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Sequence stratigraphic study of lesser Himalayan succession in parts of Mussoorie Syncline, Dun Valley, Uttrakhand, India

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Abstract

The Neoproterozoic – lower Cambrian terrigenous and carbonate rocks of the Lesser Himalayan successions were studied in parts of Mussoorie syncline, Dun valley, Uttrakhand employing standard concepts and methods of Sequence Stratigraphy. The succession rests unconformably over the folded Jaunsar Group of Mesoproterozoic age. The Blaini – Krol succession is overlain by the Tal Group of rocks belonging to Cambrian age. Early Permian and Late Cretaceous / Early Eocene successions unconformably overlie the Tal Group. Two sequence boundaries – the one at the base of the postglacial cap carbonate, i.e. Blaini Formation and the other a regional flooding surface within the Tal Formation close to the Krol – Tal contact have been identified on the basis of abrupt lithofacies changes. A complex of glaciomarine – tidal environment has been envisaged for the development of lesser Himalayan succession.

Keywords: Sequence stratigraphy, lesser Himalaya, sequence boundary, unconformity.

Introduction

The Himalaya is a very good example of collision-type orogenic belt. Severe tectonic impulses triggered the crustal shortening through uplift activities causing thrusting of Higher Himalayan crystallines over the Lesser Himalayan sediments along the Main Central Thrust (MCT) and development of nappes in the Lesser Himalaya due to it thrusted over the Siwaliks along the Main Boundary Thrust (MBT). In Mussoorie Syncline of Doon valley, the Lesser Himalayan sediments are divided into two important groups, one is Jaunsar Group and other one is Blaini-Krol-Tal Sequence. The Mesoproterozoic (ca 1200-1500Ma) Jaunsar Group is the older one composed of low grade metamorphic rocks, which is further subdivided into two formations, namely Chandpur and Nagthat. The Blaini-Krol-Tal Sequence is the younger one represented by carbonate and siliciclastic mixed sediments of Ediacaran (Neoproterozoic) to Cambrian-Ordovician (Early Palaeozoic) age. The Subathu limestone of Eocene and Shell limestones of Cretaceous are also recorded in the study area as thin sections.

The Sahansahi Ashram-Jharipani-Mussorie section exposes excellent outcrops of Blaini-Krol-Tal formation of the Lesser Himalayan succession which is of Ediacaran to Ordovician age. The Blaini Boulder beds or the Blaini Diamictites occurs at the base of this Blaini-Krol-Tal succession is equated with the glaciation of lower Ediacaran age (ca. 635-542 Mya). These Diamictites are also correleted with the glacial event of Varanger / Marinoan (ca. 630-600Ma). This unconformable sequence is sandwiched between the Jaunsar Group constituting Chandpur and Nagthat Formations of Mesoproterozoic age in its base and the Late Cretaceous / Early Permian successions overlying the same. The Himalayan orogenic movement (HOM-1) folded and shortened this sequence and as a result this lesser Himalayan Sequence is found in many separate synclines of present geologic time. The Mussorie Syncline has been studied in detailed by number of geologists for its litho-and biostratigraphy[1-9].

Regional Geology and Tectonic framework: The Sahinsahi Ashram - Mussoorie section displaying terminal Proterozoic sequence comprises the Blaini and Krol group of rocks. The succession rests unconformably over the folded Jaunsar Group of Mesoproterozoic age. The Blaini-Krol-Tal sequence is overidden by the Tal Group of rocks belonging to Cambrian age. Early Permian and Late Cretaceous / Early Eocene successions unconformably overlie the Tal Group (Figure-1, 2).

The Blaini Group transgressively overlaps the Jaunsar/Simla groups and is divided into the Blaini Formations and Infra Krol Formations. The Blaini Formation comprises lenticular diamictite and/or conglomerates, interbedded shale and quartz-arenite and quartz-wacke. The Blaini formation is sub divided into A, B, C, D, E, F and Gseven members (sub-formations) based on different characteristics. The diamictite appears at two to three levels. The top most bed of member F i.e. Diamictite is covered by a pink dolomitic unit and member G shale. There are differences of opinion about the origin of diamictite. One group considers it to be mud glaciomarine while the other regards it to be mud flows. The Blaini Formation is conformably underlain the Infra Krol Formation which is represented by black shale bleaching to ash grey with thin silt layers.

