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A SYNOPTIC REVIEW OF EOCENE-MIOCENE FAUNAL RECORDS OF THE INDO-BURMA RANGE (IBR), NE INDIA AND COEVAL NORTHWESTERN HIMALAYA: PALEOENVIRONMENTAL AND TECTONIC INFERENCES

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ABSTRACT

A synoptic review of the Eocene-Miocene fossil records of the Indo-Burma Range (IBR), NE India and its paleoenvironmental comparisons with the better documented coeval sediments of the NW Himalaya of India is documented to infer tectonic settings and throw light on the collision of the Indian and the Eurasian plates.

Keywords: Eocene-Miocene, Indo-Burma Range (IBR), NW Himalaya, Paleoenvironment, tectonic set-up.

INTRODUCTION

The northward drift of the Indian plate led to its convergence and subsequent subduction under the Eurasian plate along the Tethyan zone in the northwest (Klootwijk *et al.,* 1992; Gaina *et al.,* 2007; Kumar *et al.,* 2007; Kent and Muttoni, 2008) and beneath the Burmese microplate in the Indo Burma Range (IBR) in the northeast (Curry *et al.,* 1979; Sengupta *et al.,* 1990; Acharrya, 2007; Steckler *et al.,* 2016). The collision paved way for continental sedimentation all along the Himalayan foreland basin (Warwick *et al.,* 1998; Johnson *et al.,* 1999) and obduction/ emplacement of the Naga-Manipur Ophiolites in the IBR and the Ladakh Ophiolites of the north-western Indian Himalaya. The Himalaya builds up in a series of tectonic episodes and the imprints of these tectonic episodes are identifiable in the Cenozoic successions in the form of marine transgression/ regression events and pronounced hiatuses in the sedimentary record (Kumar, 1997). The change of regime from marine to continental sedimentation is well recorded in the various parts of the Himalayan foreland basin.In Simla region of the foreland basin of Northwest Himalaya, the "passage beds" consisting of variegated shale of the Subathu Formation and white-grey sandstone of the Dagshai Formation, demarcate the transition from marine to continental conditions (Raiverman and Raman, 1971; Mathur, 1977; Bhatia and Bhargava, 2006; Najman, 2006, 2007; Bera *et al.,* 2008; Ravikant *et al.,* 2011; Srivastava *et al.,* 2013). In eastern part of the Himalaya, the Indo-Burma mountain ranges towards north of the Sumatra–Andaman subduction zone mark the boundary between the Indian and Eurasian plates (Steckler *et al.,* 2016). Furthermore, the IBR contains Cretaceousto Eocene pelagic sediments overlain by Eocene to Oligocene flysch sediments. The Paleogene sediments are overlain by Miocene to Pleistocene molasses. Further to the easternmost part of the Naga Hills, the ophiolitic suites are exposed that were scraped off an oceanic crust of the Indian plate in collision with the Burma microplate Plate (Curray *et al.,* 1979; Sengupta *et al.,* 1990). The Naga-Manipur Ophiolites represents a segment of the Tethyan oceanic crust that was involved in an eastward convergence and collision of the India and Burma plates during the Late Cretaceous-Eocene (Ghose *et al.,* 2010, Bhowmik and Ao, 2016; Khogenkumar *et al.,* 2016).The IBR evolved as an accretionary prism formed due to continuous eastward subduction of the Indian plate beneath the Burma micro plate from late Cretaceous to Miocene. Mallet (1876) was the first to work on the Disang Group of rocks on account of the coalfields of the Naga Hills. Later, Oldham (1883) correlated the Disang rocks with Axials of Arakan Yoma. Maclaren (1904) and Pascoe (1912) considered that the bulk of the Disangs was more in common with the Negrais bed of ArakanYoma.

The objective of this synoptic review is to synthesize the Eocene-Miocene faunal findings from the Indo-Burma Range (IBR) and make a paleoenvironmental correlation with the better documented coeval foreland deposits of northwest Himalaya to infer the tectonic implications on the western and eastern extremes of the Indian Himalaya.

REGIONAL GEOLOGICAL FRAMEWORK OF THE INDO - BURMA RANGE (IBR), NE INDIA

The geological studies of the IBR were initiated in the 19th Century by the Geological Survey of India (GSI), the Burma Oil Company (BOC) and the Assam Oil Company (AOC), Mallet, 1876 and Oldham, 1858 and Medlicott, 1868 and Evans, 1932. Evans (1932) was the first to give a comprehensive account of the stratigraphy of the region and later updated by Evans (1964). The north-eastern region represent a complex tectonic set-up due to the juxtaposition of the Indian, Burmese and the Eurasian plates (Alam *et al.,* 2003; Sahu *et al*., 2006; Aier *et al.,* 2011; Kayal *et al.,* 2012; Bora *et al.,* 2014). The geo-tectonic setup and the dynamic nature of the north-east region are attributed to the interaction of the Indian, Eurasian and the Burma microplates (Fig.1). The Shillong-Mikir basement ridge represents NE continuation of the Precambrian rocks from the Peninsular India to the north-eastern region of India (Evans, 1964; Acharrya, 2007). The Brahmaputra River separates the Shillong Plateau

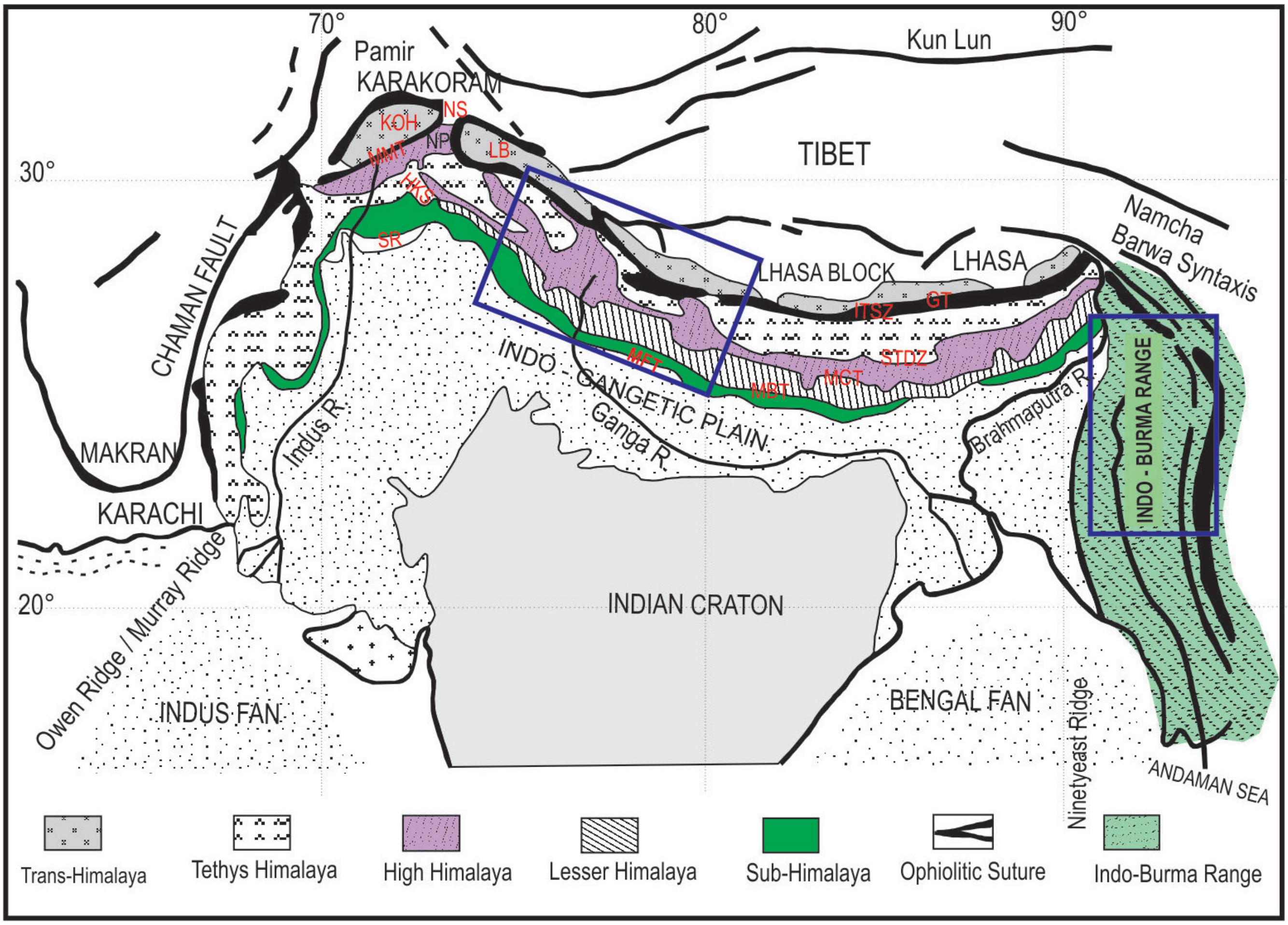

Fig. 1. Holistic view of the Himalayan mountain orogeny with its divisions showing the two locations of the present study. AfterCritelli and Garzanti, 1994; Najman, 2006. KOH=Kohistan Island Arc, MMT=Main Mantle Thrust, HKS=Hazara-Kashmir Syntaxis, LB=Ladakh batholith, NP=Nanga Parbat, NS=Northern Suture, S=Salt Range, GT=Gangdese thrust, ITSZ=Indus Tsangpo suture Zone, STDZ=South Tibetan Detachment Zone, MCT=Main Central Thrust, MBT=Main Boundary Thrust, MFT=Main Frontal Thrust.

