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PLEISTOCENE VERTEBRATE PALAEONTOLOGY IN INDIA AT THE THRESHOLD OF THE MILLENNIUM

G.L. BADAM

DECCAN COLLEGE POSTGRADUATE AND RESEARCH INSTITUTE, PUNE 411 006

ABSTRACT

The last hundred years or so have seen great advances in the area of Pleistocene Vertebrate Palaeontology in India. The thrust has shifted from classical and objective type of study, to studies with more emphasis on stratigraphical position, lithological associations and geographic ranges. Gradually, research progressed to include the ecological and biogeographical aspects of the fossils. In subsequent studies, much emphasis was laid on the evolutionary aspects of the various animal groups, ancestor- descendant relationship and taxonomic affinity of one group of animals with the other. Also for research during the Pleistocene the integration of various data from anthropology, archaeozoology, conchology, palaeo and archaeobotany, palynology and modern ecology has made the field truly interdisciplinary and worthwhile.

Several fossil sites have been discovered and some new faunal elements have been identified from all over India. These discoveries have thrown meaningful light on the spatial and temporal distribution of the animals, their migration patterns, evolutionary history and problems of provenance. The numerous discoveries of microvertebrates, particularly micromammals, has opened new avenues for a precise chronological and ecological framework. One of the landmarks of palaeontological research of the Pleistocene period, however, has been the discovery of a partial cranium of *Homo erectus narmadiensis* from Hathnora in M.P. which is the only authentic discovery of its kind in India so far and has filled, to some extent, lacunae in our understanding of hominid evolution in South Asia as a whole.

Some of the techniques applied to the study of palaeontology during the last few decades include the various dating methods, taphonomy, studies in dental histology and enamel ultrastructures, biomolecular studies, isotope studies, population dynamics studies etc.

Though application of the above techniques has shed light on the animal behaviour and evolution during the Pleistocene, it is hoped that more techniques would be applied to this science in future and that concerted efforts by archaeologists, anthropologists, geologists, palaeontologists and other scientists be made for conducting applied research in palaeontology (like ethnobiology) to unravel the mysteries of the immediate past with which man is directly concerned.

Key Words : Palaeontology, Taphonomy, Ethnobiology, Biomolecular studies, Isotope studies, Population dynamics.

INTRODUCTION

First of all I deem it a great privilege to deliver the 18th M.R. Sahni Memorial lecture before this august gathering of geologists, palaeontologists and other specialists some of whom have been my colleagues and some my esteemed teachers. I profusely thank the Palaeontological Society of India for this honour of inviting me to deliver this prestigious lecture. I deem it also an honour to one of the premier Institutions of India, the Deccan College, Post graduate and Research Institute, Pune. It is an excellent opportunity for me to share my research experience with you all as well as to learn from the distinguished scholars by way of interaction.

In the early nineteenth century palaeontological researches included descriptive studies with emphasis on diagnostic features and taxonomy. Subsequently, the emphasis shifted to studies on stratigraphical positions, geographical ranges and lithological associations. With the passage of time areas of ecology, biogeographical and evolutionary aspects of the fossils received more attention. During the last few decades the researches have progressed qualitatively with the application of several new techniques like dating methods, taphonomy, dental histology and enamel ultrastructures, biomolecular studies, isotope studies and palaeodiet, palaeopathology and population dynamics studies. In addition to this, several new fossil complexes as well as isolated sites have been discovered in India, and several new species identified. Detailed studies involving multidisciplinary approaches have been undertaken which have shed new light on the chronology of fossils and their spatial and temporal ranges, index fossil assemblages, migration patterns, problems of provenance, boundary problems, faunal turnover, etc.

Prof. M.R. Sahni was a father figure of Indian Palaeontology who founded the 'Palaeontological

The 18th Prof. M.R. Sahni Memorial Lecture delivered on Ist March, 2000.

Society of India' at the Department of Geology, University of Lucknow in 1950. Subsequently, he established the Geology Department of Panjab University at Chandigarh where major advances were made in the field of vertebrate Palaeontology and other disciplines of Geology.

An attempt is made here to present the varied Pleistocene faunal data (mainly the reptiles and mammals) in India in the light of the new techniques and researches outlined above and, to build up a composite bio-cultural and chrono-stratigraphic history.

HISTORICAL REVIEW

In India, the importance of fossils as relicts of organic material came to be recognised in the early part of the nineteenth century (1832 onwards) when the earliest and the most well preserved fossils were discovered from the Siwaliks of NW India (Falconer, 1837). There were also isolated occurrences of fossils from other parts of the country, e.g., from Bengal (Colebrooke, 1821 from 'Caribari') and during the later part of the century in Karnataka (Foote, 1876) and Andhra Pradesh (Lydekker, 1886). It must be mentioned here that the discoveries of fossils gained momentum with the establishment of Geological Survey of India in 1851 when the geologists of British India made remarkable collections and conducted objective studies of the palaeontological wealth. It is not possible to refer to all the works here but palaeontological researches would be incomplete without mentioning the works of pioneers like Falconer and Cautley (1836, 1836-1849). Further details of the earlier researches may also be found in the works of Colbert (1935), Sahni (1954) and Badam (1979).

During the twentieth century, a host of workers contributed a great deal towards vertebrate palaeontological researches from the viewpoints of biostratigraphy, biochronology, palaeoenvironment, palaeogeographic distribution and migration patterns. Mention may be made of Pilgrim (1915, 1925, 1926, 1932, 1939), Matthew (1929), Chakravarty (1937, 1957), Mook (1932, 1933), Colbert (1935), Osborn (1935, 42), Gregory *et al.* (1938), de Terra and Paterson (1939), Hooijer (1949, 1955), Deraniyagala (1956, 1957), Sahni and Khan (1961, 1964), Khan (1962), Prasad (1962, 1964, 1970, 1974), Khatri (1961), Tripathi (1964), Badam (1972, 1973), Tewari and Badam (1969), Hussain (1971), Johnson and Vondra (1972), Nanda (1973 a, b), Nanda and Halstead (1975), Nanda and Tandon (1976), Dassarma and Biswas (1976) and many others.

A word about the collections. Obviously the most complete and the best collection of the Pleistocene vertebrate fossils made by the British Indian geologists and palaeontologists (who also later led expedition teams from abroad) is housed in various museums of the world, notably the American Museum of Natural History (New York), the Yale Peabody Museum (Yale) and the British Museum of Natural History (London). There are other museums in the world where many of the Type Specimens of the Indian fossils are stored in repositories or displayed in the visitors' galleries. A list of about three hundred Type specimens of the Siwalik fauna can be found in Badam (1979, pp. 117-137). Details about the other Type Specimens will be published as soon as information about these becomes available. The Indian Museum, Calcutta is the best place where the Indian fossils can be studied by thousands. It may be emphasised that the fossil collections made by E. Khan (a former student of M.R.Sahni) and displayed in the Museum of the Panjab University Geology Dept. at Chandigarh ranks second only to the one displayed in the Indian Museum, Calcutta. Many students, have tremendously benefited from these collections in both Calcutta and Chandigarh and have used part of this material for further study or for comparative research.

Amongst the active workers on Pleistocene Palaeontology today mention may be made of Ashok Sahni, G.L.Badam. A.C.Nanda, B.S.Kotlia, Rajiv Patnaik, Rajan Gaur, R.N.Vashist, P.K.Basu, S. Biswas, D.C. Dassarma, Arun Sonakia and a few others. It may be mentioned that several students have secured their Ph.D degrees on various aspects of Palaeontology under the guidance of some of the above mentioned scholars adding new dimensions to the study of Vertebrate Palaeontology.

G.L.Badam and A.C.Nanda were the first two students during the last thirty years who joined under Prof. M.R. Sahni for Ph. D. their degrees in Geology

Department of Geology, Panjab University which was then the only centre of research in Vertebrate Palaeontology in India. Badam's thesis (1973) was concerned with the geology and palaeontology of the upper Siwaliks of a part of Pinjor-Nalagarh area and Nanda (1973) completed his thesis on the stratigraphy and palaeontology of the upper Siwaliks of a part of Naraingarh Tehsil, Ambala. At that time, these were the only Ph.D theses submitted on Pleistocene vertebrate palaeontology. These were later published in the form of books or research papers.

In 1968, Ashok Sahni returned to the University of Lucknow from USA after specialising in palaeohistology and the scanning electron microscopy technique for vertebrate material, which he later pioneered in India at the University of Lucknow and the Panjab University, Chandigarh, and in which area several students obtained Ph.D degrees under his guidance. By 1973, in addition to the Geological Survey of India, three centres had actively become enganged in researches on Vertebrate Palaeontology, the one at Panjab University, Chandigarh, which, of course, had already established a long tradition, and the two new centres at the Deccan College, Pune and Wadia Institute of Himalayan Geology, Dehra Dun. The last two in the years to come also became the internationally recognised centres. Also, the Dept. of Ancient History, Culture and Archaeology of the Allahabad University built up a large and varied collection of Quaternary fossils, most of these in association with Stone Age tools, from various areas in the Indo- Gangetic region like the Son and Belan valleys. The Calcutta office of the Zoological Survey of India and Indian Statistical Institute, Calcutta were also quite active in the study of the vertebrate fossils till about two decades ago. Some universities (Vikram University, Ujjain; University of Lucknow, Lucknow; Magadh University, Gaya, etc.) and NGOs have also collected Pleistocene fossils from various river valleys which await a thorough study.

