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Carbon and oxygen isotope trends in late Precambrian–Cambrian carbonates from the Lesser Himalaya, India

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δ^{13}C and δ^{18}O records of the Late Precambrian–Cambrian (Pc–C) carbonates from the Lesser Himalaya are reported here. The data depict two distinct cycles of ^{13}C maxima-minima and one distinct ^{18}O maxima for these carbonates. We suggest that isotopic variations across Pc–C stages relate to marked changes in the carbon and oxygen fluxes.

CARBON isotope signatures of the Precambrian–Cambrian boundary carbonates have been studied from a number of localities of the world[1-6], but their implications are still controversial. The preservation of original δ^{18}O records[3] in Pc–C boundary carbonates has also been questioned. We present here the result of a carbon and oxygen isotope study of two marine carbonate successions of Late Precambrian–Cambrian age from the Lesser Himalaya. The isotopic data are evolved in relation to sedimentary carbon budget and atmospheric oxygen level (?) changes etc.

In the northwestern Himalaya, two major carbonate-bearing successions, namely, the Deoban Formation of Lower to Middle Riphean age and the Krol Formation of Late Vendian (Ediacaran) age are present[7-9] (Figure 1). The Deoban Formation contains an approximately 1000 m thick succession of carbonate rocks (stromatolitic dolomites, dolomitic limestones, cherty limestones an oolitic limestones) with intercalated beds of shales. It is followed by a shallow marine sequence of the argillo-siliciclastic deposits known as the Simla/Jaunsar Group which comprises of Mandhali, Chandpur and Nagthat formations. The Simla/Jaunsar Group is overlain by the Blaini Formation of early Vendian (Varanginian) age, consisting of diamictite beds and minor deposits of microbial dolomites, siltstones and shales. The Krol Formation of Vendian age includes an ~ 2000 m thick succession of stromatolitic dolomites, cherty limestones, shales, sedimentary breccia, oolites and grainstones. It

