CONTRIBUTIONS FROM THE MUSEUM OF PALEONTOLOGY

THE UNIVERSITY OF MICHIGAN

Vol. 25, No. 5, p. 105-116 (3 text-figs.) January 26, 1979

RECONNAISSANCE SURVEY AND VERTEBRATE PALEONTOLOGY OF SOME PALEOCENE AND EOCENE FORMATIONS IN PAKISTAN

BY

PHILIP D. GINGERICH, DONALD E. RUSSELL, DENISE SIGOGNEAU-RUSSELL, J.-L. HARTENBERGER, S. M. IBRAHIM SHAH, MAHMOODUL HASSAN, KENNETH D. ROSE, AND ROBERT HOLT ARDREY

MUSEUM OF PALEONTOLOGY
THE UNIVERSITY OF MICHIGAN
ANN ARBOR

CONTRIBUTIONS FROM THE MUSEUM OF PALEONTOLOGY

Gerald R. Smith, Director

Robert V. Kesling, Editor

Diane Wurzinger, Editor for this number

The series of contributions from the Museum of Paleontology is a medium for the publication of papers based chiefly upon the collection in the Museum. When the number of pages issued is sufficient to make a volume, a title page and a table of contents will be sent to libraries on the mailing list, and to individuals upon request. A list of the separate papers may also be obtained. Correspondence should be directed to the Museum of Paleontology, The University of Michigan, Ann Arbor, Michigan, 48109.

VOLS. II–XXV. Parts of volumes may be obtained if available. Price lists available upon inquiry.

RECONNAISSANCE SURVEY AND VERTEBRATE PALEONTOLOGY OF SOME PALEOCENE AND EOCENE FORMATIONS IN PAKISTAN

By

Philip D. Gingerich[1], Donald E. Russell[2], Denise Sigogneau-Russell[2], J.-L. Hartenberger[3], S. M. Ibrahim Shah[4], Mahmoodul Hassan[4], Kenneth D. Rose[1], and Robert Holt Ardrey[1]

Abstract.– In 1977 we spent approximately two months in the field in Pakistan studying three geological formations to assess their potential to yield identifiable fossil mammals. The middle Eocene Domanda Formation was examined at six localities spanning a 100 km distance along the east side of the Sulaiman Range in southwestern Punjab. This formation yielded abundant fish remains, including skulls and skeletons, and some reptilian bone. Mammalian remains included a poorly preserved skull fragment and postcranial elements of cetaceans. Land mammals may also be represented, but they are too poorly preserved to be useful for study. The Domanda Formation appears to be entirely a shallow water marine formation, with little potential to yield land mammals unless localized deltaic facies can be found.

The Paleocene Bara Formation was examined at five localities in the Lakhi Range in Sind. This formation yielded only fragmentary remains of crocodilians and turtles, but the middle part of the formation appears to be fluvial in origin, and with further work it could eventually yield mammals.

The early-middle Eocene Kuldana Formation was examined at six localities in Kohat District, North-West Frontier Province. All of these localities yielded reptilian and mammalian bone and tooth fragments, and one locality near Chorlakki village yielded a diverse assemblage of mammals. The vertebrate fauna of the Kuldana Formation is becoming increasingly well known in Punjab and Jammu-Kashmir on the east side of the river Indus, and our work indicates that good collections can also be made west of the Indus as much as 100 km west of previously known localities.

[1] Museum of Paleontology, and Department of Geology and Mineralogy, The University of Michigan, Ann Arbor
[2] Institut de Paléontologie, Muséum National d'Histoire Naturelle, Paris
[3] Laboratoire de Paléontologie, Université des Sciences et Techniques du Languedoc, Montpellier
[4] Paleontology and Stratigraphy Branch, Geological Survey of Pakistan, Quetta

INTRODUCTION

The University of Michigan Museum of Paleontology and the Geological Survey of Pakistan recently completed the first field season of a projected four to five year joint research project studying the paleontology and stratigraphy of continental Paleocene and Eocene sediments in Pakistan. A total of seven weeks was spent in the field in November and December of 1977 surveying potential areas for future concentrated research to better our understanding of the early Tertiary mammalian faunas of Pakistan. This report summarizes the results of our preliminary survey.

The first early Tertiary mammals from Indo-Pakistan were mentioned by Lydekker (1887), but his specimens were never adequately described or figured. Pilgrim (1940) was the first to name and fully describe Eocene mammals from the subcontinent. He named several new genera and species from Lammidhan and Jhalar in northern Pakistan, and in addition described an edentulous mammalian maxilla from Safed Tobah in the central part of the country (see map, text-fig. 1). Dehm and Oettingen-Spielberg (1958) described another collection from localities near Ganda Kas in Pakistan, their specimens being derived from the same geological formations as Pilgrim's specimens. Gingerich (1977) made a small collection of Eocene vertebrates from Lammidhan and Chharat. Buffetaut (1976, 1977) has discussed the crocodilians from these collections. Hussain, de Bruijn, and Leinders (1978) recently described the rodent fauna from this area. As a result, a reasonably diverse vertebrate fauna is now knwon from the middle Eocene of Pakistan, including representatives of six mammalian orders: Tillodontia(?), Condylarthra(?), Creodonta(?), Perissodactyla, Artiodactyla, and Rodentia (Gingerich, *et al.*, 1978, table 1).