from the Himalaya on its way to the Bay of Bengal by flowing along Brahmaputra River fault (Nandy, 2001, 2017). The north-eastern region has wide spread Assam-Arakan Basin covering 70% of the total area. Much of the Assam-Arakan Basin is either unexplored or has received a cursory attention till recent times. In last three decades, the work has been focused on the geological surveys/studies in the region by Geological Survey of India (GSI), Oil and Natural Gas Corporation (ONGC), universities of the northeast region and premier research national institutions of Wadia Institute of Himalayan Geology (WIHG) Dehradun, Birbal Sahni Institute of Paleosciences (BSIP) Lucknow and National Geophysical Research Institute (NGRI) Hyderabad. The sedimentary successions in the Assam-Arakan Basin range in age from late Mesozoic to Cenozoic. However, the bulk of the succession is represented by the Cenozoic age. The intensity and pattern of plate-to-plate interaction varied with time, affecting the basin architecture and sedimentation (Alam *et al.,* 2003).Tight anticlinal folds intercepted by cross fault system and comparatively wide synclines represent the IBR fold belt. Tectonically, the Tripura-Mizoram region is characterised by a series of sub-parallel, elongated, arcuate, doubly plunging, tightly folded asymmetrical anticlines arranged enechelon and separated by wide, flat and more or less symmetrical open synclines (Ganguly, 1975; Singh *et al.,* 2009) with deformation progressively younging towards the west (Ganju, 1975; Ganguly, 1975). The Mesozoic-Cenozoic sediments of the IBR were interpreted to be deposited in two distinct lithofacies viz. shelf shelfal and basinal facies for shelf and deep basin. The well reserved faunal control and distinctive rock types characterise the shelfal deposits which yielded foraminifera, nannofossils, dinosaur bones, algae, spores and pollen, which have helped in resolving the biostratigraphic settings of the region (Pandey, 1990; Jauhri, 1996, 1998; Mishra and Sen, 2001; Whiso *et al.,* 2003; Jauhri *et al.,* 2006; Kalita and Gogoi, 2006; Sarma and Ghosh, 2006; Tewari *et al.,* 2009a; 2009b). However, the basinal sediments on the other hand, lack detailed geological investigation and reliable data for biostratigraphic correlation due to poor faunal control and also inadequate studies which are restricted to a few deep wells and outcrop sections (Barauh *et al.,* 1987; Barauh *et al.,* 1996; Bhatia, 1996; Bhatia and Dave, 1996; Jauhri *et al.,* 2003; Lokho *et al.,* 2004a; 2004b, 2011a, 2011b; Venkatachalapathy *et al.,* 2007; Lokho and Raju, 2007; Lokho and Kumar, 2008; Raju and Lokho, 2010; Lokho and Tewari., 2011, 2012; Lokho and Singh, 2013; Rai *et al.,* 2014; Lokho *et al.,* 2016; Lokho *et al.,* 2017; Lokho *et al.,* 2018).

A. EOCENE-MIOCENE FOSSIL RECORDS OF IBR

(i) *Eocene faunal records from the Disang Group*

Hayden (1910) recorded *Ammonite* from the Disang Group and assigned to Cretaceous-middle Eocene age. Subsequently, Evans (1932) recorded *Nummulites* and pronounced that the Disangs were more altered and practically unfossiliferous equivalent of the Laungshe shales of Burma, which were believed to range from Paleocene-Eocene. Further, Evans (1964) considered Disang shales are 'very like those of Kopili Formation' and suggested that the Disang represent a deeper water facies of the Jaintia Group and perhaps lower horizons equivalent to Ranikot, Laki and Kirthar and possibly the upper most Cretaceous. Later on, Nagappa, (1959) recorded foraminiferal genera *Ammobaculites* sp*., Ammodiscus* sp*., Bathysiphon* sp., *Cyclammina* sp*., Gaudryina* sp. and *Haplophragmoides* sp.from the Disang Group of Naga Hills and suggest that the top of the Disang Group is probably not younger than late Eocene and the lower limit extend into the Cretaceous. Baruah *et al.* (1987) recognized *Cribrohantkenina inflata-Hantkenina alabamensis* and *Nummulites pengaronensis–Pellatispira madraszi– Discocyclina-dispansa* foraminiferal zones and assigned middle to late Eocene age (Zone P16 and early part of Zone P17 of Blow, 1969). Bhatia and Dave (1996) documented three foraminiferal biozones viz. *Nummulites acutus-Fasciolites elliptica*, *Nummulites dicorbinus*-*Assilina* and *Nummulites pengaronensis* and a poorly fossiliferous zone ranging in age from middle Eocene to Oligocene in five exploratory wells viz. Chumukedima, Tynyphe, Naojan, Kasomarigoan and Barpathar across the Dhansiri Valley, Assam from the Kopili Formation and Barail Group. Lokho *et al.* (2004a) documented *Uvigerina* and other benthic and planktic foraminifers of middle-late Eocene age and suggested a deeper marine (upper bathyal) paleobathymetry for the Upper Disang Formation in Nagaland. Further, Lokho and Kumar (2008) recorded fossil pteropods provisionally referable to the families Limacinidae, Creseidae, and Cliidae from Nagaland. The combined assemblages of pteropods and foraminifers from the Upper Disang Formation indicate a palaeobathymetry of ~500 m, i.e., upper bathyal zone, and a tropical-subtropical climate. Venkatachalapathy *et al.* (2007) identified 54 foraminiferal species belonging to 29 genera, 23 families, 17 superfamilies and 5 suborders from the Upper Disang Formation in the south eastern part of Nagaland and placed them under three Planktonic Foraminiferal biozones viz. *Globogerinatheka semiinvoluta* (P15), *Cribrohantkenina inflata* (P16) and *Turborotalia cerroazulensis* (P17) of middle-late Eocene age for the Upper Disang Formation of Nagaland. Sijagurumayum *et al.* (2014) recorded fourteen molluscan species from the Upper Disang Formation of Imphal Valley, Manipur. The bivalve genera listed are *Nucula* sp., *Barbatia* sp., *Protonoetia* sp., *Septifer* sp., *Aviculoperna* sp., *Venericardia* sp., *Trachycardium* sp., *Tellina* sp., *Callista* sp., *Lentidium* sp., *Pholas* sp*.,* and gastropods include *Patella* sp. and *Natica* sp. Dinoflagellate cysts comprising of *Homotryblium* sp., *Cordosphaeridium* sp., *Fibrocysta* cf. *axialis, Hystrichokolpoma* cf. *riguadiae* and *Operculodinium centrocarpum* were recorded from the Upper Disang Formation of southern Manipur suggesting late Eocene for the UDF and a shallow marine depositional environment (Singh *et al.,* 2017).