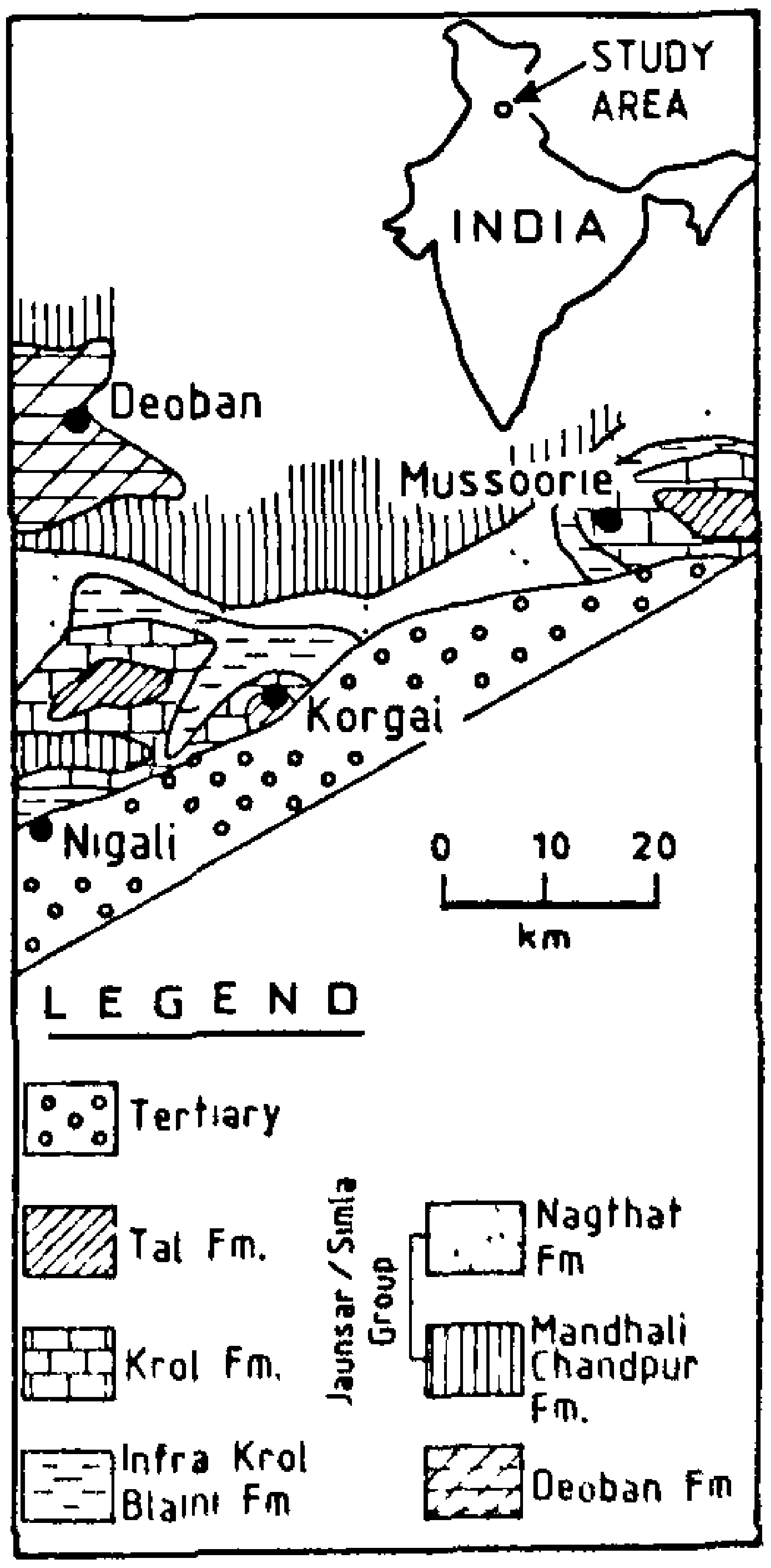

Figure 1. Geological sketch of the Deoban, Blaini and Krol–Tal sedimentary succession of the Lesser Himalaya, showing location of the study area (map after Chaudhri and Kalita[22])

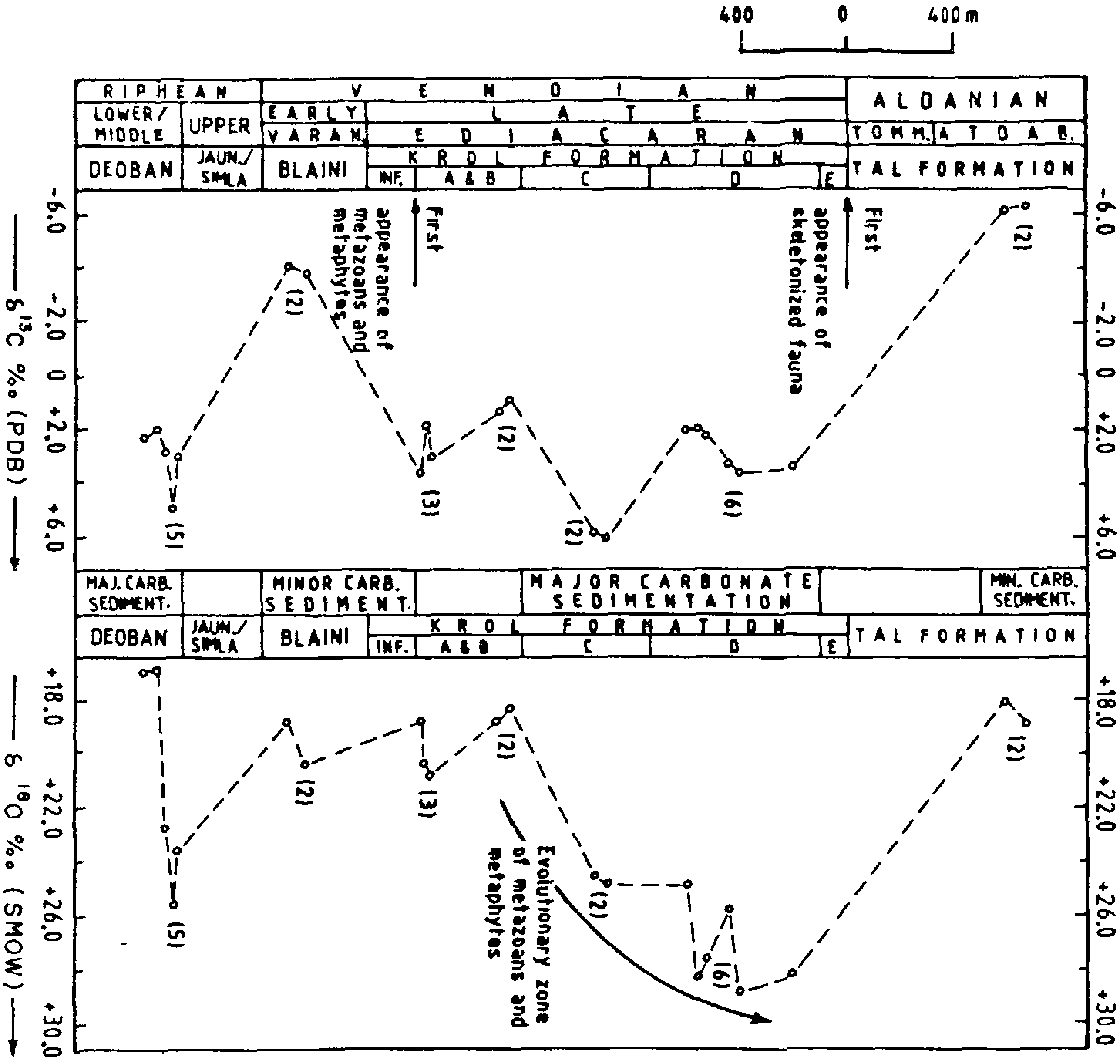

Figure 2. $\delta^{13}C$ and $\delta^{18}O$ records of the Deoban, Blaini, Krol and Tal carbonates in relation to their stratigraphy (the numbers in the bracket refer to number of samples analysed from each formation).