The Krol is a carbonate-evaporite succession divisible into three formations lower, middle and upper krol formations, namely the Krol A as Mahi, the Krol B as Jarashiand KrolC+KrolD+krolE as Kauriyala formations respectively in ascending order.

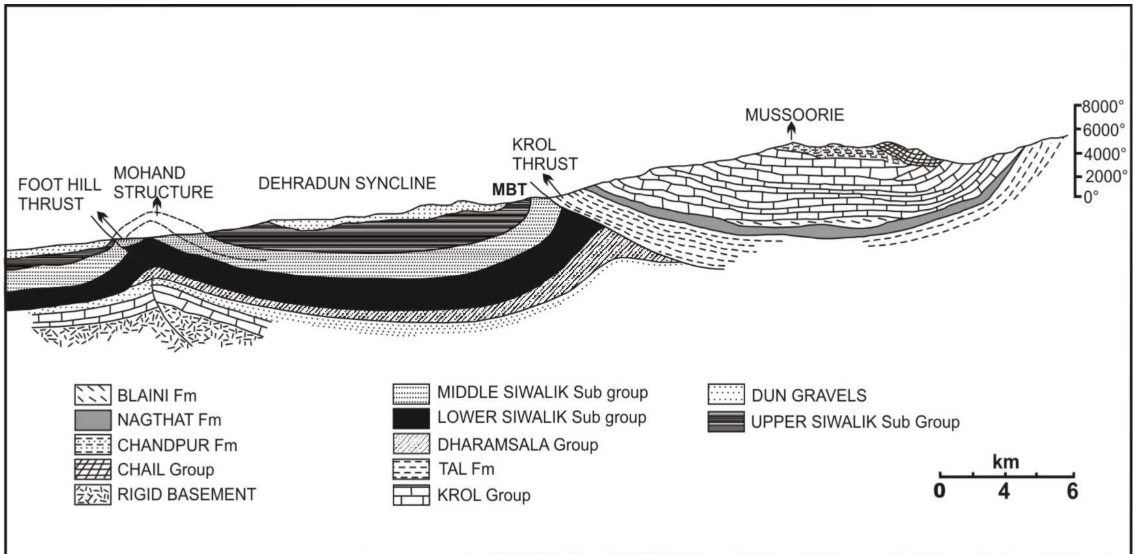

Figure-1: Geological section across Mohand and Lesser Himalaya after Rao et al.[10] and Shankar[11].

