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Stratigraphic Significance of the Cambrian Ichnofauna of the Zanskar Region, Ladakh Himalaya, India

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Abstract: The Cambrian succession in the Zanskar Basin of Tethys Himalaya contains an abundant ichnofossils like in the other Tethyan Himalayan successions. The ichnofossils are stratigraphically important as they occur below the trilobite body fossils and are useful to define the basal part of the Cambrian. The ichnofossil assemblage reported from the Zanskar Basin of Ladakh Himalaya is significant to demarcate the Early Cambrian age due to lack of other faunal elements so far. The body fossils of trilobites recorded from the overlying beds indicates the earliest part of the Middle Cambrian age. Sixteen ichnogenera identified include: *Bifungites, Cruziana, Diplichnites, Dimorphichnus, Isopodichnus, Lockeia, Merostomichnites; Monomorphichnus, Psammichnites, Palaeophycus, Planolites, Rhizocorallium, Skolithos, Taphrhelminthopsis, Teichichnus, Trepitichnus* and trilobite scratch marks etc. The ichnogenera reported so far from this part of the Tethyan Himalayan region belongs mostly to the traces of arthropod origin. The ichnofauna ranges in age from Lower Cambrian to late part of the Middle Cambrian. The ichnofaunal assemblage can be assigned to repichnial, cubichinial, pascichnial, to fodinichnial behaviour. The distribution of ichnofossils in the studied sections shows that the ichnofossils are predominately less in occurrence in the sections were trilobites dominates and higher in the successions the abundance of ichnofossils decreases.

Keywords: Ichnofossils, Cambrian, Zanskar, Ladakh Himalaya.

INTRODUCTION

The Zanskar Basin lies between the Great Himalayan Range in the southeast and the Indus valley in the northeast. The Zanskar region exposes a thick succession of Cambrian strata. The geological studies of the Lower Paleozoic sequences of the Zanskar Basin as well as the ichnofossil studies, in particular, are rather scanty. The studied Cambrian rocks are located in the Karsha, Purni, Phuktal, Kuru, Tanze Thaple and Kurgiakh areas of the Zanskar region. The study area lies within the latitude 33° 00' to 33°15' N and longitude 77°05' to 77°15' E in southeastern part of the Zanskar Basin of the Kargil district in Jammu and Kashmir. The area is situated 200 km southeast of the Kargil village and 49 km southeast of Padam village in the Niri-Tsarap Chu and Kurgiakh valleys (Figs.1a, b and c).

The ichnofossils have been recorded from the Tethyan Himalayan regions of Kashmir, Spiti, Kinnaur, and Kumaun from late Proterozoic and early Paleozoic and also from the Cambrian successions in some parts of the Lesser Himalayan regions. The presence of trace fossils is very much useful for providing broad stratigraphical and paleoenvironmental constriction. The ichnofossils from Lower Cambrian succession of the Himalayan regions have a great significance for the demarcation of Precambrian-Cambrian boundary since no body fossil have been reported from the Lower Cambrian successions of Spiti and Zanskar. However, in recent years ichnofossils have been described in the Cambrian rocks from the Tethyan as well as from the Lesser Himalayan regions. The present ichnological studies are of considerable significance for tracing out the biogenic record in the pre-trilobitic Cambrian strata of the Zanskar region. They are equally useful in establishing the biostratigraphy of the Lower Cambrian succession in this region.

Hughes and Droser (1992) reported few trace fossils from the Doda Member of the Phe Formation. Parcha (1998) gave a systematic account of the few trilobite traces along with other traces from the Kurgiakh valley. Subsequently, Shah et al. (1998) reported some ichnofossil from the Zanskar valley. Hughes (2002) reported Late Middle Cambrian trace fossils from the *Lejopyge armata* horizon of the Zanskar Basin. The earlier record of ichnofossils from the studied sections of the Zanskar region is inadequate; consequently, the present ichnological studies are of considerable significance.

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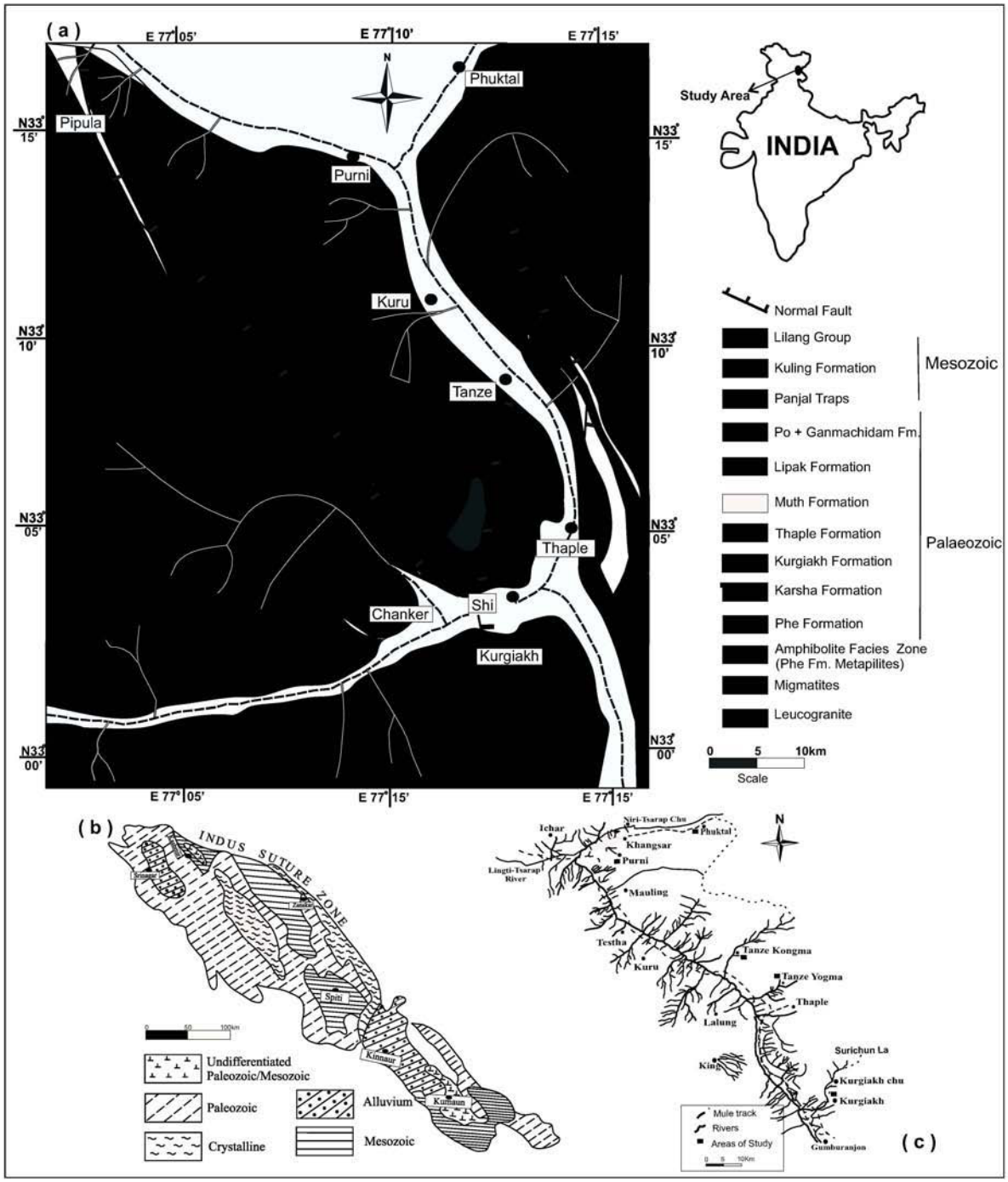

