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Tertiary continental deposits of Northwestern Pakistan and remarks on the collision between the Indian and Asian plates

Leinders, J.J.M., Arif, M., De Bruijn, H., Hussain, S.T. & Wessels, W., 1999 - Tertiary continental deposits of Northwestern Pakistan and remarks on the collision between the Indian and Asian plates - in: Reumer, J.W.F. & De Vos, J. (eds.) - ELEPHANTS HAVE A SNORKEL! PAPERS IN HONOUR OF PAUL Y. SONDAAR – DEINSEA 7: 199-213 [ISSN 0923-9308]. Published 10 December 1999

The initial docking of the Indian Subcontinent with Asia resulted in the west-to-east closure of the Tethys sea. As a consequence the oldest continental sediments were deposited in the west. This event is documented by the presence of an earliest Eocene mammalian fauna located on the westernmost edge of the Indian Subcontinent (H-GSP 300). Since this fauna has Eurasian affinities, it documents the time of contact between the continental crusts of the two plates. All other Eocene mammalian faunas known from the northern part of the Indian Plate are located more eastward, are younger in age and show local endemism. Eocene sedimentation in the northern part of the subcontinent was succeeded by a period of erosion, with sedimentation not recommencing until early Miocene, as documented by the rodent fauna from the base of the Murree Formation (locality H-GSP 116).

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Keywords: Pakistan, Indian subcontinent, Siwaliks, paleobiogeopgraphy

INTRODUCTION

The Howard University - Geological Survey of Pakistan project (H-GSP) started the investigations in the Banda Daud Shah area (Fig. 1) in 1976. A stratigraphic section south of Banda Daud Shah was studied and fossil mammals were collected during several field seasons. The sediments in this section range in age from early Eocene to late Miocene. Different faunal assemblages have either been described (De Bruijn *et al.* 1981 and 1982, Wessels *et al.* 1982, Thewissen *et al.* 1983, Maas *et al.* in prep.). The geology of the Kohat Quadrangle has been described by Meissner *et al.* (1974) and Pivnik & Wells (1996). Wells (1983) reported on the sedimentology of the Eocene redbeds near Banda Daud Shah.

The purpose of this paper is to contribute to the reconstruction of the geological and paleontological history of the northern rim of the Indian plate during the Eocene-Miocene interval. This is achieved by studying a section which is located in the southern part of an eastward plunging anticline just south of the village of Banda Daud Shah (Figs. 1 and 2), Kohat, Northwest Frontier Province (N.W.F.P). The southern limb of the anticline just south of Banda Daud Shah dips towards SSE at an angle of about 60 degrees. However, the dip of the beds increases and eventually they are overturned toward the

