Physical, geochemical and biological changes across 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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सारांश

उत्तर-पश्चिम हिमालय में कॅम्ब्रियनपूर्व-कॅम्ब्रियन सीमा परिवर्तन पर भौतिक, भूरासायनिक एवं जैविक बदलाव

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लघु हिमालय तथा काश्मीर, स्पिती-जन्सकर एवं कुमायुँ के उच्च तथा टेथीय हिमालय की क्रोल-ताल पट्टी में कॅम्ब्रियनपूर्व-कॅम्ब्रियन सीमा परिवर्तन का विस्तृत अध्ययन किया गया है। इन दोनों क्षेत्रों से शैलविज्ञान, भूरसायन एवं जैविक अवशेषों पर अभी तक उपलब्ध सभी आँकड़ों का विश्लेषण किया गया है तथा सभी सम्भव निष्कर्ष इस शोध-पत्र में प्रस्तुत किये गये हैं।

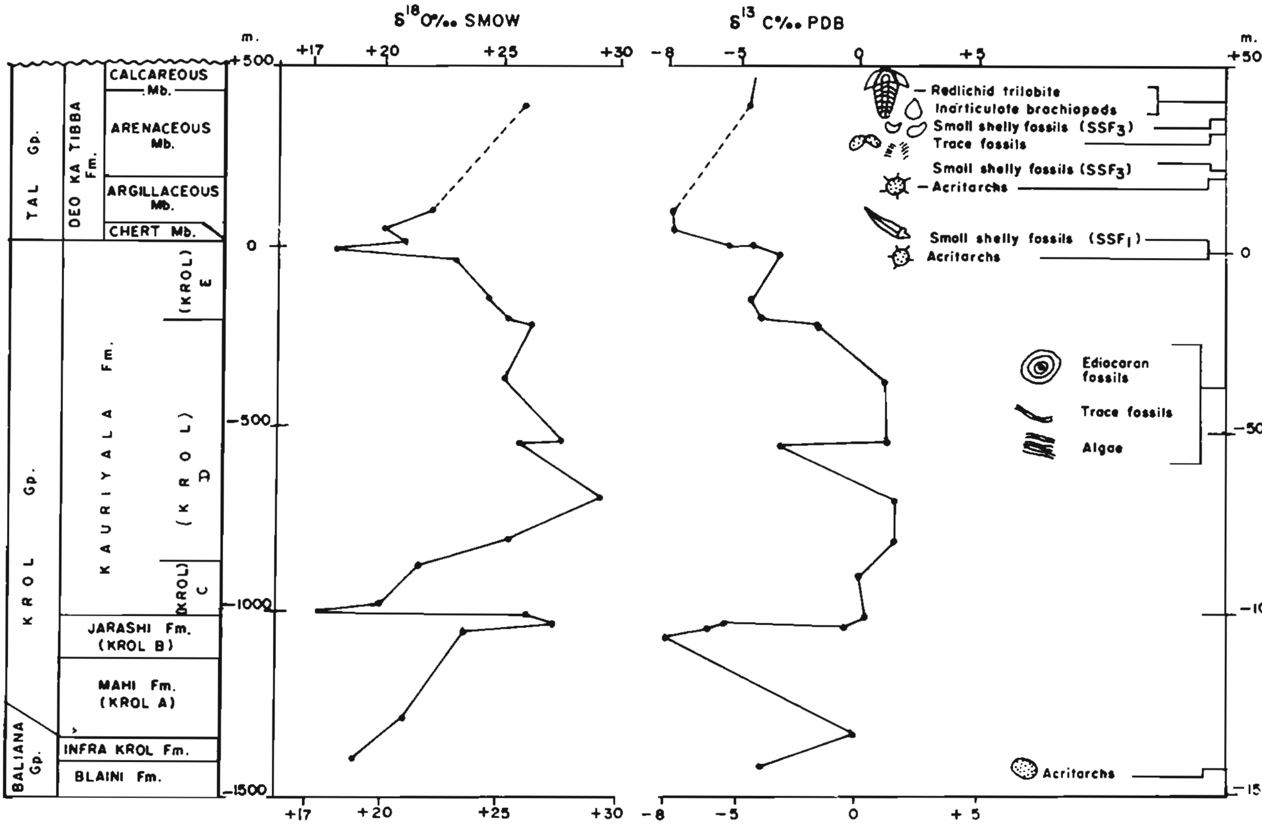
PRECAMBRIAN-CAMBRIAN transition is marked by major biotic changes, viz., emergence of soft bodied Ediacaran fauna and their subsequent extinction; emergence of fauna with hard parts or skeleton and chemical changes, particularly variations in the C- and Sr- isotopic compositions of the carbonates. All 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 Super-sequence-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 Karihul Formations in Kashmir, the Batal, Kunzam La and Parahio Formations in Spiti-Zanskar and the Rilkot, Bilju and Milam Formations in Kumaun; the Karihul and Parahio Formations are of Middle to early Late Cambrian age. Of these, the basal formations, the Baliana and Ramsu, are arenoargillaceous in nature with impersistent bands of conglomerate and or diamictite deposited under unstable shallow marine environment. The middle part of the succession is dominated by carbonate evaporate 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 $\delta^{13}C$ values in the Baliana-Krol-Tal groups. The first depletions in $\delta^{13}C$ 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 $\delta^{13}C$, noticed in the carbonates



