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THE PRECAMBRIAN-CAMBRIAN TRANSITION INTERVAL IN HIMALAYA WITH SPECIAL REFERENCE TO SMALL SHELLY FOSSILS - A REVIEW OF CURRENT STATUS OF WORK

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ABSTRACT

The recognition and biostratigraphic evaluation of small shelly fossils (SSF) in the strata of Himalayan region in recent years has led to proper understanding of the Precambrian-Cambrian transition levels, both in the Lesser Himalaya as well as in the Higher Himalaya ('Tethyan Himalaya'). Prior to this breakthrough the transition from Precambrian to Phanerozoic was poorly and imprecisely understood in the Himalayan sequences.

The demarcation of Meishucunian Zone I, Meishucunian Zone III and Qiongzhusian (upper part) levels, defining the latest Precambrian-Early Cambrian time-span in the Tal Formation in the western Lesser Himalaya, is achieved. This is based on the identification of varied assemblages of SSF, supported and confirmed by the records of fossil brachiopod and trilobite assemblages.

A SSF-bearing probable Meishucunian Zone I level has also been identified in the Higher Himalayan sequence in Kashmir, yielding fossil-facies containing elements similar to that of the Tal Formation in Lesser Himalaya. This in conjunction with the presence of redlichiid trilobite assemblages both in the Higher Himalaya and in the Lesser Himalaya may indicate sedimentational link between the two domains in the Late Precambrian - Early Cambrian.

A SSF assemblage, tentatively put equivalent to Meishucunian Zone I, has been recorded from the topmost part of Krol Formation in the Nainital Syncline. This has imparted a more precise chronostratigraphic status to the Krol Belt sequence at Nainital also.

The previously published record of SSF from the supposedly Krol strata of the Mussoorie area is concluded to be the SSF yield of the Tal sequence, tectonically wedged within the Krol Formation.

Many other recently published records of SSF from Lesser Himalaya are evaluated to be mineral grains, sediment pellets, pseudofossils or laboratory contaminations.

INTRODUCTION

The concept that links the bio-event marking the initial appearances of shelled metazoa on the globe, manifested by small shelly fossils (SSF), with the emergence of Phanerozoic Eon in the earth's stratigraphic column lately has become an universally accepted tenet of chronostratigraphy (Cowie, 1985). Thus the latest concept of the base of Cambrian System has come to acquire a direct bearing on the presence and distribution of SSF.

The SSF include a variety of animals at the lowest of the evolutionary tree that possessed, for the first time, the modern organic ability to generate biomineralization in the period prior to the oncoming of trilobites into the scene. The shelled cover thus evolved bestowed upon this ancient animal community the essential character for mass preservation as fossils. Thus the SSF-phenomenon has come handy for biostratigraphic work in the latest Precambrian-earliest Cambrian sequences, when the conventional metazoa, starting with the trilobites, had not yet begun inhabiting the earth's oceans and seas.

The near-sudden and spectacular adaptive radiation in metazoa, which gave them the first hard cover, is still far from clear both in terms of causative factors and processes (Stanley, 1976; Lowenstam and Margulis, 1980). Nevertheless, workers more or less unanimously agree for directly or indirectly relating this radiation event to some fundamental factor or factors effecting the entire globe, like, for example, the contemporary and well-established Late Precambrian/Early Cambrian global phosphogenic episode (Cook and Shergold, 1986). Consequently, the widespread distribution of SSF on the globe is increasingly realized to render them an unrivalled utility for inter-continental correlation.

In India, the strata of Krol Belt of western Lesser Himalaya were the source of the first understanding and record of SSF (Azmi et al., 1981; Singh and Shukla, 1981; Bhatt et al., 1983). The first record of Himalayan SSF not only helped to bring to rest the century old controversy on the chronostratigraphic status of the Krol Belt succession (Oldham, 1888; Holland, 1908; Pilgrim and West, 1928; Auden, 1934, 1937; Singh, 1976, 1979; Bhargava, 1979) but added new and better data-based dimensions to our thoughts towards modelling of the geological evolution of the Himalayan mountain chain. The implications of the SSF discoveries in Himalayan sediments, for example, have tended to demolish the 'two geosyncline theory' proposed for the origin of Himalayan sediments (Saxena, 1971), which entailed the supposed equivalency of the 'unfossiliferous' Krol-Tal succession of Lesser Himalaya and the abundantly fossiliferous Upper Palaeozoic-Mesozoic succession of Higher Himalaya.

More recently, the coming on record of SSF from the Higher Himalayan domain as well (Tiwari, 1988, 1989; Raina, Bhatt and Gupta, 1988, 1990) has added further significance to the study of SSF from Himalaya, helping to discern the Precambrian-Cambrian transition strata within the thick pile of sedimentaries, long dated arbitrarily.

LESSER HIMALAYA

AREA AND SOURCE MATERIAL

The succession of Blaini, Krol and Tal Formations (Auden, 1934), disposed in a 350 kms long chain of large synclines, extending from Solan in Himachal Pradesh to Nainital in Uttar Pradesh (Fig. 1), is included in Mussoorie Group by Valdiya (1980). The succession, which is presently of our interest, comprises a sequence characterized by the diamictite-argillite-subordinate limestone association of the Blaini Formation at the base. The Blaini Formation is succeeded by the predominantly carbonate-rich Krol Formation; the latter, in turn, is overlain by the chert-phosphate-argillite-quartzite association of the Tal Formation.