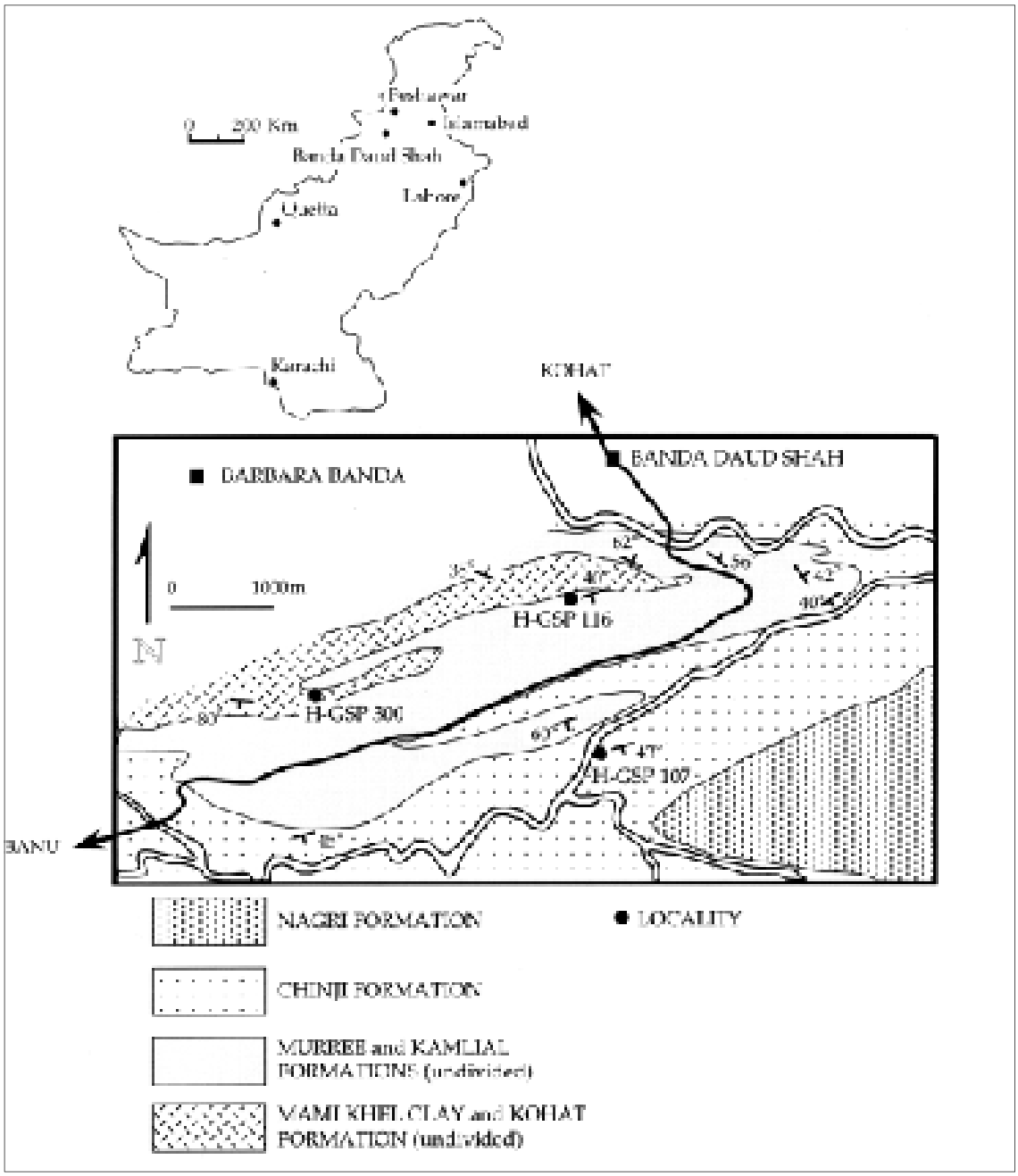

Figure 1 Geological sketch-map of the area south of Banda Daud Shah.

west. The sediments in the core of the anticline have been deformed tectonically, especially in the overturned part of the anticline. We are aware of the fact that formation names of various lithostratigraphic units of the Siwalik Group should not be used outside the type areas. Since it is beyond the scope of this paper to review the lithostratigraphy of the Kohat Quadrangle, we will use the same lithostratigraphic names as suggested by Meissner *et al.* (1974).

EOCENE

The continental redbeds exposed in the core of the Banda Daud Shah anticline were mapped as the Mami Khel Clays by Meissner *et al.* (1974). Wells (1983) considered the Mami Khel Clays as part of the Kuldana Formation representing the same regressive phase as the 'classic' Eocene mammal bearing deposits in the Kala Chitta Hills, west of Rawalpindi (see also Dehm & zu Oetingen-Spielberg 1958, Hussain *et al.* 1978 and West 1980). Pivnik & Wells (1996) grouped the Mami Kehl Clays and the Kuldana Formation in a new lithostratigraphic unit: the Mami Khel Formation, with a synchronous age throughout the Kohat - Rawalindi area (late early Eocene). The Mami Khel Clay in the Banda Daud Shah area consists mainly of a brownish-red to red coloured silty clay sequence with intercalations of thin sandy channels containing calcrete nodules. Wells (1983) reported that the Kuldana Formation consists of about 95% red mudstone and 5% channel sands. The presence of numerous calcrete nodule beds and the absence of coarse clastics in the Mami Khel Clay (as well as in the Kuldana Formation in the Kala Chitta Hills) indicates the presence of extensive and flat floodplains.

Two localities with vertebrate fossils have been reported from the Mami Khel Clay, south of Banda Daud Shah: Barbara Banda I (code indication H-GSP 300) and II (De Bruijn *et al.* 1982, Thewissen *et al.* 1983). The thickness of the redbeds near Mami Khel is about 130 m (Meissner *et al.* 1974). Barbara Banda I is about 55 m below the contact between the Mami Khel Clay and the overlying Kohat Formation. The Barbara Banda (I and II) locality has yielded the following taxa:

Rodentia
Cocomyidae
gen. indet., sp. I and II
Paramyidae
gen. and sp. indet.

Artiodactyla
Dichobunidae
Diacodexis pakistanensis THEWISSEN *et al.* 1983

Primates
Omomyidae
Kohatius sp. RUSSELL & GINGERICH 1987

Perissodactyla
A new Isectolophid Tapiroid, MAAS *et al.* in prep

The following suggestions are made based on the fauna:
1 *Diacodexis pakistanensis* is the smallest and most primitive artiodactyl yet known. It retains a clavicle, has five complete digits in the manus and four in the pes and it is digitigrade (Thewissen *et al.* 1983, Thewissen & Hussain 1990).
2 The Perissodactyl from Barbara Banda is the most primitive tapiromorph known from the Indian subcontinent (Maas *et al.* in prep.).
3 The rodent material from Barbara Banda indicates the presence of a relatively diverse fauna, with representatives of the Paramyidae and the Ctenodactyloidea. The latter group probably is ancestral to the Chapattimyidae (De Bruijn *et al.* 1982), which are reported from the Eocene deposits near Chorlakki (Hartenberger 1982 and Gingerich *et al.* 1979) and Kala Chitta (Hussain *et al.* 1978). The comparison of a very primitive Ctenodactyloid from Barbara Banda with an unpublished association of Chapattimyidae from a locality near the base of the Kuldana Formation at the Jhalar section in the Kala