APPLICATION OF NEW TECHNIQUES

Palaeobiological research in India in the past had been mostly of the classical and objective type and in the nineteenth century when fossils were first reported, this was the only method to study them (see Falconer and Cautley 1836-1849). The classical palaeontology primarily included descriptive and stratigraphic studies with emphasis on diagnostic features and morphological descriptions. Subsequently, stratigraphical studies were mostly pioneered by Medlicott (1873), Pilgrim (1905, 1925, 1944), Colbert (1935) and others which laid emphasis on the stratigraphical position, geographical range and lithological associations of the fossils. Research progressed gradually to include the ecological and biogeographical aspects of the fossils (Badam, 1984 and references therein) and much emphasis was laid on the evolutionary aspects of various animal groups, ancestor- descendant relationship and taxonomic affinity of one group of animals with the other. In the past three decades or so a change in vertebrate palaeontological research has become evident with the application of several new techniques. Also for research on the Quaternary period the integration of various data from anthropology, archaeozoology, conchology, palaeobotany, palynology and modern ecology made this field truly interdisciplinary and interesting.

In recent years, new workers have studied microvertebrates, particularly micromammals, techniques of scanning electron microscopy and taphonomy. Studies on stable isotope analysis, and biomolecular palaeontology are still in an experimental stage. Apart from the traditional dating techniques, some sophisticated techniques have now been used on fossils for absolute and relative chronology. Some of the new techniques as applied to Vertebrate Palaeontology are outlined below.

DATING METHODS

In India, a major advance in Pleistocene vertebrate palaeontology is seen in the application of absolute dating techniques such as C^{14}, TL, ESR, K-Ar, U-Series, Palaemagnetism, etc. Though it is not the place to go into the details of these dating techniques, it is worthwhile to mention that many of the problems of biochronology have been resolved to a great extent by using these methods. Let us take the example of the Neogene/ Quaternary boundary problem in NW India which has been one of the most debatable stratigraphical problems in India. Earlier, scholars used to base the delineation of the boundary on stratigraphic, palaeontologic, palaeoclimatic, sedimentary and tectonic considerations. In recent years, the application of palaeomagnetic dating techniques has provided a firm basis for correlation of Siwalik beds with the standard Magnetic Polarity Time Scale (MPTS). Magneto-stratigraphic studies in the Indian subcontinent were initiated first in Pakistan on the upper Siwaliks of the Pabbi Hills (Keller *et al.* 1977) and other parts of northern Pakistan (Opdyke *et al.* 1979) according to which the Pleistocene epoch commences at the Olduvai Event which has been dated to 1.8 myr ago. Palaeontologically, the N/Q boundary corresponds with the Gauss/ Matuyama boundary which has been dated to 2.48 myr ago coinciding with the first appearance of *Equus, Elephas, Cervus* to mark the beginning of the Pleistocene. Also, according to Azzaroli and Napoleone (1982) and Tandon *et al.* (1984), who worked on some sites northeast of Chandigarh, the Plio-Pleistocene boundary corresponds with the G/M transition at 2.48 myr ago. Nanda (1973 a,b), Badam (1973, 1979) and Gaur and Chopra (1984) documented the presence of *Equus* in the Pinjor beds at various levels falling into the Matuyama epoch. Though there is a difference of opinion in the use of palaeontologic data and the MPTS in respect of dating the N/Q boundary in NW India, the INQUA Commission (1991) now accepts the base of Matuyama as the beginning of the Quaternary. Thus absolute dating adds a new dimension to this vexed problem in which fauna also does play an important role and the presence of even any one of the above mentioned fossils (*Equus, Elephas and Cervus*) if found *in situ* is a sufficient proof for assigning a Pleistocene age to the bed yielding the same (Hopwood 1935), a fact which is valid even after sixty five years of research.

Another important contribution of dating techniques with regard to palaeontology (though of the pre-Pleistocene period) based on magnetic polarity stratigraphy, has been made in the Siwaliks whereby the primate fauna at Haritalyangar in Himachal Pradesh is assigned a Last Appearance Datum (LAD) age. The youngest assigned age for *Sivapithecus indicus*, *S. sivalensis* and *Ramapithecus punjabicus* in Asia is 7-7.5 myr. The age of Holotype specimen of *Gigantopithecus bilaspurensis* is about 6.3 myr (Johnson *et al.,* 1983).

The ESR (Electron Spin Resonance) dating of bone and dental material was for the first time attempted in India by Gogte and Murty (1986) on a bone sample from the Upper Palaeolithic site of Kurnool Caves in Andhra Pradesh. The samples selected for ESR dating belonged to five layers at MCG II in the cave complex. The ESR dates were obtained from two trenches, Trench F and Trench B. The dates for the two levels at Trench F: (1) 893 B.P. for F 20 cm-40 cm and (2) 5247 B.P. for F 40 cm -60 cm can provide a time sequence for the upper levels of cave sediments. The date for Trench B4 (120 cm- 135 cm) being 9498 B.P. supports the association of this level with the Mesolithic. The dates for the preceding levels 16,686 B.P. for B4 (150 cm- 165 cm) and 19.224 B.P. for B4 (165 cm- 180 cm) confirm the Upper Palaeolithic age of these levels. The ESR dating for B4 (165 cm- 180 cm) is almost in agreement with TL date of 17,390 B.P.(Murty and Nambi, 1983) from burnt clay within the sediment from the same level.

The above dating methods, which have a direct bearing on the fauna, and those like palaeomagnetism, fission track and TL which have an indirect bearing, have amply demonstrated their usefulness to palaeontology in one way or the other. It has also been confirmed now that the biostratigraphic chronology of the Indian Pleistocene (which was mainly based on taxonomic and morphological studies of fossils and their cultural associations) is not precise. However, palaeontologic and stratigraphic dating, index fossil assemblages, the First Appearance Datum (FAD) of an allochthonous faunal element, and the LAD of an index fossil are crucial to building up a biostratigraphical chronology. It is important that these should be supplemented by other parameters which include physical and chemical dating methods.

Amongst the chemical methods, Fluorine dating of bones and fossils was attempted for the first time in India by Joshi and Kshirsagar (1986) and subsquently on samples collected from various geographic regions (Kshirsagar and Paddayya 1988-89; Kshirsagar and Badam 1990 and Kshirsagar 1993). These studies have established the positive role that Fluorine analysis can play in relative dating of faunal material from different geological and archaeological periods. For example, the Acheulian sites of Hunsgi (Karnataka) and Chirki (Maharashtra) have F/P ratios in the range of 6.73-8.39 and 8.11 -8.29 respectively. Both these ranges indicate a Middle Pleistocene age for the fossil yielding levels. The fluorine/ phosphate ratios in Tertiary fossils fall in the range of 8.15-8.67 which is close to the saturation value of 8.92. Another example can be cited from the site of Hathnora in M.P where the cranium of *Homo erectus narmadiensis* gives a F/P ratio of 7.53 which places the cranium in late Middle Pleistocene time bracket. The range of most of the fossils dated by this method can be favourably compared on the basis of archaeological, geological and palaeontological data. The usefulness of fluorine analysis for establishing a chronological framework for the Indian Quaternary deposits has been realised for the last two decades and this study will continue to occupy an important place in palaeontological research in years to come.

Amongst the other relative dating methods in palaeontology, nitrogen analysis was attempted on some of the Narmada valley fossils. This method has some limitations because nitrogen disappears rapidly from bones in a tropical climate and hence may not give an accurate result. The figures of 0.97 % nitrogen for a fossil from the surface and of 1.20 % for a buried fossil, both from the Devakachar area in the Central Narmada Valley, were considered by K.P.Oakley to be similar to upper Pleistocene in Africa and Europe. However, as said earlier, these results may not be considered as reliable dating evidence (Badam and Grigson 1990) any more.

Recently, Szabo *et al.* (1990) obtained half a dozen radiometric dates using the U-series technique on a faunal assemblage of the Acheulian culture of the Hunsgi- Biachbal valleys in North Karnataka. These dates confirm the middle Pleistocene - early late Pleistocene time bracket for these cultures. F/P ratios obtained on bone samples from these sites (8.39- 5.06 for Acheulian and 5.28- 0.22 for Middle Palaeolithic to Neolithic) confirm the dating (Kshirsagar and Paddayya 1988-89). Two of these dates were calibrated on travertine samples from the site of Kaldevanhalli in the Hunsgi valley. The remaining four dates were obtained on enamel samples of teeth from Sadab, Teggihalli and Kudalgi in the Baichbal valley. A fragment of molar of *Elephas* from Sadab has given a date of 290, 405 B.P. The *Bos* sample from Teggihalli gave a date of 287,731 B.P. whereas the *Elephas* sample from the same area gave a minimum age of 350 kyr.