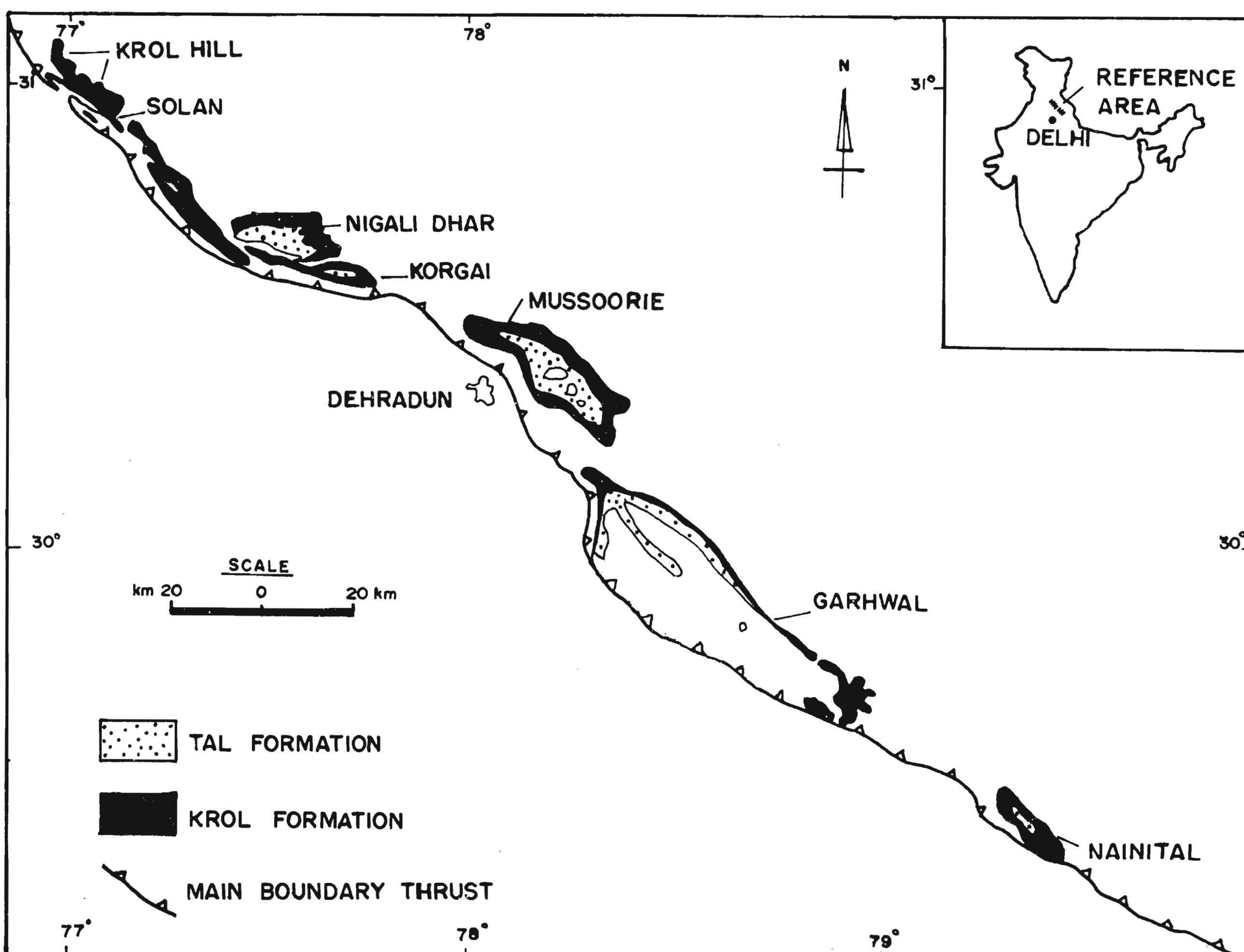

Fig. 1. The disposition of Krol Belt synclines in Lesser Himalaya, India (modified from Singh and Rai, 1983).

The basal Chert-Phosphorite Member of Tal Formation revealed the first SSF from Himalaya (Azmi *et al.*, 1981; Singh and Shukla, 1981; Bhatt *et al.*, 1983). This basal member of Tal Formation, consisting of an association of black chert-bedded phosphate-pyritiferous, black carbonaceous shale-thin phosphatic dolomite with stromatolites, representing deposits of restricted, tidal flat sub-environment, shows characteristic and thickest development in Mussoorie Syncline (Shanker, 1975). Its strata show considerable facies variation between its two principle constituents, viz. black chert and bedded phosphate/phosphatic shale. The thickness of the member varies between 150m and 2m. Generally the upper part is phosphate-rich. The thicker sections show preponderance of chert, i.e. Toneta-Kaphulti sector of Mussoorie Syncline. The phosphate rich sections show condensation of sequence. The best known example of the latter type is the Maldeota section, where the different adit-levels, exposed due to mining activities of Pyrite, Phosphate and Chemicals Ltd., have been extensively studied for SSF (Azmi et al., 1981. Azmi, 1983; Singh and Shukla, 1981; Bhatt et al., 1983, 1985; Brasier and Singh, 1987), within a total thickness of some 15-20 m of the Chert-Phosphorite Member exposed on the mine face.

The phoshate rock is the prime source of SSF at Maldeota; the thin purer chert horizon towards the base does not yield SSF. There is no record of SSF yet from the younger strata of Tal Formation in the Mussoorie Syncline. There, however, exists a published report mentioning presence of fossil worm tubes (mis- spelled in the original publication as 'worn' tube) in the strata of Arenaceous Member exposed in the Chipaldi *nala* section of Mussoorie Syncline (Shanker, 1971; Pers. comm. Shri Ravi Shanker, G.S.I., August, 1990).

In the Ganga valley section exposed in the Garhwal Syncline, the relatively thin stratigraphic interval included in the Chert-Phosphorite Member, consists of phosphatic, ferruginous sandstone and has yielded SSF similar to the Maldeota section of the Mussoorie Syncline (Kumar et al., 1987). Although exhibiting a somewhat differing association of lithologies than in the Mussoorie area, this basal member of the Tal sequence in the Garhwal section too represents clastic succession overlying the stable carbonate shelf deposits of Krol Formation as in the Mussoorie section or elsewhere in the Krol Belt.