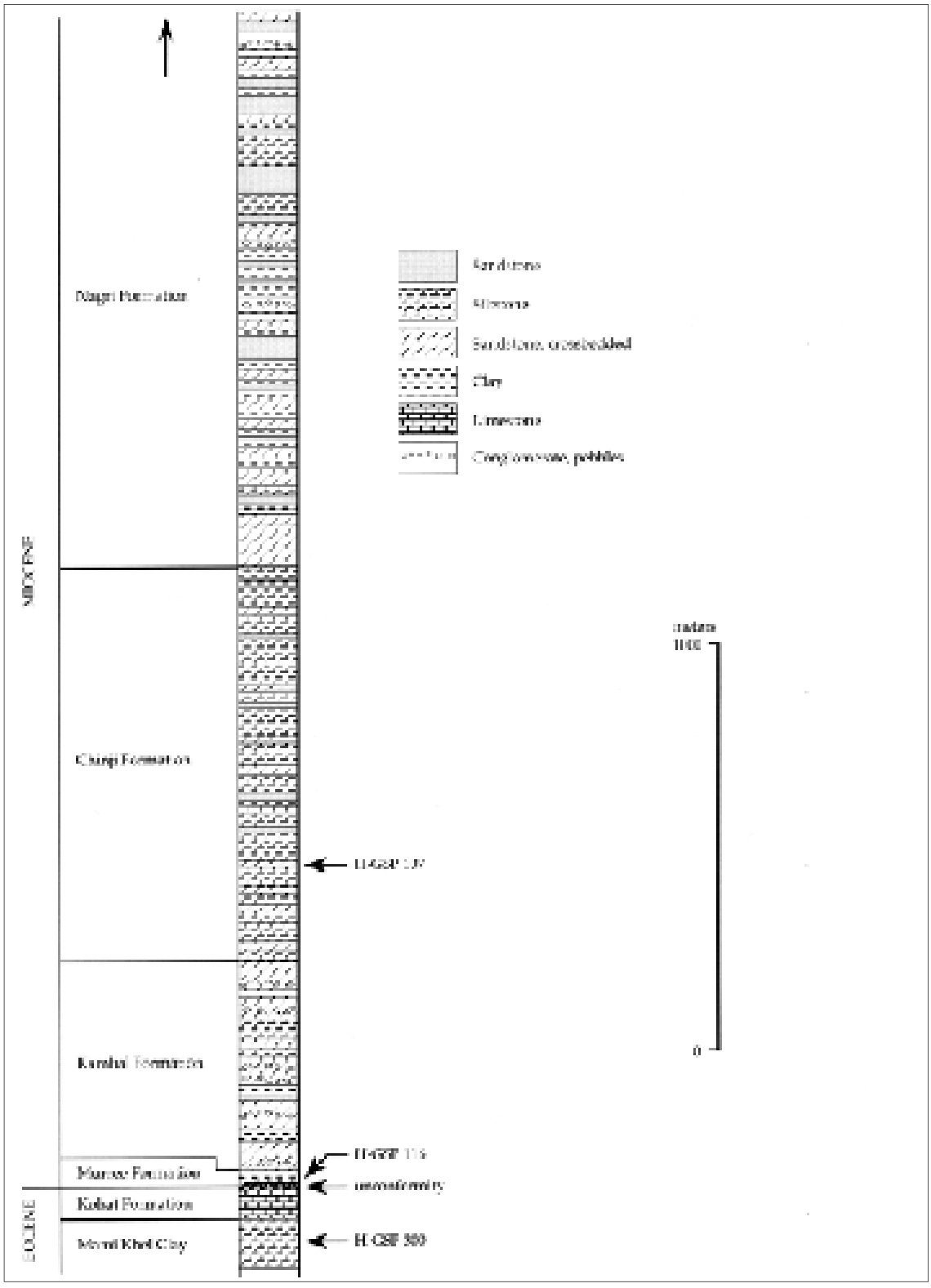

Figure 2 Diagrammatic section of the Tertiary sediments near Banda daud Shah (after Meisssner *et al.* 1974). The fossil localities are plotted by us.

Chitta Hills (loc. H-GSP 223) suggests that the former locality is much older than the latter. The association from locality H-GSP 223 is quite similar to the one described from locality H-GSP 144 in the Kala Chitta area (Hussain *et al.* 1978), but very different from that of Barbara Banda.

We consider the Barbara Banda fauna to represent the early part of the early Eocene rather than the late early Eocene as suggested by Thewissen *et al.* (1983) on the basis of a global regression of the sea near the end of the early Eocene (see also Pivnik & Wells 1996). An earliest Eocene age corroborates with the evolutionary stage of the various mammalian groups and solves the dilemma reported by Thewissen *et al.* (1983, p. 175): 'Also, there is still uncertainty about the exact age of the Barbora Banda faunule. If it is late early Eocene, *Diacodexis pakistanensis* would be younger than the Wasatchian North American forms. In this case it might be a relict form, prolonging to a certain degree the primitive state.'