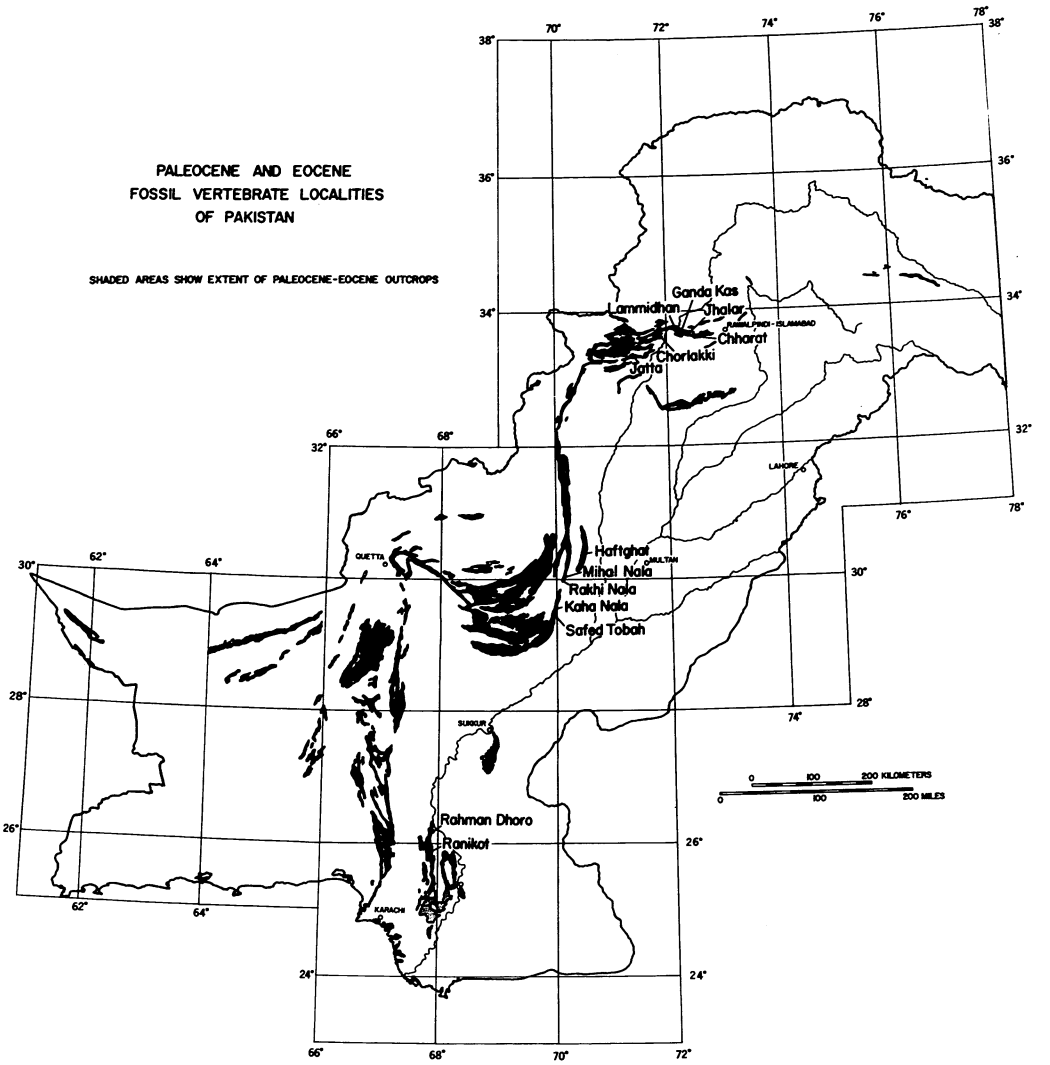
In recent years, Indian paleontologists have also collected middle Eocene mammals from localities in the vicinity of Kalakot in Jammu-Kashmir, and Baranda in Kutch (see map in Gingerich, *et al.*, 1978, fig. 1). The fauna from Kalakot includes some taxa found in northern Pakistan, and several other taxa as well (Ranga Rao, 1971, 1972, 1973; Ranga Rao and Obergfell, 1973; Sahni and Khare, 1972, 1973; Sahni and Srivastava, 1976, 1977). These workers have reported a total of 18 species, most of them new, placed in 17 genera of Rodentia, Creodonta, Perissodactyla, and Artiodactyla. In addition, Sahni and Mishra (1972, 1975) described two new cetaceans *Protocetus sloani* and *Indocetus ramani*, from Baranda in Kutch.

Paleocene mammals are not yet known from the Indo-Pakistan subcontinent.

The Paleocene and Eocene geological formations of Indo-Pakistan are described in a series of papers and monographs, the principal ones by recent authors being by Eames (1952a,b), Nagappa (1959), Bakr and Jackson (1964), Latif (1970), Hemphill and Kidwai (1973), Fatmi (1974), Sahni and Kumar (1974), Meissner, *et al.* (1974, 1975), Calkins, *et al.* (1975), Gupta (1976), Karunakaran and Ranga Rao (1976), Cheema, Raza, and Ahmad (*in* Shah, 1977). As a result of this work, much of it published within the past ten years, there is now a good basic knowledge of the outcrop pattern and lithological character of early Tertiary formations in Pakistan.