(ii) *Oligocene Faunal records from the Barail Group*

The term Barail was adopted from Barail Range in North Cachar Hills. The Barail sediments were first studied by Mallet (1876) in Namsang river section of Makum coalfield. Later, Evans (1932) proposed the name Barail Group to a thick succession of interbedded sandstone and shales overlying the Disang and Jaintia Groups. Rangarao (1983) discovered *Nummulites* and *Operculina* from the ferruginous sandstones at Heningkunglwa in the south-western part of Nagaland and dated the base of Laisong Formation as Late Eocene. Singh *et al.,* (2008) recorded ichnogenera *Arenicolites, Helminthopsis, Ophiomorpha, Phycodes, Planolites, Rhizocorallium, Thalassinoides* and *Skolithos* from central part of the Manipur, and stated that the Barail Group were deposited in a shallow marine environment with occasional high energy conditions. Plant remains consisting of gymnospermous, monocotyledonous and dicotyledonous forms were recorded from the Laisong Formation of Thoubal and Senapati districts of Manipur indicating tropical to subtropical climate in the vicinity of the area during the deposition of the host rocks (Singh *et al.,* 2012). Rajkumar and Klein (2014) documented *Perissodactyl* footprints from the Laisong Formation of Manipur and suggest marginal marine setting. Khaidem *et al.* (2015) recently described a well preserved and varied assemblage of trace fossils indicating shallow marginal marine setting such as tidal flats, deltas and shoreface from the Laisong Formation of central and southern part of Manipur. Lokho *et al.* (2017) described fossil leaf impressions from the Laisong Formation of the Barail Group (late Eocene-early Oligocene) from Mao-Pfutsero road section in Phek District, Nagaland. These plant fossils are biogeographically significant and throw light on the possibility of migration of plants between the Indian sub-continent and Burma as a result of collision of the Indian and the Burmese plates. In the Naga Hills, three ichnofabrics namely *Ophiomorpha-Palaeophycus* (upper shoreface), *Thalassinoides* (middle shoreface) and *Chondrites-Planolites* (lower shoreface) have been identified from the the late Eocene-early Oligocene Laisong Formation, basal Barail Group (Lokho *et al.,* 2018). Their finding suggest that the ichnofabric distribution is primarily controlled by the change in depositional energy levels from low to high and supports the presence of a proximal part of the hyperpycnallobes of delta-fed marine coarse-grained turbidite system for the Laisong Formation of Barail Group in the Naga Hills.

(iii) *Miocene Faunal records from the Surma Group*

Evans (1932) introduced the term Surma series for the succession lying between the Barail Group and the Tipam Group. Later, Evans (1964) named it Surma Group. One of the pioneer worker of the Surma Group in the IBR is R. P. Tiwari, who has extensively worked on the Miocene biota (Tiwari, 1997, 2001, Tiwari and Kachhara, 2003; Tiwari *et al.,* 1997, 2007, 2011). The Surma Group is divided into two sub-groups; Bhuban and Bokabil. The Bhuban sub-group is subdivided into Lower, Middle and Upper Bhuban formations. A detailed foraminiferal biostratigraphy scheme for the Bhuban and the overlying Bokabil sediments in the Tripura-Cachar region was given by Bhatia (1996) which led to the recognition of nine biozones ranging from late Oligocene to early Pliocene. Bhatia (1996) suggest a transgressive phase in the lower part of the Bhuban and interpreted that the Middle and Upper Bhuban formations were deposited in a shallow, slightly hyposaline environment with increased rate of subsidence and sedimentation. The lower and middle part of overlying Bokabil Formation have been inferred to be deposited in a normal marine, particularly inner to middle neritic environment (Bhatia, 1996). Baruah *et al*. (1996) recorded *Globorotalia praebulloides, G. obesa, G. peripheronda, G. siakensis, Neogloboquadrina continuosa, Globigerina falconensis, Globigerinoides immaturus* and *G. trilobus* from the Middle Bhuban Formation and a species of *Globigerinoides* from the Upper Bhuban Formation at Well Bhubandar-A (Cachar area, Assam). Based on bio and lithofacies analysis, Baruah *et al.* (1996) suggest a fluvio-deltaic condition in the entire Cachar area during the early part of the Surma sedimentation and was followed by a major transgression during early to middle Miocene leading to destruction and submergence of the earlier formed deltaic deposits. Jauhri *et al.* (2003) recorded two species of foraminifera viz. *Pseudotaberina malabarica* and *Boreli spygmaeus* from the Upper Bhuban Formation of Mizoram and suggest N6-N9 Planktonic Foraminiferal Zones (late Burdigalian to Langhian) for the Upper Bhubhan Formation of Mizoram and inferred that the carbonate beds were deposited in a lagoonal environment which was shoreward in position and marked by low energy conditions during latest early to earliest Middle Miocene. Ramesh (2004) reported abraded benthic foraminifera *Planulina* sp., *Uvigerina* sp., *Lenticulina* sp., *Baggina* sp., *Ammonia* sp., *Roephax* sp., *Haplophragmoides* sp., *Karrerulina* sp. and *Trochamminoides* sp., *Globorotalia* sp., *Globogerinoides* sp., *Globoquadrina* sp., *Globigerina* sp., *Recurvoides* sp., *Cyclammina* sp., *Bathysiphon* sp., *Gerochammina* and radiolarian from the Middle Bhuban Formation from subsurface of Cachar area and envisaged that the Bhuban sediments were deposited under bathymetric conditions ranging from outer neritic to upper slope on a ramp like situation as slump, slides and debris flows. Lokho and Raju (2007) described *Ammonia umbonata, Baggina* sp., *Orbulina* cf. *bilobata, Praeorbulina glomerosa circularis, Praeorbulina* cf. *transitoria, Clavatorella* cf. *sturanii* and *Lagena* sp. and suggest occurrence of zones N8-N9 (early middle Miocene) and a paleobathymetric range of 60-80m (middle shelf) for the Upper Bhuban Formation of Mizoram. Additional findings by Lokho *et al.* (2011b) recorded planktonic foraminiferal assemblage consisting of *Globorotalia* (*Fohsella*) *peripheroronda, Globigerinoides bisphericus, Clavatorella sturanii, Orbulina universa, Orbulina bilobata, Praeorbulina cf. glomerosa glomerosa* representing Planktonic Foraminiferal Zones of N8-N9 (Langhian age) and benthic foraminifera consisting of *Uvigerina schencki, U. substriata, U.* cf. *kernensis, Uvigerina* cf. *sparicostata, U. pilulata, U.* cf. *rutile, Ammonia beccarii, A. ikebei, A. umbonata* and inferred a paleobathymetric setting of upper part of outer shelf for the Upper Bhuban Formation of Mizoram. A detailed ichnological study was presented by Tiwari *et al.* (2011) on the Bhuban Formation, Surma Group (early to middle Miocene) of Mizoram which reveals the occurrence of rich and diverse ichnofossils. They presented 20 ichnospecies of 14 ichnogenera which include *Arenicolites* isp., *Cochlichnus anguineus*, *Helminthopsis abeli*, *Laevicyclus mongraensis*, *Ophiomorpha borneensis*, *Palaeophycus tubularis*, *Palaeophycus heberti*, *Palaeophycus sulcatus*, *Palaeophycus alternatus*, *Pholeus abomasoformis*, *Pholeus bifurcatus*, *Planolites beverleyensis*, *Planolites annularis*, *Polykladichnus irregularis*, *Rhizocoralliumi* sp., *Skolithos linearis*, *Taenidium satanassi*, *Teichichnus rectus*, *Thalassinoides horizontalis* and *Thalassinoides paradoxicus*. These ichnogenera indicate foreshore to shoreface-offshore zone of shallow marine environment for the deposition of the rocks of the Middle Bhuban Formation of Mizoram. Later, Lokho and Singh (2013) also documented ichnofossils comprising of *Psilonichnus upsilon, Ophiomorpha* isp., *Teichichnus spiralis, Skolithos* isp., *Paleophycus* isp. from the Middle Bhuban Formation (Mizoram) and suggest shallow marginal-marine channel complex dominated by tidal channels in the inactive, brackish-water portions of a delta plain for the deposition of Middle Bhuban Formation of Mizoram. Rai *et al.* (2014) recorded Mio-Pliocene calcareous nannofossils assemblage from the Surma Group of Mizoram and inferred a relatively shallow water depositional environment. Recently, Lokho *et al.* (2016) also recorded nannofossils comprising of eleven species of eight genera. Based on the occurrences of FADs, LADs and the Concurrent Range Zones (CRZ) of the recorded calacareous nannofossil species, the studied interval correlates with the upper part of NN4 and NN5 zones, representing early part of the middle Miocene and the relatively good abundance of *Helicosphaera,* the presence of Discoasters and the published foraminiferal data indicate hemipelagic depositional setting for the UBF of Mizoram.