At Bori in the Kukdi valley, typical Acheulian artefacts and fossils of *Bos, Elephas* and *Equus* have been recovered from a well from cemented sandy pebbly gravel which is underlain by a compact brown silt, fissured clay and pebble. A 2 m thick tephra layer, dated to 670,000 yr B.P. is embedded in the clay sediments. Fossil samples from different locations at Bori gave a F/P ratio ranging from 8.05-3.22. At location 4 in Bori the value of F/P is close to the saturation point at 8.92, indicating an older antiquity, possibly Middle Pleistocene for the fossils. The other ratios are in the range of 4 and 5 being comparable with the ratios obtained for the late Pleistocene period (Kshirsagar and Badam 1990). The Th/Ur dates at Bori also indicate a higher antiquity (400 kyr B.P.). At Nevasa Th/Ur dates, more than 350 kyr B.P., on calcrete cement of gravels containing Acheulian artefacts along with fossils of *Bos, Elephas* and fossil wood, indicate an antiquity (Lower to Middle Pleistocene), much higher than assumed earlier.

The above new dating techniques have revolutionised our thinking on the chronology of Stone Age cultures in Peninsular India, for example the antiquity of Acheulian in India and also some of the fossils have now been placed in an accurate chronological framework. Of course, further refinement in biochronology iis expected from time to time.

TAPHONOMY

A brief introduction to taphonomy, the most talked about branch of palaeontology during the last two decades, with relevant examples from various areas will help us understand better the mode of deposition of the fossils from different locations.

The term Taphonomy was proposed by a Russian palaeontologist, J.A. Efremov in 1940 for the study of the transition of animals from the stage of biosphere to that of lithosphere (Efremov, 1940). The word has a Greek origin, *taphos* means burial and *nomos* means law. Literally therefore, taphonomy means *laws of burial.* It is a process in which animals pass out of different parts of the biosphere, get fossilised and become part of the lithosphere. This branch started off primarily as a sub-discipline of palaeoecology but has now evolved into an independent area dealing with various stages of preservational record (Behrensmeyer and Kidwell, 1985) and also helping to resolve the problems of provenance, biogeography and palaeoenvironmental reconstruction and to a better overall understanding of the fossil history.

In the US, where such studies have received tremendous attention, there has been a change in emphasis from descriptive taphonomic studies of fossil assemblages to more experimental, process-oriented multidisciplinary investigations (Behrensmeyer, 1990). It has been emphasised that continuing research in modern analogues and theoretical modelling is critical to the further growth of taphonomy as is the interaction between biological and geological processes.

Taphonomy can be divided into two fields, biostratinomy and diagenesis. Biostratinomy includes the circumstances occurring between the death of an individual and its subsequent burial whereas diagenesis includes the effects upon the interred remains brought about by burial conditions and subsequent exposure until the time of discovery. Gilbert (1979) correlates these fields with events in fossil history as shown below.

As stressed by Behrensmeyer (1990) some of the problems generally connected with fossilisation and the role of taphonomy in solving them are given below:

1. Bones from older strata and those from younger strata react differently to the process of fossilisation. In the former the state of preservation of fossils is often poor and the number of individuals fewer because chances of destruction increase with time. However, it is the fauna from the younger strata that are more often subject to destruction on account of tectonic events, floods, ploughing, trampling, etc.

2. Faunal assemblages, especially those of vertebrates, may not always be autochthonous. Although a complex of terrestrial mammals found together in one place is usually called a fauna (a term implying that the animals were associated in life), such a complex may have come together accidentally either at or after death.

3. The sudden appearance in the fossil record of a new fauna, without its ancestors in the preceding strata, may or may not reflect a genuinely new group of species. This may be an artefact of preservation. Sometimes strata may be subjected to disturbances resulting in a lack of a continuous series of fossil species.

4. Various parts of skeletons are preserved and fossilised differently in different sedimentary environments. Sometimes the assemblages of a single synchronic and sympatric community may be mistaken for different fauna because of different sedimentary processes and different methods of sampling.

5. In case bones of different animals are found together in a particular sedimentary deposit it is difficult to say whether these bones were buried together or transported together or whether the animals lived and died at the same site.

The problems outlined above have a direct or indirect bearing on palaeoecology and the sedimentary environment and can be understood better by studying taphonomy which is a prerequisite to palaeoecological studies. Apart from giving precise information on palaeoecology, the study of taphonomy also helps to solve the problems of mode of occurrence, taxonomic diversity and paucity of small mammals (if any) and explains various aspects regarding the concentration of fossils, patterns of disarticulation, varieties of damage, etc.

In recent years, taphonomy has been increasingly used in archaeology and geology for a more precise reconstruction of chronology and the palaeoenvironment. Since taphonomy throws light on the autochthonous/allochthonous nature of fossils (primary and secondary context) we can know whether these are related or not to the sediments yielding them. However, in the Indian context discrepancies have crept in while relating fossils to sediments. For example, in the Siwaliks of NW India, where earlier collections came from mixed contexts, without a clear-cut stratigraphic control (Badam and Rajaguru, 1991) the chronological

	Palaeontological subdisciplines	Events in Fossil History
		Discovery
	Diagenetic studies	
		Final burial
Taphonomy	Biostratimony	
		Death
	Palaeoecology	
		Birth

The various stages in taphonomical processes from the death of an animal to its recovery as a fossil have been diagrammatically shown as below.

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                 Thanatic          Perthotaxic,        Sullegic
                 Factor            Taphic & Anataxic   Factor
                                   Factors
        +--------|-----------------|-----------------|-----------+
    +-----------+ | +-----------+  | +------------+ |  +-----------+
            | Life    | | Death     |   | Fossil     |   | Sample     |
         |Assemblage| | Assemblage|    | Assemblage|    | Collection|
   +------+------+  +-------+---+    +--------+--+    +---------+-+
            | Paleoecologic |  Taphonomic   |  Collection  |
             | Processes     |  Processes    |  biases      |
      +------------------+--------------------+--------------------+
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Diagrammatic History of Taphonomy

Explanations for the various terms used in the above figure are given below:-

Life Assemblage	Biocoenosis	Population of living animals
Death Assemblage	Thanatocoenosis	Population of dead animals
Fossil Assemblage	Perthotaxic	variables affecting bone preservation subsequent to death but prior to burial
	Taphic	mode of burial of animal remains
	Anataxic	site erosion, nature and rate of sedimentation, depth of burial, sediment chemistry, bioturbation etc.
Collection	Sullegic factor	manner of collecting fossils and the collecting bias

framework established was somewhat erroneous till the methods of physical and chemical dating became available. In several cases the matrix enclosing the fossils is different from the lithological units from which the fossils are extracted (Saxena, 1968). A detailed taphonomy of the Siwalik fossils will help throw new light on the provenance and mode of deposition of these fossils which in turn may have an important bearing on the biochronology of the Siwalik sediments.

A similar difficulty arises in respect of Narmada fossils. Our extensive work in the Central Narmada

Valley has shown that taphonomically two modes of deposition can be distinguished in the Devakachar area of Narsinghpur District, Madhya Pradesh. The majority of the fossils found in the lag deposit of the bouldery and cobbly horizon are fragmented and seem to have undergone some transportation. Fresh and unabraided fossils are derived from the overlying silty sandy horizon (channel fill and overbank alluvial fill deposits) and probably the animals represented by these fossils were autochthonous.

An interesting case of a redeposited fossil which raises some doubts about its *in situ* position, is that of the partial cranium of *Homo erectus narmadiensis* found in a channel bar environment at Hathnora in Madhya Pradesh (Sonakia, 1984). The cranium is heavily mineralised and has been found associated with Late Acheulian artefacts. Its position in the bar deposits, combined with taphonomic features, indicates that the cranium was redeposited in this section after having been transported over some distance (Badam, 1989). This aspect if overlooked would give erroneous results regarding the dating of the cranium. Thus the sedimentary context and the associated cultural materials warrant a detailed taphonomic study to arrive at a precise chronology and palaeoenvironmental history of the site.

It may be stressed here that research in the new discipline of taphonomy and its related branches on the Quaternary fossils of India, was initiated at the Deccan College with a preliminary study of a small collection of fossils from the Central Narmada Valley (Badam *et al.*, 1986). Subsequently, additional aspects of this fascinating study were undertaken on collections from Karimnagar, Andhra Pradesh (Badam and Jain, 1988), Son Valley in Uttar Pradesh and partly in M.P.(Badam *et al.*, 1989), and other areas in central and western India (Badam, 1990 a and b).

Studies on the decomposition and scatter patterns of modern animals have been carried out at various National Parks in Africa. They provide a modern analogue for reconstructing past taphonomic stages leading to their preservation and subsequent fossilisation of the skeletal remains. Studies on similar lines have been carried out at the Mudumalai Sanctuary in Tamil Nadu by the author. This preliminary effort is rather broad based but a rigorous follow-up study will throw more precise light on the depositional environment of the fossils in relation to archaeological, geological and palaeontological sites in India.