Fig.1. (a) Geological map of the Zanskar valley showing the Paleozoic- Mesozoic rocks of the Zanskar region of Ladakh Himalaya, India (modified after Dezes, 1999). **(b)** Inset showing the distribution of Tethyan basin of the Himalayan regions. **(c)** Route map of the study area

STRATIGRAPHY

In the Zanskar Basin of Ladakh Himalaya a complete succession of rocks ranging in age from Precambrian to Eocene are exposed. The Cambrian rocks of the Zanskar region belong to the Haimanta Group. Nanda and Singh (1976) classified the Lower Paleozoic rocks of the Southeastern Zanskar region under the Crystalline Suru Formation, Phe Formation, Karsha Formation and Thaple Formation. Subsequently, Srikantia et al. (1980) revised the stratigraphy of this region and adopted the same stratigraphic nomenclature as that of Spiti Basin. They divided the Haimanta Group into two formational units, the Batal and

Kunzum La Formations and further subdivided Kunzum La Formation into lower and upper Kunzum La Formation. Garzanti et al. (1986) revised the stratigraphy of the area and classified the rocks as Phe, Karsha and Kurgiakh Formations; they divided the Kurgiakh Formation into two members namely Surichun and Kuru Members. Myrow et al. (2006) introduced the term Parahio Formation for the rocks succession, which includes major part of the Phe Formation of Nanda and Singh and the overlying Mauling Member of the Karsha Formation of Garzanti et al. 1986 in this formation. However, in the present paper the litho-stratigraphic nomenclature of Garzanti et al. (1986) is followed.

The Phe Formation represents the lower most formational unit of the Haimanta Group. Garzanti et al. (1986) assigned a Late Precambrian to Early Cambrian age based on its stratigraphic position. On the basis of the trace fossils Late Precambrian to Early Cambrian age was assigned to the Phe Formation by Hughes and Droser (1992). The Phe Formation is succeeded gradationally by the Karsha Formation with the first appearance of the rusty dolomite band. The Karsha Formation comprises of olive green shale, siltstone, argillites, slate, phyllites, quartzite, which in turn is overlain by thickly bedded to massive dolomitic bands in regular alteration. In present course of studies, it was found that many quartz and calcite veinlets are traversing the rocks of Phe and Karsha Formations. The Kurgiakh Formation is characterized by lower shaly layer succeeded by siltstone, sandstone and dolomitic layers interbedded with shaly layers. The present ichnofossil assemblage was collected from Purni- Phuktal, Kurgiakh- Surichun La and from the Tanze-Yogma – Kogma sections (Figs. 2a, b).

The distribution of ichnofossils recorded from these sections are shown in Table 1. The distribution of the ichnogenera includes the fauna collected presently as well as collected by the earlier workers in these sections. The ichnofaunal distribution along these sections indicates that the simplest ichno forms occurs in the lower part of these sections, whereas the diversity and the complexity of ichno taxa increase as we go higher in the succession.

Repository: All the material is housed in the repository section of the Wadia Institute of Himalayan Geology Museum, Dehradun. The specimens are numbered from WIHG/A/1533 to 1547 and WIHG/A/1577-1584.

SYSTEMATIC ICHNOLOGY

In the present study sixteen ichnogenera were identified along with some trilobite scratch marks etc. The behavioural pattern of ichnofossil preservation represents basic biological functions such as feeding, crawling, dwelling, locomotion etc. The binomial system with alphabetical order has been followed to describe the ichnofossils.

Table 1. Distribution of Ichnofossils in the Southeastern Part of the Zanskar Basin of Ladakh Himalaya

Ichnogenera	Purni-Phuktal Section	Tanze-Kuru Section	Kurgiakh-Surichun Section
Bifungites	+	–	–
*Cruziana**	+	–	+
Chondrites	–	–	+
Didymaulichnus	–	–	+
Dimorphichnus	+	–	+
*Diplichnites**	+	–	+
Heliminthopsis	–	–	+
Isopodichnus	+	–	–
Lockeia	+	–	–
Merostomichnites	–	–	+
Monomorphichnus	+	–	+
Palaeophycus	+	–	–
Pasmmichnites	+	–	–
Planolites	+	+	+
*Protichnites**	–	–	+
Phycodes	–	–	+
Rhizocorallium	+	–	–
*Rusophycus**	–	–	+
Skolithos	+	+	+
Segmented Tubes	–	–	+
*Taphrhelminthopsis**	+	–	+
Teichichnus	+	–	–
Trepitichnus	+	–	+
Trilobite scratch marks*	+	+	+

Recorded + Not recorded —, * Earlier collections

Ichnogenus: *Bifungites* Desio, 1940
Ichnospecies: *Bifungites* isp. Fig. 3 (15)

Material: One block of thinly bedded siltstone. The specimen is preserved as positive hyporelief. The specimen is photographed in the field at outcrop.

Description: Spherical to semispherical openings partially connected by intermediate line, forming dumb-bell shaped structure, the trace have a width of 0.8 mm to 1.2 mm and are separated by distance of 0.3 mm to 0.4 mm.

Remarks: The Specimen shows resemblance with the ichnogenus *Bifungites* in the pattern of dumbbell shaped structure. *Bifungites* is known from the Lower Cambrian Successions of Pakistan (Seilacher, 1955) and from the Lower Cambrian succession of the Onega Peninsula.