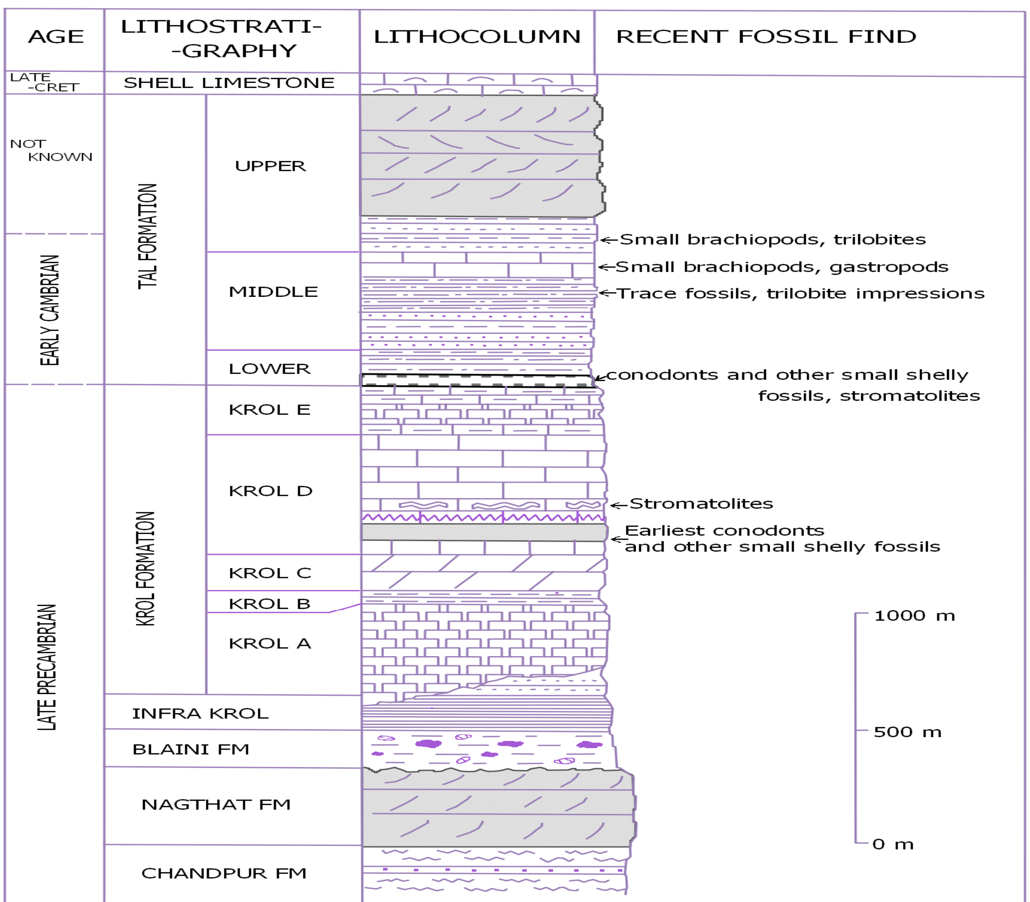

Figure-2: Revised time-stratigraphy of the Krol belt succession after Azmi & Joshi[12]; Kumar et al.[1]; Singh & Rai[2]; Tewari[3].

The Mahi Formation is mainly calc-argillaceous sequence whereas the Jarashi Formation is characterized by red siltstone and shale with or without gypsum beds. The Kauriyala Formation is dominantly a sequence of carbonate rocks with thin beds of shale. It is further subdivided into Krol C, Krol D and Krol E. The lower Member (Krol C) is a dark grey to black limestone/dolomite giving smell of H_2S on hammering, and may contain lenticular pockets of gypsum. The Middle Member (Krol D) is a thick bedded dolomite and grey shale or silty shale with lenticular thin beds or nodules of black chert. The Upper Member or Krol E comprises calcareous ferruginous red shale interbedded with argillaceous limestone. The Lower Tal Formation thickness varies from 75m to 880m and Upper Tal Formation from 70 to 1600m from one section to another. Phosphorus is earlier commercially mined at Maldeota and Durmala mines.

Methodology

Meticulous field observations, measurements and description of the Lesser Himalayan succession along Sahinsahi Ashram - Mussoorie section and Maldeota form the basis of data collection and interpretation in terms of sequence stratigraphy using standard concepts and methods after Miall[13,14]. Besides thickness and nature of boundaries, the composite vertical profile section was measured with respect to five parameters viz. Lithology (including grain- size), geometry, sedimentary structures, palaeocurrents and fossils (Figure-4). A chemical test to confirm phosphorus in the Tal Formation was performed by taking 100gm of powdered sample in a test tube and treating with concentrated nitric acid (HNO_3) followed by ammonium molybdate $(NH_4)_6Mo_7O_{24}$. On heating the test tube for a few minutes yellow color precipitate appeared confirming the presence of phosphorus in the Tal Formation.

Results and discussion

The Chandpur Formation argillite / phyllites of Lesser Himalaya are separated from the Middle Siwalik sediments of Sub-Himalaya by a thrust plain, named as the Main Boundary Thrust (MBT, Figure-3a). The thrusted contact between the two is evident as Chandpurphyllite overrides the Siwaliks, and the Chandpur sediments are highly crushed and myolinised.

Chandpurphyllites and argillites are myolinised and crushed close to MBT with development of quartz veins. Associated orthoquartzite / sandstone show laminations and pass upward into the arenaceous sequence of Nagthat Formation (Figure-3C). Depositional environment is interpreted as low energy lagoons in the near-shore shelf setup. The thinly bedded Chandpur Formation passes transitionally into thickly bedded arenaceous unit associated with thin laminations of siltstone and argillites (Figure-3B). Arenaceous sequence of Nagthat Formation displays various sedimentary features, such as stratification, ripple marks and current bedding (Figure-3D). A mixed to tidal flat depositional environment is inferred for the Nagthat Formation after Ghosh[6]. Along the Shahansahi Ashram - Jharipani mule track a very thick section of Blaini Boulder beds and associated argillaceous and arenaceous sediments are exposed. The contact between Blaini and Nagthat is unconformable. A well-developed Blaini Boulder Beds comprising different shapes, sizes and composition of clasts is observed on the west bank of the Song River along the road (Figure-3E). These boulders are equated with globally marker basal Ediacaran boulder beds referred to as the Maroneon / Varanger glacial episode (ca 630-600Ma)[8]. Black carbonaceous shale and slate at places pyritiferous constitute the Infra Krol Formation (Figure-3F) indicating a very low energy restricted basin with seasonal fluctuations as represented by quartz laminae. This is supposed to be a good source facies for hydrocarbon generation in Lesser Himalaya[15].