In a more recent work, the writer (Badam, 1994) presented some of his observations of taphonomic studies from three different situations — modern, archaeological and geological. The integration of the data involving different time periods was thought necessary in order to observe how similar taphonomic processes would operate on assemblages in different ecological settings representing different time periods. It was also demonstrated that individual sites, levels or assemblages may have their own taphonomic history. It is necessary, therefore, that as much taphonomic information as possible be gathered at the site itself for accurate interpretations.

While using taphonomy as a tool in interpreting fossils and their modes of occurrence Badam (1996) discussed the various processes from biosphere to lithosphere which occur as a result of many interrelated geological, biological and chemical phenomena viz., causes of death, decomposition and disarticulation, weathering and transport, diagenetic factors, collection and documentation. In addition the writer also gave a brief checklist of vertebrates for taphonomic purposes as below, the careful observation and systematic monitoring of which will ensure a correct picture of the taphonomic losses.

Locality

1. Date of observation
2. Map reference and specific locality with scale
3. General climate (temperature, humidity etc.) at various times of observation
4. Exposure of specimen to sun (daily, weekly, monthly) depending on the size and weight of the carcass
5. Degree and agent of burial, degree of decay, moisture and organic content, angle of slope etc.
6. Transport of specimen (water, wind, human, animal etc.)

7. Proximity of specimen to water source

Biotic Factors

1. Vegetation and its density
2. Predators or scavengers sighted
3. Parts of specimen eaten by scavengers/ predators
4. Tracks, feathers, burrows in proximity of the specimen
5. Evidence of human activity
6. Bioturbation (insect/ rodent activity etc.)
7. Recent fauna and flora in the area

Specimen

1. Specific identification, age and sex
2. Plot of specimen with landmark positions
3. Presence of soft parts including skin and ligaments
4. Distortion due to dehydration
5. Degree of disarticulation and scattering of various parts of the body in relation to rest of the specimen
6. Area of scatter
7. Missing elements
8. Surface features of bones
9. Mechanical breakages, cracking, crushing and fractures
10. Bone flaking and dissolution
11. Abrasion, tooth marks
12. General state of weathering

Finally and importantly, there is a need for more data from recent specimens, as observations of recent skeletons undergoing taphonomic processes show many analogies with fossil occurrences and provide a firm basis for their interpretation. More data will strengthen our understanding and appreciation of taphonomy in Vertebrate Palaeontology and will also provide a comprehensive data bank for taphonomic research in India.

DENTAL HISTOLOGY AND ENAMEL ULTRA-STRUCTURES

One of the major advances in Palaeontology has been the application of scanning electron microscopic (SEM) studies on palaeozoological material. These studies were pioneered in India at the Geology Dept. of the Panjab University by Ashok Sahni to document the diversity of enamel ultrastructures in various mammalian taxa, to trace the evolution of enamel tissues and to understand the relationship between enamel ultrastructure and functional dental morphology. The results of these studies have given a new dimension to the interpretation of phylogeny, taxonomy, dietary habits, and the diseases from which animals suffered in the past. SEM has also been used to study Precambrian biota, softpart anatomy of fossil organisms and other microscopic forms of life that cannot ordinarily be studied by light microscopy (Sahni 1989). Furthermore, the biomineralised structure of molluscan shells, vertebrate egg shells and dental tissue is ideally suited for such studies. However, in India SEM studies have been widely conducted on tooth enamel.

Tomes (1850) was perhaps the first to carry out pioneering work on the dental constituents of the enamel of marsupial and rodent teeth. Poole (1956) suggested that the true prismatic enamel originated with early mammals. It may be mentioned here that the basic prism patterns in mammals have been classified by Boyde (1964) into Pattern I, Pattern 2 and Pattern 3. The pattern I is found in insectivores, cetacea, sirenia and many extinct mammals whereas Pattern 2 is found generally in ungulates, marsupials and lagomorphs. Pattern 3 is common in carnivores, proboscideans, man and his anthropoid ancestors. In addition, there are three basic crystallite orientations (viz., structureless, pseudoprismatic and prismatic) which represent evolutionary trends in the enamel of vertebrates from reptiles to mammals (Sahni, 1985). The prismatic arrangement in mammals is controlled by stresses which occur during mastication.

Kozawa (1978) carried out SEM studies on tooth enamel of *Moeritherium, Mastodon, Stegodon and Elephas* and confirmed that *Stegodon* represented an evolutionary intermediate stage between *Mastodon* and *Elephas*, something that was being suggested for a long time as based on palaeontological record. As a result of changes in the prismatic pattern with respect to tooth morphology, he suggested a gradual transition in the dietary habits of the four elephant species from omnivorous to herbivorous.

Grine *et al.* (1986) analysed the enamel of *Ovis aries* and *Capra hircus* in order to differentiate these species on a parameter other than dental morphology. Owing to the similarity of the prismatic pattern at the qualitative level, quantitative parameters are shown to be of great value, as they tend to differ in the enamel of intermediate depth. This is an important contribution in the case of such closely related taxa where tooth morphology may not help in a precise identification.

Sahni (1984, 1985, 1989) carried out detailed ultrastructural investigations of cetaceans, rodents, proboscideans, multituberculates and other groups bringing out the evolutionary aspects of enamel development. Studies on the dental histology of Subathu vertebrates (Kumar, 1983), Siwalik mammals (Tiwari, 1983), and rodents from the Karewas of Kashmir (Prakash, 1986) are some of the major contributions to our understanding of the dietary habits of ancient vertebrates and their palaeoenvironmental condition. Srivastava (1997) examined the chewing stresses in dentition of a few mammals and reptiles and their relationships with the internal structure of enamel as observed under the SEM. According to him the internal structure of dental enamel of various mammals has been found to be closely related to the chewing stresses produced due to masticatory forces. Also, the biomechanical analyses of various dentition in relation to their shape and enamel microstructure suggest that to dissipate chewing stresses better structural mechanisms have developed in mammalian dental enamel through time.

On the whole, it is felt that more research on Pleistocene and contemporary mammals will bring out important aspects like their phylogenetic relationships, dietary habits, palaeopathology and even domestication processes. This underlines the vital importance of proper documentation of both qualitative and quantitative traits of enamel prismatic patterns for a more precise knowledge of phylogenetic relationships, hitherto based mainly on gross dental morphology and skeletal anatomy (Badam and Sathe, 1995).

BIOMOLECULAR STUDIES

During the last one decade biomolecular studies have contributed immensely to various aspects of palaeontology and archaeology. In India, such studies may be considered to be still in an experimental stage with regard to fossil material. This area has great potential and has been briefly discussed by Thomas (1993) while highlighting its inter-disciplinary applications. Molecular biology can contribute to the study of the past in a number of ways e.g., hominid origins and macro- evolution, the palaeobiology and biogeography of human species, environmental reconstruction, past human diets, etc. Recent successes in recovering DNA from ancient materials have opened up new areas of potential research (Brown and Brown, 1992). DNA has been recovered from a fossil leaf of *Magnolia* dating to the Miocene period (Golenberg 1991) and from termites fossilised in amber dated to Oligocene-Miocene periods (DeSelle *et al.*, 1992), from the skin of Egyptian mummies (Paabo, 1985) and from 7000 year old brain tissue (Paabo *et al.*, 1988). However, at present the results of biological molecules with regard to palaeontology seem to be patchy even though they are ideal for the study of hominid origins. According to Dover (1991) there is a need for more systematic work on the survival of ancient biomolecules in the whole range of organic materials that can be recovered from archaeological and geological sites and of the effect of age, type of site, context, soil conditions, macro and micro climate, etc. This study promises to make, in the coming years, a significant contribution to the various aspects outlined above.

DNA (Deoxyribose nucleic acid) is a macromolecule consisting of two complementary strands of repeating units wrapped around each other in the form of a double helix. The repeating units are of four kinds, each consisting of a base, a sugar and a phosphoric acid. Each one is a nucleotide, and the four bases — thymine, adenine, guanine and cytocine - give infinite variety to the DNA molecule. They also supply the genetic information to the cell and the organism and pass it on to the offspring.

DNA has certain physical and chemical properties and can be isolated from nearly every organism- ranging from viruses to man. Only certain of the viruses lack DNA and in such viruses DNA is replaced by a comparable molecule, RNA (Ribose nucleic acid). No matter where it is found, all DNA has much the same chemical and physical properties.

Collaborative research on the extraction of DNA from ancient bones and fossils with Centre for Cellular and Molecular Biology, Hyderabad is gradually bringing out interesting results but not enough for interpretation at present. It takes a long time to analyse a normal bone, the older the bone the longer is the time taken for extraction of DNA. For a better understanding, we may give here examples from the work of Paabo (1993), a pioneer in research on biomolecular palaeontology. During the past decade scientists have learnt that ancient DNA sometimes survives the ravages of time. Scholars have used DNA from bone and soft tissues to establish reliable sequences of seven extinct mammals, the oldest being the woolly mammoth found in the permafrost of Siberia. One can learn much more about the genetic relations among extinct species by this study. It has also been confirmed that DNA can survive for long periods after the death of an individual. Allan Wilson (University of California at Berkeley) studied the quagga, a member of the horse family, that lived in southern Africa until becoming extinct at the end of the past century. Samples from a 140 year old quagga skin in a German museum yielded bacterial clones containing sequences from the mitochondrial DNA, which exists in many copies outside the cell nucleus. By comparing these clones with sequences of modern zebra it was shown that quagga was closely related to the zebra and more distantly related to other equids. These were the first sequences determined from an extinct species.