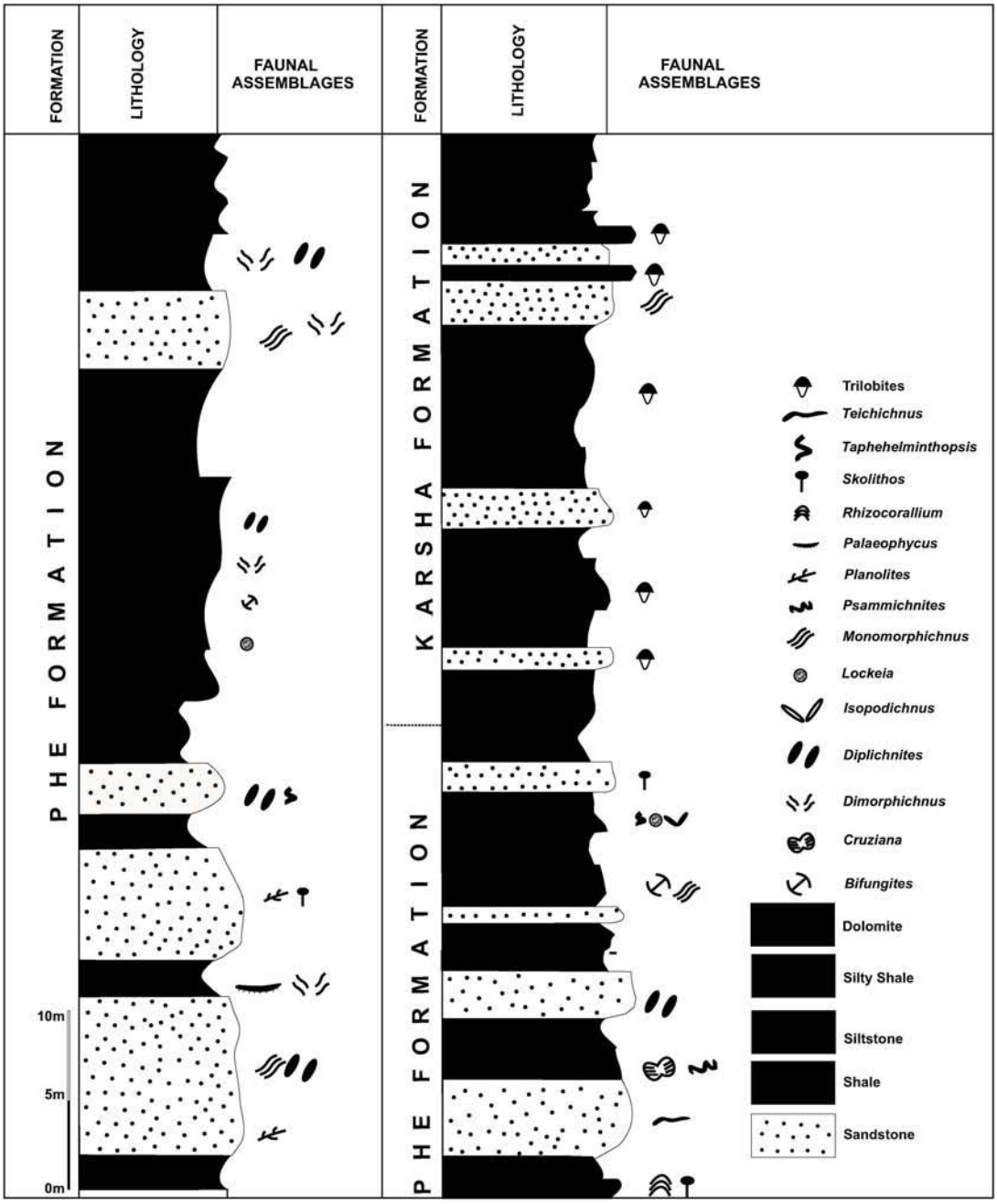

Fig.2a. Lithostratigraphic column of the Purni-Phuktal section showing the stratigraphic position of trace fossils

Occurrence: In the Purni – Phuktal section of Niri Tsarap Chu valley of the Zanskar region.

Ichnogenus: ***Cruziana*** D' Orbigny, 1842
Ichnospecies: *Cruziana* isp.
Fig.3 (3a)

Material: Single block of siltstone. The specimen is preserved as positive hyporelief.

Description: Bilobate, elongate two parallel ridges with slightly oblique scratch marks. Scratch marks are present on both the ridges, a well marked groove present, separating two lobes. The trace is 18 mm to 25 mm in width and 2 to 3 mm in depth.

Remarks: The specimen shows resemblance with the ichnogenus *Cruziana* in the pattern and nature of claw markings. This specimen of *Cruziana* may represent a new ichnospecies due to lack of good material and the absence of some diagnostic features prevents defining it as a new ichnospecies.

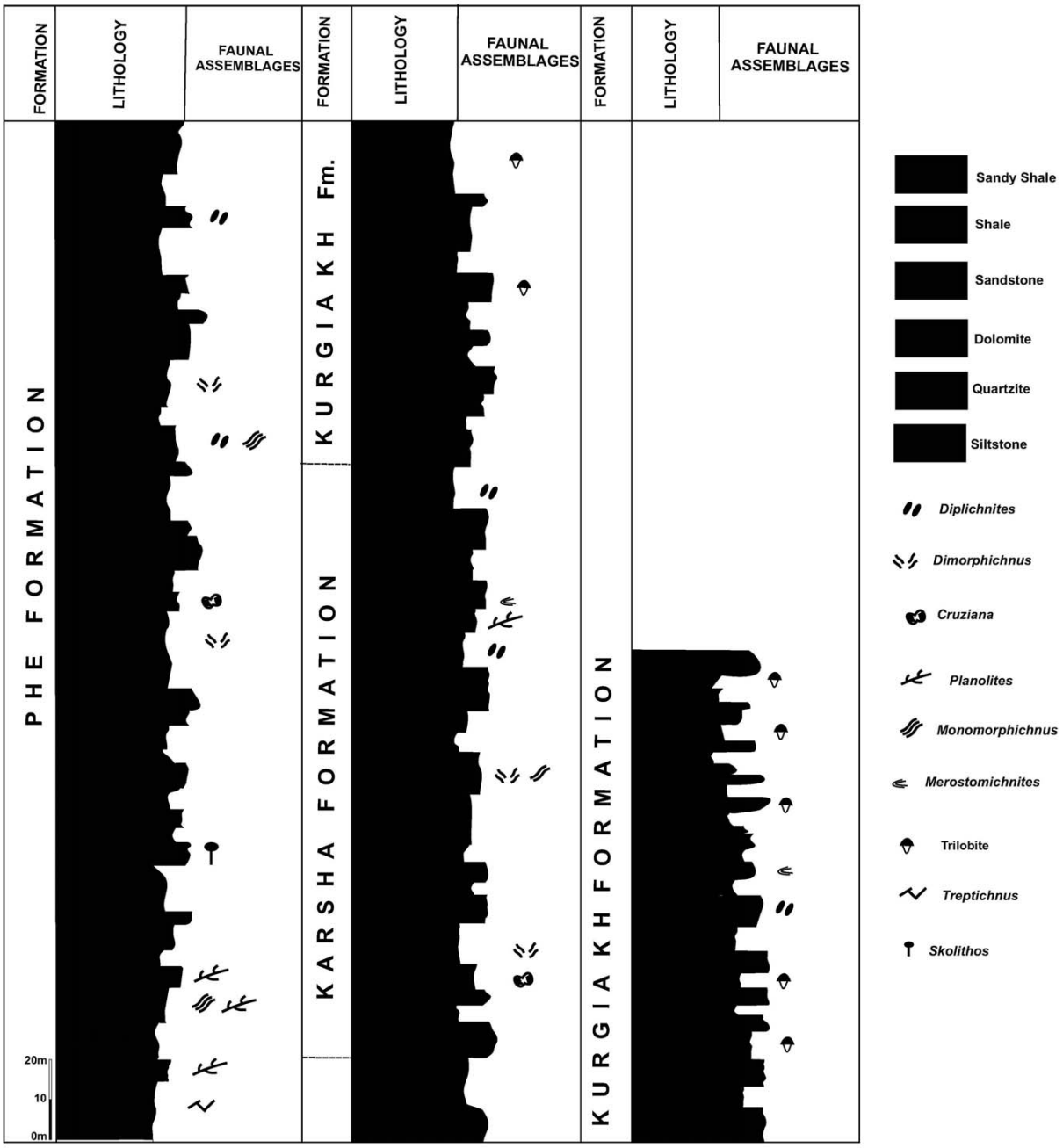

Fig.2b. Lithosratigraphic column of the Kurgiakh – Surichun La section showing the stratigraphic position of trace fossils.

