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# EVIDENCE FOR PAN AFRICAN-CADOMIAN TECTONIC UPHEAVALS IN HIMALAYA*

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ABSTRACT

The strong diastrophic movements initiated towards the close of the Proterozoic and repeated in early and late Cambrian times, brought about wholesale cessation of sedimentation throughout the Peninsular India and Lesser Himalaya, caused interruption in basin-filling in the Tethyan belt, and resulted in widespread emplacement of granitic bodies in the northern part. The termination of sedimentation practically all over the subcontinent indicates its emergence above the sea. It appears that the Indian shield was gradually lifted up—the Vindhyan province in the Vendian times, the Lesser Himalayan terrain towards the close of the Lower Cambrian and the Tethys marginal basin in the later Upper Cambrian.

The break in sedimentation in the Tethys domain is mainfest in, among other things, (1) the absence of fauna of later Upper Cambrian and Lower Ordovician in the Palaeozoic successions of Kashmir, Zanskar-Lahaul, Spiti, and Kumaun (2) the occurrence of Middle Ordovician conglmerates atop the Cambrian flyschoid successions in Spiti, Lahaul and Zanskar areas, southern flank of the Pir Panjal in Kashmir and on the Precambrian crystallines in the Lingshi and Black Mountain basins in Bhutan, (3) and the intriguing absence of sediments bearing Cambrian and Lower Ordovician fossils east of Kumaun. There was explosive volcanism accompanied presumably by earthquake-induced submarine slides, such as discernible in central Bhutan in the Cambro-Ordovician times.

The extensive emplacement of 500+25 m.y. old Cambro-Ordovician granites is a consequence of attenuation and anatexis of the continental crust, possibly related to the sea-floor spreading that isolated Laurentia from South America and East Antarctica- Australia in the Late Proterozoic-Early Cambrian times.

## INTRODUCTION

Revival of strong tectonic movements in the Late Pliocene-Middle Pleistocene and in the later Holocene times have given the Himalaya its formidable height and forbiddingly rugged topography (Valdiya, 1993), even though the climactic upheaval occurred in the Middle Miocene epoch 20-18 m.y. ago. There was yet another diastrophic event in the distant past towards the end of the lower Cambrian, which considerably influenced tectonic design and sedimentation history of the Himalaya. Alluding to its effects, the author (Valdiya, 1973, 1984) had described this intracontinental diastrophism as Baikalian orogenic phase which happened 600 m.y. ago. Fuchs (1968, 1987) had long realized the significance of the break in sedimentation and described it as manifesta-

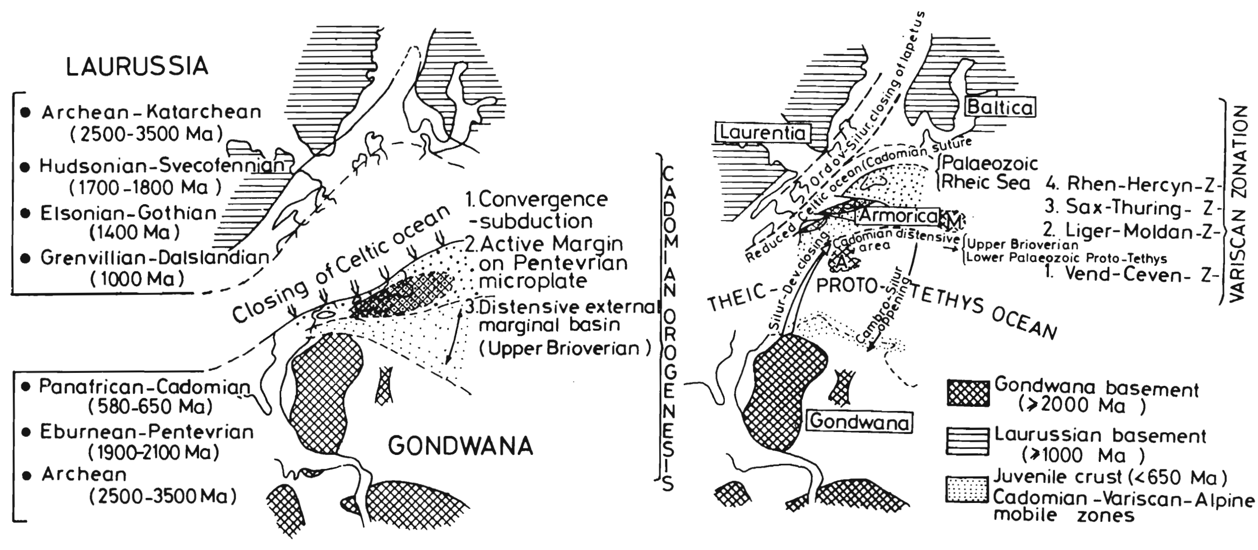


Fig. 1A. Cadomian orogeny in western Europe.
A. Convergence of continental plates (Dupret *et al.*, 1990).

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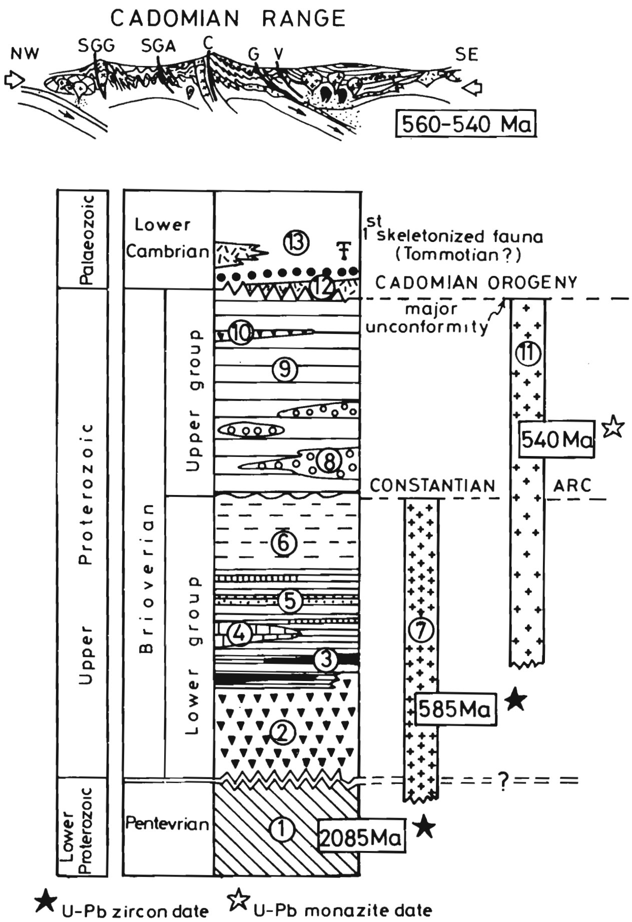