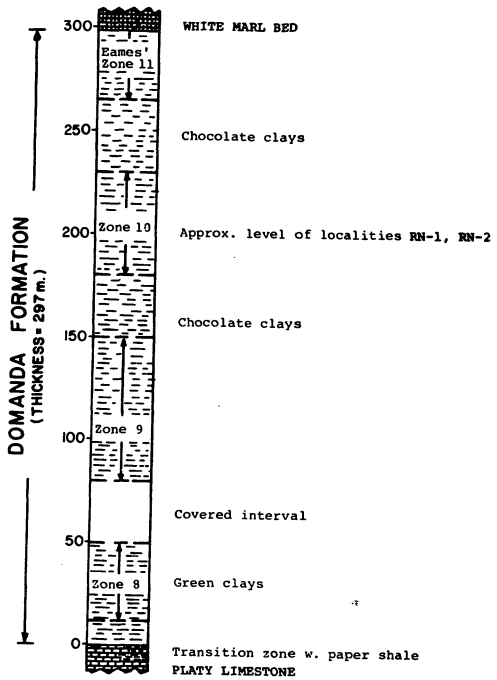
PROJECT OBJECTIVES

Our work in 1977 was directed toward three principal objectives: (1) a paleontological survey of the middle Eocene Domanda Formation in the vicinity of Safed Tobah in the Sulaiman Range of central Pakistan; (2) a paleontological survey of the Paleocene Bara Formation in the Lakhi Range in southern Pakistan; and (3) a more wide-ranging paleontological survey of the middle Eocene Kuldana Formation in the Kala Chitta Range and its lateral equivalents than was possible when reconnaissance of this formation was begun in 1975 (see report in Gingerich, 1977). Vertebrate



TEXT-FIG. 1 – Map of Pakistan, showing fossil localities mentioned in the text, and their relationship to Paleocene and Eocene outcrops in Pakistan. Northern cluster of localities is in the Kuldana Formation, central cluster is in the Domanda Formation, and southern cluster is in the Bara Formation. Vertebrate fossils were collected in all three formations, but only the Kuldana Formation in the north yielded identifiable mammalian remains.

fossils have been reported in the literature from all three of these formations, the latter having yielded the well known collections from Lammidhan, Jhalar, and Ganda Kas mentioned above. Due to the short time available in each area, work was limited to detailed reconnaissance of the best exposed and most accessible parts of each formation to determine if it might yield significant mammalian remains. Between one and two weeks were devoted to each of the three objectives in turn, beginning with work in the Domanda Formation. The remainder of the time spent in the field was required for moving from one field area to another.



TEXT-FIG. 2 – Measured stratigraphic section of the Domanda Formation in Rakhi Nala (29°56′N, 70°7′E). Fauna from localities RN-1 and RN-2 is listed in Table 1.

PALEONTOLOGY AND STRATIGRAPHY OF THE DOMANDA FORMATION (MIDDLE EOCENE)

Hemphill and Kidwai (1973) proposed the term "Domanda Shale Member" of the Khirthar Formation (Middle Eocene) to replace the "lower chocolate clays" of Eames (1952a,b) and other authors in the foothills of the Sulaiman Range. This member has been raised to full formational status as the Domanda Formation by Cheema, Raza, and Ahmad (*in* Shah, 1977). Pilgrim (1940) reported an edentulous maxilla of a "mesonychid" mammal from what is now called the Domanda Formation at Safed Tobah (text-fig. 1), and the partial cranium of an undescribed primitive cetacean in the British Museum (Natural History) was collected from this formation at Rakhi Nala by E. S. Pinfold in 1943. The following excerpt of a letter from Pinfold to A. T. Hopwood at the British Museum describes paleontological prospects in the Domanda Formation:

> The cranium was obtained from the Lower Chocolate Clays in the Rakhi Nullah valley, a short distance east of Rakhi Gaj . . .
>
> I do not remember whether the 'snout' came from the same locality, or from Safed Tobah . . .
>
> These beds are beautifully exposed over literally hundreds of miles in easily accessible country and very rich collections could be made from them. The fossils are sometimes coated with gypsum and ochre and are then easily seen in the red or chocolate clays.
>
> [Letter dated 28 February, 1956]

The fact that mammals (apparently including terrestrial forms) had been found in the Domanda Formation, together with Pinfold's high recommendation for further prospecting, led us to spend two weeks prospecting in this formation in 1977.

TABLE 1 – Localities and preliminary identification of fossils found in the Domanda Formation

1) North side Rakhi Nala (RN-1), about 200 m above base of formation (29°56′N, 70°7′E)
   Fauna includes: Mollusca: *Turritella rakhiensis*, cf. *Plicatula* or *Spondylus* sp., ?*Venericardia* sp., etc.
   Crustacea: crab fragments, Xanthidae, genus indet.
   Vertebrata: fish skull and partial skeleton, otoliths of *Apogon* sp., and teleostean teeth

2) South side Rakhi Nala (RN-2), same level as RN-1 (29°56′N, 70°7′E)
   Fauna includes: Mollusca: *Turritella rakhiensis, Conus* sp., Turridae and other snails; *Lucina* and/or *Anodonta* sp., ?*Astarte* sp., *Corbula* sp., ?*Mya* sp., ?*Tellina* sp. or venerid, *Trachycardium pseudogigas*, cf. *Panopea* sp., Arcidae (probably *Arca* sp. and *Barbatia* sp.), *Venericardia* or *Cardita* sp., and other clams; matrix with small scaphopods
   Echinodermata: small echinoids including *Fibularia* sp.
   Coelenterata: matrix with small coral
   Crustacea: carapaces and some claw fragments of crabs, including *Xanthosia* sp. and *Callianassa* sp.
   Vertebrata: Unidentified fish skulls and partial skeletons, sawfish rostrum fragments, teeth of shark *Galeocerdo latidens*, vertebra of sea-snake *Pterosphenus* sp., cetacean vertebrae, sacrum, and skull fragments, coprolites