The younger litho-column of Tal Formation in the Garhwal Syncline has also been searched for SSF, with positive results (Kumar et al., 1987). The carbonaceous black shale sequence that immediately succeeds the Chert-Phosphorite Member, viz. the Argillaceous Member, has so far remaied bereft of the SSF. But the succeeding Arenaceous Member, consisting of 234 m thick dominantly siltstone sequence has yielded SSF, displaying an appreciably younger affinity with definite newer elements than the SSF assemblage of the Chert-Phosphorite Member. The thin calcareous siltstone bed that succeeds the Arenaceous Member, viz. the Calcareous Member, has also revealed chronostratigraphically significant SSF (Kumar *et al.,* 1983, 1987). This is showever, the youngest horizon yielding SSF, not only in the Tal sequence of Garhwal Syncline, but in the entire Krol Belt, so far.

The southeastern extremity of the Krol Belt is formed by the succession exposed in the Nainital Syncline, where also SSF have been recorded recently (Bhatt and Mathur, 1990 a). The SSF- yielding interval in the Nainital section includes the topmost 77 m of the phosphatic dolomite sequence constituting the youngest part of Krol Formation, i.e. Krol E (Auden, 1934) or Sherwood Member (Valdiya, 1988). The succeeding 73 m of the increasingly argillitic basal Tal sequence in the Nainital Syncline, viz. the Krol F. (Fuchs and Sinha, 1974) or the Giwalikhet Member of Tal Formation (Valdiya, 1988), consisting of pyriteferous black shale/slate and phosphatic, algal mat-or occasional stromatolite-bearing dolomite interbeds, also yields elements of SSF (Bhatt and Mathur, 1990 a).

DISPUTED REPORTS OF SSF IN THE KROL BELT

The controversial SSF-yielding 'Krol D' horizon of Durmala area in Mussoorie Syncline (Azmi and Pancholi, 1983) was recently examined in the field and samples taken from it were re-studied for microfossils. The data briefly discussed in the following is taken from Bhatt and Azmi (in preparation). The geological map, the cross-section and the structural succession met with are illustrated in Fig. 2. From the illustrations it is clear that a series of three *en echelon* faults has dragged-up and squeezed two patches of Tal strata which occur in the section sandwiched within isoclinally dipping Krol beds, imparting the apparent impression of their being part of rhe somewhat Krol succession.

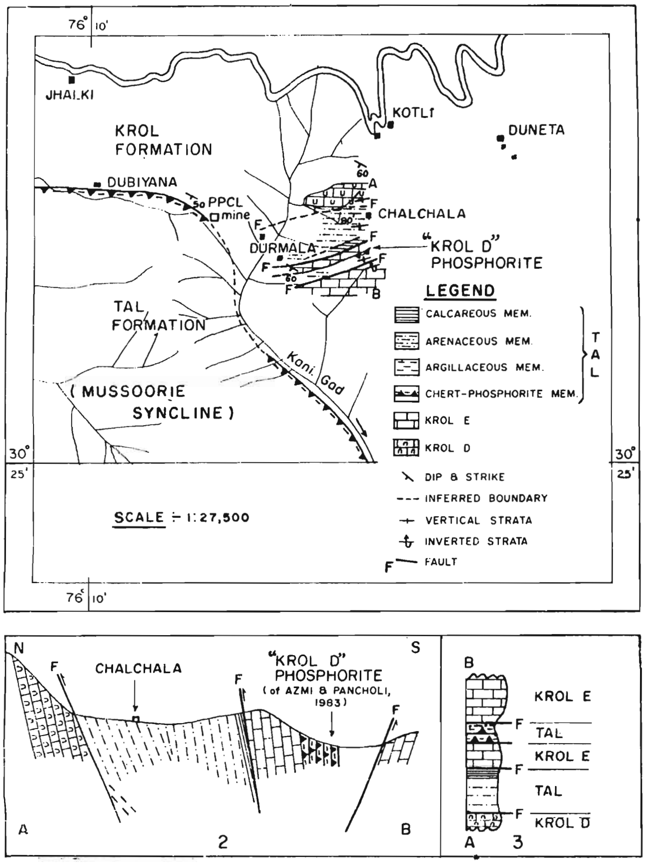

Fig. 2. Sketch geological map 1, stratigraphic cross-section 2, and tectono-stratigraphic succession, 3, Durmala Chalchala tract, eastern part of Mussoorie Syncline.

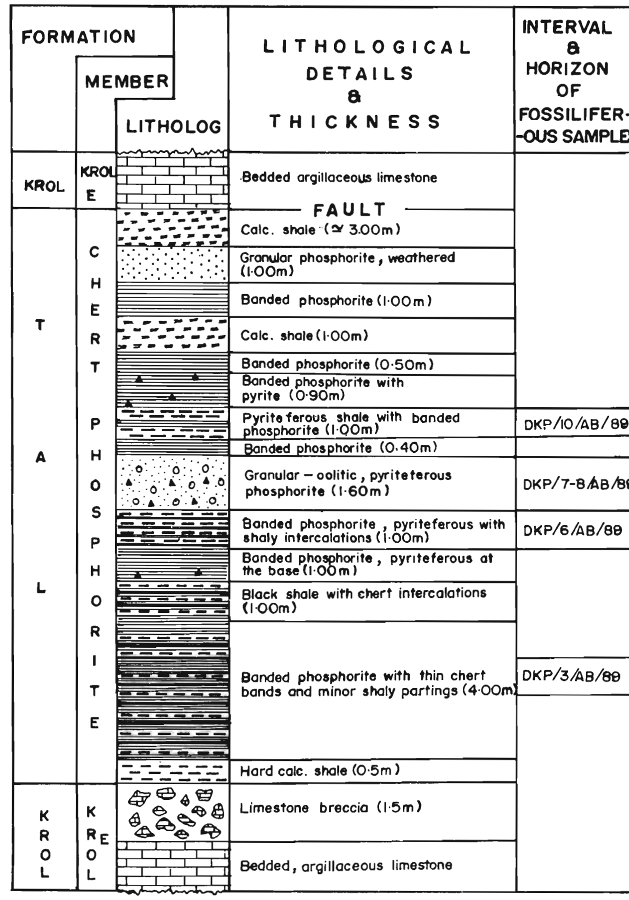

Fig. 3. Diagramatic litho-column, stratigraphic succession and fossiliferous intervals, Durmala village section (modified from Azmi and Pancholi, 1983).