Occurrence: In Purni- Phuktal section of the Niri Tsarap Chu valley of the Zanskar region.

Ichnogenus: ***Dimorphichnus*** Seilacher, 1955
Ichnospecies: *Dimorphichnus* isp.
Fig. 3 (10b, 14b, 17) and Fig. 4 (8, 11, 16)

Material: Comprises two block of siltstone, one block of shale. The specimens are preserved as convex hypo-relief.

Description: Parallel, paired, series of asymmetrical dots, wedges and rib shaped markings of varying size. The largest track is 113 mm long and 3 mm to 6 mm aparted from one another. The longest pairs of rib shaped markings are varying from 9 mm to 16 mm in length and in width these markings vary from 0.5 mm to 1.2 mm. Some markings are too small; it is difficult to measure the width of each marking. Some markings shifted towards the other side, thereby suggesting the changes in the movement of the animal on the substrate. In one row, maximum 17 pairs of imprints are present.

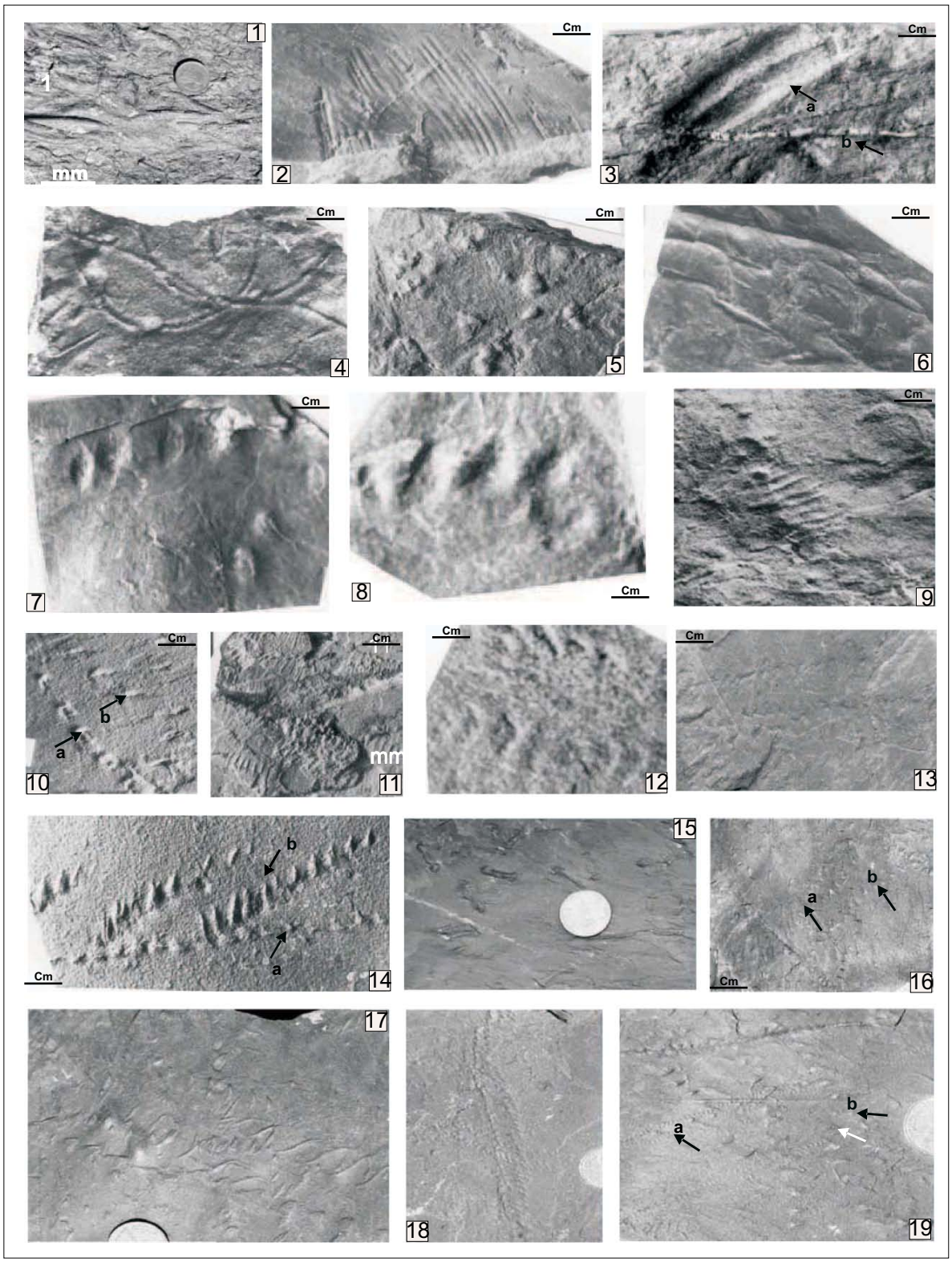

Fig.3. 1. *Treptichnus pedum,* **2.** *Monomorphichnus* isp. A. **3a.** *Cruziana* isp., **3b** *Psammichnites* isp. **4.** *Taphrhelminthopsis* cf. *circularis.* **5.** *?Isopodichnus* isp., **6.** *Planolites* isp. A, **7-8.** *Lockeia* isp., **9-11.** *Monomorphichnus* isp., B. **10a.** *Diplichnites* isp. A. **10b**. *Dimorphichnus* isp.*,* **12.** *Merostomichnites* isp., **13.** *Diplichnites* isp. B. **14a.** *Diplichnites* isp. B. **14b**. *Dimorphichnus* isp.*,* **15.** *Bifungites* isp.*,* **16a.** *Psammichnites* isp. **16b.** *Diplichnites* isp. A., **17.** *Dimorphichnus* isp., **18.** *Diplichnites* isp. B., **19a.** *Psammichnites* isp. B. *Diplichnites* isp. A. Coin = 2.5 cm

Remarks: The specimens apparently show the resemblance with the *Monomorphichnus* in the one set of curved and sub parallel ridges, whereas in the present form the ridges are sub parallel and paired which makes it comparable with *Dimorphichnus*. Probably it may represents side way moving traces of single clawed trilobite. The specimens differ from the ichnospecies of *Dimorphichnus* described by Bhargava et al., (1982) from Spiti in the nature and pattern of markings of the traces. The present specimen differs from all other known ichnospecies of *Dimorphichnus*. The ichnogenus *Dimorphichnus* is known from the Lower Cambrian successions of Salt Range (Seilacher, 1955), Wales (Crimes, 1970a), Middle Cambrian of Sweden (Martinson, 1965), from Upper Cambrian of Poland and USSR (Radwanski and Roniewicz, 1963).

Occurrence: In the Purni-Phuktal section of the Niri Tsarap Chu valley and in the Kurgiakh section of the Zanskar region.