Although the Eocene rock sequences in various areas show resemblances, appreciable differences in lithology are present. Freshwater limestone beds, variegated clays and oyster beds are present in the Kala Chitta area, but they do not occur in Barbara Banda. The red beds in the latter area are overlain by 75 metres of marine limestones (the Kohat Formation), of which the lower part consists of thinly bedded compact limestones and shale beds (Kaladhand Member) and the upper part of thick bedded, massive and cliff forming limestone (Habib Rahi Member). In the Kala Chitta Range (e.g. in the section near Jhalar railway station) the Kuldana deposits are overlain by yellow, soft shales and marls with abundant large Foraminifera. The thickness of this lower shallow marine interval at Jhalar is around 200 m and is separated from the upper shallow marine interval by a succession which consists of numerous emersion horizons. These emersion horizons consist partly of thin gypsum beds and some major lignite intervals. Generally, the Kuldana deposits in the Kala Chitta area consist of thick mudstones with intercalations of thin sandy channels and thin bedded lacustrine limestones containing abundant *Planorbis*. The upper part of the shallow marine sediments mainly consists of thick marls (about 200 meters) with abundant Foraminifera. The upper shallow marine interval shows a more restricted marine character as can be seen from the intercalations of numerous thin gypsum beds. These 'nummulitic shales' are generally considered as a third member of the Kohat Formation: the Sadkal Member (Meissner *et al.* 1974). The type area of this member is located in the Kala Chitta Range. In the Kohat quadrangle, this member of the Kohat Formation can only be recognised in the Northeast between the Kaladhand and the Habib Rahi Members (Meissner *et al.* 1974). Both latter members of the Kohat Formation are not present in the Kala Chitta area.

Because of lithological differences it is not possible to trace the lithological units all the way from Kuldana to Barbara Banda (Hartenberger 1982: fig. 1). It is therefore not correct to include all the Eocene continental deposits in northern Pakistan in the same formal formation (Kuldana Formation, Thewissen *et al.* 1983 or Mami Khel Formation, Pivnik & Wells 1996). Furthermore, the redbeds in the different areas may well represent the development of more or less the same (continental) facies at different times. The late early Eocene age of the redbeds near Banda Daud Shah suggested on the basis of lithology (Russell & Zhai 1987, Pivnik & Wells 1996) and a supposed world wide regression (Gingerich *et al.* 1983, Thewissen *et al.* 1983) is certainly not convincing.

Wells (1983) explained the relatively small number of taxa and the presence of articula-

ted bones in Barbara Banda as an entrapment of a herd of *Diacodexis* accompanied by some other animals by a sudden flood. This interpretation seems questionable because it is not known whether or not these small artiodactyls lived in herds, and does not explain that the same faunal composition is reported from two different localities (Barbara Banda I and II). It also does not account for the presence of a primitive Perissodactyl in Barbara Banda, which is absent in the Kala Chitta area and extremely rare in the intensively exploited locality Chorlakki (one premolar of an isectolophid has been reported by Thewissen *et al.* 1987). It also does not account for the difference between the rodent associations of Barbara Banda and these two localities (De Bruijn *et al.* 1982). Therefore, we conclude that appreciable differences in age exist between the various Eocene continental deposits in northern Pakistan and that the deposits near Banda Daud Shah are the oldest yet known.

The reconstruction of the collision between the continental crusts of the Indian and Asiatic plates by Tapponier *et al.* (1981: fig. 5), based on geologic and structural evidence, shows a near collision about 50 My. This date is confirmed by Haq (1989). Klootwijk (1979: fig. 6) and Klootwijk *et al.* (1985: fig. 3), however, suggested a far more southern position (near the equator) of the northern rim of the Indian plate at the beginning of the Eocene (about 55 My) than Tapponier. The composition of the diverse land mammal assemblages of the Chorlakki and the Kala Chitta localities indicates that faunal exchange with Eurasia was possible during the deposition of these redbeds. The fauna from Barbara Banda only contains a limited number of taxa (unbalanced fauna) which suggests limited faunal exchange (by 'sweepstake' or 'island-hopping' route) during the earliest Eocene, indicating that the Indian plate was very close to Asia. The sudden drop in the rate of seafloor spreading in the Indian Ocean at about 55 My (practically no spreading between 55 and 45 My; see Wensink 1975) corroborates the idea that the continental crusts of the two plates collided during the earliest part of the Eocene.

The differences in composition of the faunas from the Eocene deposits of the northern part of the Indian subcontinent have been interpreted as resulting from different ecological circumstances rather than from differences in age (West 1980, Wells 1983). Hartenberger (1982) discusses the Eocene rodent assemblages and concludes that the faunas from Pakistan are contemporaneous, but that 'Kalakot and Mekta in India may be more recent.' We agree with Thewissen *et al.* (1987) that the faunal differences are due to differences in age and consider the Barbara Banda fauna of earliest Eocene age, and the Chorlakki, Kala Chitta and Kalakot faunas of younger early and middle Eocene age (see Table 1).