Fig. 1B. Evolution of the mountain and the stratigraphic column (Rabi *et al.*, 1990).
1, migmatites and gneisses of La Hague; 2, volcanic formations; 3, schists and black cherts of La Lande des Vardes; 4, limestones of La Meauffe; 5, snadstones of Rampan; 6, siltites and sandstones of Saint-Pair; 7, quartz diorite of Coutances; 8, diamictites of Granville; 9, siltites and grewackes of La Laize; 10, spilites of Vassy; 11, Mancellian granitoids; 12, ignimbrites of Saint-Germain-le-Gaillard; 13, Lower Cambrian sediments.

tion of the Caledonian orogeny, which occurred in the Late Cambrian to Ordovician times (Fuchs, per. com., 1993). Metha (1977), Bhargava (1980) and Mitchell *et al.* (1983) consider the large scale granite activity as a strong evidence for Late Cambrian orogeny, and Garzante *et al.* (1986), Shah (1991), Bagati (1991) and Bhargava *et al.* (1991a) attribute the break in sedimentation to the last epeirogenic pulse of Pan African orogeny in the Himalaya. Pronounced break in basin-filling in the Tethyan domain in the north, and wholesale cessation of sedimentation in the Lesser Himalaya and in all Purana basins of the Peninsular India, coupled with wide occurrence of 500+25 m.y. - old granites in the northern belt of the Himalaya argue strongly for the hitherto little appreciated orogenic cycle in the Cambro-Ordovician times. This would be broadly contemporaneous with the Pan African-Cadomian orogeny (fig. 1), so well recognised in Africa and western Europe (Duppret *et al.*, 1990; Rabi *et al.*, 1990).

The various lines of evidence leading to the postulation and corroboration of the effects of Pan African-Cadomian orogeny in the Himalaya is discussed below.

### CESSATION OF SEDIMENTATION IN LESSER HIMALAYA

The long, almost unbroken cycle of Purana (Proterozoic) sedimentation suddenly came to an end towards the close of the Lower Cambrian throughout the Lesser Himalaya and a little earlier in all the Peninsular basins. As a matter of fact, already there were movements in the Himalayan domain in the Vendian (Eocambrian) times, heralding impending unpheaval that teraminated the cycle of Purana sedimentation. This fact is borne out by numerous cases of diamictites generated by debris avalanches and of horizons of euxinic sediments in lithological sequence (fig. 3) of the Vendian-Lower Cambrian formations, such as the Tal and the Mandhali-Basantpur.

In central sector of the Lesser Himalaya, the terminal formation of the very thick lithological succession (fig. 2) is represented by the Tal in the outer belt, the Mandhali-Basantpur in the inner zone (fig. 3). The homotaxial formations are known as Sincha in Jammu, Robang (uppermost Nawakot) in Nepal and Saleri in western Arunachal Pradesh. The dolomites of the Mandhali-Basantput are characterized by Late Riphean to Vendian gymnosolonid stromatolites (Valdiya, 1969). Interestingly, more than thirty years ago, the Calc Zone of Pithoragarh (combined Deoban-Mandhali succession, now called Tejam Group) was assigned Late Precambrian to Cambrian age (Misra and Valdiya, 1961). While the carbonaceous slates resting on the Deoban limestones at Lameri in the Alaknanda valley yielded acritarchs and associated organisms of Cambro-Ordovician affinity (Agrawal, 1974), the magnesite stratum in upper succession of sediments – presumably the Mandhali in north-eastern Nepal – revealed Cambrian sporocysts palaeobasiospores (Brunel *et al.*, 1985). On the basis of the occurrence of conodonts (Azmi and Pancholi, 1983), small shelly fauna (Bhatt *et al.*, 1983; Bhatt and Mathur, 1990), brachiopods (Tripathi *et al.*, 1984) and trilolites (Kumar *et al.*, 1987), the Tal is assigned to the Lower Cambrian (Tommotian to Botomian).

In the Paristan area (District Doda) in the Lesser Himalayan Kashmir, the Precambrian Ramsu flysch

