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AN INTEGRATED APPROACH TO THE QUATERNARY FAUNA OF SOUTH AND SOUTH EAST ASIA – A SUMMARY

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ABSTRACT

The Quaternary fauna of South and South East Asia as a whole is well known for its significance in hominid evolution, biodiversity (of ecosystems and of species), migration patterns, evolutionary trends and other related aspects. In this geographical region, diverse ecosystems like the savanna, wetlands, deserts, mountain forests, etc. are amply present and provide a suitable ambience for the growth and diversity of the faunal material. These environmentally sensitive areas with richness of both endemic and exotic species, have been successfully mapped. The most well-known Quaternary faunal site complexes in India include the Siwaliks (the NW and the NE regions), the Indogangetic region, the Peninsular India (notably, the river valleys of Narmada, Godavari, Krishna, etc., and cave deposits of Andhra Pradesh) and other isolated fossiliferous pockets. The Nepal Siwaliks, fossiliferous regions of Myanmar, Sri Lanka and Indonesia also constitute important prehistoric hot spots in S. Asia and SE Asia which throw important light on the migration patterns and man/land relationship in the past.

A large variety of faunal remains comprising mammals, birds (especially the ostrich egg shells pieces), reptiles, amphibians, fishes, microvertebrates and molluscan shells have been obtained from the above-mentioned deposits, many of these in association with Stone Age tools manufactured by Early Man and this occurrence helps in a better interpretation of man–land relationship. A brief account of the fossiliferous sites and fossils found therein is provided in the paper with remarks on migration patterns, evolutionary history, palaeoenvironmental aspects, causes of extinction and allied factors that offer a challenging field of investigation for the geologist as well as palaeobiologists. As mentioned above, the subject matter has been discussed only briefly here leaving the details for a separate treatment of the subject elsewhere encompassing the prehistoric environments in S and SE Asia.

Keywords: Quaternary fauna faunal sites, South and South East Asia, evolutionary history, palaeoenvironment

INTRODUCTION

The South and South East Asian faunal elements of the Quaternary Period are very varied in terms of abundance and diversity. Starting from the Siwaliks of the Sub-Himalayan region (the Northwest India, Nepal, Northeast India, Myanmar), the Indo-Gangetic region, Central India, Peninsular India, Sri Lanka and Indonesia (Fig.1), the geographical components react differently to different environmental and climatic factors. The species diversity depends on geographic locations wherein most of the resources are concentrated. Incidentally, South and South East Asia provide varied ecosystems, with savanna, desert, wetland, mountain forests, riverine situations, dry, aeolian landscape, etc. which helped in a proliferation of a large number of ecological niches for the organic life to thrive. Various environmentally sensitive formations with richness of both endemic and exotic species have been extensively studied and mapped. At the beginning of the Tertiary period, several physical and biological changes took place in various sectors of the regions under discussions. Reptiles underwent serious decline and mammals began to replace them. Amongst the invertebrate fossils, cephalopods, belemnites and ammonites suffered widespread extinction and gastropods entered into a period of maximum development. Change from marine Nummilitic limestone of Eocene (forams, corals, echinoids, etc.) to the fluviatile deposits of succeeding age (mammals, fossil wood, etc.) is a striking climatic revolution in India.

THE IMPORTANT REGIONS

The Siwaliks of NW India

These are by far the most prolific fossil-bearing sites in India and one of the best in the world, extending from the Indus River in the northwest to the Brahamputra in the northeast (Fig.2). These are composed of fluviatile sediments, the grain size of which ranges from a clay fraction to boulders, derived from the rising Himalaya and laid down in giant alluvial fans (Wadia, 1966). The sub-aerial waste of alluvial detritus has been swept down the mountains by rivers and streams and deposited at their foot. As is well known, the Siwaliks have been divided into Lower, Middle and Upper, mainly on the basis of palaeontological evidence taking also into consideration the type area lithology and in recent years a few dating techniques. About the nature of the basinal deposition it is widely accepted that the Siwalik Formation was laid down in a single large river flowing from Assam to Kashmir, which was named as 'the Indobraham' (Pascoe, 1973) or the 'Siwalik river' (Pilgrim, 1919). It was also suggested that the basin of deposition of Siwaliks was in the form of a continuous lagoon or foredeep formed in front of the Himalayan range (Krishnan and Aiyanger, 1940). That the sediments represented fresh water or partly continental deposits of lacustrine or fluviatile origin is also well known (Krishnan, 1968). The presence of lamellibranchs, gastropods, ostracodes, charophytes, etc. in various pockets of the Siwaliks also suggest a fresh water mode of deposition.

The Siwaliks as a whole have yielded numerous fossils but here reference will be made only to the area mapped by the author, between Pinjor and Nalagarh. It is in general characterized by rugged terrain and north-south trending dun valley terrace development and comprises hard and soft rock formations, the hills are marked by deep gullies and knife edged serrated ridges, as a result of which the area has acquired bad-land topography. A number of streamlets with their numerous branches wind through the rocks finally converging into ephemeral streams, Sukhna Cho, Patiali Rao, Jainta Devi Ki Rao and Siswan Nadi and other smaller streams which flow westward and feed the Sukhna Cho, a source stream for the artificial Sukhna Lake of Chandigarh. The Tatrots are generally

Fig.1. Map of South and South East Asia.

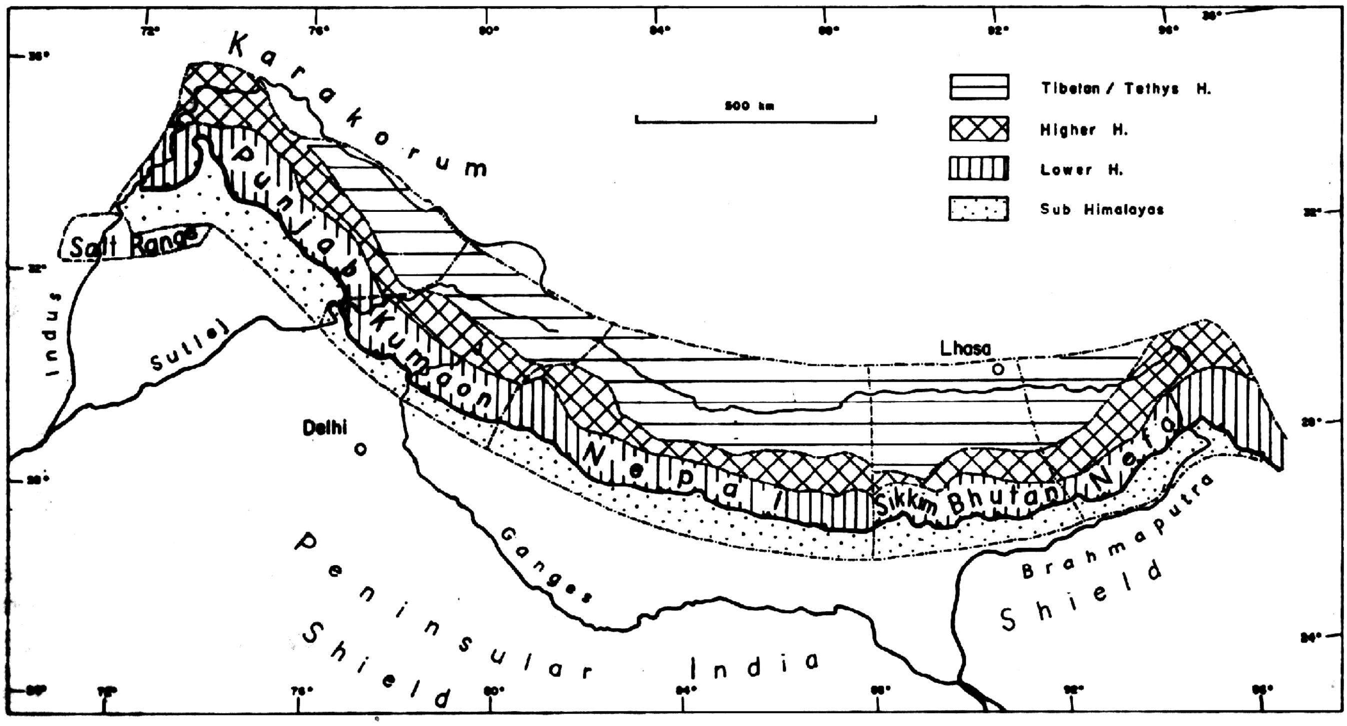


Fig.2. Extent of the Siwalik Sub-Himalayas from North West to North East India.

exposed hugging the Jhajra Nadi on the eastern side and part of Naipli on the western side. The Pinjors are extensively exposed around the areas Mirzapur, Siswan, Masol, Surajpur, Nathuwala, Naipli, etc. and also along the Ghaggar River at Nadah village (Fig.3), whereas the Boulder Conglomerate is mainly exposed around Saketri, Kala Tibba, part of Surajpur Cement Factory, Kotla, etc. (Figs.4 & 5). Overlap of more than one geological formation can be observed at various exposures. Rest of the area is covered by alluvium.

(Note: There has been a report of an incisor, suspected to be of a hominoid, from the Pinjor Formation at Nadah village).

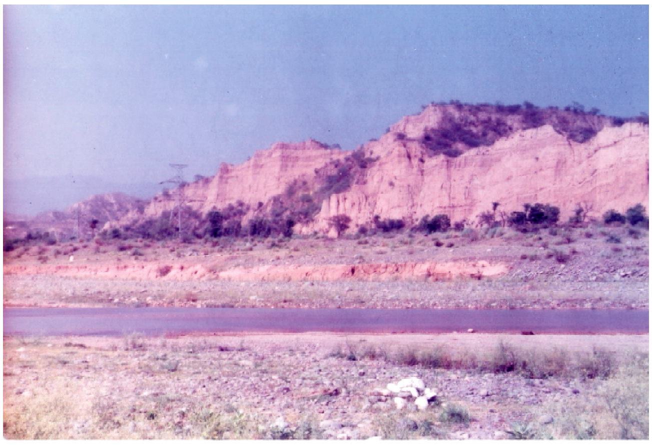


Fig. 3. Pinjor Formation at Nadah village along the Ghaggar river.

The much debated Neogene–Quaternary boundary problem in NW India, can be discussed with respect to the present area of investigation where all the three formations are exposed in a limited area. In the past, the delineation of the boundary was based on stratigraphic, palaeontologic, paleoclimatic, and sedimentary considerations. However, in recent years, the application of palaeomagnetic dating technique has provided a firm basis for correlation of Siwalik beds with standard magnetic polarity time scale (MPTS). Such studies were initiated in the Pabbi Hills of Upper Siwaliks (Keller *et al*., 1977) and other parts of northern Pakistan (Opdyke *et al.,* 1979), according to which the Pleistocene epoch commences at the Olduai event dated to 1.8 mya. Palaeontologically, the N/Q boundary corresponds with the Gauss/Matuyama boundary which has been dated to 2.48 mya coinciding with the first appearance of *Equus, Elephas, Cervus* and *Bos* to mark the beginning of the Pleistocene (IGC, 1948). The INQUA Commission (1991) now also accepts the base of the Matuyama as the beginning of the Quaternary notwithstanding the difference of opinion in the use of the palaeontologic data and the MPTS in respect of dating the N/Q boundary in NW India. It may be mentioned that several enrichment dating techniques have been applied by scientists in India and abroad in an attempt to solve the vexed problem of dating the Neogene-Quaternary boundary problem which has received a near universal acceptance now.

Faunastically, most of the fossils collected from the area include many related representatives of the recent fauna. Hence, the history of the physical environments, under which the Siwalik fauna flourished can best be traced by studying the ecological habits of the animals which once lived in the present area. The fossil reptiles (*Geoclemys sivalensis, Colossochelys atlas, Trionyx gangeticus, Gavialis browni, Crocodylus biporcatus, Crocodylus palaeindicus*) indicate that the present area, traversed by a number of rivers, was occupied by lakes and swamps and was subjected to seasonal flooding suggestive of rhythmic deposition. The presence of fossil bovids and those of cervids and equids (*Bos acutifrons, Hemibos triquetricornis, Bubalus* cf. *B. platyceros, Bison* sp., *Cervus punjabiensis, Equus sivalensis, Hipparion antelopinum, Hipparion theobaldi*) indicate that the grounds surrounding the lakes and rivers were comparatively hard and dry with pockets of rich vegetation scattered all around. The presence of rhinoceroses (*Rhinoceros sivalensis*, *Rhinoceros palaeindicus, Chilotherium intermedium*) and also of a few camels (*Camelus sivalensis*) in the area supports the fact that in addition to the hard ground, the extensive swamps and water sheets that were present during the earlier phases of deposition of the Tatrots became shallower and fewer and gradually dried up as a result of which open plains dominated the area during the Pinjor times. Hence, there was a corresponding reduction of water and its further distribution into isolated shallow lakes. The presence of current bedding structures, ripple marks and poor sorting also favour the shallow nature of the basin. The pale red colour in the sediments of the Tatrots indicates moist conditions while the pink colour of the Pinjor sediments (Fig.6) suggests drier conditions. On the whole, the environmental studies during the deposition of the Siwaliks indicate that both the Tatrots and Pinjors are fresh water deposits. The Tatrots are predominantly lacustrine, while the Pinjors have been laid down in valley and open savanna grassland by river sediments arising from the adjacent rising hilly region. The Boulder Conglomerate deposits are the result of coalescence of vast boulder fans emanating from the northern rising Himalayas. All this ecological framework (except for the Boulder Conglomerate Stage which was a cold phase and associated with mountain building activity) gave rise to a profusion of large number of prehistoric animals, most of which are now extinct at the species level (Badam, 1979).

Jammu and U.P. Siwaliks

The Jammu region has preserved significant exposures of Lower, Middle and Upper Siwalik sediments. The Upper Siwaliks have been divided into Paramandal Sandstone (arenaceous facies with thin mudstone beds), Nagrota Formation (alternations of mudstone and sandstone with occasional conglomeratic beds) and Boulder Conglomerate Formation (boulders, cobbles and pebbles with sandstone and limestone matrixes). The most significant feature of the Nagrota Formation is the presence of two volcanic tuff horizons dated to 2.8 +_0.56 mya and 2.31 +_0.54 mya by fission track dating (Ranga Rao *et al*., 1988). The characteristic fossils from the Paramandal sandstone include *Stegodon bombifrons, Hipparion antelopinum, Cormohipparion theobaldi, Propotamochoerus hysudricus,* etc. The Nagrota Formation has yielded *Panthera* cf. *cristata, Elephas hysudricus, Equus sivalensis, Rhinoceros palaeindicus, Coelodonta platyrhinus, Cervus* sp., *Sivatherium giganteum, Sivacapra* sp., *Hemibos triquetricornis*, *Bos* sp., *Sivacapra* sp., etc. (Nanda and Sehgal, 2007). The Boulder Conglomerate Formation is generally unfossiliferous except for a few broken, secondary, unidentifiable fossil fragments.