3) North and south sides of Mihal Nala (30°2′N, 70°9′E)
   Fauna includes: Mollusca: same fauna as RN-2 listed above, and cf. *Rangia* sp., cf. *Nuculana* sp., ?Solenidae, Naticidae, ?Volutidae, Bullidae
   Echinodermata: echinoids *Fibularia* sp., *Echinopsis* sp., and spatangoid indet.
   Crustacea: well-preserved carapaces and claws of crabs, Xanthidae, genus indet.
   Vertebrata: fish skulls and skeletons (some in paper shale), sawfish rostrum fragments, shark teeth and vertebral centrum, cetacean vertebra, sacrum, acetabulum of ?land mammal, coprolites

4) 1.6 km north of Rakhi Nala (29°58′N, 70°7′E)
   Fauna includes: Mollusca: Same fauna as RN-2 listed above, and a different species of *Cardium* sp., *Conus* or *Voluta* sp. (large with teeth on columella), Ovulidae, large ?*Venericardia* sp.
   Crustacea: carapace of crab, Xanthidae, genus indet.
   Vertebrata: fish skull, cetacean vertebra, coprolites

5) Matkund, north side Kaha Nala, west of Harrand (29°35′N, 69°59′E)
   Fauna includes: Mollusca: small unidentifiable fauna
   Crustacea: crab claw
   Vertebrata: fish bone

6) Haftghat, on east flank of Zinda Pir dome (30°25′N, 70°30′E)
   Fauna includes: Mollusca: small unidentifiable fauna
   Echinodermata: echinoid
   Vertebrata: fish bone

The most accessible exposures of the Domanda Formation in the Sulaiman Range are in Rakhi Nala, where Pinfold's cetacean skull was found, and we began work there. Rose, Hassan, and Hartenberger measured a stratigraphic section of the Domanda Formation in Rakhi Nala with a total thickness of 297 meters, which compares reasonably with Eames' (1952a) thickness of 930 feet. The formation consists almost exclusively of mottled red, chocolate, green, and gray clays, with some shale and beds of paper shale, especially near the base (text-fig. 2). Exposures in this area are not extensive, and in a total of two days spent prospecting here we adequately surveyed all accessible outcrops in Rakhi Nala. Geographical coordinates and a list of fossils found at this and other localities in the Domanda Formation are given in Table 1.

We spent one day prospecting at Mihal Nala, about 11 miles north of Rakhi Nala, and part of a day was spent prospecting at Haftghat and at Matkund in Kaha Nala (text-fig. 1). The latter two localities were so difficult of access that little time remained for prospecting at either, but we were able to establish that the Domanda Formation at Mihal Nala, Haftghat, and Kaha Nala is essentially the same as at Rakhi Nala. In all four localities the formation clearly represents a shallow water marine facies. All mammalian remains found were poorly preserved and represented either cetaceans or badly abraded isolated bones of land mammals washed into the marine depositional province.

Gingerich and Hassan attempted to reach Safed Tobah, the locality mentioned by Pilgrim (1940), but it is deep in the mountains and can only be reached by a camel or horseback ride of several days duration. To reach Kaha Nala they rode the last nine miles from Harrand on horseback, and Safed Tobah is considerably farther from Harrand.

In conclusion, the Domanda Formation appears to represent a shallow marine facies, with only rare and poorly preserved mammalian remains, mostly of cetaceans. Fish are reasonably common, especially in paper shales at Mihal Nala, and a good marine invertebrate fauna has been described by Eames (1952b). Reptiles are also rare, and poorly preserved when found, suggesting that the environment represented is probably some distance off shore. The edentulous "mesonychid" described by Pilgrim (1940) could possibly represent an archaeocete rather than a land mammal. It appears unlikely that significant collections of land mammals will be made from the Domanda Formation unless a more deltaic facies can be found.

