour and occasionally includes lenses of conglomerates. Rafted boulders of considerable size (up to 1m) are commonly dispersed. Grains of undecomposed felspar occur persistently in the sandstones.

The sandstone (member 4) occurring above the band of laminated shales is coarse grained in the lower part and occasionally include lenses of conglomerates containing well-rounded pebbles of quartzite and granite gneisses. In the upper part, this member becomes compact, fine grained and show fine laminations of light olive in colour. Reworked shale fragments occur frequently in this sandstone.

The sandstone (member 6) above the khaki-green shale member is fine to medium-grained in nature.

Laminated shales

A thin band of laminated shales (member 3) is exposed in the lower part of the sequence. These are fine grained and characterized by the thin laminations of dark grey and light green colour (Pl. 1, fig. 4).

Khaki-green shales

The shales are khaki-green in colour, fine grained and show thin laminations of light and dark green colour in the basal part but not in upper portions. They break up into thin splinters. This horizon is conspicuously persistent and forms a considerable thickness above the sandstones (member 4) in order of succession. Thin bands of siltstone are interbedded within these shales. In the upper reaches of this horizon the shales are highly crushed probably through a minor fault of local value, and are topped by the sandstones.

Upper Boulder Bed

This horizon marks the uppermost limit of the Talchir sediments and is present at the top of the youngest sandstone in succession. It consists of boulders of smaller size as compared to the basal boulder bed (tillite). The boulders are also comparatively better sorted and less angular in nature. The striations have not been observed in these boulders which are embedded in greenish silt-sand matrix, and frequently include reworked needle shales. This bed is persistent and well-developed in the sequence throughout the area.

Sandstones intercalated with Carbonaceous shales

Overlying the Upper Boulder Bed, there is a sequence of sandstone, carbonaceous shale, coal and sandstone. The carbonaceous shales are considerably thick and are developed closely above the Talchir sediments. These represent the first carbonaceous facies in this succession. The associated sandstones are coarse to medium grained, current-bedded and frequently include grits.

PALYNOLOGY

Lele (1966, 1975) studied the miofloral succession in the Talchir Formation of Dudhi River, West Bokaro Coalfield. Two miofloral assemblages, one from the base and the other from the top of the Talchir Formation, are chiefly dominated by *Parasaccites*, *Plicatipollenites* and *Potonieisporites*. The radial monosaccate pollen grains total up to 96 per cent. The mioflora in the older sample is less diversified as compared to the one in the younger sample of the Tachir sequence. The miofloral assemblages described from Korba Coalfield (Bharadwaj & Srivastava, 1973), North Karanpura Coalfield (Kar, 1973), Jayanti Coalfield (Lele & Makada, 1972) and Johilla Coalfield (Lele & Chandra, 1973) contain similar dominance of monosaccates.

The maceration of the Talchir sediments in the present investigation has not yielded satisfactory results. However, the first carbonaceous/coal bed occurring above the Upper Boulder Bed in succession contains a rich mioflora. The assemblage obtained from member 8 (in sample D/18-see Table 1) is chiefly dominated by *Callumispora* (25%), and is associated with *Microbaculispora* (18%), *Leiotriletes* (12%), and *Parasaccites* (11%-Histogram 1). The genera next in

TABLE 1 — LIST OF SAMPLES COLLECTED FROM DUDHI RIVER SECTION BETWEEN JARWA VILLAGE AND THE ROAD BRIDGE, WEST BOKARO COALFIELD

SAMPLE NOS.	LITHOTYPES
D/1	Sandstone with conglomerate bands
D/2	Green sandstone
D/3	Laminated shale
D/4	Green sandstone
D/4a	Green sandstone
D/5	Boulder conglomerate and reworked shales
D/6	Green sandstone
D/7	Laminated sandstone
D/8	Laminated sandstone
D/8a	Laminated sandstone
D/9	Intercalated mudstone
D/10	Khaki-green shale
D/11	Khaki-green shale
D/12	Khaki-green shale
D/13	Khaki-green shale
D/14	Khaki-green shale
D/15	Khaki-green shale
D/16	Khaki-green shale
D/17	Boulder Bed (Upper)
D/18	Carbonaceous shale (Bottom portion)
D/18a	Dull Coal (Middle portion)
D/18b	Carbonaceous shale (Top portion)
D/19	Shaly sandstone (Roof of D/18b)

order of dominance are *Plicatipollenites* (7%), *Accintisporites* (6%), *Vestigisporites* (4%), ? *Striatites* (4%) and *Brevitriletes* (4%). The total percentage of laevigate triletes (37%) exceeds the radial monosaccates (27%). The group Varitriletes, including *Brevitriletes*, occurs next (25%) in abundance. Cingulate triletes, although poor in representation (6%), are also characteristic of this assemblage. The disaccates are very poor being represented only by ?*Striatites*.