The Kalagarh Basin of Uttaranchal State (formerly Uttar Pradesh) is known for vertebrate fossils, especially for the primate collection from the Dhara locality. The prominent

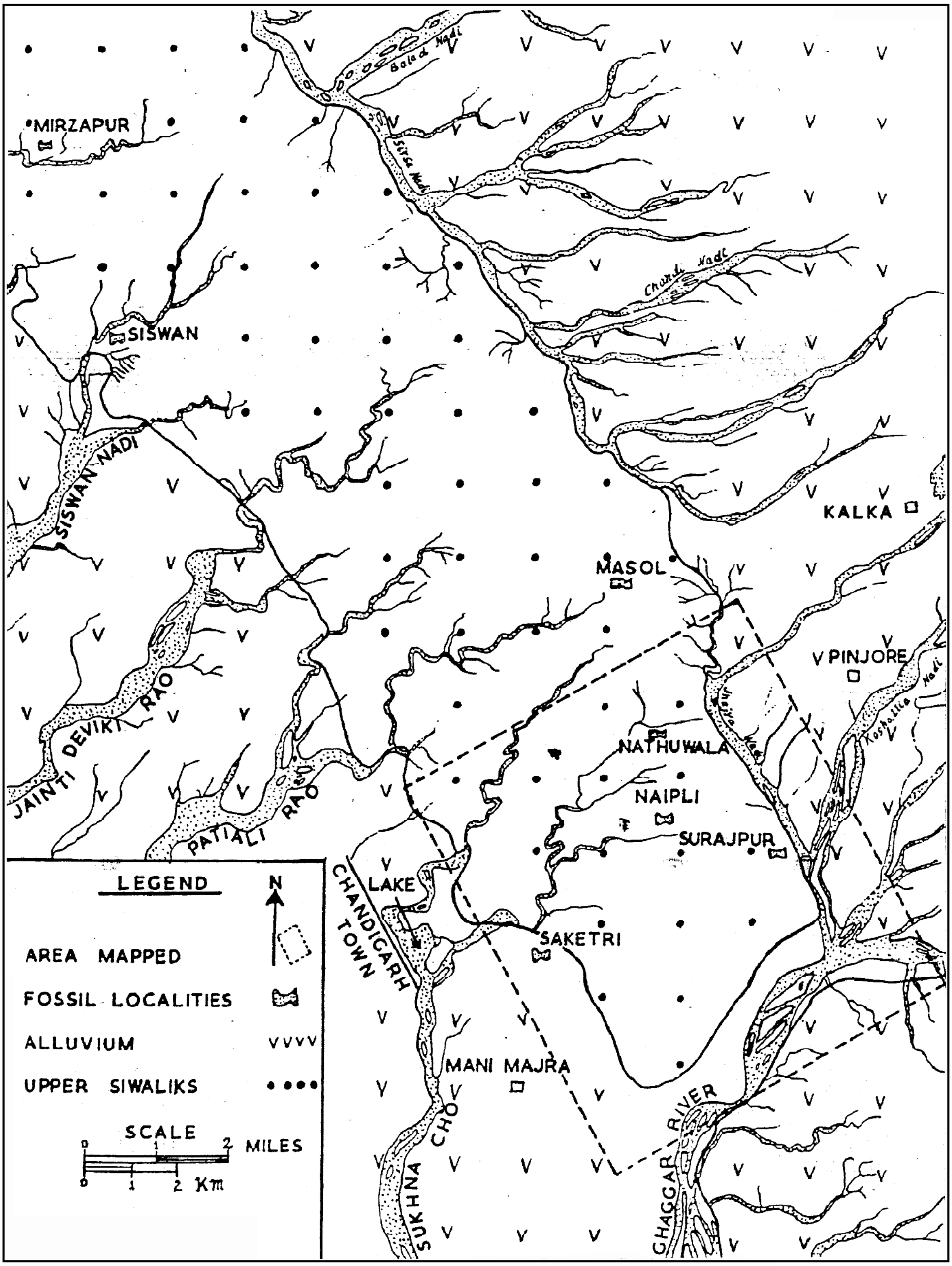


Fig.4. Exposures of the Upper Siwaliks around Chandigarh showing some fossil localities (after Badam, 1979).

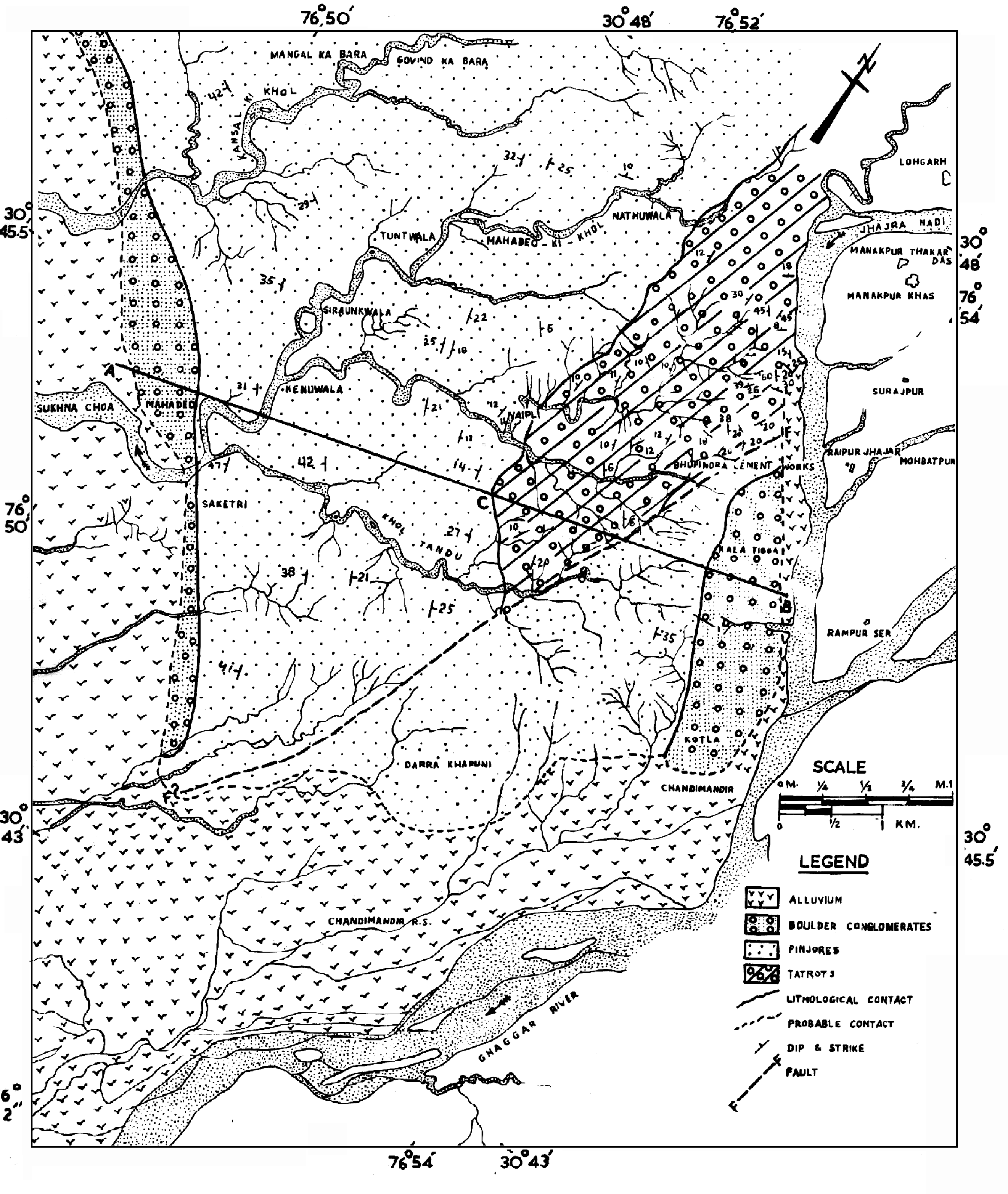


Fig.5. Geological map of the Upper Siwaliks around Chandigarh (the area investigated) (after Badam, 1979).

genera include *Indraloris himalayensis, Sivaladapis nagri, Gigantopithecus giganteus, Sivapithecus indicus Sivapithecus sivalensis, Ramapithecus punjabicus,* etc. Most of these are from the Lower and Middle Siwaliks. The other fauna includes Insectivora, Rodentia, Carnivora, Proboscidea, Perissodactyla, Artiodactyla, Bovidae, Giraffidae, etc.

On the basis of habitat spectra analysis, Gaur (2007) suggests that the Kalagarh mammals indicate higher value for woodland, slightly less for forest and least for bush land. In fact forest ecology with dominant woodland with some wooded savannah is suggested for the Siwaliks of the Kalagarh area. The Upper Siwalik fauna is not well documented at the present stage of our knowledge.

Nepal

Kathmandu Valley is the largest intermontane basin in Nepal, second only to the intermontane basin of Kashmir. Till a few decades ago, the stratigraphic and palaeontologic record of Nepal was poorly known. Recent work of West *et al.* (1978) and West (1984) and that of Corvinus (1993, 1995, 2005) helped in correlating the Quaternary sequence of Nepal with other areas in the Himalayas. However, the Pokhra Valley, where there is evidence of a glacial record, has received little attention so far.

The valleys (Duns) of Dang and Deokhuri in western Nepal (Figs.6, 7 & 8) were formed during the folding and faulting of the Siwalik foothills in early Pleistocene times. Subsequently, these got filled up by alluvial, lacustrine and aeolian sediments. Early Man who migrated from the Indian subcontinent, occupied these valleys from the upper part of the Middle Pleistocene to the Holocene (Corvinus, 2005). Corvinus (1995) surveyed several valleys like Tui, Babai, and Rapti and discovered handaxes, choppers, cores, flakes, scrapers, etc. as a result of excavations that helped establish a cultural chronology in western and eastern parts of Nepal. The most well-known and complete sequence of the Siwaliks of Nepal, locally called the Surai Khola beds (Fig.9), are 5500 m thick exposed uninterruptedly in western Nepal incorporating sequence from Chinji to Pinjor formations. The sequence contains rich plant and animal fossils that suggest various environmental changes during deposition of the sediments.

The Nepal Siwaliks are locally known as Churia Hills stretching about 800 km from east to west. Lower part of the Nepal Siwaliks is fine-grained sandstone and siltstone, cemented by carbonate. Rapti Valley in western Nepal has exposed beds equivalent to the Tatrot, Pinjor and Boulder Conglomerate formations of the Upper Siwaliks of NW Himalayas. Species like *Crocodylus, Potamochoerus palaeindicus, Hexaprotodon sivalensis, Cervus, Bos/ Bubalus, Stegodon insignis, Elephas planifrons, E. hysudricus, Gazella,* etc. have been recorded from these beds. Primates, carnivores and rodents are less in number. One of the important discoveries, that of *Ramapithecus punjabicus* (9 mya), was made from Tinau Khola north of Butwal in association with a Lower Siwalik suid *Conohyus indicus* (Munthe *et al.,* 1983). The Tinau Khola specimen is the left upper first molar (10 mm long and 11 mm wide) and similar to Miocene hominoids from India and Pakistan. Some scholars opine that this specimen should be redesignated as *Sivapithecus.* Apart from variations in measurements, the Tinau Khola specimen is similar to GSP 5019 from the Potwar region, K56 675 (GSI) from Ramnagar (J&K) and YPM 13799 from Haritalyangar (H.P) (see Fig.10). It would be interesting to know that the Ramnagar area has a few more hominoid fossil localities in Dalser Talab and Kirmu (Nagri beds). From the latter, the K56 675 specimen was reported. The third locality lies on the Dhar-Udhampur Road, 3 km from Udhampur (Nagri beds) where plant fossils were also discovered. On the whole, other non primate fossils from Nepal (Nanda and Corvinus, 1992; Corvinus and Nanda, 1994) in addition to the ones listed above, also include perissodactyles, rodents, fish, etc. and can be correlated with the Pinjor of Siwaliks/Karewas of Kashmir at 1.5 mya to 2.9 mya.

Pollens, e.g. *Pinus* (pine), *Quercus* (oak), *Alnus* (alder) were collected from Nakku Kola, south of Kathmandu indicating a temperate climate similar to that of the present day. In the terraces, there was a marked increase in pinaceous species suggestive of cooler and drier climate late in the Pleistocene. On the whole, the flora indicates tropical to subtropical evergreen forest and vegetation in a very warm humid climate. Aquatic taxa are dominant but channel deposits are not prominent. Terrestrial animals would indicate lowland environment, but some fossil groups were found well into the

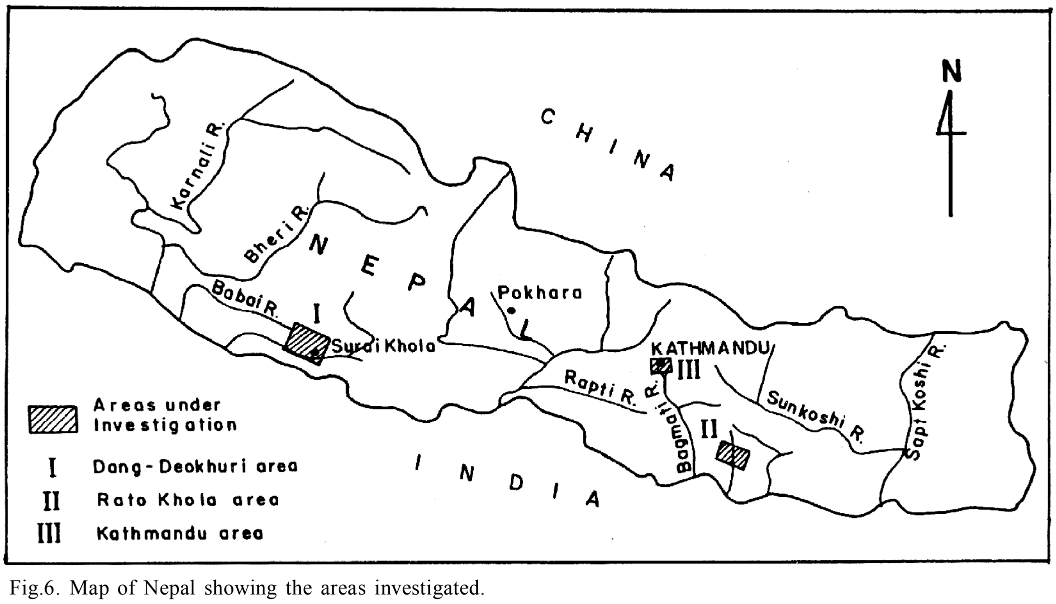


Fig.6. Map of Nepal showing the areas investigated.