(B) A BRIEF INTRODUCTION OF EOCENE-OLIGOCENE-MIOCENE FAUNAL RECORDS OF NORTHWEST HIMALAYA

On the western flank of the Northwest Himalaya the Cenozoic rocks are exposed in Kangra Valley, Simla Hills and Jammu region and are known as Subathu Group, Dharamsala Group/Dagshai-Kasauli/Muree Group and Siwalik Group. While marine Eocene (Ypresian-Lutetian) biota is known from the Subathu Group (Mathur and Juyal, 2000; Bhatia, 2000; Bhatia *et al*., 2013), younger non-marine horizon yielded terrestrial life including that of large and small Siwalik mammalia from the middle Miocene and younger horizons.

Fossils recovered from the horizons of Subathu Group of the western Himalaya comprises of *Nummulites burdigalensis burdigalensis, N. subramondi, Musculus nuttalli, Parinomya blanfordiana, Assilina spira abrardi, A. laxispira, A. placentulagrande, N. rotularius, Steginoporella* sp., *Cordiopsis subathooensis, Turritella subathooensis* (Mathur and Juyal, 2000). These fossils have been used in refining biostratigraphic zonation and paleodepositional setting of the Subathu Group. The late Eocene–Oligocene is marked by faunal gap and is plausibly construed as the unconformity (Najman *et al.,* 1993; Najman, 2007, DeCelles *et al.,* 1998) which is correlative with the largest extinctions of marine invertebrates in the world oceans and of mammalian fauna in Europe and Asia (Sun *et al.,* 2014). The early Miocene terrestrial biota are known from the Upper Dharamsala in Kangra Valley (Bhandari, 2009; Bhandari and Tiwari, 2014), from Kasauli Formation in the Shimla Hills (Arya *et al.,* 2004, 2005) and Upper Murree Formation of Jammu region (Kumar and Kad, 2002). The earlier important contributions on stratigraphy and palaeontology were carried out by Sahni and Bhatnagar (1958), Tewari and Dixit (1972), Lakhanpal *et al.* (1983, 1984), Kumar and Sahni (1985), Kumar and Loyal (1987), Kumar (1992), Rangarao (1986), Nanda and Sahni (1998), Sahni and Kad (1998). Marine deposits are recognised till the Eocene (Lutetian) and characterized by marine fossils and fossils of coastal habitat represented by faunal assemblage comprising mammalian, reptilian and associated forms (Bhatia *et al.,* 2013). On the basis of fauna from the foreland deposits of the Kangra and Simla hills of northwest sub-Himalaya, it was inferred that the paleoenvironmental conditions were marine till middle part of the Eocene, followed by freshwater deposits of the Dharamsala (=Dagshai-Kasauli=Muree Group) and succeeded by the deposition of the Siwaliks of the terrestrial deposition.

CORRESPONDING TERTIARY INTERVALS FROM IBR, NORTHEAST INDIA AND NORTHWEST HIMALAYA WITH SUMMARY

The correlation of the Eocene-Miocene successions of the IBR in NE India and the northwest Himalaya (Table 1) exhibit a different set-up of the geological evolution. In the northwest Himalaya, shallow marine paleoenvironmental setting persisted during the deposition of ?Maastrichtian to middle Eocene Subathu Formation (Singh, 1980; Kumar and Sahni, 1985; Kumar and Loyal, 1987; Juyal and Mathur, 1990; Najman *et al.,* 1993; Mathur and Juyal, 2000; Najman *et al.,* 2004; Kumar, 1996; Sarkar and Prasad, 2000; Gupta and Kumar, 2013; Bhatia *et al.,* 2013). There is a vertebrate faunal hiatus from late Eocene-Oligocene in the western sub-Himalaya (Kumar and Kad, 2002; Tiwari, 2005, Najman, 2007). However, in the IBR during middle-late Eocene, deeper water facies of upper bathyal to outer neritic shelf setting persisted (Evans, 1932; Brunnschweiler, 1966; Lokho *et al.,* 2004; Lokho and Kumar, 2008). During the Oligocene, a shallow marginal marine depositional setup existed in IBR which is corroborated by the finding of the shallow marine trace fossils from the Laisong Formation of Barail Group, Manipur (Singh *et al.,* 2008; Rajkumar and Klein, 2014; Khadem *et al.,* 2015) and from the Naga Hills (Lokho *et al.,* 2018). In northwest, the Murree Group (late Eocene to early Miocene) (= Dharamsala = Dagshai and Kasuali) represents non-marine fluvial facies which indicate that the Subathu Sea was completely vanished before the deposition of these units (Najman *et al.,* 2004; Arya *et al.,* 2004, 2005; Sehgal and Patnaik, 2012; Patnaik, 2013; Bhandari *et al.,* 2014; Bhandari and Tiwari, 2014). However, a tidal influence of estuarine environment was recorded in the Lower Murree Group (Singh, 2013; 2014) and in lower part of the Dagshai Formation of Shimla Hills (Juyal and Mathur,1990; Bhatia *et al.,* 2013). In the IBR region, however shallow marine condition existed till the deposition of the Surma Group of late Oligocene to Miocene (Bhatia, 1996; Bhatia and Dave, 1996; Ramesh, 2004; Rai *et al.,* 2014, Lokho *et al.,* 2017). Earlier workers who have focussed on the issue of withdrawal of the Tethys from the Himalayan region are Sahni *et al.* (1983) and Mathur and Juyal (2000). Sahni *et al.* (1983) documented the withdrawal of the Tethys with the successive strandline positions through the Paleogene-Neogene

Table 1. Stratigraphic units, fossil markers and depositional environment of the cenozoic of IBR, Northeast India and Northwest Himalaya.

International Chronostratigraphic Chart 2018					IBR, Northeast India				Northwest Himalaya			
Era	Period	Epoch	Stage	Age	Group	Formation	Characteristic features, fossil remains	Depositional environment	Group	Formation	Characteristic features, fossil remains	Depositional environment
CENOZOIC	Neogene	Pliocene	Piacenzian	2.58	TIPAM	Tipam	Wood fossils	Fluvial	SIWALIK	Upper	Primates, rodents, carnivores, probocideans, perissodactyls, artiodactyls and Sivapithecus	Fluvial (fresh water molassic deposits)
			Zanclean	3.600								
		Miocene	Messinian	5.333	SURMA	Bokabil	Planktonic and benthic foraminifera; nannofossils	Inner to middle neritic		Middle		
			Tortonian	7.246								
			Serravallian	11.63						Lower		
			Langhian	13.82		Bhubhan: Upper	Planktonic and benthic foraminifera; nannofossils	Middle to upper part of outer neritic				
			Burdigalian	15.97		Bhubhan: Middle	Ichnofossils	Shallow marginal marine	MURREE AND COEVALS	U. Murree/ U. Dhramsala /Kasuali	Gastropods, fossil insects wood logs, leaves flowers, tree trunks, roots, Prodeinotherium and rodents	Fluvial environment
			Aquitanian	20.44		Bhubhan: Lower	Planktonic and benthic foraminifera	Inner to middle neritic				
	Paleogene	Oligocene	Chattian	23.03	BARAIL	Renji	Ichnofossils	Shallow marginal marine				
			Rupelian	28.1		Jenam	Ichnofossils	Shallow marginal marine		L. Murree/ L. Dhramsala /Dagshai	Planer and cross bedding; Thalassinoides and Ophiomorpha burrows	Tidal influenced estuarine environment
						Laisong	Ichnofossils	Shallow marginal marine				
		Eocene	Priabonian	33.9	DISANG	Upper	Planktonic and benthic foraminifera; pteropods	Deep marine (upper bathyal)				
			Bartonian	37.8					SUBATHU	Subathu: Red facies	Land mammals and rodents	Continental
			Lutetian	41.2		Lower	Metamorphosed slates and phyllites	? Shallow marine		Subathu: Green facies	Marine mammals, echinoides dinoflagellates, foraminifers, gastropods, pelecypods, ostracodes, fishes and oysters	Marine facies, near shore and tidal flat conditions with proximity of terrestrial habitats
			Ypresian	47.8						Subathu: Black grey facies		
		Paleocene	Thanetian	56.0						Kakara	Microvertebrates, Ziphodent crocodilian foraminiders and ostracodes	
			Selandian	59.2								
			Danian	61.6								
				66.0								

Legend: Deep marine; Shallow marine; Fluvial; Continental; Estuarine

IBR, Northeast India Sources:
Evans, 1964; Ranga Rao, 1983; Baruah *et al*., 1987; Bhatia, 1996; Barauh *et al*., 1996; Ibotombi, 1998; Jauhri *et al*., 2003; Ramesh, 2004; Lokho *et al*., 2004a,b; Tiwari *et al*., 2007 Lokho and Raju, 2007; Lokho and Kumar, 2008; Lokho, 2009; Raju and Lokho, 2010; Lokho *et al*., 2011a,b; Lokho and Singh, 2013; Rai *et al*., 2014; Rajkumar and Klein, 2014; Khaidem *et al*., 2015; Lokho *et al*., 2016; Lokho *et al*., 2017; Lokho *et al*., 2018.