The evidence provided by land mammals suggests that the (near) collision between the Indian and Asian plates took place around 55 ma. At that time the position of the northern edge of the Indian subcontinent was near the equator (Klootwijk 1979, Klootwijk *et al.* 1985). Consequently, the southern edge of the Asian plate must have been near the equator too and it was after the collision that the Asian plate moved further north. The suggested time difference between the western and the eastern Eocene continental deposits in the northern part of the Indian subcontinent corroborates the idea that the first contact between the Indian and Asian plates took place at the north-western part of the Indian plate followed by a counter-clockwise rotation of the subcontinent (Klootwijk *et al.* 1985) resulting in the closure of the Tethys seaway from west to east. However, Klootwijk *et al.* (1985) conclude: 'collision between Greater India's northern boundary and southern Asia occurred at equatorial latitudes, with progressive suturing from Paleocene in the north-western Himalayans

Table 1 Faunal distribution on the Indian subcontinent during the Eocene (Barbara Banda being the westernmost and Kalakot the easternmost locality).

AGE	AREA	FAUNAL EVENTS
middle Eocene ?	Kalakot (India)	New arrival and radiation of more evolved tapiroids. Continued dominance of Chapattimyidae.
	Kala Chitta	Reduction in the number of small artiodactyls. Dominance of Chapattimyidae.
	Chorlakki	Better connection with Eurasia, many new arrivals. Different types of small artiodactyls resulting from radiation or from new arrivals. Strong reduction in number of primitive tapiroids. Radiation of the Chapattimyidae. Local extinction of the Paramyidae.
earliest Eocene	Barbara Banda	First arrival of land mammals on the Indian subcontinent by sweepstake route: primitive tapiroid, most primitive artiodactyl (*Diacodexis pakistanensis*), Ctenodactyloidea (ancestors of the Chapattimyidae), Paramyidae. First primates (*Kohatius*).

until early Eocene in the eastern.' This is slightly older than we have concluded on the basis of the mammalian faunas.

MIOCENE

The thick neogene continental deposits of the sub-Himalayas contain an almost uninterrupted record of the last 20 million years history of the Indo-Pakistan subcontinent. We follow Hussain *et al.* (1979) and consider these deposits to belong to the Siwalik Group, unlike Meissner *et al.* (1974) and Pivnik *et al.* (1996), who divided them into Rawalpindi and Siwalik Groups.

Murree Formation

The top of the Habib Rahi Limestone (Upper member of the Kohat Formation) shows a weathered surface of 3-4 meters thickness (Fig. 3), which indicates a period of non-deposition before the deposition of the Murree Formation. The measured section along the southern limb of the anticline shows a 30 meters thick sequence of the Murree Formation. Meissner *et al.* (1974) measured a thickness of 5 meters assuming