is followed by the Tal Formation (Early Cambrian) which consists of a Chert Phosphorite Member of Tommotian age and argillo–calcareous and siliciclastic member of Atdabanian–Botomian age. The carbonate sedimentation in the Tal Formation is minor. A late Precambrian to early Cambrian age for these formations has recently been established by biostratigraphic studies based on: i) discovery of microfossils of Late Precambrian age[7]; ii) identification of stromatolites of Late Precambrian affinity[8,9]; iii) documentation of Ediacaran metazoans and metaphytes[10,11] in the Lower Krol Member; and iv) records of the early Cambrian small shelly fauna[12,13], trilobites[14], brachiopods[15] and trace fossils[16].

The carbonates investigated in this study have been sampled from the Deoban Formation developed in the Deoban Mountains (30°45′ 77°54′) and those from the Blaini, Krol and Tal formations in the Korgai and Nigalidhar synclines (30°34′50″, 77°39′15″, cf. Figure 1).

$\delta^{13}C$ and $\delta^{18}O$ trends of the Deoban, Krol and Tal carbonates are plotted in Figure 2 in relation to stratigraphy of these carbonates. The isotope trends are drawn through the 'δ' values. $\delta^{13}C$ values become generally more positive from the Middle Deoban reaching ^{13}C maximum of +4.9‰ (PDB) in the Upper Deoban. This is followed by a decline of ^{13}C to a minimum of –4‰ in the Blaini. The carbon isotope profile shows a second rise in the Krol-C depicting a ^{13}C maximum of +6‰ which drops to a minimum of –6.2‰ within the Tal. $\delta^{18}O$ varies from +17.2 to +29.2‰ (SMOW) and exhibits a marked positive shift in the Upper Krol.

The previous workers[5] have opined that the carbon isotope variations of Krol–Tal sedimentary carbonates of the Lesser Himalaya represent pristine isotopic signatures as these successions have not been subjected to any metamorphism, deformation and excessive burial. We therefore consider that the $\delta^{13}C$ data reported here represent unaltered signatures.

The isotopic trends presented in Figure 2 show that ^{13}C maxima of $+4.9‰$ and $+6‰$ (PDB) relate to the major carbonate successions of the Deoban and Krol, and that the ^{13}C minima of $-4‰$ and $-6.2‰$ (PDB) are associated with terrigenous clastic deposits with minor carbonates of the Blaini and Tal formations, respectively. The marked increase in carbonate sedimentation during Deoban and Krol times would imply increased fixation of carbon dioxide in the form of carbonate carbon (C_{carb}). Deoban and Krol carbonate sedimentation represents a time span of Riphean to Vendian[7–17], a time interval much larger than the residence time of carbon (~ 10^5 years)[18] in the exogenic cycle. The increased fixation of carbon dioxide in the form of C_{carb} will therefore mean increased availability of CO_2 in the environment existing during Deoban and Krol times. The Deoban and Krol carbonate formations are mainly microbial in nature and their large-scale deposition indicates a relative enhanced build-up of microbial communities which preferentially fixed ^{12}C in the form of organic carbon (C_{org}), this resulting in ^{13}C enrichment in carbonate carbon. ^{13}C maxima thus relate to overall increase in sedimentary carbon ($C_{carb} + C_{org}$) budget, increased availability of carbon dioxide in the prevailing environment, enhanced rate of photosynthesis and possibly warmer climates. Conversely, ^{13}C minima associated with the Blaini and Tal formations may go along with decrease in the total sedimentary carbon budget (as evident from field observations and marked negative $\delta^{13}C$ signatures), reduced rate of photosynthesis, lower concentration of CO_2 in the prevailing environment and possibly colder climates. The colder climates during Blaini times is envisaged by its possible association with the Varangian glaciation event[4]. There is no evidence of colder climates during Tal times.

The $\delta^{18}O$ records of Late Precambrian–Cambrian carbonates are considered to be artifacts of diagenetic alterations[3] or post-depositional isotope exchange equilibration processes[19], but we suggest that this may not be the only possible reason. The Krol carbonates depict a distinct ^{18}O maxima that associate with carbon isotope maxima (Figure 2). ^{13}C maxima has been interpreted in terms of increased carbon burial and enhanced rate of photosynthesis which has been the main source of oxygen build-up in the atmosphere. Further, the Krol sedimentary succession exhibiting distinct ^{13}C and ^{18}O maxima may be related to the evolutionary transition from unicellular life forms to multicellular metazoans and metaphytes, these must have originated in high oxygenated environment[4,20,21]. Therefore, we associate ^{13}C and ^{18}O maxima with intervals of high environmental oxygen level similar to or higher than the present one. However, the causative reason for link between ^{18}O maxima and higher oxygen levels still remains questionable.

It is concluded that $\delta^{13}C$ and $\delta^{18}O$ variations across Pc–C stages relate to the marked changes in the carbon and oxygen fluxes.

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