Krol A composed of thick layers of calcareous shale which is in terbedded with calcareous limestone and also marl. Bluish grey to dark grey parallel laminatedlimestones are characteristics of Krol A formation. Krol B is the most unmistakable markers of entire Krol, which is marked by colourful purple to red, laminated to blocky shale. The Krol-C is represented by massive limestone of grey to dark grey colourand shale. Presence of easily identifiable elephant skin weathering makes it peculiar. Layers of Gypsum and calcite, Stratified stromatolites, oolites are observed in the Jharipani road section. Krol C is conformably overlying by Krol D. Krol D is also characterized by massive limestone composed of thick shale interbeds with dolomitic limestone (Figure-3G). Oncolites, algal mats, are found in the upper part. The KrolD depositional set up is marked as intertidal with alternating siliciclastic and carbonate depositional environments. Krol E is a dolomitic mudstone of grey to dark grey, bluish grey, off white to pale cream color. The solution pores of these mudstones are filled with gypsum, dolomite and calcite. Which indicate toward a supratidalpalaeo environment, convergence with lagoonal environment of low energy condition[8].

The Tal Formation with its variable thicknesses and phosphorite deposits is well exposed at Maldeota. Phosphorite nodules are well developed in Lower Tal Formation (Figure-3H).

Depositional environments and sequence boundaries: It has already been stated that the Standard concepts and methods of sequence stratigraphy have been applied to the study area of Lesser Himalayan succession at Mussoorie Syncline. This is achieved by lateral tracing of Physical surfaces in the outcrop level on the basis of five parameters of facies. Starting in small scales by mapping of the key beds to regional scale, comprising landsliding slopes, dense vegetation, structural complexities gives evidences towards two prominent discontinuous surfaces. Regardless of discontinuation of lateral tracing of surfaces in some places, the detailed investigation gives convincing interpretations to demarcate two noticeable sequence boundaries.