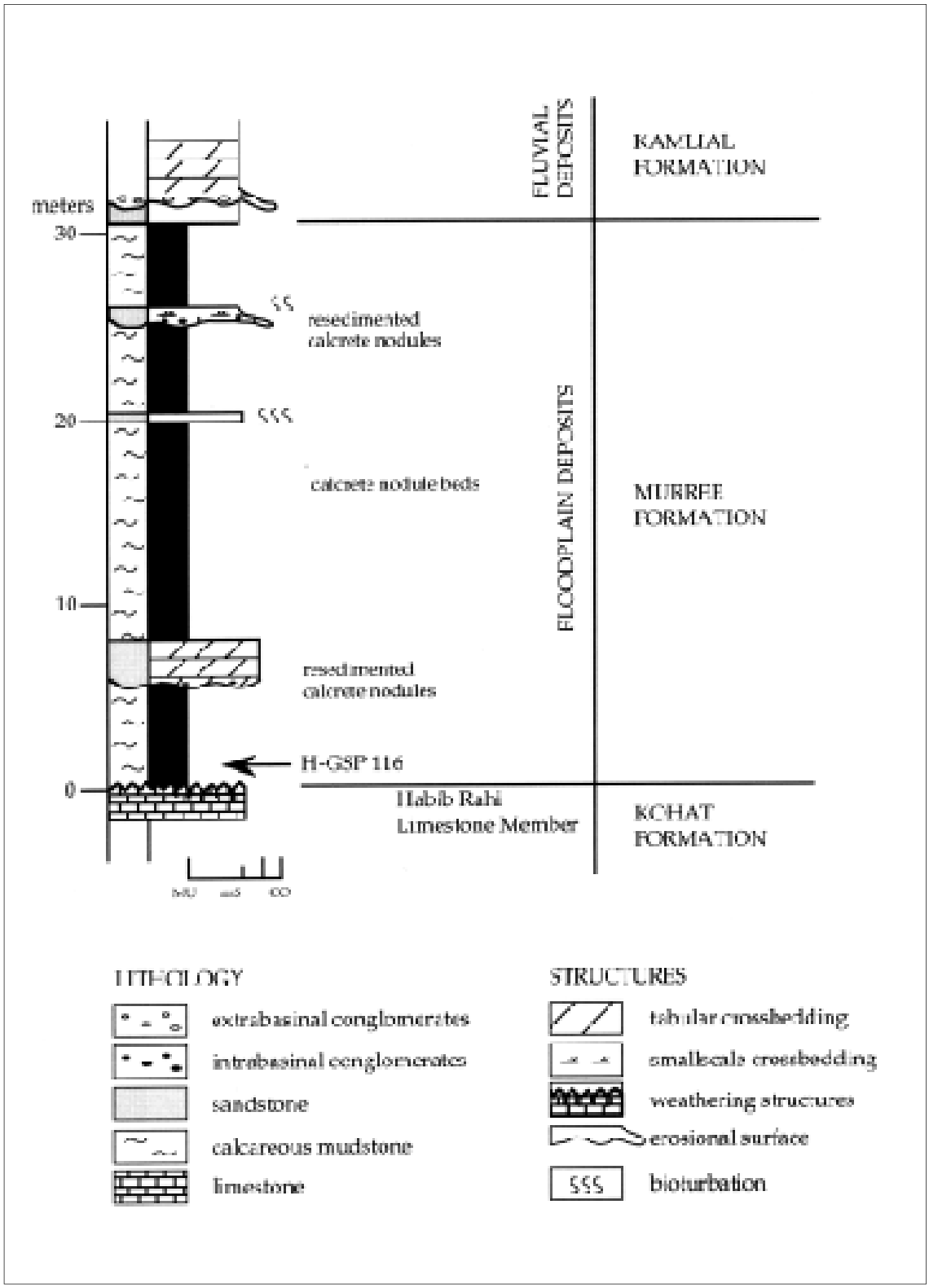

Figure 3 Sedimentological log of the Murree Formation south of Banda Daud Shah.

that the first massive channel sandstone belonged to the overlying Kamlial Formation. However, in the Murree sequence several intercalations of thin channel sandstones can be observed within the thick reddish mudstone interval. These channel sandstones occasionally display well developed tabular cross-bedding (current direction to the east) and contain abundant redeposited calcrete nodules (Fig. 3). The thick reddish mudstone intervals also contain abundant calcrete nodules. The entire sequence is moderately bioturbated (Fig. 3); however, the channel sandstones are generally more intensely bioturbated. The transition into the Kamlial Formation is sudden and consists of parallel laminated medium-grained sandstone beds. This sandstone is heavily eroded by the overlying thick channel sandstone body, which we consider to belong to the Kamlial Formation. Its lithology is distinctly different as it contains much less calcrete nodules and quartz components. Generally, the Kamlial Formation consists of lithic sandstones; the Murree Formation however, consists of quartz sandstones.

The red clays assigned to the Murree Formation overly the Kohat Formation unconformably. They mark the beginning of the continental (fluviatile) sedimentation and the time the Siwalik Basin came into existence. This basin became a catchment area for the erosional products from the initial Himalayan uplift. Meissner *et al.* (1974) consider these 5-10 meters (in our opinion 30 meters) of red clays as Murree Formation. However, it may be noted that in the Kala Chitta area the Murree Formation is much thicker (3000 meters; Shah 1977) and consists of monotonous series of sandstone, siltstone and shale. In the Jhalar section (Kala Chitta area), the base of the Murree Formation consists of a very thick cross-bedded channel sandstone with abundant redeposited larger Foraminifera. The base of the channel sandstone is strongly erosive and probably a large part of the Kohat Formation below has been eroded by the Murree channel-system. Whether or not the red clays on top of the Kohat Formation near Banda Daud Shah should be regarded as a separate formation, it is evident that they represent the beginning of the Neogene sedimentation in the northern part of the Indian subcontinent. The rodent fauna from a thin caliche bed about two meters above the contact between the Kohat and Murree Formations (locality H-GSP 116; De Bruijn *et al.* 1981) is of interest for dating the beginning of the Neogene sedimentation.

The Murree formation near Banda Daud Shah has yielded the following rodent taxa:

Rhizomyidae
Prokanisamys arifi DE BRUIJN *et al.* 1981
Cricetidae
Primus microps DE BRUIJN *et al.* 1981
Spanocricetodon khani DE BRUIJN *et al.* 1981
Spanocricetodon lii DE BRUIJN *et al.* 1981
Chapattimyidae
Fallomus sp. Flynn *et al.* 1986
Ctenodactlidae
Sayimys minor DE BRUIJN *et al.*,1981
Thryonomyidae indet.
Sciuridae indet.

The association of rodents from the Murree Formation is dominated by Muroidea and according to Downing *et al.* (1993) resembles the fauna from the base of the upper unit of the Chitarwata Formation in Baluchistan. Both fauna's share only one genus (*Fallomus*) with the next older association from the lower unit (= Bugti member, Raza & Meyer 1984) of the Chitarwata Formation (Flynn *et al.* 1986, Downing *et al.* 1993). Downing *et al.* (1993) report an age of 20.5 My for the basis of upper unit of the Chitarwata Formation based on paleomagnetic data (Friedman *et al.* 1992). Although correlation of the endemic Bugti fauna from the lower unit of the Chitarwata Formation - containing Chapattimyidae only - remains uncertain, Raza & Meyer (1984) and Flynn *et al.* (1986) assign it to the early Miocene. The correlation of the association from the

Murree (and that of the upper unit of the Chitarwata Formation) with biostratigraphical zonations developed outside the Indian subcontinent is difficult. However, the succession of rodent faunas from Central Anatolia, Turkey (Sümengen *et al.* 1989) contains two faunal elements that are similar to the taxa described from the Murree Formation near Banda Daud Shah. Comparison of the *Spanocricetodon* material from Kilçak and Harami 3, faunas that are correlated with zone MN1, with the type material of *S. khani* and *S. lii* from locality H-GSP 116 shows the same stage of evolution (Theocharopoulos in prep.). The second indication is the occurrence of *Sayimys* in Keseköy (De Bruijn, 1999) and in Horlak 1a and 1b (Sümengen *et al.* 1989), localities that are tentatively correlated with zones MN3 and MN4. These teeth from Anatolia are morphologically indistinguishable from *S. minor* from the Murree Formation, but their size is somewhat larger. Similar specimens are known from the lower levels of the Lower Manchar Formation of Sind, southern Pakistan (De Bruijn *et al.* 1989) and from the Potwar Plateau (Bashin 1996).