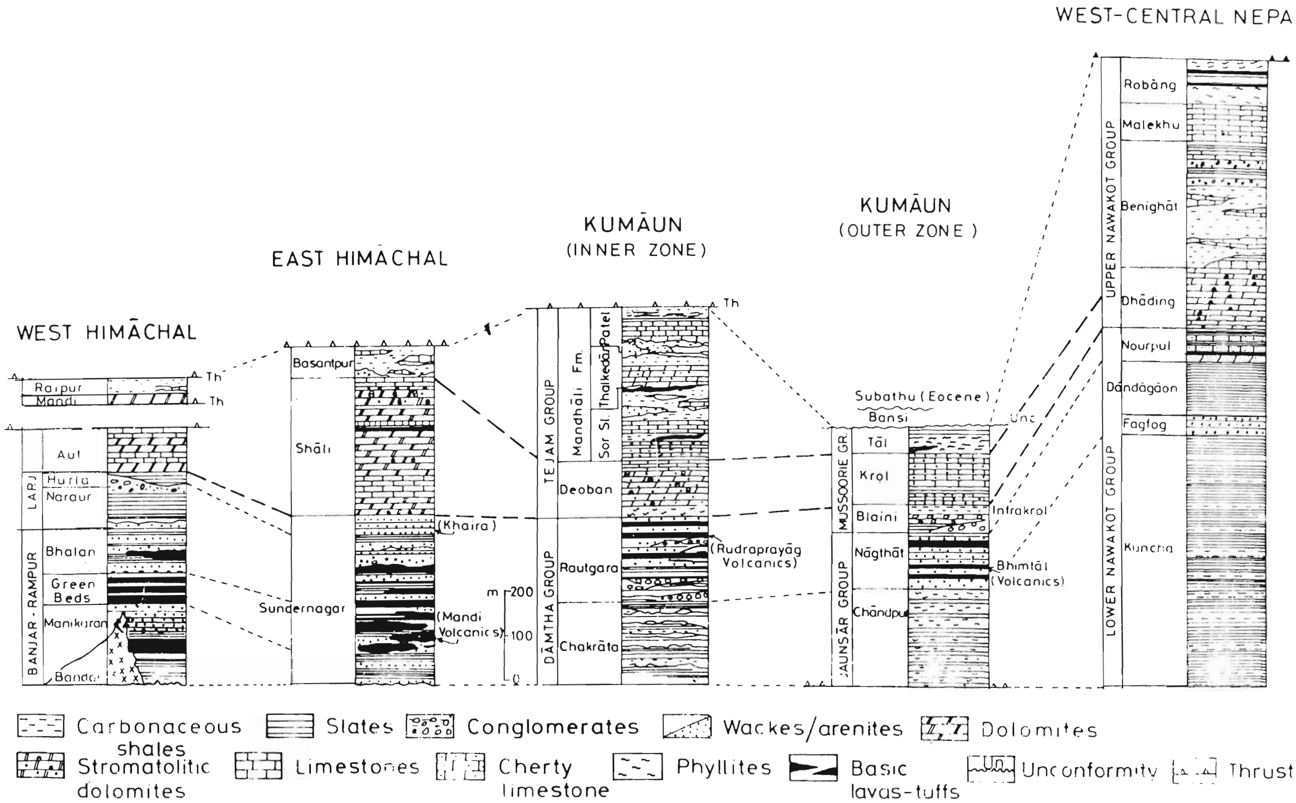


Fig. 2. Lithostratigraphic columns of different sectors of the Lesser Himalaya, ending up in the Lower Cambrian or Vendian formations.

is capped by the Zilant Formation made up of chert, shale and limestone characterized by Lower Cambrian skeletal microfossils, including *Calceoloides typicus* (Raina *et al.*, 1981). The Zilant is unconformably overlain by the Panjal Volcanics of the Lower Permian. In the so-called "Parautochthonous zone" (Wadia, 1934) in the Pir Panjal, the Ramban-Sincha succession of slates, arenites and dolomitc limestones

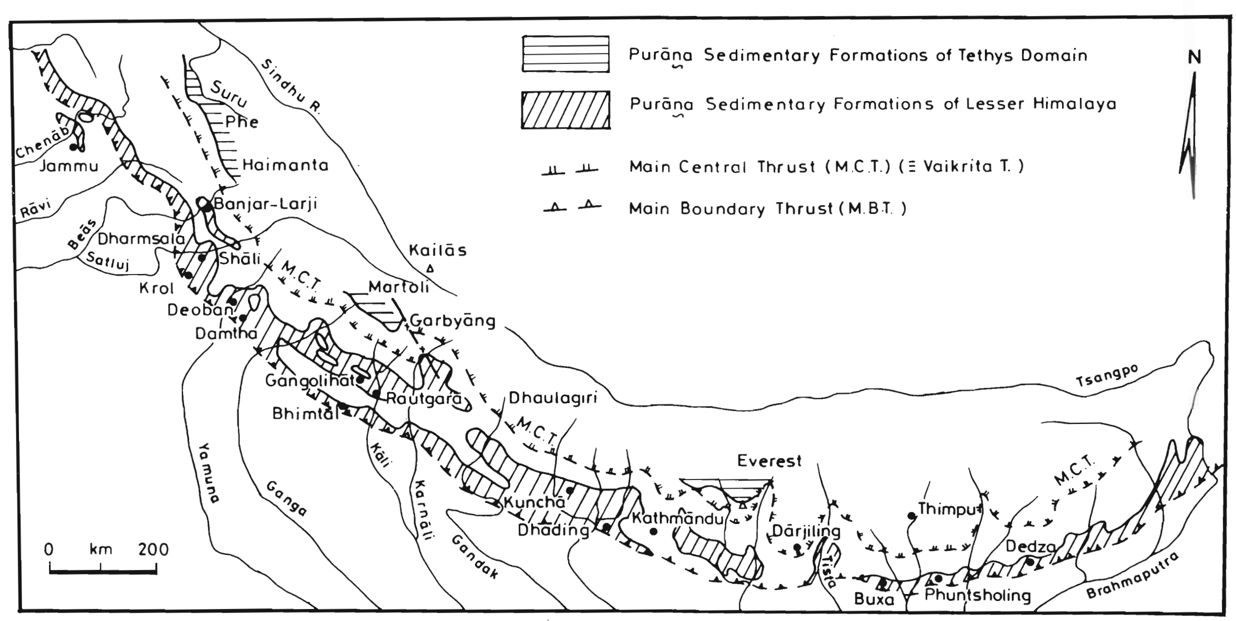


Fig. 3. Geological sketch map of the Himalaya showing Proterozoic to Lower Cambrian sediments.

with diamictites and pockets of gypsum represent the homotaxial of the Mandhali of Upper Riphean-Vendian age. To the northwest, the Ramban is unconformably overlain, albeit interruptedly, by Permian formations (Agglomeratic Slates-Panjal Volcanics). It would not be surprising if the strata of Sincha reveal Lower Cambrian fauna. Practically the entire Palaeozoic is thus missing altogether. Very similar is the situation in the Hazara-Chitral region in northern Pakistan, where the Dogra Slate (=Ramban/Ramsu) is unconformably overlain by the dimaictites of the Agglomeratic Slates. In the Salt Range (fig. 4) the Eocambrian-Lower Cambrian sequence is unconformably covered by the conglomerates of the "Talchir" beds of Lower Permian age. Thus the whole of northern Pakistan was a "high" throughout most of the Palaeozoic times (Wadia, 1934; Coward *et at.*, 1988).

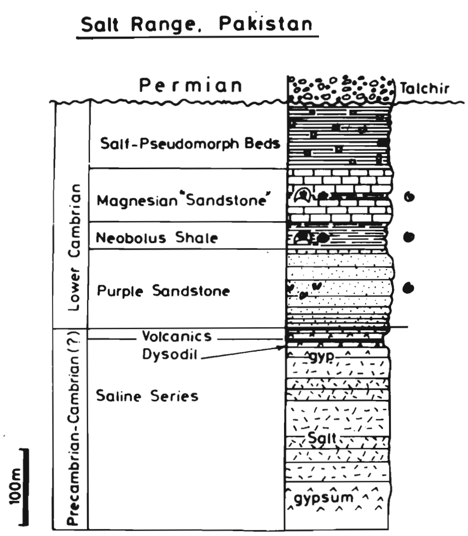


Fig. 4. In Salt Range (Pakistan) the Lower Cambrian marks the end of sedimentation until the Lower Permian "Talchir" (Gansser, 1974).

In the northwestern part of the Peninsular India, the upper formation of the Marwar (Vindhyan) Supergroup, the Bilara (fig. 5) is reported to have *Orthis* of the Cambrian age (Barman, 1980). The Marwar appears to be the southeasterly extension of the Purana formations of the Hazara-Salt Range in Pakistan, as evident from the common occurrence of a thick succession of evaporites (Das Gupta *et al.*, 1988).