Ichnogenus: *Diplichnites* Dawson, 1873
Ichnospecies: *Diplichnites* isp. A
Fig.3 (10a, 16b, 19b)

Material: Comprises of two blocks of shale and two blocks of sandstone. The specimens are preserved as hyporelief.

Description: Parallel series of ridges, individual ridges elongate and oblique to the track axis. The distances between the two rows are about 1 mm to 4 mm, thickness and length of each ridge varies from 2 mm to 3.5 mm, distance between the two ridges varies from 0.5 mm to 2 mm. The paired marks occur in a row up to a distance of 39 mm and then shift towards the left and right. This disposition of tracks suggests that the animal have moved laterally. It is considered that the traces have been produced by an arthropod while walking or striding

Remarks: Diplichnites has been recorded widely in Cambrian rocks (Seilacher, 1955; Dzulynski and Zak, 1960; Radwanski and Roniewicz, 1963; Martinson, 1965; Hecker and Zahakov, 1966; Crimes, 1970a). The present specimens are grouped under the ichnogenus *Diplichnites* due to its similarity in the nature and pattern of ridges.

Occurrence: In the Purni-Phuktal section of the Niri Tsarap Chu valley and in the Kurgiakh–Surichun La section of the Zanskar region.

Ichnospecies: *Diplichnites* isp. B
Fig.3 (13, 14a, 18) and Fig.4 (3, 9, 14)

Material: The material comprises of two block of sandstone and one block of siltstone. The specimens are preserved as epirelief as well as in hyporelief.

Description: Series of parallel ridges, which are wedge shaped and dissimilar. The length of an individual ridge varies from 1.5 mm to 3 mm and the width of each ridge varies from 0.5 mm to 1 mm. The distances between the two rows are about 1 mm to 1.5 mm, while the individual ridge is parted from one other by a distance of 3 mm to 5 mm.

Remarks: The present specimen differs from the *Diplichnites isp*. A, in the nature and pattern of ridges. The specimen differs from the species of *Diplichnites* described by Bhargava et al. (1982) from the middle part of the Kunzum La Formation of Spiti. The specimen equally differs from the species described by Shah et al. (1998) from the Kurgiakh section of Zanskar region

Occurrence: In the Purni-Phuktal section of the Niri Tsarap Chu Valley and in the Kurgiakh –Surichun La section of the Zanskar region.

Ichnogenus: *Isopodichnus* Bornemann, 1889
Ichnospecies: ? *Isopodichnus* isp.
Fig.3 (5)

Material: Comprises one block of siltstone. The specimen is preserved as positive relief.

Description: Cluster of five to six small almond shaped ridges; arranged in radial pattern preserved as hyporelief, the ridges are 5 mm to 8 mm in length and 2 mm to 3 mm in width.

Remarks: The specimen resembles with the ichnogenus *Isopodichnus* in the nature of median ridge, which is weak in the present specimens and with the shape of the trace. It is mostly considered as dimorphus trace.

Occurrence: In the Purni-Phuktal section of the Niri Tsarap Chu valley of Zanskar.

Ichnogenus: *Lockeia* James, 1879
Ichnospecies: *Lockeia* isp.
Fig.3 (7, 8) and Fig.4 (7)

Material: Comprises of two blocks of siltstone. The specimens are preserved as positive relief.

Description: Small almond shaped structures preserved as convex relief on bedding plane and concave relief on sole of the bed. An individual is composed of 4 to 6 small structure varies from 2 mm to 8 mm in length and 2 mm to 5 mm in width. The structures are parted from each other nearly by 1 mm to 6 mm.

Remarks: The specimens resemble with the ichnogenus

Lockeia (= Pelecypodichnus) in the morphology and in the relief features. The majority of workers e.g. (Seilacher, 1953; Osgood, 1970; Hallam, 1970; Hakes, 1977; Kamola, 1984) have interpreted these almond shaped traces to have resulted from resting bivalves. Maples and West, (1989) addressed the confusion caused over the past two decades by the dual use of *Lockeia* and *Pelecypodichnus* (Seilacher, 1953) for this singular trace fossil, citing strong evidence for the valid use of the ichnogenus *Lockeia* (Bromley and Asgaard, 1972), although subsequently rejected by (Bromley and Asgaard, 1979; Pollard, 1981; Metz, 1989; Pollard and Hardy, 1991). Metz, 1995 also reported *Lockeia* from the southeastern Pennsylvania. The specimens differ with the all known species of *Lockeia (=Pelecypodichnus)* described by Hakes in Crimes and Harper, 1977.

Occurrence: In the Purni-Phuktal section of the Niri Tsarap Chu valley of Zanskar.

Ichnogenus: *Merostomichnites* Packard, 1900
Ichnospecies: *Merostomichnites* isp.
Fig. 3(12)

Material: Comprises of single block of sandstone. The specimen is preserved as epirelief.

Description: Spindle, bow shaped transversely expanded opposite impressions; impressions are parallel and nearly at 6 mm interval; each spindle is nearly 8 mm in length and 2 mm in width

Remarks: The specimen shows close resemble to the ichnogenus *Merostomichnites* in bow shaped ridges. The specimen differs with the *Mersitomichnites* ichnospecies described by Parcha and Pandey from the Spiti Basin in its morphological characters particularly in the length and width of the spindles (paper communicated)

Occurrence: In the Kurgiakh- Surichun La section of the Kurgiakh valley of the Zanskar region.

Ichnogenus: *Monomorphichnus* Crimes, 1970a
Ichnospecies: *Monomorphichnus* isp. Type A
Fig. 3 (2) and Fig. 4 (13)

Material: Comprises of three blocks of sandstone and three blocks of siltstone. The specimens are preserved as positive epirelief.

Description: A set of isolated, slightly curved, sigmoidal ridges, repeated laterally. The ridges vary in length from 0.8 mm to 34 mm. The width of each ridge varies from 0.5 mm to 0.8 mm. Ridges are parted from one another by 0.4 mm to 0.7 mm. In some specimens the tracks form a series of sigmoidal grooves.

Remarks: The present specimens differ from the species of *Monomorphichnus* described by Bhargava et al. (1982) from the Spiti valley of Himachal Himalaya. The present species differ from *Monomorphichnus bilineatus* Crimes, (1970a) in the pattern, shape and size of the ridges. The specimens equally differ with the species of *Monomorphichnus monolinearis* described by Shah and Sudan, (1983) from Kashmir and from Zanskar by Shah et al. (1998) in the pattern, shape and size of the ridges.

Occurrence: In the Purni-Phuktal section of the Niri-Tsarap Chu valley and in the Kurgiakh-Surichun La section of the Kurgiakh valley of the Zanskar region.

Ichnospecies: *Monomorphichnus* isp. Type B
Fig. 3 (9, 11)

Material: Comprises of two block of siltstone, the specimen are preserved as positive relief.

Description: Slightly curved grooves, grooves are 0.2 mm to 0.5 mm in length and are about 0.5 mm to 0.1 mm wide. The present specimen comprises of eleven curved grooves.

Remarks: The present specimen differs from the *Monomorphichnus monolinearis* as the latter have a single and nearly parallel pattern of ridges, which is lacking in the present specimens. The specimens differ from the *Monomorphichnus isp*. Type A, in size, pattern and width of grooves. Parcha (1998), also reported *Monomorphichnus isp* from the Kurgiakh section of Zanskar. The specimen also differs from the species described by Shah et al. (1998) from the Zanskar region.