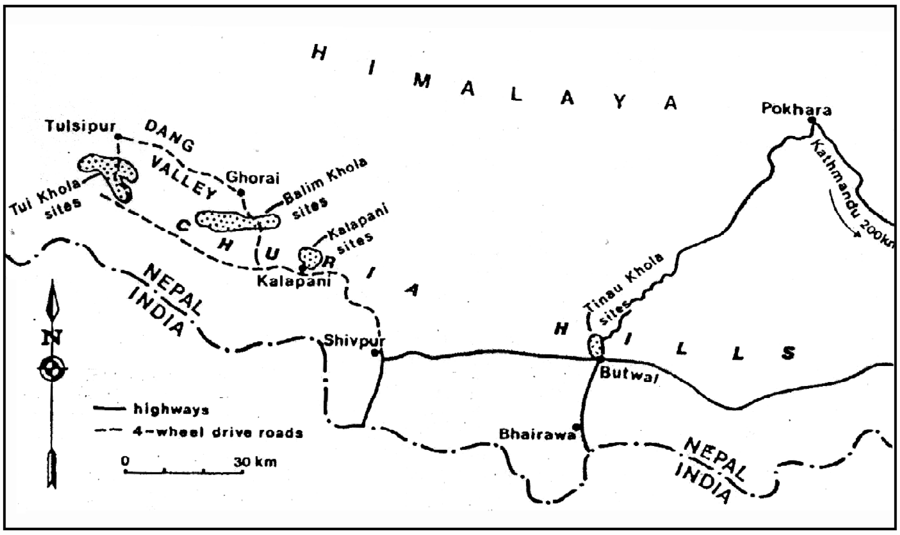


Fig.7. Sites investigated in Nepal. Tinau Khola is the site that yielded a hominoid molar.

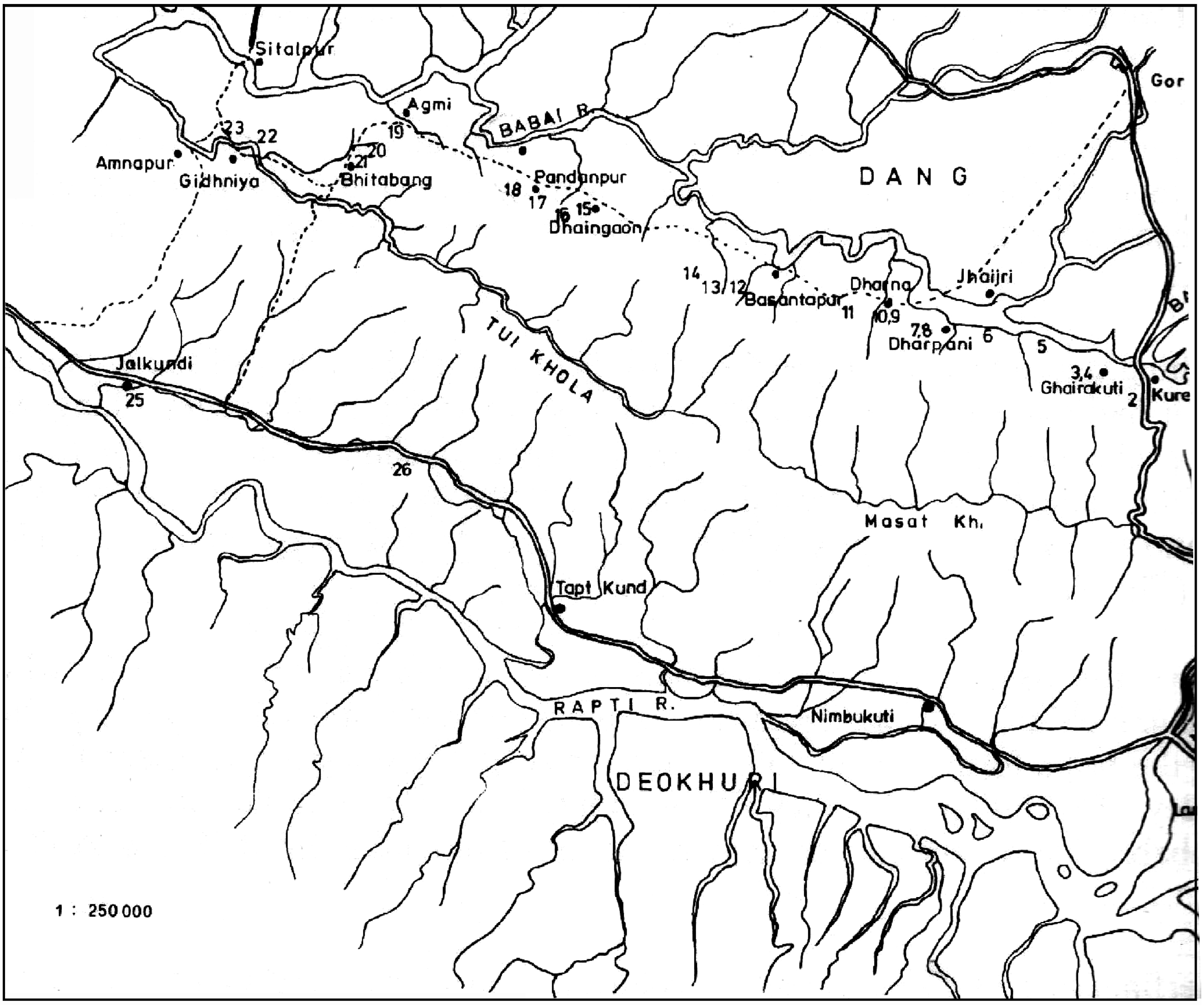


Fig.8. Site map of the areas (Dang- Deokhuri) investigated by G. Corvinus.

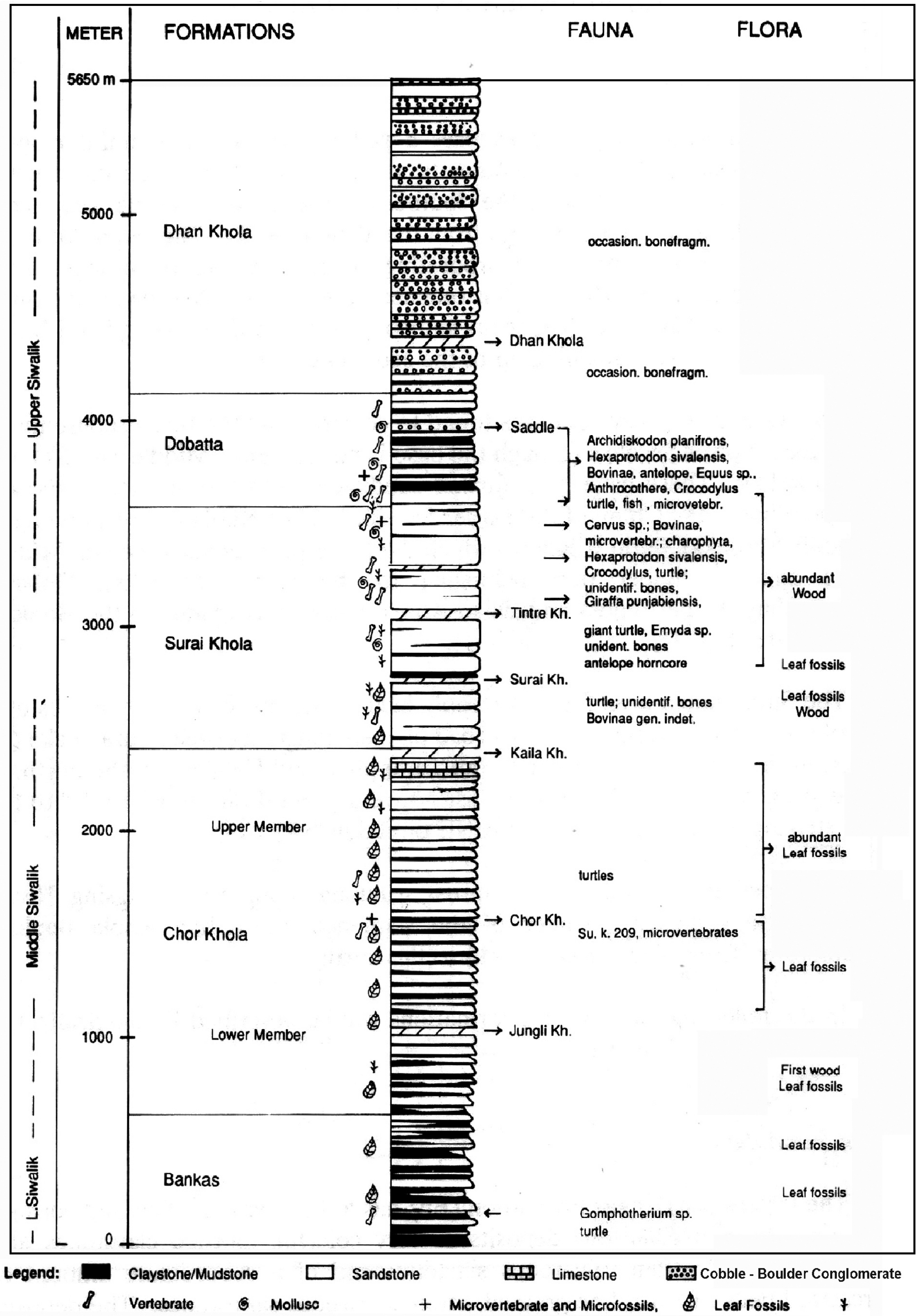


Fig.9. Surai Khola, a complete sequence of Siwaliks in West Nepal (after Corvinus, 1993).

Fig. 10. An exposure of the Middle Siwaliks at Haritalyangar, Himachal Pradesh which yielded *Ramapithecus* tooth YPM 13799.

top of the sections, e.g. a turtle graveyard with about 500 or so carapace and plastron fragments. Erosion in the sediments and gradual uplift is thus very evident.

On the whole, the Nepal region forms a part of the physical and tectonic part of the entire Siwalik range and was deposited in the poorly drained areas characterized by ponds and sluggish streams. The main palaeoecological difference between the Siwaliks of Nepal and those of India is probably due to the environmental influence of the Himalaya. The Nepal Siwaliks are closer to the Bay of Bengal and are thus subjected to a different seasonal monsoon climatic cycle (West, 1984).

North East India

The Tertiary deposits in the North East (Eocene to Pliocene) are extensively developed with a total average thickness of around 50,000 ft. starting from Lower Miocene (Jaintia, Barail), onto Upper Miocene (Surma), Pliocene (Tipam, Dupi Tila, Dihing) and Quaternary (part of Dihing, alluvial terraces, gravels, etc.). However, there are some breaks in geological succession in the North East caused because of the retreat of sea which was replaced by estuaries (Brahamputra in Assam and Irrawaddy in Myanmar). Interestingly, some stratigraphic correlations have been successfully made with the Irrawaddy System of Myanmar, the alluvium of Brahamputra in upper part of Assam and with the Tertiary of NW India. It is well known that the rise of the Himalayan chain to its present height had a profound bearing on the landforms and biota of the region as in other sub-Himalayan regions.

Recent researches in archaeology and palaeoanthropology of the NE Himalayas suggests that this region along with Bangladesh and Myanmar holds great possibility for the occurrence of Early/Middle Pleistocene as the *Homo erectus* of Java might have migrated from South Asia to SE Asia (Mishra *et al*., 2010). It is presumed that the uplands along the Himalayan foothills might have served as a course for human movements in absence of such a possibility along the Brahmaputra and other river valleys which were difficult to cross (Dennel, 2009). It may be emphasized that Nepal, NE India and Myanmar must be studied as a single unit which would facilitate better insights into environmental history of the regions and that of migration of cultures.

There are a few fossil findspots in NE as a whole but many of these have remained unexplored. Some of these were recently compiled by the author along with the inputs from archaeological findings (Badam, 2009); detailed work, however, is under way. It was Maclaren (1904) who recorded Pleistocene river gravels along the foothills of the Himalaya of Upper Assam. One of the earliest records of fossil vertebrates is from the Karibari region of the Garo Hills (Pentland, 1828), followed by finding of a lower molar of *Elephas hysudricus* from the same general area in recent years.

Some other find spots are from near the village Morikona, Kamrup Dist. Assam, where a part of tooth of *Elephas maximus* was discovered (Badam, 1974). This specimen, embedded in

Fig. 11. Important localities in NE India bearing Late Pleistocene/Early Holocene sites.

bluish clayey matrix, was discovered by the late Dr. T.C. Sharma of the Guwahati University at a depth of 15 m from the surface level. In addition, the author identified a late Pleistocene faunal assemblage from Manipur as *Cervus* sp., *Sus* sp., bovids and wild fowl.

As can be seen from the above, the reports of faunal material from the North East are scanty and concerted efforts are needed to discover these and put them in a chronological sequence with regard to the whole of the country and also for palaeoecological interpretation. However, elephant fossils are more in number than other taxa as this area receives more rainfall, supports a more luxuriant flora and maintains more stable aquatic environment than northwestern region.

West Bengal

In West Bengal, several sites have come to light recently which have enriched our knowledge about the prehistoric environment in the region. Two areas are particularly known for the Quaternary history, the Gandheswary river valley near Susunia Hill in Bankura district and the Tarafeni river valley in Midnapur district. However, the first evidence of Quaternary fossil goes as far back as early nineteenth century (Pentland, 1828) from the northeast border of the then Bengal (Karibari region) of the Garo Hills which incidentally also provides one of the oldest fossil records from the whole of India. In fact, not much information on the Quaternary history was available in West Bengal for a long time. However, recent extensive research in some areas (like Gandheshwary and Tarafeni) has shown that the western upland covering an area of 3,000 sq.km or so of Purulia and the western parts of Bankura, Birbhum, Burdwan and Midnapur have a great potential for studying the Quaternary history in the state (Basak, 2005).