The thin Tal sequence, represented by Chert-Phosphorite Member, between the middle and the southernmost of the three faults, has a normal contact with the underlying argillaceous limestone bed of Krol E, characteristically represented by a brecciated zone, 1.50 m, thick (Fig. 3). The earlier comprehensive mapping data reveal that a 1.50m to 2.00m thick brecciated zone in the topmost Krol E in contact with the overlying Chert-Phosphorite Member of Tal Formation is present in most of the sections in Mussoorie area (Shankar, 1971, Table I). Therefore, not only the SSF-yielding horizon near Durmala is part of the structurally caught-up patch of the Chert-Phosphorite Member of Tal Formation – a view expressed earlier also by Singh and Rai (1983), it is also underlain by the characteristic brecciated zone of Krol E (Fig. 3). The thick-bedded to massive-looking, fragmentary dolomitic limestone of Krol D is met only up-dip of Durmala section, at the Chalchala village, where it is stromatolite-bearing and occurs subjacent to rippled, cross-bedded and bioturbated siltstone of Areanaceous Member, with a faulted contact (Fig. 2). The thickness of phosphate zone in Durmala village section, viz. 15m-20m, and its lithological association, consisting of black shale, chert and bedded phosphate, are similar to that of Chert-Phosphorite Member in the nearby Durmala phosphate mine, which lies in the zone of structurally normal disposition of Krol-Tal strata. The SSF elements recorded by Azmi and Pancholi (1983) and now by the present writer from Durmala section (Fig. 4) are also identical to those from Chert- Phosphorite Member (Bhatt et al., 1985. Kumar et al., 1987; Brasier and Singh, 1987), albeit inferiorly preserved in case of the former, possibly for the close proximity to tectonized zone. In the published literature there is no report of the presence of thick chert-phosphate-black shale association within Krol sequence. The occurrence, therefore, of this lithofacies association restricted to a few tens of sq m of Krol country at a solitary location, as implied by Azmi and Pancholi (1983) for Durmala area, is obviously inexplicable, otherwise also.

Singh and Rai (1983) have mentioned presence of unidentified tubular and globular shaped microfossil

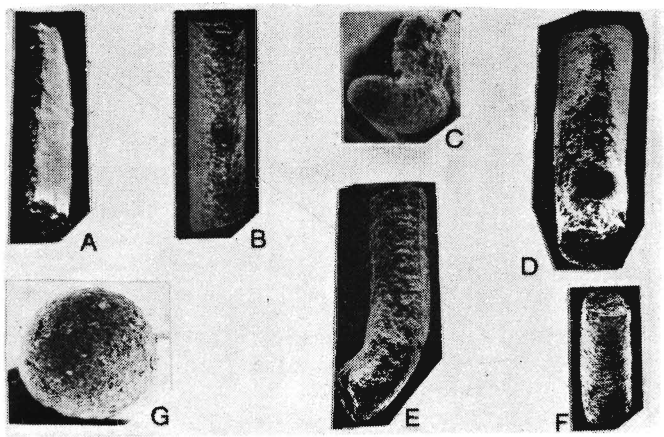

Fig. 4. Small shelly fossils (SSF) recovered from the Chert-Phosphorite Member of Tal Formation, tectonically sandwiched within the carbonate succession of Krol Formation in the Durmala village section, Mussoorie Syncline;

A, *Protohertzina anabarica* Missarzhevsky; X 40; DKP/3/AB/88.

B, ? *Tiksitheca* sp.; X 40; DKP/9/AB/88.

C, *Spirellus shankeri* (Singh & Shukla); X 40; DKP/3/AB/88.

D,E, *Coleoloides typicalis* Walcott; X 30; D, DKP/10/AB/88,E, DKP/6/AB/88.

F, *Hyolithellus* sp., X 40; DKP/7-8/AB/88.

G, *Olivooides multisulcatus* Qian; X 50; DKP/3/AB/88.

elements in the Upper Krol sediments of Nainital Syncline, referrable to Krol D, according to them. The present writer, in association with his colleague Dr. A.K. Mathur of GSI, examined a host of grab samples drawn from the strata of Krol A to Krol E in the Nainital Syncline, but the presence of microfossils was observed only in the strata of the upper part of Krol E (Sherwood Member of Valdiya, 1988), which were subsequently systematically examined for SSF, yielding fairly abundant microfaunal content (Bhatt and Mathur, 1990a). Singh and Rai (1983) did not state the exact location of the microfossil-yielding samples collected by them from the Nainital area. This has added element of stratigraphic uncertainty to their samples.

Das *et al.* (1987) illustrated an 'assemblage of SSF' from the Krol sequence of Nainital. It is difficult, however, to discern morphological attributes assignable to SSF in the illustrated material. Many of them could pass for sediment-pellets or pseudofossils. The authors have referred the majority of the illustrated 'elements' to gen. indet. or to only doubtfully assigned taxa. Based upon such an 'assemblage', the assignment of age of the host strata to Tommotian, as proposed by the authors (Das *et al.,* 1987), may not be justified.

Two more, short and only abstracted, reports (without illustrations) have also come in recently in the literature—one announcing presence of SSF in the Blaini Formation and the Krol C of Garhwal Syncline (Kalia and Trivedi, 1988) and the other in the 'Blaini Formation' of the Nainital area (Kalia and Trivedi, 1989). Both these reports can not be evaluated in detail for the present, for the lack of taxonomic information made available. However, these reports of SSF are possibly globally exclusive, announcing presence of SSF in conglomeratic/diamictitic beds. The section in the Nainital area, viz. Pine-Lariya Kanta section, which is shown to have yielded shelly microfossils from 'Blaini' (Kalia and Trivedi, 1989), in effect, does not expose strata of Blaini Formation, but only beds of pre-Blaini conglomerates, associated with a quartzite sequence (= Nagthat Formation = Lariyakantha Quartzite, vide Valdiya, 1988), in the upthrown block of the Kuriya Fault (Bhatt and Mathur, 1989; 1990b).