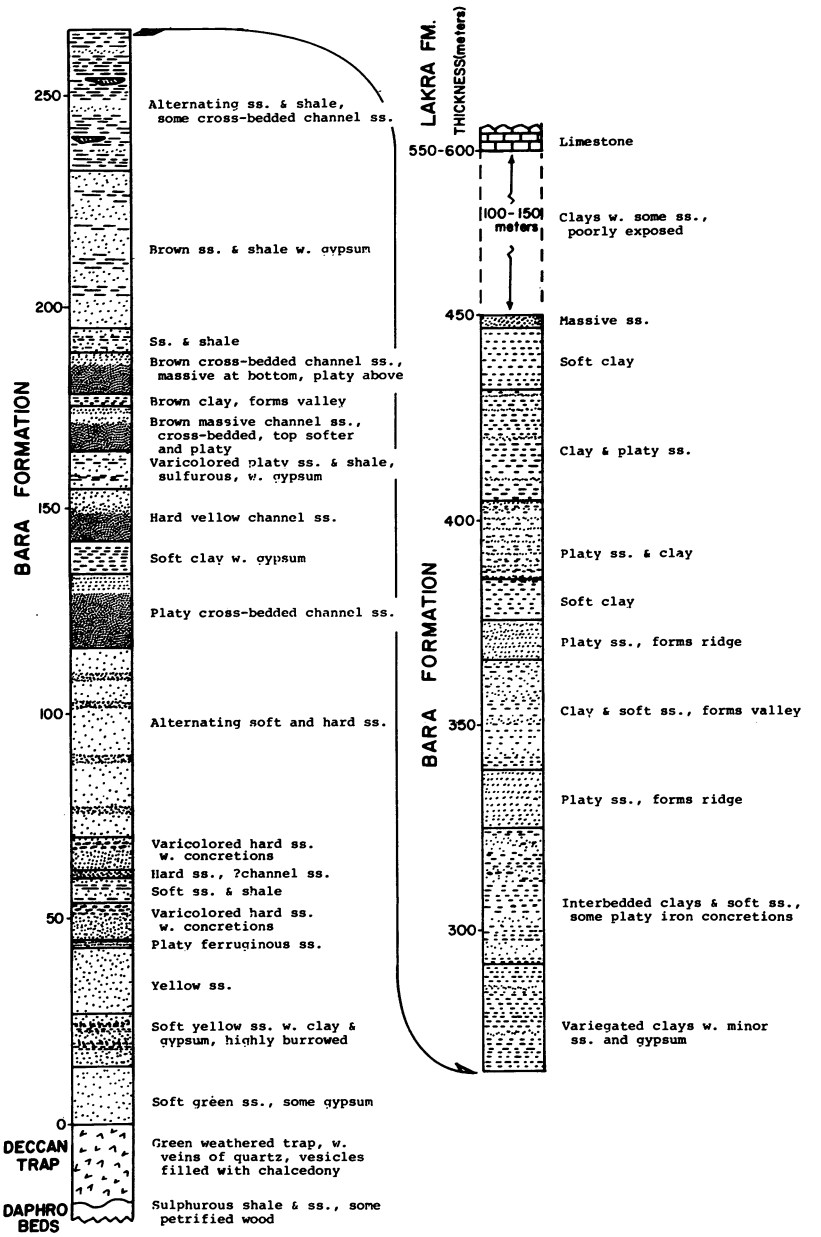
PALEONTOLOGY AND STRATIGRAPHY OF THE BARA FORMATION (PALEOCENE)

The second part of the 1977 expedition was spent prospecting in the Bara Formation. Several days were spent in Rahman Dhoro prospecting on both the east and west limbs of the northward plunging Bara Dome anticline exposed there. The Bara Formation exposed on the east limb of the anticline is approximately 550-600 meters thick. Gingerich and Hassan measured a stratigraphic section of the formation here that is 450 meters thick, and an estimated 100 to 150 meters of additional clays and soft sandstones belonging to the Bara Formation overlie this before the base of the Lakhi Limestone is exposed (text-fig. 3).

The Bara Formation overlies a sequence 19 meters thick of soft weathering Deccan trap basaltic lava. The lower Bara Formation includes several repeated cycles of sandstone, each with a concretion or "clay pebble" conglomerate bed developed at the top, which is in turn overlain by shale. The sandstone with concretions is varicolored red, yellow, purple, and white. The concretion or conglomerate beds themselves include coprolites, burrows, some *Turritella*-like snails, and oysters. Fossil wood is also abundant, as is a distinctive oval fossil fruit or seed pod. One isolated crocodilian tooth and fragments of turtle shell were found in these concretion beds. We interpret the lower part of the Bara Formation to represent an intertidal mud flat environment.

The middle part of the Bara Formation is somewhat different, with a greater development of sandstone lenses, less shale, and less lateral continuity of bedding than in the lower part of the formation. These sandstone lenses are cross-bedded and appear to represent fluvial channel sands. One crocodilian tooth and a dozen or so fragments of chelonian bones are the only vertebrate remains found in the middle part of the Bara Formation. The upper part of the formation was not studied in detail, but our preliminary observations indicate that the upper part is more like the lower part than like the middle part, suggesting a return to a shallow water intertidal mud flat environment.

In addition to the survey in Rahman Dhoro, we studied the Bara Formation within the Talpur fortified valley at Ranikot. The lithologies observed at Ranikot are very similar to those in the



TEXT-FIG. 3 – Measured stratigraphic section of the Bara Formation on the northeast flank of Bara Dome in Rahman Dhoro (26°8′50″N, 67°54′15″E). Middle part of section between 100 m and 300 m appears to offer the best potential for preserving land mammals.

lower and middle Bara Formation at Rahman Dhoro, with the middle part of the formation again appearing to be more fluviatile. We also attempted to locate exposures of the Bara Formation in the vicinity of the Lakhra coalfield. Coal is mined from this formation in the subsurface, but after interviewing mine supervisors at all the major mines, we were unable to find evidence that the Bara

TABLE 2 – Localities and preliminary identification of fossils found in the Bara Formation

1) West flank of Bara Dome in Rahman Dhoro (26°9′10″N, 67°53′40″E)
   Fauna includes: Mollusca: including "*Cardita*" (*Glyptoactis* sp.), *Ostrea* sp., ?*Turritella* sp.
   Vertebrata: tooth of a crocodilian, turtle shell fragments
   Petrified wood, seed pods, and coprolites are common at this locality. The wood and oysters show abundant evidence of boring.

2) North side of Ranikot Dhoro, lower part of formation (25°53′20″N, 67°54′50″E)
   Fauna includes: Vertebrata: unidentifiable bone fragment
   Petrified wood and seed pods or fruits are common at this locality.

3) Northeast flank of Bara Dome in Rahman Dhoro (26°8′50″N, 67°54′15″E)
   Fauna includes: Mollusca: miscellaneous unidentified
   Vertebrata: tooth of a crocodilian, turtle shell fragments
   A palm leaf impression was also found at this locality.