Occurrence: In the Purni-Phuktal section of the Niri-Tsarap Chu valley of the Zanskar region.

Ichnogenus: *Psammichnites* Torell, 1870
Ichnospecies: *Psammichnites* isp.
Fig. 3 (3b, 16a, 19a)

Material: Comprises of three blocks of siltstone. The specimens are preserved as positive hyporelief

Description: Horizontal burrow, burrow shows meniscate structures and central, straight to slightly sinuous cord and axial depressions prominent in the middle level of the trace. Length of the burrow ranges 35 mm to 45 mm and width from 6 mm to 9mm and the preserved thickness from 2.0 mm to 5.0 mm.

Remarks: The sinuous track and axial depressions are prominent in the middle level of the trace, which shows that the present specimens resembles closely to the ichnogenus *Psammichnites* in its morphological characters particularly

in the sinous nature of the tracks.. This ichnogenus is reported from Europe by Gamez et al. (2006) from the Lower Cambrian successions.

Occurrence: In the Purni-Phuktal section of the Niri-Tsarap Chu valley of the Zanskar region.

Ichnogenus: *Planolites* Nicholson, 1873.
Ichnospecies: *Planolites* isp. Type A
Fig. 3 (6) and Fig.4 (15)

Material: Comprises five blocks of sandstone. The specimens are preserved as positive relief.

Description: Straight to slightly irregularly curved burrows, tubes 8 mm to 24 mm long and 0.5 mm to 4 mm wide circular tubes. These burrows, tubes are unbranched, curved, irregularly developed and slightly expanded at one end. Overall structures are gently inclined to bedding plane. The sediment filling of the tubes are made up of same material as of the host rock. One of the specimens is like a horizontal shaft with the openings like a funnel and slightly curved and is comparatively wider than the other tubes.

Remarks: The specimen shows some resemblance with the ichnogenus *Planolites*. *Planolites – Palaeophycus* nomenclature and its dilemma is discussed by Pemberton and Frey (1982), while discussing the ichnofossil nomenclature of *Planolites*. Several authors (Pemberton and Frey, 1982; Fillion, 1989; Fillion and Pickerill, 1990) have provided detailed information between the similar appearance of the ichnogenera *Planolites*, *Palaeophycus* and *Macaronichus*. Pemberton and Frey (1982) suggested that a free moving, deposit- feeding organism could be responsible for *Planolites*.

The present trace seems to fit under the given criterion of *Planolites* by Pemberton and Frey (1982). *Planolites beverleyensis* is equally reported from the Middle Cambrian of the Barrandian area of Czech Republic by Mikulas (2000). However, the present specimens differ from the *Planolites beverleyensis* in the nature and pattern of burrow. It is why they have been put in an open nomenclature.

Occurrence: In the Purni-Phuktal section of the Niri-Tsarap Chu valley and in the Kurgiakh – Surichun La and Tanze – Yogma area of the Zanskar region.

Ichnospecies: *Planolites* isp. Type B
Fig. 4 (4, 5)

Material: Comprises of two blocks of sandstone, the specimens are preserved as positive hyporelief.

Description: Unbranched, partially infilled burrows, slightly curved at one end, the burrows varies from 20 mm to 45 mm in length and 3 mm to 4 mm in width; burrows lacking wall lining and collapsed features, in the second specimen burrows are very poorly filled and are shorter in length.

Remarks: The specimen differs with the *Planolites isp*. Type A, in the pattern and nature of burrow and in the dimensions. The present specimen equally differ with the *Planolites* ichnospecies described by Parcha (1998) from the Kurgiakh section of the Zanskar region in its burrow pattern.

Occurrence: In the Purni-Phuktal section of the Niri-Tsarap Chu valley and in the Tanze Yogma area of the Zanskar region.

Ichnogenus: *Palaeophycus* Hall, 1847
Ichnospecies: *Palaeophycus* isp.
Fig.4 (10)

Material: Comprises of single block of siltstone, the specimen is preserved as positive relief.

Description: Simple slightly curved, undulose, thinly lined burrow oriented horizontally to bedding plane, burrow filled with finer sediments but same as of the host rock. The burrow is 75 mm long and 70 mm in width, but the width increase towards one end of the burrow.

Remarks: The specimens resembles with the *Planolites* in the unbranched nature of the burrow. It differentiates with *Planolites* primarily because of wall linings and burrow sculpting. It differs from the specimens of *Palaeophycus tubularis, P. rugosus*, and *P. simplex* described by Pemberton and Frey (1982) in the nature of burrow. The specimens also differ from the ichnospecies *P. sulcatus* and *P. tubularis* described by Mikulas (2000) from the Middle Cambrian of the Barrandian area in the pattern and nature of burrow. The present trace seems to fit under the given criterion of *Palaeophycus* by Pemberton and Frey (1982).

Occurrence: In the Purni-Phuktal section, of the Niri-Tsarap Chu valley of the Zanskar region.

Ichnogenus: *Rhizocorallium* Zenker, 1836
Ichnospecies: *? Rhizocorallium* isp.
Fig.4 (1)

Material: Comprises of two blocks of siltstone. The specimens are preserved as positive relief.

Description: U-shaped transverse with a set of rows mostly oblique or parallel to bedding plane. The markings are turning outward on the margins; they are thick in the middle. The distance between the two markings is nearly 2 mm.