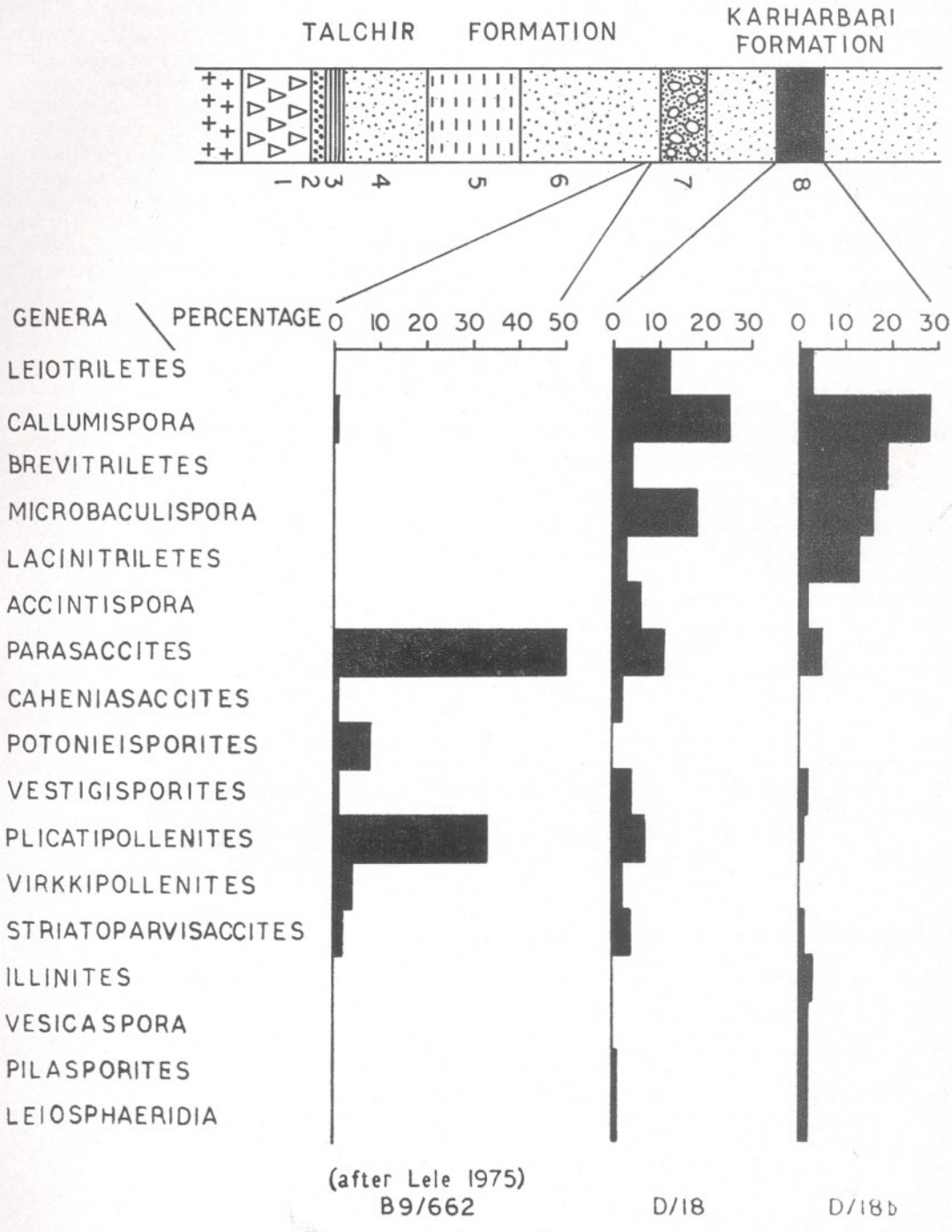
In the upper part of the coal bed (Sample no. D/18b) the percentage of *Callumispora* slightly increases while the apiculates and varitriletes increase in their total representation significantly. The monosaccates, on the other hand, decline appreciably. However, this represents a variation in the total representation of various groups in the vertical sequence within the same coal bed. The preservation of miospores is also poor and they are not completely released from the matrix.

