Physical, geochemical and biological changes across the Precambrian-Cambrian transition, northwest Himalaya, India

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The Precambrian-Cambrian transition has been extensively studied in the Krol Belt of Lesser Himalaya and in Higher and Tethys Himalayan part in Kashmir, Spiti-Zanskar and Kumaun. A substantial amount of data that has now accumulated in both the areas on lithology, geochemistry and biological changes is analysed and possible inferences are drawn.

**Key-words**—Lithology, Geochemistry, Biological changes, Precambrian-Cambrian transition, Northwest Himalaya, India.

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**सारीक्षण**

उत्तर-पश्चिम हिमालय में कैदियांपूर्व-कैदियांपूर्व युगी अवधि पर भौतिक, भौगोलिक एवं जैविक बदलाव

**प्रक्रियाएँ**

प्रेरित-कांब्रियन युग का अन्तिम फेरा, विशेष रूप से उत्तर-पश्चिम हिमालय के क्षेत्र में साक्षात्कार फूल एवं जैविक संस्कृति में बहुत बड़े परिवर्तनों का साक्षरण हुआ है। इसके संबंध में प्रमुख बाध्यताओं के लिए यह साहित्यिक सूचनाएँ प्रदान किए गए हैं।

**रूपरेखा**

*PRECAMBRIAN-CAMBRIAN* transition is marked by major biotic changes, viz., emergence of soft bodied Ediacaran fauna and their subsequent extinction; emergence of fauna with hard parts or skeleton and chemical changes, particularly variations in the C- and Sr-isotopic compositions of the carbonates. All of them provide significant stratigraphic information which may be used for the correlation of Terminal Proterozoic-Early Cambrian strata (Knoll & Walter, 1992; Narbonne et al., 1994). Nutrient-enriched water masses (NEW) with high levels of dissolved phosphate and silica, and low levels of oxygen have left a clear imprint on the history of fossil records of the latest Proterozoic-Early Cambrian (Brasier, 1992).

**PHYSICAL CHANGES**

The sedimentation of the Terminal Proterozoic-Cambrian succession, constituting the Supersequence-IV (Shanker et al., 1989, 1996), commenced with a widespread marine transgression in parts now forming the northwestern Himalaya over the Supersequence-III comprising Salkhala with grandis ca 750 Ma, Simla Group and equivalent of Mesoproterozoic-Early Neoproterozoic age (Shanker et al., 1996) in response to global warming after the Varangian glaciation (610-590 Ma, Knoll & Walter, 1992). It terminated with Pan-African orogeny in late Upper Cambrian. These sediments are now exposed in the Krol Belt, Lesser Himalaya, in Kashmir Basin in Higher Himalaya, and Spiti-Zanskar and Kumaun Basins in Tethys Himalaya. The sequence shows considerable variation in lithology due to variable conditions of depositional environment and climate and hence has been subdivided into three different formations; three groups in different sectors. In Krol belt it constitutes the Baliana, Krol and Tal Groups (Shanker et al., 1993), the Ramsu, Machhal, Lolab and Karhul Formations in Kashmir, the Batal, Kunzam La and Parahio Formations in Spiti-Zanskar and the Rilkot, Bilju and Milam Formations in Kunaun; the Karhul and Parahio Formations are of Middle to
early Late Cambrian age. Of these, the basal formations, the Baliana and Ramsu, are arenargillaceous in nature with impersistent bands of conglomerate and or dianomite deposited under unstable shallow marine environment. The middle part of the succession is dominated by carbonate evaporite succession—the Krol Group, in the Krol belt. It is an algal mat facies deposited under stable platform conditions in an arid climate; lenticular and nodulous black chert in upper part indicating deepening of the basin. The development of chert may be related to Caldecote igneous event (ca 560-540 Ma; Brasier, 1985) recorded in English Midlands. The Machhal, Batal and Rilkot-Bilju Formations, dominantly argillaceous in nature, are the corresponding successions deposited in deeper euxenic environment. The upper part of the sequence constituting the Lolab and Kunzam La Formations is dominantly arenaceous indicating upliftment of the source area. The corresponding succession in the Krol Belt continues to be argillaceous with development of thick black chert with or without phosphorite forming the lower part of the Tal Group deposited in reducing environment under shallow marine neritic zone (Shanker, 1971). The upper part of the Tal Group is, however, dominantly arenaceous. The entire sequence in the Krol Belt bears close lithological similarity with the corresponding succession in Yangtze Platform, China (Kumar, 1984).