HIGHER HIMALAYA

AREA AND SOURCE MATERIAL

Two simultaneous announcements of the presence of SSF in the Higher Himalayan strata ('Tethys Himalaya') were published recently (Tiwari, 1988, Raina, Bhatt and Gupta, 1988). Tiwari (1988) reported and later illustrated and described (Tiwari, 1989) SSF, characterising Precambrian-Cambrian beds, from a level consisting of greyish black slates in the lower part of Lolab Formation in northwestern Kashmir. The SSF-yielding level falls stratigraphically below the horizon that contains trilobites and trace-fossils (*Cruziana-Rusophycus)* and is exposed in a *nala* east of Paripora village in the Kupwara area.

The other SSF-yielding locality was reported from southeastern Kashmir, at Hinzan Gali, on the southern flank of Pir Panjal Range near Banihal in the Doda district (Raina, Bhatt and Gupta, 1988). At this locality, a thin chert bed (possibly phosphatic), forming the top of Brarsul Member of Zilant Formation, has yielded SSF of the Precambrian-Cambrian transition level. The detailed mapping data show that the SSF-yielding chert bed is irregularly developed, showing facies variation laterally (Raina, Bhatt and Gupta, 1990).

BIO - AND CHRONOSTRATIGRAPHIC EVALUATION OF THE HIMALAYAN SSF ASSEMBLAGES

LESSER HIMALAYA

The assemblage of SSF, demarcating the latest Precambrian-Early Cambrian bio- and chronostratigraphic levels, are known only from Mussoorie, Garhwal and Nainital Synclines. No reports of SSF have appeared so far from the two more Krol Belt synclines, viz. Korgai and Nigalidhar Synclines, westward in the Himachal Pradesh Lesser Himalaya, where also appropriate sequences and lithofacies are developed (Shanker, 1975).

Mussoorie Syncline : It was the work of Azmi et al. (1981) that brought to light the occurrence of oldest SSF in the Chert- Phosphorite Member of Tal Formation in the Mussoorie Syncline (Krasheninnikov in Azmi et al., 1981; Bhatt et al., 1983, 1985). The SSF elements from the Maldeota section of Mussoorie Syncline were interpreted earlier variously as reworked gondolellid conodonts of Cretaceous age (Srivastava, 1974), Upper Palaeozoic foraminifera or porifera (Ahluwalia, 1978), moravamminid problematica (Patwardhan, 1978), Permian endothyrid foraminifera (Kalia, 1982), Jurassic foraminifera (Srivastava et al., 1982) and Cretaceous annelid remains (Singh and Shukla, 1981) and Cambro-Ordovician boundary conodonts (Azmi *et al.*, 1981; Azmi, 1983). All these earlier assessments of the microfauna, except the last one mentioned, were grievously biased in favour of the traditionally held view of the Upper Palaeozoic-Mesozoic age for the Krol Belt succession. Significantly, the last study (Azmi et al., 1981; Azmi, 1983) broke this bias for the first time, bringing out fossil evidences for a starkly new view on the chronostratigraphic status of the Krol Belt succession; it, however, still required a correct taxonomic assessment of the recovered microfauna.

Bhatt *et al.* (1983) re-determined the fossil elements of the phosphorite sequence in Mussoorie Syncline and interpreted them to include hyolithids and protoconodonts, characterising the basal part of Tommotian Stage, which represents the pre-trilobite Cambrian sequence in the Siberian Platform (Rozanov et al., 1969). Many of these Tommotian elements were also documented by Azmi (1983), but their presence in the assemblage was attributed to re-working from supposedly an older stratigraphic level (Azmi, 1983), viz. 'Krol D' of Azmi and Pancholi (1983). This theory of re-working was found unacceptable by Singh and Rai (1983) and also later by Bhatt *et al.* (1985). Bhatt *et al.* (1985) revised many of their determinations made earlier (Bhatt *et al.*, 1983) but further confirmed the presence of *Protohertzina, Circotheca, Olivooides,* etc., alongwith other elements like *Spirellus*, typical of the Chinese province, and a complete lack of archaeocyathids. These observations led to the obvious inference to put the Tal material closer to the Meishucun material, which in addition to showing identicality of certain exclusive elements with that of Tal, also shows a complete lack of archaeocyathids (Xing Yusheng and Luo Huilin, 1984). In case of the Tommotian sequence, on the other hand, archaeocyathids form characteristic fossil elements (Rozanov *et al.*, 1969). Bhatt *et al.* (1985) thus showed the characterizing similarity of SSF elements of the Chert- Phosphorite Member of Tal Formation and those of the Zhongyicun Member of Yuhucun Formation in the Yangtze Platform of South China; the latter demarcates the Zone I of the Meishucunian Stage.

Brasier and Singh (1987), while supporting the view on the biochronological equivalency of the Mussoorie phosphorite and the Zhongyicun phosphorite, made a deeper probe into the taxonomic details of the SSF elements of Chert-Phosphorite Member at Maldeota, Mussoorie. The earlier studies on the Indian material were mainly concerned with establishing chronostratigraphic level of the host strata based on the few characteristic but morphologically unambiguous SSF elements like *Protohertzina anabarica* Missarzhevsky, *Olivooides multisulcatus* Qian, etc., without going much into the taxonomic details. Brasier and Singh (1987) proposed re-definition of the conoidal phosphatic element *Maldeotaia bandalica* Singh & Shukla, based on an earlier designation (Singh and Shukla, 1981). *Maldeotaia bandalica* Singh & Shukla was proposed to possess a wide range of morphologic variation, which included in its synonymy a majority of the morphotypes earlier determined as Cambro-Ordovician conodonts (Azmi, 1983). Brasier and Singh (1987) also illustrated and described a few undetermined elements and referred them either as trumpet-shaped or as acicular elements, which are yet to be fully examined for a more precise taxonomic slot.