The Peninsular India and Lesser Himalaya have a singularly unvarying, uniform history. Everywhere there was no sedimentation at all after the Lower Cambrian – not until the sea returned through narrow elongate basins in the Lower Permian. The marine transgression is represented by the diamictites (Talchir and its equivalents) and fossiliferous marine sediments; and this was followed by rift-related volcanism in many sectors throughout the Lesser Himalaya.

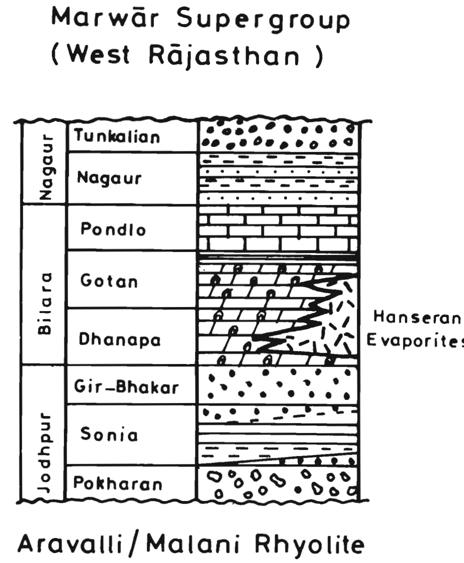


Fig. 5. The Bilara Fm in the upper part of the Marwar Supergroup in western Rajasthan yielded Lower Cambrian *Orthis* (After Barman, 1980).

## INTERRUPTION OF SEDIMENTATION IN TETHYS DOMAIN

While there was wholesale halt of sedimentation throughout the Lesser Himalaya, the Tethyan basin experienced merely interruption in basin-filling. This interlude of non-deposition varied in time from sector to sector.

In the Kupwara-Hundwara and Liddar valley sections in Kashmir (fig. 6) the flyschoid sequence of the Dogra Slate (Machhal formation) is succeeded by the Lolab-Khaiyar formations (Shah *et al.*, 1988) containing shelly fossils and sponge spicules of the Precambrian-Cambrian transition age (Meera Tiwari, 1989). The Precambrian Ramsu-Machhal formations of argillites, wackes and diamictites (with lenses of carbonates) grade up into the Lolab in the Kupwara district (NW) and the Khaiyar in the Liddar valley (SE). The Lolab/Khaiyar have yielded Lower Cambrian *Redlichia noetlingi*, primitive brachiopods and prolific trace fossils (Shah, 1982; Shah and Sudan, 1987; Shah *et al.*, 1988, 1991). The Lolab/Khaiyar are succeeded transitionally by the Nutunus/Karikul formation bearing Middle Cambrian *Ptychoparia - Tonkinella* fauna. Overlying is the Trahagam formation containing *early* Upper Cambrian *Damesella*. Overlain are conglomerates and quartzarenites with argillites and carbonates of the Marhaum/Margam formation containing abundant Orthids, Strophomenids, brachiopods, trilobites and corals of the Ordovician to Silurian age (Shah *et al.*, 1988). There is apparently no physical break in sedimentation in the Kashmir sub- basin (fig. 6), but a faunal break encompassing upper part of Upper Cambrian and Lower Ordovician is unmistakable (Shah, 1991).

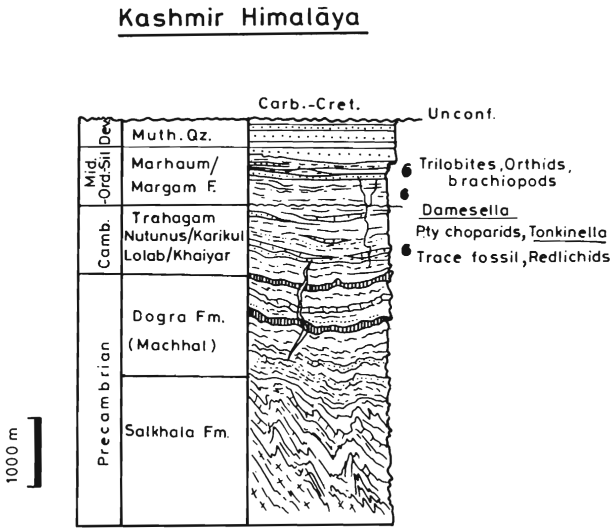


Fig. 6. In the Kashmir sub-basin there is no break between the Late Precambrian and Cambrian (Modified after Gansser, 1964 and Shah *et al.*, 1988).

In the Zanskar-Lahaul sector where the Trans-Himadri Fault (Valdiya, 1989) has not eliminated lithological units, polymetamorphic Vaikrita basement is disconformably overlain without discordance by very mildly metamorphosed flyschoid of the Batal Formation, followed upward by the Lower Kunzamla of wackes and slates characterised by a variety of turbidite features like tool-marks, load cast and mud cracks, and by *Cruziana* trace fossils (fig. 7) (Srikantia *et al.*, 1978; Bhargava and Srikantia, 1985; Fuchs, 1987). The Lower Kunzamla (=Phe) is overlain transitionally by carbonates (Karsha) followed upwards locally by the bioturbated pelites and greywakes (Kurgiakh), the two making the Upper Kunzamla (Srikantia, 1981; Srikantia *et al.*, 1978; Baud *et al.*, 1984). Dungrakoti *et al.* (1974) have recovered Middle (to possibly (?) Upper) Cambrian fossils (*Lingulella, Ptychoparia*, etc.) from the grey, green shales at the top of the Kunzamla. The marine Kurgiakh facies of the Kunzamla is unconformably overlain by the conglomerates and red sandstones of continental molassic facies of the Thango (Thaple) Fm. The Thango is doubtfully assigned to the Upper Ordovician-Lower Silurian age (Srikantia *et al.*, 1978; Bhargava *et al.*, 1991b). The gap between the Upper Kunzamla, which is Middle Cambrian (to possibly ? early Upper Cambrian in age), and the Thango of the Upper Ordovician, is quite obvious. Significantly, in southern Lahaul, the pre-Kunzamla Batal is succeeded directly by the Tandi Group of the Permian to Jurassic sedimentary rocks (Srikantia and Bhargava, 1979). The big gap may be partly tectonic.