Northwest Himalaya Sources:
Singh, 1980; Sahni *et al*., 1983; Kumar and Sahni, 1985; Ranga Rao, 1986.; Kumar and Loyal, 1987; Juyal and Mathur, 1990; Najman *et al*., 1993; 2004; Najman, 2007; Kumar, 1992; 1996; Kumar *et al*., 1997; Sahni and Kad, 1998; Sarkar and Prasad, 2000; Kumar and Kad, 2002; Arya *et al.* 2004; 2005; Tiwari, 2005; Kumar and Loyal, 2006; Tiwari *et al*., 2006; Gupta and Kumar, 2013; Seghal and Patnaik, 2012; Patnaik, 2013; Bhandari and Tiwari, 2014; Singh, 2013; 2014.

and suggest towards southwest direction. According to Mathur and Juyal (2000) and Juyal (2006), the regression of the Tethys Sea from the Indus Tsangpo Suture Zone (ITSZ) took place in the beginning of the late Ypresian, from the Zanskar (Tethyan Himalaya) towards the end of Ypresian and from the Himalayan foothills in the early Lutetian times. In the IBR, the withdrawal of the Tethys Sea was from east to west and the Tethys seaway remained till Miocene.

SUMMARY

A synoptic view of the Eocene-Miocene successions of the IBR (northeast India) and the foreland basin deposits of the NW Himalaya on eastern and western extremes of the Indian Himalaya brings to fore the following inferences:

1. While on the eastern extreme represented by IBR, adjacent collisional regimes allowed marine deposition for a much longer duration till the Miocene but collisional tectonic environment on the western Himalaya guided marine deposition to end by middle Eocene at equatorial latitudes.
2. Comparable existing biostratigraphic data of the Cenozoic successions of the IBR, northeast India and the northwest Himalaya suggest plausibility of progressive south-west withdrawal of the Tethys Sea in a stepwise manner due to the episodic associated tectonics in the NW Himalaya but in the IBR, the progressive withdrawal of the Sea is from east to west.

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REFERENCES

Acharyya, S. K. 2007. Collisional emplacement history of the Naga Andaman ophiolites and the position of the eastern Indian suture. *Journal Asian Earth Sciences,* **29:** 229-242.

Aier, I., Luirei, K., Bhakuni, S. S., Thong, G. T. and Kothyari, G. C. 2011. Geomorphic evolution of Medziphema intermontane basin and Quaternary deformation in the Schuppen Belt, Nagaland, NE India. *Zeitschriftfii Geomorphologie*, **55**(2)**:** 247-265.

Alam, M., Alam M. M., Curry, J. R., Chowdhury, M. L .R. and Gani, M. R. 2003. An overview of the sedimentary geology of the Bengal Basin in relation to the regional tectonic framework and basin-fill history. *Sedimentary Geology,* **155:** 179-208.

Arya, R. Ambwani, K., Sahni, N. and Sahni, A. 2004. First mammal and additional fossil flowers from the Kasauli Formation, Kasauli, Himachal Pradesh. *Journal of the Geological Society of India*, **64:** 317-324.

Arya, R. Sahni, A. and Loyal, R. S. 2005. Molluscan and Insect remains from the type Kasauli Formation and their significance. *Journal of the Palaeontological Society of India,* **50**(1)**:** 115-120.

Baruah, R. M, Singh, N. P. and Rao, D. C. 1987. Foraminiferal biostratigraphy of Disang and Barail Groups of a part of Nagaland. *Proc. Nat. Sem. Tert. Orogeny*, 305-327.

Baruah, R. M., Datta, K. and Murthy, M. S. 1996. Biofacies, lithofacies and depositional environment of sub-surface Surma sediments in Cachar area, Assam, p. 305-316. In: *XV Indian Colloquium on Micropaleontology and Stratigraphy* (Eds. Pandey, J., Azmi, R.J., Bhandari, A., and Dave, A.), *Dehradun*.

Bera, M. K., Sarkar, A., Chakraborty, P. P., Loyal, R. S. and Sanyal, P. 2008. Marine to continental transition in Himalayan foreland. *Geological Society of America Bulletin,* **120:** 1214–1232.

Bhandari, A. 2009. Systematic study of fossil assemblage of the Dharmsala Group of Himachal Pradesh, India and its significance in understanding early Miocene phase of the Himalayan evolution. *D. Phil. Thesis*, Garhwal University, pp.248.

Bhandari, A., Kohler, F. and Tiwari, B. N. 2014. Neogene fresh water gastropods from the Siwalik Group in Uttarakhand, northern India: first fossil record of the protoconch of a fresh water cerithioidean snail (mollusca, caenogastropoda). *Himalayan Geology*, **35**(2)**:** 182-189

Bhandari, A. and Tiwari, B. N. 2014. Rodent fossils from Dharmsala Group in Himachal Pradesh (India), addition to pre-Siwalik Himalayan Miocene fauna, *Journal of the Geological Society of India,* **83:** 676-680.

Bhatia, M. L. 1996. A paleontological approach to the stratigraphic investigation of Neogene sediments of Tripura-Cachar region p. 283-294. In: *XV Indian Colloquium on Micropaleontology and Stratigraphy,* (Eds. Pandey, J., Azmi, R.J., Bhandari, A. and Dave, A.), Dehradun.

Bhatia, M. L. and Dave, A. 1996. Paleogene biostratigraphy of Dhansiri Valley, Assam, p. 133-141. In: Pandey, J., Azmi, R. J., Bhandari, A. and Dave, A. (Eds.), *XV Indian Colloquium on Micropaleontology and Stratigraphy,* Dehradun.

Bhatia, S. B. 2000. Faunal and floral diversity in Subathu–Dagshai Passage Beds: a review. *Himalayan Geology,* **21:** 87–98.

Bhatia, S. B. and Bhargava, O. N., 2006. Biochronological continuity of the Paleogene sediments in the Himalayan foreland Basin: Palaeontological and other evidences. *Journal of Asian Earth Sciences,* **26:** 477–487.

Bhatia, S. B., Bhargava, O. N, Singh, B. P. and Bagi, H. 2013. Sequence stratigraphic framework of the Paleogene succession of the Himalayan foreland basin: a case study from the Shimla Hills. *Journal of the Palaeontological Society of India*, **58**(1)**:** 21-38.

Bhowmik, S. K. and Ao, A. 2016. Subduction initiation in the Neo-Tethys: constraints from counterclockwise P–T paths in amphibolite rocks of the Nagaland Ophiolite Complex, India. *Journal of metamorphic Geology,* **34:** 17–44.

Bora, D. K., Hazarika, D., Borah, K., Rai, S. S. and Baruah, D. 2014. Crustal shear-wave velocity structure beneath northeast India from teleseismic receiver function analysis. *Journal of Asian Earth Sciences,* **90:** 1-14.

Brunnschweiler, R. O. 1966. On the geology of the Indoburman ranges, *Journal of the Geological Society of Australia*, **13:** 137-194.

Critelli, S., Garzanti, E. 1994. Provenance of the Lower Tertiary Murree red beds (Hazara–Kashmir Syntaxis, Pakistan) and initial rising of the Himalayas. *Sedimentary Geology,* **89:** 265–284.

Curray, J. R., Moore, D. G., Lawver, L. A., Emmel, F. J., Taitt, R. W., Henry, M. and Kieckhefer, R. 1979. Tectonics of the Andaman Sea and Burma, p. 189-198. In: *Geological and geophysical investigations of continental margins* (Eds. Watkins, J.S., Montadert, L. and Dickinson, P.). American Association of Petroleum Geologists, Memoir*,* **29**.