**CHEMICAL CHANGES**

Studies by Bhattacharya et al. (1996) on Carbon isotopes in the Krol Belt indicate the existence of four substantial depletions in δ¹³C values in the Baliana-Krol-Tal groups. The first depletions in δ¹³C values are noticed in the pink carbonates of Baliana Group, and the fourth in the carbonates of Kauriyala Formation (Krol E) and continues into lower part of Deo Ka Tibba Formation of Tal Group. The Baliana depletion corresponds to the end of Varangian glaciation. The fourth, in fact, occurs immediately above Ediacaran fossiliferous horizon in Precambrian-Cambrian transition sequence throughout the world (Knoll & Walter, 1992; Narbonne et al., 1994). The other two depletions in δ¹³C, noticed in the carbonates

![Text-figure 1](image-url)
of Kauriyala Formation (Krol D), may be due to local basinal conditions. Most of carbonate samples of the sequence with δ18O values range from 20 to 30 per cent. SMOW are characteristic of Proterozoic sedimentary carbonate of inorganic origin.

Preliminary analytical data on clay separates of seven samples from the Baliana-Krol-Tal sequence show LREE enriched HREE depleted (fractional) pattern with no Eu anomaly from Baliana to middle part of Kauriyala (Krol D) Formation. However, the upper part of Kauriyala (Krol E) to lower part of Tal Group (Deo Ka Tibba Formation) shows LREE enriched pattern with a small sized -ve Eu anomaly. Similar decrease in concentration of Eu is observed in sediments at Precambrian-Cambrian transition which also coincides with upper Carbon isotopic excursion in the sequence (Bhattacharya et al., 1996).

BIOLOGICAL CHANGES

In Himalayan Precambrian-Cambrian transition sequences of stromatolites, algae, acritarch, microphytolite, Ediacaran fossils, small shelly fossils, trace fossils besides redlichid trilobites and inarticulate brachiopods, are now well-known (Kumar, 1995). Rapid evolution and diversification of biota leading to the appearance of hard parts or skeleton in animals noticed above the fourth depletion in δ13C values, i.e., above the Ediacaran fossiliferous horizon in the Baliana-Krol-Tal sequence in Krol Belt is globally identified.

The stromatolites in Baliana Group are simple stratified type - *Stratifera undata* (Sharma et al., 1994) and become columnar and domal in Krol and Tal Groups. Recorded forms are *Conophyton garganicus* and *Batcalia batcalica* (Singh & Rai, 1977), *Aldania mussoorica*, *A. bitpa*, *Collumnefacta vulgaris*, *Boxonia gracilis* and *Illica talica* (Tewari, 1988; Tewari et al., 1988). Maithy et al. (1995) reported *Hyellacea* forms in Baliana Group. Tewari (1988) reported Vendotaenid from Mahi Formation of Krol Group. Singh and Rai (1983) reported *Epiphyton* and *Renalcis* from the Kauriyala Formation. Ahluwalia and Bhargava (1987) recorded the spirally coiled form of algae *Obruchevella* in the chert Member of Deo Ka Tibba Formation. Microphytolite-oncolites and catagraphs are known from Kauriyala Formation (Gundu Rao, 1970). These forms are known from Late Precambrian of Siberian Platform, Russia. Prasad et al. (1990) and Venkatachala et al. (1992) have reported the assemblages of acritarch from Baliana-Krol-Tal sequence. Analysis of the reported forms shows that Leiosphaeridia Group is dominant in Baliana and Krol Groups while in Tal Group ornamented forms are the main constituents.

In Higher Himalaya, acritarch belonging to Sphaeromorphida, both simple and ornamented types, have been reported from the Machhal and Llob Formations (Kumar et al., 1984a, 1984b; Maithy et al., 1988).

First multicellular animals in the form of Ediacaran fossils—*Beltanella* sp., *Tirastana* sp., *Medustites* sp., *Peridinium* sp., *Kimberellasp.*, cf. *K. quadrata*, *Cyclomedusa davidii*, *Conomedistles lobatus*, *Charniodiscus* sp. and *Zolotytska biserialis* (Mathur & Shanker, 1989, 1990; Shanker & Mathur, 1992; Shanker et al., 1997) have been recorded from the Kauriyala Formation (Krol D). The above reported forms are known world wide and are important time marker. Ediacaran assemblage in India also occurs in the rocks deposited during relatively stable δ13C interval of +1 to +2 per cent PDB that occurs below Precambrian-Cambrian boundary.

The small shelly fossils are mainly recorded from the Chert Member to Calcareous Member of Deo Ka Tibba Formation (Azmi, 1983; Azmi & Pancholi, 1983; Bhatt et al., 1983, 1985; Kumar et al., 1983, 1987; Brasier & Singh, 1987). They have been grouped into following three assemblages in ascending order:

1. *Anabartites-Proterobenzina-Cicerotheca*,
2. *Dimidia-Allonia*, and

Small shelly fossils of assemblage-I and II are correlated by Kumar et al. (1987) with Meishucunian Zone I and II of China. Small shelly fossils have also been recorded from the underlying Krol Group (Das et al., 1987; Bhatt & Mathur, 1990). The biogenicity and identification of these records have been doubted by Bhatt (1989) and Kumar (1995).