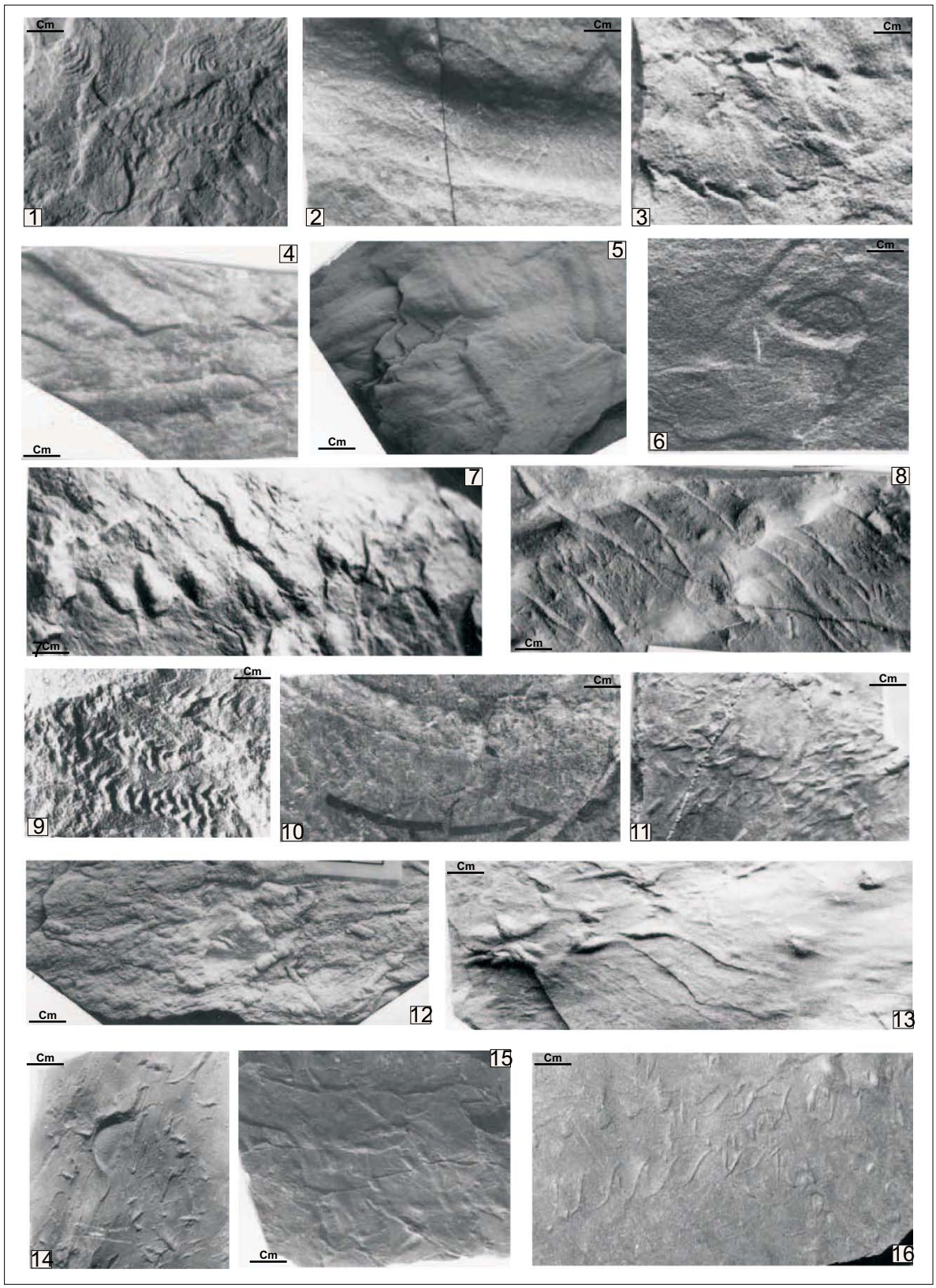

Fig.4. 1. *Rhizocorallium* isp., **2.** *Teichichnus* isp., **3.** *Diplichnites* isp. B. **4-5.** *Planolites* isp., B, **6.** *Skolithos* isp., **7.** *Lockeia* isp., **8.** *Dimorphichnus* isp., **9.** *Diplichnites* isp., B. **10.** *Palaeophycus* isp., **11.** *Dimorphichnus* isp., **12.** *Treptichnus pedum,* **13.** *Monomorphichnus* isp. A. **14.** *Diplichnites* isp. B., **15.** *Planolites* isp., A **16.** *Dimorphichnus* isp.

Remarks**:** The specimens show some similarity with the ichnogenus *Rhizocorallium* in the oriented burrow system. However, due to lack of other morphological characters, which seems may have been destroyed; the present specimens have been assigned tentatively to this ichnogenus. Fursich (1974), gives the detailed discussion regarding the ichnogenus *Rhizocorallium.* The present specimen does not show any resemblance with the known species of this ichnogenus.

Occurrence: In the Purni-Phuktal section of the Niri Tsarap Chu valley of the Zanskar region.

Ichnogenus: *Skolithos* Haldemann, 1840
Ichnospecies: *Skolithos* isp.
Fig.4 (6)

Material: Comprises two blocks of siltstone and one block of sandstone. The specimens are preserved as dwelling structure.

Description: Vertical, unbranched sub cylindrical burrows, the diameter of burrows ranges from 3 mm to 6 mm. The diameter of the burrow ranges from 0.4 mm to 0.8 mm; the burrows are widely spaced in the present specimen.

Remarks: In the entire material, no vertical sections are available in the material. The presently described ichnospecies shows some similarity with *Skolithos linearis* Haldemann (1840). The specimen differs with the species of *Skolithos isp*. described by Parcha (1998) from the Kurgiakh section in the nature and pattern of the burrow. *Skolithos* is interpreted as a dwelling structure produced by a wide variety of animals including polychaetes and phoronuids (Osgood, 1970; Alpert, 1974)

Occurrence: In the Purne-Phuktal section of the Niri Tsarap Chu and Tanze-Yogma area of the Kurgiakh valley of the Zanskar region.

Ichnogenus: *Taphrhelminthopsis* Sacco, 1888
Ichnospecies: *Taphrhelminthopsis* cf. *circularis*
Fig.3 (4)

Material: Two blocks of siltstone and one block of sandstone, the specimen are preserved as epirelief.

Description: Deep, narrow, bilobate trace with broad well defined central furrow, exhibiting irregularly circling habit with crossing pattern. Burrow width is ranging from 5 mm to 6 mm. The two lobes are separated by 0.1 mm to 0.2 mm wide medium furrow. No complete circles were observed.

Remarks: The presently described specimens show close resemblance with the *Taphrhelminthopsis circulari*s described by Crimes et al. (1977) from the Lower Cambrian strata of northern Spain. However, the specimen differs from the *Taphrhelminthopsis circularis* in absence of striations and lack of complete circles. The similarity is in the circling habit and fragmentary nature of the traces. The specimens differ from *Taphrhelminthopsis auricularis* (a freely winding form) and with the *Taphrhelminthopsis,* a rectum, which are more or less straight and shows a close similarity with the *Taphrhelminthopsis* cf. *circularis* described by Hughes and Droser (1992) from the upper part of the Tsarap Member of the Phe Formation. But in the present form, there are various bilobate traces exhibiting irregularity, while in the ichnospecies described by Hughes and Droser (1992) there is only one bilobate structure present.

Occurrence: In the Purni-Phuktal section, of the Niri-Tsarap Chu valley of the Zanskar region.

Ichnogenus: *Teichichnus* Seilacher, 1955
Ichnospecies: *Teichichnus* isp.
Fig. 4(2)

Material: The material comprises of single block of sandstone. The specimen is preserved as hyporelief.

Description: Large burrow forming, simple horizontally oriented, burrow, 133 mm in length, in which 70 mm are straight and rest of 66 mm are curved and width varies from 23 mm to 26 mm; maximum width is at the curvature point. Surface of the trace usually composed of small number of troughs, oriented upwards by concave surface. Troughs are moderately curved, surface of the troughs are smooth.

Remarks: The specimen differs with the *Teichichnus stellatus*, *T. zigzag* and *T. multiplex* in the nature and pattern of burrow, but shows resembles with *Teichichnus rectus* in unbranched and straight nature of burrow. The specimens differ from the *Teichichnus rectus* Seilacher (1955), reported from the Lower Cambrian successions of the *Neobolus* Sandstone beds of Salt Range in lack of burrow walls. The presence of faint transverse and parallel striations reflecting internal spreite structures are present in the specimen, due to which the present form can be grouped under ichnogenus *Teichichnus*. The ichnogenus *Teichichnus* is a very frequent inner feeding trace known from the Latest Precambrian to Cenozoic (Hantzschel, 1975).