No published study of SSF from the younger lithounits of Tal Formation in the Mussoorie Syncline is yet available.

Garhwal Syncline : The first report of SSF from the Garhwal sequence was published by Kumar et al.

(1983), wherein they illustrated and described microgastropod *Pelagiella* sp. from the strata of Calcareous Member of Tal Formation, which is represented there by a relatively thin calcareous siltstone unit, 16 m thick, in the section near Kauriyala. This material was originally examined for SSF by the present writer; the material contained an overwhelming number of well-preserved elements of *Pelagiella*, specifically determined later as *P. lorenzi* Kobayashi (Kumar et al., 1987). The fossiliferous layer within the thin Calcareous Member probably marks an acme level for the microgastropod. This is significant chronostratigraphically, for in a recent scheme of inter-regional faunal analysis the level containing profuse distribution of gastropods of *P. lorenzi* Kobayashi group has been inferred to demarcate the upper part of Qiongzhusian Stage of China (Brasier, 1989). Additionally the upper part of Qiongzhusian Stage is definitively put concurrent with the Botomian Stage of Siberian Platform (Brasier, 1989). This gastropod-bearing horizon in the Calcareous Member of Tal Formation marks the youngest small shelly fossil-yielding level of Early Cambrian so far in the Himalayan sections. This by no means should, however, be construed to understand that all the older levels are known and stand demarcated. Actually there are still large gaps in our knowledge between the oldest kown SSF level, viz. Zone I of Meishucunian Stage, demarcated by the Chert-Phosphorite Member in Mussoorie and Garhwal Synclines and the youngest level, viz. Qiongzhusian Stage, demarcated by the Calcareous Member in Garhwal Syncline, as discussed below.

Kumar *et al.* (1987) identified three distinctive SSF assemblages in the total succession encompassed by the Chert-Phosphorite to Calcareous Members of Tal Formation in the Garhwal Syncline. A thin, about 1.50 m thick, sequence of Chert-Phosphorite Member, near Kauriyala in the Garhwal Syncline yielded the distinctive Meishucunian Zone I element *Anabarite trisulcatus* Missarzhevsky, which, for some reason, remains unrecorded so far from the extensively examined Mussoorie section at Maldeota. In the material from Kauriyala also only a single specimen was recovered, albeit well-preserved. The other elements that accompany *A. trisulcatus* in the assemblage are *Olivooides multisulcatus* Qian, *Spirellus shankeri* (Singh & Shukla), etc., which impart an unmistakable stamp of Meishucunian Zone I to this assemblage from the Chert-Phosphorite Member of Garhwal Syncline (Kumar et al., 1987).

The overlying 177 m thick Argillaceous Member, consisting mainly of black shale, has so far proved unfossiliferous in respect of SSF. The Argillaceous Member may be largely equivalent to the Zone II of Meishucunian Stage, considering the underlying and the overlying SSF assemblages (Kumar et al., 1987).

The next younger SSF assemblage, mainly consisting of chancelloriids *Allonnia erromenosa* Jiang and *Dimidia* sp. cf. *D. simpleca* Jiang, is first recorded some 30 m above the base of Arenaceous Member (Kumar *et al.,* 1987). This chancelloriid assemblage demarcates the level of Meishucunian Zone III in the Tal column of Garhwal section (Kumar *et al.*, 1987). This chronostratigraphic assignment is also supported by a later scheme of correlative faunas proposed by Brasier (1989). In the current Chinese literature, however, this distinctive assemblage is sometimes interpreted representing the post-Meishucunian Zone III or the Qiongzhusian level (Xing Yusheng et al., 1984). Whenever so, the inherent contention behind the Chinese interpretation appears to be the belief that the *Allonnia* fauna was contemporary of the oldest trilobite *Parabadiella* fauna in Meishucun type section and therefore it could not have formed part of Meishucun Stage assemblage as the latter has a sub-trilobitic position. More lately, by a consideration of global data on the vertical distribution of *Allonnia tripodophora* (Brasier, 1989), it is indicated that only the higher levels of occurrences of *Allonnia* are contemporaneous with the first appearances of trilobites. Obviously, the trilobite-free older *Allonnia* interval, as in the case of the basal part of Arenaceous Member in the Garhwal Syncline, will form part of the latest Meishucunian Stage or the Meishucunian Zone III. The younger *Allonnia*-yielding level in the sequence of Arenaceous Member in Garhwal Syncline (about 200 m above the older level; Kumar *et al.,* 1987) also contains redlichiid trilobites *Redlichia* and *Tungusella* (Joshi *et al.,* 1989), alongwith obolellid and lingulellid brachiopods (pers. comm. : Dr. A. Joshi and Shri V.K. Mathur, GSI), marking the post-Meishucunian or probably the Qiongzhusian level in the Tal succession. It is likely that the *Redlichia*-bearing probable Qiongzhusian level in the Tal Formation is equivalent to *Eoredlichia* Zone of China and thus delineating the upper part of Qiongzhusian Stage. In this inter-regional correlation proposal, it is presumed that the trilobite *Redlichia* has a lower stratigraphic range of occurrence in Himalaya than in China, where its lower range of occurrence is restricted to the post-Qiongzhusian level or the Tsanglangpuian Stage. The assignment of Qiongzhusian age to the *Redlichia*-bearing strata of Arenaceous Member is apparently supported by the characteristic presence of microgastropod of *Pelagiella lorenzi* Kobayashi group in the strata of the overlying Calcareous Member, as we shall examine subsequently in the text. The still older trilobite- bearing *Parabadiella* Zone of China, defining the lower part of Qiongzhusian Stage, remains yet to be detected in the Lesser Himalayan sequence. The Meishucunian/Qiongzhusian boundary would, therefore, lie astride the column of Arenaceous Member at the level where the first trilobite fauna would be found to occur. Future researches would finallly fix this boundary, considering the possibility of the presence of an additional older trilobite-bearing horizon in the Arenaceous Member, stratigraphically below the strata containing the *Redlichia* fauna.