Although we are aware of the fact that such indirect long-distance correlations based on a few taxa are not very reliable, our Murree fauna is tentatively correlated with MN1-2. Such correlation implies an age of about 22 - 23 Ma for the fauna from H-GSP 116, which is only slightly older than the 20.5 Ma age of the similar fauna from the upper part of the Chitarwata Formation as reported by Downing *et al.* (1993). This means that the base of the Murree formation in the Kohat area might be older than was previously assumed. The almost complete change in composition of the rodent associations that occurred between Bugti and Murree times (Flynn *et al.* 1986) seems to have occurred within a very short period and to have coincided with the first uplift of the Himalayas.

Kamlial Formation

The Kamlial Formation near Banda Daud Shah is 525 meters thick and primarily consists of medium grained, greenish gray sandstones with crossbedding. The sandstones contain abundant mica and dark minerals. Most of the sandstone bodies are single or composite fluvial channel complexes. In the middle part of the formation, the sandstones are interbedded with brown silty claybeds. The sandstones in the lower and the upper parts of the Kamlial Formation are ridge forming. No bone concentrations were found in this formation; however, a few unidentifiable bone fragments have been collected. A horizon with silicified wood is present at about 50 meters below the contact with the Chinji Formation. Meissner *et al.* (1974) report the presence of an angular unconformity of 10 degrees between the Kamlial and Chinji Formations. However, we can not confirm this unconformity. In the crossbedded channel fillings, a 10 degree angularity is hardly measurable. Furthermore, we have not observed indications of a break in sedimentation. On the contrary, the transition from the Kamlial into the Chinji Formation is rather gradual. The thick sandstone bodies interbedded with red clays of the Lower Chinji Formation resemble the Kamlial sandstones. In the Banda Daud Shah area, there is no justification for placing the Kamlial Formation in a different group (top formation of the Rawalpindi Group) than the Chinji Formation (lowest formation of the Siwalik Group) as proposed by Meissner *et al.* (1974).

Chinji Formation

The Chinji Formation (about 960 meters thick) is characterised by the large amount of brown-red to brick-red clay and siltstones, interbedded with gray to brown sandstone bodies. The first appearance of red clays on top of thick-bedded greenish sandstones marks the boundary between the Chinji and the Kamlial Formations. The Chinji Formation forms valleys in the landscape in between the ridge-forming sandstones of the

Upper Kamlial and the lower Nagri Formations. The Lower Chinji near Banda Daud Shah is fossiliferous and concentrations of bones occur in brown calcrete nodule beds. Most of the bones in these beds are non-mammalian vertebrates (fish and crocodiles). However, a few teeth of large mammals are found. They occur in the gray sandstone beds and are represented by rhinoceroses, ruminants, suids (*Listriodon pentapotaminae*), tragulids and gomphotherids. Meissner *et al.* (1974) collected a complete lower jaw of *Tetralophodon falconeri* in this lower part of the Chinji Formation and on this basis they assigned a Pliocene age to the formation. This age, however, is no longer tenable.

The rodent locality, H-GSP 107 (Wessels *et al.* 1982) is about 210 meters above the contact between the Kamlial and Chinji Formations. This fossil locality was situated within a relatively large, probably slightly meandering fluvial system. The fossil concentrations can particularly be found within the fluvial cut-off or ox-bow lake facies of this fluvial system. H-GSP 107 yielded the following fossil rodents (Wessels *et al.* 1982 and Wessels 1996):

Cricetodontinae
Democricetodon kohatensis WESSELS *et al.*, 1982
Myocricetodontinae
Dakkamys berryi LINDSAY 1988.
Punabemys downsi LINDSAY 1988
Muridae
Potwarmus primitivus (WESSELS *et al.* 1982)
Antemus chinjiensis JACOBS 1977
Rhizomyidae
Kanisamys indicus WOOD.1937
Kanisamys sp.
Gliridae
Myomimus cf. *sumbalenwalicus* MUNTHE 1980
Sciuridae
Tamias urialensis MUNTHE 1980
Marmotini gen. et sp. indet.
Sciurinae gen. et sp. indet.
Thryonomyidae
Paraulacodus aff. *indicus* HINTON 1933

The rodents from locality H-GSP 107 may, except for *Myomimus*, be derived from groups known to occur in the Murree Formation. The two primitive murids and the two myocricetodontids (the teeth described by Wessels *et al.* 1982 as *Megacricetodon* sp. and Zapodidae gen. et sp. indet. are now known to represent the genus *Punjabemys*. Lindsay (1988) indicate local diversification of these two (related?) families. The association is diverse and widespread because similar faunas are present in the upper parts of the lower Manchar Formation near Sehwan Sharif, Sind (De Bruijn & Hussain 1985 b, Wessels 1996).