The trace fossils are rich and diverse below the lowest occurrence of Lower Cambrian redlichid
trilobites and inarticulate brachiopods of Botomian Stage (early Tsanglangpuian Stage of China) both in Lesser and Higher Himalaya. In Krol Belt, trace fossils recorded from the upper part of Krol Group are simple and are represented by *Gordia* sp., *Bitinitichnus bisertalts* and ichnogenus A (Shanker *et al.*, 1997). Complex type of trace fossils, viz., *Rusophybus* sp., *Cruziwana* sp., *Monomorphichnus* sp., *Diplichnites* sp., *Astropolichnus* sp. and *Skolthis* sp. Assemblages equivalent to Ichnozone III of Crimes (1987) have been recorded from the Arenaceous Member of Deo Ka Tibba Formation of Tal Group (Kumar *et al.*, 1983; Singh & Rai, 1983; Mathur *et al.*, 1988).

The fossils from Kashmir are in fact of advanced organisation and have been grouped into following four assemblages in ascending order:

Assemblage I—*Planolites beverleyensis*-P. reticulatus,

Assemblage II—*Arentocolsites*-*Gordia*-*Phycodes* (? *P. pedum*),

Assemblage III—*Monomorphichnus*-Diplichnites-Astoiopolithon (*Astropolichnus*) Tephrelminthopsis circularis, and

Assemblage IV—*Rusophybus didymus*-Isopodichnus-Kupwara fusiformis.

Assemblage I is from the basal part of Razdain Member of Lolab Formation and has been assigned to Late Precambrian (Kumar *et al.*, 1984a, 1984b). In addition to *Planolites*, it also contains *Skolithos* and *Burgaurta*. Assemblage II contains *Skolithos* and *Monomorphichnus*. In Assemblage III, trace fossils are ubiquitous and occur in upper part of Razdain Member (Kumar *et al.*, 1984a, 1984b), in Kunzam La Formation of Spiti (Bhargava *et al.*, 1982; Bhargava & Srikantia, 1982) and Arenaceous Member of Deo Ka Tibba Formation of Tal Group (Singh & Rai, 1983; Mathur *et al.*, 1988). The other characteristic fossils of this assemblage are *Dtmorphichnus*, *Gyrochorte*, *Planolites corugatus*, *Phycodes palmatum*, *Bifasciculus*, *Bifungites*, etc. (Shah & Sudan, 1983; Bhargava & Srikantia, 1982). The ichnofossils of Assemblage IV are well developed in Spiti (Bhargava & Srikantia, 1982). Assemblages II, III and IV correspond to Assemblage II of Kumar (1988) that has been assigned an Upper Tommotian-Lower Atadabanian age as it contains SSF of Assemblage II correlatable to Meishucunian Zone III of China and Ichnozone III of Crimes (1987). Trace fossil assemblages I and II from Kashmir may possibly be correlated with Ichnozone I and II of Crimes (1987). Still more data is required for its establishment.

Based upon the above discussion the following inferences are drawn:

1. The stable carbon isotopic studies in Krol Belt, Lesser Himalaya record four depletions in δ¹³C values in Baliana-Krol-Tal succession. The first corresponding to end of Varangian glaciation is in the basal part and the fourth lies in Precambrian-Cambrian Transition Zone, above the Ediacaran fossiliferous horizon.

2. There was a rapid evolution and diversification of biota with the appearance of hard parts above the level of fourth depletion in δ¹³C values, which is globally identified.

3. Significantly, like many diverse assemblages of Ediacaran fossils of the world including type assemblage in Ediacaran hills of South Australia, Ediacaran assemblage in India also occurs in rocks deposited during relatively stable δ¹³C interval of + 1 to + 2 per mil PDB that occurs below the Precambrian-Cambrian Boundary.

4. The record of -ve Eu anomaly in Krol-Tal sequence is also significant as it is known worldwide in Phanerozoic sediments only.

5. Assemblage I (Small shelly fossils) recorded from the Chert Member of Deo Ka Tibba Formation of Tal Group is of earliest Cambrian age.

6. Precambrian-Cambrian Boundary has been globally demarcated in between Ichnozone I and II. The same is not marked in Indian subcontinent, as such the basal part of Cambrian may be missing in India.

7. Trace fossils of Ichnozone III are ubiquitous. Their presence is known in NW Himalaya and is correlatable with GSSP.

8. The Krol Belt succession bears close lithostratigraphic and biostratigraphic similarity with that of Yangtessse Platform, China excepting that the Meishucunian Zone II fauna has not been recorded so far from India.
REFERENCES