DeCelles, Peter G., Gehrels, G. E., Quade, J. and Ojha, T. P. 1998. Eocene-early Miocene foreland basin development and the history of Himalayan thrusting, western and central Nepal. *Tectonics*, **17**(5): 741-765.

Evans, P. 1932. Tertiary succession in Assam. *Transaction Mining Geological Institute,* India, **27:** 155.

Evans, P. 1964. The tectonic framework of Assam. *Journal of the Geological Society of India*, **5:** 80-96.

Gaina, C., Muller, R. D., Brown, B. and Ishihara, T. 2007. Breakup and early seafloor spreading between India and Antarctica. *Geophysical Journal International.* **170:** 151–169.

Ganguly, S. 1975. Tectonic evolution of the Mizo Hills. *Geological Mining and Metallurgical Society India, Bulletin,* **48:** 28-40.

Ganju, J. L. 1975. Geology of Mizoram. *Geological Mining and Metallurgical Society India, Bulletin,* **48:** 17-26.

Ghose, N. C., Agrawal, O. P. and Chatterjee, N. 2010. Geological and mineralogical study of eclogite and glaucophane schistsin the Naga Hills Ophiolite, Northeast India. *Island Arc,* **19:**336–356.

Gupta, S. and Kumar, K. 2013. Ziphodont Crocodilian and other biotic remains from the Paleocene–basal Eocene Kakara Formation, NW Sub- Himalaya: palaeogeographic and palaeoecologic implications. *Himalayan Geology*, **34**(2)**:** 172-182.

Hayden, H. H. 1910. Some coal fields in North–Eastern Assam. *Geological Survey of India Records,* **11**:283-319.

Ibotombi, S. 1998. On the Geology of Manipur. *Ninth Manipur Science Congress,* 12-17.

Jauhri, A. K. 1996. *Ranikothalia nuttalli* (Davies), a distinctive early Ilerdian marker in the South Shillong Plateau, NE India, p. 209–218. In: *XVIndian Colloquium on Micropaleontology and Stratigraphy,* (Eds. Pandey, *et al*.) Dehradun.

Jauhri, A. K. 1998. *Miscellanea* (Foraminiferida) from the South Shillong region, NE India. *Journal Palaeontological Society of India*, **43:**73–83.

Jauhri, A. K., Mandaokar, B. D., Mehrotra, R. C., Tiwari, R. P. and Singh, A. P. 2003. Corals and Foraminifera from the Miocene (Upper Bhubhan Formation) of Mizoram India. *Journal Palaeontological Society of India*, **48:** 135-138.

Jauhri, A. K., Misra, P. K., Kishore, S. and Singh, S. K. 2006. Larger foraminiferal and calcareous algal facies in the Lakadong Formation of the South Shillong Plateau, NE India. *Journal Palaeontological Society of India*, **51**(2)**:** 51-61.

Johnson, E. A., Warwick, P. D., Roberts, S. B. and Khan, I. H. 1999. Lithofacies, depositional environments and regional stratigraphy of Lower Eocene Ghazij Formation, Balochistan, Pakistan. *United States Geological Survey Professional Paper* **1599:** 1–76.

Juyal, K. P. and Mathur, N. S. 1990. Ostracoda from the Kakara and Subathu Formations of Himachal Pradesh and Garhwal Himalaya, India. *Journal of Himalayan Geology,* **1**(2): 209-223.

Kalita, K. D. and Gogoi, B. 2006. First report of coralline red algae in the Late Paleocene Lakadong Limestones of Mawsynram area, Meghalaya. *Journal Geological Society of India,* **68:** 779–783.

Kayal, J. R., Arefiew, S. S., Baruah, Saurabh, Hazarika, D., Gogoi, N., Gautam, J. L., Baruah, Santanu, Dorbeth, C., Tatevossian, R. 2012. Large and great earthquakes in the Shillong plateau–Assam valley area of northeast India region: pop-up and transverse tectonics. *Tectonophysics,* **532**(53): 186–192.

Kent, D. V. and Muttoni, G. 2008. Equatorial convergence of India and early Cenozoic climate trends. *Proceedings of the National Academy of Sciences,* **105:** 6065–16070.

Khaidem, K. S., Hemanta, S., Rajkumar, H. S., Soibam, I. 2015. Attribute of trace fossils of Laisong flysch sediments, Manipur, India. *Journal Earth System Science,* **124:** 1085–1113.

Khogenkumar, S., Singh, A. K., Singh, R. K. B., Khanna, P. P., Ibotombi Singh, N. I. and Singh, W. I. 2016. Coexistence of MORB and OIB-type mafic volcanics in the Manipur Ophiolite Complex, Indo-Myanmar Orogenic Belt, northeast India: Implication for heterogeneous mantle source at the spreading zone. *Journal of Asian Earth Sciences,* **116:** 42-58.

Klootwijk, C. T., Gee, J. S., Peirce, J. W., Smith, G. M. and McFadden, P. L. 1992. An early India–Asia contact: paleomagnetic constraints from Ninety East Ridge, ODP leg 121. *Geology,* **20***:* 395–398.

Kumar, K. and Sahni, A. 1985. Eocene mammals from the Upper Subathu Group, Kashmir Himalaya, India. *Journal of the Vertebrate Paleontology,* **5**(2)**:** 153-168.

Kumar, K. and Loyal, R. S. 1987. Eocene icht hyofauna from the Subathu Formation, northwestern Himalaya, India. *Journal Palaeontological Society of India*, **32:** 60-84.

Kumar, K. 1992. *Paratritemnodonindicus* (Credonta: Mammalia) from the early Middle Eocene Subathu Formation, NW Himalaya, India and the Kalakot mammalian community structure. *Paläont. Z.* **66:** 387-403.

Kumar, K. 1996. Microvertebrate assemblage from the Kakara Formation (Paleocene–Eocene), Himachal Pradesh, Northwest Himalaya, India, Dehradun, p. 493-506. In: *Pandey, J., Azmi, R. J., Bhandari, A., and Dave, A.* (Eds.), *XV Indian Colloquium on Micropaleontology and Stratigraphy*.

Kumar, G. 1997. Geology of Arunachal Pradesh. Geological Society of India, 215 p.

Kumar, K., Loyal, R. S. and Srivastava, R. 1997. Eocene Rodents from New Localities in Himachal Pradesh, Northwest Himalaya, India: Biochronologic Implications. *Journal Geological Society of India,* **50:** 461-474.

Kumar, K. and Kad, S. 2002. Early Miocene cricetid rodent (Mammalia) from the Murree Group of Kalakot, Rajauri District, Jammu and Kashmir, India. *Current Science,* **82**(6)**:** 736-740.

Kumar, K. and Loyal, R. S. 2006. Excursion guide on Sub-Himalayan Paleogene succession of Simla Hills. *DST National field workshop on sub-Himalayan Palaeogene in the context of India-Asia collision*, 1-38.

Kumar, P., Yuan, X., Kumar, M. R., Kind, R., Li, X. and Chadha, R. K. 2007. The rapid drift of the Indian tectonic plate. *Nature,***449:** 894–897.

Lakhanpal, R. N., Sah, S.C.D., Sharma, K. K. and Guleria, J. S. 1983. Occurrence of *Livistona* in the Hemis Conglomerate of Ladakh, p. 177-185. In: *Geology of Indus Suture Zone of Ladakh* (Eds. Thakur, V. C. and Sharma, K.K.). W.I.H.G Publication, Dehradun.

Lakhanpal, R. N., Prakash, G., Thussu, J. L. and Guleria, J. S. 1984. A fossil fan palm from the Liyan Formation of Ladakh (Jammu and Kashmir). *The Palaeobotanist,* **31**(3)**:** 201-207.

Lokho, K., Venkatachalapathy, R. and Raju, D. S. N. 2004a. Uvigerinids and associated foraminifera, their value as direct evidence for shelf and deep marine paleoenvironments during Upper Disang of Nagaland, Eastern Himalaya and its implications in hydrocarbon exploration. *Indian Journal of Petroleum Geology,* **13**(1): 79-96.

Lokho, K., Venkatachalapathy, R. and Raju, D. S. N. 2004b. Stratigraphic tables for Northeast basins of India: With brief notes compiled by D.S.N. Raju. *Indian Journal of Petroleum Geology*, **13**(1)**:** 1-7.

Lokho, K. and Raju D. S. N. 2007. Langhian (early Middle Miocene) foraminiferal assemblage from the Bhuban Formation, Mizoram, NE India. *Journal Geological Society of India,* **70:** 933-938.