In 1985, K.B.Mullis introduced a method, the polymerase chain reaction (PCR) which allows the multiplication in the test tube of a particular piece of DNA. This technique is extremely sensitive and can generate billions of copies from a single DNA molecule. It was also shown later that PCR can reconstruct intact DNA from several partially degraded ancient molecules. By this method several DNA extractions (leaf of Magnolia, termites in amber etc.) have been successfully carried out. Desalle and his colleagues have shown that their sequences, from termites, are compatible with those from a modern termite.

Future studies of ancient DNA will 'help us learn more about the dynamics of genetic change in populations over time.' We may be able to understand better the history of ourselves and other species and also 'to frame more rational strategies to limit the ongoing erosion of biodiversity'.

ISOTOPE STUDIES

Isotope studies have recently been initiated in palaeontology to know about the diet of extinct animals. A successful attempt was made at reconstructing cave bear (two species) palaeoecology from skeletons by Stiner *et al.* (1998) from a cave in Turkey where the nature of wear and breakage to the adult cave bear teeth indicates that extensive mastication was necessary while eating food. The patterns of tooth damage indicate a diet rich in tough, abrasive materials such as nuts, tubers and associated grit. The results also suggest that both species were highly omnivorous and obtained most of their food from terrestrial and fresh water habitats. Also bone pathologies, usually originating from trauma, occur in some of the adult bears, testifying to long lifespans of some individuals in fossil population.

Isotope analysis has been carried out successfully on contemporary elephant population (Sukumar *et al.*, 1987) and on archaeological bones (Nautiyal *et al.*, 1995). Similar studies are being experimented in collaboration with scientists of an American university, (university of Arizona, Tuscon) on extinct and extant animal populations from India ranging from Miocene to Holocene, to work out the dietary habits of herbivorous animals and other related aspects.

POPULATION DYNAMICS STUDIES

This is another area that could be initiated in

India but it has its limitations in the context of palaeontological accumulations unless vast *in situ* thanatocoenoses are available. Kurten (1954) mentioned that this study is a mature branch of ecology with an important bearing on the problem of evolution mechanics. As suggested by him, in order to study the 'survival of the fittest' we need data on actual survival and mortality in natural populations. Badam and Sathe (1995) reaffirm that good results concerning avian populations have been achieved by 'banding' method by ornithologists. The basic tool of the scientist in this field is the life table which summarises information on survivorship, rates of mortality and expectation of life within a population. Control on movements, habits and habitats, e.g., that of cave bears, ecological niches and eating habits are areas that could help in a study of population dynamics.

According to Kurten (1954) the sample should be statistically respectable (study of 30-40 individuals can yield good results), relative or absolute age of individuals at death should be known, and some estimate should be made regarding the way in which sample represents the population (biased, comparable to a census record of a living population, or to a mortality record). Kurten (1959) also suggests that taxonomic rates of evolution can be studied on the basis of survival data for taxa on the genus or species level.

PALAEOPATHOLOGY

Palaeopathological studies have not seriously been undertaken on fossil populations in India (they have been attempted on human and animal skeletal remains) even though some of them do have signatures of diseases as revealed by SEM studies. Some instances of pathology in the form of excessive growth on the bones have been reported on some fossils from the Son Valley but it needs detailed examination.

It is expected that more techniques will be applied to the palaeontological researches in future which will help gather as much precise information as possible on the aspects mentioned above.

NEW FOSSIL DISCOVERIES

Several new fossil complexes, isolated fossil sites and some new species of animals have come to light during the last few decades. Though this is expected in a normal course of research these discoveries do throw important light on the palaeogeographic distribution of animals in the past, their evolutionary and chronological significance and migration patterns. We give here examples of three recent discoveries which have had a great impact on the palaeontological scene of India during the Pleistocene period.

a) The Hominid Fossil

One of the greatest lacunae in Indian palaeontology and prehistoric archaeology has been the absence of the physical remains of pre- *Homo sapiens* man. This is rather puzzling considering the fact that cultural material ranging in age from Lower Palaeolithic to Mesolithic has been found in abundance in various parts of India. In the past there have been reports, though doubtful, about the finding of a human cranium from either the Narmada Valley or from the river Koana in Uttar Pradesh but either its provenance or its identification was not correctly documented. The specimen, first reported by Theobald (1881), was subsequently lost in the collections of the Asiatic Society of Bengal.

It is pertinent to mention here that a scheme entitled "Explorations for the Remains of Early Man" was approved by the Council of Scientific and Industrial Research (CSIR) under the direction of the late Prof. M.R. Sahni at Panjab University, Chandigarh. This project resulted in the discovery of Lower Palaeolithic tools of the Sohanian pebble chopper types from terrace I of the Middle Pleistocene age and of several Stone Age sites in the valley of the Sirsa. The vertebrate fossils collected under this project are amongst the best found in the country though no fossils of the pre- *Homo sapiens* man were discovered. However, it may be mentioned here that before and after the implementation of this project, several primate discoveries were made in the Siwaliks, viz., Lewis (1934), Gregory *et al.* (1938), Prasad (1962), Simons and Chopra (1969), Chopra and Kaul (1975) etc., most of these from the pre-Quaternary deposits.

As an extension of the work done in NW Himalaya, the CSIR scheme was later transferred to the Deccan College Postgraduate and Research Institute, Pune for further work in the peninsular river valleys under the overall supervision of the late Prof. H.D. Sankalia. However, the physical remains of the Early Man continued to elude the scientific community although tens of thousands of Stone Age tools and non- primate fossils were collected from various valleys.

It is in the context of what is written above that the recent discovery of *Homo erectus narmadiensis* (Sonakia, 1984) from Hathnora (22° 52'N: 77° 53'E), a place 40 km northeast of Hoshangabad in Madhya Pradesh assumes great significance. At the fossil site a section of about 15 m is exposed which is distinguishable into five lithological units. The basal unit of 1.5 m thickness comprises greyish, cemented cross - bedded sand and matrix supported pebbles at the top. Overlying this unit is the cemented bouldery/ pebbly gravel unit of about 0.5 m thickness which has yielded the partial cranium of fossil hominid. Also fossil bovids, proboscideans, reptiles and Late Acheulian artefacts have been collected from this horizon. This unit grades into a 5 m thick unconsolidated sandy/ pebbly gravel having sub-rounded to rounded and unimbricated matrix supported pebbles/ gravels. This is the most richly fossiliferous unit elsewhere in the Central Narmada Valley having also yielded Middle Palaeolithic and late Acheulian tools. A pebbly/ cobbly and silty clay unit of about 2 m thickness overlies the previous unit and this also yielded Middle Palaeolithic artefacts. Capping it is the yellow silty clay of 4 m thickness which is in turn overlain by Black Cotton Soil.

Though there has been some controversy with regard to the nomenclature of the Narmada Man, its discovery, which is the first of its kind in India, has helped fill in the gap in our understanding of the South Asian hominids as a whole. Morphometric and comparative investigations lead to the conclusion that the Narmada man should be designated as *Homo sapiens* (Kennedy *et al.*, 1991). According to these scientists, while the calvarium shares some anatomical features with Asian *Homo erectus* specimens, it exhibits a broader suite of morphological characteristics suggesting an affinity with early *Homo sapiens* fossils from Asia, Europe and Africa.

Even on the basis of archaeological investigations at the Hominid site of Hathnora and the close similarity of the associated tools with other late Acheulian complexes in and outside India a critical investigation into the identification of the specimen was suggested (Badam, 1989).

Some scholars have claimed the discovery of pre - *Homo sapiens* man from the Pinjor Formation of the Siwaliks (Singh *et. al.*, 1988) and from the Narmada Valley (Sankhyan, 1997) but confirmation of these claims is awaited.

b) Microvertebrates in the Narmada Valley

One of the areas in palaeontology that has received tremendous attention in recent years is the study of microvertebrates. In the past this area remain almost neglected not only because of paucity of such material in geological/ archaeological contexts but also because of the lack of interest in these vertebrates.

Perhaps the earliest work in this direction was that of Lydekker (1886) who listed a number of rodents (*Tatera, Bandicota, Mus, Millardia, Hystrix, Lepus,* etc. and insectivores (*Sorex*) from late Pleistocene deposits of the Kurnool Caves in Andhra Pradesh; perhaps they are in the Indian Museum repository. However, no further details about this collection are available. Sahni (1979) and Kumar (1983) studied vast assemblages of microvertebrates from Himachal Pradesh, Uttar Pradesh and Jammu and Kashmir, essentially from Lower and Upper Tertiary deposits. This study helped understand better the palaeogeographic distribution of various groups and their chronology.