The Gandheshwary valley has yielded fossils belonging to Proboscidea, Rodentia, Carnivora, Equidae, Bovidae, Cervidae, Suidae, crocodiles, turtles etc. (Sastry, 1968). Most significant among the collection are carnivores, *Panthera* cf. *leo* (lion) and *Crocuta* cf. *sivalensis* (spotted hyaena), this being the first definite record of fossil lion from India and that of spotted hyaena from any Pleistocene deposit in Peninsular India (Dutta, 1976). It may be of interest to note here that fossils of carnivores are generally found less in number in the Quaternary deposits of India as compared to other taxa and this situation fits in well as per the ecological pyramid reconstructions.

For a long time, the only record of fossil lion in India was that of an upper premolar and limb bones of doubtful '*P*. cf. *tigris* (or *leo)*' from the Pleistocene deposits of Kurnool Caves in Andhra Pradesh (Lydekker, 1886). The spotted hyaena (*C. sivalensis*) occurs in the Pinjor Formation of the Upper Siwaliks and is represented by several species in other Siwalik formations of India and also in Ariyalur, Tiruchirapalli Dist. of Tamil Nadu (Pilgrim, 1930), suggesting a wide spatial extent once occupied by the genus in India. In fact, Susunia *Crocuta* is similar to the Siwalik *Crocuta* in dental characters. According to Kurten (1968), the spotted hyaena, now restricted to Africa, had its origin in India, while the striped hyaena, mainly restricted to India today, originated in Africa. The probable ancestor of both lion and tiger is from the Lower Pleistocene of Africa (Ewer, 1964). From the foregoing, it can be suggested that the Susunia collection provides important clues into the migration pattern of some animals within India and outside.

In a recent survey of the Quaternary of the region, Badam and Bhattacharya (2008) reported *Equus namadicus, Bos namadicus, Axis axis*, cervids, turtle shells and other fossil fragments which are under study. The present author also identified, from a repository of the West Bengal State Archaeology Dept., sites like Aduri, Khayerbain, Balakhuri, Pancka Siuralia, Dhankora, etc. which yield fossils like *Ovis/ Capra, Bubalus* sp., *Bos namadicus, Axis axis, Antilope cervicapra, Equus namadicus,* etc. The aim is to map these areas and study the artefacts and fossils both in horizontal and vertical dimensions including the sedimentological characteristics of the deposits for an understanding of the dynamic change of environment and man- land relationship in these areas.

A number of prehistoric (Upper Palaeolithic to Mesolithic) sites have been discovered in and around the district of Midnapur along with fossils of *Axis axis, Antilope cervicapra, Equus, Bos namadicus, Bubalus,* cervids and reptiles which do indicate congenial climate (semi-aridity) for the survival of man and animals in this part of the country (Basak *et al*., 1998). (See also Fig. 12).

Considering the palaeoenvironmental histories of both Susunia and Tarafeni, it is clear that there are variations in ecological models of both the valleys. For example, from the Gandheshwary river (near Susunia Hill, Bankura dist.) which is approximately 90 km or so to the north of Tarafeni Valley (Midnapur dist.), the palaeofauna is varied and quantitatively well documented. Predators, scavengers, herbivores and a few arboreal genera have been reported which give better inputs for the reconstruction of an ecological pyramid. The fauna includes Proboscidea, Rodentia, Carnivora, Equidae, Bovidae, Cervidae, Suidae, Crocodilia, Chelonia (Sastry, 1968; Dassarma *et al*., 1982; Badam, 1979). Obviously, the concentration of varied animals in a restricted area would depend on ecological resources which were perhaps better available in the Susunia Valley. The environmental systems in Tarafeni Valley include not only the physical and biological characters of the environment but also the social and cultural factors and the impact of man on the environment. The ecological equilibrium of the area which has a fragile geological base seems to have been affected due to a combination of climatic factors and biotic interference (loss of tree and ground cover) which prevented accumulation of sediments suitable for better preservation of palaeobiota. In addition, the smaller animals have a high productive potential than the larger ones and usually fall prey to the larger ones. On the whole, the preservational and taphonomical aspects of the fossils and collection strategies may have resulted in a poor yield of the fauna. Added to this is the continuous expansion of cultivation, extermination of *Sal* jungle and the anthropogenic factors (O'Malley, 1908). However, both these areas in West Bengal may prove to be strategic in understanding the ecological history and hunter-gatherer land use pattern in these areas.

Myanmar (Burma)

The Lower and Upper Pegu formations in Myanmar are Eocene and Miocene in age respectively. The Lower Pegu (5000- 10,000 ft) consists of shale, sandstone with coal seams and is fossiliferous at the base. The Upper Pegu (10,000 ft) comprises sandstone, clay and shale and is more fossiliferous than the lower group. The overlying Irrawaddy System (Plio-Pleistocene) consists of fresh water sandstone, fossil wood, reptilian and abundance of mammalian fossils. Based on various faunal elements during the Palaeozoic age

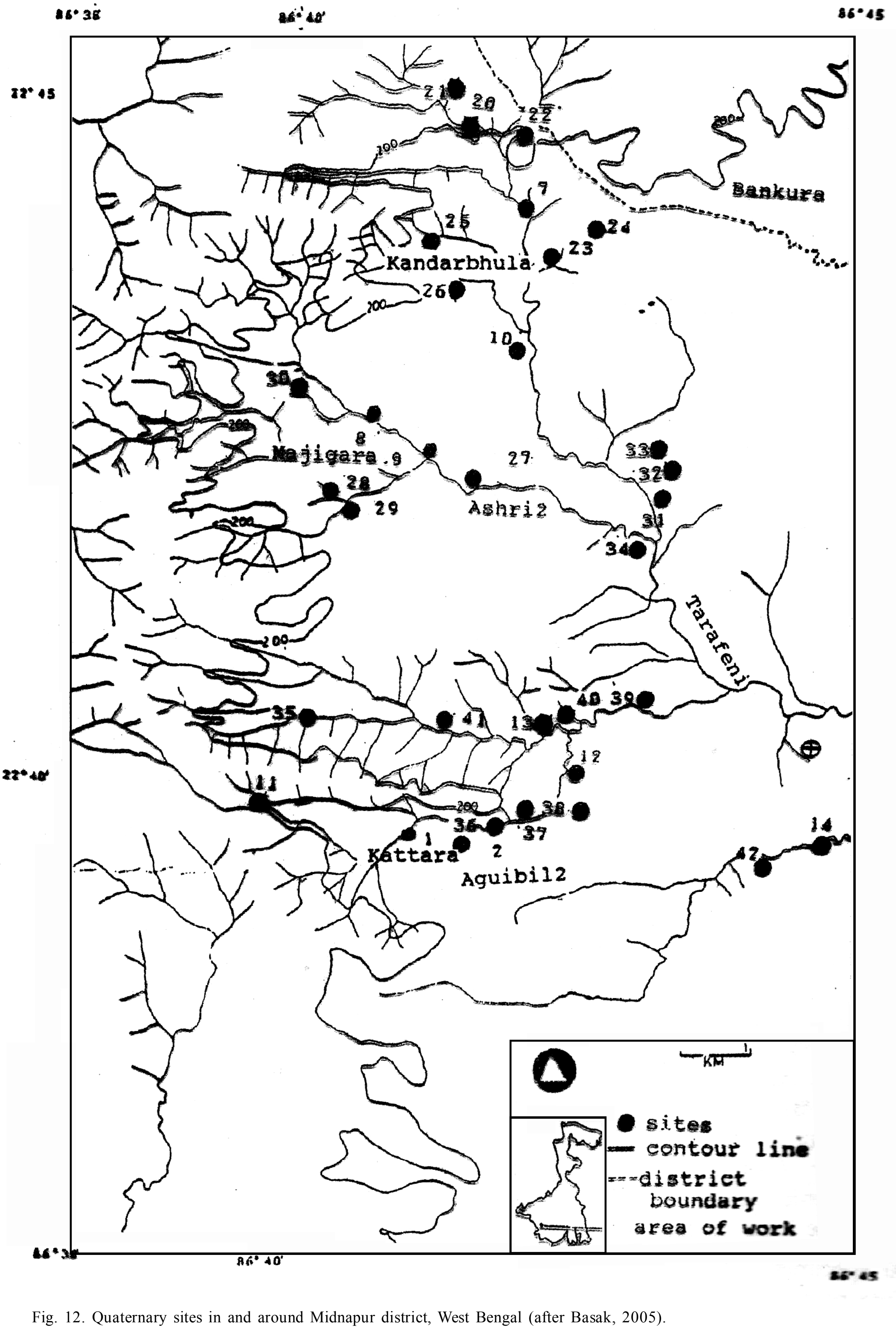


Fig. 12. Quaternary sites in and around Midnapur district, West Bengal (after Basak, 2005).

(brachiopods, corals, polyzoa etc.), there seems to be a close relationship of part of Myanmar (Shan States) with Salt Range, Spiti and Kashmir and this prompted Dr. K. Diener to consider these regions as belonging to the same zoogeographical province. Wadia (1966) considers the differences in the above regions due to "environmental accidents, isolation through temporary barriers and differences in the depth and salinity of waters". This can help in understanding better the Quaternary history of Myanmar as a whole.

The highest member of the Tertiary in Myanmar was originally known as Fossil Wood Group because of the proliferation of silicified wood. Apart from that, the Irrawaddy system of Burma, as it is popularly known, has yielded numerous vertebrate remains belonging to Chelonia, Crocodiles, Proboscidea, Perissodactyla, Artiodactyla, similar to the ones found in other parts of the Himalayas. In fact *Elephas hysudricus, Stegodon* sp., *Equus yunnanensis, Rhinoceros sivalensis, Cervus* sp., *Hemibos* sp., *Bos* sp., *Hexaprotodon sivalensis, Gazella* sp. of the Upper Irrawaddy have affinities with the Pinjor fauna of NW Himalayas except perhaps *Equus yunnanensis* (Colbert, 1943). It is interesting to know that remains of *Elephas antiquus* (namadicus) have been discovered in rolling table lands in the Central Burma, just opposite Mandalay (Pascoe, 1973). In the important limestone cave deposits on the eastern side of the Mogok Valley have been discovered fossils of pigs, deer, antelopes, *Stegodon* etc. which are placed in the Pleistocene time bracket. Other cave deposits have yielded carnivores *(Aelureidopus), Bos* sp. (with evidence of human workmanship), *Rhinoceros* sp., *Sus scrofa, Cervus* sp. etc. among other faunal elements (Pascoe, 1973). Clift (1828) had earlier described fossils of mastodons, hippopotamus, rhinoceros, crocodiles etc. from various localities in the Irrawaddy System, based on the collection made by Crawford.

The general character of the mammalian fauna in the Irrawaddy system indicates that Burma was isolated from India and formed a separate zoological province especially during the Miocene. The Proboscidea (especially of the pre-Pleistocene deposits) show a far closer affinity with those of Borneo and Java than with Indian forms. In the case of Bovidae, Suidae and Perissodactyla, a close parallel with India does, however, exist. The existence of long marine gulf would account for the isolation of the Burmese mammals and probably their parallel development with those of Indian forms. Since most of the forms here are supposed to have originated either in India or in countries to the west, it seems possible that they entered Burma from India or Persia through Central Asia and China. However, given the fragmentary nature of the fossil record the question of migration needs further inputs. The botanical remains, invertebrate fossils and economically rich lithological deposits have to be taken into consideration in a study of the environmental issues of the region.

Sri Lanka

The occurrence of bones in the gem gravel in Sri Lanka was known in 1930s. Much earlier, in 1861, some miners near Ratnapur had encountered plant fossils, elephant tusks and other bones. Some horse teeth, *Equus zeylanicus,* (fossilized or semi fossilized) were identified from a drainage in 1916 by E. J. Wayland (the then Govt. Mineralogist of Sri Lanka). Subsequently, under the leadership of P.E. P. Deraniyagala, a rich collection of elephant molars, antlers, cervids, hippopotamus, bovids, reptiles etc. was made by 1935.

As is well known, Sri Lanka is a geological extension of peninsular India from where the island was separated during the Miocene period. The island, interestingly, is characterized by what is known as radial drainage. The Quaternary deposits have undergone considerable re-deposition because of major uplifts during the Pliocene and Pleistocene (and earlier during the Miocene and Jurassic as well). Hence the Quaternary deposits are spread throughout much of the island, though superficially at places.

Sri Lanka's extinct Pleistocene fauna is termed as Ratnapur Fauna (Deraniyagala, 1945) which is a branch of Indian Siwaliks with its ramifications into Myanmar, Malaya, Java and other regions. It is evident that several groups of animals had entered Sri Lanka during various epochs, some evolved into new genera and species while the recent ones remained generally unchanged. The parent stock of some of the resulting endemic forms probably entered Sri Lanka at various intervals during Miocene, Pliocene and Pleistocene. The Ratnapur Fauna indicated a savannah country with rain forest and many large natural lakes and rivers fed by heavy rainfall which existed prior to the cool phase. Turtles and crocodiles indicate swamps and lakes; lions, wild cats, elephants, rhinoceros, pigs, hippopotamus, bovids, cervids etc. suggest savannah with rivers, lakes and forests. The fauna found in cave deposits (Batadoma-lena, Beli- lena Kitulgala etc.) is distinct but the Ratnapur Fauna (*Palaeoloxodon, Hippopotamus, Rhinoceros* etc.) is absent in the caves. The endemic character of some of the fauna is possibly due to the intermittent geographic isolation from the Peninsular India (Chauhan, 2008).

A temperate fauna and flora not existing in the low plains of South India but allied to the similar Himalayan biota, pockets of Assam, Malay Peninsula and Java is present here. Occurrence of a Himalayan plant *Rhododendron arbireum* and that of a Himalayan mammal like *Martes flavigula* in Ceylon mountains (Wadia, 1966) is interesting. The animals inhabiting the Peninsula and the Ceylonese hills are identical with those of Himalayan and Assamese hill forms but are unknown throughout the plains of India. It is possible that the species common to Ceylon and the Nilgiris may have migrated at different times when the country was damper. However, the process is difficult to comprehend. A large number of fossil elephants, hippopotamus, rhinoceros, turtles, suids, cervids, molluscan shells, bone tools, various artifacts have been collected in large numbers. Most of them indicate a savanna landscape with rivers, lakes and forests. Reptiles suggest swamps and lakes and some mammals like *Rusa* and *Bibos* indicate mountains with savanna tracts and forest. Mittre and Robert (1965) suggest that the fossil wood fragments found at Ratnapur beds, along with pollen samples, indicate a mosaic environment with an extensive drainage pattern.