4) Head of Rahman Dhoro, on west side (26°7′15″N, 67°53′10″E)
   Fauna includes: Vertebrata: bone fragments

5) Bara Formation (underground) at Lakhra coal field (25°40′N, 68°9′E)
   Fauna includes: Mollusca: diverse assemblage of estuarine snails and clams, including a ?*Mya*-like burrowing form; also the nautilid cephalopod *Eutrephoceras* sp.

Formation is exposed at the surface anywhere near Lakhra. Coordinates of localities, and a list of fossils found at each locality in the Bara Formation are given in Table 2.

In conclusion, some potential remains for discovering Paleocene mammals in the Bara Formation of Pakistan. We have confirmed all previous reports that this formation is fluvial in origin (at least in the middle part of the formation), and we have confirmed that it yields reptile bone. To date no mammals have been found, but a longer survey concentrating on the middle Bara Formation in Rahman Dhoro, Ranikot Dhoro, and elsewhere, might well yield positive results.

PALEONTOLOGY AND STRATIGRAPHY OF THE KULDANA FORMATION (EARLY-MIDDLE EOCENE)

The final part of the 1977 expedition was spent prospecting in the Kuldana Formation in Campbellpore and Kohat Districts in northern Pakistan. Our results here were more positive than they were in either of the other two formations investigated. Lammidhan localities 2, 11, and 12 of Gingerich (1977) were revisited for one day, and they continue to produce isolated teeth and jaw fragments of mammals. The final few days were spent in Kohat District where we discovered several new fossil mammal localities, the most important being near Chorlakki and Jatta (text-fig. 1).

Our new localities in the Kuldana Formation are the first in Kohat District to yield identifiable fossil mammals, although Pascoe (1964, p. 1527) mentioned that bone fragments are found in the course purple sandstones at the top of the Kuldana Formation in Kohat District. Assuming that the fossil mammals from localities in the Subathu Formation of India are a more eastern equivalent of the fauna from the Kuldana Formation, a reasonably good mammalian fauna is now known from localities extending approximately 350 kilometers along the northwestern edge of the middle Eocene Indo-Pakistan subcontinent. The new localities in Kohat are the most western localities yet discovered of this series, and they extend the geographic range of the faunas by almost 100 kilometers. Further-

TABLE 3 – Localities and preliminary identification of fossils found in the Kuldana Formation

1) 4 km NNW of Chorlakki village, Kohat (33°37′20″N, 71°55′20″E)
Fauna includes: Mollusca: *Planorbis* sp.
Vertebrata: percoid and siluriform fishes, and representatives of the following mammalian taxa:
Artiodactyla
Khirtharia dayi
Anthracobune pinfoldi
Indohyus cf. *indirae*
Gen. et sp. nov., see Gingerich, *et al.*, 1978
Creodonta (?)
Ichthyolestes pinfoldi
Rodentia
Saykanomys sp.
Cf. *Tamquammys* sp.
Several edentulous mandibles and maxillae, and abundant miscellaneous bone were also found at this locality during the two half-days spent here.

2) 2½ km NE of Mami Khel village, Kohat (33°22′05″N, 71°11′58″E)
Fauna includes: Vertebrata: bone fragments common, but broken and water worn, none identifiable.

3) Shekhan Nala, Kohat (33°35′40″N, 71°30′30″E)
Fauna includes: Mollusca: *Planorbis* sp. in dolomite bed
Vertebrata: broken tooth fragments, unidentifiable

4) Jatta Ismail Khel, Kohat (Bannu Road on Salt Mine branch, 33°20′04″N, 71°18′45″E)
Fauna includes: Vertebrata: maxilla of small mammal with buccal part of two molars, additional tooth fragments, two caudal vertebrae of mammals

5) 0.3 km south of Panoba village, Kohat (33°36′14″N, 71°53′40″E)
Fauna includes: Vertebrata: mammal tooth fragments

6) Shadi Khel, Kohat (33°26′30″N, 71°31′00″E)
Fauna includes: Vertebrata: mammal tooth and bone fragments

more, there is some suggestion, based on invertebrate faunas, that the mammals from the Subathu Formation of India are from the upper part of the middle Eocene, while those from the Kuldana Formation at Lammidhan and Ganda Kas are from the lower middle Eocene. The Kuldana Formation in Kohat is listed by Meissner, *et al.* (1974) as being from the upper part of the lower Eocene – suggesting that the new localities may be the oldest in the series (however, this hypothesis requires further corroboration based on comparative study of the mammalian faunas as they become better known).

The coordinates of localities, and the fauna from each of the localities in the Kuldana Formation of Kohat are listed in Table 3. The locality near Chorlakki village yielded a large number of bones and thirty-two teeth and jaw fragments in one full day of collecting. The best specimen, representing a new genus and species of artiodactyl, is described in the following paper by Gingerich, Russell, Sigogneau-Russell, and Hartenberger (1978). Much work remains to be done at this locality, and it appears potentially to be one of the richest middle Eocene mammalian localities yet discovered in Pakistan. One other locality, near Jatta, produced a very small maxillary fragment with two broken teeth that could be either a very small artiodactyl or possibly a primate. All localities that we examined in Kohat produced bone and occasionally broken teeth, but the greatest concentration found to date is at Chorlakki.