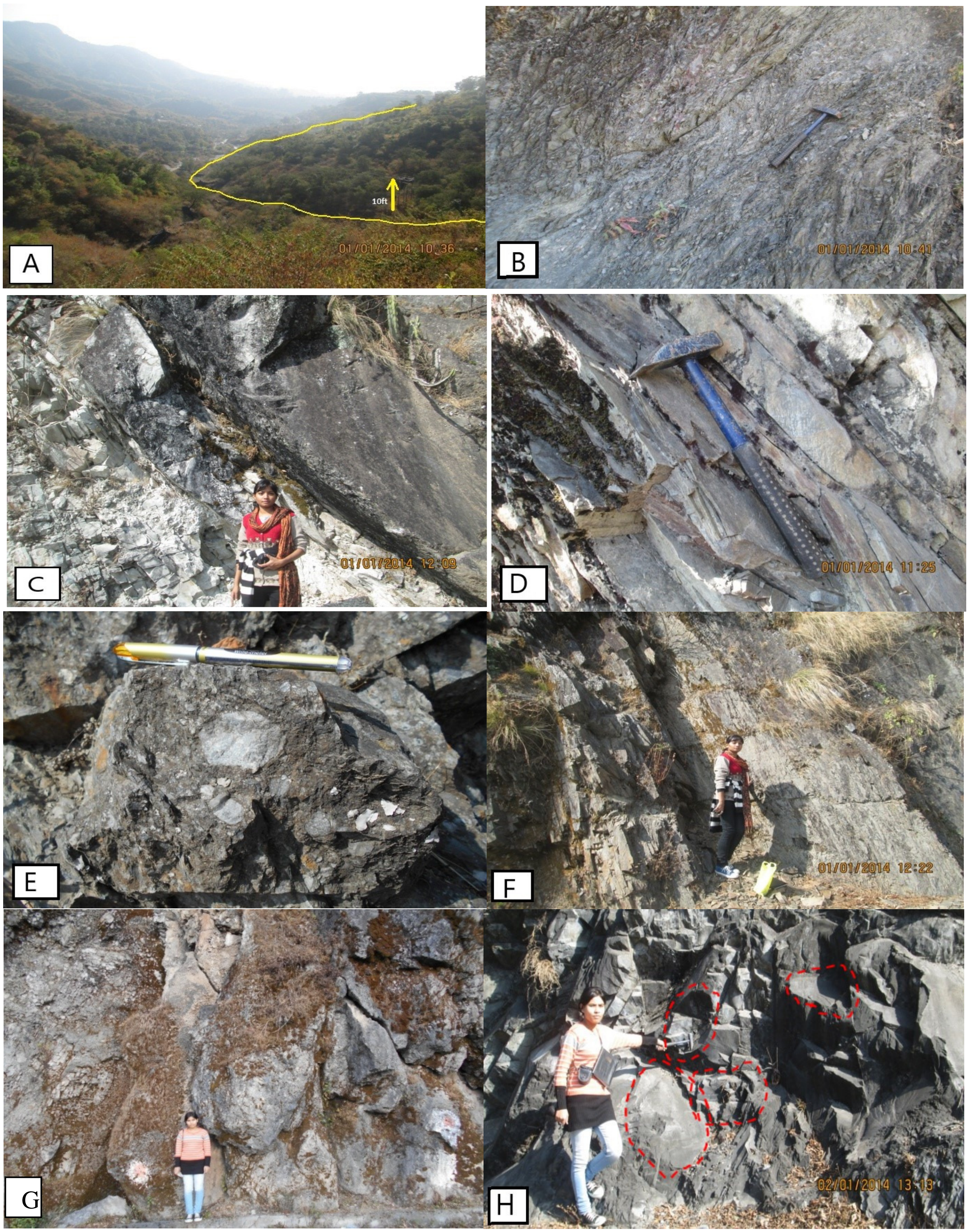

Figure-3: (A) MBT, separating Lesser Himalaya (Jaunsar group) from Sub-Himalaya (Siwalik group), (B) Black to steel grey argillaceous unit of Chandpur Formation, (C) Chandpur-Nagthat contact, (D) Thick arenaceous unit of Nagthat Formation, (E) Unsorted cobble-pebbles in Blaini Formation, (F) Black shales of Infra Krol Formation, (G) Massive Limestone of Krol Formation, (H) Nodular Phosphorite in lower Tal Formation.