Lokho, K. and Kumar, K. 2008. Fossil pteropods (Thecosomata, holoplanktonic Mollusca) from the Eocene of Assam-Arakan Basin, north-eastern India. *Current Science*, **94**(5)**:** 647-652.

Lokho, K. 2009. Stratigraphy of northeast India. *ONGC bulletin,* **44**(2)**:** 252-265.

Lokho, K., Saxena, R. K., Singh, B. P. and Raju, D. S. N. 2011a. Fossil study from the Middle and Upper Bhuban Formation (Surma Group), Mizoram, NE India-implications on age and paleoenvironment. *XXIII Indian Colloquium on Micropaleontology and International Symposium on Global Bioevents in the Earth History*, Bangalore. Abst. 41.

Lokho, K., Raju, D. S. N. and Azmi, R. J. 2011b. Paleoenvironmental and Biostratigraphic significance of uvigerinids and other Foraminifera from the Bhuban Formation, Assam-Arakan Basin, Mizoram. *Journal Geological Society of India,* **77:** 252-260.

Lokho K. and Tewari, V. C. 2011Q. Biostratigraphy, sedimentation and chemostratigraphy of the Tertiary Neotethys sediments from the NE Himalaya, India, p. 607-630. In: *STROMATOLITES: Interaction of Microbes with Sediments, Cellular Origin, Life in Extreme Habitats and Astrobiology (Eds. V.C. Tewari and J. Seckbach)*. Springer Science, **18**.

Lokho, K. and Tewari, V. C. 2012. Global paleoclimate change during Cretaceous-Tertiary Boundary (KTB), Late Eocene, Middle Miocene and their implications in the Northeast Himalaya: a focus on paleontological evidence. *Journal of the Indian Geological Congress,* **4:** 37-41.

Lokho, K. and Singh, B. P. 2013. Ichnofossils from the Middle Bhuban Formation (Miocene), Mizoram, Northeast India and their Paleoenvironmental Significance. *Acta Geologica Sinica,* **87**(5): 1460-1476.

Lokho, K., Saxena, R. K., Raju, D. S. N. and Kumar, A. 2016. Middle Miocene calcareous nannofossils from the Upper Bhuban Formation of Mizoram, Indo-Burma Range. *Microplaeontology,* **62**(5):341–352.

Lokho, K., Srivastava, G. and Mehrotra, R. C. 2017. A note on plant remains from the Paleogene sediments of the Naga Hills, Indo-Burma suture zone. *Himalayan Geology,* **38**(1): 86-90.

Lokho, K., Singh, B. P., Whiso, K and Ezung, O. C. 2018. Ichnology of the Laisong Formation (late Eocene-early Oligocene) of the Naga Hills, Indo-Burma range (IBR): Paleoenvironmental Significance. *Journal of Asian Earth Sciences,***162:** 13-24.

Maclaren, J. M. 1904. The geology of Upper Assam. *Records of the Geological Survey of India,* **31**(4)**:** 188.

Mallet, F. R. 1876. On the coalfields of the Naga Hills bordering the Lakhimpur and Sibsagar Districts, Assam. *Memoirs Geological Survey of India,* **12**(2): 14-94.

Mathur, N. S. 1977. Age of the Tal and Subathu formations in the Garhwal region, Uttar Pradesh, India. *Bulletin of the Indian Geologists Association,* **10:** 21–27.

Mathur, N. S. and Juyal, K. P. 2000. Paleontological evidence for the upheaval history of western Himalaya during the Paleogene. *Himalayan Geology*, **21** (1, 2)**:** 109-131.

Medlicott, H. B. 1868. Coal in Garo Hills. *Records of the Geological Survvey of India,* **1**: Pt. 1.

Mishra, U. K. and Sen, S. 2001. Dinosaur bones from Meghalaya. *Current Science,* **80**(8)**:** 1053-1056.

Nagappa, Y. 1959. Foraminiferal biostratigraphy of the Cretaceous-Eocene succession in the India-Pakistan-Burma region. *Micropaleontology,* **5**(2)**:** 145-192.

Najman, Y., Clift, P., Jhonson, M. R. W. and Robertson, A. H. F. 1993. Early stages of foreland basin evolution in the Lesser Himalaya, N. India. *Geological Society Special Publication,* **74***:* 541-558.

Najman, Y., Jhonson, K., White, N. and Oliver, G. 2004. Evolution of the Himalaya foreland basin, NW India. *Basin research,* **16:** 1-24.

Najman, Y. 2006. The detrital record of orogenesis: A review of approaches and techniques used in the Himalayan sedimentary basins. *Earth-Science Reviews,***74:** 1–72.

Najman, Y. 2007. Comment on ''Biochronological continuity of the Paleogene sediments of the Himalayan foreland basin: Paleontological and other evidences''–Bhatia, S.B. and Bhargava O.N., 2006, *JAES* **26,** 477–487. *Journal of Asian Earth Sciences,* **30**: 417–421.

Nanda, A. C. and Sahni, A., 1998.*Ctenodactylid* rodent assemblage from Kargil Formation, LadakhMolasse Group: Ladakh Himalaya age and palaeobiogeographic implications for the Indian Subcontinent in the Oligo-Miocene. *Geobios,* **31**(4)**:**533-544.

Nandy, D. R. 2001. Geodynamics of Northeastern India and the adjoining region. *ACB publication,* Calcutta, 209p.

Nandy, D. R. 2017. Geodynamics of Northeastern India and the adjoining region. Revised Edition. *Scientific book centre,* Guwahati, 272p.

Oldham, T. 1858. On the geological structure of a portion of the Khasi Hills, Bengal. *Memoirs Geological Survey of India,* **1**(2)**:** 270.

Oldham, R. D. 1883. Reports on the Geology of parts Manipur and Naga Hills. *Memoirs Geological Survey of India,* **19**(4)**:** 217-42.

Pandey, J. 1990. Cretaceous/Tertiary boundary iridium anomaly and foraminiferal breaks in the Um Sohryngkew River section, Meghalaya*. Current Science,* **59:** 570-575.

Pascoe, E. H. 1912. A traverse across the Naga Hills of Assam from Dimapur to the neighbourhood of Saramati Peak. *Records of the Geological Survvey of India,* **13**(4)**:** 254-265.

Patnaik, R. 2013. Neogene Siwalik mammalian biostratigraphy: an overview, p. 423–444. In: *Fossil mammals of Asia: Neogene biostratigraphy and chronology*. (Eds. Wang, X., et al.) Columbia University Press, New York.

Rai, J., Malsawma, J., Lalchhanhima, C., Lalnuntluanga, P., Ralte, V. and Tiwari, R. P. 2014. Nannofossil biostratigraphy from Bhuban Formation, Mizoram, Northeastern India and its paleoenvironmental interpretations, p. 121-134. In: *Indian Miocene: A geodynamic and chronologic framework for palaeobiota, sedimentary environments and paleoclimates* (Ed: Tiwari, R.P.), *Special publication of the Palaeontological Society of India,* **5**.

Raiverman, V. and Raman, K. S. 1971. Facies relations in Subathu sediments, Simla Hills, N.W. Himalaya, India. *Geological Magazine,* **108**: 329–341.

Rajkumar, H. S. and Klein, H. 2014. First perissodactyl footprints from the flysch deposits of the Barail Group (Lower Oligocene) of Manipur, India*. Journal Earth System Science*, **123**(2): 413-420.

Raju, D. S. N. and Lokho, K. 2010. Status of Litho-Bio-Chrono-Sequence Stratigraphic Framework and Depositional Environments of Northeast India, Bangladesh and Myanmar-charts and explanatory notes. *Memoir Geological Society of India,* **75**: 131-142.

Ramesh, P. 2004. Reassessment of depositional environments during sedimentation of Lower and Middle Bhuban Formation subsurface of Cachar area, Assam-Arakan Basin, India, pp.1-12. In: *2nd Association Petroleum Geologists Conference and exhibition,*Khajuraho.

Rangarao, A. 1983. Geology and hydrocarbon potential of a part of Assam-Arakan Basin and its adjacent region. Petroliferous Basins of India. *Petroleum Asia Journal,* **6**(4)**:** 127-169.

Rangarao, A. 1986. North-West Himalayan Foothills: Its stratigraphical record and tectonics phases. *Bulletin of ONGC,* **239**(2)**:** 109-128. .