Text-figure 1—Integrated chemostratigraphy and biostratigraphy of Baliana-Krol-Tal succession, Lesser Himalaya, India (modified after Bhattacharya *et al.*, 1996).

of Kauriyala Formation (Krol D), may be due to local basinal conditions. Most of carbonate samples of the sequence with $\delta^{18}O$ 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 $\delta^{13}C$ 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 *Baicalia baicalica* (Singh & Rai, 1977), *Aldania mussoorica, A. birpa, Collumnefacta vulgaris, Boxonia gracilis* and *Ilicta talica* (Tewari, 1988; Tewari *et al.*, 1988). Maithy *et al.* (1995) reported Hyellace forms in Baliana Group. Tewari (1988) reported Vendotaenid from Mahi Formation of Krol Group. Singh and Rai (1983) reported calcareous algae *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 Lolab Formations (Kumar *et al.*, 1984 a, 1984b; Maithy *et al.*, 1988).

First multicellular animals in the form of Ediacaran fossils—*Beltanella* sp., *Tirasiana* sp., *Medusinites* sp., ? *Pteridinium* sp., *Kimberella* sp., cf. *K. quadrata, Cyclomedusa davidi, Conomedusites lobatus, Charniodiscus?* sp. and *Zolotytsia 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 $\delta^{13}C$ 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. *Anabarites-Protohertzina-Circotheca,*
2. *Dimidia-Allonia*, and
3. *Pelagiella-Auriculatespira.*

Small shelly fossils of assemblage-I and II are correlated by Kumar *et al.* (1987) with Meishucunian Zone I and III 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., *Bilinichnus biserialis* and ichnogenus A (Shanker *et al.*, 1997). Complex type of trace fossils, viz., *Rusophycus* sp., *Cruziana* sp., *Monomorphichnus* sp., *Diplichnites* sp., *Astropolichnus* sp. and *Skolithos* 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—*Arenicolites-Gordia-Phycodes* (? *P. pedum*),

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

Assemblage IV—*Rusophycus didymus-Isopodichnus-Kupwaria 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 *Burgauria*. 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 *Dimorphichnus, 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 Atdabanian 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 $\delta^{13}C$ 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 $\delta^{13}C$ 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 $\delta^{13}C$ 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 world wide 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 Yangtesse Platform, China excepting that the Meishucunian Zone II fauna has not been recorded so far from India.

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