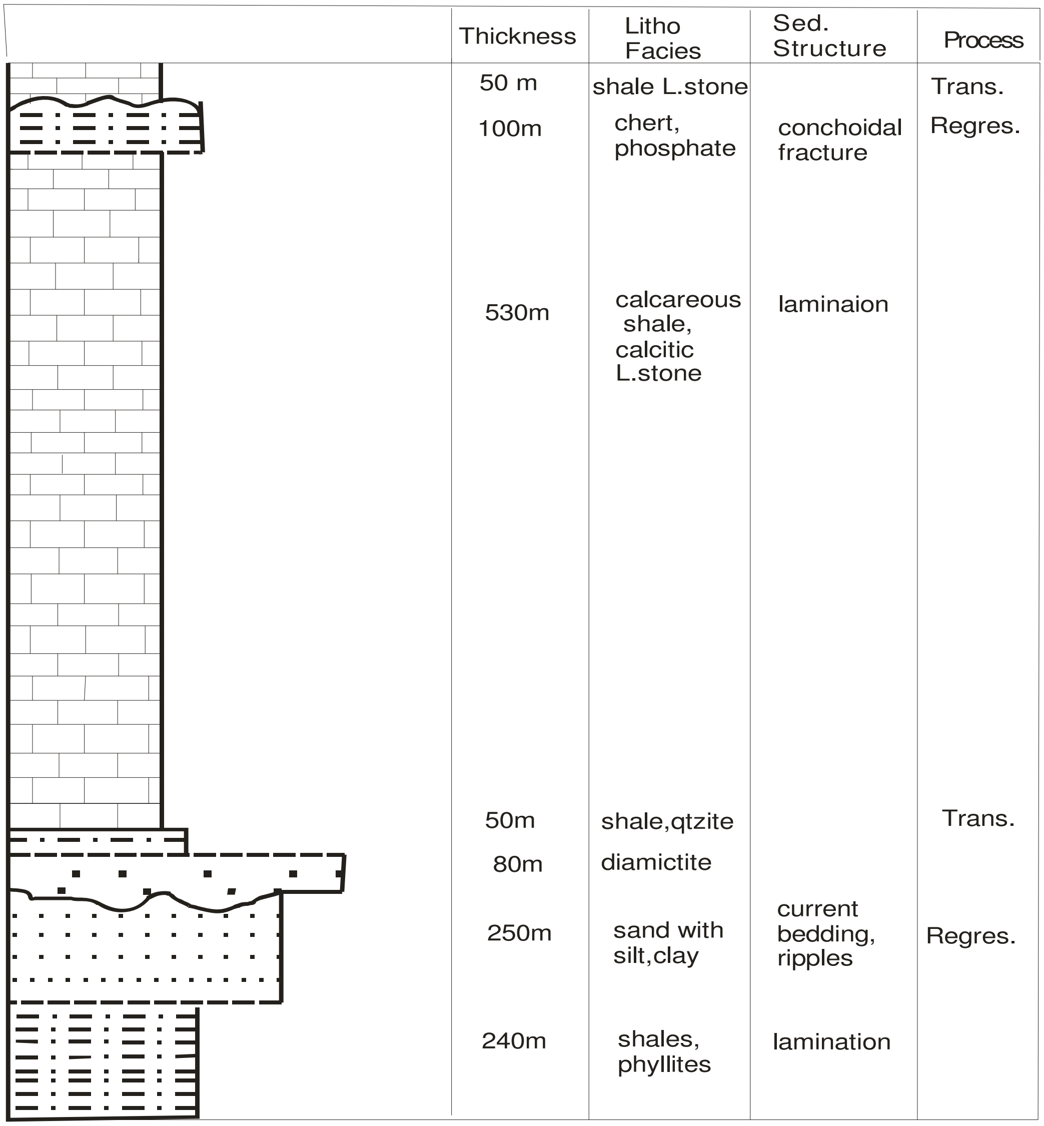

Figure-4: Composite Vertical profile section of Lesser Himalaya, Mussoorie Syncline.

The two prominent sequence boundaries are identified and correlated on the basis of following two main factors.: i. Abrupt change in an individual facies section, ii. Architecture of the facies in regional level.

From the entire study, the two identified prominent sequence boundaries are: one at the base of the Diamictic Blaini Formation and, the other one is the regional flooding surface in the Tal Formation, close to the Krol–Tal contact.

Surface-1: Surface 1 or the 1st sequence boundary lies at the base of Blaini boulder bed overlying unconformably the Nagthat Formation. The occurrence of Blaini Boulder Bed at the base of Infra Krol - Krol sedimentary column in a normal stratigraphic succession has invariably been equated with the glaciogenic Upper Carboniferous - Talchir Boulder Beds of Indian Peninsula since the first proposition of this idea by Oldham 1883[16]. It can well be considered as a glacio-eustatic origin, but so far there has been no evidences found for pronounced sea level lowering at other surfaces, Jiang et al.[17].

Surface-2: Surface 2 is near Krol-Tal contact, which was studied in the outcrops near Maldeota in the Mussoorie syncline. This surface is indicated by abrupt change in the regionally persistent facies from dolomitic mudstone of Krol E tophosphorite containing précised greyish black shale and chert of Tal Group. Presence of microbial laminae and gypsum lenses in the dolomitic mudstones of uppermost unit of Krol group i.e. Krol E denotes the characteristics of an intertidal environment. But just above this surface the shale and phosphorite deposits of Tal Group contains syngenetic to diagenetic pyrite layers pointed towards an anoxic set up of sediment deposition[18]. Therefore the basal Tal Group which contains pyrite clearly indicates a deep marine depositional environment.