Ravikant, V., Wu, F. Y. and Ji, W. Q. 2011. U–Pb age and Hf isotopic constraints of detrital zircons from the Himalayan foreland Subathu sub-basin on Tertiary palaeogeography of the Himalaya. *Earth and Planetary Science Letters,* **304:** 356–368.

Sahni, A., Bhatia, S.B. and Kumar, K. 1983. Faunal evidence for the withdrawal of the Tethys in the Lesser Himalaya, Northwestern India. *Bollettino Della Societa PaleontologicaItaliana,* **22**(1-2): 77-86.

Sahni, A. and Kad, S. 1998. Evidence of the Tectonic Events in the Foreland Basin: Phase Relationship with Himalayan and Tibetan Uplifts. *Himalayan Geology*, **19**(2): 49-53.

Sahni, M. R. and Bhatnagar, N. C. 1958. Fresh water mollusca and plant remains from the Tertiaries of Kargil Kashmir. *Records Geological Survey India,* **87**(3): 467-4676.

Sahu, V. K., Gahalaut, V. K., Rajput, S., Chadha, R. K., Laishram, S. S. and Kumar, A. 2006. Crustal deformation in the Indo-Burmese arc region: implications from the Myanmar and Southeast Asia GPS measurements. *Current science,* **90**(12)**:**1688-1693.

Sarkar, S. and Prasad, V. 2000. Paleoenvironmental significance of dinoflagellate cysts from the Subathu Formation (Late Ypresian–Middle Lutetian) of Koshalia Nala section, Shimla Hills, India. *Himalayan Geology,* **21**(1, 2): 167-176.

Sarma, A. and Ghosh, K. 2006. A new record of calcareous algae from Shella Formation (Jaintia Group) of South Jaintia Hills, Meghalaya, India. *Current Science,* **90**(9): 1276-1281.

Sehgal, R. K. and Patnaik, R. 2012. New muroid rodent and *Sivapithecus* dental remains from the Lower Siwalik deposits of Ramnagar (J and K, India): Age implication*. Quaternary International,* **269:** 69-73.

Sengupta, S., Ray, K. K. and Acharyya, S. K. 1990. Nature of ophiolite occurrence along the eastern margin of the Indian plate and their tectonic significance: *Geology,* **18:** 439-442.

Singh, B. P. 2013. Evolution of the Paleogene succession of the western Himalayan foreland basin. *Geoscience Frontiers,* **4:**199-212.

Singh, B. P. 2014. On some sedimentological and paleontological aspects of Subathu-Dagshai-Kasauli succession of Simla Hills. *Journal of the Palaeontological Society of India,* **21-22:** 19-28.

Singh, M. C. H., Kushwaha, R. A. S., Srivastava, G. and Mehrotra, R. C. 2012. Plant Remains from the Laisong Formation of Manipur. *Journal Geological Society of India,* **79:** 287-294.

Singh, P. 1980. The Subathu Group of India. *Nav Jyoti Scientific Publications of India*, 1-90.

Singh, R. H., Tovar, F. J. R. and Ibotombi, S. 2008. Trace fossils of the Upper Eocene-Lower Oligocene transition of the Manipur, Indo-Myanmar Ranges (Northeastern India). *Turkish Journal of Earth Sciences,* **17:** 821-834.

Singh, R. K., Singh, H. J., Dattatraya, K. and Lokho, K. 2009. Assam and Assam-Arakan basins. *ONGC bulletin,* **44**(2)**:** 248-251.

Singh, Y. R., Singh, B. P., Singh, A. K. and Devi, S. R. 2017. Palynology and mineral composition of the Upper Disang Formation flyy schoid sediments from the southern Manipur, Northeast India: Age, paleoenvironment and provenance reconstruction. *Himalayan Geology,* **38**(1)**:** 1-11.

Sijagurumayum 1, U., Singh, R. and Kachhar R. P. 2014. Eocene molluscan fossils from the Upper Disang Formation of Imphal Valley, Manipur, India. *Journal of the Palaeontological Society of India*, **59**(1): 59-68.

Srivastava, P., Patel, S., Singh, N., Jamir, T., Kumar, N., Aruche M. and Patel, R. C. 2013. Early Oligocene paleosols of the Dagshai Formation, India: A record of the oldest tropical weathering in the Himalayan foreland. *Sedimentary Geology*, **294:**142–156

Steckler, M. S., Mondal, D. R., Akhter, S. H., Seeber, L., Feng, L., Gale, J., Hill, E. M and Howe, M. 2016. Locked and loading megathrust linked to active subduction beneath the Indo-Burman Ranges. *Nature Geoscience,* **9:** 615-618.

Sun, J., Ni, X., Bi, S., Wu, W., Ye, J., Meng, J. and Windley, B. F. 2014. Synchronous turnover of flora, fauna, and climate at the Eocene-Oligocene Boundary in Asia. *Scientific Reports*, **4**(74-63): 1-6.

Tewari, B. S., and Dixit, P. C. 1972. A new gastropod from freshwater beds of Kargil Ladakh, J and K. state. *Bulletin Indian Geologists Association,* **4:** 61-67.

Tewari, V. C., Kumar, K., Siddaiah, N. S. and Lokho, K. 2009a. Lakadong Limestone: Paleocene–Eocene boundary carbonate sedimentation in Meghalaya, northeastern India. *Current Science,* **98**(1)**:** 88- 95.

Tewari, V. C., Lokho, K., Kumar, K. and Siddaiah, N. S. 2009b. Late Cretaceous-Paleocene basin architecture and evolution of the Shillong shelf Sedimentation, Meghalaya, Northeast India. *Journal of the Indian Geological Congress,* 61-73.

Tiwari, B. N. 2005. Tertiary vertebrates from the Himalayan Foreland of India: An explication of Late Eocene–Oligocene Faunal Gap. Spl. Publ. *Palaeontological Society of India*, **2:** 141-153.

Tiwari, B. N., Verma B. C. and Bhandari, A. 2006. Record of *Prodeinotheriumorlovii* (Proboscidea: Mammalia) from mid-Tertiary Dharmsala Group of Kangra Valley, NW Himalaya, India: biochronological and palaeogeographical implications. *Journal of Palaeontological Society of India,* **51**(1): 93-100.

Tiwari, R. P., Barman, G. and Satsangi, P. P. 1997. Miocene crabs from Mizoram India. *Journal of the Paleontological Society of India,* **42**:127-132.

Tiwari, R. P. 2001. Neogene palaeontology of the Surma Group, Mizoram, India. The *Arcoida* (Mollusca: Bivalvia). *Journal of the Palaeontological Society of India,* **46:**147-160.

Tiwari, R. P. and Kachhara, R. P. 2003. Molluscan biostratigraphy of the Tertiary sediments of Mizoram India. *Journal of the Paleontological Society of India,* **48**: 65-88.

Tiwari, R. P., Malsawma, J., Sangode, S. J. and Arora, B. R. 2007. Magnetostratigraphy of a part of Middle Bhuban sequence (Surma Group) Aizawl, Mizoram. *Journal Society India.***70:** 667-674.

Tiwari, R. P., Rajkonwar, C., Lalnuntluanga, P., Malsawma, J., Ralte, V. Z., Patel. 2011. Trace fossils from Bhuban Formation, Surma Group (Lower to Middle Miocene) of Mizoram India and their palaeoenvironmental significance. *Journal of Earth System Science,* **120**(6): 1127-1143.

Venkatachalapathy, R., Lokho, K. and Whiso, K. 2007. New frontiers for energy resources: A study of microfossils in identifying the source rocks for oil in Nagaland, NE India. *Gondwana Geological Magazine,* Special Volume, **9:** 33-45.

Warwick, P. D., Johnson, E. A. and Khan, I. H. 1998. Collision-induced tectonism along the northwestern margin of the Indian subcontinent as recorded in the Upper Paleocene to Middle Eocene strata of central Pakistan (Kirthar and Sulaiman Ranges). *Palaeogeography, Palaeoclimatology, Palaeoecology,* **142:** 201–216.

Whiso, K., Ramesh, P., Venkatachalapathy, R. and Kachhara, R. P. 2003. Occurrence and age significance of *Planorotalites palmerae* (Cushman and Bermudez) in the Dillai Parbat area of Assam, NE India p. 141–144. In: Micropaleontology: *Application in Stratigraphy and Paleooceanography* (Ed. Sinha, D. K.). Narosa Publishing House, New Delhi.

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