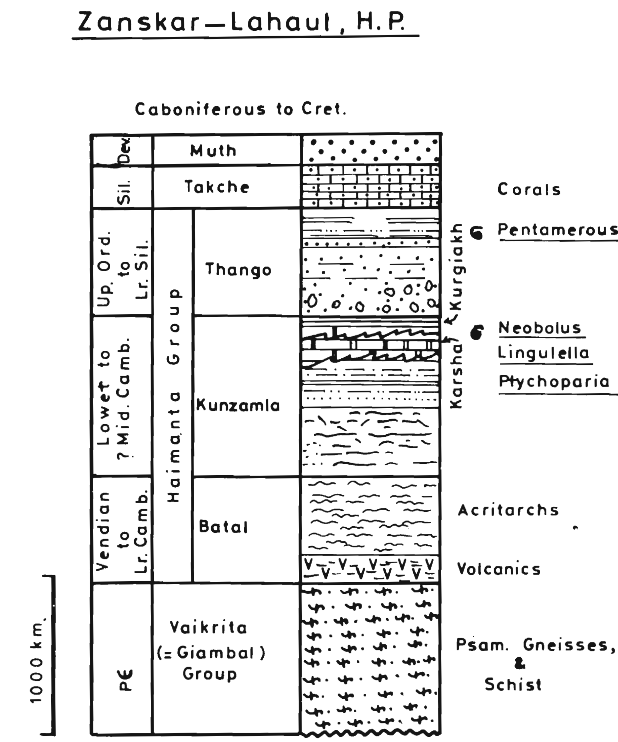


Fig. 7. Pre-Permian lithological successions of the Tethyan sub-basins in Zanskar and adjoining Lahaul (Based on Srikantia *et al.*, 1978; Bhargava *et al.*, 1991b; Baud *et al.*, 1984).

In Spiti, the greywacke and slate assemblage of the Lower Kunzamla — making the middle part of the Haimants Group—passes upwards into the fossiliferous sediments of the Upper Kunzamla or Parahio unit (Srikantia, 1981; Ranga Rao *et al.*, 1984; Bhargava *et al.*, 1991b). The upper part of the Parahio succession, characterized by *Olenus* of early Late Cambrian age, is unconformably overlain by a horizon yielding Middle Ordovician brachiopods—without the remaining part of the Upper Cambrian and Lower Ordovician (Shah *et al.*, 1991). In the spiti area, the Ordovician conglmoerates transgress on the Haimanta and Parahio with angular unconformity (Fuchs, 1987). There is thus a clear evidence for tectonic disturbance in the post-Kunzamla times but within the larger temporal span of the Haimanta.

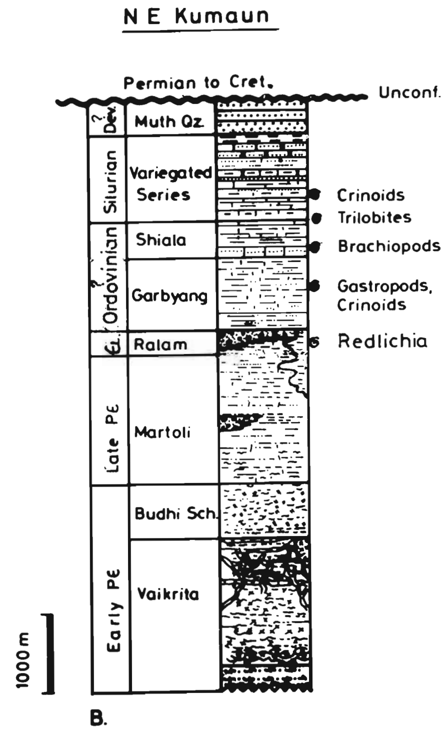


Fig. 8. Pre-Permian Tethyan succession in NE Kumaun (Modified after Gansser, 1964, fig. 65).

In northeastern Kumaun (fig. 8), the top slates of the Late Precambrian Martoli flysch succession, which pass upward through a prominent horizon of orthoquartzite and oligomictic conglomerate (Ralam) recently, yielded Lower Cambrian *Redlichia noetlingi* (Kakkar and Srivastava, 1992-93). The Ralam is succeeded by a great thickness of carbonate sediments of the Garbyang Group, comprising alternating carbonates and calcareous argillites, ferruginous concretionary limestone and limonitic shales and marlites. The strata contain badly preserved crinoids and large gastropods of the doubtful Cambrian (Heim and Gansser, 1939) or more probably of Middle Ordovician age. However, the profusely occurring trace fossils including *Cruziana, Phycodes* and *Rusophycus* in the middle Garbyang have been assigned to the Lower Cambrian by Tandon and Bhatia (1978). The Garbyang is overlain without discontinuity or even a suggestion of discontinuity by the Shiala, the top of which is bearing *Calymene, Orthis, Rafinesquina, Leptaena sphaerica* of Ordovician age (Heim and Gansser, 1939; Gansser, 1964).

In the Dolpo-Dhaulagiri-Ganesh Himal region (Fuchs *et al.*, 1988) in north-central Nepal (figs. 9A and 10A), the basement crystalline (Annapurna Geniss) is succeeded with a sharp break (Bordet, 1961,) by an attenuated horizon of phyllites, greywackes and acid tuffs called the Sanctuary Fm (Colchen *et al.* 1986). Then follows a 3000-4000 m thick sequence of mildly metamorphosed carbonate sediments, divided into Annapurna unit showing trace fossils and the Pi and Nilgiri containing characteristic Middle Ordovician fauna. Thus the first level which has been reliably dated is the base of the Nilgiri Limestone, characterized by Llanvirnan (Middle Ordovician) brachiopods (Colchen *et al.*, 1980).

In the Sagarmatha region in northeastern Nepal

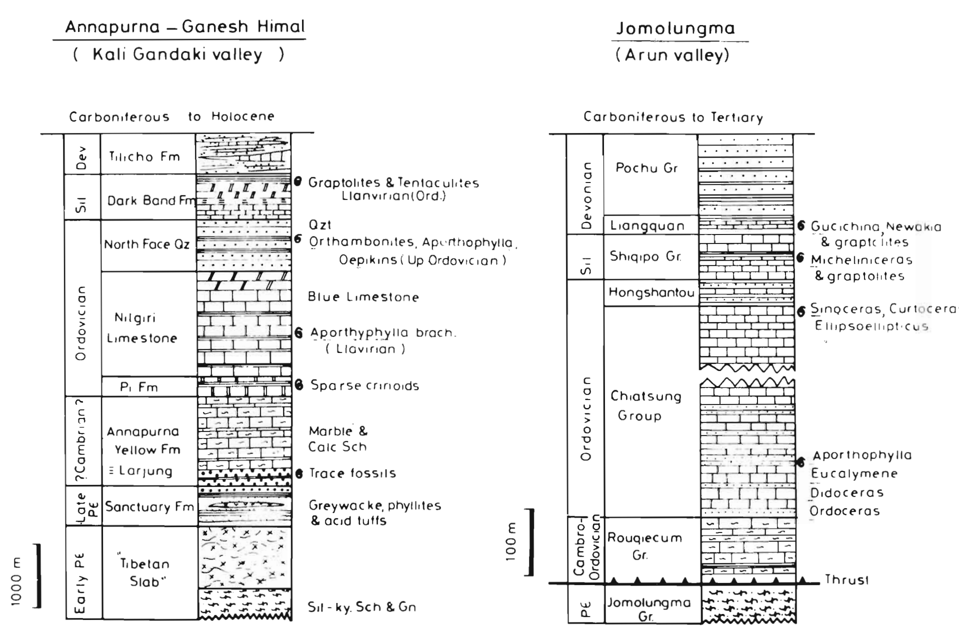


Fig. 9. Pre-Permian Tethyan succession in north-central and southeastern Nepal.
A. After Colchen *et al.*, (1986).
B. After Mu *et al.*, (1973).