Java

So far as the human evolutionary history is concerned, the most important area in Java is Sangiran located about 10 km north of Surakarta (Fig.13). A number of human fossil bones of *Pithecantropus* (Fig.14) and *Meganthropus* have been discovered here which has made the area world famous. A structural dome trending NNE-SSW occupies its central part. This dome is roughly 8 km long and 4 km wide and is dissected by tributaries of the Solo River. von Koenigswald discovered human fossils from Comere river in 1936 in association with Trinil fauna (*Pithecanthropus* II) (Fig.15). *Pithcanthropus* I

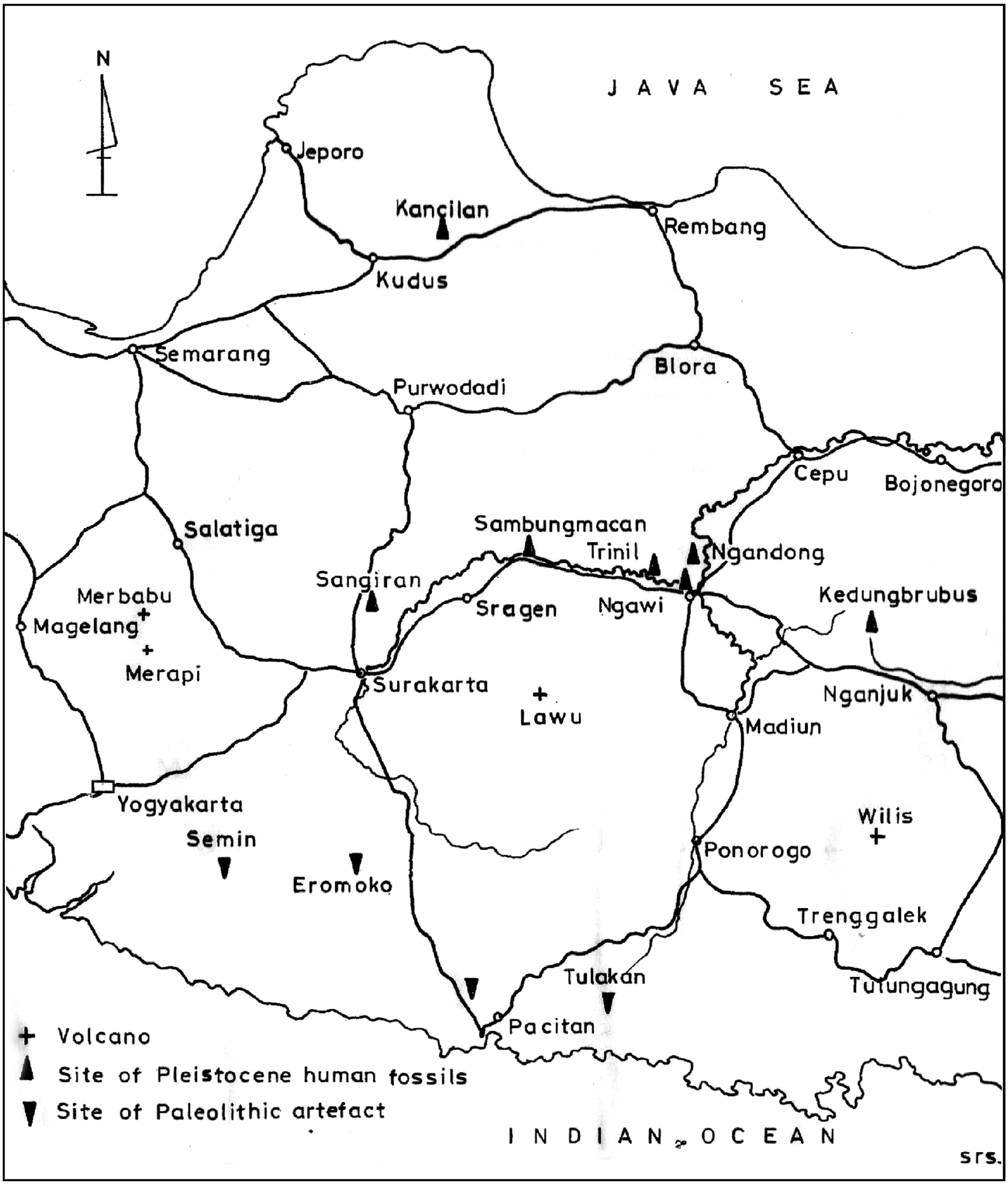


Fig.13. Pleistocene localities in Indonesia.

was Dubois' discovery. This was followed by several other discoveries of human and animal fossils. The geological range is from Pliocene to Holocene and these include the formations Kalibeng, Pucangan, Kabuh, Notopuro and Brangkal.

On the whole, the morphologies of the human fossils from Java suggest the existence of two separate genera, an australopithecine and a *Homo*. The first one is represented by *Meganthropus* and the other one by *Pithecanthropus erectus* and *Homo erectus*. Although both genera can be separated easily from each other, their morphologies suggest a close resemblance to each other indicating a link during their evolutionary processes in time and space. The end of the Pliocene was generally marked by terrestrial environment. The earliest human fossils are found within the Pucangan Formation. In the younger formations, more specimens were obtained from the overlying Kabuh Formation and in younger terrace deposits of the Upper Pleistocene age. It may be of interest to know that the *Meganthropus* specimens are closely

Fig.14. *Pithecanthropus erectus* skull.

Fig.15. Trinil - location of the *Pithecanthropus erectus* discovery in Indonesia.

similar to FLK NN I "Homo habilis Type specimen from Olduvai Gorge in Tanzania (Tobias and von Koenigswald, 1964). The earliest *Pithecanthropus* specimens are much more primitive than the *Homo erectus* forms that lived in Asia in the Middle Pleistocene (Kennedy, 1980). Luchterhand (1984) suggests that the early Pleistocene hominids of southern China and Southeast Asia constitute the easternmost extension of a Plio-Pleistocene distribution of australopithecine and/or earliest hominin hominids that stretched from southern Africa to Java.

The important non-hominid fauna from Java include *Tetralophodon bumiajuensis, Hexaprotodon simplex*, cervids, *Geochelone* sp., (from Sangiran); *Stegodon trigonocephalus, Hexaprotodon sivalensis*, *Panthera* sp., *Boselaphus tragocamelus*, cervids (from Sangiran, Kaliglagah); *Stegodon trigonocephalus, Panthera tigris, Rattus trinilensis, Rhinoceros sondaicus, Muntiacus muntjak, Axis lydekkeri, Bubalus* sp., *Sus* sp., *Bibos* sp. (from Trinil); *Panthera tigris, Elephas hysudrindicus, Tapirus indica, Hexaprotodon*

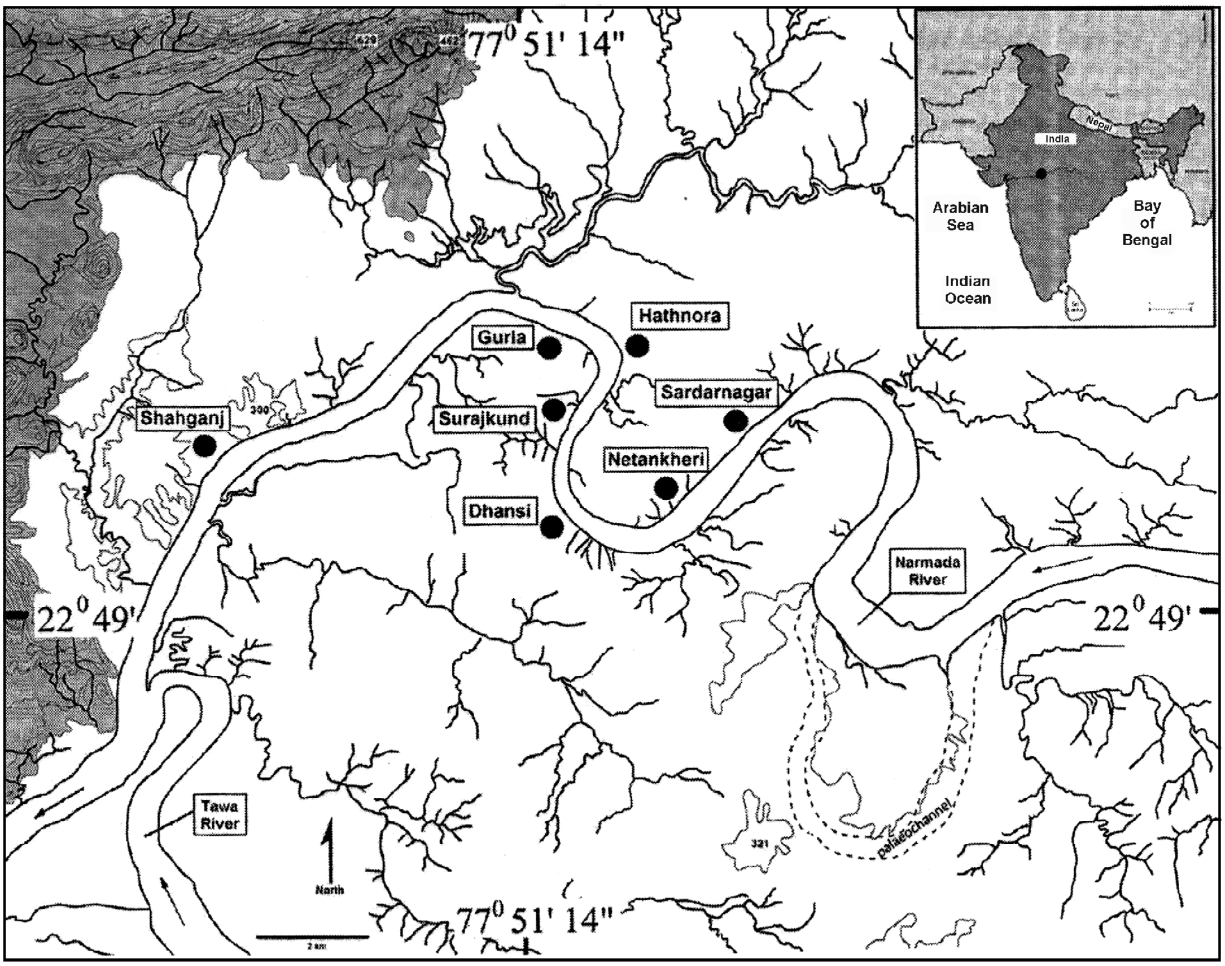


Fig.16. Sites in the Central Narmada Valley which have yielded hominid and non-hominid fossils, the latter in abundance.

sivalensis, Bibos sp.*, Sus* sp., *Axis lydekkeri* (from Ngandong). Most of the specimens have a close affinity with the Indian forms on generic level.

In general, the succession of beds shows a tendency of shallowing of the basin, for example, in the area of Kalibeng, beginning from marine as limestone changes into marine claystone. Fresh water molluscan shells and *Mastodon* have been collected from this bed and hence there is a changing palaeoenviromental trend from marine to terrestrial. However, the possibility of the mode of migration of terrestrial fauna from island to island in Java has some disagreement. But a combination of climatic and geologic processes must have been somewhat responsible for the migrations. Large predatory animals are generally lacking; elephants, cervids, hippopotamids seem to be endemic species and these are known to be excellent swimmers. Most of the fauna from Central Java and part of Sangiran indicate island circumstances. The other fauna is continental with some endemic species caused probably by the zoogeographical position of Java. Most fauna of this type indicate an open woodland environment, drier than the present day conditions.

OTHER IMPORTANT FOSSILIFEROUS COMPLEXES/ SITES

It would be pertinent to quote late Professor M. R. Sahni, the eminent palaeontologist, who wrote (Sahni, 1954) "References to fossils in early Indian literature are, however, few and far between, for our ancients do not appear to have devoted themselves much to the biological sciences except in so far as these concerned the practice of indigenous medicine. This naturally hampered the initiation of palaeontologic and palaeobotanic research in India". Much progress has been made since that statement was made and the subject of palaeontology has successfully passed through the stages of classic nature of research to scientific applications and the new palaeontologic researches. Several new fossil complexes and sites have been discovered and new genera/ species have been added to the exhaustive list of well known fossil fauna of India (Badam, 1979, 1984, 2000, 2002 and references therein).

In addition to the areas/sites outlined above, mention may here be made to the important and famous Narmada Valley in Central India. This is considered the richest fossil complex in India after the Siwaliks of NW India and has yielded the first evidence of hominid fossils of archaic *Homo sapiens / Homo erectus* in the form of a partial cranium, rib fragments, clavicle, parts of long bones etc. (Sonakia,1984; Badam, 1989; Sankhyan, 2005) (For sites see Fig.16). In addition to this, the valley has, for the first time, yielded microvertebrates in this part of the country (Patnaik, 1995) and is considered to be a bench mark between the north and south in India with an admixture of Old World and New World faunal elements, throwing significant light on the endemic and exotic forms of animals and their migration patterns in time and space along with palaeoenvironmental histories (Badam, 2013) (Fig.17) . The question of migration of pre *Homo sapiens* to SE Asia is a matter of further research. However, brief comments have been made regarding this in the section on North East. The faunal wealth along with Stone artefacts from this region have been extensively studied resulting in the production of several M.Phil and Ph.D dissertations, project reports, books and research articles.