Quaternary microvertebrates have been studied in more detail than the pre- Quaternary vertebrates possibly because of their resemblance to modern microfauna. One of the significant works comes from the Siwaliks of NW India (Sahni and Khare, 1976) and Karewas of Kashmir where several insectivore and rodent species, along with fish, have been found (Sahni and Kotlia, 1985; Prakash, 1986; Kotlia, 1991). The microtine rodents have been shown to be important both as dating markers as well as indicators of climatic change. The diversity in the enamel pattern of rodents and their significance in the evolutionary framework has also been highlighted in these works.

Recently, microvertebrates were recovered, for the first time, from Middle- Late Pleistocene sediments of the Central Narmada Valley at Gurariaghat near Devakachar (23° 23' N: 79° 07' E) in Narsinghpur Dist. of Madhya Pradesh. This assemblage includes micromammals, fish, amphibia and reptiles and it is suggested that the small mammals, derived from scats, were deposited by fluvial processes. Rodents like *Millardia* cf. *meltada*, *Bandicota* cf. *bengalensis*, *Tatera* cf. *indica*, and *Gerbillus* sp. indicate an early emergence of these modern rodents in the Indian subcontinent (Patnaik *et al.* 1995, Patnaik 1995). In addition, the discovery of microfauna assumes importance in the area because so far taphonomical and palaeoecological interpretation of the Narmada Valley was based on large vertebrate assemblages only and now this can provide another and even more precise tool for interpretations. However, because of the meagre record of fossil micromammals any inter-relationship between the Narmada and Siwalik rodents can not be ascertained at present. The discovery has raised the hope that further microvertebrate discoveries in the Narmada Valley as well as other river valleys in Peninsular India will be made which would provide still better evidence for reconstructing a clear picture of biostratigraphy and palaeoenvironmental conditions in Peninsular India.

c) Ostrich in the Indian Pleistocene

An interesting discovery in recent years has been the finding of ostrich egg shells, plain or engraved, from the late Pleistocene levels in India, archaeologically equivalent to the Upper Palaeolithic culture. With several discoveries of such shells various aspects of taxonomy, palaeoecology, distribution of the bird in the past and its importance in archaeological and palaeontological contexts became clearer.

The first discovery of ostrich egg shells in India was made in 1860s by Archibald Carlyle from the Ken river in Banda Dist. of Uttar Pradesh (Kumar 1988; Neumayer 1990). It was suggested that the Ken river egg shells resemble those of *Struthio molybdophanes* (the Somali Ostrich). Sali's discovery (1980) of ostrich egg shells from an Upper Palaeolithic site in Patne in the Jalgaon Dist. of Maharashtra evoked a lot of interest followed by the discovery of about sixty sites in Rajasthan, Madhya Pradesh and Maharashtra some of which were dated (e.g., Patne, Maharashtra: 25,000 B.P.; Chandresal, Rajasthan: 38,900 B.P. and 36,500 B.P.; Ramnagar, M.P.: 31,000 B.P.), etc. Kumar *et al.* (1988) and Badam and Sathe (1990) have given a detailed list of shell discoveries in India, the latter authors have also added details about the taxonomy, palaeogeographic distribution and probable ancestry of the ostrich about which there was a difference of opinion amongst some scholars for a long time. Sahni *et al.* (1990) conducted microstructural studies on an extensive collection of the ostrich egg sgells.

Lydekker (1884) was the first to describe the fossil bones of ostrich in a geological context (*Struthio asiaticus*) from Dhok Pathan Stage of the Middle Siwaliks. This is perhaps the earliest record (Lower Pliocene) of the fossil ostrich in India. To explain the absence of ostrich in India during the gap of 6 myr or more is rather problematic. Whether the evolutionary history of ostrich during this gap is unrecorded, whether the ostrich disappeared from India after the Lower Pliocene or whether it was an immigrant to India during the late Pleistocene and disappeared again during the Holocene are questions that await answers. Overkill hypothesis (Francis 1983), climatic changes at the end of the Pleistocene (Kumar *et al.,* 1988), or spread of an epidemic (Badam and Sathe, 1990) are some of the possible reasons (singly or combined) forwarded for the disappearance of the ostrich in the time gap between the lower Pliocene and late Pleistocene and during the Holocene. In any case these discoveries have helped us appreciate better the significance of ostrich in archaeological and geological contexts.

NEW FAUNAL SITE COMPLEXES

Since the time when fossils were first discovered in India in early nineteenth century, numerous fossil sites have come to light bearing upon important aspects which came to light with the application of new techniques as enumerated above. Large collection of fossils have been made from the

Karewas of Kashmir; Siwaliks of the Punjab, Haryana, Himachal Pradesh and Uttar Pradesh; the alluvial deposits of the Narmada, Godavari and Krishna basins; the Son, Belan, Paimar and Seoti valleys in the Indo- Gangetic region; the Mahanadi Valley (M.P. and Orissa) and Parvati Valley in M.P.; the Susunia and Tarafeni valleys in West Bengal; and the Kurnool Caves in A.P. In addition to these faunal complexes, a few fossil localities (including solitary occurrences) have been reported from the alluvial deposits in Tamil Nadu, some areas in Northeast (Assam, Manipur, Tripura and Nagaland out of which the Tripura fauna is better documented), Tapi Basin, Gujarat, etc. As much of the material is already published, we will refer only to the latest discoveries.

a) The Manjra Valley, Maharashtra

The Manjra, a major southerly tributary of the Godavari has yielded one of the richest palaeontological treasures in South India. The importance of the fossils with regard to provenance and palaeoecology has been emphasised in earlier publications (e.g., Joshi *et al.,* 1978; Badam, 1979, 1984). A reconnaissance survey of the valley carried out in 1976-77 by a team of Deccan College, Pune as part of a major UGC sponsored project brought to light a host of palaeontological and archaeological sites in the Manjra Valley and also on the main channels of the river Godavari. A large number of fossils of *Elephas hysudricus, Stegodon insignis ganesa, Sus* sp., *Bos namadicus, Bubalus palaeindicus, Equus namadicus, Axis axis, Antilope cervicapra, Cervus unicolor, Cervus duvauceli, Hexaprotodon palaeindicus, Crocodylus* sp., and Chelonia were discovered in the low energy overbank flood deposits of the Upper Manjra at Dhanegaon (18° 36' N: 76° 10' E), Wangdari (18° 35' N: 76° 25' E), Tadula (18° 35' N: 76° 25' E) and Ganjur (18° 35' N: 76° 24' E). As can be seen, the sites are close to each other and it can be presumed that the varied fauna occupied the area as a suitable niche. However, in this niche there were marked variations to which the animals adjusted comfortably. It is of interest to note that fossils of Proboscidea were predominantly found in abandoned ox- bow lake formations near Dhanegaon. The old channel deposits at Wangdari (about 30 km east of Dhanegaon) yielded the maximum number of ungulates out of which fossils of *Bos namadicus* account for nearly 70 % of the total collection. The dominance of elephants suggests a heavily vegetated environment while cattle indicate a savannah landscape. A large number of fresh water molluscan shells, both bivalves and univalves, were also found in the gravel deposits. The total faunal occurrence substantiated by sedimentological studies attests that distribution of these animals was controlled by local ecological factors. Therefore, the fauna in the valley has a profound bearing on the palaeoecological conditions during the deposition of the sediments. The Manjra Valley enjoyed a good vegetation cover, probably a savannah forest with several deep water pools and generally the climate in the valley was more humid than prevails today in the region. Fossils similar to those found in the Manjra valley have been found from the yellowish sandy bed of the upper horizon of Central Narmada Valley dated to about 31,750 B.P. and from the Godavari and Bhima valleys which date from 40,000 B.P. onwards. The similarity of faunal material with those of other areas has helped understand better the origin and early history of many vertebrate groups in India. The C^{14} dates, based on molluscan shells from the Manjra Valley, range from 27,000 to 32, 000 B.P. which securely place the findings in the late Pleistocene time bracket.

b) Ghod Valley, Maharashtra

Ghod is a tributary of the Bhima river which is in turn a tributary of the Krishna river. Large scale excavations of a Chalcolithic site on the left bank of the Ghod by Deccan College prompted the discovery of Late Pleistocene faunal sites on the opposite bank close to the village of Wangdari. Excavations of the fossil sites for five seasons resulted in the discovery of one of the richest fossil treasures in Maharashtra. Here three lithounits can be identified, about 5 m thick basal sandy pebbly gravel capped by 5-10 m thick unit of fine sands, silts and clays which is in turn overlain by about a meter thick Black Cotton Soil of Early Holocene age.

Fossils identified are those of *Elephas maximus, Elephas hysudricus, Bos namadicus, Bubalus* sp., *Cervus unicolor, Canis* sp., *Sus palaeindicus, Hexaprotodon palaeindicus, Equus namadicus, Trionyx* sp., *Unio* sp., *Ceritherium* sp., etc. Some of these fossils were associated with the Middle Palaeolithic cultural material and some with Upper Palaeolithic culture while a few were associated with both. It may be mentioned here that Wangdari is perhaps one of the few sites indicating a clear cut separation of Middle and Upper Palaeolithic tools even though the fauna is long ranging.