The overlying Calcareous Member in the Tal Formation, revealing the acme horizon of the gastropod *Pelagiella lorenzi* Kobayashi, also yields two additional gastropod taxa, viz. *Auriculatespira madianensis* Zhou & Xiao and *A. andunca* He & Pei, which are morphologically very close to *P. lorenzi* Kobayashi and could as well be place within its variation range. In acordance with the data of inter-regional faunal analysis and the scheme of correlation proposed by Brasier (1989), the profuse occurrence of *Pelagiella lorenzi* Kobayashi in Calcareous Member affirms the equivalence of the host strata to the upper part of Qiongzhusian Stage, which, in the Siberian chronostratigraphic parlance, would be placed in the Botomian Stage (Fig. 5). The still younger *Redlichia*-bearing horizon in the overlying Phulchatti Member is also, for the present, being assigned Qiongzhusian age (Fig. 5), for the changed chronostratigraphic connotation of the trilobite *Redlichia* in the Tal section of Lesser Himalaya, as discussed above. However, with the analogy of Chinese section, this higher *Redlichia*-bearing level can as well be assigned to the Tsang- langpuian Stage of the latest Lower Cambrian, until additional faunal data comes to light to confirm either of the age-assignments.

Nainital Syncline : The presence of *Coleoloides typicalis* Walcott and *Olivooides multisulcatus* Qian in the microfauna of the single fossiliferous interval recently demarcated in the Nainital section (Bhatt and Mathur, 1990a, 1990b) indicates its correlative potential with Chert-Phosphorite Member of Tal Formation in Mussoorie Syncline. The globomorph *O. multisulcatus* is indicative of Meishucunian Zone I age and the pattern of fair abundance of *C. typicalis* in the Nainital material is similar to that of the Maldeota material in Mussoorie. More than half of the 150 m thick fossiliferous interval at Nainital falls in the Krol succession; this is unlike in the Mussoorie section where the SSF are known to be restricted to the strata of Tal. Therefore, if the fossiliferous interval at Nainital is chronocorrelatable to the sequence of Chert-Phosphorite Member of Tal Formation, then regionally the contact of Krol-Tal Formations would represent a time-transgressive plane. This contention will impart additional, faunal support to the lithological and other field observations leading to the inference regarding the continuity of the Krol-Tal sedimentation (Bhargava, 1979).

A variety of queer-looking bedding-surface features, apparently genetically related to the sedimentation and tectonics of the strata that also yielded SSF in the Nainital section, as discussed in the preceding, were interpreted as 'Ediacaran soft-bodied metazoan fossils' by Mathur and Ravi Shanker (1989). Misra (1990), and Bhatt and Mathur (1990b, 1990c) have strongly questioned the veracity of these 'fossils'. Mathur and Ravi Shanker (1990) again illustrated few medusoids from the strata in Nainital from which they had earlier reported 'Ediacaran metazoa' Bhatt (1990) has argued against the Ediacaran time-tag to these medusoids from Nainital and has shown that with the analogy of Chinese and Siberian sequences (Luo Huilin, 1989; Runnegar, 1989), a Meishucunian age for the medusoid-bearing strata of Nainital section was more logical, in the framework of SSF data available for the medusoid-yielding horizon.

HIGHER HIMALAYA

The two reports of SSF from the Higher Himalayan region come from Kashmir only, which, nevertheless, have opened new field of palaeobiological research in that region.

Southeastern Kashmir : The SSF assemblage from the Banihal region of Kashmir consists of *Coleoloides typicalis* Walcott (Raina, Bhatt and Gupta, 1988, 1990). The other element reported by these workers is yet indeterminate. However, the presence of *C. typicalis* in the Pir Panjal material has been assumed to indicate correlatibility to Meishucunian Zone I, in analogy with Lesser Himalayan assemblage. This is a significant addition of SSF data, coming as it is from the relatively inaccessible Higher Himalayan region and where the thick pile of Late Proterozoic successions are chronostratigraphically poorly understood.

Northwestern Kashmir : Tiwari (1988, 1989) first reported and later illustrated and identified a SSF assemblage from northwestern Kashmir; the illustrations provided are not very clear in morphological details. Nonetheless, the SSF elements, some of them fragmentary, have been determined as *Protohertzina, Taliella* (a proposed new and yet underscribed genus by Azmi) and a sponge spicule, comparable to *Allonnia*. Whereas *Protohertzina* may connot a Meishucunian Zone I age, the *Allonnia* type chancelloriid are known to be appreciably younger in age. The total assemblage thus determined points to an ambiguous chronostratigraphic status, rather than its placement in the Meishucunian Zone I, as implied by the author.

PRECAMBRIAN-CAMBRIAN INTERVAL IN HIMALAYA

PRESENT DATA ON BIO- AND CHRONOSTRATIGRAPHY BASED ON SSF

1. The oldest chrono-level based on SSF known presently in the Himalayan sequence is the Zone I of Meishucunian Stage of the Chinese stratotype section (Fig. 5). The strata at the Krol-Tal transition in the Lesser Himalaya define Meishucunian Zone I succession and consist of sediments of coastal, restricted environment as well as those of carbonate shelf, in an open, tidal-flat environment and are characterised by the presence of phosphate rock. At the northwestern extremity of Garhwal Syncline (Fig. 1), in the Ganga Valley section at Kauriyala, the distribution of Meishucunian Zone I SSF is restricted only to a 1.50 m thick succession (Kumar et al., 1987), although this region apparently formed the central part of the Krol-Tal basin. Further northwest to this central part, in the Mussoorie area, the Meishucunian Zone I SSF are distributed in 15-20 m thick succession of Chert-Phosphorite Member of Tal Formation (Azmi, 1983; Bhatt et al., 1985; Brasier and Singh, 1987). In the southeasternmost Nainital Syncline, which may represent an extreme southeastern fringe of Krol-Tal basin, the SSF elements characterising Meishucunian Zone I in Lesser Himalaya are distributed through a 150 thick succession (Bhatt and Mathur, 1990a). The stratigraphic successions in the Meishucunian Zone I interval in the three Krol-Tal synclines show considerable variation in lithofacies. These lithological and faunal distribution data strongly suggest appreciable input of facies control in the presence/preservation of SSF. The global phosphogenic episode at the level of Meishucunian Zone I, which is distinctly manifested in the Himalayan section, may be an important facies factor.