The dominant lithology at the Chorlakki locality is red clay, with some beds of *Planorbis*-bearing limestone and a calcareous conglomerate unit. The limestone is marl-like, includes an abundant freshwater mollusc fauna, and typically displays a birdseye texture, suggesting subaerial exposure during lithification. This unit is extensively burrowed and it appears to represent a marl lake deposit. Most bones and teeth were found in the calcareous conglomerate, which is made up of clasts of micrite loosely held together by red calcareous clay. It is apparent from the well rounded clasts, which are up to 1 cm in diameter, that active transport took place prior to deposition. This lithology appears to represent a lag deposit, either from stream transport or from a laterally extensive sheet flow. A more indurated conglomeratic unit is found at the locality near Mami Khel village. Here also bone is commonly found in the conglomerate, and the unit was probably laid down as a channel lag deposit. It is apparent that the terrain being drained by streams depositing these conglomerates had abundant limestone exposed, and most sediment in the Kuldana Formation was derived by weathering and erosion of pre-Kuldana limestones.

CONCLUSIONS

As a result of the investigations described above, we have a much better understanding of the paleontological potential of the Bara Formation, the Domanda Formation, and the Kuldana Formation. The Kuldana Formation has proven paleontological potential, and we propose to concentrate future efforts on this formation. The Bara Formation should be investigated further and, in view of the importance of discovering Paleocene mammals in Pakistan, we hope to spend a longer period of time working in southern Pakistan on this formation in the near future. We do not anticipate further investigations of the Domanda Formation, but these might be worthwhile if carried out on a larger scale than we were able to in 1977.

The Kuldana Formation deserves a broad scale study throughout its range of exposure. This would involve detailed study of the formation along nearly 300 km of northeast-southwest trending exposures along strike and roughly parallel to the Tethyan strand line of the middle Eocene. There is also some potential to study the formation perpendicular to this trend, which would be approximately at right angles to the middle Eocene strand line, giving a good perspective on middle Eocene marine–continental facies relationships. Such a broad stratigraphic study should give a much better understanding of (1) the age and possible time-transgressive nature of the Kuldana Formation throughout its geographical range, (2) the depositional environment or environments represented by the formation, which are at present necessarily quite speculative, and (3) the mammalian fauna and its correlation with sedimentological facies within the Kuldana Formation. Additional paleontological collecting in the Kuldana Formation will undoubtedly greatly increase our knowledge of middle Eocene vertebrate and invertebrate faunas and paleobiogeography. These stratigraphical and paleontological aspects of the Kuldana Formation are particularly important when placed in the context of the paleobiogeography of the Tethyan Sea and its bordering continents. Further study should also contribute to understanding the closing of the eastern Tethys, which had an important effect on the history of mammals in southern Asia.

ACKNOWLEDGMENTS

We thank Mr. S. Tayyab Ali Shah, Director General, Geological Survey of Pakistan, for his encouragement and cooperation. Field research was sponsored by the Geological Survey of Pakistan, and by the Smithsonian Institution (Grant SFC-70760400). Additional financial support was provided

by the research group on the Anthropology of Fossil Man and Vertebrate Paleontology of the Tertiary and Quaternary of Africa and Tropical Asia, directed by Dr. Y. Coppens. We thank Dr. H. Cappetta for identifying the sharks, Dr. S. Secrétan for identifying the crabs, and Dr. J. Roman for identifying the echinoids in our collections. We also thank Dr. J.-C. Rage for confirming identification of *Pterosphenus* sp. from the Domanda Formation, Dr. J. C. Koeniguer for examining the fossil wood, and Dr. S. Freneix for examining some of the molluscs. We are particularly indebted to Mr. Pierre Louis, who helped with field work in the Domanda and Bara Formations. Karen Payne drafted text-fig. 1, and Karna Steelquist assisted with photography.

LITERATURE CITED

BAKR, M. A. and R. O. JACKSON. 1964. Geological map of Pakistan. Publ. by Geol. Surv. Pakistan, 1 sheet.

BUFFETAUT, E. 1976. Sur la répartition géographique hors d'Afrique des Dryosauridae, Crocodiliens mésosuchiens du Crétacé terminal et du Paléogène. Comptes Rendus Acad. Sci., Paris, 283: 487-490.

____ 1977. Données nouvelles sur les Crocodiliens paléogenes du Pakistan et de Birmanie. Comptes Rendus Acad. Sci., Paris, 285: 869-872.

CALKINS, J. A., T. W. OFFIELD, S. K. M. ABDULLAH, S. T. ALI. 1975. Geology of the southern Himalaya in Hazara, Pakistan and adjacent areas. U.S. Geol. Surv., Prof. Paper, 716-C: 1-29.

DEHM, R. and T. OETTINGEN-SPIELBERG. 1958. Paläontologische und geologische Untersuchungen im Tertiär von Pakistan. 2. Die mitteleocänen Säugetiere von Ganda Kas bei Basal in Nordwest-Pakistan. Abh. Bayer. Akad. Wiss., Math-Nat. K1., 91: 1-54.

EAMES, F. E. 1952a. A contribution to the study of the Eocene in western Pakistan and western India: A. The geology of standard sections in the western Punjab and in the Kohat district. Quart. J. Geol. Soc., London, 107: 159-171.

____ 1952b. A contribution to the study of the Eocene in western Pakistan and western India: D. Discussion of the faunas of certain standard sections, and their bearing on the classification and correlation of the Eocene in western Pakistan and western India. Quart. J. Geol. Soc., London, 107: 173-200.