The sites in the Indogangetic region (Son, Belan, Paimar, Bhagalpur, Kalpi etc.), especially the Son Valley, have exposed a wealth of fossils in association with Stone Age tools. The fauna is generally similar to the one that obtains in the Narmada-Godavari complex (*Bos namadicus, Bibos gaurus, Bubalus palaeindicus, Antilope cervicapra, Cervus* spp., *Tetraceros quadricornis, Muntiacus muntjak*, *Gazella, Sus* spp., *Rhinoceros* sp., *Equus namadicus, Panthera* sp., *Axis axis* and a host of other fossils which have been published in part (Badam *et al*., 1989). Blumenschine and Chattopadhyaya (1983) opine that the fauna is consistent with the geological evidence for arid conditions during the Terminal Pleistocene glacial maximum which supported mosaic vegetation with grasslands occurring over much of the floodplain and woodland. Badam (2002) postulated that a riverine environment, galleria forests along the banks and flood plains of the rivers and tall grasses with sufficient pools along the channels were perhaps some of the factors responsible for a rich faunal survival particularly in

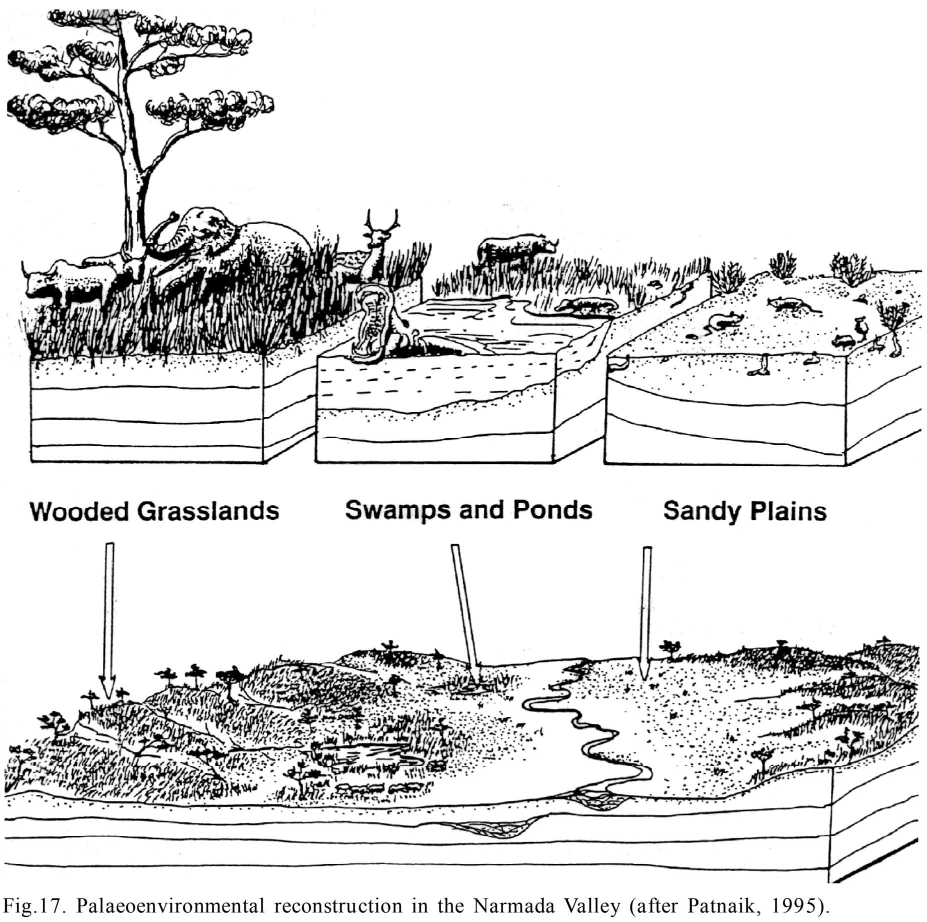


Fig.17. Palaeoenvironmental reconstruction in the Narmada Valley (after Patnaik, 1995).

the Son Valley. Hill slopes and areas away from the rivers must have supported a thin grass, thorn and scrub cover. Flood plain zones, channel pools and mixed grassland-woodland environment of the flood plains were the favourable ecological niches.

Sites in the Godavari Valley have been considered as equivalent to those in the Narmada Valley in chronology, fossil content, Stone Age complexes and mode of deposition (Pilgrim, 1905). Prominent faunal collections include *Elephas antiquus (Elephas namadicus), Hexaprotodon palaeindicus, Equus namadicus, Crocodylus* sp. etc. from Nandur Madhmeshwar (Pilgrim, 1905), ranging in age from Middle to Late Pleistocene. Tributaries like Pravara and Mula have yielded *Bos namadicus, Bubalus palaeindicus, Equus namadicus, Hexaprotodon namadicus, Palaeoloxodon namadicus, Stegodon insignis, Cervus* sp., *Crocodylus* sp. and Chelonia in addition to Acheulian and Upper Palaeolithic tools (Tripathi, 1967). The Manjra Valley in the Godavari complex has recently yielded a varied and rich herbivorous fauna that provides important insights for understanding the faunal distribution pattern in the valley as a whole (Badam, 1979, 1984).

The Krishna Valley is not palaeontologically as prolific as the other valleys. Most important discovery was that of *Bos namadicus* and *Rhinoceros deccanensis* reported by Foote (1876) from Chikdauli. Badam (1979) identified *Bos namadicus, Elephas* sp. and cervid antlers from Hunsgi as a result of excavations conducted by K. Paddayya. One of the richest collection was brought to light from seven localities along the river Ghod, a tributary of the Bhima, wherein *Sus palaeindicus, Bos namadicus, Hexaprotodon palaeindicus, Bubalus* sp., cervids, Chelonia , gastropods and lamellibranchs, dated to 20,000 B.P., were recovered from excavations and explorations (Badam, 1979). Despite similar ecological history and mode of deposition with other peninsular rivers, the Krishna basin has yielded less faunal data, possibly due to collection bias, taphonomic processes and strong erosive forces affecting the sediment morphology and preservation of biota.

There are several caves in the limestone formations of the Kurnool Dist. in Andhra Pradesh (Fig18) which are well known for the yield of fossils, mostly of endemic nature, dated to Late Pleistocene and also for lithic and bone artefacts. During the period, the area indicated the presence of wooded grassland, gallery forests and a well watered landscape. Today the area is an arid shrub land and a lot of fauna has been exterminated. This fact may be due to a very arid phase of Late Glacial Maxima (LGM). Anthropogenic factors, particularly during the Holocene, may have affected the survival of genera like *Rhinoceros, Equus, Bubalus, Bos, Boselaphus, Antilope, Gazella* etc. (Patnaik *et al.,* 2008). The warm and humid conditions that followed may have prompted animals like *Sus, Tetraceros quadricornis, Boselaphus tragocamelus, Cervus, Gazella, Bos, Bubalus* etc. to thrive again. Based on researches on evolution, distribution and migration of Kurnool Cave fauna, faunal links between Africa and India have been suggested (Lydekker, 1886; Badam, 1979, 1984).

Apart from the above mentioned faunal complexes, there are several fossil sites in Maharashtra (Tapi Valley), Madhya Pradesh (Bhimbetka, Bhanpura), Gujarat (Meshvo river), Tamil Nadu (Santhakulum, Elur, Trichinopoly, Madurai, etc. (Badam,1979; Badam and Jayakaran, 1993) and other areas which have been published briefly from time to time. For an update reference may be made to two tabular sheets summarizing components of fauna, cultural traits and dominant climate (Tables 1 and 2) during the Quaternary of India.

CONCLUDING REMARKS

The wide distribution in time and space of some biological materials may be accounted for by a similarity of ecological niches, climatic conditions, and geographical history prevailing in most parts of central and southern India. The animals, for example, seem to have had a zonal distribution pattern in these areas without any definite ecological barriers between them. In general, most of the forms appear to be late survivals from the Siwaliks having migrated to other suitable areas in India

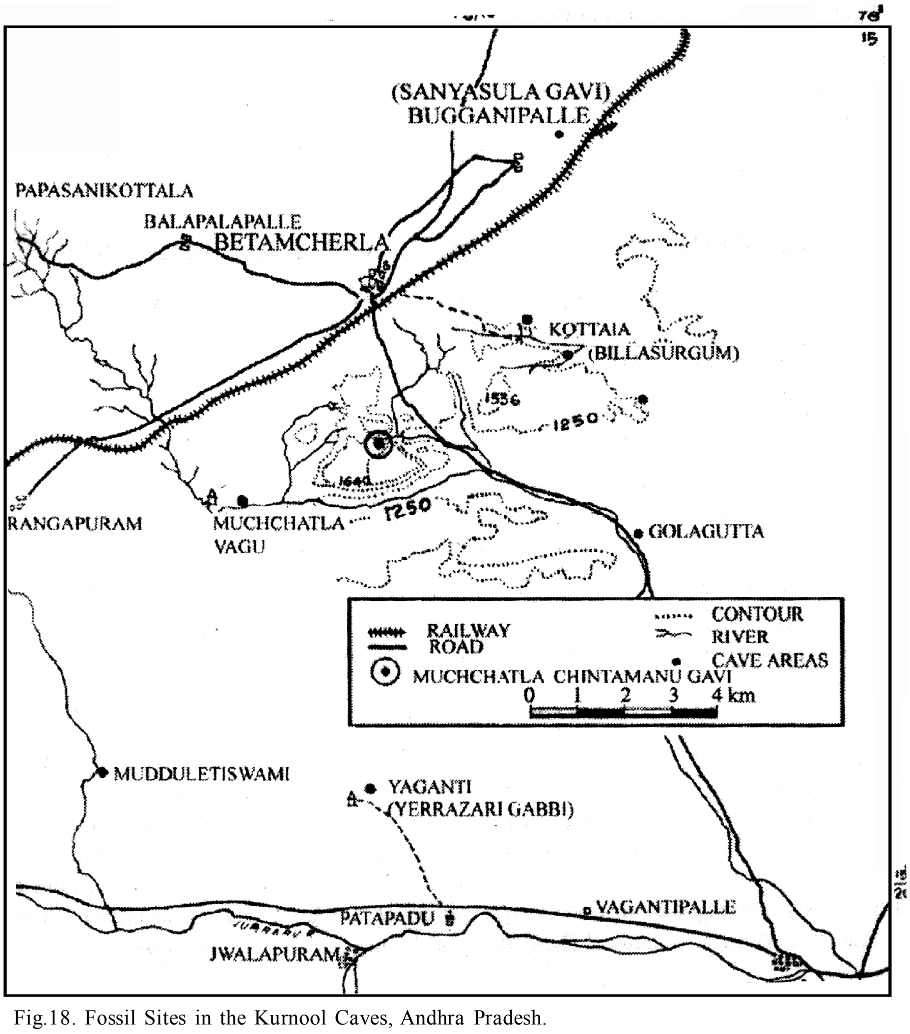


Fig.18. Fossil Sites in the Kurnool Caves, Andhra Pradesh.

Table1: Distribution of Important Fauna and Associated Cultures during the Pleistocene of India. The table is updated till 2000. Although there have been some reports of cultural findings recently, these must be confirmed before their presence is accepted.

Locality	Important Fauna	Stone Age Tools	Associated Cultures	Probable Age	Environment
Kurnool, Ghod, Manjra, Pravara, Godavari	*Canis* sp., *Bubalus* sp., *Cervus* sp., *Bos namadicus*	Bone tools, Burins, Blades, Points	Upper Palaeolithic	Late Upper Pleistocene (also dated by C-14; 40,000 to 15,000 B.P.)	Savannah type with pockets of forests and swamps (humid in Kurnool)
	Elephas hysudricus, Elephas maximus, Rhinoceros unicomis, Bos indicus, Hexa-protodon palaeindicus	Scrapers, Flakes, Blades, Points, Borers	Late Middle Palaeolithic		
Central Narmada (Upper Group); Paimar	*Equus namadicus, Bos namadicus, Hexa-protodon palaeindicus, Elephas hysudricus, Stegodon insignis-ganesa, Cervus* sp.	Scrapers, Flakes, Flake-blades, Points, Borers, Handaxes, Cleavers, Polyhedrals, Discoids, Choppers.	Middle Palaeolithic (Late Acheulian)	Early Upper Pleistocene.	Savanna grassland interspersed with swamps
Central Narmada (Lower group)	*Equus namadicus, Bos namadicus, Hexa-protodon namadicus, Sus namadicus, Elephas hysudricus, Stegodon insignis ganesa*	Choppers. Handaxes, Cleavers Flakes	Lower Plaeolithic (Acheulian)	Middle Pleistocene	Savanna grassland interspersed with swamps
Lower Karewa, Pinjor of Upper Siwaliks	Equus sivalensis, Rhinocerous sivalensis, Rhinoceros palaeindicus, Bos acutifrons, Archidiskodon planifroms, Sivatherium giganteum	No authetic or *in situ* Stone Age Tools Elephas hysudricus		Lower Pleistocene	Valley and open savanna grassland with lakes and swamps.

Note : 1. This table is updated till 2000.
2. Although thee have been some reports of cultural findings recently, these must be confirmed before their presence is accepted.

(especially the Narmada/ Godavari complex) when the conditions in NW became unfavourable on account of glaciations, as a result of which the ice sheet extended repeatedly from the NW. It acted as a physical and climatic barrier to the movement of animals northwards. Some species became extinct in course of such migrations due to adverse climatic factors, and allied reasons like non-adaptability. Evolutionary and population pressures added to the phenomena of migration (Russell, 1962). A few forms did evolve into advanced forms in the Holocene. In fact, in many cases there is an uninterrupted linkage between two or more species of the same genus. For example, *Stegodon insignis ganesa – Elephas namadicus—Elephas hysudricus—Elephas maximus*; *Hexaprotodon sivalensis—Hexaprotodon namadicus—Hexaprotodon palaeindicus; Equus namadicus – Equus hemionus; Sus cautley—Sus namadicus—Sus palaeindicus; Bos acutifrons—Bos namadicus – Bos indicus; Bubalus platyceros—Bubalus namadicus—Bubalus palaeindicus—Bubalus arnee (?)— Bubalus bubalis; Rhinoceros sivalensis—Rhinoceros palaeindicus—Rhinoceros unicornis,* and the list can go on to include several deer species, carnivores and other groups. Interestingly, some of the animals like blackbuck, deer, chital, nilgai, etc. range from Late Pleistocene to the Holocene, without undergoing appreciable micromorphological changes. Animals like buffalo, cattle, elephant, pig etc. have direct or indirect bearing on similar Pleistocene genera and do reflect minor micromorphological changes in their osteology and general morphology. We are of the opinion that the fauna during the later part of the Pleistocene and the Holocene indicates endemic species having evolved and diversified within the India sub-continent.