The discovery of *Hexaprotodon palaeindicus* is of special significance as it increases the geographical range of the animal to the south of Godavari before becoming extinct. This fossil was found in a gravel bed associated with molluscan shells which have been C^{14} dated to 20,000 B.P. This species and the *Sus palaeindicus*, also reported for the first time in the valley, have an important bearing on the chronology of the sediments and the palaeogeograpic distribution of these animals in the past.

The sedimentary formations in the Ghod Valley were deposited by a series of water pools within the braid bar or point bar. The periodic flooding of the river is indicated by the occurrence of lenticular bands of silt and clay in the pebble gravel. Such pools, probably with tall grass cover, might have provided suitable habitats for water loving animals like *Hexaprotodon palaeindicus*. This animal would have normally inhabited swampy plain areas where sluggish water predominated, although the contemporary presence of fossil elephants, horses, buffaloes, cattle, deer, carnivores etc. indicates a tropical semi- arid monsoonal climate with plateaux and lowlands probably covered by dense grass and stunted trees (Kajale *et al.,* 1976). The presence of Middle and Upper Palaeolithic tools in the same geological layers as the animal bones suggests that biotic factors played an important role in attracting the Palaeolithic settlers to this location. However, the exact role of prehistoric man in exploiting the contemporary fauna will remain enigmatic till primary/semi primary sites are discovered and excavated in the area.

It may be mentioned in passing here that excavations of the Chalcolithic mound (c 3600- c 2700 B.P.), just opposite to the fossil site of Wangdari, have yielded important faunal data belonging to both wild and domesticated varieties, Further, a Mesolithic site (c 1200 B.P.) has also been discovered in the vicinity of the Chalcolithic site (Rajaguru *et al.*, 1980) but a palaeontological record for this period is lacking at present. However, it is expected that in future important light would be thrown on the possible process of domestication in this area, if any, as a few of the Pleistocene animals discovered here are directly or indirectly related to some of the domesticated animals found at the archaeological site, like cattle, elephant, deer, buffalo etc.

c) Tarafeni Valley, West Bengal

The Tarafeni is a west bank tributary of the Kansabati river. It originates in the hills of Bankura which form the northwestern border of Midnapur district and flows through a Precambrian terrain. Covering an area of 512 km the Tarafeni Valley forms the southeastern fringe of the Chotanagpur plateau with Singhbhum district of Bihar as its western boundary.

A systematic study carried out recently in the Tarafeni Valley, brought to light an assemblage of animal fossils dating to late/terminal Pleistocene in relation to their association vis-a-vis geology and archaeology at Dhuliapur (22° 38' N : 86° 50' E). Fossils identified include *Equus* sp., *Bos namadicus, Axis axis, Antilope cervicapra* , fragments of turtle carapaces, etc. (Basak *et al.,* 1998). Six other sections were examined and documented in the area but these yielded only Microlithic sites and no faunal materials. A detailed palaeoecological study indicates that the region during part of late Quaternary was sub- humid with savanna habitats, waterpool situations, abundant grass in the foothill region and hard ground towards the watersheet. However, the possibility of the past prevalence of minor environmental fluctuations in the region can not be ruled out. It is emphasised that even if there were phases of semi-aridity during the Last Glacial Maximum, the animals mentioned above would have survived this onslaught reasonably well provided there were sufficient grasslands and water pools present in the area.

It may be mentioned that Das Sarma *et al.* (1982) had discovered fossil vertebrates from late Quaternary deposits of several river basins in parts of Bankura, Burdwan and Purulia districts of West Bengal that fall to the north and northwest of the present area. They identified *Bos namadicus, Antilope cervicapra, Axis axis, Sus* sp., *Gavialis* sp., *Batagur* sp., *Hystrix* sp., *Palaeoloxodon* sp., and *Crocuta* sp., (ranging from late Pleistocene to Holocene). The present fauna of the Dhuliapur region is impoverished due to continuous expansion of cultivation, extermination of the Sal jungle and the anthropogenic factor (O'Malley, 1908). However, the collection from Bankura, Burdwan and Purulia districts has also been taken into consideration while attempting to build up a palaeoecological history of the entire region.

d) Son Valley, Madhya Pradesh

The Son Valley covers an area of about 14000 sq km and has a varied Quaternary geology subdivided into four formations, namely (from top to bottom) Khetaunhi Formation, Baghor Formation, Patpara Formation and Sihawal Formation. Culturally, Lower Palaeolithic to Microlithic tools are found from bottom to top, in majority of the cases associated with the faunal material (Badam *et al.*, 1989).

A preliminary study of about a thousand fossils (out of a total collection of 6000 fossils) housed in the Dept. of Ancient History, Culture and Archaeology of the Allahabad University was carried out some time back which brought to light an interesting assemblage of fossils bearing upon biochronology, distribution pattern and palaeoecology during the Quaternary period in the Middle Son Valley. However, it is to be admitted that a fuller picture of the faunal wealth of the valley and its various aspects would be known only after the study of the entire collection is complete.

The fauna so far studied comprises species referable to *Bos namadicus, Bibos gaurus, Bubalus* sp., *Antilope cervicapra, Boselephas tragocamelus, Tetraceros quadricornis, Gazella gazella, Axis axis, Axis porcinus, Cervus unicolor, Cervus duvauceli, Muntiacus muntjak, Sus* sp., *Hippopotamus* sp., *Rhinoceros* sp., *Equus namadicus, Equus asinus/ hemionus, Elephas* sp., *Gavialis* sp., *Trionyx* sp., *Emys* sp., *Panthera* sp., other carnivores, rodents, etc.

The most fossiliferous horizon is the Baghor Formation (Unit II) and the next in order of abundance is the junction of Patpara and the Baghor Formation (Unit I). The basal and the topmost members in the litholog (Sihawal and Khetaunhi formations respectively) are almost devoid of fossils.

Taphonomic observations indicate that more than half of the studied fossils are unbraided and less affected by fluvial activity. In fact most of the fossils (especially from the Baghor Formation) may be treated as autochthonous as there are no appreciable indications of their transport for long distances from their place of death or burial. This formation comprises silts, sands and clays and represents a channel fill deposit. The junction of the Patpara and Baghor formations represents a channel lag deposit and it comprises pebbly, gravelly clays and sands with heavier and robust faunal elements. Evidences of bioturbation, gnawing, flaking, splitting etc. are present in the collection and may be attributed to various taphonomic factors operating on the bones.

It is suggested that some of the fossils ranging from late Pleistocene to Holocene (e.g., blackbuck, spotted deer, barking deer, nilgai, four- horned antelope, deer etc.) collected from the Son Valley and also found in the Pleistocene deposits of Tarafeni Valley (two species), Manjra Valley (three species), Narmada Valley (four species) etc. are endemic varieties, multiplying in diversity and numbers during the Holocene. 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 the rich faunal survival in the Son Valley. Hill slopes and areas away from the rivers must have been bare or supporting a thin grass, thorn and scrub cover. Flood plain zones, channel pools (water holes) and mixed grassland- woodland environment of the flood plains were the favourable ecological niches. A similar palaeoecological condition emerges from the study of the Narmada valley fossils many of which, however, were severely affected by fluvial transport and abrasion.

e) Mahanadi Valley, Madhya Pradesh

The Mahanadi is one of the major easterly flowing rivers of peninsular India. The river originates in the hills of Sihawa, about 100 km south of Raipur dist. in M.P., and traverses through geologically varied landforms before emptying into the Bay of Bengal near Cuttack in Orissa. Palaeolithic sites were discovered in the lower reaches of the river by Mohapatra (1962) and Tripathi (1972). A number of vertebrate fossils (*Bos namadicus* , *Bos* sp., *Cervus* sp., *Equus namadicus* etc.) were for the first time, discovered from the valley at Nandghat (20° 01' N: 81° 48' E), Sigma (21° 37' N: 81° 42' E), Somnath (21° 34' N: 81° 48' E) and Rajnandgaon (21° 06' N: 81° 02' E) (Pandey 1977; Badam 1979; Joshi *et al.* 1980). Middle Palaeolithic tools were found associated with the fossils at all the sites except at Rajnandgaon. The presence of the fossils, though scanty in terms of diversity, indicates that the valley was a savannah land with abundant vegetation and water to support these ungulates. During the late Pleistocene the nearby forests must have provided a varied assemblage of wild animals. Even today wild animals like jackal, wolf, hare, nilgai, chital, antelope, deer, buffalo, bear, lion, leopard etc. abound in the hilly and forested areas surrounding the main channel of the Mahanadi and its tributaries.

f) Tamil Nadu Sites

Fossil sites in Tamil Nadu are very few and isolated because Pleistocene formations in Tamil Nadu are generally 2 to 4 m thick and in most cases overlie the Cretaceous rocks in the form of detached outcrops which have naturally not attracted much attention. Though a large number of invertebrate fossils comprising ammonites, lamellibranchs, gastropods, cephalopods and echinoids have been reported from the Cretaceous beds of Trichinopoly very little information is available about the Quaternary vertebrate fossils from Tamil Nadu as a whole. Matley (1929) collected fossils of *Bos, Bubalus* and *Equus* from a nala bed in Kalamedu (11^0 11' N: 79^0 08' E), 12 Km NE of Ariyalur while prospecting for dinosaur fossils which had been discovered earlier from around the same area. Tripathi (1964) discovered fossils of *Bos* cf. *B. namadicus, Stegodon insignis, Cervus* cf. *C. unicolor* and *Lissemys punctata* from a few well sections near Sayamalai (90^0 04' N: 77^0 40' E) in Tirunelveli dist. and assigned an age from middle to late Pleistocene to these fossils, considering part of the lithounits at Sayamalai to be roughly equivalent to the Older Alluvium of the Indo- Gangetic region and to the Narmada, Godavari and Krishna river valleys.