and adjoining Sikkim (figs. 9B, 10B), the Precambrian Everest Pelites and Everest Limestone are overlain by the Permian Lachi Group, the base of which is marked by prominent conglomerate horizon (Wager, 1934). In the Tibetan region on the northern face of the massif the Jomolungma (=Everest Pelites) and Rouquiecum (=Everest Limestone) groups are overlain by the Chiatsung-Hongshantou containing fossils of Lower Ordovician age (Mu *et al.*, 1973).

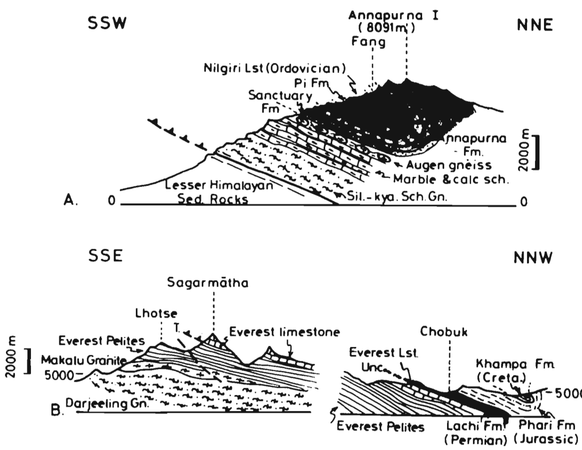


Fig. 10. Cross-section of the Nilgiri massif and Everest mountain in north-central and northeastern Nepal.
A. After Colchen *et al.* (1986), B. After Wager (1939).

In the Chandragiri Hill (Auden, 1935) of the Mahabharat Range in south-central Nepal (fig. 11) the Precambrian Bhimphedi Group of metamorphics and intrusive granites is overlain by a great thickness of sedimentary rocks. The earliest recorded fossils, including *Caryocrinites* crystoid belong to upper part of the Middle Ordovician-Middle Silurian (Bordet, 1961; Stocklin *et al.*, 1977). The Cambrian and Lower Ordovician are unrepresented in the Chandragiri succession.

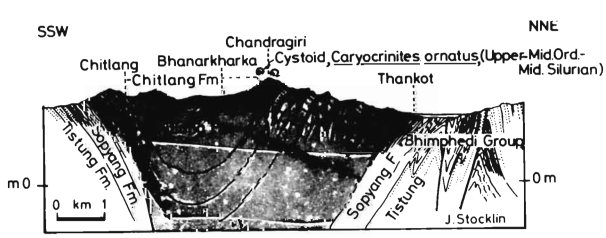


Fig. 11. Chandragiri Hill in the Mahabharat Range in south-central Nepal (After Stocklin *et al.*, 1977).

In Bhutan, there are three basins of marine Palaeozoic sedimentation. In the TangChu Basin (Fig. 12) the high-grade Thimpu metamorphics give way

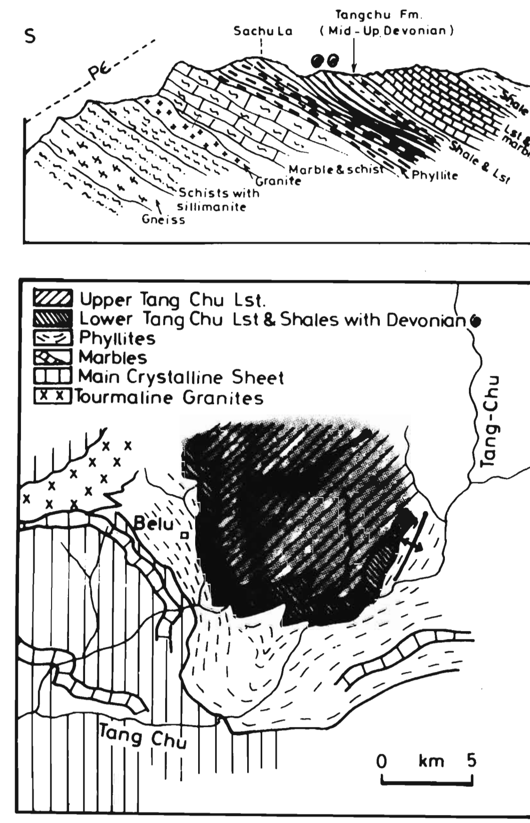


Fig. 12. Tang Chu basin in Central Bhutan showing Precambrian crystallines succeeded by Devonian sediments (After Termier and Gansser, 1974).

gradually through marbles and phyllites to the shales and limestones containing Middle to Upper Devonian Atrypidae, Elythidae, trilobite and crinoid fossils (Termier and Gensser, 1974). In the Black Mountain, the high-grade Thimpu metamorphics transitionally pass upward into low-grade metamorphics — carbonates, slates and subgreywackes — of the Maokhola (=Chekha Group) (Chaturvedi *et al.*, 1987). The Maokhola is unconformably overlain by 15-20 m thick conglomerates with phyllites and quartzites of the greywackes, conglomerates and tuffs containing trilobites, brachiopods of the ManeTing Fm of Middle to Upper Ordovician age (Bandopadhyay and Gupta, 1990). Significantly, the Ordovician ManeTing is characterized by acid tuffs and debris-flow deposits (diamictites) resulting from submarine slumping, presumably triggered by tectonic upheaval.