Occurrence: In the Purni-Phuktal section of the Niri-Tsarap Chu valley of the Zanskar region.

Ichnogenus: *Treptichnus* Miller, 1889
Ichnospecies: *Treptichnus pedum* (Seilacher, 1955)
Fig. 3 (1), and Fig.4 (12)

Material: Comprises two blocks of sandstone. One sample is observed *in situ*. The specimens are preserved as hyporelief.

Description: Crowded short and curved burrows having branches. The burrows vary in width from 3 to 5 mm and in length from 7 to 20 mm. the main furrow bifurcating frequently to give rise to minor branches.

Remarks: The specimens differ from all other species of *Trepitichnus* in the nature of burrows, but closely resemble *Treptichnus pedum* in the pattern and nature of burrows. The specimens show some similarity with the specimens of Glaessner (1969) described from Lower Cambrian sequences of Central Australia. Seilacher (1955b) described similar traces earlier as *Phycodes pedum* from the salt Range, Pakistan. Jensen (1997) has given the generic shift to this ichnogenus from *Phycodes pedum* to *Treptichnus pedum* as this trace is formed by addition of segments.

Occurrence: In the Kurgiakh-Surichun La section of the Kurgiakh Valley of the Zanskar region.

DISCUSSION

Ichnofossils are abundant and diverse in many clastic sequences spanning the Precambrian-Cambrian boundary and may prove to be the most useful palaeontological method for global correlation in this stratigraphic interval (Crimes, 1987). Crimes (1970, 1975) and Seilacher (1970) have discussed the possibility of using ichnofossils to correlate Phanerozoic strata. The trace fossils have been reported from the Lower Cambrian succession of the Spiti, (Bhargava et al., 1982; Bhargava and Bassi, 1988; Bhargava and Srikantia, 1985; Sudan et al. 2000; Sudan and Sharma, 2001; Parcha et al. 2005); Zanskar (Hughes and Droser, 1992; Parcha, 1998; Shah et al. 1998; Hughes., 2002); Kumaun (Banerjee et al. 1975; Sudan and Sharma, 2000); Kashmir (Bhargava and Srikantia, 1982; Shah and Sudan, 1983; Raina et al. 1983) Tal Formation (Banerjee and Narain, 1976; Singh and Rai, 1983; Bhargava et al. 1998; De et al. 1994; Tiwari and Parcha, 2006) and Rajasthan by (Kumar and Pandey, 2008).

The ichnofossil collected from the Cambrian successions of the Zanskar region are important elements in deciphering the age of pre-trilobite bearing beds. The distribution pattern shows that there is no record of body fossils so far from the basal part of the Haimanta Group in the Zanskar region of Ladakh Himalaya. The presence of trace fossils of arthropod origin and in particular that of trilobites are of much stratigraphic significance, due to the relationship of the morphospecies with their genetic body form (Parcha, 1998). In the Niri Tsarap Chu and Kurgiakh valley of the Zanskar, the ichnofossil assemblages occurs much below the trilobites bearing beds and it has been observed that the horizons rich in ichnofossils are devoid of body fossils. Exceptionally there are few horizons particularly in the Kurgiakh – Surichun La section and in the Tangze Yogma – Kuru section were few trace fossil occur within the same horizons in which body fossils are present. Absence of trilobites in the trace fossil rich horizons appears to be worldwide phenomenon (Seilacher, 1955; Radwanski and Roniewicz, 1963; Crimes, 1970b). In the Zanskar region of Tethys Himalaya, the trilobite traces like *Cruziana Rusophycus*, *Monomorphichnus* and *Dimorphichnus* are reported from the Kurgiakh valley (Parcha, 1998; Shah et al. 1998). In the present study, the recorded trace fossils from all the three sections represent age from Early to Middle Cambrian. The distributional pattern of trace fossils shows increase in taxonomic and morphological diversity up in the sections. It has been noticed that in the lower horizons traces produced by vermiform animals like *Planolites, Taphrhelminthopsis* and *Trepitichnus* are present. Whereas, higher levels are characterized by the presence of *Cruziana, Diplichnites, Monomorphichnus,* scratch marks, with the appearance of traces of arthropod origin in association with other traces of unknown origin equally dominates with these trace fossils. *Planolites* is known from the late Precambrian (Narbonne and Hoffman, 1987) as well as from the Pleistocene sediments (Wetzel, 1981), is a facies independent form (Crimes, 1970). *Monomorphichnus* is known from the Earliest Cambrian (Narbonne and Myrow, 1988) to Triassic (Shone, 1979), is a facies independent from the shallow marine, estuarine and fluvial environments (Fillion and Pickerill, 1990). *Trepitichnus* ranges in age from the Lower Cambrian to the Carboniferous (Jensen, 1997) and indicates a low energy shallow marine environment. *Skolithos*, is known from the Late Precambrian (Fedonkin,1985) to the Pleistocene (Pemberton and Jones, 1988), is found mainly in shallow marine high energy environment, but is also reported from the deep waters (Alpert, 1974) and also in the flood plains (Curran and White, 1987). *Taphrhelminthopsis circularis* is known to occur in the pre-trilobitic Cambrian and in some cases ranges low into the trilobite bearing Cambrian (Crimes, 1987; Pillola et al. 1994; Macnaughton and Narbonne, 1999) thus have a utility for biostratigraphical resolution. The co-occurrence of *Cruziana* and *Diplichnites* indicates a low energy environment, *Cruziana* ranges in age from Cambrian to Triassic (Bromley and Asgaard, 1979). *Diplichnites* is widely known from the Cambrian and equally from the Triassic fresh water sediments of Greenland (Bromley and Asgaard, 1979) indicate a low energy environment (Crimes et al. 1977). These traces occur much below the Middle Cambrian trilobite bearing horizons, while only few

ichnofossils like *Skolithos* and *Planolites* are found in the trilobite bearing beds.

On the basis of the traces fossils of the Kurgiakh – Surichun La section with trilobite bearing horizon, it is true one can assign the age of that level on the basis of trilobites as well as trace fossils occurring at the same level at same horizon. But in the present studies not only the Kurgiakh-Surichun La section but infact in other two well exposed and well preserved sections namely Purne-Phuktal and Tanze-Yogma-Kuru sections trace fossils were recorded from the Lower Cambrian, whereas the body fossils have not been recorded so far from any of these sections. While observing the distribution of ichnofossils it has been found that the traces of definite arthropod origin are well preserved and documented in the Purne-Phuktal section as well as in the Kurgiakh-Surichun La section. It is fact that the ichnofauna alone are not useful to provide a high-resolution stratigraphy for the Himalayan Cambrian successions. However, in absence of trilobites particularly in the earliest part of the Lower Cambrian these ichnofossils are key element to decipher the stratigraphy of the Lower Cambrian successions in all most all the part of the Tethyan and Lesser Himalayan successions in general and in particularly for the Zanskar region. So in absence of typical diagnostic trilobite fauna of the Lower Cambrian age the ichnofossils has a significant role in assigning the age of the strata in the Tethyan Himalayan successions. Hence, the present collection of ichnofaunal assemblage in absence of body fossils has a greater significance in assigning a Lower Cambrian age of the Zanskar region.

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