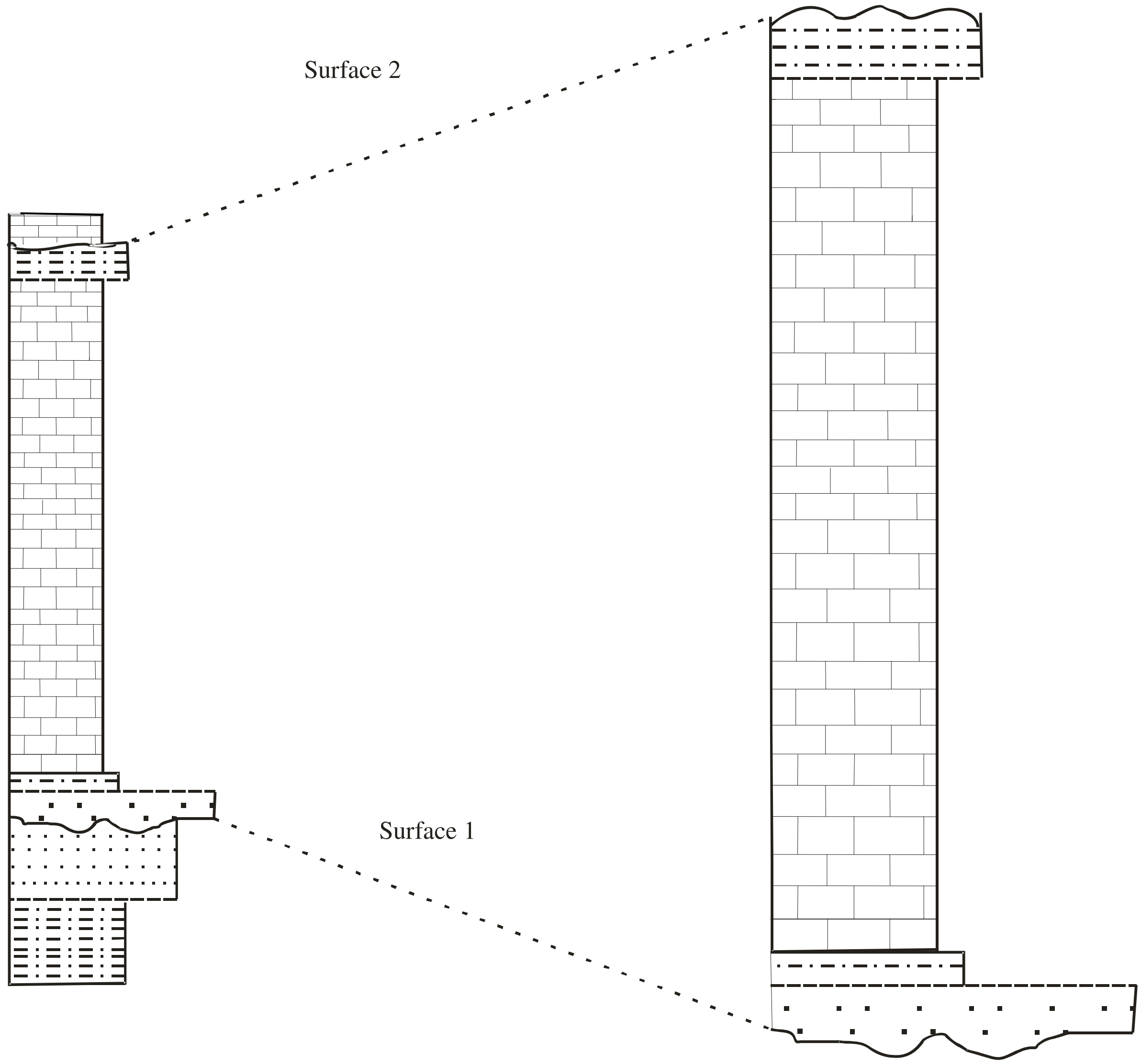

Figure-5: Sequence boundaries in Lesser Himalayan succession, Mussoorie Syncline.

Conclusion

The Neoproterozoic – lower Cambrian terrigenous and carbonate rocks of the Lesser Himalayan successions were studied in parts of Mussoorie syncline, Dun valley, Uttrakhand employing standard concepts and methods of Sequence Stratigraphy. The succession rests unconformably over the folded Jaunsar Group of Mesoproterozoic age. The Blaini – Krol succession is overridden by the Tal Group of rocks belonging to Cambrian age. Early Permian and Late Cretaceous / Early Eocene successions unconformably overlie the Tal Group. Two sequence boundaries –one at the base of the postglacial carbonate cap, i.e. Blaini formation and another one is a regional flooding surface within the Tal Formation close to the Krol – Tal contact have been identified on the basis of abrupt lithofacies changes. A complex of glaciomarine – tidal environment has been envisaged for the development of lesser Himalayan succession.

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