FATMI, A. N. 1974. Lithostratigraphic units of the Kohat-Potwar Province, Indus Basin, Pakistan. Mem. Geol. Surv. Pakistan, 10: 1-80.

GINGERICH, P. D. 1977. A small collection of fossil vertebrates from the middle Eocene Kuldana and Kohat Formations of Punjab (Pakistan). Contr. Mus. Paleont., Univ. Michigan, 24: 190-203.

____ D. E. RUSSELL, D. SIGOGNEAU-RUSSELL, and J.-L. HARTENBERGER. 1978. *Chorlakkia hassani*, a new middle Eocene dichobunid (Mammalia, Artiodactyla) from the Kuldana Formation of Kohat (Pakistan). Contr. Mus. Paleont., Univ. Michigan, 25(6): 117-124.

GUPTA, V. J. 1976. Indian Cenozoic stratigraphy. Hindustan Publ. Corp. (India), Delhi, 344 p.

HEMPHILL, W. R. and A. H. KIDWAI. 1973. Stratigraphy of the Bannu and Dera Ismail Khan areas, Pakistan. U.S. Geol. Surv. Prof. Paper, 716B: 1-36.

HUSSAIN, S. T., H. de BRUIJN, and J. M. LEINDERS. 1978. Middle Eocene rodents from the Kala Chitta Range (Punjab, Pakistan). Proc. Kon. Ned. Akad. Wetenschap., Amsterdam, Ser. B, 81: 74-112.

KARUNAKARAN, C. and A. RANGA RAO. 1976. Status of exploration for hydrocarbons in the Himalayan region – contributions to stratigraphy and structure. *In* Himalayan Geology Seminar, New Delhi (India), Himachal Times Press, Dehra Dun, p. 1-72.

LATIF, M. A. 1970. Explanatory notes on the geology of southeastern Hazara, to accompany the revised geological map. Geologischen Bundesanstalt (Austria), Wein, Sonderband 15: 5-19.

LYDEKKER, R. 1887. The fossil Vertebrata of India. Records Geol. Surv. India, 20: 51-79.

MEISSNER, C. R., J. M. MASTER, M. A. RASHID, and M. HUSSAIN. 1974. Stratigraphy of the Kohat Quadrangle, Pakistan. U.S. Geol. Surv. Prof. Paper, 716D: 1-30.

____ M. HUSSAIN, M. A. RASHID, and U. B. SETHI. 1975. Geology of the Parachinar Quadrangle, Pakistan. U.S. Geol. Surv. Prof. Paper, 716F: 1-24.

NAGAPPA, Y. 1959. Foraminiferal biostratigraphy of the Cretaceous-Eocene succession in the India-Pakistan-Burma region. Micropaleont., 5: 145-192.

PASCOE, E. H. 1964. A manual of the geology of India and Burma (3rd edition). Govt. India Press, Calcutta, v. 1-3, 2130 p.

PILGRIM, G. E. 1940. Middle Eocene mammals from north-west Pakistan. Proc. Zool. Soc., London, ser. B, 110: 127-152.

RANGA RAO, A. 1971. New mammals from Murree (Kalakot Zone) of the Himalayan foot hills near Kalakot, Jammu & Kashmir State, India. Jour. Geol. Soc. India, 12: 125-134.

_____ 1972. Further studies on the vertebrate fauna of Kalakot, India. New mammalian genera and species from the Kalakot zone of Himalayan foot hills near Kalakot, Jammu & Kashmir State, India. Directorate of Geology, Oil & Natural Gas Commission, Dehra Dun, Spec. Paper, 1: 1-22.

_____ 1973. Notices of two new mammals from the upper Eocene Kalakot beds, India. Directorate of Geology, Oil & Natural Gas Commission, Dehra Dun, Spec. Paper, 2: 1-6.

_____ and F. A. OBERGFELL. 1973. *Hyrachyus asiaticus*, new species of an upper Eocene tapiroid (Mammalia, Perissodactyla) from Kalakot, India. Directorate of Geology, Oil & Natural Gas Commission, Dehra Dun, Spec. Paper, 3: 1-8.

SAHNI, A. and S. K. KHARE. 1972. Three new Eocene mammals from Rajauri District, Jammu and Kashmir. Jour. Palaeont. Soc. India, 16: 41-53.

_____ and S. K. KHARE. 1973. Additional Eocene mammals from the Subathu Formation of Jammu and Kashmir. Jour. Paleont. Soc. India, 17: 31-49.

_____ and V. KUMAR. 1974. Palaeogene palaeobiogeography of the Indian subcontinent. Palaeogeography, Palaeoclimatology, Palaeoecology, 15: 209-226.

_____ and V. P. MISHRA. 1972. A new species of *Protocetus* (Cetacea) from the middle Eocene of Kutch, western India. Palaeontology, 15: 490-495.

_____ and V. P. MISHRA. 1975. Lower Tertiary vertebrates from western India. Monogr. Paleont. Soc. India, 3: 1-48.

_____ and V. C. SRIVASTAVA. 1976. Eocene rodents and associated reptiles from the Subathu Formation of northwestern India. Jour. Paleont., 50: 922-928.

_____ and M. C. SRIVASTAVA. 1977. Eocene rodents of India: their palaeobiogeographic significance. Geobios, Mem. Spec., 1: 87-95.

SHAH, S. M. I. 1977. Stratigraphy of Pakistan. Mem. Geol. Surv. Pakistan, 12: 1-138.