The presence of *Coleoloides typicalis* Walcott in the topmost Krol Formation of Nainital (Bhatt and Mathur, 1990a) supports assignment of Meishucunian age to the topmost part of Krol column too in the Nainital section, for in the Himalayan region like that in South China - both the areas belonging to the same palaeogeographic realm during Late Proterozoic-Early Cambrian (Kumar, 1984; Brasier, 1989), *C. typicalis* Walcott may not range down to the pre-Meishucunian sequence. *C. typicalis*, in the Mussoorie area, is known only from the basalmost Tal rocks. This distribution data of Meishucunian SSF in the two distant sections of the Krol Belt would point to a time-transgressive nature of the Krol-Tal contact.

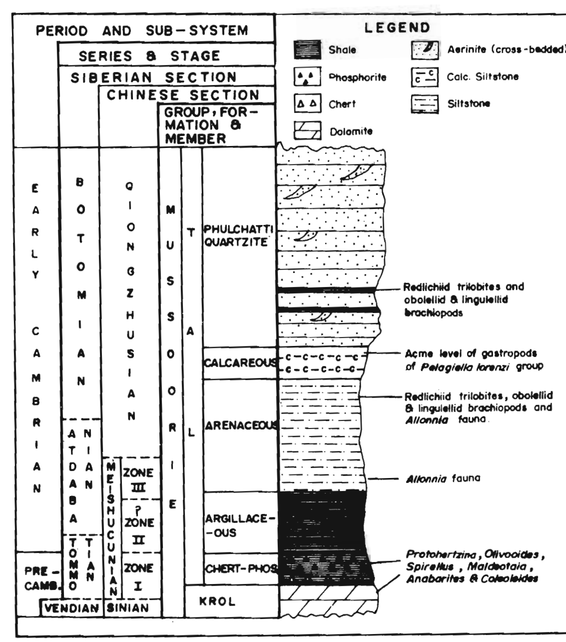

Fig. 5. The composite biostratigraphic data pertaining to SSF in the Krol Belt succession (Mussoorie, Garhwal and Nainital Synclines) and the present status of its chronostratigraphic implication. The base of Tommotian Stage is shown synchronous with that of Meishucunian Stage following Bhatt (1989).

2. The succeeding Zone II of Meishucunian Stage remains undetected yet in Lesser Himalaya, for the Argillaceous Member of Tal Formation, which may be equivalent to Zone II, has proved unfossiliferous in respect of SSF (Fig. 5).

3. The poriferiid *Allonnia* fauna in the lower part

of Arenaceous Member in Garhwal Syncline demarcates the level of Zone III of Meishucunian Stage. The lower boundary of Zone III remains undelineated for the unfossiliferous nature of Argillaceous Member.

4. The topmost interval of Arenaceous Member, 25 m thick, in Garhwal Syncline reveals the oldest trilobites in the Lesser Himalaya and demarcates the upper part of Qiongzhusian Stage of the Meishucun type Section of South China. It is possible that a still older trilobite level in the sequence of Arenaceous Member, equivalent to the lower part of Qiongzhusian Stage, may be revealed in future. In any case the boundary between the Meishucunian and Qiongzhusian Stages would lie astride the column of Arenaceous Member of Tal Formation in Garhwal Syncline, which, for the present, is still imprecise (Fig. 5).

5. The succeeding Calcareous Member of Tal Formation in Garhwal Syncline reveals acme level of the gastropod *Pelagiella lorenzi* Kobayashi group, supporting its placement in the upper part of Qiongzhusian Stage. This is the youngest SSF-yielding horizon in the Lesser Himalaya.

6. The still younger *Redlichia* level in the lower part of Phulchatti Member of Tal Formation (Kumar, Joshi and Mathur, 1987; Mathur and Joshi, 1989) could as well be part of Tsanglangpuian Stage of the latest Early Cambrian of China. However, for the association of trilobite *Redlichia* with typical Qiongzhusian SSF elements below in the sequence of Tal, it may need further fossil evidence to label the upper SSF-free *Redlichia* horizon of Phulchatti Member (Fig. 5) as Tsanglanguian.

7. In the Higher Himalaya ('Tethyan Himalaya'), the basal strata of Lolab Formation (NW Kashmir) and Zilant Formation (SE Kashmir) have yielded elements of SSF, which are neither so prolific or varied nor connote a definitive age as in the case of the Lesser Himalayan Chert-Phosphorite Member of Tal Formation. The poor SSF assemblage containing, however, *Coleoloide typicalis* Walcott, as in SE Kashmir (Raina, Bhatt and Gupta, 1990), could point to the Meishucunian age of the host strata. These SSF reports from Higher Himalaya significantly reveal fossil elements similar to that of Lesser Himalaya. This similarity in the SSF facies and the common prevalence of redlichiid trilobite fauna in the Lesser Himalaya and the Higher Himalaya points to the sedimentational link between the two areas during Late Precambrian-Early Cambrian.

8. According the present provisional mandate of IUGS, the contact of Meishucunian Zone I and Meishucunian Zone II would define the level of Precambrian-Cambrian boundary. This IUGS mandate marks the PC/C boundary in Lesser Himalaya at the top of Chert-Phosphorite Member of Tal Formation or still above it. The precise delineation, however, remains indefinite for the unfossiliferous nature of the immediately succeeding strata, i.e. the Argillaceous Member.

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