To summarise, east of Kumaun, nowhere in the Tethys domain are there records of Cambrian life. Not only the Cambrian fossils but even the Lower Ordovician remains are altogether missing from the faunal succession (fig. 13). In some areas even the Late Pro-

BREAKS IN PRE-MESOZOIC STRATIGRAPHY OF HIMALAYA (GENERALIZED)

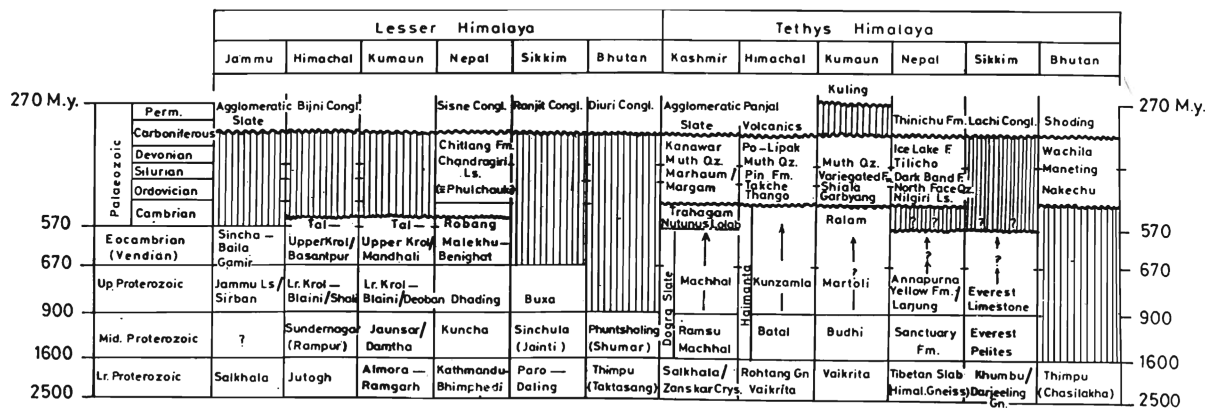


Fig. 13. Throughout the lesser Himalaya, there was no sedimentatiin after the Lower, and in the Tethys basin there was pronounced interruption, variable in temporal span, in the Late Cambrian. Based on the pattern of shanker *et al.* (1989).

terozoic-Eocambrian sediments are absent. The Lesser Himalaya remained a landmass from the end of Lower Cambrian to the beginning of Permian. The conclusion that there was diastrophic movement towards the close of Lower Cambrian (and which happened a little later in the Tethys domain) is inescapable). The post-Lower Cambrian epoch saw the initiation of the drama of diastrophism which climaxed in the retreat of the sea from all over Lesser Himalaya. In the Tethys domain, the spell of quiet sedimentation was broken towards the later part of the Upper Cambrian times and the basin-floor rose above the cradle of the sea for various time span in different sectors. Usually until the beginning of the Middle Ordovician, it seems that the Indian craton with its Tethyan marginal basin was gradually lifted up — the Vindhyan part in the Vendian, the Lesser Himalaya terrain towards the close of the Lower Cambrian and the Tethys realm in the later Upper Cambrian.

## STRUCTURAL DEFORMATION AND INTRABASINAL UPWARPS

The NNE/NE---SSW/SW trending transverse folds, usually plunging northward in the Lesser Himalaya, have long been interpreted as representing prolongation of the Precambrian orogenic belts like the Aravali, Bundelkhand, Satpura (Auden, 1935; Gansser, 1964; Valdiya, 1973, 1976).

In northern Pakistan near the older sedimentary rocks occur tilted strata beneath the acritarch-bearing Cambrian Abbotabad Fm (Coward *et al.*, 1988). The NE-SW trending folds in the Great Himalayan (Rohtang) Range, and the NE/ENE-SW/WSW trending basinal highs in the Spiti basin (Bhargava *et al.*, 1991b) discernible only beneath the unconformable pile of the Tandi Group of Permian to Jurassic rocks suggest strong pre-Permian folding (Srikantia and Bhargava, 1979; Bhargava, 1980). In the same perspective is to be viewed the marked angular unconformity between the upper Kunzamla and the younger Thango conglomerates in the Zanskar-Lahaul region, the transgressive relationship between the Ordovician conglomerate overlying the Haimanta-Parahio succession and the Thimpu basement and the NakeChu conglomerate in central Bhutan. Srikantia *et al.*, (1978) designate this phase as the Tangdze orogeny, and Fuchs (1982, 1987) recognises it as a manifestation of the Caledonian orogeny. There is no doubt that a clearly discernible regional unconformity exists between the greywackes and slates of the early Upper Cambrian Trahagam Fm and the Middle Ordovician conglomerates of Marhaum in the Kupwara and Margam (Liddar valley) in Kashmir (Shah *et al.*, 1988), between the Middle to possibly early Upper Cambrian upper Kunzamla of flyschoid with turbidites and the fluvial conglomerate of the (? Upper or Middle) Ordovician Thango Fm in the Zanskar-Lahaul region (Nanda and Singh, 1976, Gaetani *et al.*, 1985; Garzanti *et al.*, 1986), and between the Late Proterozoic Haimanta with early Late Cambrian Parahio succession and the conglomerates and red sandstone of the Middle Ordovician (= Thango) in Spiti basins (Hayden 1904; Fuchs, 1982, 1987; Bhargava *et al.*, 1991a, b). In NE Kumaun, the Martoli flysch yielding Lower Cambrian trilobites is capped with Ralam conglomerate of great extent, implying a hiatus. The conglomerate is overlain by possibly Ordovician carbonates of the Garbyang.

Taking into consideration the pre-Permian folding and the incidence of total termination of sedimentation in the Lesser Himalaya and the Purana basins in the Peninsular India and the pronounced interruption in basin-filling in the Tethys realm (fig. 13), it is but logical to surmise that a major tectonic upheaval engulfed the Indian subcontinent, lifting up in stages as already adumbrated.

## GRANITE EMPLACEMENT AND VOLCANISM

The histogram of age data obtained by Rb-Sr and U-Pb methods of granites (Trivedi, 1990) reveal three major peaks of igneous activity. The peak at 450-600 m.y. (fig. 14) indicates a strong tectonic thermal event penecontemporaneous with the PanAfrican orogeny. Prominent among the Cambro-Ordovician granites of Kazinag (477+24 m.y.) in the Pir Panjal, Kangan (480+16 m.y.) in the Zanskar, Mansehra (516+16 m.y.) in northern Pakistan, Polokanka (487+25 m.y.) and Karzog (487+14 m.y.) in southeastern Ladakh, Lahaul (495+16 m.y.), Rohtang (581+9 m.y.), Kulu (500+8 m.y.), Manikaran (467+45 m.y.) of the Great Himalaya, Dalhousie (456+50 m.y.) and Mandi (500+100 m.y.) in the Dhauladhar Range in H.P., Ranikhet (485+55 m.y.), Almora (560+20 m.y.) and Champawat (565+22 m.y.) in central Kumaun, Palung (486+10 m.y.), Dudhkosi (550+32 m.y.), Kangmar (486+6, 484+14, 435+37 m.y. in Nepal, and Thimpu (508+15 m.y.) in Bhutan (fig 14).