The climatic variability and diversity during the Pleistocene resulted in profusion the large and varied fauna which was not totally indigenous to India. Some primates, many giraffe- like forms, musk deer, goats, buffaloes, bovids and pigs were possibly of local origin. The mammals which were shared with the contemporary fauna of Europe were the sabre-toothed cats, hyaena, wolves, rhinoceroses, horse (*Equus*), various deer, antelopes and hippopotamus. As is well known, the migratory routes lay east and west of the Himalaya (Pilgrim, 1925), the western route being more active initially and the eastern route becoming active later during the Middle Siwalik times as some of its fauna are also found in Myanmar and Southeast Asia. Most of the larger animals migrated from Egypt, Arabia, Central Asia and North America on routes across Alaska, Siberia and Mongolia. Hippopotamus and elephants, had their early origin

Table 2: Quaternary Bio-Cultural and Chrono-stratigraphy in India (Compiled by G.L.Badam and S.N.Rajaguru, Deccan College Postgraduate and Research Institute).

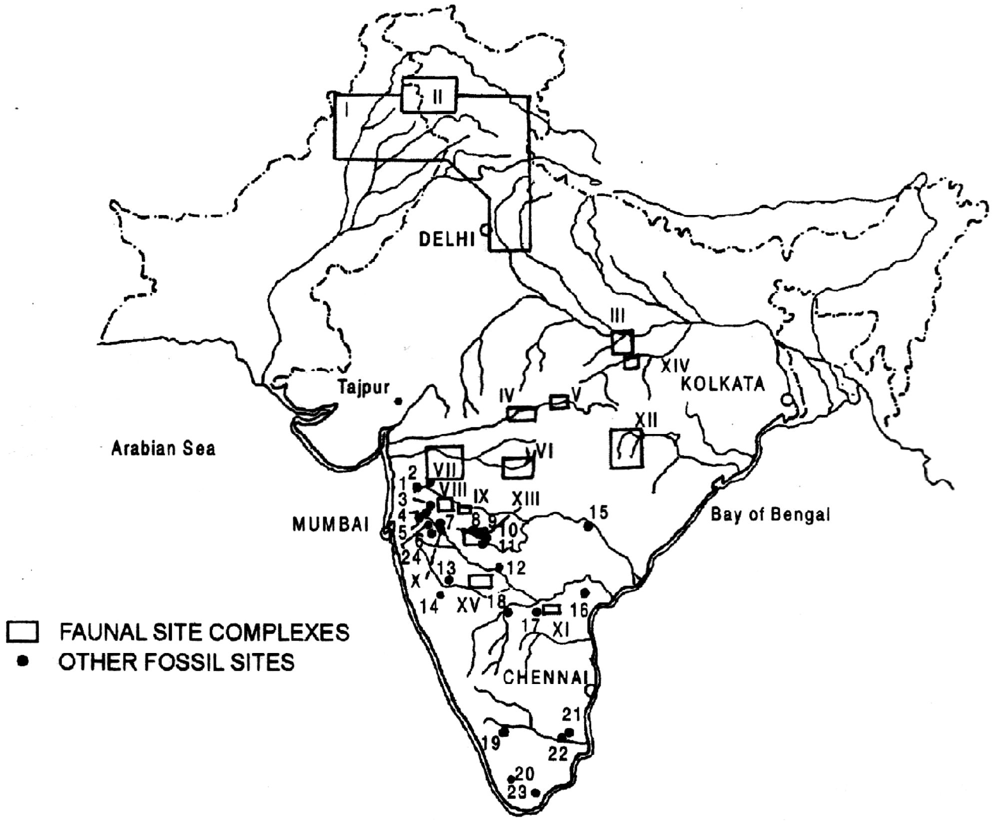
Geo Time Scale	Archeo Time Scale	Approx Age (BP)	Significant Cultrual Traits	Fauna	Dominant Climate
Late Holocene	Historical (Iroin Age)	3000 B.P. onwards	Writing, Iron technology and Advanced agriculture known	Modern animals	Good monsoons prior to A.D. 1000, Bad monsoons between 14th and 17th c.A.D.
Mid Holocene	Chalcolithic/ Neolithic	4500-3000 B.P.	Use of copper and stone, Beginning of agriculture. Advance town planning, Knowledge of writing, Plished tool technology	Domesticated and wild animals	Weak monsoons around 3000 B.P.
Early Holocene	Mesolithic	10-12.000 to 4,000 B.P.	Composite tool-technology, Pastoralism and fishing dominant	Beginning of domestication of animals	Very good monsoons (8000-4000 B.P.), Winter rains strong
Terminal Pleistocene	Upper Palaeolithic	40,000 to 10-12000 B.P.	Palaeolithic art and blade tool technology, Hunting and food gathering	*Equus hemionus, Bos namadicus, Rhinoceros* sp., *Bubalus* sp., *Elephas maximus, Cervus* sp., etc	Poor monsoons
Late Pleistocene	Middle Palaeolithic	130,000 to 40,000 B.P.	Hunting and food gathering, use of fine grained chalcedony, chert etc. for making scrapers and flake tools, use of quartzite and basalt continues	Same as above + *Equus namadicus, Bos namadicus Hexaprotodon* sp., *Elephas hysudricus, Sus* sp., etc	Good monsoons around 120,000 B.P., Moderate to weak monsoons from 75,000 yrs onwards
Middle Pleistocene	Lower Palaeolithic (Early to Late Acheulian)	700,000-130,000 B.P.	Hunting and food gathering, use of quartzite, basalt for making handaxes, scrapers, cleavers, flakes, choppers etc.	Same as above + *Hexaprotodon namadicus, Sus namadicus*, etc.	Fluctuating monsoons, Strong to weak
Lower Pleistocene	Suspected Lower Palaeolithic in Pakistan (Peshawar) and India (Maharashtra)	2.0 My-0.7 My (Peshawar 2 My, Bori: 670,000 Yrs)	Hunting and food gathering, use of basalt for making flakes and choppers	*Equus sivalensis, Bos acutifrons, Rhinoceros sivalensis, Hexaprotodon sivalensis, Stegodon Insignis ganesa, Archidiskodon planifrons*, etc.	Fluctuating monsoons, Strong to weak.
Plio-Pleistocene		2.47 My-1.87 My		First Appearance of *Equus* and Extinction of *Hipparion*	Transition from tropical humid climate to seasonal monsoonic climate.
Pliocene		5 My-2.5 My		Hipparion predominant	Transition from torpical humid climate to seasonal monsoonic climate.
Miocene		20 My - 5 My			

Note : 14C Dates upto 40,000 B.P., UR-Th Dates upto 400,000 B.P., K/AR Dates for a period 1 My and beyond.

in Central Africa, from where they migrated outward and entered India during the Tertiary period through Arabia and Iran. Rhinoceros, horse and camel, all originating in North America, evolved in some countries of Central and Western Asia before migrating to India. The elephant and horse populated to almost every country except Australia. Between India and Africa the interchange of faunas took place more easily. There is sufficient evidence for the existence of a land bridge across the straits at the entrance to the Persian Gulf. A corresponding bridge across the Red Sea would have provided a ready means of communication between India and Africa through Arabia. Within India, the Pinjor fauna has been widespread through the sub-Himalayan tract up to Myanmar while the post Siwalik fauna was distributed through the Central and Peninsular India though there are evidences of Lower Pleistocene fauna being found in parts of Tamil Nadu and Andhra Pradesh as well indicating large scale faunal migrations that must have taken place in the past (Badam, 1979).

A detailed study on the aspects of migration of animals within India by Badam (1984) and Nanda (2008) indicates that evidences of faunal migration may be recorded in the aggradational and rejuvenation phases of various river valleys from time to time. Of course, the migration of Pinjor fauna took place to the intermontane valleys of Kashmir and Kathmandu as suggested above. According to Valdiya (1993) the Lesser Himalayas during the Late Pleistocene times had not attained a height of more than 1000 m. Nanda (2008) has mentioned that the Upper Pleistocene localities of the Indo-Gangetic plain (Gurgaon, Banda, Varanasi, Allahabad, Kalpi etc.) fall within the present course of Yamuna river which in fact facilitated the migration of animals to southern parts of India. Similar situation may have occurred in the valleys of Narmada, Godavari, Krishna and other smaller rivers (see Figs.19 & 20). In the Kurnool Cave area transitional faunal forms of Late Pleistocene—Holocene time bracket are found and some of these may have been of endemic origin as discussed above.

Regarding the aspect of provinciality, as rightly suggested by Azzaroli (1985), the land mammals began to colonize the



I	Śiwālik hills — Punjab-Haryana-Jammu-Himachal Pradesh	1	Nasik	17	Betamcherla
II	Karewa formation — Kashmir	2	Nandur	18	Nittur
III	River Belan — Allahabad dist.	3	Kalamb	19	Coimbatore
IV	River Narmadā — Hoshangabad	4	Bori	20	Sayamalai
V	River Narmadā — Narsinghpur	5	Chandoli	21	Ariyalur
VI	River Pūrnā — Akolā	6	Bhivari	22	Maruvattoor
VII	River Tāpī — Dhūliā dist.	7	Inamgaon	23	Ayyanidipu
VIII	River Pravarā — Ahmednagar	8	Dhanegaon	24	Walki
IX	River Godāvarī — Aurangabad	9	Tadula		
X	River Ghoḍ — Pune dist.	10	Wangadari		
XI	Kurnool caves — Kurnool dist.	11	Ganjur		
XII	River Mahānadī — Raipur dist.	12	Hagargundi		
XIII	River Manjra — Bhir and Latur dist.	13	Sirguppi		
XIV	River Son — Sidhi dist.	14	Chikdauli		
XV	Hunsgi Baichabal — Gulbarga dist.	15	Servaipet		
		16	Venukonda		

Fig.19. Important fossil complexes and localities in the Indian Pleistocene.

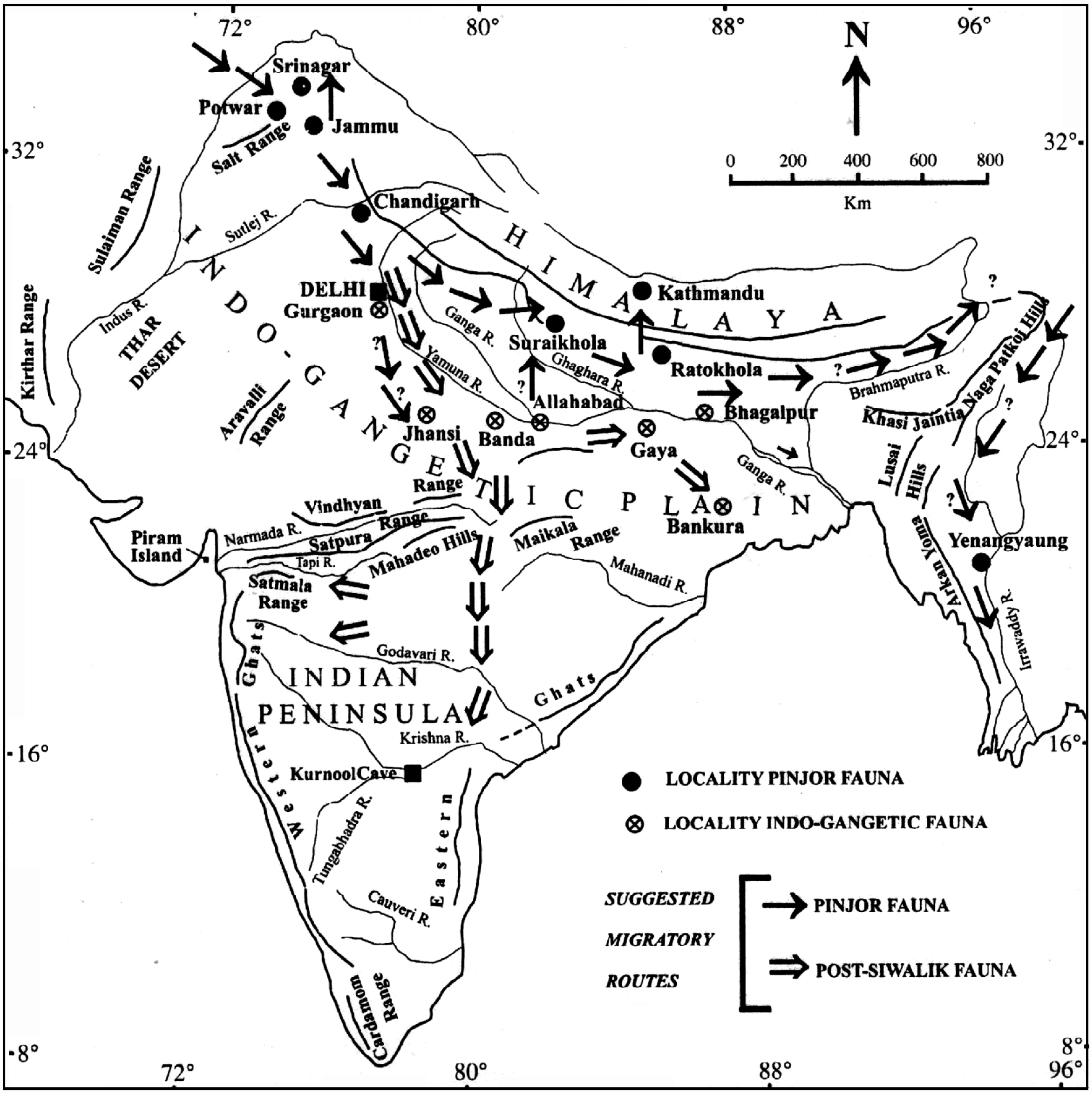


Fig.20. Possible Migratory routes of the Pleistocene fauna in northern and southern India.

Indian Sub-continent from Central Asia during the early Tertiary period and the faunas later started developing endemic features resulting in restricted exchanges with the rest of Asia. The separation of faunas between India and Central Asia was almost complete in late Miocene and early Pliocene. Moderate exchanges, however, continued till late Pliocene around 2.5 mya. Indian faunas maintained this provinciality character onto the Mesolithic where the archaic fauna was replaced by advanced faunas as evidenced by faunal turnover and followed by the domestication process.

The sudden and widespread reduction of the biota is a most startling event for geologist as well as the biologist. While the effects of intense cold of glaciations may have threatened the survival of many forms of life in the NW, the anthropogenic factors may have been responsible for the reduction of biota in Central and Peninsular India. This rich heritage of India can be preserved by developing a relationship with the common man in the form of building fossil and biological parks, some of which do exist at present but more are in fact necessary if we have to save this heritage of our country.

Note: 1) The individual faunal lists of the fossil complexes/ sites have not been included in this paper as these are already published from time to time. The fossiliferous sites have been briefly described here (see also Fig.19).