Mamgain and Sastry (1967) reported the discovery of *Bos* sp. from late Pleistocene sediments near Ariyalur and Prasad and Daniel (1968) discovered a skull of *Hypselephas hysudricus* from Ayyanidipu (8^0 45'N: 78^0 07' E) in Tirunelveli dist. Subsequent discoveries included an isolated tooth of *Equus namadicus* from Ariyalur (Khan, 1971), limb bones of *Bubalus maruvattoorensis* n. sp. from about 15 km SSW of Ariyalur (Ghosh *et al.,* 1972) and teeth of *Equus* and *Bos* from the bank sections of the Marudiyar river (Saha, 1976).

Jayakaran (1980) and Badam and Jayakaran (1993) gave detailed taxonomic descriptions of a partial skull of *Rhinoceros unicornis* collected from Sathankulum (8^0 27' N: 77^0 55' E) in Tirunveli dist. and also of bovid teeth and horncores collected from Elur (10^0 49' N : 77^0 00' E) in Coimbatore dist. Subsequently Badam and Jayakaran (1997) described teeth of *Bos* and *Elephas* from Tiruchirapalli and *Bos* from Madurai. They also discussed the chronology, geology and palaeogeographic distribution of these findings and updated, to a large extent, our knowledge of Quaternary vertebrate fossils of Tamil Nadu. As can be seen from the above only Tirunelveli and Tiruchirapalli districts have yielded several fossil sites whereas other sites are single or double fossil sites.

With the faunal data at hand reconstruction of environment becomes rather imprecise. Controls provided by accompanying pollen, sediment and other data and the detailed characteristics of bone assemblages themselves play a significant role in a secure palaeoecological interpretation. However, the existence of savannah grassland interspersed with aquatic surrounding is ideal to maintain a balance of cattle population. *Equus, Cervus, Stegodon* and *Elephas* did flourish in savannah landscape with abundance of water and tall grasses/ trees which is also one of the prominent supplementary diets of *Rhinoceros* and *Bos*. Some of the sites, e.g. Sathankulum may have been deposited in turbulent conditions as indicated by the signatures of current bedding. The climate here was probably moist. On the whole the conditions during the Pleistocene in Tamil Nadu seem to have been quite favourable for the existence of various animal species mentioned above. Taphonomic work and more fossil collecting in the area will throw better light on the depositional environment of the sediments.

CONCLUDING REMARKS

One of the landmarks of palaeontological researches of the Pleistocene period has been the discovery of a partial cranium of *Homo erectus* from the Narmada Valley. This discovery has filled in, to a great extent, the lacunae in our understanding of the hominid evolution in South Asia as a whole. And it is the wish of every anthropologist, archaeologist, geologist, palaeontologist and all those interested in the history of human evolution that more findings of fossil hominids be discovered in India. The discovery of microvertebrates from various sites (Karewas, Siwaliks, Son, Narmada and Kurnool) has its own importance in chronology and palaeoenvironment. It is expected that with concerted efforts and bed to bed dry and wet sieving more microvertebrates will be discovered in future and documented.

It is of importance to note that the various sub-divisions of the Pleistocene period into lower, middle and upper are essentially based on Vertebrate Palaeontology and Palaeolithic archaeology. However, there has been a mixing up of various fossils as also the Palaeolithic artefacts through time which has hampered the precise demarcation of subdivisions of geo- time scale as also the archaeo-time scale. With more discoveries of fossils and refinement of techniques, especially the dating techniques, this problem has been resolved to some extent. The lower Pleistocene deposits in the northwest are generally characterised by the first appearance of *Equus sivalensis, Elephas hysudricus, Bos acutifrons, Cervus punjabiensis* and *Archidiskodon planifrons*. The placement of the Neogene- Quaternary boundary is now accepted to coincide within the time bracket of 1.8 myr ago or 2.48 myr ago - the latter date also accepted by the INQUA Commission of 1991. Lack of appropiate index fossil assemblage, the secondary context of fossils and paucity of radio metric dates (to a large extent this lacuna has also been removed in recent years) have hampered the precise dating of the middle Pleistocene period which starts with 0.7 myr ago at present. On the basis of distribution pattern of some fossils in time and space it has been suggested that *Hexaprotodon namadicus* and *Sus namadicus* be considered as index fossils for the middle Pleistocene (Badam, 1984). Late Pleistocene had a wide range of fossils like several species of deer, blackbuck, nilgai, chital, barking deer, four-horned antelope, etc. (which continue upto Holocene). *Equus namadicus, Bos namadicus, Bubalus* spp., *Hexaprotodon* spp., *Sus* spp., *Stegodon* spp., etc. range from middle to late Pleistocene except the two varieties of *Hexaprotodon* and *Sus* bracketed strictly in middle Pleistocene. Keeping in view the distribution pattern of animals, our concepts of what constitutes an index fossil assemblage for the late Pleistocene is a matter of further research. However, *Hexaprotodon palaeindicus* and *Sus palaeindicus* may also be included in late Pleistocene time bracket in view of the advanced jaw structure in both species and their presence in relatively younger sediments.

Discovery of the enormous faunal data comprising mammals, ostrich egg shells (and also bones of the bird in earlier geological periods), reptiles, few amphibians, fish and microvertebrates has thrown new light on the depositional environment of the fossil-bearing sediments during the Pleistocene in India which was characterised by one of the most diverse climates — being at times warmer and more humid and at times much drier and cooler than today. In fact during the Plio- Pleistocene there was a transition from tropical humid climate to seasonal monsoonic climate. The climatic changes during the lower and middle Pleistocene were reflected by strong to weak fluctuating monsoons. late Pleistocene was characterised by good monsoons around 120,000 B.P. and moderate to weak monsoons from 75,000 yrs onwards.

The wide distribution in time and space of some animals in central and southern India may be attributed to a similarity of ecological niches, climatic conditions and geographical history prevailing in these parts. The animals seem to have had a zonal distribution in these areas without any definite ecological barriers between them. Most of these forms are late survivals from the Siwaliks of northwest, having migrated to other suitable areas, e.g. the Narmada- Godavari complex, when the conditions in northwest became unfavourable on account of Pleistocene glaciation and other factors. As a result of the glaciation the ice - sheet extended repeatedly from the northwest thereby acting as a physical and climatic barrier to the movement of animals northwards and thus forcing them to move southwards. Naturally many of the species became extinct in course of such migrations because of non-adaptability. Some of them, however, did evolve into advanced forms in the terminal Pleistocene/ Holocene like blackbuck, deer, chital, nilgai etc. without undergoing appreciable micromorphological changes. Animals like buffalo, cattle, elephant, pig etc. have direct or indirect bearing on similar genera found during the Pleistocene and reflect minor morphological changes. It is, therefore, suggested that faunal wealth during the later part of the Pleistocene comprises endemic species having evolved and diversified within the sub-continent.

It is well known that this varied assemblage af animals was not totally indigenous to the sub-continent. Mammals which were shared with the contemporary fauna of Europe were the sabre-toothed cats, the hyaena, wolves, rhinoceros. some varieties of horses, some varieties of deer, antelope and hippopotamus. The migratory routes lay east and west of the Himalaya (Pilgrim, 1925). Most of the larger mammals migrated from Egypt, Arabia, Central Asia and North America through routes across Alaska, Siberia and Mongolia. Hippopotamus and elephants, which had their early origin in Central Africa, 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 of the world except Australia. The interchange of faunas between India and Africa probably took place more easily. Sufficient evidence indicates the existence of a land bridge at the entrance of the Persian Gulf. Probably a corresponding bridge across the Red Sea provided a ready means of communication between India and Africa through Arabia. Important causes of migration include population pressure, evolutionary pressure and climatic fluctuations throughout the Tertiary (Russell, 1962) and of course the glaciation which was a global phenomena. These could also account for the sudden and widespread reduction of vertebrates in India, especially in the northwest, whereas anthropogenic factors may have had a role to play in the reduction of animals in central and Peninsular India.

In conclusion, Pleistocene faunal researches offer a challenging field of investigation to natural and earth scientists. As indicated above, several new techniques have been applied to these studies which have become truly multidisciplinary in nature. Therefore, concerted efforts by archaeologists, anthropologists, geologists, palaeontologists, and other scientists (botanists, biochemists, chemists, etc.) are recommended for applied researches in palaeontology to unravel the mystries of the immediate past with which man is directly concerned.

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