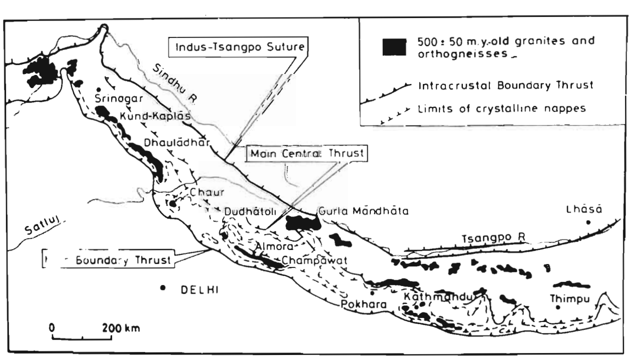


Fig. 14. Distribution of Cambro-Ordovician granites in the Himalya. Those occurring in the outer Lesser Himalaya have come there due to thrusting of the rock masses (After LeFort *et al.*, 1986).

Characteristically porphyritic, these 500+25 m.y. old granites in the upper part of the Lesser Himalayan nappes of crystalline rocks and in the northern upwarped edge of the Indian crust represent a thermodynamic event coinciding with the PanAfrican- Cadomian orogeny. The high initial strontium isotope ratio of these dominantly peraluminous granites indicate anatexis under rather dry condition of attenuated continental crust (LeFort, 1988; LeFort *et al.*, 1986). These Cambro-Ordovician granites form more than 10,000 km long girdle encompassing Afghanistan, Himalaya, Australia and Antarctica of the once supercontinent Gondwanaland.

The genesis of the granites denote events in the Himalayan front related to the rifting of the distal continental crust which isolated Laurentia from South America and East Antarctica-Australia. This rifting is related to the sea floor spreading in the Late Proterozoic-Early Cambrian period (Dalziel, 1991) (fig. 15). It may be emphasized that the event was intracontinental, as evident from the emplacement of the 600+70 m.y. Jalor Granite in western Rajastahn (Sharma *et al.*, 1975); the 510+20 to 480+10 m.y. old Sendra Granite (Chaudhary *et al.*, 1984); the 550+50 m.y. granites of southwestern Rajastahn (Gangopadhyay and Lahiri, 1986); and the 550+15 m.y. incipient charnockite of Ponmudi in Kerala (Chaudhary *et al.*, 1992).

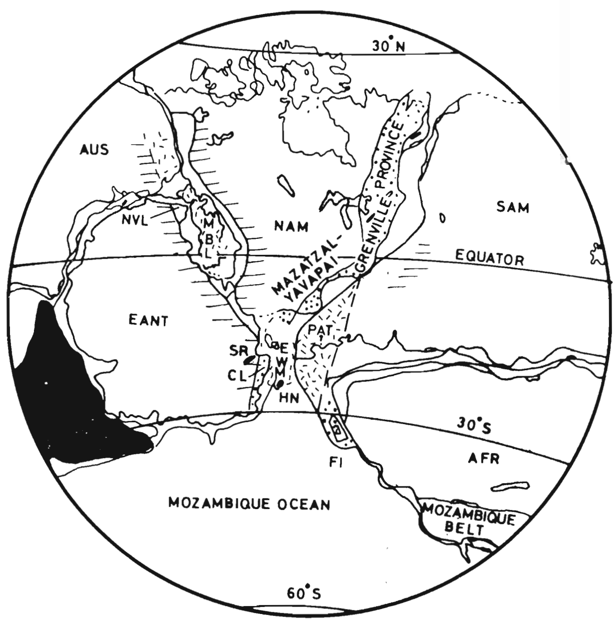


Fig. 15. Just before the Pan African Orogeny, India was a part of the supercontinent comprising Laurentia, S. America, East Antarctica Australia and Africa (Dalziel, 1991).

The magmatic activity was possibly related to the volcanism, as evident from the sparse and scattered occurrence of volcanic tuffs towards the top of the Purana sequence in the Lesser Himalaya and in the basal part of the sedimentary column in the Tethyan Palaeozoic. In the Tal Basin in south-central Lesser Himalaya, the passage sequence contains tuffs between the Krol and Tal stradding the Precambrian-

Cambrian boundary (Bhargava *et al.*, 1991a).

The top of the Saline Series in the Salt Range comprises volcanics (fig. 4, Gansser, 1964). In the Suran valley (District Punch) in western Kashmir, spilitic lavas, tuffs and associated keratophyre dykes of the Bafliaz Volcanics between the Dogra Slate and Tanawal Fm (Wakhaloo and Shah 1968; Sharma and Gupta, 1972) represent the volcanic activity synchronous with the interval of non-deposition. Significantly, the spilitic lavas, keratophyres and basic tuffs are interbedded with slates that bear *Cruziana* and *Rusophycus* trace fossils together with fragments of trilobites (Sharma and Gupta, 1972). In the Zanskar region, the lower part of the Upper Kunzamla Fm includes beds of basaltic tuffs interbedded with greywackes and slates. According to Fuchs (1987), the volcanic activity was possibly coeval with the subsidence of the basin in the Middle Cambrian. Acid tuffs are reported from the Precambrian-Cambrian Hilap Group in the Kinnaur area (Bassi *et al.*, 1983). The chloritic schist bands in the lower part of the Garbyang succession in NE Kumaun have been interpreted as altered products of basic tuffs similar to the K-Bentonite of America (Heim and Gansser, 1939).

In northcentral Nepal, the Annapurna Yellow Fm (figs. 9A, 10A) is the Precambrian-Cambrian transition interval but possibly belonging to Precambrian is made up of acid tuffs and possibly basic volcanics, while the older formation with limestones and sandstones is characterized by slump structures (Colchen *et al.*, 1986). In the Black Mountain in central Bhutan (fig. 12) the Middle to Upper Ordovician ManeTing Fm includes andesitic lavas and tuffs associated with greywackes, diamictes and phyllites (Bandopadhyay and Gupta, 1990).

It appears that the volcanism in the Himalaya is strongly related to the Cambro-Ordovician granitic activity. Indeed there was a gigantic explosive volcanism in the Ordovician times in the Laurentia supercontinent about 454 m.y. ago. This is borne out by 1-2m thick ash beds in eastern North America (Millbrig K-Bentonite with 50 beds and in Baltoscandis (Big Bentonite with 150 beds) (Huff *et al.*, 1992). Needless to state, in that distant past the Indian subcontinent formed a part of the supercontinent comprising Laurentia, South America, Antarctica-East, Australia and Africa (fig. 15). It is therefore plausible to assume that the Himalayan province could not have escaped the rains of this volcanic ash, but this happened a little earlier.

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