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REFERENCES

Azzaroli, A. 1985. Provinciality and Turnover Events in Late Neogene and early Quaternary Vertebrate Faunas of the Indian Subcontinent, p. 27-37. In: *Contributions to Himalayan Geology* **3** (Eds. Gupta, V.J. *et al.,* Hindustan Publishing Corporation (India).

Badam, G.L. 1974. Fossil Elephants from the Brahmaputra Valley of Assam, India. *Journal Assam Science Society,* **17**(1-2): 75-78.

Badam, G.L. 1979. *Pleistocene Fauna of India with special reference to the Siwaliks*. Pune, Deccan College Publication.

Badam, G.L. 1984. Pleistocene Faunal Succession of India, p. 746-775. In: *The Evolution of the East Asian Environment,* **2** (Ed. Whyte, R.O), Centre of Asian Studies, University of Hong Kong.

Badam, G.L. 1989. Observations on the Fossil Hominid site at Hathnora, Madhya Pradesh, India, p. 153-171 In: *Perspectives in Human Evolution* (Eds. Sahni, A. and Gaur, R.), Renaissance Publishing House, Delhi.

Badam, G. L. 2000. Pleistocene Vertebrate Palaeontology in India at the threshold of the Millennium. *Journal of the Palaeontological Society of India,* **45**, 1-24.

Badam, G. L. 2002. Quaternary Vertebrate Palaeontology in India: Fifty years of Research, p. 209-246. In: *Indian Archaeology in Retrospect- Archaeology and Interactive Disciplines* **3**, (Eds. Settar,S. and Korisetter, R), Manohar and Indian Council of Historical Research. New Delhi.

Badam, G. L. 2009. Brief Geological, Palaeontological and Archaeological Background of the North East. *Purvottari (Spirit of the North –East).* Abstract, 45-46. Indira Gandhi National Centre for the Arts, New Delhi.

Badam, G.L. 2013. The Central Narmada Valley: A Paradise of Prehistoric Life in South Asia, p. In: *Heritage (Palaeontological and Iconographical Aspects)* (Eds. Badam G.L. and Ali, R) Sharada Publishing House, Delhi.

Badam, G.L. and Bhattacharya M. 2008. Early Human History Dug Out. *Times of India,* 9, Press Information Bureau, Govt. of India.

Badam, G.L. and Jayakaran S.C. 1993. Pleistocene Vertebrate Fossils from Tamil Nadu, India, p. In: *Evolving Landscapes and Evolving Biotas of East Asia since the Mid- Tertiary.* (Ed. Jablonski N. G.), Centre of Asian Studies, the University of Hong Kong.

Badam, G.L., Misra V.D., Pal J.N. and Pande J.N. 1989. A Preliminary study of Pleistocene Fossils from the Middle Son Valley, Madhya Pradesh, *Man and Environment*, **13:** 41-47.

Basak, B. 2005. Microlithic Culture in the Tarafeni Valley: a Holistic Study, p. In: 153-167.In: *River Valley Cultures of India.*(Eds. K.K.Chakravarty and G.L.Badam), Indira Gandhi Rashtriya Manav Sangrahalaya, Bhopal and Aryan Books International, New Delhi.

Basak, B., Badam G. L. Kshirsagar, A. and Rajaguru S.N. 1998. Late Quaternary Environment, Palaeontology and Culture of Tarafeni Valley, Midnapur district, West Bengal - a preliminary study. *Journal of the Geological Society of India,* **51**, 731-740.

Blumenschine, R. J. and Chattopadhyaya U.C. 1983. A preliminary report on the Terminal Pleistocene Fauna of the Middle Son Valley, p. 281-284. In: *Palaeoenvironments and Prehistory of the Middle Son Valley, Madhya Pradesh, North Central India* (Eds. Sharma, G.R. and Clark J.D.), Abinash Prakashan, Allahabad.

Chauhan, P. R. 2008. Large mammal fossil occurrences and associated archaeological evidence in Pleistocene contexts of Peninsular India and Sri Lanka. *Quaternary International,* **192**: 20-42.

Clift, W. 1828. On the fossil remains of two new species of Mastodon, and of other vertebrated animals found on the left bank of Irrawaddy. *Transactions of the Geological Society of London (second series),* **2** (3): 369-376.

Colbert, E.H. 1943. Pleistocene vertebrates collected in Burma by the American Southeast Asian Expedition. *Transactions of the American Philosophical Society (New series),* **32**: 395-429.

Corvinus, G. 1993. The Surai Khola Siwalik sequence in Western Nepal (A Contribution to the Biostratigraphy of the Siwalik Group in Nepal), p. 69-89. In: *Evolving Landscapes and Evolving Biotas of East Asia since the Mid- Tertiary* (Ed. Jablonski), Centre of Asian Studies, the University of Hong Kong.

Corvinus, G. 1995. Quaternary Stratigraphy of the Intermontane Dun Valleys of Dang-Deokhuri and Associated Prehistoric Settlements in Western Nepal. *Memoirs of the Geological Society of India* **32**: 124-149.

Corvinus, G. 2005. Prehistoric River Valley Cultures in Nepal, p.3-6. In: *River Valley Cultures of India* (Eds. Chakravarty K.K. and Badam, G.L.), Indira Gandhi Rashtriya Manav Sangrahalaya, Bhopal and Aryan Books International, New Delhi.

Corvinus, G. and . Nanda A. C, 1994. Stratigraphy and Palaeontology of the Siwalik Group of the Surai Khola and Rato Khola in Nepal. *Abhandlungen Neues Jarbuch Geologie und Palaeontologie* **191** (1):25-68.

Dassarma, D.C., Biswas S. and Nandi A. 1982. Fossil Vertebrates from the Late Quaternary deposits of Bankura, Burdwan and Purulia Districts, West Bengal. *Palaeontologia Indica*, **44**: 1-65.

Dennel, R.W. 2009. *The Palaeolithic Settlements of Asia.* Cambridge University Press, Cambridge.

Deraniyagala, P.E.P. 1945. Some Fossil Animals from Ceylon (4), *Journal of the Royal Asiatic Society,* **98**: 80.

Dutta, A. K. 1976. Occurrence of Fossil Lion and spotted hyaena from Pleistocene deposits of Susunia, Bankura District, West Bengal. *Journal of the Geological Society of India*, **17**(3): 368-391.

Ewer, R. F. 1964. Large Carnivora of Bed II, p. 21-22. In: *Olduvai Gorge, 1951-1961* (Ed. Leakey, L. S. B), Cambridge University Press.

Foote, R.B. 1876. The Geological Features of the South Mahratta Country and Adjacent districts. *Memoir of the Geological Survey of India,* **12** (1): 1-265.

Gaur, R. 2007. Palaeoecological scenario of the Indian Siwaliks during Mio-Pliocene. p. 91-111. In: *Human Origins, Genome and People of India (Geonomic, Palaeontological & Archaeological Perspective)* (Eds. Sankhyan, A.R and Rao, V.R), Allied Publishers Private Ltd. New Delhi and Kolkata.

IGC. 1948. International Geological Congress Report, 18th Session, Great Britain, pt.9, London, also 1950, p.6.

INQUA Symposium. 1991. Proceedings of the International Union for Quaternary Research. 13th Congress. Beijing, 2-9 August.

Keller, H.M., Tahirkheli, R.A.K., Mirza M.A., Johnson, G.D., Johnson, N.M. and Opdyke N.D. 1977. Magnetric Polarity Stratigraphy of the Upper Siwalik Deposits, Pabbi Hills, Pakistan. *Earth and Planetary Science Letters,* **36**: 187-201.

Kennedy, G.E. 1980. *Palaeoanthropology.* McGraw Hill Book Company, New York.

Krishnan, M.S. 1968. *Geology of India and Burma.* Higginbothams Ltd., Madras, (Revised Edition).

Krishnan, M.S. and Aiyanger K.N.A. 1940. Did the Indobrahm or Siwalik River exist? *Records of the Geological Survey of India*, 75, Prof. Paper **6**: 1-24.

Kurten, B. 1968. *Pleistocene Mammals of Europe*. Weidenfeld and Nicholson, London.

Luchterhand, K. 1984. Mammalian Endemism and Diversity and Middle Pleistocene Hominid distribution and adaptation in Eastern Asia, p. 848-863 In: *The Evolution of East Asian Environment (II)* (Ed. Whyte, R.O.),University of Hong Kong, Centre Of Asian Studies.

Lydekkker, R. 1886. The Fauna of Kurnool Caves. *Palaeontologia Indica,* Ser. C, **4**(2): 23-58.

Maclaren, J.M. 1904. The Geology of the Upper Assam. *Records Geological Survey of India*, **31**(4):179-204.

Mishra, S., Gaillard, C., Hertler, C., Moigne, A.M., and Simanjunlark T., 2010. India and Java: Constricting records, Intimate connection. *Quaternary International*, 233-224, 265-270.

Munthe, J., Dongol B., Hutchison, J. H., Kean, W.F., Munthe, K and West R. M. 1983. New Fossil Discoveries from the Miocene of Nepal include a Hominoid. *Nature*, **303** (5915): 331-333.

Nanda, A.C. 2008. Comments on the Pinjor Mammalian Fauna of the Siwalik Group in relation to the post- Siwalik faunas of Peninsular India and Indo-Gangetic Plain. *Quaternary International*, **192**:6-13.

Nanda A. C. and Corvinus, G., 1992. A Report on the occurrence of Tatrot and Pinjor faunas from the Siwalik Group of Nepal. *Himalayan Geology*, **3**: 209-211.

Nanda, A.C. and Sehgal, R.K. 2007. Geology and Mammalian Faunas of the Siwalik Group of Northwestern Himalayas: Recent Investigations, p. 77-90. In: *Human Origins, Genome and People of India (Genomic, Palaeontological and Archaeological Perspectives)* (Eds. Sankhyan A.R. and Rao, V.R.), Allied Publishers Pvt.Ltd., New Delhi and Kolkata.

O'Malley L.S.S. 1908. *Bengal District Gazetters—Bankura*. Calcutta.

Opdyke, N.D., Lindsay, E., Johnson, G.D., Johnson, N., Tahirkheli, R.A.K. and Mirza, M.A. 1979. Magnetic Polarity Stratigraphy and Vertebrate Palaeontology of the Upper Siwalik Subgroup of Northern Pakistan. *Palaeogeography, Palaeoclimatology and Palaeoecology,* **27**:1-34.

Pascoe, E.H. 1973. *A Manual of the Geology of India and Burma, 3*. Geological Survey of India Publication, Kolkata.

Patnaik, R. 1995. Narmada Valley Microvertebrates, Systematics, Taphonomy and Palaeoecology. *Man and Environment,* **22**(2), 75-90.

Patnaik, R., Badam, G. L. and Murty, M. L. K. 2008. Additional vertebrate remains from one of the Late Pleistocene — Holocene Kurnool Caves (Muchchatla Chintamanu Gavi) of South India. *Quaternary International*, **192**: 43-51.

Pentland, J. B. 1828. Description of Fossil Remains of some animals from the northeast border of Bengal. *Transactions of the Geological Society of London,* **2**(2):394-395.

Pilgrim, G.E. 1905.On the Occurrence of *Elephas antiquus (namadicus)* in the Godavari alluvium with remarks on the species, its distribution and the age of the associated Indian deposits. *Records of the Geological Survey of India,* **32** (3): 199-218.

Pilgrim, G. E. 1919. Suggestions concerning the history of the drainage of northern India, arising out of a study of the Siwalik Boulder Conglomerate. *Journal of the Asiatic Society of Bengal* (N.S.), **15**(2): 81-99.

Pilgrim, G. E. 1925. The Migration of Indian Mammals. Presidential Address, *Section of Geology, 12th Indian Science Congress.*

Pilgrim, G. E. 1930. *Crocuta* sp. *Journal of the Asiatic Society of Bengal*, **26.**

Ranga Rao, A., Agrawal R.P., Sharma, U.N., Bhalla M.S. and Nanda, A. C. 1988. Magnetic polarity stratigraphy and Vertebrate Palaeontology of the Upper Siwalik Subgroup of Jammu Hills, India. *Journal of Geological Society of India* **31**(4): 361-385.

Russell, L. S. 1962. Mammalian Migrations in the Pleistocene. *Problems of the Pleistocene Epoch and the Arctic Area* **2** (2): 48-55.

Sahni, M. R. 1954. A Century of Palaeontology, Palaeobotany and Prehistory of India and adjacent countries. *Journal of the Palaeontological Society of India,* **1**: 7-51.

Sankhyan, A. R. 2005. New Fossils of Early Stone Age Man from Central Narmada Valley. *Current Science*, **88** (5):704-707.

Sastry M. V. A. 1968. Pleistocene Vertebrates from Susunia, Bankura District, West Bengal. *Indian Minerals*, **22**: 20.

Sonakia, A. 1984. The skull cap of Early Man and Associated Mammalian fauna from Narmada Valley Alluvium, Hoshangabad area, M.P. (India), *Records Geological Survey of India* **113**:159-172.

Tobias, V. and G.H.R. von Koenigswald 1964. A comparison between the Olduvai hominines and those of Java and some implications for hominid phylogeny. *Nature*, **204:** 515-518.

Tripathi, C. 1967. The Pleistocene Alluvial deposits around Nevasa, Ahmednagar, distt., Maharashtra. *Records of the Geological Survey of India*, **95**(2): 355-366.

Valdiya, K.S. 1993. Uplift and geomorphic rejuvenation of the Himalaya in the Quaternary Period. *Current Science,* **64**: 873-885.

Mittre, Vishnu and Robert, R. D. 1965. Pollen Analysis of the Middle Pleistocene samples from the Gem Pits of Ceylon. *Spolia Zeylanica,* **30** (2): 3-6.

Wadia, D.N. 1966. *Geology of India*. Third Edition. Macmillan & Company, London.

West, R.M. 1984. Siwalik Faunas from Nepal: Palaeoecologic and Palaeoclimatic implications, p.724-744. In: *The Evolution of East Asian Environment II (Palaeobotany, Palaeozoology and Palaeoanthropology* (Ed. Whyte, R.O.), University of Hong Kong, Centre of Asian Studies.

West, R.M., Lukacs, J. R, Munthe, J. and Tasseer Hussain, S. 1978. Vertebrate Fauna from the Neogene Siwalik Group, Dang Valley, western Nepal. *Journal of Paleontology,* **52(**5):1015-1022.

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