The overall representation of the genus *Callumispora* associated with high percentage of radial monosaccates is a characteristic feature of the miofloral assemblage described here. Such a mioflora is usually associated with the first carbonaceous/coaly sediments occurring immediately above or in close proximity with the underlying Talchir sediments (a coal-less sequence) of the Lower Gondwana of India. In the neighbouring North Karanpura Coalfield (Kar, 1973), the mioflora obtained above the Talchir Stage contains similar dominance of trilete miospores followed by subdominant monosaccates. In this respect it compares very closely with the Dudhi River assemblage described here but differs in having lower percentage of *Callumispora* and very low incidence of *Microbaculispora*. The occurrence of *Callumispora* dominant phase is also recorded from the subsurface of Korba Coalfield (Bharadwaj & Srivastava, 1973) where it occurs immediately above the coal-less Talchir sediments. The genus *Microbaculispora* occurs up to 16 per cent in sample no. 130 but decreases to less than 5 per cent in younger sample of the Korba Coalfield. However, the zonate triletes are almost absent and thus, it differs from the Dudhi River assemblage. The first coal bearing sediments associated above the Tachir sediments in Giridih (Srivastava, 1973) and Jayanti (Lele & Makada, 1974) coalfields also contain *Callumispora* dominant assemblage. The former compares with the present assemblage in having higher percentage of *Brevitriletes* but differs in the total absence of zonate triletes. The Jayanti Coalfield mioflora described from Banskupi and Misra Village compares in view of the high incidence of *Callumispora* but differs distinctly in the absence of *Microbaculispora*, *Brevitriletes* and zonate triletes.

Thus, the present available evidences indicate that *Callumispora* + monosaccate rich zone occurs immediately above the Talchir Stage and represents the Lower Karharbari Stage of the Lower Gondwanas of India. In West Bokaro Coalfield also the *Callumispora* rich assemblage confirms the occurrence of Lower Karharbari Stage in the first coal bearing sediments associated above the Talchir Stage.

DISCUSSION

The presently studied Dudhi River section is a good representative sequence of Talchir Formation. The polished pavement of



HISTOGRAM 1 — Showing miofloral composition of Talchir Formation and Karharbari Formation.

metamorphics, although limited in outcrop, exhibits groove-like markings, whose trend as mentioned earlier, is north-west—south-east. The present day slope of the metamorphics is towards south-east with a probability of little change in the slope of the pavement rocks. Therefore, it can be presumed that the ice would have moved from north-west to south-east along the slopes under the influence of gravity. However, at present there is no evidence at hand about the palaeoslope of the metamorphics in this region.

The suggested probability of palaeoslope direction conforms the observations of Ghosh and Mitra (1967) except the presence of grooves over the basement metamorphics from the Dudhi River section which is being reported here for the first time. The direction of grooves trending north-west—south-east agrees with that proposed by the above authors who deduced the direction of ice flow indirectly from a study of dimensional fabric exhibited by the clasts embedded in the tillite. The earlier record of similar markings from Penganga River at Irai suggests a SW-NE direction while that from the Adjai (or Ajai) River indicates almost N-S alignment (Smith, 1963, 1963a). In Son Valley the pavement striations are oriented south-east to north-west (Ahmad & Hashimi, 1974). In Giri River section (Himachal Pradesh) the pavement striations are oriented north-west to south-east (Singh, 1975). Obviously, the direction of striations from these exposures and that of the present one do not coincide with each other. It has been concluded by Robinson (1967) that in general the movement of Talchir glaciers was towards north or north-east on the Indian Peninsula. However, Pascoe (1959) generalized that ice flowed from west to east at the beginning of Talchir sedimentation in Damodar Valley. Lately Ghosh and Mitra (1975) have studied the history of sedimentation of Talchir sediments in various basins of Damodar Valley and on the basis of fabric studies they concluded that the general trend of ice movement in this valley has been from north-west—south-east or due east-south-easterly except in Raniganj Coalfield. Therefore, the south-east trend of the glacier movement depicted by the groove-like markings at Dudhi River is obviously in perfect harmony with these observations.

The groove-like markings reported here are very much unlike the known record of striations in India. These are about 2 to 5 cm wide and deep furrows in the polished granitic basement. Though the outcrop is limited in extent, the grooves were observed carefully in view of their authenticity and usefulness as the most reliable indicators of glacial movements. The authors have critically observed these features in view of the following possibilities.

These linear depressions are only superficial in nature and, hence, are different than the set of joints present in the granites. The vertical continuity in the joints can be very well traced, whereas in the grooves it is absent. The possibility of grooves being formed due to veins, which are now dissolved leaving their traces in the form of furrows, is also ruled out as the grooves are not so straight and regular like a vein.

Therefore, these marks seem to be of glacial origin as they cannot be made through other agency. Their glacial origin is also supported by the fact that their trend is north-west—south-east. The ice movement from north-west—south-east has also been proposed by Ghosh and Mitra (1975) from the same area on the basis of fabric studies. The irregular pattern of these groove-like markings, however, is the character which is not comparable with the known regular glacial striations seen in other areas.