Nagri Formation

The base of the Nagri Formation near Banda Daud Shah consists of light gray, thick bedded and cliff forming sandstone beds. The sandstones are thinner and interbedded with clays and silts higher in the section. According to Meissner *et al.* (1974), the Nagri Formation in this part of the Kohat quadrangle is almost 4000 meters thick. Isolated mammalian fragments were found throughout the area prospected. In the lower part of the formation fragments of suids, rhinoceroses, giraffids and tragulids were found. In the upper part of the Nagri formation (2500 meters above the Chinji-Nagri boundary), two tooth fragments (molars or premolars) and a fragment of a metapodial of hipparionine horses were collected. It may be concluded that the arrival of hipparions in Banda Daud Shah was not contemporaneous with the start of the Nagri sedimentation, which is similar to the situation at the Potwar-plateau area (south of Rawalpindi). The arrival of hipparionine horses in the Potwar area is dated at about 9.5 My (Barry *et al.* 1982). According to Hussain & Bernor (1984) and Bernor & Hussain (1985) the '*Cormohipparion*' (*Sivalhippus*) group was the first to enter the Indo-Pakistan subcontinent.

CONCLUSIONS

The Eocene continental redbeds of the Kala Chitta and Barbara Banda areas have different lithological characteristics. The freshwater limestone beds, variegated clays and oyster beds are present in the Kala Chitta but they are absent in the Banda Daud Shah area. Since the continental deposits are different lithologically and are not physically traceable between these two areas, we do not consider them as part of the same formal formation. The redbeds probably represent the development of similar facies at different places and at different times and the deposits near Banda Daud Shah are probably the oldest (early part of the early Eocene). The initial contact between the Indian and Asian plates took place at about 55 My along the north-western border of the Indian plate followed by a counter-clockwise rotation of the subcontinent. This resulted in the accumulation of younger continental deposits towards the east. The land mammals first arrived on the Indian subcontinent by sweepstake route / island hopping. This mammalian fauna, as represented by the collection from Barbara Banda (locality H-GSP 300), has an unbalanced composition and is of earliest Eocene age. The Eocene mammalian faunas become younger as we go towards the east: Barbara Banda being the westernmost locality and Kalakot the easternmost (Table 1).

The Eocene deposits were succeeded by a break in deposition and a period of erosion, which was followed by the sedimentation of the red clays of the Miocene Murree Formation. This Formation marks the beginning of the fluvial sedimentation and the time when the Siwalik Basin came into existence. The beginning of this new fluvial sedimentation is documented by the rodent fauna from a thin caliche bed about two meters above the contact between the Kohat and the Murree Formations (Locality H-GSP 116), which is tentatively correlated with zones MN 1-2 indicating an age of about 22 - 23 My. A similar fauna has been reported from the Zinda Pir Dome in Baluchistan whith an age of 20.5 My (Downing *et al.* 1993). *Fallomus* is the only rodent genus that survived the faunal transition between Bugti and Murree times. Faunal similarities also exist between the Murree Formation from Banda Daud Shah and Miocene deposits from Sind (Manchar Formation) and Central Anatolia, Turkey.

The Kamlial Formation has yielded a few bone fragments and silicified wood was found at about 50 meters below the contact with the Chinji Formation. An angular unconformity noted by Meissner *et al.* (1974) between the Kamlial and Chinji Formations has not been recognised by us. On the contrary, we have seen a gradual transition between these two formations.

The Chinji Formation is characterised by red clays with intercalated sandstone bodies. One fossil rodent locality is situated about 210 meters above the contact with the Kamlial Formation. The locality represents an ox-bow lake facies of a fluvial system. Except for *Myomimus* and the Muridae, all rodents can be derived from the taxa known from the Murree Formation. Similar taxa of rodents are also present in the lower Manchar Formation near Sehwan Sharif, Sind.

The Nagri Formation consists of light gray, cliff forming sandstone beds. The earliest remains of Hipparionine horses are found 2500 meters above the Chinji - Nagri Boundary. The first appearance of these horses is dated at 9.5 My in the Potwar area.

ACKNOWLEDGEMENTS

Since 1974 many people have been involved in the Howard University - Geological Survey of Pakistan Project. We are especially indebted to the Director General, Geological Survey of Pakistan who has given us his fullest co-operation and support at all stages of the work. We are particularly grateful to Messrs. Iqbal Cheema, Naseer Khan and Drs. A.J. van der Meulen, R.M. West and J.

Munthe for their able assistance in the field. Work was supported by several grants from the Smithsonian Institution (current number 7087120000-13), National Science Foundation (number DEB-8003601) and National Geographic Society (numbers 3140-85 and 3494-87) awarded to S.T. Hussain.

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received 9 February 1999

DEINSEA - ANNUAL OF THE NATURAL HISTORY MUSEUM ROTTERDAM
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