In the present investigation, the samples from typical Talchir lithology have not yielded miospores but available evidences (Lele, 1975) show the presence of radial monosaccates in them. The Talchir sediments from other contemporaneous horizons are also known to contain similar dominance of radial monosaccates. The first carbonaceous bed, immediately overlying it, contains the *Callumispora* + monosaccate rich mioflora and represents the Lower Karharbari Stage in Dudhi River section of West Bokaro Coalfield.

The evidence of plant life is generally very scanty in the typical glacial Talchir sediments. The tillites associated with the archaean basement in Korba Coalfield (Sample nos. 145-143; Bharadwaj & Srivastava, 1973) and West Bokaro Coalfield (Sample nos. B16/662, B19/662; Lele, 1975) contain very rare amount of miospores. These provide an additional evidence that plants although coexistent with the Talchir

glaciation could not diversify due to the extreme severity of the palaeoclimatic conditions. On the other hand, as the palaeoclimate ameliorated towards a more congenial habitation, the plant life developed significant diversification. This fact is evident as rich miospore assemblages are recorded from the younger part of the Talchir sediments only. In West Bokaro Coalfield (Sample no. B9/662; Lele, 1975) the mioflora of the topmost siltstone is amply rich containing 26 per cent of radial monosaccates. Similarly, in Korba Coalfield (Bharadwaj & Srivastava, 1973), Jayanti Coalfield (Lele & Karim, 1971; Lele & Makada, 1972) and Johilla Coalfield (Potonié & Lele, 1961; Lele, 1966) the diversified miospore assemblages are associated with the younger part of the Talchir sequence.

The end of the Talchir sedimentation in Dudhi River section is lithologically marked by the Upper Boulder Bed which is overlain by a thick succession of sandstone containing intercalations of shale and coal. The mioflora also changes at this level as the monosaccate reign of the Talchir sequence declines to subdominance while *Callumispora* makes up the replacement — a mioflora typical of the Lower Karharbari Stage. The existence of Karharbari Stage in this part of West Bokaro Coalfield has remained debatable. Recently Ghosh and Mitra (1975) have distinguished it on the basis of distinct lithological variations. The occurrence of *Callumispora*-rich zone provides additional evidence of the existence of Karharbari Formation above the Talchir Formation in Dudhi River Section of West Bokaro Coalfield.

CONCLUSION

The Dudhi River section provides a fairly complete sequence of the Talchir Formation overlain by Karharbari Formation. The polished pavement bearing groove-like markings trending north-west—south-east provides additional evidence of glaciation at the dawn of Talchir sedimentation. The tillites and rythmites at the basal part of the sequence yielded a limited amount of miospores but in the upper part of the sequence as the conditions of sedimentation changed from glacial to fluvioglacial or fluvial, the mioflora diversified both qualitatively and quantitatively. The end of the Talchir sedimentation is marked by the Upper Boulder Bed overlain by coarse grained sandstone with grits containing intercalations of shale and coal. At this juncture monosaccate mioflora of the Talchir Formation is replaced by *Callumispora*-rich mioflora of Lower Karharbari Stage.

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EXPLANATION OF PLATE

PLATE 1

1. General view of the grooves on the basement rock, distant view.
2. Another view of the same as in fig. 1-a close up.
3. Basal Boulder Bed (Tillite) showing unsorted nature of boulders showing striations on one of them.
4. A portion of the laminated shale exposed in basal part of the sequence (Bed no. 3).

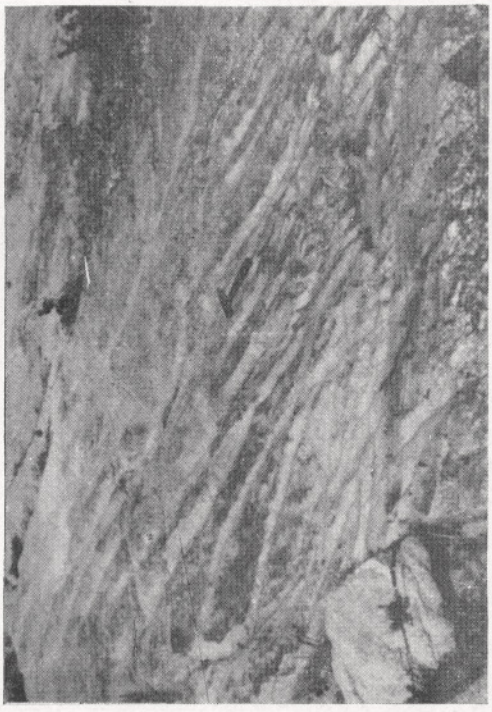

PLATE 1